A Profile of Traditional and Emerging Industry Clusters:

A Report to the American Society of Mechanical Engineers

by

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of

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About New Economy Strategies

NES is a national strategic consulting firm based in Washington, D.C. with a focus on regional economic development through technology. A staff of six individuals link and leverage a network of over twenty experts in the fields of research and development, infrastructure, capital formation, workforce and skill development, university-industry partnerships, entrepreneurial management, and economic analysis of cluster growth. NES currently tracks 40 U.S. regions and 18 global regions where technology and innovation are drivers of the economy. This quarterly tracking identifies research, commercialization, workforce, infrastructure, capital formation and tax/incentive economic development trends influencing regional tactics for industry clustering.

Over the past five years, NES has conducted cluster-based and economic development-related projects in Southwest Pennsylvania, Upper New York State, Cincinnati, Saint Louis, Arizona, Texas, Kansas City, and Glasgow-Edinburgh Scotland. Two projects – the National Project on Regional Innovation of the Life Sciences Cluster and the National Project on University-Industry Life Science Partnerships – have afforded NES to analyze best practices and critical benchmarks in basic research, infrastructure, talent and skills, convergent technologies, and capital formation.

NES’s network includes affiliations with several organizations including the Milken Institute and its Regional Studies Group, which is responsible for an annual national technopolis study and the ‘Best Places’ quarterly reports for Forbes Magazine. Through the Milken Institute, NES has enhanced access to information on current and emerging trends in technology clusters throughout the U.S.

NES is a member of the Association of University Research Parks (AURP), Association of University Technology Managers (AUTM), the International Economic Development Council (IEDC), the National Association of Business Economists (NABE), the National Business Incubation Association (NBIA), and the Biotechnology Industry Organization (BIO).

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Executive Summary

The following report is a high-altitude snapshot of six industries and offers an overview of their relevance to the engineering world, both today and in the future. These industries were chosen because they collectively capture a significant portion of the world’s engineering activity and are all undergoing a transformation that will open up new opportunities and challenges for scientists and engineers. Two industries are traditional in nature (the energy sector and the pressure equipment manufacturing industry), and four of which are newer, emerging industries (water management technology, national and homeland security, computing hardware and software, and bioscience and pharmaceuticals). Together these industries serve as good examples of some of the more important, interesting, challenging, and exciting trends facing engineers today.

S&E Trends

The report begins by outlining some important trends in the education and employment of engineers which will impact engineers across all sectors of the economy. On the education side, these trends include the increased importance of cross-disciplinary work and the troubling shortage of American Science and Engineering (S&E) graduates. On the employment side, these trends include the continuing gradual decline of traditional manufacturing industries in the United States, opportunities for rapid employment growth in emerging industries and technologies, and the rise in importance of foreign S&E workers, both in the US and abroad.

Links Between Industries

Although these six industries represent distinct categories of activity they are not mutually exclusive and exhibit a high degree of interconnectivity. The pressure equipment manufacturing industry, for example, is closely tied to both the traditional and alternate energy industries. The petrochemical industry is the single biggest user of high pressure equipment, and the nuclear power industry is also an important user of pressure technology. Pressure technology is also linked to the fuel cell industry, through the high-pressure storage containers needed for alternate fuels such as hydrogen and compressed natural gas. The water management industry is linked in obvious ways to both the pressure industry and the energy industry (through hydroelectric power plants). National and homeland security touches all of these industries, especially the biotech and pharmaceuticals industry and the water management industry (through bioterrorism issues), the computer industry (through networking technology), and the energy industry (through nuclear safety and energy independence issues).

Over-arching Trends

There are larger, more universal links as well: All of the industries, even the traditional ones, are being reshaped by the forces of technology. In that respect there is little distinction between our traditional and emerging industry clusters; the future of any of these industries will rely, in large part, by how well they adapt to the opportunities presented by new technology. There are other
commonalities among our six industries. They are all coming to terms with globalization - the increasing ease and speed by which products, services, technology, ideas, and workers cross national borders. They are all going to be shaped significantly by increased international competition, especially from rising economic powers such as China and India. They are all experiencing a long-term shift away from traditional resources and materials (fossil fuels, iron and steel) and towards newer resources and materials (renewable energy sources, biotech products, composite materials designed with nanotechnology).

Cluster Explanation

The basic definition of an industry cluster is a geographical concentration of industries that gain performance advantages through co-location. Within a cluster, related or complementary businesses share specialized infrastructure, labor markets and services that can result in synergies, efficiencies and, ultimately, a critical mass of entrepreneurial and industrial strength in a region. The diagram below shows this phenomenon visually by displaying what some of the key elements to any successful cluster are, and how they are linked together.

Cluster Map: A Sample of Stakeholders

Cluster Activity in Engineering

Engineering is truly a global occupation – every region and country across the globe both produces and employs engineers. These activities are increasingly concentrated in a growing number of education and industry clusters. Much of that concentration still resides in North
America and Europe; however, over the last twenty years there has been a significant shift in the
geography of both the education and employment of scientists and engineers.
A primary goal of this report is to identify geographic clusters of activity relevant to the
engineering world (whether it be R&D, employment, new technologies, sales of goods and
services, or some other metric) in the sectors which we profiled. While industry-level and sub-
industry-level cluster activity was different in each sector, certain broad geographical trends did
emerge. Traditional engineering activity is clustered around the manufacturing heartland of the
United States in the Great Lakes region and the Midwest, and around the petrochemical industry
in Texas, Oklahoma, Louisiana, and along the East Coast. Engineering activity involved with
emerging technology is more likely to be located on the coasts, especially in the states of
California, Washington, Massachusetts, and New York. Internationally, there are signs of
continued strength in Western Europe, Japan, Canada, Australia, Israel, and within the Asian
Tigers (Hong Kong, Singapore, South Korea, and Taiwan). And evidence continues to support
the view that isolated clusters within China, India, Brazil, Taiwan, and Russia are quickly
becoming global competitors in technology and engineering.

All of these geographic and technological changes, as well as others, will continue to alter the
landscape of challenges and opportunities facing engineers. This report highlights some of the
more significant changes within that dynamic and outlines the new geography impacting
scientists and engineers in several important industries.

**Flexibility and Initiative**

A challenge to future cluster-based activities for ASME will be the role of just-in-time networks
among smaller, flexible firms and individuals. As recognized in prior engineering studies
conducted by the Plexus Consulting Group, ASME is challenged by individuals with a
perception that joining a large association is no different than affiliation with a global corporate
entity – bureaucratic, slow to innovate, cautious without an entrepreneurial mindset. A cluster-
based approach coupled with out-of-the-box offerings that aggregate membership interests and
competencies to emerging market trends *must* be a consideration of the ASME Corporate
Services Unit.

**Promising New Technologies**

The following table shows twelve examples of new and exciting emerging technologies that
show great promise for engineering. Some of these technologies will have niche applications,
whereas others may have a lasting impact on the lives of millions of people. It is quite possible,
however, that “the next big thing,” the technology which will fundamentally alter the course of
engineering and of ASME, is not even listed here. This exercise, however, is not intended to
serve as a comprehensive crystal ball. Rather, the purpose of cherry-picking twelve technologies
is to cause the reader to begin thinking in terms of the opportunities offered by these and other
emerging technologies, and to begin discussing the necessary steps to embrace and profit from
 technological change.
<table>
<thead>
<tr>
<th>#</th>
<th>Technology</th>
<th>Description</th>
<th>Who/Where</th>
<th>Benefits</th>
<th>Obstacles/Drawbacks</th>
<th>Time Frame</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wireless Sensor Networks</td>
<td>Networks of wireless battery-powered sensors that monitor people, nature, machines, etc.</td>
<td>UC Berkeley, University of Washington, UCLA, Intel</td>
<td>Enormous potential for gathering information. Will be inexpensive when mass-produced.</td>
<td>Privacy issues, limitations in computing power and battery power.</td>
<td>Currently being field-tested.</td>
</tr>
<tr>
<td>2</td>
<td>Injectable Tissue Engineering</td>
<td>Injections of specially designed mixtures of polymers, cells, and growth stimulators that solidify and form healthy tissue.</td>
<td>Johns Hopkins, Harvard, Rice University, University of Michigan, Genzyme</td>
<td>Less invasive and cheaper than surgery.</td>
<td>Research relies upon stem cells, a politically sensitive issue in the US.</td>
<td>Early stages. Successful experiments have been done in mice.</td>
</tr>
<tr>
<td>3</td>
<td>Nano Solar Cells</td>
<td>Using nanotechnology to produce a photovoltaic material that can be spread like plastic wrap or paint.</td>
<td>UC Berkeley, UC Santa Barbara, Cambridge, Swiss Federal Institute of Technology, Johannes Kepler University</td>
<td>Potentially much cheaper than current silicon-based solar cells, and could easily be mounted almost anywhere.</td>
<td>Commercial viability not yet proven.</td>
<td>Early stages. Working prototypes exist.</td>
</tr>
<tr>
<td>4</td>
<td>Mechatronics</td>
<td>The integration of familiar mechanical systems with new electronic components and intelligent-software control.</td>
<td>Darmstadt University of Technology (Germany), Swiss Federal Institute of Technology, UC Berkeley, University of Karlsruhe, Carnegie Mellon</td>
<td>Increases efficiency, versatility, performance of mechanical products such as cars, planes, cameras, photocopiers.</td>
<td>Lingering safety concerns, high (but falling) cost.</td>
<td>Already in extensive use.</td>
</tr>
<tr>
<td>5</td>
<td>Grid Computing</td>
<td>Networks which act like electric power grids between computers, giving home and office machines the ability to reach into cyberspace, find resources wherever they may be, and assemble them on the fly into whatever applications are needed.</td>
<td>Argonne National Laboratory, USC, NSF, IBM, Sun Microsystems, and Microsoft, UVA, Entropia, University of Wisconsin (Madison)</td>
<td>Promises a vast increase in computing power and efficiency. The location of computational resources would no longer matter.</td>
<td>Network security, limitations of internet, logistics of applying it on a large scale.</td>
<td>Dozens of grid computers are already under construction globally, including the NSF’s giant TeraGrid.</td>
</tr>
<tr>
<td>6</td>
<td>WiMax</td>
<td>A wireless internet technology that uses microwaves to send data seven times faster and 1,000 times farther than WiFi technology.</td>
<td>Intel, Nokia, Alcatel, Pyramid Research LLC, Alvarion</td>
<td>Promises broadband wireless internet within a 30 mile radius. Of particular interest to the developing world, which has less infrastructure.</td>
<td>Stiff competition from other technologies, a business model dependent upon assuming costs will fall.</td>
<td>Will be on the market by the end of 2004.</td>
</tr>
<tr>
<td>#</td>
<td>Technology</td>
<td>Description</td>
<td>Who/Where</td>
<td>Benefits</td>
<td>Obstacles/Drawbacks</td>
<td>Time Frame</td>
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</tr>
<tr>
<td>7</td>
<td>Molecular Imaging</td>
<td>A set of techniques that let researchers watch genes, proteins, and other molecules at work in the body.</td>
<td>Massachusetts General Hospital, Memorial Sloan-Kettering Cancer Center, UCLA, Harvard Medical School, University of Manchester, Washington University</td>
<td>Promises to help track underlying causes of cancer, detect cancer earlier, and monitor treatments in real-time.</td>
<td>High cost, difficulties in molecule detection, and other limitations mean it will augment, not supplant, conventional imaging.</td>
<td>Early stages. Successful experiments have been done in mice. Might be on the market in 10 years.</td>
</tr>
<tr>
<td>8</td>
<td>Nanoimprint Lithography</td>
<td>A manufacturing technique for nanotechnology that uses lasers and a printing press-like machine.</td>
<td>Princeton University, NanoOpto, Nanonex, Stanford University, Hewlett-Packard, Bell Labs, Harvard.</td>
<td>Promises to drastically reduce the cost of mass-producing nanotech devices.</td>
<td>Making more complex, multi-layered chips is still very challenging.</td>
<td>Nanoimprinted optical-networking components are already on the market.</td>
</tr>
<tr>
<td>9</td>
<td>Glycomics</td>
<td>The effort to understand and ultimately harness sugars for pharmaceutical purposes.</td>
<td>Scripps Research Institute, Cytel, Abaron Biosciences, Amgen, GlycoGenesys, Progenics Pharmaceuticals, Oxford Glycoscience, UC Berkeley, UC San Diego.</td>
<td>Manipulating glycosylation (a process by which sugar units are attached to other molecules) may help researchers shut down disease processes, create new drugs, and improve existing ones.</td>
<td>Sugars can be more difficult to study than genes or proteins. Massive amounts of research are required.</td>
<td>Still in the beginning stages of research.</td>
</tr>
<tr>
<td>10</td>
<td>Quantum Cryptography</td>
<td>Allows the transmission of encoded information in such a way that any effort to eavesdrop will be detectable.</td>
<td>University of Geneva, Los Alamos National Laboratory, id Quantique, IBM, Caltech, QinetIQ, MagiQ Technologies</td>
<td>A new encryption method will be necessary in the future, as more powerful computers allow today’s codes to be broken.</td>
<td>Long distance transmission is currently not possible.</td>
<td>Systems using the technology are already on the market.</td>
</tr>
<tr>
<td>11</td>
<td>Swarmbots</td>
<td>Small robots that operate in groups, communicating and cooperating with one another without a centralized command system.</td>
<td>MIT, iRobot, Swiss Federal Institute of Technology in Lausanne</td>
<td>Possible applications include military, search and rescue, space exploration.</td>
<td>Success so far is limited to the laboratory.</td>
<td>Working prototypes exist.</td>
</tr>
<tr>
<td>12</td>
<td>Voice Over Internet Protocol (VOIP), Voice Over Wi-Fi</td>
<td>Sending phone calls over the internet or over private Wi-Fi networks.</td>
<td>Vonage, AT&amp;T, Qwest, Cisco Systems, Motorola, Avaya, Proxim</td>
<td>VOIP brings the cost of phone calls close to zero. Wi-Fi phone networks eliminate the dead spots associated with cell phones.</td>
<td>Less reliable and lower clarity than traditional phone networks. Promises upheaval amongst telecoms.</td>
<td>Already on the market. May take off by 2008.</td>
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Educational and Employment Trends in Engineering

