

POWERING THE FUTURE OF MANUFACTURING WITH

COMPUTERS & ELECTRONICS

RESEARCH PREPARED FOR
THE ADVANCED MANUFACTURING
JOBS AND INNOVATION ACCELERATOR CHALLENGE GRANT,
INNOVATIONS IN ADVANCED MATERIALS AND METALS MANUFACTURING PROJECT,
AND THE
GREATER PORTLAND EXPORT INITIATIVE

AUTHOR: DR. BETH FITZ GIBBON
OREGON MICROENTERPRISE NETWORK
APRIL 2014

THIS REPORT WAS PREPARED UNDER AN AWARD FROM THE
U.S. DEPARTMENT OF COMMERCE
ECONOMIC DEVELOPMENT ADMINISTRATION GRANT NUMBER 07 79 06921



#3-09 "In the Pulpit"; oil on canvas 60 X 36", © 2014 by Donna Steger

#3-09 "In the Pulpit" depicts the "eyes and heart" of the rolling mill at Cascade Steel Rolling Mills in McMinnville, Oregon. All communications, video monitors, set-ups and execution of operation are controlled in this room electronically. It is also a gathering point for crews to communicate and plan shift production to ensure the system is operating correctly for each product.

Original artwork reproduced with permission of the artist, Donna Steger: **THE ART OF WORK AS WORKS OF ART™**.

Powering the Future of Manufacturing With
COMPUTERS & ELECTRONICS

Research prepared for:
Advanced Manufacturing Jobs and Innovation Accelerator Challenge Grant,
Innovations in Advanced Materials and Metals Manufacturing Project,
and the Greater Portland Export Initiative

Author: Dr. Beth Fitz Gibbon
Senior Research and Policy Advisor
Oregon Microenterprise Network
June 2014

This publication was prepared by the Columbia River Economic Development Council.
The statements, conclusions, and recommendations are those of the author and do not
reflect the views of the Economic Development Administration.

CONTENTS

Preface	1	Industry Employment	29
Executive Summary	2	Competition	31
Regional Voices	6	U.S. Industry Geography	34
History	8	Supply Chain	36
Industry Market Segments	11	Computer & Electronics Regional GIS Map	43
Semiconductor Industry	14	Regional Assets & Gaps	44
Semiconductor Products & Materials	17	Supplier Commodities	45
Semiconductor Manufacturing Process	19	International Trade	51
Market & Business Trends	20	Success Stories	64
Disruptive Technology Trends	22	Findings & Implications	66
Industry Drivers & Operating Environment	25	References & Resources	72

TABLES, CHARTS & GRAPHS

Figure 1 Computers & Electronics Product Manufacturing Exports 2005-2014	8
Figure 2 Outsourcing Continues to Lower Revenue	14
Figure 3 Most Chips Built on 350mm Wafers	16
Figure 4 U.S. Product Segmentation	17
Figure 5 Semiconductor Process Manufacturing Process Flow	19
Figure 6 Global Semiconductor Sales	20
Figure 7 Industry Drivers	25
Figure 8 Industry Risks	25
Figure 9 Regional Computers & Electronics Employment Forecast	29
Figure 10 Major Players	33
Figure 11 Industry Geography	34
Figure 12 Semiconductor Value Chain	38
Figure 13 Regional Location Quotients	39
Figure 14 Supplier Commodities	45
Figure 15 Degree Holders by Profession	46
Figure 16 Metropolitan Employment by Industry Component	47
Figure 17 Number of Computer & Electronics-Related Jobs	47
Figure 18 Computers & Electronics Manufacturing Employment Forecast	48
Figure 19 Job Specific Employment Forecast	49
Figure 20 Global Supply Chain	51
Figure 21 Top 10 U.S. Imports	52
Figure 22 Imports Into U.S. by Country	52
Figure 23 Major Market Segmentations	53
Figure 24 Manufacturing Industries Drive Top 100 Metro Export Growth	55
Figure 25 Export-Intensive U.S. Metropolitan Statistical Areas	56
Figure 26 Top U.S. Computer & Electronics Export Metros	56
Figure 27 Oregon Electronics Related Exports 2012	57
Figure 28 Oregon Computers & Electronics Exports 2012	58

APPENDICES

A: Regional Computers & Electronics Business List	75
B: Major Manufacturers & Their Suppliers	80
C: National & Regional Assets: Industry Organizations, Professional Associations, Publications & Conferences	85
D: Regional & National Export Related Resources	89
Acknowledgements	92

PREFACE

The federal government has awarded a grant in support of advanced manufacturing and advanced materials to five counties in Northwest Oregon and Southwest Washington: Multnomah, Clackamas, Washington, Clark and Cowlitz. The Greater Portland-Vancouver region is one of only ten U.S. regions to receive this opportunity.

The Jobs and Innovation Accelerator Challenge Grant for Innovations in Advanced Materials and Manufacturing (JIAC IAM²) is a three-year award (2012-2015) funded by the Small Business Administration, the National Institute of Standards & Technology and the Economic Development Administration of the Department of Commerce, the Employment and Training Administration of the Department of Labor, and the Department of Energy. It focuses on specific industries with the greatest potential for the regional manufacturing ecosystem.

Two aspects of success singled out the Portland, Oregon-Vancouver, Washington region for this distinctive recognition: first, the collaborative approach among multiple organizations across five counties in two states; and second, the region's manufacturing heritage and its export success as detailed in the Greater Portland Export Initiative (MEI) completed in partnership with the Brookings Institution.

The goal of this research is to provide insights and guidance for strengthening the region's economy by directly affecting its manufacturing capabilities and capacity in two distinct ways:

- Enable small and medium manufacturers to improve and expand through business and technology improvements, market diversification, and exporting, so they become more productive, hire more employees, and make greater direct financial contributions through wages and taxes.
- Provide insights that help regional economic development agencies retain existing companies, attract new businesses, and support high-potential businesses.

This report is the second part of a four-part research portfolio addressing advanced manufacturing and advanced materials in major Portland-Vancouver regional industries. The other reports include: (part one) Advanced Manufacturing & Advanced Materials; (part three) Aerospace & Defense; and (part four) Metals & Machinery.

Thirty companies have been selected to receive direct technical assistance. None will receive financial payments; all will receive substantial support in terms of advanced manufacturing process improvements, advanced materials implementation knowledge, workforce training for incumbent and new employees, market research, and exports.

The focus of this report is on semiconductors and related electronic products, since this segment is crucial to regional manufacturing and exporting. The concentration of regional workers employed in this sector of the computers and electronics industry is four times the national average. This report does not address consumer electronics or computer components, as most are now manufactured overseas. Semiconductors and circuits are intrinsic to sensors, optoelectronics, instruments and other electronic products that are of most value to the economy of the Pacific Northwest.

While prepared for the Columbia River Economic Development Council by the Oregon Microenterprise Network, this research has been developed in collaboration with many regional entities including: Business Oregon, Oregon Manufacturing Extension Partnership, Impact Washington Manufacturing Extension Partnership, Pacific Northwest Defense Coalition, Southwest Washington Workforce Development Council, and Worksystems, Inc.

All product or company names mentioned in this publication are trade names, trademarks or registered trademarks of their respective owners.

1 Note: This research includes industry and employment statistics that vary depending on sources; data reflects the seven-county Portland Metropolitan Statistical Area (MSA), even though only five of the seven counties were included in the award. However, the variances are not significant enough to affect the overall meaning of the information provided about the grant region.

EXECUTIVE SUMMARY

The greater Pacific Northwest region, known as Silicon Forest, is part of the U.S. “Silicon Nation,” along with Silicon Valley, California; Silicon Alley, New York; the Silicon Cowboys (Texas, Arizona); and now Silicon Beach (Miami, Florida), whose market extends into Latin America.

The computers and electronics (C&E) industry, and in particular semiconductors, forms the core of the Greater Portland region’s economy and its exports. It is part of a technological ecosystem that includes global corporations as well as small and medium companies, forming a robust and growing worldwide supply chain.

Findings

C&E are intrinsic to advanced manufacturing in all industries from aerospace and defense to metals and machinery, energy and biotechnology. The industry employs nearly 33% of the Greater Portland region’s durable goods manufacturing workers,² and represents 70% of the region’s exports.³ Recent productivity gains in regional gross metropolitan product are “attributed largely to the growing and highly automated semiconductor industry.”⁴

With a foundation in semiconductors and other embedded electronics, the industry offers regional opportunities to build success in growing sectors such as communications, optoelectronics, photoelectronics, medical devices, and marine, air and rail transportation.

Innovative technologies enabled by electronics and new materials are driving disruptive trends in mobile communications, transportation, health care, robotics, and especially manufacturing. “Mechatronics” – the marriage of electronics, computers, software and manufacturing – is the newest engineering. Advanced materials such as graphene and new advances in 3D printing, also known as *additive manufacturing*, are revolutionizing how things are made.

Extensive interviews with industry experts, senior management at large corporations, and leaders of small and medium companies in the C&E supply chain provided an in-depth look at the region’s many assets. They also revealed opportunities to fill gaps by building on regional strengths.

The greatest regional gap identified by global corporations as well as small and medium suppliers is an educated, qualified, motivated workforce.


C&E supply chains are global, complex, and highly fragmented. Regional suppliers must be able to provide high-quality products on time with value-added services and the latest technology. To scale up, they must also be willing to participate in exporting.

Businesses and economic development providers must work together to provide the resources that ensure a robust regional supply chain. The following recommendations are explored in depth in the Findings & Implications section of this report.

2 Oregon Employment Department, September 2013.

3 Business Oregon, February 2013: U.S. Census Bureau, www.wisertrade.org.

4 Portland Business Alliance Check-up on the Portland Region’s Economic Health.



“The more highly specialized a regional economy is, the more vulnerable it is, especially in an era of rapid global change and increasing competition.

“To create a more diversified and sustainable regional economy, metro areas need to research and develop additional opportunities to match local specializations with global demand . . . Portland . . . is a national leader in exports based on its specialization in computers and electronics . . .”

Brookings Institution Global Cities Initiative
Export Nation, September 2013

Implications

For Small and Medium Suppliers:

- Upgrade processes, equipment and materials
- Plug in to the global supply chain
- Invest in R&D
- Invest in employee training
- Have the necessary certifications
- Understand the regulatory environment
- Expand product, market and industry capabilities
- Export

For Regional Economic Development Support:

Helping small and medium companies grow in capacity and capabilities enables them to serve higher tiers in their supply chain and strengthens the regional economy.

- Connect suppliers with industry and manufacturing expertise
- Network regional suppliers to buy from each other, share leads, and collaborate
- Address underserved high-opportunity market segments
- Recruit new supplier companies that fill regional supply chain gaps
- Protect and promote the region's abundant and affordable clean water and hydroelectric power

Encourage Participation in International Trade

The C&E industry is global and highly competitive. Computer manufacturing and assembly is almost entirely in Asia and supported by local suppliers there, so U.S. exports of C&E continue to shrink. Strengthening the regional C&E supply chain by diversifying its export base is key to achieving the region's goal of doubling exports over the next five years. This research highlights opportunities for accomplishing that ambitious goal.

- Continue educational export seminars for companies and economic development professionals
- Promote available federal, state and regional resources

Strengthen the Workforce

- Provide workforce training and certification support
- Increase the technically skilled workforce
- Educate and retain more engineering-oriented software designers and computer programmers
- Increase the highly educated workforce: electrical, mechanical and process engineers, metallurgists, physicists, scientists
- Improve the business and interpersonal skills of all workers: communications, teamwork, leadership potential

Invest in STEM and Technical Education

- Invest in science, technology, engineering and math (STEM) education in grades K-12, as well as at the secondary and graduate school levels
- Create apprenticeship programs

Support Research and Development

U.S. original equipment manufacturers (OEMs) and original design manufacturers (ODMs) have a slight edge, given their reputation for innovation and quality. For the U.S. C&E industry to retain that status, companies and regions must invest in R&D.

- Invest in regional and state signature research centers
 - Support state university R&D and commercialization efforts
 - Strengthen ties between universities, R&D centers, and businesses

Increase Access to Capital

- Provide greater financial access for companies expanding their manufacturing capabilities, from grants to loans to investment capital
- Invest in early-stage funding for high-technology startups with potential to scale

REGIONAL VOICES & VIEWS

TECHNOLOGY

“There’s a blurring of hardware and software in growth areas of connected devices and chips.”

“... massive computing power for smart grids, living labs, transit, smart cities ...”

“... electronics in lasers, micro-machines, bio-analytics, imaging systems ... nanoscale instruments ...”

“Tech is the integration of electronics with other industries – machinery, scientific instruments, aviation, energy, smart transit.”

INDUSTRY

“Semiconductor plant life is five to ten years. Their reason to stay evaporates if we don’t have clean water, cheap electricity and a reliable, competent workforce.”

“As evidenced by Intel and GLOBAL-FOUNDRIES, there will be more, not less, semiconductor production.”

“The value chain here is heavily concentrated in semiconductors and electronics for aerospace and defense ... microfluidics, sensors, monitors, two-way communications ... nanotechnology is at the heart.”

PRODUCTS

“... biggest product trend is 3D semiconductor chips, stacked integrated circuits.”

“U.S. quality and technology advantage is only ¼” deep. Asia is catching up fast.”

“3D printing can embed electronics right in the hardware.”

“The goal is finer pitch ... narrower separation between two pieces ... enabled by nanotechnology.”

SUPPLIERS

“The supply chain is huge ... facilities are built in areas with support systems and financial incentives. Fifteen to twenty manufacturers are here because of Intel.”