<table>
<thead>
<tr>
<th>Future Trends</th>
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</table>
| **Workforce** | • 40% of engineering employment in America is in traditional manufacturing industries, which are experiencing a long-term, gradual decline.  
• High-tech sectors have to fill strong demand with foreign workers due to a lack of qualified Americans. |
| **Education/Training** | • The trend towards specialization experienced over the last century will reverse. Integration and collaboration will be key in the 21st century.  
• Multidisciplinary and interdisciplinary approaches are needed to steer engineering services away from compartmentalized view. |
| **Industry** | • While in the past engineers dealt mostly with other engineers, in the future engineers will increasingly work in teams that include non-engineer members, such as representatives with business, marketing, sales, or other backgrounds. Success will require new skill sets.  
• Increased cross-disciplinary work will require engineers to have a greater knowledge of fields outside of their areas of expertise. |
| **Sectors** | • IT/Telecom, Software/Systems, Civil/Infrastructure, Petroleum, Environmental, Aerospace, Transportation |
| **Technology** | • Engineering at the nanotechnology level (creating the materials with the desired properties, instead of making due with known materials).  
• The innovative use of ergonomics offers largely untapped growth potential.  
• Success depends upon taking advantage of increased applications for IT. |
| **US Clusters** | • Traditional (MI, OH, NY, PA), Petroleum (TX), Environmental (CA) |
| **Global Clusters** | • All developed countries have their own indigenous engineering services capacity. The United States is still the global leader in the engineering services industry, although international competition is increasing. Other leaders include, in approximate order of industry strength: England, France, Germany, Canada, Japan, India, Australia, Hong Kong, and Ireland. China, in the past concentrated more on manufacturing than on design, is also a growing leader. |
| **Globalization** | • Revolutions in communications and technology, combined with a growing international labor pool of highly-trained engineers, enable companies to outsource many of their engineering needs to lower-cost foreign suppliers.  
• The key to surviving international competition and off-shoring is to solidify American firms’ competitive advantage in innovation.  
• Demand for S&E workers is rising while the number of Americans pursuing S&E degrees is falling, therefore domestic engineering services providers will increasingly rely on foreign-born workers, and American companies’ share of the industry at large will increasingly slip. |
Employment Profile

There are over 1.5 million engineers employed in the US today. Engineering jobs are very diverse (see figure ii below), as are the companies and industries that employ engineers, hence the propensity of engineers to specialize in specific areas of expertise. Engineering disciplines include transportation, environmental consulting, civil engineering, telecommunications, electronics, information technology, aerospace, public infrastructure, facilities management, and software and systems engineering, just to name a few. A large portion of engineering jobs are concentrated in manufacturing industries that are experiencing slow, stagnant, or even negative growth, but some newer areas offer opportunities for rapid growth. The department of Labor projects that from 2002 – 2012, engineering employment will only grow by about 3% - 9% overall, with declines occurring in the employment of mining, geological, petroleum, and nuclear engineers, and growth occurring in the burgeoning field of environmental engineering.\(^2\) However, although growth in overall employment is slight, wage growth has outpaced employment growth (see figure i above), and a demographic bulge in the workforce nearing retirement age means that employment opportunities will continue to exist for young graduates.

\(^2\) US Department of Labor
Evidence of Regional Clusters

Engineering disciplines are not highly concentrated geographically – firms can be found in every major city in every US state. However, to a degree engineering shows some concentration by specialization – petroleum engineering is strongest in Texas, whereas engineering services firms related to traditional manufacturing industries tend to be concentrated where those industries have historically existed, in states like Michigan, Ohio, New York, and Pennsylvania. Environmental engineering firms are highly concentrated in the state of California.

College/University Engineering Programs

There are about 340 engineering programs (of all disciplines) at colleges and universities across the country that have been accredited by the Accreditation Board for Engineering and Technology (ABET). Since there is often a high level of correlation between geographic concentrations in industry and academia, it is useful to note where these ABET-accredited programs are located. The following maps (figures iii and iv), a product of original research by New Economy Strategies, show the total number of ABET-accredited engineering programs and the number of ABET-accredited mechanical engineering programs in each US state.
Traditional Industries

Pressure Equipment Manufacturing

Energy
Pressure Equipment Manufacturing

Baselines

<table>
<thead>
<tr>
<th>Workforce</th>
<th>Sectors</th>
<th>US Clusters</th>
<th>Global Clusters</th>
</tr>
</thead>
</table>
| A steady decline in employment in traditional sectors, commensurate with overall decline of US manufacturing employment. Growth possibilities exist due to new technologies, international sales. | **STEADY GROWTH**  
- Miscellaneous (valves, hoses, gauges, etc.)  
**IN TRANSITION**  
- Commercial boilers  
- Nuclear Equipment  
**IN DECLINE**  
- Fluid Power | **TIER ONE**  
- Midwest (NY, PA, OH, IN, IL, WI, MI, IA) | **TIER ONE**  
Canada, Europe (UK, France, Germany, Benelux)  
**TIER TWO**  
China  
**TIER THREE**  
Singapore, South Korea, Hong Kong |

Tier selections were determined by analyzing volume of output, size of local market and through background research on the health of the local economy including physical infrastructure, technology inputs, financial markets and human capital.

Future Trends

**Industry**
- The supplier-customer relationship is changing. Consumer behavior is dictating supplier actions (ex: an increased emphasis on direct sales).
- Profits are being squeezed from both ends (suppliers and consumers).
- The market is shrinking in many aspects of the industry, leading to overcapacity. The industry is responding by focusing on cost-reduction.

**Technology**
- Raw materials will change and become increasingly high-tech (ex: increased use of silicone and polyethylene linings).
- Increased use of ceramic matrix composites, including corrosion and erosion-resistant continuous fiber ceramic composites (CFCCs).
- Increased energy efficiency is possible from existing products.
- The Internet is changing distribution channels, squeezing producers and putting more power in the hands of consumers.

**R&D**
- R&D budgets are being cut because of lower profits.

**Globalization**
- The US market is in decline, but international opportunities, especially in rapidly-developing economies such as India and China, are rising.
- Increased competition, especially from overseas, has prompted the formation of alliances and partnerships, and consolidation via acquisition.
- The trade balance has shifted from a $200 million surplus in the fluid power industry in 1989 to a $300 billion deficit in 2002.
Industry Definition

The pressure equipment industry cuts across many broader industries, and is therefore not easily classified. High pressure products are manufactured by and for the automotive, pharmaceutical, aerospace, petrochemical, and nuclear power industries, to name a few of the more important players in the pressure equipment field. For the purposes of this review, four manufacturing categories are outlined below which, together, offer an accurate snapshot of current activity in this field:

1. heating equipment (boilers, stoves, furnaces),
2. power boilers and heat exchangers,
3. fluid power valves and hose fittings, and
4. fluid power cylinders and actuators.

<table>
<thead>
<tr>
<th>Leading Companies*</th>
<th>Location</th>
<th>Products/Technology Strengths</th>
<th>2003 Sales (mil. $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enerfab, Inc.</td>
<td>Cincinnati, OH</td>
<td>Fabricated metal products, including storage and brewery tanks, tank heads, and piping systems.</td>
<td>207.2</td>
</tr>
<tr>
<td>Johnston Boiler Company</td>
<td>Ferrysburg, MI</td>
<td>Boilers, deaerators, surge tanks, and blow down heat recovery systems</td>
<td>15.0</td>
</tr>
<tr>
<td>Interpump Group S.p.A.</td>
<td>Calerno, Italy</td>
<td>high-pressure water plunger pumps, nozzles, valves</td>
<td>25,179.0</td>
</tr>
<tr>
<td>Haskel International, Inc.</td>
<td>Burbank, CA</td>
<td>hydraulic and pneumatic high-pressure pumps, gas boosters, air-pressure amplifiers</td>
<td>NA</td>
</tr>
<tr>
<td>Pentair, Inc.</td>
<td>Golden Valley, MN</td>
<td>pumps, sump pumps, valves</td>
<td>2,724.4</td>
</tr>
<tr>
<td>The Gorman-Rupp Company</td>
<td>Mansfield, OH</td>
<td>Pumps used in agriculture, construction, sewage treatment, petroleum refining, and fire fighting.</td>
<td>195.8</td>
</tr>
<tr>
<td>Flowserve Corporation</td>
<td>Irving, TX</td>
<td>The world's largest provider of pumps for the chemical, petroleum, and power industries.</td>
<td>2,404.4</td>
</tr>
<tr>
<td>Aluminum Precision Products, Inc.</td>
<td>Santa Ana, CA</td>
<td>high-pressure aluminum gas cylinders</td>
<td>100.0 (est.)</td>
</tr>
<tr>
<td>Luxfer Gas Cylinders</td>
<td>Riverside, CA</td>
<td>high-pressure aluminum gas cylinders</td>
<td>150.0 (est.)</td>
</tr>
<tr>
<td>Manuli Rubber Industries S.p.A.</td>
<td>Milano, Italy</td>
<td>high-pressure rubber hoses, fittings, and components, and systems for transmitting fluids</td>
<td>364.6</td>
</tr>
<tr>
<td>Webster Engineering</td>
<td>Winfield, KS</td>
<td>Gas and oil burners, steam and hot water boilers</td>
<td>20.0 (2002)</td>
</tr>
<tr>
<td>T-3 Energy Services, Inc.</td>
<td>Houston, TX</td>
<td>high pressure oilfield equipment</td>
<td>125.6</td>
</tr>
<tr>
<td>The Clark-Reliance Corporation</td>
<td>Strongsville, OH</td>
<td>boiler and fluid control products</td>
<td>50.0 (est.)</td>
</tr>
</tbody>
</table>

* Leading companies were chosen based on a number of factors, including overall size, strengths in innovative technologies/products, and importance within industry sub-sectors. This list is not intended to be comprehensive.

Evidence of Regional Clusters

Although the pressure equipment manufacturing industry is spread out across a wide range of products and sectors, the older, more traditional pressure equipment industries such as boilers and fluid power equipment are relatively highly concentrated. As evident in figures i and ii below, a large regional cluster exists in these industries in the Midwest, with smaller clusters in California and in the Southwest.
Fluid Power Valve and Hose Fitting Manufacturing Manufacturing (Red) and Fluid Power Cylinder and Actuator Manufacturing (Blue):  
Top Seven States Each by Employment, 1997

Heating Equipment (Except Warm Air Furnaces) Manufacturing (Red) and Power Boiler & Heat Exchanger Manufacturing (Blue):  
Top Seven States Each by Employment, 2002

Figures v and vi show the total number of people employed in the respective industries mentioned, by state.

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Global Leaders

The strongest areas internationally in the pressure equipment sector are Canada and Europe (specifically the UK, France, Germany, and the Benelux countries). Hong Kong, Singapore, South Korea, and increasingly China are also competitive in this field.

New Developments

Ø New Growth Areas

Examples of promising new growth areas include fuel cell technologies (the design, manufacturing and marketing of fuel storage cylinders and systems for compressed natural gas and hydrogen), and electrolyzer high-pressure hydrogen energy generators (which are able to produce high-pressure hydrogen gas without a compressor).

Ø The European Union Pressure Equipment Directive (PED)

Adopted in 1997, the PED came into partial force in 1999 and into full force in 2002. Its goal is to harmonize standards regarding the design, manufacture, testing and conformity assessment of pressure equipment across the 25 member European Union. Standardization promises to significantly increase the international competitiveness of European manufacturers by ensuring all EU members share the same high quality standards and by allowing them to take advantage of the economies of scale present in a unified European market for pressure equipment which is estimated to be more than €65 billion a year ($80.6 billion). The PED is helping to open up new markets and facilitate the application of new technologies by European companies.

Employment Profile

Employment in the traditional industries has shown a gradual but steady decline in recent years (see figures vii and viii below), due to increased competition from low-wage countries, but this has been compensated for to some degree by robust growth in newer fields such as fuel cell technology.


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<table>
<thead>
<tr>
<th>Year</th>
<th>Employment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>27576</td>
</tr>
<tr>
<td>1998</td>
<td>28604</td>
</tr>
<tr>
<td>1999</td>
<td>26789</td>
</tr>
<tr>
<td>2000</td>
<td>26695</td>
</tr>
<tr>
<td>2001</td>
<td>25867</td>
</tr>
<tr>
<td>2002</td>
<td>20103</td>
</tr>
</tbody>
</table>

The Seven Largest States in the Heating Equipment (Except Warm Air Furnaces) Industry by Employment, 2002

California: 3070
Pennsylvania: 2005
Indiana: 1852
Tennessee: 1218
New York: 1191
Ohio: 1123
Kentucky: 1058

There is a large geographical concentration in the Heating Equipment sector located in California, as well as significant activity in the traditional manufacturing states of the East Coast/Mid-West (figure ix).

The Seven Largest States in the Power Boiler & Heat Exchanger Industry by Employment, 2002

New York: 2614
Texas: 2414
Oklahoma: 2377
Ohio: 1316
Pennsylvania: 993
Wisconsin: 785
Illinois: 704
Many firms in pressure equipment industries, such as the heating equipment industry, are of a medium to small size. This is not an industry dominated by large multinationals – about one quarter of employees in the heating equipment industry work for firms that employ between 100 and 249 total employees, and about 85% of employees work for firms with less than five hundred total employees (figure xi). Figure xii shows private sector R&D expenditures in some of the more important sectors of the high-pressure manufacturing industry in 2002 and 2003.*

*Includes industries classified under NAICS codes 332410 (Power Boiler and Heat Exchanger Manufacturing), 333414 (Heating Equipment [except Warm Air Furnaces] Manufacturing), 333415 (Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing), and 333911 (Pump and Pumping Equipment Manufacturing)
### Take-aways:

- Employment in the traditional sectors is slowly but steadily declining.
- The Internet has shifted the balance towards customers, squeezing profits.
- The US Industry is highly concentrated in California and in the traditional manufacturing states.
- Significant opportunities exist overseas, especially in selling products based on older technologies in China and India.

### Impact on ASME Corporate Services:

- Strategies are needed to address the workforce transitions for the remaining US employment base, including partnerships with the US Department of Labor.
- It is necessary to identify the specific market demands of US firms seeking an introduction to new global opportunities – a global match-making system amongst members.
- A higher priority needs to be placed on the internal hiring of bilingual staff (especially individuals with abilities in Mandarin Chinese and Indian dialects).
**Energy**

**Baselines**

<table>
<thead>
<tr>
<th>Workforce</th>
<th>Sectors</th>
<th>US Clusters</th>
<th>Global Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>In traditional sectors, declining employment will be offset by job opportunities for young graduates caused by the retirement of an aging workforce. Required skill level is rising. High-tech job opportunities will rise in emerging sectors.</td>
<td><strong>STEADY GROWTH</strong>&lt;br&gt;• Nuclear&lt;br&gt;• Electricity&lt;br&gt;• Coal&lt;br&gt;• Natural gas</td>
<td><strong>TIER ONE</strong>&lt;br&gt;• Texas&lt;br&gt;• Louisiana&lt;br&gt;• Oklahoma&lt;br&gt;• California</td>
<td><strong>TIER ONE</strong>&lt;br&gt;• OPEC&lt;br&gt;• Canada&lt;br&gt;• Russia&lt;br&gt;• Mexico</td>
</tr>
<tr>
<td><strong>IN DECLINE</strong>&lt;br&gt;• Petroleum</td>
<td><strong>EMERGING</strong>&lt;br&gt;• Renewable&lt;br&gt;• Fuel Cells</td>
<td><strong>TIER TWO</strong>&lt;br&gt;• Alaska&lt;br&gt;• Appalachia</td>
<td></td>
</tr>
</tbody>
</table>

*Tier selections were determined by analyzing volume of output, size of local market and through background research on the health of the local economy including physical infrastructure, technology inputs, financial markets and human capital.*

**Future Trends**

- **Industry**
  - Increasing importance of cutting-edge technology.
  - Hybrid oil companies will use fossil fuel operations to support increasing investment into renewable energy.
  - Future will be highly influenced by government policy (gasoline tax vs. support for increased drilling, environmental policy, investment in emerging technologies, and movement away from dependence on foreign oil).
  - Despite the growth in renewable energy, fossil fuels will continue to dominate the energy sector for the near future.
  - Consolidation amongst larger firms will continue. Many small firms, lacking the resources to expand abroad, invest in expensive R&D and equipment, and weather severe price swings, will fail.

- **Technology**
  - Hydrogen fuel cells
  - Increasing cost-effectiveness of solar power.
  - Research into viable, large-scale electricity production from nuclear fusion.
  - New extraction techniques (ex: off-shore drilling, oil sands extraction)

- **Globalization**
  - Traditional US energy firms will increasingly abandon the domestic market in search of exploration and extraction opportunities abroad.
  - Growth in demand will be strongest in developing countries (non-OECD).
Industry Definition

The political and economic importance of the energy industry is second to none – questions of supply and demand of fuel sources drive our foreign policy, and fluctuations in the price of energy have the ability to roil the economies of the entire developed world. Every other sector of the economy and every aspect of our lives rely upon the energy industry.

The energy industry is best viewed as having two distinct halves: the traditional half involves extracting natural resources from the earth and converting them into energy, whereas the emerging sector focuses on alternate, often renewable, sources of energy such as solar power. Although increasingly high-tech in its methods, the traditional sector relies primarily on the same fuel sources today that it has relied on since the dawn of the industrial revolution – “fossil fuels” such as petroleum, coal, and natural gas. While fossil fuels account for the lion’s share of today’s energy consumption, it is the emerging sector which will offer the highest growth in the future.

The emerging energy sector is characterized by new technologies and new sources of energy which move away from traditional fossil fuels. Growth in the emerging sector is being driven by a number of factors, such as knowledge of the finite nature of fossil fuels, a desire to reduce pollution, and a political desire (especially in the US) to reduce dependence on oil-producing regions. Bridging the gap between the traditional and emerging sectors is the nuclear power industry. Once heralded as the answer to all of our energy problems, nuclear power has failed to deliver on its ambitious promises. However, it is a large and growing source of energy in the world which is cleaner than fossil fuels and not subject to political or economic fluctuations abroad. Nuclear power is also much safer and more cost-effective than in the past.

Global Overview of Energy Supply

![World Total Primary Energy Supply by Fuel, 1973 and 2002](image)

In the past three decades nuclear energy and natural gas have increased considerably with respect to the energy sources (see figure xiii). Coal retains its importance to our economies, and oil has declined respectively, although it is still by far the single most important energy source.
Government investment in energy sector R&D as a whole has remained relatively steady over the past fifteen years (figure xiv). Japan has overtaken the US, but both countries spend much more than the rest of the world. The apex of US government investment in energy R&D came during and immediately after the oil crises of the 1970s, but rapidly fell after those crises passed.