“Look to your competition for opportunity. Microsoft and Oracle are an unholy match but they have a cloud collaboration ... Intel is Samsung’s biggest supplier and its competitor.”

“A day or two late is not acceptable.”

“Ninety percent of electronic parts are not made in the U.S. Resistors, diodes, capacitors are all made overseas.”

“What’s missing here is software to run machines.”

SUPPLY CHAIN GAPS

"We need machine shops that can pass our ISO certification process and a trial run to prove they meet requirements and can deliver on time."

"We struggle with local suppliers of raw circuit boards . . . quality and delivery issues . . ."

"Standard tolerance is plus three to four mils; we require plus one mil . . . much tighter than standard."

"Chemicals are not here . . . that's a whole separate spider web of supply."

". . . chemicals and gasses . . . a metal forge . . . all on the East Coast or Midwest."

WORKFORCE

". . . Ph.D. physicists, chemical and electrical engineers . . . mechanical engineers."

". . . need technically trained process technicians, electrical and radio frequency engineers . . ."

"Engineers here can crank on tools and equations, but there's no critical thinking."

"Soft skills are horrible . . . interpersonal skills . . . not just engineers, it's planners, accountants, machinists . . ."

REGION

". . . fiber-optic trunk running along the Columbia River."

"The industry is not here because of a skilled educated workforce or even lifestyle. It's here because of low-cost energy driven by hydroelectric power."

"We need the region's cheap hydroelectric power. Our power bill is \$700,000 a month."

"We don't have a premier research university like MIT or Stanford with ties to technology businesses."

"There are few Ph.Ds. here and no professors doing the research we need."

"Hydropower is zero carbon . . . a big deal for utilities and public companies that have to report where they get their energy."

"Clean, cheap, reliable, plentiful water . . . 12" fabs use two to three million gallons a day."

EXPORTS

"Markets have special needs. China was disadvantaged in PCs because of (keyboard) characters, so now it leads in voice control systems."

"Business is where the demand is. Go there."

"Feds and the State should identify 20 high-potential exporters and support them at international trade shows."

Confidential interviews were conducted with company managers, supply chain professionals, manufacturing experts, and researchers at regional R&D labs. Their insights are included to provide a living picture of the business realities faced by small and medium manufacturers.

HISTORY

British scientist Michael Faraday discovered the semiconductor in 1833. He found that silver sulfide, otherwise known as tarnish, conducted electricity and acted as a switch. When voltage was applied, the switch allowed electricity to flow; when there was no voltage, the switch did not conduct so electricity did not flow. Hence, it “semi-conducted.”

Following Thomas Edison’s refinement of the electric light bulb in 1879, the vacuum tube, a diode with two electrodes, was invented in 1902, launching the age of radio engineering. Bell Labs physicists refined the semiconductor, also known as the integrated circuit, and invented the transistor in 1947. That achievement won the Nobel Prize and led to the development of solid-state electronics and the refinement of the modern computer. Following Intel’s 1970 invention of microprocessors, IBM introduced the first personal computer in 1981.

Computers and electronics (C&E) have since led the U.S. and the Greater Portland region on an economic roller coaster, rising to the dot.com boom of the late 1990s and plummeting with the exodus of electronics manufacturing to Asia in the 2000s.

Computers used to take up entire rooms, “then desktops, laptops and palms. Now they’re down to micro-chip-sized casings and atom-powered transistors invisible to the eye.”⁵ Forward-thinking C&E companies such as Intel look to the near future and see atomic transistors replacing chips. Advances in digital and electronic technology have already empowered robotics and autonomous vehicles. Within the next eight years, they may also empower holographic communications.⁶

Not only has technology moved from science fiction to fact, it is also rapidly moving offshore. As the chart below illustrates, U.S. exports of C&E continue to shrink due to overseas competition. If U.S. suppliers want to compete, they will have to learn to go where the action is by exporting.^{7,8}



Figure 1

5 <http://electronics.howstuffworks.com/future-tech/10-futurist-predictions-in-the-world-of-technology.htm#page=1>.

6 Intel Futurist Brian David Johnson interview with Intel Lab Strategy Director, Jeff Demain, www.intel.com/tomorrowproject.

7 <http://research.stlouisfed.org/>, September 12, 2013.

8 Federal Reserve Economic Data, 2013.

Regional History of Computers & Electronics

The Pacific Northwest, known as Silicon Forest, is not a newcomer to hosting semiconductor companies.

Electronics has been a key industry in the Northwest since Tektronix was formed in 1946. Intel, formerly Integrated Electronics, was founded in California in 1968 and arrived in Hillsboro, Oregon in 1974. Hewlett-Packard (HP) arrived from California in 1976. Micron Technology, Inc., a designer and manufacturer of semiconductors, headquartered in Boise, Idaho, with offices in Hillsboro, Oregon, started in 1978. Tektronix, an industry pioneer and leader in many different applications for semiconductors, had its headquarters in Beaverton, Oregon, for more than 20 years until Danaher bought it, greatly reducing capabilities and staff. Intel, Oregon's largest private sector employer, has designed and manufactured chips at their Hillsboro, Oregon, plant since 1982. HP, another well-known player in the semiconductor field, has kept a long-time presence in the Pacific Northwest, with facilities in Corvallis, Oregon, and Everett, Washington. HP and Tektronix were once major employers in this region; both went through massive downsizing, devastating the regional economy and C&E employment.

By the 1990s, regional manufacturing centered on the high technology complex of computers, electronics, electrical machinery, and computer services. Oregon high technology employment passed timber-related employment in the mid-1990s;⁹ and by the late '90s, C&E businesses employed nearly 73,000 regional workers, double the number a decade earlier. The two largest firms in 1998 were Intel and Tektronix, both centers of innovation and sources of new, high technology spin-offs. Oregon's other electronics cluster, with more than 10,000 employees, was Corvallis-Albany with HP.

C&E employed 57,000 people in 2012.¹⁰ Intel employs nearly 17,000 of those people.¹¹ Silicon wafer and semiconductor plants, in addition to other microelectronics suppliers, are located throughout Portland, Oregon; Hillsboro, Oregon; Gresham, Oregon; Vancouver, Washington; and Camas, Washington; in support of huge new global demand for mobile devices. Yet, Tektronix now employs only 1,000 – half the number who worked there in 2007.¹² HP employs 2,000.¹³ These cases illustrate the pitfalls facing large, inflexible companies and demonstrate the need for strong small and medium suppliers. Firms can survive dips in demand and changes in technology by diversifying their product lines and distribution channels.

WaferTech and other semiconductor firms supply OEMs such as Intel and Samsung, and ODMs or branded companies such as Apple Inc. Smaller suppliers need to sell to and purchase from large suppliers and each other and export throughout the U.S. and the world. The supply chain is not linear and it has four levels: a Tier One supplier like WaferTech assembles and packages chips, or, like Cascade Microtech, tests finished chips; Tier Two suppliers manufacture and etch them; Tier Three suppliers provide the basic components and machinery; and Tier Four suppliers, such as SEH, grow the crystal boules that get sliced into thin wafers.

9 Oregon History Project, www.ohs.org.

10 www.oregonlive.com/silicon-forest/index.ssf/2012/07/investment_in_oregon_tech_comp.html

11 Ibid.

12 The Oregonian, December 8, 2012, www.oregonlive.com.

13 Corvallis Economic Development Strategy, 2012.

Computer manufacturing is a mature industry that has moved mostly to Asia via extensive outsourcing over the past 12 to 15 years. Comprising a variety of products, including computer peripherals, mobile phones and MP3-players, the electronics manufacturing sector is among the largest and fastest growing industries in the world, accounting for almost one-quarter of world trade in manufactured products.

Electromechanics combined with software, better known as “mechatronics,” now runs most manufacturing machinery. C&E enable the fabrication and application of advanced materials such as light metals, polymers/plastics, ceramics, and composites. For instance, quartzware is made of silica or glass fused into quartz crystals with thermal and optic properties finer than glass. It is used in the manufacture of semiconductors and in optical industry applications.

The Greater Portland region has doubled exports in the last ten years and plans to double them again in the coming five years, leveraging its strengths in C&E for innovation in other industries which use electronics for everything from sensors to power generation.

Intel and other large manufacturers do not require regional services to expand their exports. Therefore, increased export growth in C&E must come from an integrated supply chain of small and medium regional companies willing to diversify their products and their markets. The region has many companies dependent on electronics beyond semiconductors, including suppliers and OEMs in audio/video, optics, aviation, defense, medical devices, and transportation that can sell to each other and contribute to exports.

Anchored by Intel, TriQuint, WaferTech, and ElectroScientific Industries (ESI), the industry dominates regional exporting. The Greater Portland region ranked fourth of all U.S. export-intensive metropolitan areas in 2012, with export volume of \$34 billion. C&E represented 67% of total 2012 exports versus a national metropolitan area average of 53%.¹⁴ Without C&E exports, the region falls to the “middle of the pack.”¹⁵

14 Ibid.

15 Brookings Institution
Metropolitan Export Initiative Report, 2012.



A Location Quotient (LQ)

is a way to quantify how concentrated a particular industry is, compared to the national average. It indicates what makes one region unique. An LQ of one (1) is the national average. An LQ above that is above the national average.

As indicated by their LQs, special industries are sources of growth for Greater Portland’s regional economy. Using total U.S. employment as a base, the LQ for the Portland metropolitan statistical area for C&E Product Manufacturing is 4.14 (NAICS 334)
– more than four times the national average.

The LQ for semiconductor and electronic component manufacturing (a subset of C&E) is 9.26 (NAICS 3344)
– almost ten times the national average.

INDUSTRY MARKET SEGMENTS

Computer & Electronic Product Manufacturing Includes Ten Major Segments¹⁶

1. COMPUTERS

Analog computers are capable of simulating mathematical models and contain analog control and programming elements. Computers can also be digital or hybrid. Digital computers, the most common type, are devices that: (1) store the processing program or programs and the data immediately necessary for the execution of the program; (2) can be freely programmed in accordance with the requirements of the user; (3) perform mathematical computations specified by the user; and (4) execute, without human intervention, a processing program that requires the computer to modify its execution during the processing run. Hybrid computers have the simulation abilities of analog computers as well as some or all of the functionality of digital computers.

The manufacture of computers includes the assembly or integration of processors, coprocessors, memory, storage, and input/output devices into a user-programmable final product. This industry manufactures and assembles electronic computers, such as mainframes, personal computers, laptops, servers and workstations. Production has, for the most part, moved out of North America to Asia. Components such as motherboards and graphics cards are also purchased from manufacturers mostly located in Asia.¹⁷

Suppliers to the industry include semiconductor and circuit manufacturers such as Intel, and wire and cable manufacturers, such as Allied and Okonite.

2. ELECTRONICS

Electronics is a branch of physics associated with the design and manufacture of solid-state integrated circuits composed of transistors, microchips and other electrically powered components using low voltage current for the transmission and processing of analog and digital data. It is also a primary component of avionics, the electronic systems designed for aircraft by companies such as Rockwell Collins in Wilsonville, Oregon.

3. COMPUTER PERIPHERALS

Manufacturers in this segment make computer monitors, light-emitting diode (LED) displays, keyboards, mice, printers, scanners and webcams, as well as self-service kiosks, point-of-sale terminals, ATMs and biometric readers. Those sectors provide opportunity as new technologies are spurring growth in demand. This sector does not include routers, modems, data storage systems or telecom networking equipment. Peripherals rely on semiconductor machinery manufacturing and fill demand from computer makers, computer and packaged software developers, wholesalers, and computer stores. The sector is driven by demand for smartphones, tablets, and new virtualization technology that allows one computer to seamlessly use the resources of another computer over a network connection.¹⁸ New technologies

16 Ibis Global NAICS; Portland Pulse LQs

17 U.S. Census Bureau Business & Industry Statistics, July 2013.

18 IBISWorld, March 2013.

include organic LED monitors and solid-state drives. Revenue growth will not keep up with unit sales, as the price of computer peripherals continues to fall; however, manufacturers face improving conditions over the next five years.¹⁹ Printer manufacturing is dominated by Japan (Canon), China, Singapore and Taiwan. Many computer peripheral OEMs and contract manufacturers serve the industry, including Logitech (Switzerland) and Wincor Nixdorf (Germany). There are about 650 U.S. companies with combined annual revenues of about \$9 billion. The U.S. industry is concentrated, with 50 companies accounting for 80% of revenue.²⁰ They include HP and NCR.

4. SEMICONDUCTOR MACHINERY

This industry makes equipment used to manufacture semiconductors, more commonly known as “chips” or “integrated circuits.” That includes wafer manufacturing and processing equipment, semiconductor assembly and packaging equipment, and other machinery used in making semiconductors. Demand comes from computer makers, computer peripherals manufacturers, semiconductor and circuit manufacturers, circuit board and electronic components manufacturers, and mobile device makers. Suppliers to this industry include ball bearing makers, electrical equipment manufacturers and wholesalers. They produce etching equipment, testers, microlithography equipment, chemical vapor deposition (CVD) equipment, and surface mount machinery for making printed circuit boards. They also make equipment for thin layer deposition, ion implantation, wafer processing, photolithography and microelectromechanical systems (MEMS) manufacturing. Making semiconductor machinery is the most complex advanced manufacturing process. Major producers are in Japan and Europe with a few in the U.S.

5. SEMICONDUCTORS & CIRCUITS

Asia is now the world’s biggest producer of electronic products, as its suppliers of materials and components manufacturing and assembly services continue to increase. While opportunity exists in the R&D-intensive high end of innovation for this sector, U.S.-based semiconductor manufacturing is expected to continue its decline as production and supply chains continue their shift to Asia. However, companies such as Intel still produce the highest-quality, leading-edge technology in the U.S. As they are a major contributor to the economy of the Pacific Northwest, this report concentrates on that sector.

6. CIRCUIT BOARDS & ELECTRONIC COMPONENTS

Electronic component makers produce printed circuits, circuit boards, capacitors, transformers, connectors and switches. They make their products from glass, laminated plastics, semiconductors and circuits, and wire and cables. They are used in solar panels as well as computers. As production continues to move offshore, the U.S. industry struggles. Demand comes from manufacturers of solar and electrical equipment, components, and appliances. Suppliers to this sector include makers of glass products and laminated plastics.

19 IBISWorld, September 2013.

20 First Research, August 5, 2013.

7. SEMICONDUCTOR AND RELATED DEVICES, INCLUDING OPTOELECTRONICS

This sector is engaged in manufacturing semiconductors and related solid-state devices. Product examples include integrated circuits, memory chips, microprocessors, diodes, transistors, solar cells and other optoelectronic devices. They use electronics and light in hardware devices to convert electrical signals into photon signals. Products include lasers, fiber optic communications, LEDs, electric eyes, remote sensors, medical diagnostic systems and optical information systems produced by companies such as ESI Inc. and Flir in Portland, Oregon.

8. STORAGE BATTERIES

Lithium ion and lithium polymer batteries store energy and are rechargeable. Industries supplying this sector include metals, plastics, inorganic chemicals, forging, rolling and stamping. Particularly relevant for C&E are lithium batteries that provide high levels of power and can generate high heat. They are used in mobile devices, medical equipment, copier and optical machinery, audio/video equipment, and for automotive power. They are lighter for their size than lead-acid batteries, hold charges longer, do not have to be completely discharged before recharging, and can handle hundreds of charge/discharge cycles. While Pacific Northwest National Laboratory leads major R&D efforts for batteries, China, Japan and Korea dominate production.

9. CABLE & WIRE

Electronics and semiconductors require cable, wire and wiring devices, a regional strength with room for more suppliers. Cable and wire are necessary components of devices, vehicles and power grids. Expansions in building activity, corporate investment and industrial activity have spurred increased demand for wire and cable as the economy recovers. Emerging nations need more wire and cable to support their growing infrastructure. The industry will continue to expand globally in the coming years, as increasing profit margins attract new players. Manufacturing cable and wire includes rolling, drawing and extruding. Materials used include copper, aluminum and other non-ferrous metals.

10. WIRING DEVICES

Increasing electrical equipment demand (including semiconductors) and growing construction demand will support industry growth. Manufacturers in this sector supply semiconductor and circuit makers and provide parts and components to electrical equipment and glass product manufacturers. They procure metalworking machinery, ball bearings and plastic products. They produce current-carrying and noncurrent-carrying devices for wiring electrical circuits. Products include outlet and switch electrical wiring boxes, electrical insulators, transmission pole and line hardware, electrical metallic tubes, switches, conductor connectors, electric sockets, plugs and cords.

SEMICONDUCTOR INDUSTRY

The Beating Heart of Computers & Electronics

For more than 50 years, the U.S. semiconductor market led technology development, transforming communications, transportation and entertainment worldwide. It is the core of the C&E industry in the Greater Portland region. Semiconductors are transforming health care, meteorology, energy, biosciences and manufacturing. As chips have become smaller, faster and cheaper – thus doubling the number of transistors on integrated circuits – new products are bringing economic growth, productivity gains and even new industries.

Semiconductors power computers, phones, and the planes and weapons used to transport and protect us. They are used to reduce power consumption, dissipate heat, capture solar energy, and create more efficient lighting solutions. Typical functions of semiconductors include information processing, information display, power handling, data storage, signal conditioning, sensing and monitoring. While production and backend operations have mostly moved overseas, the R&D sector of the industry is one of the biggest U.S. employers and has a significant effect on the Northwest's regional economy.

The biggest opportunity for increasing C&E manufacturing and exports is at the intersection of new technologies, new hardware materials, and software . . . all enabled by electronics and computer processing. C&E are central to every business, but most especially those in advanced manufacturing for aerospace and defense, and machinery and equipment.

Computers and consumer electronics use 60% of semiconductor production,²¹ and the line between those two industries has blurred as technologies merge in electronic devices like notebooks, LCD TVs and smartphones. Growth is negligible in mature markets, but emerging markets like China and Brazil provide huge growth opportunities.

After a slight decline in 2012, the worldwide semiconductor market recovered in 2013, up 2.1% to \$300 billion. The U.S. market is estimated to be 48% of that at \$144 billion.²² The world market is predicted to grow steadily, reaching \$325 billion by 2015.²³

Outsourcing continues to lower revenue and limit US industry growth.²⁴

2013 Global Revenue (est.) ²⁵	\$322.3 billion
2013 U.S. Revenue (est.)	\$78.1 billion
2013 U.S. Profit	\$10.6 billion
CAGR 08-13	1.9%
Projected CAGR 13-18	0.2%
U.S. Exports	\$27.5 billion (35%)
Number of US businesses	772
Major Players' Market Share	Intel 13.4% / Samsung 12.6%

Figure 2

21 Semiconductor Industry Outlook, Investopedia, January 2013.

22 <http://selectusa.commerce.gov/>, 2013.

23 World Semiconductor Trade Statistics, June 4, 2013, www.wsts.org.

24 IBISWorld, June 2013.

25 iSuppli Market Watch, March 18, 2013.

U.S. revenue includes direct exports and foreign sales of U.S.-owned subsidiaries overseas. It takes into account R&D, intellectual property creation, design, and other high value-added work. North American spending on semiconductor fabrication equipment surged 61% in 2011 to \$9.3 billion. There are currently 159 semiconductor fabrication facilities in North America, with Intel and GLOBALFOUNDRIES the largest.²⁶

Sales related to personal computers are expected to decline from 2012. Most demand is coming from smartphone, tablet and automotive manufacturers. Automotive uses will be an especially significant driver of demand as new cars and trucks are built with increased communications, safety and fuel efficiency capabilities driven by computers and electronics.

PCs, laptops and other consumer electronics are now made from components manufactured and assembled almost entirely overseas. Apple Inc. is expected to remain the world's biggest chip buyer, with \$27 billion worth of semiconductor purchases in 2012. It has recently signed a contract with WaferTech that could be of great benefit to Portland metropolitan regional production. Apple has also pledged a "made in USA" effort to assemble Mac computers in Texas.

Industrial use of semiconductors was predicted to rise 7.7% in 2013,²⁷ as demand is driven by the need for production efficiencies, from sensors to robotics, which in turn drive the need for semiconductor solutions for power management. Much of that demand is filled by overseas production; but high quality technology and production from the U.S. is a competitive advantage.

Semiconductor technology is increasingly global via overseas patenting, licensing and other forms of technology transfer, in addition to alliances and international investment. Over 85% of U.S. semiconductor sales happen overseas, and the U.S. industry share of the global market is 48%.²⁸ Overall, semiconductor sales totaled \$53.5 billion in the first quarter of 2013, increasing by just 2% compared to the same quarter in 2012.

26 <http://www.semi.org/en/>.

27 IBISWorld, 2013.

28 <http://selectusa.commerce.gov/>, 2013.



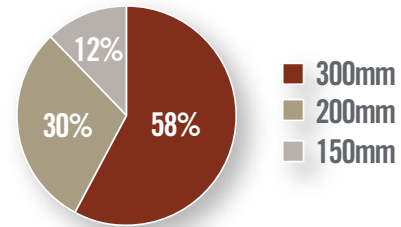
The Computers & Electronics industry consistently ranks at the top of all U.S. export industries and has maintained a trade surplus.

Fast Paced and Highly Competitive

The semiconductor industry lives and dies by the benefits of “tiny.” Finer lines mean more transistors can be packed onto the same chip. The more transistors on a chip, the faster it can work. Fierce competition has led to new technologies that lower the cost of production per chip; prices can fall 50% within months.

There is constant pressure on chip manufacturers to invent better than what was state-of-the-art only months earlier, so chipmakers are always at the drawing board to design superior goods. Even in a down market, weak sales are seen as no excuse for failing to develop better products for customers who want to upgrade their computing and electronic devices.

To keep costs down, manufacturers need to be able to use larger wafers that can hold more chips. Eight inch (200mm) wafers were the industry standard and are still in production. The average 12" (300mm) wafer, today's industry standard, can hold hundreds to thousands of chips, depending on their size. The industry is transitioning to 18" (450mm) wafers, but that is not expected to be standard until 2018.²⁹



Most Chips Built on 300mm Wafers
Source: IC Insights

Twelve inch (300mm) wafers represent about 57.8% of installed capacity in chip production, and the figure will rise to 70% in 2017. The introduction of 18" wafers, newer 24" wafers, and stacked 3D chips will affect supplier capabilities and require adaptation or retooling of existing manufacturing equipment.

Figure 3

Four Main Semiconductor Product Categories³⁰

1. Memory Chips

Memory chips are temporary storehouses of data that pass information to and from computer devices' integrated circuits. Consolidation of this market continues, driving prices so low that only a few giants like Toshiba, Samsung and NEC can afford to stay in the game.

2. Microprocessors

Central processing units (CPUs) contain the basic logic to perform tasks. Intel's domination of the microprocessor segment has forced nearly every other competitor, with the exception of Advanced Micro Devices, Inc., out of the mainstream market and into smaller niches or different segments altogether.

3. Commodity Integrated Circuits

Sometimes called “standard chips,” these are produced in huge batches for routine processing purposes. Dominated by very large Asian chip manufacturers, this segment offers razor-thin profit margins for which only the largest semiconductor companies can compete.

4. Complex “Systems-on-a-Chip” (SoCs)

Integrated circuit chips contain an entire system's capability. The market reflects growing demand for consumer products that combine new features and lower prices. With the market for memory, microprocessor, and commodity integrated circuits overtaken by exports, the SoC segment is arguably the only one left with enough opportunity to attract a wide range of companies.

29 Digikey Supply Chain HQ, July 31, 2013 www.digikey.com

30 Investopedia Industry Handbook: Semiconductors. September 2013.

SEMICONDUCTOR PRODUCTS & MATERIALS

Industry Products³¹

- Semiconductors
- Photovoltaics (PV)
- Optoelectronics
 - High brightness light-emitting diodes (LEDs)
 - Laser diodes
 - Photovoltaics
 - Electric eyes
 - Monitoring and control systems
 - Optical fiber communication systems
- Microelectronic mechanical systems (MEMS)
- Flat panel displays
- Lithium batteries
- Emerging technologies:
 - Printed, large area and organic electronics for displays, touch screens, solar energy, memory and logic
 - Power semiconductor devices made from silicon, silicon carbide and sapphire substrates for solar energy and storage, smart grids, electric vehicles, and renewable energy
 - Thin film technologies for batteries and fuel cells
 - Medical electronics for drug delivery and monitoring
- Plastic/flexible electronics

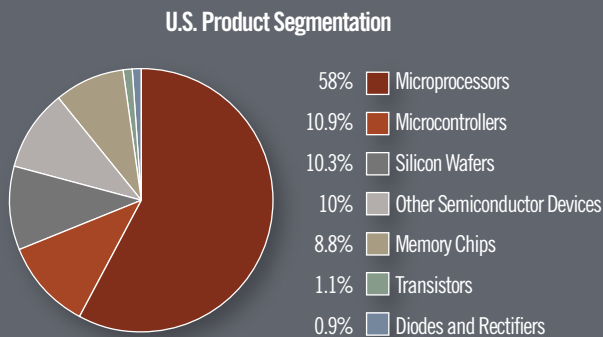


Figure 4

Microprocessors comprise more than half of the products in the semiconductor electronics industry.³²

Materials commonly used in the manufacture of semiconductors include:

- Silicon: *made of ordinary sand*
- Quartzware
- Copper
- Gold
- Aluminum
- Ceramics
- Glass
- Polymers/plastics
- Composites
- Silicon On Insulator (SOI) Technology
- Photomasks
- Resist: *thin layer used to transfer a circuit pattern to the semiconductor substrate it is deposited upon*
- Gases
- Chemicals

31 Semi.org, September 2013.

32 IBISWorld, 2013.

Semiconductor Packaging Materials are necessary for protecting wafers and their circuits. Wafers are thin, inflexible and fragile, and are shipped around the world during their manufacturing and distribution processes.

- Organic substrates
- Lead frames
- Mold compounds
- Underfill materials
- Bonding wires
- Liquid encapsulates
- Solder balls
- Die-attach adhesives
- Wafer level package dielectrics connecting integrated circuits to their devices
- Thermal interface materials to control heat generated by semiconductors
- Plastics for housing and packaging chips

Semiconductor Equipment used in the manufacture of integrated devices is located in facilities known as “fabs” or foundries. In manufacturing terms, *fabrication* commonly refers to operations that are performed on thin fragile metal plates known as “wafers.”

Traditionally, semiconductor companies controlled the entire production process from design to manufacture. A semiconductor fabrication foundry is a huge investment, costing from \$3 billion to \$8 billion (\$5 billion on average), and it can become outdated in only three to five years as technology advances rapidly. Today, many chip makers delegate production to others. Foundry companies, whose sole business is manufacturing, are providing attractive outsourcing options. Suppliers are becoming increasingly specialized, and the number of chip design and testing companies is growing.