### Leading Companies*

<table>
<thead>
<tr>
<th>Leading Companies*</th>
<th>Location</th>
<th>Products/Technology Strengths</th>
<th>2003 Sales (mil. $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Nuclear Fuels plc (includes Westinghouse)</td>
<td>Warrington, UK</td>
<td>provides an atomic array of nuclear power-related services</td>
<td>4,571.8 (2004)</td>
</tr>
<tr>
<td>GE Energy</td>
<td>Atlanta, GA</td>
<td>design, manufacture, maintenance of gas, nuclear, wind, and steam-driven plants</td>
<td>18,462.0</td>
</tr>
<tr>
<td>ChevronTexaco Corporation</td>
<td>San Ramon, CA</td>
<td>oil and gas production and refining, power generation</td>
<td>112,937.0</td>
</tr>
<tr>
<td>ConocoPhillips</td>
<td>Houston, TX</td>
<td>oil and gas production and refining, chemicals, fuels technology, power generation</td>
<td>104,196.0</td>
</tr>
<tr>
<td>BP p.l.c.</td>
<td>London, England</td>
<td>oil and gas production and refining, petrochemicals, specialty chemicals</td>
<td>232,571.0</td>
</tr>
<tr>
<td>Royal Dutch/Shell</td>
<td>The Hague, The Netherlands</td>
<td>Oil products, chemicals, renewable energy sources.</td>
<td>201,728.0</td>
</tr>
<tr>
<td>Exxon Mobil Corporation</td>
<td>Irving, TX</td>
<td>oil and gas exploration, production, supply, transportation, and marketing</td>
<td>213,199.0</td>
</tr>
<tr>
<td>Plug Power Inc.</td>
<td>Latham, NY</td>
<td>on-site power generation systems, proton exchange membrane (PEM) fuel cells</td>
<td>12.5</td>
</tr>
<tr>
<td>FuelCell Energy, Inc.</td>
<td>Danbury, CT</td>
<td>carbonate fuel cells and electrochemical engines</td>
<td>33.8</td>
</tr>
<tr>
<td>Global Thermoelectric Inc.</td>
<td>Calgary, Canada</td>
<td>thermoelectric generators that do not have moving parts</td>
<td>13.8</td>
</tr>
<tr>
<td>Idacorp, Inc.</td>
<td>Boise, ID</td>
<td>fuel cell design, coal mining</td>
<td>823.0</td>
</tr>
<tr>
<td>Teledyne Technologies Incorporated</td>
<td>Los Angeles, CA</td>
<td>hydrogen gas generators, thermoelectric and fuel cell power products</td>
<td>840.7 xiv</td>
</tr>
</tbody>
</table>

*Leading companies were chosen based on a number of factors, including overall size, strengths in innovative technologies/products, and importance within industry sub-sectors. This list is not intended to be comprehensive.*
The Middle East has declined slightly with respect to the rest of the world in crude oil production, with the difference being made up by Latin America, Asia, and the OECD (see figure xvi). However, although some new sources of oil have been discovered in the past thirty years (such as in the North Sea), and although some existing sources (such as the Canadian oil sands) have increased production thanks to new technologies, the overall geographic break-down of crude oil production has not changed significantly.

As figure xvii shows, although U.S. dependency on foreign oil has grown, the majority of our crude oil imports do not come from the Persian Gulf region. Fully half of U.S. crude oil imports come from the Western Hemisphere. In fact, of the top five suppliers to the U.S. of petroleum, only one, Saudi Arabia, is in the Persian Gulf (figure xviii). However, by the year 2020, the Persian Gulf is projected to supply between 54% and 67% of the world’s...
The US Oil and Gas Extraction Industry

“The United States is the most mature oil-producing region in the world, and much of our easy-to-find resource base has been depleted. Advanced exploration and production technologies of the past two decades have played a key role in recovering additional oil and natural gas from existing fields.”

---Source: U.S. Department of Energy, Energy Information Administration

### Major U.S. Oil and Gas Fields

- 80% of the proven U.S. oil reserves are concentrated in four states: Texas (24%), Alaska (22%), Louisiana (20%), and California (19%). U.S. proven oil reserves have declined by about 20% since 1990.
- The U.S. produces 9.4% of the world’s total of crude oil.
- Small independent businesses account for 50 and 65 percent, respectively, of domestic petroleum and natural gas production in the lower 48 states.

### Total Employment in the Oil and Gas Extraction Industry in the Two Largest Metropolitan Areas and the Four Largest States, 1993 - 2003 (in thousands)

![Graph showing total employment in the oil and gas extraction industry in the two largest metropolitan areas and the four largest states from 1993 to 2003.](image)

About 77% of the oil and gas extraction industry’s workforce is concentrated in California, Louisiana, Oklahoma, and Texas. Employment peaked in 1982, then 415,000 jobs were lost from 1982 – 1999. Employment is expected to drop by 28% from 2002 – 2012.\(^5\)

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\(^5\) US Department of Labor

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Although the petroleum industry is aging, it increasingly relies on high technology, especially for locating, extracting, and refining petroleum. Massive investments in research and development, both public and private, are crucial to success. Figure xxi shows public sector investments in R&D in key sectors of the petroleum industry in the US in the past two years.*

### International Clusters in the Energy Sector

<table>
<thead>
<tr>
<th>Country</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OPEC</strong></td>
<td>OPEC members include Iran, Iraq, Kuwait, Saudi Arabia, Venezuela, Qatar, Libya, the United Arab Emirates, Algeria, and Nigeria. OPEC members account for almost 40% of world oil production and about 2/3 of the world's proven oil reserves. Most OPEC members are in the Middle East, which holds 67% of the World’s known oil reserves.</td>
</tr>
<tr>
<td><strong>Canada</strong></td>
<td>Canada is the world’s 5th largest energy producer and the 8th largest energy consumer in the world. Canada exports 31% of its energy production. It is the main supplier of crude oil to the US, and it supplies the US with 90% of its natural gas imports.</td>
</tr>
<tr>
<td><strong>Russia</strong></td>
<td>Russia has the world’s largest natural gas reserves, the world’s second largest coal reserves, and the world’s eighth largest oil reserves. Russia is the world’s largest exporter of natural gas, the world’s second largest oil exporter, and the world’s third largest energy consumer.</td>
</tr>
<tr>
<td><strong>Mexico</strong></td>
<td>Mexico has the fourth largest proven crude oil reserves in the Western Hemisphere. Although Mexico is not a member of OPEC, it has at times worked in conjunction with the cartel to adjust global crude oil supplies.</td>
</tr>
<tr>
<td><strong>France</strong></td>
<td>France has made energy independence and environmental protection a policy priority since the 1970’s, and consequently is less dependent on oil than any other advanced nation except Canada. 78% of France’s electricity comes from nuclear power, and 11.5% comes from hydroelectric power. France is the world’s largest exporter of electricity.</td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td>Japan is the fourth largest energy consumer and second largest energy importer. Japan has an almost complete lack of exploitable natural resources, and must import almost all of its energy. 28% of Japan’s electricity is provided by nuclear power. Japan invests more government money into energy R&amp;D (especially in the nuclear sector) than any other country.</td>
</tr>
<tr>
<td><strong>China</strong></td>
<td>China is the world’s second-largest energy consumer, and the world’s largest producer and the world’s largest consumer of coal. China surpassed Japan in 2003 to become the world’s second-largest petroleum consumer. China has had an average of 7.2% annual growth in net electricity consumption in the past five years. China’s real GDP growth rate was 9.1% in 2003.</td>
</tr>
<tr>
<td><strong>Belgium</strong></td>
<td>Antwerp, Belgium is the world’s second-largest petrochemical cluster after Houston, Texas. More than 16 million tons of chemicals are produced in Antwerp each year.</td>
</tr>
</tbody>
</table>

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*Includes industries classified under NAICS codes 324110 (Petroleum Refineries), and 213112 (Support Activities for Oil and Gas Operations)
Hydroelectric power has fallen as a percentage of total world electricity generation since 1973, but as is mentioned further on in this report, it has grown significantly in certain individual countries. Renewable energy (represented in figure xxii as “other”) has grown by a factor of three, although it still represented only 1.9% of total world electricity generation in 2002. Nuclear power surged to 16.6% of world electricity generation in 2002, almost five times its 1973 level. Oil has dropped significantly, primarily because of cost. Although it is the oldest of the major energy technologies, coal continues to be used because it is cheap, plentiful, and available to developing countries without the technology or capital required for nuclear power.
Nuclear Power

Figure xxiv shows that energy production by hydropower and other renewables has remained constant, while energy production by oil has declined significantly. Energy production by nuclear power has risen significantly, despite the fact that no new nuclear power plants have been built since the early 1970s. The increase in energy output is due entirely to increased efficiencies and capacity utilization brought about by re-engineering and applying new technologies to existing plants. The decision not to build new nuclear plants was made for political, not economic, reasons - as figure xxv shows, nuclear power is very competitive as a source of electricity generation.

As we see in figure xxiii, almost 1/3 of all nuclear energy produced in the world is produces in the United States. However, the US is far from being the country in the world most committed to nuclear power, a title which goes to France, where nuclear power accounts for an incredible 78% of its domestic electricity generation (as opposed to 20% in the US). French commitment to nuclear power has allowed it to become the world’s largest exporter of electricity (the US is a net importer of electricity, almost all of which comes from Canada).
US Government R&D in nuclear power (both total nuclear [figure xxvi] and nuclear fusion [figure xxvii]) has fallen dramatically since its peak around 1979. The only country showing a significant upward trend in expenditures in nuclear R&D is Japan, which is the clear leader (they currently invest about $2.5 billion annually). The downward trend in government expenditures in nuclear fusion is particularly unfortunate, considering the enormous potential this technology has to provide safe, clean, reliable and plentiful energy in the future. A bright spot, however, is the ITER, a 500-MW experimental fusion power plant which is the result of years of collaboration between the European Union, Canada, China, Japan, Korea, Russia and the US.
Renewable energy accounts for about 6% of total energy consumption in the US. Of that 6%, 1% is solar, 47% comes from Biomass technologies (primarily alcohol fuels such as ethanol and technologies which free hydrogen for energy use), 5% is geothermal, 45% is hydroelectric, and 2% comes from wind power (figure xxviii). In figure xxix, the blue line shows that renewable energy consumption experienced relative growth in the early nineties and relative decline in the late nineties. Growth since the nadir in 2001 has brought renewable energy back roughly to the level it enjoyed in the early nineties. However, there is no evidence suggesting that renewable energy will overtake nuclear energy (at 8%, the next-largest component of US energy consumption) in the near future.
US government expenditures on renewable energy R&D has increased slightly since its low point in 1990, but is still only a fraction of the commitment that the US made to renewable energy R&D after the oil crises (figure xxx). Spending levels in other advanced countries is also stagnant. However, government spending in this area is likely to increase dramatically in the coming decades as western nations seek to increase their independence from external supplies of primary fuels and decrease their levels of pollution (especially greenhouse gases). Figure xxxi breaks down US government R&D in renewable energy into its components – solar, wind, ocean, biomass, geothermal, and hydroelectric.
Hydroelectric Power

Although hydroelectric power accounts for a small percentage of the world’s total energy production, it is a technology which is very well-suited for some specific countries, especially land-abundant countries like Canada, Brazil, the US, and Russia. Brazil relies on hydroelectric power for an incredible 82.7% of its electricity generation (figure xxxii). In Latin America overall, hydroelectric power increased from 7.2% of electricity production in 1973 to 20.1% in 2002. China has made hydroelectric power a key pillar of its energy strategy for the next century, and is currently constructing dams for hydroelectric use on a massive scale. Already China accounts for 10.8% of the world’s production of hydroelectric power, second only to the US at 13.1% (figure xxxii).

<table>
<thead>
<tr>
<th>Country</th>
<th>% of Domestic Electricity Generation by Hydro Power</th>
<th>% of World Hydro Power Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>58.3%</td>
<td>13.1%</td>
</tr>
<tr>
<td>China</td>
<td>17.6%</td>
<td>10.8%</td>
</tr>
<tr>
<td>Brazil</td>
<td>82.7%</td>
<td>10.7%</td>
</tr>
<tr>
<td>USA</td>
<td>6.4%</td>
<td>9.6%</td>
</tr>
<tr>
<td>Russia</td>
<td>18.4%</td>
<td>6.1%</td>
</tr>
</tbody>
</table>

% of World Hydro Power Production by Top Five Countries: 50.3%  

Fuel Cell Technology

Fuel cells convert hydrogen-containing fuels into electricity, and, like batteries, contain no moving parts. Since hydrogen is the most abundant element in the universe, this technology has the possibilities of creating virtually unlimited energy. Fuel cells are used both in stationary power generation facilities and in automobiles and portable electronic devices. Fuel cell technology will drive innovations in many other areas, as existing products are adapted to use fuel cells, and as new products based on fuel cell technology are invented. The industry is still in its infancy, and many challenges remain. However, significant interest and investment by both the private and public sectors guarantees that this area will grow rapidly in the coming years.

Large investments are required to establish hydrogen production facilities and a convenient hydrogen distribution system to serve the general public. In the near term, pilot hydrogen fueling facilities are being developed that are based on liquid hydrogen, natural gas (steam methane reforming), and electricity (electrolysis). As an alternative, some manufacturers are considering using fuel reformers to allow fuel cell vehicles to use conventional fuels or chemical hydrogen storage.  

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6 International Energy Agency
7 US Environmental Protection Agency
Basic Diagram of a Fuel Cell

All fuel cells contain two electrodes - one positively and one negatively charged – with a substance that conducts electricity (electrolyte) sandwiched between them.

**Take-aways:**

- The oil industry, while continuing to be the most important energy sector globally, is in a long-term decline in the United States.
- Fuel cells, nuclear fusion, and other alternative energy sources relying on high technology promise rapid growth.
- The energy industry, especially the fossil fuel industry, is characterized by large, multinational companies because of the large capital investments required.
- The rise of new economic powers such as India and China will increase the demand for energy from both traditional and novel sources.
- Although still small compared to fossil fuels, renewable energy has tripled as a percentage of global electricity generation in the last three decades.
- The energy sector is truly global, with some of the most exciting opportunities and research and development happening outside of the US.

**Impact on ASME Corporate Services:**

- The ASME Corporate Services Unit’s existing Homeland Security activities could serve as a bridge to the emerging national security discussions of independence from foreign sources of energy.
- Partnerships should be considered with the US Department of Energy, the EPA, the FERC, the Department of the Navy, and other government actors.
- An ASME Science Advisory Board should be expanded to include a working group focused on leveraging emerging technologies for traditional industries.
Traditional Industry Cluster Maps
Location of US Energy and Pressure Equipment Clusters

Key to Clusters

Tier 1: ○ Tier 2: ○

Energy
Pressure Equip.
Location of Energy and Pressure Equipment Clusters in Europe

Key to Clusters

Tier 1: Energy

Tier 2: Pressure Equip.
Global Landscape of Energy and Pressure Equipment Clusters

Key to Clusters

Tier 1: ☺ Tier 2: ☺ Tier 3: ☺

Energy ☺
Pressure Equip. ☺
Emerging Industries

Water Management Technology

National and Homeland Security

Computing Hardware & Software

Bioscience and Pharmaceuticals
# Water Management Technology

## Baseline

<table>
<thead>
<tr>
<th>Cluster Definition</th>
<th>Industry Segments</th>
<th>US Clusters</th>
<th>Global Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td><strong>STeady Growth</strong>&lt;br&gt;- Dam engineering&lt;br&gt;- Water turbines&lt;br&gt;- Hydroelectric power generation and distribution systems</td>
<td><strong>Tier One</strong>&lt;br&gt;- Chicago&lt;br&gt;- Los Angeles&lt;br&gt;- Dallas&lt;br&gt;- San Diego&lt;br&gt;- Houston</td>
<td><strong>Tier One</strong>&lt;br&gt;- Germany&lt;br&gt;- France&lt;br&gt;- Canada</td>
</tr>
<tr>
<td></td>
<td><strong>In Transition</strong>&lt;br&gt;- Purification equip &amp; technology&lt;br&gt;- Desalination &amp; filtration systems</td>
<td><strong>Tier Two</strong>&lt;br&gt;- Minneapolis&lt;br&gt;- Boston&lt;br&gt;- Atlanta</td>
<td><strong>Tier Two</strong>&lt;br&gt;- Japan&lt;br&gt;- Israel&lt;br&gt;- South Africa&lt;br&gt;- Australia</td>
</tr>
<tr>
<td></td>
<td><strong>Emerging</strong>&lt;br&gt;- New water recycling technology&lt;br&gt;- Water system modeling</td>
<td><strong>Tier Three</strong>&lt;br&gt;- Portland&lt;br&gt;- St. Louis&lt;br&gt;- Denver</td>
<td><strong>Tier Three</strong>&lt;br&gt;- China&lt;br&gt;- Brazil&lt;br&gt;- Saudi Arabia&lt;br&gt;- Czech Republic&lt;br&gt;- Russia</td>
</tr>
</tbody>
</table>

*Note: Tier selections were determined by analyzing regional output, size of local market and through background research on potential future growth including a review of physical infrastructure, technology inputs, financial markets and human capital.*
Global Profile

Water Management is estimated to be $1.9 trillion industry globally and its average annual growth over the last two decades has exceeded 7%; over the last five years growth has exceeded 11% annually. This growth is not only a result of on-going demand to service the needs of an expanding global population but also the redirection of resources by nations and communities to improve outdated water management and servicing systems.

Large scale hydroelectric projects are underway throughout Asia and parts of the Middle East and Latin America. Current demand from China, India, Laos, Thailand, Brazil and Chile alone will produce an increase in economic activity of 5% over last years global output. Fueled by a growing demand for power, expanding national wealth, and a landscape rich with rivers these nations will likely continue to expand their hydroelectric infrastructure well into the first half of the century. The manufacturers and developers of these systems tend to be clustered in North America and Europe, and to a lesser extent in Japan.

In terms of preexisting construction Western Europe and North America have by far the largest hydroelectric infrastructures which has lead to the creation of a sophisticated hydro-engineering service industry in both continents. Engineering consulting firms that service larges scale hydropower generation and water distribution systems have experienced a steady increase in demand over the last ten years. Since 1999 the industry has grow approximately 16% annually.

Investments in desalination and filtration technologies are also on the rise. Desalination of seawater and wastewater is experiencing 20 percent annual growth. There are currently 13,000

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desalination plants in operation in 120 countries. The market is expected to grow from its current size of roughly $2 billion to $70 billion by 2010\textsuperscript{10}. Population growth and the demand it creates for drinking water and - even more significantly - agricultural output is actually increasing the gap between the demand and supply of fresh water. This shortage is particularly acute in the arid zones of the world in the Middle East and North Africa, where rapid urbanization is exerting increasing pressure on already limited resources.

That said, the demand for these systems is not restricted to the world’s most parched environments. Even cities in water rich nations and with highly developed infrastructures have begun to take a serious look at making large investments in desalination technologies. In the US, communities in Nevada, California, and Texas have all begun to pursue new approaches and technologies to meet their growing demands for fresh water. In Northern Texas, several cities have begun to study the feasibility of installing desalination systems to treat water trapped below the ground in large saline aquifers.

As the technology continues to advance and the cost of water systems and their installation begins to drop, the demand for desalination and filtration technologies will begin to accelerate. Demand for such systems is assured into the near future as governments and large NGOs begin to focus investments on technologies and infrastructures that provide greater access to clean water and more efficient irrigation of agricultural lands.

Water treatment and recycling systems are also critical components of a society’s water system and investments in the installation and upgrade of these infrastructures has been rising. Recent advances in membrane technologies have opened up new opportunities for improving the supply of fresh water to water-poor cities and improve the efficiency of community water management systems.

**Science & Technology**

*Turbine Technology*

New developments in turbine engineering and harsh-environment devices including sensors and actuators have begun to open up new opportunities to improve the efficiency and reduce the cost of operating hydroelectric dams. Cost and energy efficiency will continue to be key issues in the marketability and continued adoption of hydroturbine systems. Engineering advances that improve turbine operability and expand capabilities will be a strategic priority for hydroturbine companies.

*Recycling Systems*

Recycling technologies, particularly for irrigation systems, hold perhaps the best near term solution to global water shortages and offer the greatest business opportunities. Because agriculture accounts for two-thirds of water use worldwide, even small-percentage reductions can free up substantial quantities of water for cities, ecosystems, and additional food production. Farmers in northwest Texas, for example, who have had to cope with falling water tables from depletion of the Ogallalla aquifer have reduced their water use by 20 to 25 percent by adopting

\textsuperscript{10} Sustainable Asset Management, “Investment Opportunities in the Water Sector” (2001).
more efficient sprinkler technologies, special valves to ensure even water distribution, and other water-saving practices.

Desalination

The last ten years has also seen some strong advances in water purification and desalination technologies. In particular, there has been a great deal of innovation in the areas of semi-permeable membrane technology, thermal purification methods and concentrate management. These areas are becoming the targets of research and development by both private industry and government.

Private industry is also stimulating strong demand for the technology. Semiconductor manufacturers and research labs require large quantities of high purity reagents and ultrapure water. This need has stimulated demand for purification technologies to remove contaminants from both water and other liquid reagents. Since 1998 demand for modular deionization, distillation and reverse osmosis instruments has been growing by 8% a year. Facilities that fabricate and manufacture semiconductors are the fastest growing purchasers of high end pretreatment systems.

Nanoscience maybe beginning to shape the future desalination technologies. Nanotubes, electrically charged microtubules that use electrostatic technology to adsorbed sodium and chlorine ions, hold promise as a cost effective way to develop a decentralized water desalinization infrastructure. The technology – still in development – is being funded by the US Department of Defense.

<table>
<thead>
<tr>
<th>Some Leading Companies</th>
<th>Location</th>
<th>Markets/Technology Strengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duke Energy</td>
<td>Houston/Charlotte</td>
<td>Hydroelectric generation &amp; distribution</td>
</tr>
<tr>
<td>Alstrom</td>
<td>France</td>
<td>Steam power &amp; micro-turbines</td>
</tr>
<tr>
<td>Voith-Seimens</td>
<td>Germany</td>
<td>Turbine engineering &amp; generator manufacturing</td>
</tr>
<tr>
<td>GE Hydro</td>
<td>Quebec</td>
<td>Hydro turbines &amp; generators</td>
</tr>
<tr>
<td>Maven</td>
<td>Czech Republic</td>
<td>Turbine design &amp; system architecture</td>
</tr>
<tr>
<td>Vivendi</td>
<td>France</td>
<td>Large water purification &amp; distributions systems</td>
</tr>
<tr>
<td>WGS International</td>
<td>San Diego</td>
<td>Reverse Osmosis technology &amp; desalination systems</td>
</tr>
<tr>
<td>Pure Aqua Inc.</td>
<td>Los Angeles</td>
<td>Membrane processes; Ion exchange system</td>
</tr>
<tr>
<td>Life Stream Corp</td>
<td>Irvine, CA</td>
<td>Desalination &amp; filtration technologies</td>
</tr>
<tr>
<td>Technoqua Systems</td>
<td>West Palm Beach</td>
<td>Ultrafiltration, Nanofiltration &amp; Microfiltration</td>
</tr>
<tr>
<td>Weir Techna</td>
<td>South Africa</td>
<td>Thermal processes; Biological treatment</td>
</tr>
<tr>
<td>GEA Wiegand</td>
<td>Germany</td>
<td>Evaporation &amp; crystallization technologies</td>
</tr>
</tbody>
</table>

Note: Companies were selected based on a combination of factors including revenues, market share, patents, and effective leveraging of new technologies. The list is not ranked.
Emerging markets

Hydroelectric System Maintenance &Troubleshooting

Although the manufacture and installation of water management systems is dominated by a small group of large scale developers in the US, Canada, Europe and Japan there has been steady growth in smaller companies that specialize in the maintenance and service of water management systems. Engineering service firms that provide technical, engineering and scientific support to the users and manufacturers of hydroelectric generators are growing throughout the United States, Canada and Europe. Brazil and China have extensive hydroelectric infrastructures and are also stimulating demand for such services. Furthermore, companies that specialize in maintaining and upgrading municipal water treatment facilities should experience strong demand for next generation membrane and filtration equipment. Interestingly, the global soft drink is driving much of the demand for new membrane technology as they build and expand production systems that allow them to manufacture a consistent taste for their products.