Categories of equipment in a fab include:³³

- Wafer manufacturing & processing machines
- Wafer manufacturing & processing tools
 - High-precision tweezers
 - Forceps and vacuum pick up tools
 - Wafer scribes
 - Handling wands
- Mask, reticle and sputter equipment for etching
- Surface conditioning/ cleaning/drying
- Resistance processing equipment
- Expose and write tools
- Etching equipment
- Ion implant equipment
- Thermal processing equipment
- SoC handlers
- Chemical mechanical planarization
- Chemical vapor deposition
- Inspection measurement equipment
- Assembly and packaging equipment
- Probe equipment
- System-on-a-chip, memory test & logic test equipment

33 Semi.org, September 2013.

SEMICONDUCTOR MANUFACTURING PROCESS FLOW

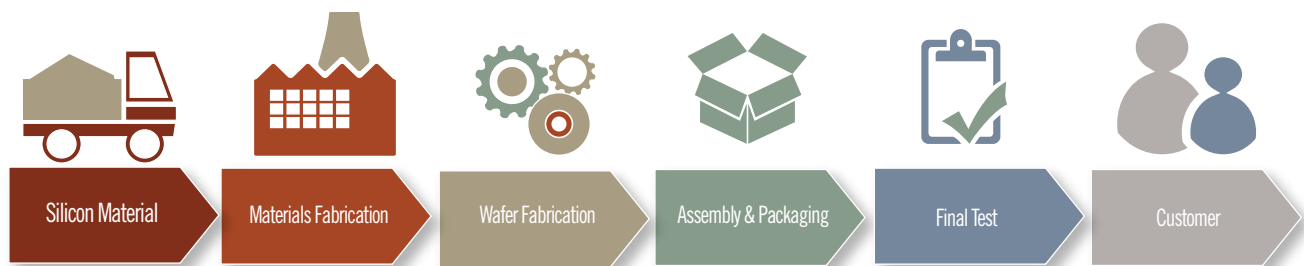


Figure 5

Semiconductor device fabrication is the manufacturing process used to create integrated circuits for microprocessors, memory chips and other devices in electronic products. Transistors are the basic electronic components that act as switches for integrated circuits. Wafers are thin slices of semiconductor material that form the foundation for electronic devices built onto the wafer. Wafers are usually made of pure, defect-free crystalline silicon grown in labs using highly temperature-controlled methods. The resulting ingots, or boules, are thin-sliced (200-300 micrometers) and polished to form wafers. Over the next five years, wafers are expected to get even thinner, with 160 micrometers standard.

The semiconductor fabrication process uses photographic and chemical methods to etch electronic circuits onto a wafer of pure semiconducting material in a four-step sequence:

1. Deposition of a thin substrate layer
2. Removal by wet or dry etching
3. Patterning using photolithography and polymers
4. Modification of the electrical properties of the chip

Cleaning and inspection follow each deposition and removal. Once wafer fabrication is complete, electrical and reliability testing is conducted at different stages of assembly. Packaging means assembling the bare die device into a “package” that provides mechanical and environmental protection. The package also provides an electrical connection between the die and the printed circuit board. There are many different package types and process techniques used in assembly and packaging.

Crystalline silicon is the most commonly used substrate material; but carbon nanotubes and graphene show promise as better options in the future. Germanium and gallium arsenide are semiconducting materials used only in special applications because they are very expensive. Manufacturing takes six to eight weeks and is done in highly specialized fabrication facilities with dust-free clean rooms.

MARKET & BUSINESS TRENDS

The U.S. long ran an export surplus in technology products for aerospace, optoelectronics and other products recognized as “high technology”; but since 2002, that surplus has turned into a deficit.³⁴ Computer manufacturing and much optoelectronics assembly have moved offshore, along with consumer electronics such as mobile phones, digital cameras and automotive electronics. However, demand for high-quality products means sales of semiconductors made in the U.S. are expected to rise between 2013 and 2018. Semiconductor sales to industrial markets are also expected to recover in 2014, as U.S. industrial manufacturing revives.

Industrial electronics was the strongest segment in third quarter 2013; wireless communications was strongest during fourth quarter. Other strong sectors included data processing, wired communications, consumer electronics and automotive electronics.³⁵

The industry is highly cyclical, because it is a capital-intensive business with undifferentiated products that are “doomed to cyclical shortages and oversupplies.”³⁶ Companies face constant ups and downs in demand, which typically follows end-market demand for personal computers, cell phones and other electronic equipment. Oversupply means prices slide, so companies reduce production; but then, capacity can’t be added again quickly as it is limited by engineering manpower, capital equipment availability, and the wafer fab ecosystem.

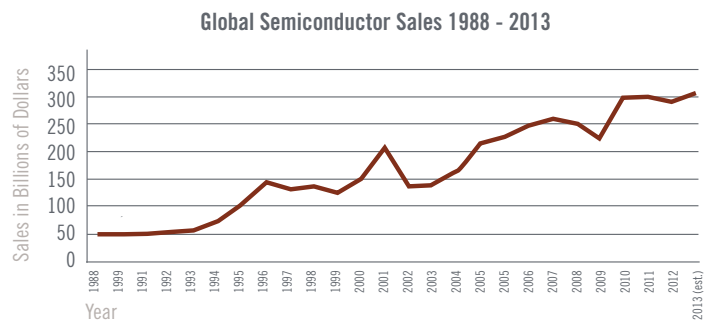


Figure 6

In the 21 years between 1988 and 2008, global semiconductor sales averaged 9% annual increase.³⁷ From 2009 through 2012, sales fluctuated from an increase of 31.8% in 2010 to a decrease of 2.6% in 2012. Sales in 2013 were estimated to reach \$309 billion, a 6% increase over 2012.

While semiconductors are still a commodity business, there are many end markets, making it unlikely that excess capacity in one area will bring down the whole industry:

- Personal computers
- Communications infrastructure
- Energy infrastructure
- Automotive
- Consumer products
- Industrial machinery

34 U.S. International Trade: Trends and Forecasts. Congressional Research Service, October 19, 2012.

35 HIS iSuppli Market Watch, November 11, 2013.

36 Is the Semiconductor Cycle Dead? Forbes Magazine, March 22, 2013.

37 1988-2008 sales: Price Waterhouse Coopers, A Change of Pace for the Semiconductor Industry, p. 19.

2009; 2010 sales: Semiconductor Industry Association, Jan. 31, 2011; 2011-2012 sales: PR Newswire, Feb. 4, 2013.

The semiconductor market is very mature and of shrinking importance to the U.S. economy, except for specialized producers such as Intel, who have significant infrastructure investments here and are known for the highest quality and most advanced technology. Semiconductor and circuit manufacturing depend on the computer manufacturing industry, where technology drives the market, but the market also drives technology.³⁸

Four trends shape the semiconductor industry:³⁹

1. Semiconductor cycles track growth in capital equipment spending.
2. Moore's Law, which drove the industry for the past three decades, is slowing down.
3. The industry is mature and growth rates are slowing.
4. Increased use of semiconductors in consumer electronics has resulted in lower margins and shorter product life cycles.

Recent technology advancements have resulted in sizeable investments again being made in building fabs and foundries, and converting fabs to accommodate larger wafer sizes and other product changes.

Fab equipment spending reached an all-time high in 2013, and 2014 is predicted to be another strong demand year, with spending increasing 21% among North American manufacturers.⁴¹

Current & Future Growth Markets Powered by Superconductors

- Mobile and "intelligent" devices
- Robotics and optics
- Health care equipment and medical devices
- Environmental technology, from monitors to smart grids
- "Smart" transit systems
- Information processing, network communications and data storage

38 Investopedia.com 2013.

39 Daniel Amir, Sr. Semiconductor Research Analyst, WR Hambrecht & Co. www.altassets.net.

40 Ibid.

41 Semi.org, September 3, 2013.

"Intel is very interested in 450mm (18")

...D1X is being [constructed] to be compatible with 450mm," said Intel's director of process architecture and integration, Mark Bohr⁴⁰, adding that equipment vendors are now interested in making 450mm tools.

Larger wafers mean there will be a greater number of chips produced per cycle, which generally means a reduced cost to the producer that translates to lower prices for the consumer.

DISRUPTIVE TECHNOLOGY TRENDS

Innovation Advances Power the C&E Industry

- Digitized artificial intelligence
- Printed body parts
- Remotely operated heart surgery from multiple locations
- Remotely driven automobiles
- Google glass for oil rigs and engine factories
- Hi-tech clipper ships that fly like the wind, powered by wind
- Unmanned vehicles for agriculture as well as defense
- Household appliances with broadcast capabilities

Moore's famous "law," theorized by Intel founder Gordon Moore in 1965, holds that the number of transistors on a semiconductor chip will double every two years. It has held true ever since. Kryder's 2005 "law" proposed that storage space costs would reduce by half every 14 months. Now, the limit to the number of electrons that can fit in a given area is being reached, as software has piled more processes on chips that do ten times the amount of work they used to do. As manufacturers are running out of surface area, Moore's Law is on the verge of no longer holding true.

The answer may lie in **advanced manufacturing** techniques. For example, "**skyscraper chips**"⁴² will literally be able to accommodate 3D storage. Today, memory chips can be written on only once, meaning one can't yet rewrite over a 3D flash drive. But 3M and IBM are working to develop an adhesive to make data travel faster through the chip. By layering chips on top of each other, the distance the signal needs to travel can be cut 100 times, providing a huge increase in performance.

Regular microprocessors have wires that inhibit the transfer of electricity. MIT engineers are working to replace those wires with **flashing germanium lasers using infrared light to transmit data**. They are using photons rather than electrons to reduce the number of cores and components that clog interconnecting wires with data. This is accomplished by mixing silicon materials with optical components called "silicon photonics." Eliminating the use of wires also reduces heat generation and uses less energy. HP is working on alternatives to double the amount of data storage and anticipates unlimited layering within ten years.⁴³ Tabula is working on **programmable chips that can reconfigure as one works** to increase circuit density and throughput.⁴⁴ Intel purchased McAfee to acquire the technology to embed security directly into its chips.

Advanced materials are another source of new capabilities. Using **graphene** instead of silicon provides a measurable increase in electronic performance. Graphene is a lattice of pure carbon only one atom

"Intel expects most people will eventually wear three to eight items with sensors and computers embedded . . . The chipmaker has a new line of processors designed to be used in small devices . . . through its venture arm, it has an investment . . . that makes tech-laden headgear for athletes."

Business Week, Nov. 4, 2103

42 The End of Moore's Law: where to next? Graeme Lipschitz, Memeburn. June 28, 2013.

43 R. Stanley Williams, HP Memory Labs. Memeburn, June 2013.

44 Steve Tieg, CTO and Pres. Tabula Inc. Memeburn, June 28, 2013.

thick. It is 40 times stronger than steel, the best conductor of heat at room temperature, and its electrical conductivity is 1,000 times greater than silicon.⁴⁵ It also uses less power and can be made with very small features, allowing speedier processing. Researchers looked into graphene as early as the 1970s, but it was not successfully produced in layers until 2004. In 2010, advances in graphene technology earned the Nobel Prize in physics.⁴⁶ The technology is flexible and compatible with standard silicon processing techniques used to make computer chips.

Because graphene can be used to make electronic structures as small as one nanometer, processors made with it are about 20 times faster than today's best silicon chip. However, they are so new and so expensive, it will be a while before they appear in consumer products. They are currently being used for special applications where cost does not matter, but speed and low power usage do.

New developments in optoelectronics and chip technology, along with increases in Internet speed, mean the world will rely less on hardware and more on cloud companies to solve storage problems.

Flexible Electronics

Materials scientists are able to slice graphene and silicon so thin that instead of being brittle, they're floppy. Electronics in development can bend and stretch without breaking. Thin films of purified silk that is bendable and water-soluble can replace aluminum or copper electrodes. Magnesium, a nontoxic metal, is highly conductive and dissolves in water. It can be used for transistors and diodes on wafers that are only 50 nanometers thick versus standard silicon wafers. Magnesium oxide, used as an antacid for stomach upset, works as an insulator in electronics. It dissolves in water, either slowly or more quickly, depending on the thickness of its layer.⁴⁷

These new electronics technologies will be used in game-changing ways:

- Surgical sutures that monitor skin temperature
- Biodegradable sensors that dissolve when their need is done
- Silicon wafers for making semiconductors sliced thinner than a human hair
- Sensors made of lightweight, stretchy material embedded with electronics that envelope the heart or brain to provide real-time measurements of activity and detect and prevent arrhythmia or seizures
- Solar cells as thin as a pencil tip that can be rolled into a tube or printed on cloth and plastic
- An orbital digital camera covered with tiny lenses, each with an individual photodetector that sees in all directions at once and renders close up and far away in perfect focus – great for surveillance systems and for invasive medical procedures such as endoscopy
- “Transient” electronics for transistors and diodes that dissolve in water or air in minutes, hours, days or weeks depending on need
 - Medical devices that monitor and prevent infection after surgery and then are absorbed into the body
 - Environmental sensors that monitor chemical contamination or oil spills and dissolve when clean-up is complete
 - Transient flexible film that kills bacteria with electricity instead of drugs, preventing them from building up resistance to antibiotics

45 The Economist, Science and Technology, p. 85, May 12, 2012.

46 Andre Geim and Konstantin Novoselov.

47 Discover, Electronics, Yong and Ross, August 2, 2013.

Printed Electronics

Circuitry printed on flexible materials such as labels, fabrics and cardboard, with electronic or optical inks, provides low-cost fabrication for low-performance electronic devices. Combined with 3D printing, this enables the manufacturing of layered circuitry so items can be printed from CAD-CAM 3D plans.