More and more these small and mid-sized firms are servicing an expanding global market. As much as 70% of the service and maintenance operations of the hydroelectric systems in China and Brazil are outsourced to firms in North America and Europe. Firms that specialize in troubleshooting of generator failures and conducting the engineering associated with upgrading equipment - from nuts and bolts, copper and insulation, to advanced research and development of generating equipment – will likely continue to see expanding opportunities in the global marketplace.

Take-aways:

- Steady global demand for hydropower and the planned construction of new hydroelectric dams will lead to expanding opportunities for engineering service and consulting firms specializing in the maintenance of turbines and power distribution systems.
- Governments and industry will likely continue to invest heavily in membrane and other pretreatment technologies. This should open up opportunities for universities and laboratories to expand research activities in feeder technologies like advanced materials, testing equipment, MEMS, and nanotechnology.
- Optimization and systems modeling software are in high demand by public utilities and municipal governments trying to improve the productivity of their water management systems. This drive for greater efficiency not only presents opportunities for systems engineers but developer and designers of ultra-efficient water treatment mechanisms and distribution systems.

Impact on ASME Corporate Services:

- The myriad activities in water technologies are fragmented and require an aggregating forum to discuss and prioritize the water industry opportunities for engineering services.
- ASME Corporate Services should form a working group focused on International Water Technologies and Standards.
National and Homeland Security

Baselines

<table>
<thead>
<tr>
<th>Cluster Definition</th>
<th>Industry Segments</th>
<th>US Clusters</th>
<th>Global Clusters</th>
</tr>
</thead>
</table>
| This industry includes all products, services and technologies related to the development of systems to identify, monitor, and suppress activities associated with terrorism and breaches of national and global security. It also includes the research and development of such products, systems and underlying technology. | **STEADY GROWTH**  
- Wireless devices  
- Thin display devices  
- Network design  
- Miniature sensors  
- Geospatial mapping  
- Data mining  
- BioScience  
**IN TRANSITION**  
- Embedded systems  
- Knowledge Mgmt Technologies  
- Portal Technologies  
**EMERGING**  
- Network design  
- Nanotechnology  
- Robotics & remote devices  
- Cryptology & Cybersecurity | **TIER ONE**  
- New York  
- Washington D.C.  
- Los Angeles  
- San Francisco  
- Boston  
- Houston  
- San Diego  
**TIER TWO**  
- Seattle  
- Research Triangle  
- Dallas  
- Chicago | **TIER ONE**  
- Germany  
- France  
- Israel  
- United Kingdom  
**TIER TWO**  
- Japan  
- South Korea  
- Switzerland  
- Canada  
**TIER THREE**  
- Taiwan  
- Mexico  
- Chile |

Note: Tier selections were determined by analyzing regional output, size of local market and through background research on potential future growth including a review of physical infrastructure, technology inputs, financial markets and human capital.
### Key Trends and Issues

<table>
<thead>
<tr>
<th>Trend</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increased Miniaturization</td>
<td>Products and devices will continue to shrink in size as both preventative and response systems focus on tracking and surveillance.</td>
</tr>
<tr>
<td>New Product Platforms</td>
<td>Traditional platforms for both wireless and hard-wired systems will continue to be modified by grafting information technology onto existing weapons to transform their capabilities or by developing new simplified interfaces that better exploit advances in information technology.</td>
</tr>
<tr>
<td>Reliance on Network Technology</td>
<td>Governments and government coalitions have begun to focus on the development of open architectures and standard interfaces to better link previously disparate defense systems and reduce the time between the observation of a threat and response.</td>
</tr>
<tr>
<td>Emphasis on R&amp;D</td>
<td>Research and development, particularly early-stage basic research, is defining the parameters the industry because much of national security planning is still in the concept-development stage. Playing an active role in R&amp;D will not only help firms determine how the basic concepts of new technologies and their applications will evolve, but also acclimate them to how program contracts will be structured within the web of agencies and departments that will shape homeland security.</td>
</tr>
</tbody>
</table>

### Global Profile

Companies and industries specializing in the development and commercialization of security technologies were well established even prior to 9/11. Extensive national security infrastructures have existed for decades in many nations and governments have long devoted significant portions of their national budgets to the development of security and safety technologies. However, the scale of that activity drastically increased after terrorist bombing of New York and the Capitol. The U.S. Federal government estimates global demand for security products and services will triple by the year 2010 reaching nearly $400 billion; research and development is expected to account for roughly one tenth of that total. That demand includes not only procurements by government agencies but also investments by private industry—where cybersecurity technology is currently a top priority. The security cluster – both in terms of production and research - is concentrated primarily in the United States and Europe; although, Canada, South Africa and Israel have sizable security industries as well.

In the United States the Department of Homeland Security has $40 billion budget, of which roughly $1.2 billion is in R&D. The amount of R&D spent on homeland security across all federal agencies is currently approximately $10 billion. The programs and areas receiving the largest line items include Project BioShield (to buy cutting-edge drugs, vaccines, and other medical supplies for biodefense), the nation’s aviation system (for the development of a state-of-the-art screening infrastructure), the Container Security Initiative (focuses on systems for pre-screening and tracking cargo) and biosurveillance (for air monitoring of biological agents in high-threat cities and high-value targets such as stadiums and transit systems). The Support Anti-Terrorism by Fostering Effective Technologies, or the Safety Act, is the mechanism through which most of the departments research is channeled.

In Europe members of the EU have laid out a plan to create a European Security Research Programme (ESRP) to manage and coordinate security among member states. The ESRP would devote roughly $1 billion a year for research in security-related technologies, which would
supplement current security research efforts underway by individual member states which itself totals about $600 million.

Within the private sector much of the intellectual property driving current security technologies resides in large airline and defense companies like Teledyne Technologies, Northrop Grumman, Seimens, and Airbus. However, there has been a strong surge in entrepreneurial activity over the last two years within the IT and software sectors of the industry. Wireless and bioscience related technologies are also showing some strong growth within the small business community. The challenge for smaller companies will be in maneuvering the procurement bureaucracy for position to capture government contracts.

**Science & Technology**

*RFID-based tracking technologies*

The illegal use of shipping containers to transport weapons or weapons building material has become a primary concern of the Department of Homeland Security. The US government as well as the European Union and Japan have begun to plan for large scale investments to build nation-wide systems to track the movements and scan the contents of shipping containers within their boarders. These systems will likely built on a foundation of radio frequency identification (RFID) and global positioning system (GPS) technologies. GPS is experiencing fast growth in the private sector market and RFID has already been adopted by much of the defense department which uses the technology to monitor the flow of material moving between depots, bases, and war zones.

As of this year, through its Free and Secure Trade initiative, the Customs and Border Protection Bureau within Homeland Security has already begun using RFID tags to identify freight trucks as they cross the border with Canada. The federal government predicts that the market for so-called “smart containers” will grow from $40 million today to $2.1 billion by 2012.

*Pattern Recognition Capabilities*

Pattern recognition software and devices both for fingerprinting and facial recognition systems is expected to experience large increases in research spending. Over the next ten years airports and other tourist gateways will be increasingly outfitted with computers that can perform two key pattern-recognition tasks: positive identification of individuals for granting access to privileged resources (bioinformatics), and rapid recognition of suspects in a crowd for law enforcement agencies.
<table>
<thead>
<tr>
<th>Some Leading Companies</th>
<th>Location</th>
<th>Markets/Technology Strengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAE Systems</td>
<td>Sunnyvale, CA</td>
<td>chemical, radiation and biological sensors</td>
</tr>
<tr>
<td>Computer Science Corp.</td>
<td>Los Angeles</td>
<td>Biometrics and smart-card technologies</td>
</tr>
<tr>
<td>PEC Solutions Inc.</td>
<td>Fairfax, VA</td>
<td>Biometric identifiers; pattern recognition technology</td>
</tr>
<tr>
<td>Titan Corporation</td>
<td>Washington DC</td>
<td>Wireless information and communication systems</td>
</tr>
<tr>
<td>Microsoft</td>
<td>Seattle</td>
<td>Network management software; mobile device platforms</td>
</tr>
<tr>
<td>Boeing</td>
<td>Seattle/Chicago</td>
<td>Explosives-detection machines; chemical-trace detectors</td>
</tr>
<tr>
<td>Northrop Gruman</td>
<td>Los Angeles</td>
<td>Micro video surveillance devices &amp; network-enabled integrated systems</td>
</tr>
<tr>
<td>Lockheed Martin</td>
<td>Bethesda, MD</td>
<td>Intelligence, Surveillance &amp; Reconnaissance (ISR) systems</td>
</tr>
<tr>
<td>Siemens</td>
<td>Germany</td>
<td>Precision electronics ; redundancy systems</td>
</tr>
<tr>
<td>Airbus Military</td>
<td>France</td>
<td>Logistic management systems ;</td>
</tr>
<tr>
<td>EADS</td>
<td>Germany</td>
<td>unmanned reconnaissance systems; on-board sensor technology</td>
</tr>
<tr>
<td>Israel Aircraft Industries</td>
<td>Israel</td>
<td>Integrated boarder defense systems; movement detection technology</td>
</tr>
</tbody>
</table>

Note: Companies were selected based on a combination of factors including revenues, market share, patents, and effective leveraging of new technologies. The list is not ranked.

**Emerging opportunities**

**Robotics & Remotely-operated Search & Detection Systems**

National utility systems and power grids are the Achilles heel of communities trying to build terrorist-resistant cities. Although distributive power networks offer perhaps the best long term solution to reducing vulnerability to large scale power failures, their development and installation is still years off. In the near term there will be much more emphasis on building intelligent systems that can immediately recognize power system failures and reroute electricity from still-functioning generators. These “power electronics” devices can help automate the flow of electricity and smooth out unwanted fluctuations. Sophisticated switches can detect lightning-speed spikes in power voltage and turn themselves on and off fast enough to tame them and let controllers redirect excess power. Using these new power processors engineers will be able to shunt power from one line to another at the touch of a button. In emergency situations, the new devices should help grid managers switch seamlessly between primary and backup generating stations and transmission lines, minimizing the effects of attacks on individual facilities.

There will also be increased attention given to improving security and safety systems at nuclear power facilities and their fuel suppliers. Robotics technology is being relied more and more for scanning and detection of contamination in the harsh environments of nuclear reactors. Recent breakthroughs in nanotechnology also hold promise as detection and neutralization devices.
Take-aways:

- Understanding the nuances of government security protocols and harnessing the ability to quickly adapt to the evolving maze of cross-agency regulations within the Homeland Security Department will be key for smaller engineering companies trying to compete with the large defense contractors for HSD contracts. One option for small firms will be to form development teams and partner with larger defense companies as subcontractors.