Convergence of Electronics, Mechanics and Software

Programmable *manufacturing*, driven by *electronics* and guided by *computer software*, is the new means of production, whether for heavy industry or 3D printing. That convergence, called "*mechatronics*," is powering innovation in all three disciplines. Examples include microbatteries and optoelectronics.

Demand from U.S. computer manufacturers is expected to decline throughout 2013 and be even lower in 2014.⁵⁰

Desktop computers and servers are the largest non-export market for semiconductor chips; but as performance and price gaps have fallen, share is increasingly being taken by laptops. Manufacturers and consumers continue to source less expensive foreign-made goods. Packaging semiconductors and circuits is labor-intensive. Labor is cheaper overseas, and many electronic device makers and suppliers are located in Asia, where it is cost effective and convenient to manufacture semiconductors.

Revenue has remained relatively flat since 2011 and industry employment is declining. Imports have grown from 26% in 2004 to 30% in 2013 and are forecast to rise to 32% by 2020.⁵¹ Industry experts anticipate sales will continue to decline, with 2013 shipments 7.8% lower than in 2012. Sales are projected to fall another 1.2% in 2014. Continued decline is expected due to increased sales of iPads, tablets and other portable computing devices that serve users' web browsing needs at a much lower cost than traditional desktop and laptop computers.

However, sales of semiconductors and related electronic devices are expected to grow with increased demand for mobile electronics, automotive electronics and industrial electronics. Sales of innovative, reliable U.S. electronics are expected to rise to meet that increased demand.

48 Business Week, Technology, pg. 34, July 22-26, 2013.

49 <http://optoelectronics.eecs.berkeley.edu/>.

50 International Data Corporation and <http://bgr.com/>, May 28, 2013.

51 IBISWorld, 2013.

"Once you 3D print the battery, design space becomes unlimited."

Jennifer Lewis, Professor of Biology,
Inspired Engineering, Harvard University

Microbatteries⁴⁸

- Form & Function: Rechargeable lithium ion batteries the size of a grain of sand, with nodes produced by a 3D printer to power electronic devices.
- Ingredients: Different lithium oxide compounds make up the anodes and cathodes. The cost of materials for each battery is less than a penny.
- Shape: 3D printing squeezes out the batteries in a zigzag pattern to keep them compact.
- Weight: Each battery weighs about 100 micrograms, 1,000 times less than the lightest lithium ion battery on the market today.
- Charging: If equipped with microphotovoltaic cells, the batteries can be recharged with sunlight or a wireless power station.
- Uses: Hearing aids, tiny flying drones called RoboBees, biomedical implants, coin-size sensors and other tiny electronics.

Optoelectronics⁴⁹ and Photoelectronics

- Form & Function: the integration of light and electronics in fiber optic and sensor systems for emitters and detectors
- Ingredients: graphene and silicon
- Dimensions: from nano to component
- Powered by: semiconductors
- Uses: fiber laser systems, electric eyes, digital cameras and solar cells for use in communications, medical diagnostic systems, space systems, surveillance and monitoring

INDUSTRY DRIVERS & OPERATING ENVIRONMENT

Industry Drivers	Impact	Measured By
Market share gains	Drive revenue and earnings increases	Units shipped vs. competition
Higher margins and profits	Absorption of higher fixed costs contributes to lower unit costs	Manufacturing process efficiencies
Higher product design, quality & performance vs. competitors	Enhances brand value and increases consumer demand	Company performance vs. competitive benchmarks

Figure 7

Industry Risks	Impact on Drivers
Weak economy and/or product environment	Shipment volumes may fall
Delayed product delivery	Loss of revenues, profits and competitive position; potential reduction in demand for current chips
Severe price competition	Shrinking profit margins
Failure to keep up with technology	Increasing chip complexity requires more advanced processes to keep costs under control
Slowdown in pace of computer replacement due to mobile devices	Depresses computer industry growth rates but spurs mobile devices
Geopolitical risk and currency fluctuations	Delayed production, shrinking profit margins, potential reduction in demand

Figure 8

Pricing & Profitability

U.S. manufacturers are also focused on growth through higher-margin products like computer processors, NAND memory (a digital storage technology that doesn't require power to retain data), and solid-state hard drives. Profit margins are expected to grow as U.S.-based firms focus on R&D to maintain competitive advantage through technologically advanced products.

Semiconductor makers deal with extreme revenue volatility in a highly capital-intensive industry. Competition is intense and barriers to entry are high because it takes years and billions of dollars to develop a chip or build a foundry. A long time passes before products make profit. It can take years for a major development to succeed and pay off . . . or fail.

Pricing is driven by technology and quality, as well as labor costs and the costs of materials and components, which fluctuate frequently. Reliable high-performance semiconductors with low levels of power consumption for satellite systems command a much higher price than commodity products for consumer devices.

The price of semiconductor and electronic components has steadily declined, shrinking margins. That decline is expected to continue through 2014 without the introduction of disruptive new technology. Semiconductor prices fall when global economic activity weakens, reducing component demand. Additionally, as U.S. currency has a high value today compared to the currency of Asian trading partners, its semiconductors are relatively more expensive.

Profit margins for 2013 were expected to be 13.5% but are highly variable depending on the economic environment. They were as low as 8.5% in 2008. Today's combination of rapidly rising prices for silicon and precious metals, with a sharp decline in computer demand, means purchases of materials are expected to increase to an estimated 24% of industry revenue.⁵²

Capital Requirements

Substantial amounts of capital investment are required to participate in this industry. Wafer foundries, etching equipment and clean-room production are very expensive; labor and utility costs are high. The rate of technology change is also very high, requiring significant ongoing investment in facilities and equipment. Building a typical fab costs an average \$5 billion in the U.S., and the lifespan of its technical capabilities is generally only three to five years. R&D is also a significant expense, averaging 15% of revenue.⁵³

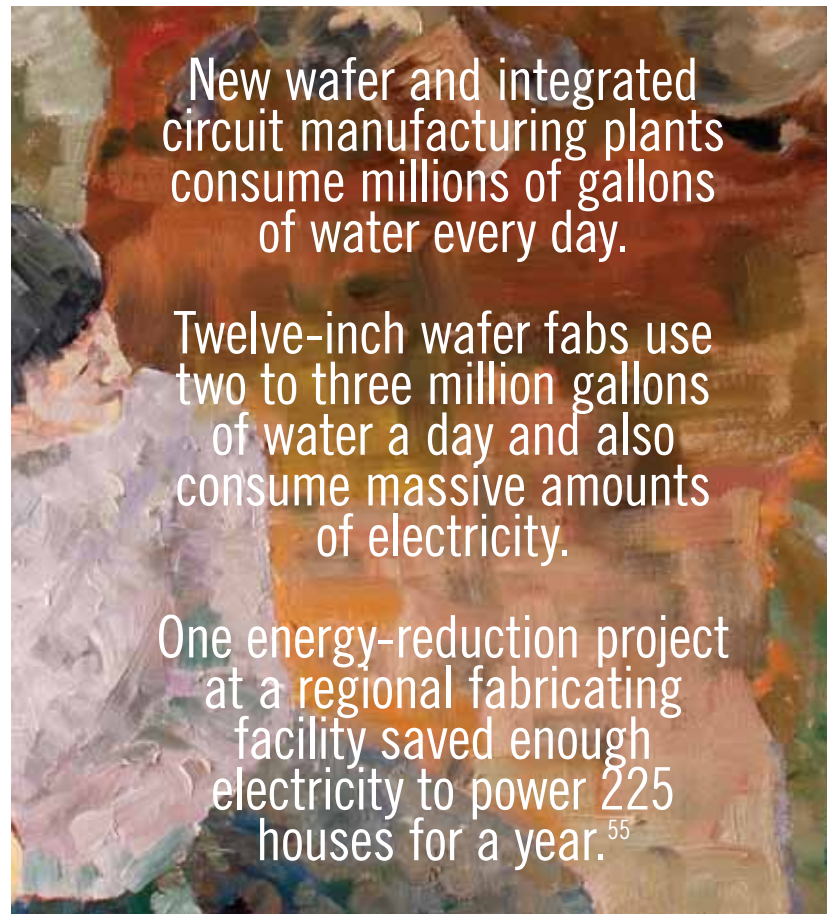
Capital investment in semiconductor equipment has steadily increased since 2010, driven by purchases of wafer fabrication equipment for new fabrication plants including GLOBALFOUNDRIES in New York State and Intel foundries in Oregon and Texas. Industry experts expect increased spending across all equipment segments including fabrication, automated testing, and packaging assembly from 2013 forward.⁵⁴ The payoff is also long term – it takes five years from concept and new process technology to production ready for market.

Power Requirements

Producing semiconductors requires significant amounts of stable energy from impeccably reliable sources. As the complexity and size of semiconductor fabrication facilities have grown, so have their resource demands. New facilities can use enough wattage to power a small city. Hydroelectric power in the Greater Portland region is a significant asset to protect, as it is a substantial competitive advantage. While the region cannot compete globally on labor costs, it offers companies substantial clean water and power resources at very competitive cost.

Legal and Regulatory Environment

The C&E industry has a moderate level of regulation. Regulations focus on standards, areas of trade, intellectual capital and the environment. The federal government regulates some uses because of their potential in military applications, and restricts exports of some high-capacity chips to protect national security. However, that can be a competitive advantage given this region's strength in aerospace and defense.



52 IBISWorld 2013.

53 IBISWorld 2013.

54 Gartner Research 2012.

55 Confidential interviewee sources.

Tariffs & Taxes Affect U.S. Export Competitive Advantage

Products subject to U.S. tariffs:

- Some light-emitting diodes (LEDs)
- Signal generators
- Electroplating machinery
- Aircraft equipment: flight data recorders, aircraft demisters and defrosters
- Telegraphic and telephonic apparatus, instruments and networks
- Flat panel displays
- Electrical machines with translation or dictionary functions

Products not subject to tariffs:

- Diodes, transistors, semiconductor devices
- Photosensitive semiconductor devices such as photovoltaic cells
- Some light-emitting diodes (LEDs)
- Piezoelectric crystals
- Wafers and unmounted chips
- Electronic, digital and application-specific integrated circuits
- Smart cards with integrated circuits
- Metal oxide semiconductors

Current tax laws require depreciation of semiconductor manufacturing equipment over a five-year period, although the life of the equipment is only three years. Europe and Japan allow more rapid depreciation and therefore have a competitive advantage over the U.S. for attracting companies.

Major regulating bodies include the National Institute of Standards and Technology (**NIST**), one of the funders of this research; the Environment, Safety and Health Committee (**ESH**) of the Semiconductor Industry Association; the Environmental Protection Agency (**EPA**); the World Semiconductor Council (**WSC** members include China, Europe, Taiwan, Japan, Korea and U.S.); the National Semiconductor Metrology Program (**NSMP**); and the Semiconductor Electronics Division (**SED**).

WSC addresses global issues, promotes fair competition, and provides best practices for intellectual property protection, emission reduction, regulation of chemicals used in semiconductor manufacturing, trade and investment liberalization, and market development.

NIST develops and promotes measurements, standards and technology to enhance productivity and foster trade. It conducts research to advance the technology infrastructure and help U.S. industries improve their products and services.

ESH and **EPA** find alternatives to hazardous chemicals used in manufacturing. Their information has made the U.S. chip industry a world leader in reducing polluting emissions such as ozone-depleting substances and finding environmentally benign solvents for use in the manufacturing process.

NSMP supports chip miniaturization and works with NIST laboratories to develop the semiconductor measurement infrastructure.

SED provides R&D leadership for the semiconductor measurement infrastructure essential to silicon and other advanced technology semiconductor needs.

Operating Environment⁵⁶

The semiconductor industry produces successively cutting-edge technology in an environment of challenging and highly volatile business conditions. Below is a summary of the business risks.

1. High Entry Barriers

In the past, semiconductor design engineers with good ideas left one company to start another. As the industry has matured and the cost of chip fabrication factories has risen to billions of dollars, the cost of entry makes it nearly impossible for all but the biggest players to keep up with state-of-the-art operations. Some semiconductor companies are forming alliances to spread out the cost and risks of manufacturing. The success of “fabless” chip suppliers that do not require large-scale fabrication resources suggests that factory ownership may be a sustainable entry barrier.

2. Suppliers Have No Power

Suppliers have no clout over large suppliers, who have little power over OEMs, many of whom have hundreds of suppliers. Diffusing risk helps chip giants retain bargaining power. As production is very expensive, smaller companies are increasingly dependent on a handful of large foundries. Only suppliers like Intel, with leading edge equipment and extensive R&D, have power to negotiate price.

3. Industry Consolidation

Most key industry segments are dominated by a small number of large players; consequently, buyers have little bargaining power and competitors without deep pockets are unlikely to become large players.

4. Intellectual Property

Legal protection may stop the threat of substitute chips for a short time; but copycats can reverse-engineer products in a matter of months. Companies spend millions or billions on state-of-the-art improvements only to find their products on the market at lower prices – often before they can recoup R&D costs and turn a profit.

5. Rivalry

What was “bleeding edge” technology a few months ago quickly becomes old news, so competition is intense. Pressure extends throughout the supply chain, from designers and suppliers to foundries and distributors.

6. Frequent Technology Disruptions

Demand for new technology forces companies to constantly reinvent to remain relevant and competitive.

56 Michael Porter, Market Forces Analysis, HBR.

INDUSTRY EMPLOYMENT

Nationally, the U.S. technology industry represents 5.4% of the entire private sector workforce, and it grew at 1.1% per year from 2012 to 2013.⁵⁷ One hundred and three U.S. companies with five hundred or more employees account for 82% of industry employment; 57.4% of firms in the industry have fewer than twenty employees. Oregon is the third largest state for semiconductor manufacturing employment after California and Texas.