- Bioscience, IT and nanotechnology are likely to be the key enabling technologies for next generation national security systems. Mobile sensors and devices that can detect and neutralize biological threats and relay that information to a security information network will be the highest priority for the DHS. Also a high priority will be system and network software that can bring structure to the management of resources and programs.

- Pattern recognition applications, network management software, and cryptology tools are capturing the majority of IT-related research dollars within defense and homeland security. Both government and the private sector will likely continue scaling up research in these areas but will impose ever greater pressure on providers to quickly move the technology out of the development stage and into the field.

Impact on ASME Corporate Services:

- Capture the current process by which ASME’s Corporate Services Unit has approached and organized its DHS relationship as a framework for other clusters and institutionalize the critical elements of success.

- Identify the 7 – 9 key states where both homeland security issues are aggregated, and industry strength to serve those demands is located.

- A consortium of ASME chapters can organize industry in these key states to meet homeland security demands.
The computer hardware and programming cluster includes all activities related to the design, development and manufacture of computer systems and their component parts and devices. It also includes all software programming designed for both digital and analog systems.

<table>
<thead>
<tr>
<th>Cluster Definition</th>
<th>Industry Segments</th>
<th>US Clusters</th>
<th>Global Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEADY GROWTH</td>
<td>• Computing &amp; Networking hardware • Application • Wireless systems • Storage devices</td>
<td>TIER ONE</td>
<td>TIER ONE</td>
</tr>
<tr>
<td>IN TRANSITION</td>
<td>• Lithography • Peer-to-peer • Displays • Open source OS</td>
<td></td>
<td>Germany • United Kingdom • Sweden • Finland • Singapore • Japan • India</td>
</tr>
<tr>
<td>EMERGING</td>
<td>• Modular applications • Computer science applications</td>
<td>TIER TWO</td>
<td>TIER TWO</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>China • Israel • Taiwan • South Korea • Canada</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>TIER THREE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Poland • Romania • Brazil • Russia • South Africa</td>
</tr>
</tbody>
</table>

Note: Tier selections were determined by analyzing regional output, size of local market and through background research on potential future growth including a review of physical infrastructure, technology inputs, financial markets and human capital.
**Global Profile**

In many ways the computing industry is the tale of two industries. Much of the hardware component of this industry is entering into a mature phase in terms of its manufacture. The assembly of computer systems and circuitry boards has become quite automated and economies of scale are driving the development of large production facilities throughout the globe and particularly in Asia.

However, new breakthroughs in chip design technologies and recent advances in system architecture and distributed intelligent systems have led to the development of a variety new product lines and manufacturing processes that are stimulating new demand. In particular, entertainment systems and their underlying software have been experiencing exceptional and consistent growth over the last seven years. The growth in sales of gaming systems and new music and video applications has fueled triple digit export growth in Japan (home gaming systems) and Scandinavia (mobile phone platforms).

On the cutting edge there are also a host of technologies that are seeking applications. Research in computer science and computing devices remains strong. Universities and private industry have expanded research in several key areas including chip design, distributed computing, and pattern recognition programming.

One striking phenomena is how the geography of the software and IT industries has changed; it is no longer centered on Silicon Valley. The new landscape is the result of two distinct shifts that are reshaping the business. For some time, its centre of gravity has been moving away from the Valley to places such as Seattle, Austin, Armonk and Walldorf (in Germany), where four industry leaders—Microsoft, Dell, IBM and SAP, respectively—are based.

At the same time, large parts of the business are migrating offshore, mainly to India, but also to such places as China, Russia and Vietnam. This is already being likened to what happened to
manufacturing in the 1970s and 1980s, when companies in the rich world moved many of their operations overseas. The IT industry is now developing something that it has not had before (except in hardware manufacturing): a fully operational, international supply chain.

Science & Technology

Photolithography & micromirrors

Photolithography - the standard manufacturing technique for making computer chips – has become extremely expensive over the last ten years and efforts to improve efficiency and reduce cost have become a priority for large chip designers like Intel. A significant part of that cost is the stencil-like "masks" that filter the light beam used to pattern millions of transistors onto a chip.

However, recent improvements in micromirror technology are leading to more productive techniques for photolithography and ultimately possibly eliminating the need for masks all together. With micromirrors designers can simply reprogram the light arrays and make the fabrication of customized chips for things like synthesizing speech in toys, MP3 players, handheld computers, and processors much more cost effective.

Micromirror technology is well suited for patterning the chambers and channels that help process biological samples in microfluidic chips, which could be used for drug discovery or in handheld diagnostic devices.

Distributed programming and decentralized databases

On-going improvement in processing speeds has continued to increase the appetite for capabilities and devices to analyze of large and complex datasets. Large super computers are out of the reach of the budgets of many organizations that would like to run programs on mammoth datasets including meteorological and genetic databases. Companies and universities are increasingly looking to distributed programming techniques and the internet to meet their data collection and number crunching needs. By adding definition tags to information in Web pages and linking PC across an organizations computer infrastructure – no matter how vastly distributed - computers can isolate, collect, process, and maintain data more efficiently and form new associations between pieces of information, in effect creating a globally distributed database and processing system.

Distance Learning

After much hype and ballyhooing distance learning finally appears to be transitioning from provocative idea to real market opportunity. Primarily in the United States but expanding in East Asia too, education institutions have begun to incorporate distance learning into their curriculum. The interest is not limited to universities as primary and secondary schools have also begun to use such systems to help build collaborative programs with colleges and other schools. The result has been that over the last five years there has be 65% increase in the purchases of technology,
software and systems dedicated to delivering lessons via the Internet, television, videotape, CDs, and radio.

<table>
<thead>
<tr>
<th>Some Leading Companies</th>
<th>Location</th>
<th>Markets/Technology Strengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>PeopleSoft</td>
<td>San Jose</td>
<td>ERP; cross-platform communication software</td>
</tr>
<tr>
<td>NetEffect</td>
<td>Austin</td>
<td>InfiniBand networks</td>
</tr>
<tr>
<td>Sonera</td>
<td>Finland</td>
<td>Mobile handsets; telecommunication software</td>
</tr>
<tr>
<td>Toshiba</td>
<td>Japan</td>
<td>Digital video platforms (Blu-Ray &amp; HD DVD)</td>
</tr>
<tr>
<td>RealNetworks</td>
<td>Seattle</td>
<td>Streaming video; VOIP;</td>
</tr>
<tr>
<td>SAS</td>
<td>Research Triangle</td>
<td>Statistical application software</td>
</tr>
<tr>
<td>BEA Systems</td>
<td>San Jose</td>
<td>Enterprise infrastructure &amp; productivity software</td>
</tr>
<tr>
<td>LGPhillips</td>
<td>South Korea</td>
<td>Thin display technology; durable mobile displays</td>
</tr>
<tr>
<td>Infosys Technologies</td>
<td>India</td>
<td>High-end business applications; financial service software</td>
</tr>
<tr>
<td>EMC</td>
<td>Boston</td>
<td>Storage hardware; RAID systems</td>
</tr>
<tr>
<td>Robert Bosch</td>
<td>Germany</td>
<td>Platforms for remote sensors &amp; actuators</td>
</tr>
<tr>
<td>Maxtor</td>
<td>Singapore</td>
<td>Magnetic discs; polymer storage technology</td>
</tr>
</tbody>
</table>

Note: Companies were selected based on a combination of factors including revenues, market share, patents, and effective leveraging of new technologies. The list is not ranked.

Emerging Technologies

Gesture recognition technology

Gesture recognition technology has been the focus of the video gaming industry for years. Research into the technology by Sony and Microsoft alone has shaped the creation of this small sub-industry. Recently both the automotive and medical industries have begun to invest in the research. Last year the U.S. Army contracted with a company to create a gesture-based computerized training system. Further military applications are likely given the priorities and funding of the Department of Homeland Security.

Chemically assembled circuits

Many researchers believe that the ability to continue to shrink silicon-based devices is likely to grind to a halt somewhere around 2010. Finding cost effective alternatives to manufacturing processors is a hot priority among chip manufacturers. Several chip firms believe computing will one day rely on nanometer-scaled components cheaply and easily assembled using simple chemistry. Instead of today's technique of precisely carving features onto silicon chips to create complex and near-perfect patterns, technicians will dip substrates into vats of chemicals. And if the mix is right, wires and switches will chemically assemble themselves from these materials. It would make possible tiny, inexpensive and immensely powerful computers. Several prototypes and working models have been developed.
Take-aways:

- Computing hardware manufacturing has quickly become a mature industry but new chip design techniques and advanced material technology are beginning to infuse hardware fabrication processes with new cost-competitive options for mass assembly. Technologies linked to MEMS, advanced materials, and nanoscience are driving the evolution.

- Entertainment devices and their applications will continue to face strong demand over the next decade. As voice and gesture recognition technologies improve gaming capabilities, entertainment devices will continue to evolve into more elaborate systems with multiple interfaces. Development of these high-end systems is underway despite a shortage of skilled designers and programmers with experience in digital recognition technologies.

- Globalization will continue to shape both hardware manufacturing and software development. These activities will continue to be spread more evenly over the global landscape as regions continue to develop core capabilities and niche markets. Companies are aggressively pursuing strategies to leverage the distinctiveness of a region’s culture and history as sources of product and service innovation.

Impact on ASME Corporate Services:

- ASME Corporate Services should consider creating an investment fund partnership or a joint venture (such as an ASME Cluster Venture Fund) that allows its clustered membership to take advantage of the profound new technology applications attracting industry attention.

- Corporate Services must lead the discussion and realignment of clustered membership mindset around design and innovation supply chains to leapfrog past the current branding position of the Institute of Electrical and Electronics Engineers (IEEE).
The industry consists of all research, development, commercialization and production of drugs and treatments related to the identification, mitigation and prevention of diseases, infections and medical problems. This includes industries focusing on drug development and/or the development of medicines that rely on the manipulation of genes and proteins.