Oregon employment growth averaged 1.8% in 2013, up from 1.2% in 2012.⁵⁸ The majority of that growth came from Leisure & Hospitality (5.8%). However, Professional & Business (3.2%), Durable Goods Manufacturing (2.9%), which includes C&E, and Construction (2.5%) also increased. In Oregon, 6.1% of the private sector workforce (81,600 people) was employed in technology in 2012, a .02% increase over 80,300 in 2011.

By comparison, the state of Washington projects 1.47% annual growth in overall employment through 2021.⁵⁹ Construction employment is estimated to increase 1% and manufacturing employment is estimated to decrease by -0.3%.

Regional Computer & Electronics Industry Employment Forecast, 2010-2020*⁶⁰

NAICS	Industry	2010	2020	Change	% Change	LQ
3353	Electrical Equipment Manufacturing	300	380	80	26.7%	3.7
3359	Other Electrical and Component Manufacturing	1,000	1,170	170	17.0%	1.0
3345	Measuring, Electro-medical and Control Instruments	4,190	4,880	690	16.5%	.86
3341	Computer & Peripheral Equipment Manufacturing	2,450	2,810	360	14.7%	1.8
3344	Semiconductor & Other Electronic Component Manufacturing	23,110	26,100	2,990	12.9%	9.3
Totals:		31,050	35,340	4,290	12.0%	
All Industries		806,540	972,570	166,030	20.6%	

Figure 9

*Tri-County Area (Multnomah, Clackamas, Washington, OR.)

An updated Employment Forecast will be published by the Oregon Employment Department in February 2014, providing estimates for 2013-2022 and including estimates for Clark and Cowlitz Counties in Washington.

57 Cyber States 2013, Washington D.C. Based on U.S. Bureau of Labor Statistics.

58 Oregon Economy Review and Forecast, State of OR; www.oregon.gov.

59 2013 Employment Projections, Washington State Employment Security Department.

60 Oregon Employment Department, 2013.

Wages

Employee wages take about 15% of U.S. industry profit. The average employee is a highly skilled electrical engineer, research scientist, or process engineer making from \$90,000 to \$96,000 a year.⁶¹ Technology work⁶² pays 123% higher wages than other private sector jobs. The average U.S. technology worker makes \$93,800 compared to \$47,700 for the average U.S. private sector worker.

Oregon technology companies paid \$7.7 billion in payroll in 2012 – 13.5% of all private sector payrolls.⁶³ The state's 81,600 technology industry workers earned an average annual wage of \$94,200, 11th highest in the nation. Oregon ranks third in the nation with 23,800 semiconductor manufacturing jobs, and tenth in the nation with 2,800 computers and peripherals manufacturing jobs.⁶⁴

“Washington State’s 191,000 tech industry workers earned an average annual wage of \$110,200 in 2012, the third highest wage rate in the nation.

These wages were 125% more than the average private sector wage ...⁶⁵

61 Industry Week Manufacturing Salary Survey, 2013.

62 Technology employment includes workers in Computers, Peripherals and Semiconductor Manufacturing, Software, and Research & Development as defined by Cyberstates and the TechAmerica Foundation, 2012.

63 Oregon Employment Department, 2013.

64 Oregon Tech Industry, TechAmerica Foundation, Cyberstates 15th Annual Ed., 2013.

65 Washington Tech Industry, TechAmerica Foundation, Cyberstates 15th Annual Ed. 2013.

COMPETITION

Semiconductors are a global business. Leaders are U.S.-based Intel and South Korea's Samsung, with a combined 26% market share. The other 74% is fragmented across a multitude of global companies, mostly in Asia.

The four companies that dominate the U.S. industry own only a combined 28.5% global market share. The industry includes many small firms. Intel, AMD and Texas Instruments (TI) dominate in specific product segments. Intel and AMD claim the highest share for desktop and mobile computing. TI says it owns 65% of the global digital signal processors market.⁶⁶ Intel and TI remain technology and quality leaders. Their major competitors in semiconductors are Taiwan Semiconductor Manufacturing Company (TSMC, owner of WaferTech), United Microelectronics Corp, GLOBALFOUNDRIES, and China's Semiconductor Manufacturing International (SMI).

Many of Intel's chips are being used in PCs, and PC sales are falling. Intel is reported to be considering a plan to expand its contract manufacturing operations and target the mobile market. Samsung's semiconductor sales were \$7.95 billion, up by 13% thanks to a boost from Apple Inc., whose chips for iPhones and iPads were manufactured and supplied by Samsung and Qualcomm. Both are ahead of Intel in the mobile devices market, supplying chips for smartphones and tablets.

In 2013 Qualcomm introduced the Toq (pronounced "talk") smartwatch that sends emails directly to the wearer's wrist. As Intel once was before its famous "Intel Inside" campaign, Qualcomm has been predominantly behind the scenes, providing microprocessors and radio chips for mobile phones and wireless networks. Now it wants to dominate by providing software and components that connect all things to the Internet, from appliances to cars to people's heartbeats. The company introduced a series of new mobile products at the 2013 Consumer Electronics Show.

Intel's semiconductor sales in first quarter 2013 were \$11.56 billion, a 3% drop from nearly \$12 billion in first quarter 2012. Revenue in 2011 was \$54 billion; 2012 revenue was \$53.3 billion, and 2013 revenue was also \$53.3 billion.⁶⁷ The company has lost ground as the world's top semiconductor company to chip suppliers benefitting from the success of mobile devices.⁶⁸ Based on revenue, it's lost market share to Samsung and Qualcomm, which design and supply chips for smartphones and tablets.

But it still has the most advanced manufacturing factories today and will start making chips using the 18" wafer process early next year. TSMC (WaferTech) and New York-based GLOBALFOUNDRIES are more competitive in chips for mobile devices and have stated they plan to catch up with Intel in the manufacturing process by making their first chips containing a 3D transistor – also called FinFET – starting next year. However, Intel is also shrinking its transistors and will still be a generation ahead in the FinFET process. They will be difficult to catch given their strong lead.

66 IBISWorld, 2013.

67 www.newsroom.intel.com.

68 IC Insights Market Study, ComputerWorld, May 13, 2013.

Consolidation continues as larger companies acquire smaller ones with valuable technology and knowledgeable workers. While vertically integrated designers and manufacturers such as Intel have advantages of scale, the trend toward outsourcing to overseas subsidiaries and foreign-owned foundries may limit their advantage. Smaller players specializing in a few niche product lines are expected to gain market share.

If Intel and Samsung do not provide steady advances in technology, electronics makers have no new products to generate new sales. Much of the growth recovery since 2010 has come from demand for smartphones and their reliance on U.S.-made solid-state drives from companies such as Samsung.

Market leaders maintain competitive advantage by researching and designing superior products for business customers wanting to upgrade their computers and electronic devices to maintain their own competitive advantage.

Generally, the more a manufacturer spends on R&D, the better its chances of developing new products. U.S. semiconductor companies invest 14% to 20% of revenue in R&D. New technologies that lower the cost of production per chip mean prices can fall 50% within a few months.⁷⁰ The lifespan of semiconductors averages three to five years, but can be as brief as 18 months.

“Fabless” chip makers design and market but outsource manufacturing to reduce overhead. Foundry companies whose only business is manufacturing, are increasingly attractive outsourcing options and have become more specialized. Chip design and testing companies are also growing and customizing their services.

Intel’s new \$8 billion fabrication foundry being built in Hillsboro, Oregon, is currently the largest construction project in the world.⁶⁹

“Right now, there are 1.4 billion transistors on a chip the size of a fingernail; that equals a city block’s worth of skyscrapers in terms of volume of information.”⁷¹

69 Intel Community Affairs Department.

70 Investopedia.com. May 2013.

71 Confidential industry interview.

Major Players

U.S. based Intel leads the top 25 companies worldwide in 2013.⁷²

Ranking	Company	HQ Location	US Presence
1	Intel	California	Manufacturing
2	Samsung	South Korea	Manufacturing
3	TSMC/WaferTech*	Taiwan	Manufacturing
4	Qualcomm**	California	20 Sales offices
5	SK Hynix	South Korea	Sales CA TX NC
6	Toshiba	Japan	Sales CA TX NC NJ
7	Texas Instruments	Texas	Manufacturing
8	Micron	Idaho	Manufacturing
9	ST	Switzerland	Sales MD
10	Broadcom**	California	Manufacturing
11	Renesas	Japan, California	Manufacturing
12	Infineon	Germany	Sales
13	Advanced Micro Devices**(AMD)	California	Sales
14	Sony	Japan	Sales
15	NXP	Netherlands	R&D and Sales
16	MediaTek**	Taiwan	Sales TX CA MA
17	GlobalFoundries*§	California, New York	Manufacturing
18	Freescale	Texas	Manufacturing
19	UMC*	Japan, China, Vietnam	None
20	Nvidia	Alabama, California, Colorado, Florida, Massachusetts, Michigan, Missouri, North Carolina, Oregon*** South Carolina, Texas, Utah, Virginia, Washington	Sales

*Foundry

**Fabless

§Part owned by AMD

***Lake Oswego, Beaverton

Figure 10

Two other U.S. companies were among the top 25 semiconductor manufacturers in 2012:

- Marvell: Santa Clara, California; Corvallis, Oregon; Redmond, Washington
- ON Semiconductor: Phoenix, Arizona; Gresham, Oregon

Success among competitors is generally measured by:

1. Units shipped
2. Manufacturing process efficiencies
3. Product performance results based on industry benchmarks

⁷² IC Insights Strategic Revenue Database, 2013.

U.S. INDUSTRY GEOGRAPHY

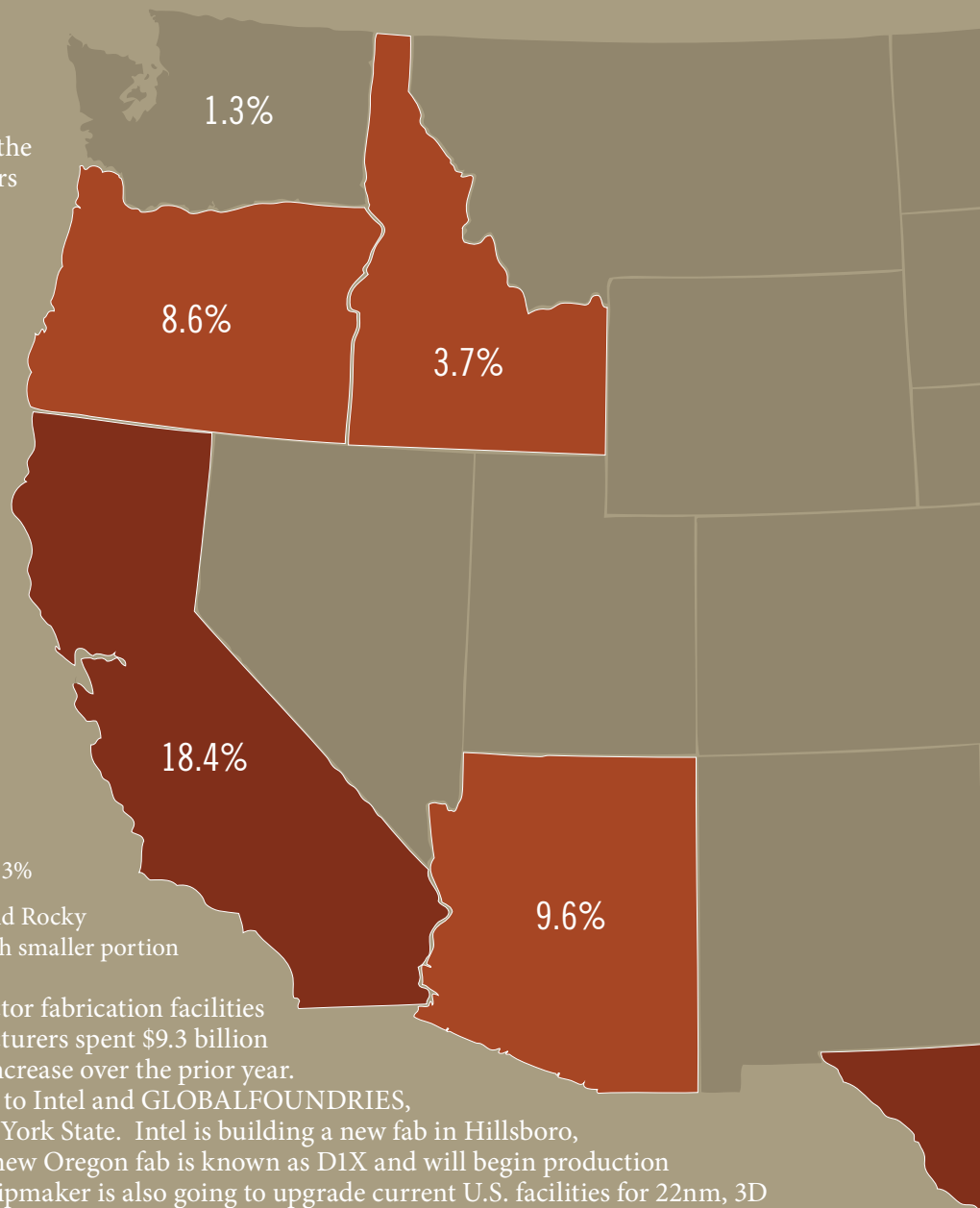
Concentrations of U.S. Electrical Equipment Manufacturing

Company location is influenced by the co-location of complementary buyers and suppliers and by a region's cost of production. State and local incentives can influence location and lower production costs.

The West accounts for 42.8% of the total number of U.S. companies in the semiconductor industry, and 30% of its revenue. Most of that is in California. The Southwest, including Arizona and Texas, accounts for 14.3% of businesses and 24% of employment. Industry revenue is concentrated as follows:

- 20% comes from companies in California and Texas
- 10% to 20% from Oregon, Idaho and Arizona
- New York accounts for 6.4%
- Washington State produces only 1.3%
- New England, the Mid-Atlantic and Rocky Mountain regions comprise a much smaller portion

There are currently 159 semiconductor fabrication facilities in North America,⁷³ where manufacturers spent \$9.3 billion on fab equipment in 2011 – a 61% increase over the prior year. Much of that spending is attributed to Intel and GLOBALFOUNDRIES, which is building a new fab in New York State. Intel is building a new fab in Hillsboro, Oregon, to handle 18" wafers. The new Oregon fab is known as DIX and will begin production in the first quarter of 2014.⁷⁴ The chipmaker is also going to upgrade current U.S. facilities for 22nm, 3D FinFET⁷⁵ production, for a total investment of between \$6 billion and \$8 billion.



73 Selectusa.commerce.gov.

74 Intel Third Quarter Earnings Announcement, October 15, 2013.

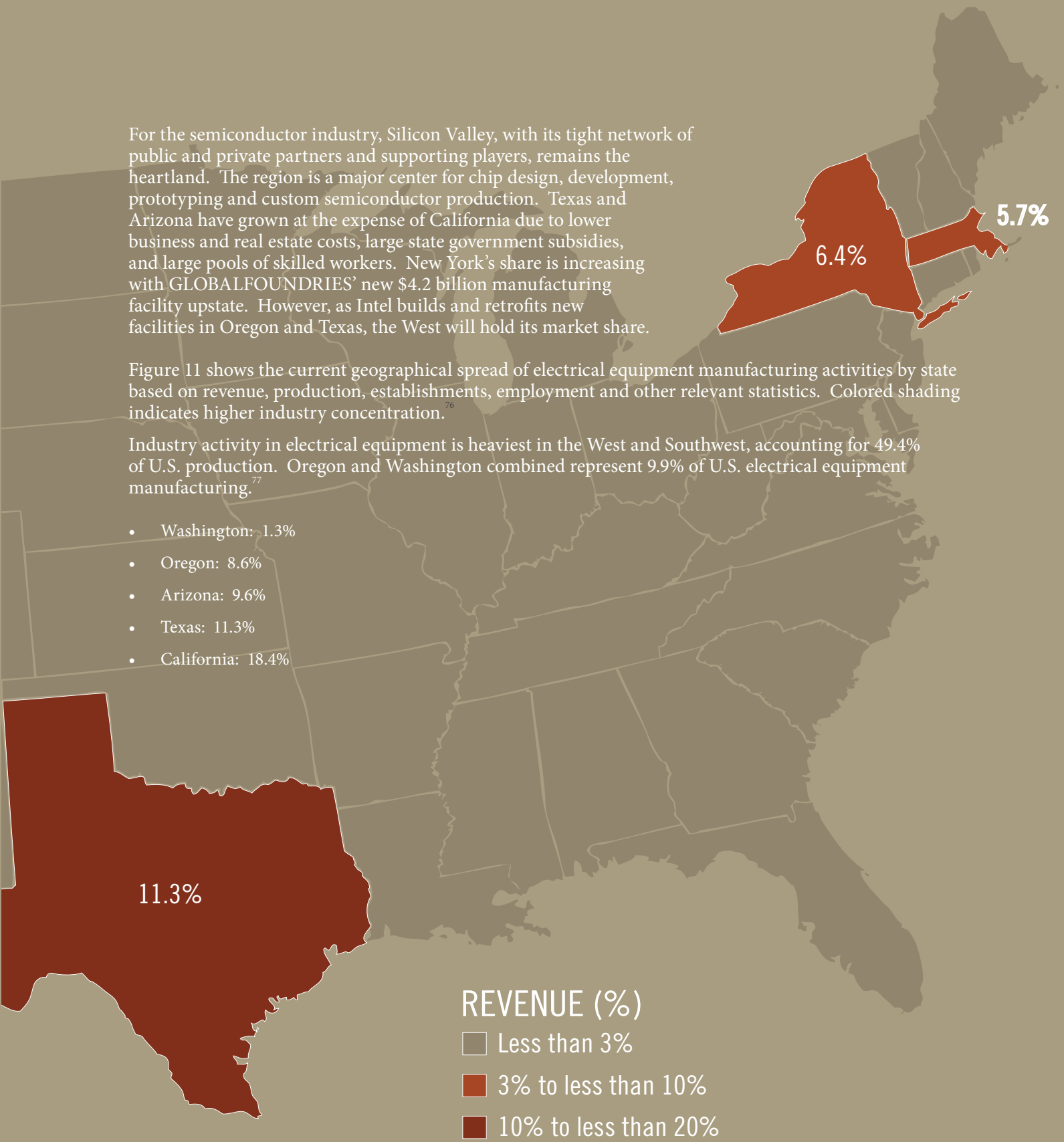
75 Multiple gate stackable transistors allowing greater speed and power. www.synopsis.com, Issue 3, 2012.

For the semiconductor industry, Silicon Valley, with its tight network of public and private partners and supporting players, remains the heartland. The region is a major center for chip design, development, prototyping and custom semiconductor production. Texas and Arizona have grown at the expense of California due to lower business and real estate costs, large state government subsidies, and large pools of skilled workers. New York's share is increasing with GLOBALFOUNDRIES' new \$4.2 billion manufacturing facility upstate. However, as Intel builds and retrofits new facilities in Oregon and Texas, the West will hold its market share.

Figure 11 shows the current geographical spread of electrical equipment manufacturing activities by state based on revenue, production, establishments, employment and other relevant statistics. Colored shading indicates higher industry concentration.⁷⁶

Industry activity in electrical equipment is heaviest in the West and Southwest, accounting for 49.4% of U.S. production. Oregon and Washington combined represent 9.9% of U.S. electrical equipment manufacturing.⁷⁷

- Washington: 1.3%
- Oregon: 8.6%
- Arizona: 9.6%
- Texas: 11.3%
- California: 18.4%



76 IBISWorld, September 2013.

77 IBISWorld, October 2013.

Figure 11

SUPPLY CHAIN⁷⁸

Demand for C&E comes from manufacturers of:

- Computers and electronic products
- Electronic devices and equipment
- Consumer electronics
- Wireless and networked telecommunications equipment
- Appliances
- All other manufacturing industries such as:
 - Aerospace & Defense
 - Industrial Machinery
 - Transportation Equipment
 - Health Care & Medical Devices

Manufacturers of the following components supply the C&E industry. They are mature sectors and supplier firms are consolidating.

- Electronic components
- Aluminum, copper and other materials for semiconductors
- Chemical products for photomasks used in printing integrated circuits
- Copper rolling, drawing and extruding for production of transistors

C&E has a complicated, global supply chain. A chip can go multiple times around the world before it arrives in a working finished product.

The Typical Electronics Supply Chain Has Four Tiers

Serving OEMs and ODMs are:

- Tier Four: Raw materials suppliers – source of commodities such as copper and aluminum
- Tier Three: Components manufacturers – source of mass-produced parts
- Tier Two: Components and sub-assembly manufacturers
- Tier One: Assembly operations and source of customized or modular parts and systems

Three additional layers in the supply chain can include:

- Logistics/Distribution: OEMs, distributors, wholesalers or retailers
- Electromechanical System Providers: Computer and electronic systems require installation, maintenance and repair. These services include plant floor and field service technicians who assemble, install, troubleshoot, repair and modify mechanical and electrical systems. They also include monitoring programmable controllers found on industrial machinery.
- Recyclers/Disposers

78 Sources: Council of Supply Chain Professionals, 2013; and CH2MHill.

Tiered supply chains are prevalent in industries such as electronics manufacturing, where final products consist of many complex components and subassemblies that must comply with strict quality and business standards.

Big OEMs and ODMs generally focus on overall design and production, often leaving other components and accessories to Tier One suppliers. They include final users such as Boeing in industrial markets, and Apple or GM in consumer markets. While large suppliers sell direct to companies like Intel, industrial suppliers down the tiers consider companies such as Intel and its suppliers as their OEMs.

Tier One suppliers provide complete components directly to OEMs and are the most important links in supply chains. They operate strategic, long-term, high-volume agreements with OEM/ODMs and are generally the largest and most technically capable with skills, resources and capacity to supply critical components and assemblies. They also have processes for managing suppliers in the tier below them. They typically have long experience in the industry, employees with accreditations and certifications, and experience managing supply chains to reduce costs and improve performance. They may even provide design concepts and manufacturing modules for entire systems. Intel is a classic regional example as a Tier One supplier for companies like Apple, Samsung and Boeing.

In some industries, Tier One suppliers provide complete manufacturing services, allowing OEMs to concentrate on final assembly and/or marketing. These are cooperative and often collaborative relationships where OEMs and suppliers work together to improve quality, eliminate waste, cut costs and reduce lead times. They often work on joint strategies to improve the supply chain. They may use data networks to exchange supply and demand information so all parties can synchronize production and logistics. Intel both supplies and competes with Samsung, and they also work on collaborative projects.

Tier One suppliers have recognized industry presence, reliability and market power.

Tier Two suppliers provide high quality components, subcomponents, and modular systems on time, with value-added services. They are “preferred” suppliers with longer-term but usually lower-volume agreements.

Tier Three suppliers provide subcomponents and other parts and services. They are considered “value-added” relationships for lower-volume agreements with infrequently used suppliers. Their demand is driven by their availability. For example:

- Manufacturer of motor in a product assembly
- Subcontractor to produce short-run specialty items

Tier Four suppliers provide raw materials and basic parts or tools. They are typically commodity suppliers or one-time procurement options with no ongoing relationships or expenditures by the companies they supply. Their demand is driven by price. For example:

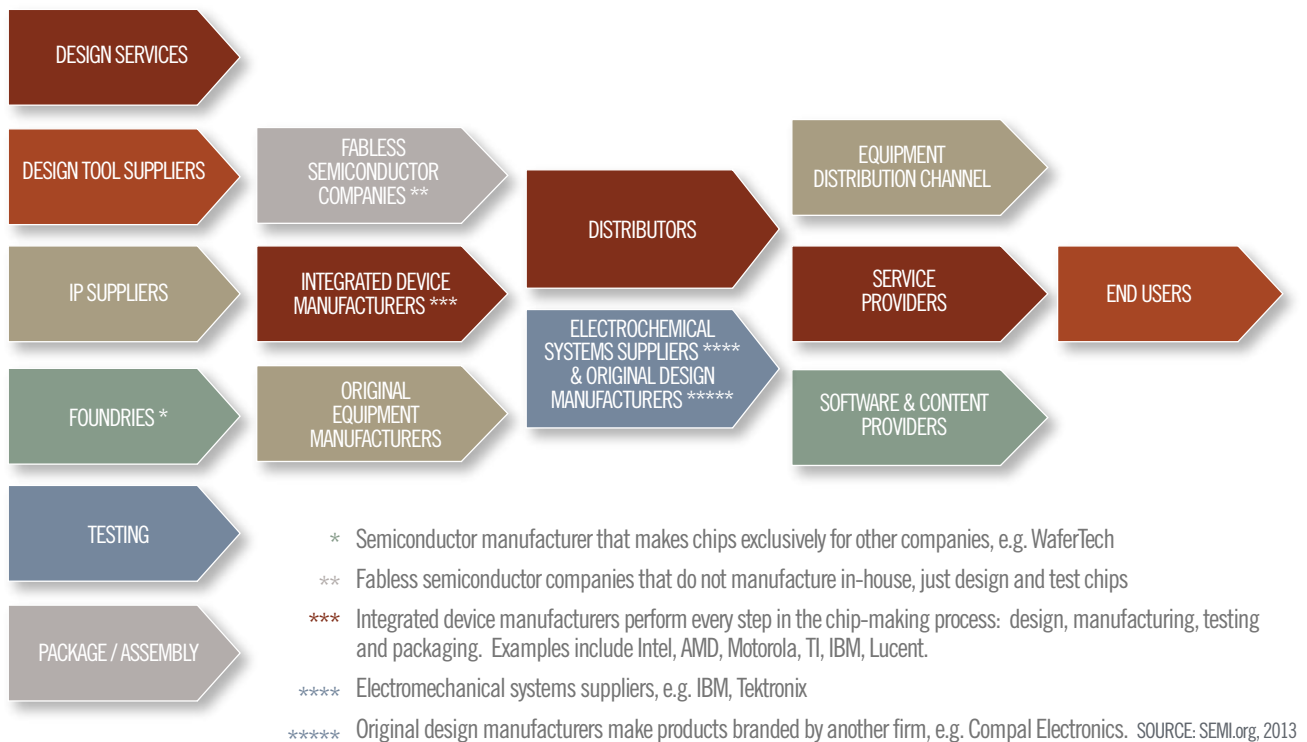
- A supplier of polyethylene pellets that get heated, then blow-molded into shapes such as fan blades
- A company that takes raw copper ingots and extrudes them into copper wire used in motors

Related industry suppliers of chemical products, computer peripherals, and metals such as aluminum and copper have matured, leading to company consolidations.

Semiconductor manufacturing companies traditionally invested in being vertically integrated; however, improving quality while reducing costs and time-to-market has led many to outsource production to “fabless” semiconductor companies. Over the past 20 years, tools, testing and packaging, IP development, and foundry services have also been delegated. As designs have become more complex, integration of development and manufacturing has created issues that can carry through to production, leading OEMs and fabless companies to outsource to experts without adding cost. While efficient, that also has led to the challenges of managing a complex supply chain.