**Baseline Table**

<table>
<thead>
<tr>
<th>Cluster Definition</th>
<th>Industry Segments</th>
<th>US Clusters</th>
<th>Global Clusters</th>
</tr>
</thead>
</table>
| **STEADY GROWTH**  | • Functional Genomics  
                      • Bioinformatics  
                      • Proteomics  
                      • Pharmacology  
                      • Toxicology  
                      • Biomolecular Screening | **TIER ONE**  
San Diego  
Boston  
Research Triangle  
Philadelphia  
San Francisco  
New York | **TIER ONE**  
United Kingdom  
Germany  
Canada  
France  
Switzerland |
| **IN TRANSITION**  | • Drug manufacturing  
                      • Tissue engineering  
                      • Stem cell research  
                      • Drug delivery technology | **TIER TWO**  
Seattle  
Los Angeles  
Minneapolis  
Austin  
West Palm Beach | **TIER TWO**  
Japan  
Ireland  
Israel  
Netherlands  
Scotland  
Australia |
| **EMERGING**       | • Microarrays  
                      • RNA interference  
                      • Transgenic research | **TIER THREE**  
Brazil  
China  
Singapore  
Hong Kong  |

Note: Tier selections were determined by analyzing regional output, size of local market and through background research on potential future growth including a review of physical infrastructure, technology inputs, financial markets and human capital.
Key Trends and Issues

<table>
<thead>
<tr>
<th>Industry Capacity</th>
<th>Producers—biopharmaceutical companies and contract manufacturers alike—are now tripling their production capacity, but new plants take three to five years to design, build, and certify. Demand is likely to outstrip supply during that time. Even at a cost of some $300 million to $500 million a plant, expansion is warranted.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emerging Market</td>
<td>Among the most promising of the new drugs filling the pipelines of pharmaceutical and biotechnology companies are compounds produced by live, genetically modified microbial or animal cells. Over the next five years, the revenues generated by protein-based therapeutics are set to grow at 15 percent a year, about twice the rate of the rest of the pharmaceutical industry.</td>
</tr>
<tr>
<td>Workforce Shortage</td>
<td>The industry faces a looming shortage of the highly trained people needed to design, build, and operate facilities. Experienced process-development scientists and engineers, validation engineers, quality assurance personnel, and plant managers are all in short supply.</td>
</tr>
<tr>
<td>New tools increase innovation &amp; productivity</td>
<td>In recent years a variety of powerful new tools and technologies has become available for life scientists, enabling them to make key advances and discoveries in biotechnology, drug discovery, and other industrial and academic fields. Tools such as DNA and protein arrays, short interfering RNA (siRNA), stem cells, and methods of transferring genes from one species to another, combined with high throughput instruments and other systems for laboratory automation, have increased productivity in many laboratories.</td>
</tr>
</tbody>
</table>

Global Profile

Since the completion of the human genome project the biotechnology industry has grown from a fragmented collection of companies and universities focusing on disparate research agendas to a full-blown industry attracting over $100 billion in investment capital and opening up an array of new opportunities in medical research and treatment. The industry is populated primarily with small and mid-sized companies with very specific research and technical capabilities. The biotechnology industry is strongest in the United States and Western Europe; however, niche markets are beginning to emerge in the Pacific Rim and Latin America.

The pharmaceutical industry by comparison is much larger and controls a much vaster portfolio of both physical assets and intellectual property. The industry is dominated by large corporations clustered primarily in the east and west coasts of North America and in Western Europe. The last few years has seen some strong growth in generic drug manufacturing in parts of Asia and Latin America.

In a new product environment dominated by a host of me-too drugs and tweaked treatment regimens, basic science will likely play an increasingly important role in directing industry movements. For manufacturers of drugs this will require evermore flexible production processes and adaptable supply networks. Drug makers in Latin America and parts of Asia, in particular, will need to maintain strong and rich relationships with their suppliers and scientists in North America and Europe.

Industry will continue to urge more discipline and greater efficiency in its drug science activities. Drug discovery holds greatest promise when there is strong alignment between curiosity-driven activities and market-driven objectives. There will be a growing impetus by industry to bring an
entrepreneurial ethic and greater manageability to the research mission at both university and corporate labs. Of particular value will be technology that allows researchers to quickly and cost-effectively validate drug targets and increase throughput coefficients.

Furthermore, drug discovery firms, their supplier and investors are beginning to move aggressively to minimize their risk exposure to unproven technologies. Risk management planning is fueling the creation of more strategic collaborations between basic science labs and development activities. The most common collaborations link research institutes with early-adopters of new products and technologies. In such partnerships proximity is a competitive advantage and is why biotech and drug discovery firms locate near medical research centers and universities. Bioscience research parks, anchored by a strong university lab, are emerging in almost every life science market across the globe.

IT technologies have made long-distance collaborations much more productive particularly among scientist, but these partnerships are most effective when connecting groups that function at the same part of the commercialization continuum: researchers with researchers, developers with suppliers. These partnerships will continue to grow and be less hindered by geography. As researchers from across the world work together in extended teams, so do individuals in the companies that develop the tools to support life science research. With the world continuing to grow smaller through the Internet and other innovations, the power of partnerships in the laboratory and in businesses continues to expand.

Science & Technology

Tissue Engineering

Mortality and illness due to cardiovascular disease continues to rise in the graying population base of the U.S. while increased concerns due to diabetes, obesity, and hypertension signal an on-going battle to protect the human heart. Invasive surgery remains the preferred method for treating serious heart problems and advanced cardiovascular diseases, though a number of new research discoveries are indicating alternatives loom on the horizon. For instance, tissue engineering technology is evolving toward providing physicians with the ability to use less invasive surgical techniques to graft healthy tissue to a damaged heart. The new tissue can gradually replace and repair the injured or diseased cells. The estimated market for tissue engineered products will be worth approximately $5 billion worldwide by 2013.

Oncology Research & Treatment

Cancer research has become the top priority for investigatory medicine. The growth of cancer incidence has grown throughout the world. In the United States new cases of cancer average over 1 million a year. The nation has built up an extensive infrastructure to feed the development of a cure for cancer.

There are 61 cancer centers in the United States. Thirty nine of those sites are considered comprehensive cancer centers, fourteen classified as clinical cancer centers, and eight are general research centers. The National Cancer Institute (NCI) remains the largest recipient of federal
research funds among all institutes within the National Institute of Health and its funds nearly $5 billion a year in research at government owned labs, universities, and within private industry. NCI has proclaimed as a goal the elimination of pain and death cause by cancer by the year 2015. Barring something dramatic and unforeseen, cancer research will continue to be the single largest domain for medical research in the United States.

The 2003 global market for cancer therapeutics has been reported to be a $21.0 billion industry. Roughly $11.1 billion of that market is in the United States, $7.1 billion in Europe, and $2.2 billion is in Japan. Advances in cancer treatment approaches are currently driven by antibody-related therapeutics such as cytokines and monoclonal antibodies.

### Some Leading Companies

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Markets/Technology Strengths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amgen Inc.</td>
<td>Los Angeles</td>
<td>proteomics; therapeutic targeting technologies</td>
</tr>
<tr>
<td>Biogen Inc.</td>
<td>Boston</td>
<td>DNA &amp; gene cloning; antibody &amp; protein detection systems</td>
</tr>
<tr>
<td>Exiqion A/S</td>
<td>Denmark</td>
<td>nucleic acid recognition assays</td>
</tr>
<tr>
<td>Life Technologies</td>
<td>Switzerland</td>
<td>functional analysis; proteomics; therapeutic targeting technologies</td>
</tr>
<tr>
<td>Bayer Co.</td>
<td>Germany</td>
<td>Drug discovery</td>
</tr>
<tr>
<td>Geron</td>
<td>San Francisco</td>
<td>Animal stem cell research;</td>
</tr>
<tr>
<td>NextGen</td>
<td>United Kingdom</td>
<td>Protein identification &amp; gene detection technologies</td>
</tr>
<tr>
<td>Bristol-Meyers-Squib</td>
<td>New York</td>
<td>Drug discovery; Immunology &amp; neurology treatments</td>
</tr>
<tr>
<td>Novartis</td>
<td>Switzerland</td>
<td>Drug discovery</td>
</tr>
<tr>
<td>Gilead Sciences Inc.</td>
<td>San Francisco</td>
<td>gene expression, SNP mapping; resequencing analysis</td>
</tr>
<tr>
<td>Glaxo-Wellcome</td>
<td>United Kingdom</td>
<td>Drug discovery; Immunology &amp; neurology treatments</td>
</tr>
<tr>
<td>Jerini</td>
<td>Germany</td>
<td>peptide technologies</td>
</tr>
<tr>
<td>Merck &amp; Co., Inc.</td>
<td>New York</td>
<td>Immunology &amp; neurology treatments</td>
</tr>
<tr>
<td>Genentech</td>
<td>San Francisco</td>
<td>Biotherapeutics; Oncology; Immunology; Vascular biology</td>
</tr>
<tr>
<td>Columbia Laboratories</td>
<td>Miami</td>
<td>Drug discovery</td>
</tr>
<tr>
<td>Pfizer Inc.</td>
<td>New York</td>
<td>Drug discovery</td>
</tr>
<tr>
<td>Abbott laboratories</td>
<td>Chicago</td>
<td>Drug discovery; Immunology &amp; neurology treatments</td>
</tr>
<tr>
<td>Ångstrom Pharmaceuticals, Inc</td>
<td>San Diego</td>
<td>Cancer treatment compounds; in vitro modeling of cell migration;</td>
</tr>
</tbody>
</table>

*Note: Companies were selected based on a combination of factors including revenues, market share, patents, and effective leveraging of new technologies. The list is not ranked.*

### Emerging Technology

**Digital Drug Discovery - Bioinformatics**

The drug discovery process today is very different than it was even a few years ago. The front end of the process, the true discovery part, more often now involves the manipulation of large databases containing terabytes of information that is then run through one or more sophisticated computer models. The back end or development portion of the process – that part that deals with increasingly larger sets of clinical trials for the most part is still performed the same way for fifty years, but that too may be changing with increasing reliance on modeling and simulation.

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Modeling and simulation is now capable of being implemented throughout the entire drug discovery and development process and even beyond through to packaging and shelf stability tests. Computational modeling is being considered by both the pharmaceutical and biotechnology industries wherever it can replace, supplement, or shorten conventional drug discovery processes.

**Neuroscience**

Neuroscience is the basic science, diagnosis, treatment and understanding of the brain and central nervous system. Neurological sciences will be one of the early areas impacted by the understanding of genomics and has massive quality of life impacts and addresses the impact on brain functions including increasing its longevity for functioning including learning and relearning.

Research focused on the treatment of neurological disorders is capturing a growing proportion of NIH research dollars. Neuroscience-related therapies are viewed as one of the best growth opportunities for pharmaceutical companies and biotechnology firms have begun to focus much attention on the development of drugs and treatments for a few specific neurological problems including Alzheimer’s, Parkinson’s and multiple sclerosis. New science is also opening up opportunities for improved treatment for spinal cord injuries, psychiatric disorder, genetic brain disorders, and problems linked to neurological pathway degradation.

**Take-aways:**

- The future of the life science industry promises more partnerships between smaller biotechnology companies (whose very existence is driven by innovative ideas) and larger corporations that have the infrastructure to do what small firms can’t – integrate different facets of technology to enable marketable applications.
- Treatments for cardiovascular disease and central nervous system disorders will continue to be a primary focus for many biotech and pharmaceutical firms and will likely capture a growing share of company research dollars.
- Large Biotech and Pharmaceutical companies will continue to bring greater focus to their IP holdings around a more productive portfolio of technologies. The greatest opportunities will exist for science and technologies that offer quicker methods for identifying drugs and treatment for trials. Improving research productivity will be a top priority for the pharmaceutical industry.

**Impact on ASME Corporate Services:**

- Engineering is emerging as the single most critical discipline for the next growth stage of life science ‘economics of science’ models. Therefore, the establishment of the Biomedical Engineering Collaborative will accelerate the notion of corporate offerings along the entire integrated lifecycle.
- Recruitment of a Biomedical Engineer in Residence should assist in augmenting the expertise of ASME’s Corporate Services Unit.
Emerging Industry Cluster Maps
LOCATION OF EMERGING TECHNOLOGY CLUSTERS IN EUROPE

Key to Clusters

Tier 1: Homeland Security Water Mgmt BioTech/Pharma Computer Equip & Programming

Tier 2:
GLOBAL LANDSCAPE OF EMERGING TECHNOLOGY CLUSTERS

Key to Clusters
Tier 1: Homeland Security
Tier 2: Water Mgmt
Tier 3: BioTech/Pharma
Computer Equip & Programming