The model used today offers a variety of options from which firms can obtain services to lower cost, lessen risk and increase flexibility. Companies even go from “fabless” to “product-less” as R&D and application expertise are left to collaborative partners.

Production choices are made from a model known as the Semiconductor Value Chain.⁷⁹



SOURCE: Gartner Research, 2005

Figure 12

79 The Changing Supply, System Level Design Insights for Chip Architects and Engineers, <http://chipdesignmag.com/index.php>, August 2013.

Greater Portland Regional Supply Chain

Location quotients greater than 1.0 represent regional supply chain strengths on which to build. Lower LQs represent supply chain gaps to fill. The Greater Portland region has many opportunities to exploit, given its industry LQs.

Value-Added Benefits Are Necessary to be Competitive

Supplier Characteristics Valued by Buyers

- Quality products
- On-time delivery every time
- Creative problem solving
- Capacity to accommodate fast delivery needs for just-in-time inventory
- Capability with electronic order processing and billing
- Willingness to collaborate
- Contacts in major markets with overseas supply networks
- Access to investment capital to finance new product development and capacity expansion
- R&D investment spending and ability to share industry knowledge

Success Factors for Competitive Suppliers

- Specialize in value-added markets
 - Intel is the world's leading microprocessor designer and manufactures for companies such as Apple and HP
 - Linear Technology (Camas, Washington) enjoys high margins as the sole maker of analog integrated circuits, filling an important niche for electric vehicles, radio frequency identification (RFID) tags and other electronic products
- Invest in leading-edge software and technologies that differentiate a company from commodity suppliers in Asia
- Invest in significant R&D in order to generate proprietary technological innovation
- Maintain a highly skilled workforce of technicians and manufacturing workers
- Have a professionally advanced workforce of engineers, scientists, and mathematicians
- Support regional organizations and institutions that provide basic and applied research plus funding and technical support for commercializing new technologies and products; they can be excellent sources of R&D assistance for product development and testing
- Look for customers beyond one's own backyard, across the country and around the world

Regional Location Quotients Are All Above Average

Sector	NAICS	LQ
Computers & Electronics	33411	9.26
Semiconductors, Circuits, Optoelectronics	33441	9.26
Electronics	33411	4.14
Circuit Boards & Electronic Components	33441	3.70
Computers & Peripherals	33441	1.83
Cable & Wire, Wiring Devices, Electrical Equipment, Lithium Storage Batteries	335	1.02

Figure 13

Key Regional Supply Chain Players

It is estimated that 5,812 technology-related regional companies generate \$37.6 billion annually and export \$7.2 billion in product,⁸⁰ most of which comes from Intel. Hillsboro, Oregon, and Camas, Washington host the largest cluster of regional technology companies. In Oregon, Hillsboro is home to Intel's largest global manufacturing facility. The volume of technology firms and skilled employees, combined with the Northwest's lower energy costs and stable hydroelectric power, make Southwest Washington/Northwest Oregon globally competitive. Regional companies have spun off technology firms employing more than 54,000 people.

OEM:

INTEL – Hillsboro, Oregon: Headquartered in Santa Clara, California, Intel opened facilities in Oregon in 1974 and is now the state's largest employer.

- Revenue \$53.5 Billion (2012)
- 17,000 local employees

Tier One:

TRIQUINT SEMICONDUCTOR – Hillsboro, Oregon: Originating in 1985 as a spin-off of Tektronix, TriQuint Semiconductor is a global provider of innovative radio frequency (RF) solutions and foundry services for the world's top communications, defense and aerospace companies, making connected mobile devices and networks that deliver voice, data and video communications. TriQuint creates standard and custom products. The company has ISO9001-certified manufacturing facilities in the U.S., production in Costa Rica, and design centers in North America and Germany. TriQuint Semiconductor is a wholly owned subsidiary of Rocky Holding, Inc., which is based in Greensboro, North Carolina.

- Revenue \$829.2 million (2012)
- 2,723 local employees

Tiers One and Two:

LATTICE SEMICONDUCTOR – Hillsboro, Oregon: Lattice Semiconductor designs and develops programmable products, which allow the end customer to determine functionality. Customers are primarily original equipment manufacturers in industrial, automotive, medical and military end markets. The company has development centers in Santa Clara, California; Shanghai; and Bangalore, India, and operations centers in Manila and Singapore. While 66% of its revenue comes from Asia, 14% comes from Europe, 12% from the U.S. and 8% from Japan. Its end markets include industrial (23%), communications (38%), consumer electronics (31%), and computing (8%)⁸¹

- Revenue is estimated to be \$280 million (27% growth projected for 2013)
- 2,500 local employees

80 Business Oregon High Technology Key Industry, www.oregon4biz.com, March 2013.

81 Lattice Corporate Overview for Investors, July 2013.

Tiers One and Two:

WAFERTECH – Camas, Washington: Established in 1996, WaferTech was the first semiconductor contract manufacturer in the U.S. It makes integrated circuits, known as computer chips, on standard eight-inch wafers. It is a division of Taiwan's TSMC, the world's largest semiconductor foundry, opened in 1987.

- Revenue \$250 million (2012, Camas only)
- 1,000 local employees

Tier Two:

TEKTRONIX – Beaverton, Oregon: Tektronix manufactures test and measurement equipment such as logic analyzers, oscilloscopes, and video and mobile test protocol equipment. It also manufactures high performance radio frequency solutions, semiconductors, switches and transistors, and assembles and packages integrated circuits. While Danaher Corporation acquired it in 2007, Tektronix has been in the region since the 1940s.

- Revenue \$1.1 billion⁸² worldwide
- 2,100 local employees, 2007 (in 2011, it reportedly laid off an unspecified number of employees)⁸³

Tier Two:

ESI – Portland, Oregon: ElectroScientific Industries, Inc. is a leading supplier of innovative, laser-based manufacturing solutions for the microtechnology industry, with global operations from the Pacific Northwest to the Pacific Rim. Founded in 1944, it manufactures pyrophotonic lasers and is a leading supplier of innovative, laser-based manufacturing solutions for the microtechnology industry. The company builds laser microfabrication tools and develops technologies related to semiconductor packaging, as well as proprietary laser technology. Their systems enable precise engineering and testing of micron to submicron features in semiconductors, LEDs, multi-layer ceramic capacitors (MLCCs), printed circuit boards (PCBs), flex circuits and other high-value components. ESI has locations in Klamath Falls, Oregon; Fremont, California; and Quebec, Canada.

- Revenue \$148.5 million (2013 estimate)
- 599 local employees⁸⁴

Tier Three:

CASCADE MICROTECH – Beaverton, Oregon: Cascade Microtech provides precision electrical measurement and testing of advanced semiconductor devices, including engineering and analytical probes and probe cards for integrated circuits, chips, circuit boards, modules, MEMS, 3D TSV, LED devices, and more. They report having 1700 customers, including the 25 largest semiconductor manufacturers in the world. Founded in 1984, it has grown through acquisitions and inventions and has offices in Germany.

- Revenue \$120 million (2012)
- 383 local employees (2013)⁸⁵

82 www.advfn.com/exchanges/nyse/TEK/financials.

83 Oregonian, November 4, 2011.

84 Wall St. Journal, November 22, 2013.

85 Seattle Times, June 11, 2013.

Tier Four:

SEH America (ShinEtsu, Japan) – Vancouver, Washington: SEH is the world’s largest producer of semiconductor silicon and wafers on which semiconductor manufacturers add circuit patterns to create “computer chips.” SEH manufactures single crystal silicon ingots along with polished and epitaxial wafers, and provides engineering and service support. It operates in the U.S., Japan, Malaysia, Europe, and Taiwan.

- Revenue \$138 million (U.S.)
- 172 local employees (Vancouver, Washington)⁸⁶

Tier Four:

LAM RESEARCH CORPORATION – Fremont, California: As a major supplier of fabrication equipment and services to the worldwide semiconductor manufacturing industry, LAM manufactures in Tualatin, Oregon, and has offices in Hillsboro, Oregon and Vancouver, Washington. The company provides leadership in thin film deposition, photoresist stripping, and versatile wafer fabrication equipment for 3D structures in advanced devices, and is scaling to 450mm wafers. LAM is a publicly traded global company.

- Revenue \$3.2 billion (2012)
- 700 local employees⁸⁷

The Final Stage – Recycling:

IMS ELECTRONICS RECYCLING – San Diego, California: IMS is a privately held, non-ferrous product recycling company with operations in Vancouver, Washington; Georgia, and Ohio. The final step in the supply chain is reclamation and disposal. Large quantities of used electronic products are collected from consumers and businesses, evaluated, and classified as working electronic goods to be refurbished and resold, or as non-working goods to be recycled as scrap material. The supply chain is a complicated network of domestic sales and exports. In 2011, exports totaled \$1.45 billion;⁸⁸ top foreign buyers were Mexico, India, Hong Kong, China, South Korea, and Japan. Large clients include Dell and Intel.

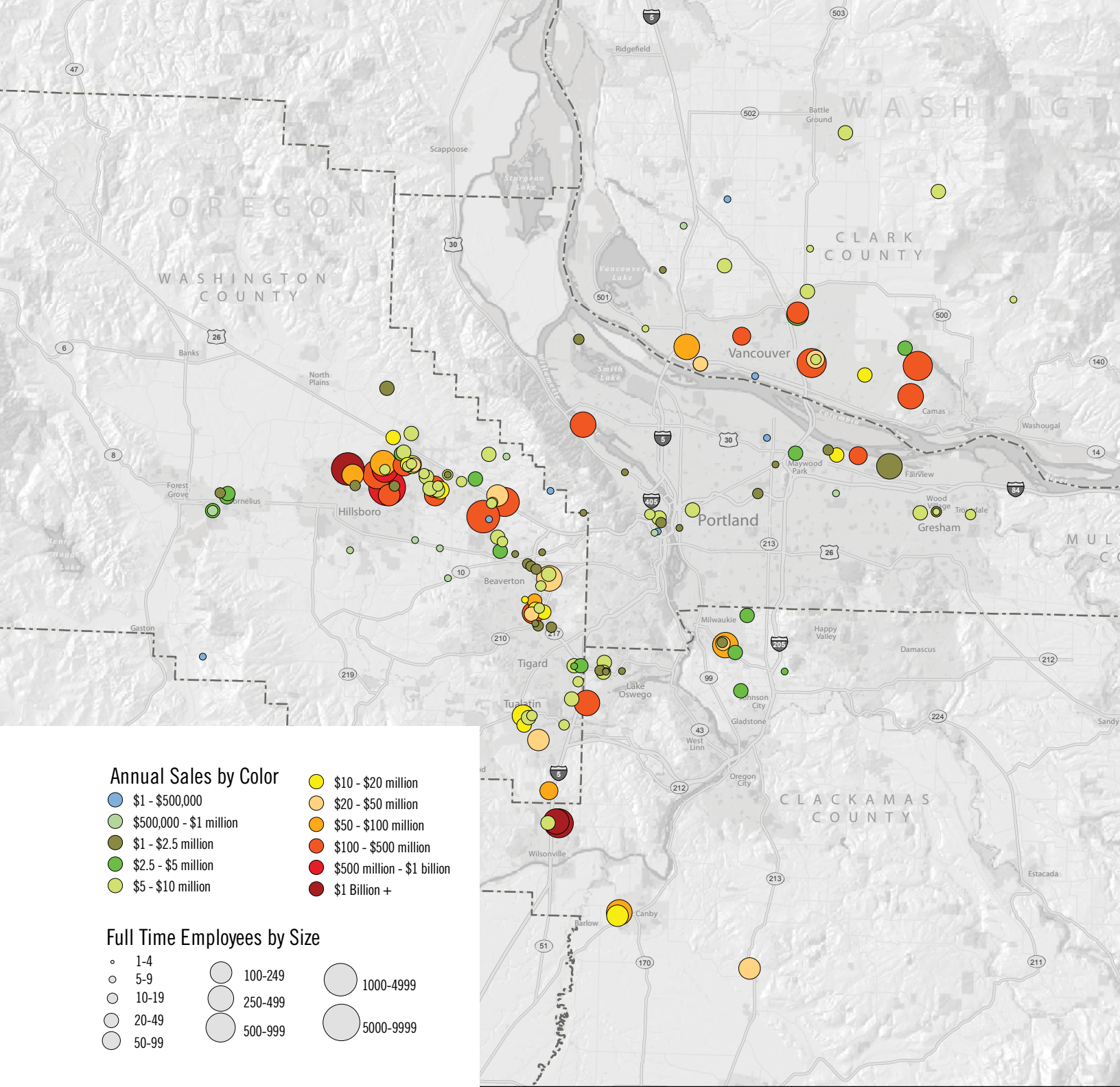
- Revenue \$13.9 million (2012)
- 60 local employees⁸⁹

86 www.OutsideView.com. December 2013; cited as 800 workers by Oregon Live, December 16, 2011.

87 The Tigard Tualatin Sherwood Times, January 24, 2013.

88 US International Trade Commission, Used Electronic Products: An Examination of U.S. Exports, February 2013.

89 The Columbian, Clark County at Work, June 17, 2012.



COMPUTERS & ELECTRONICS REGIONAL GIS MAP

This map illustrates 175 regional C&E companies located within the five-county area covered in this research. They range from small to global Fortune 500 companies and are indicated by location and number of employees. The larger the dot, the more employees the company has. The list of businesses is provided in Appendix A.

REGIONAL ASSETS & GAPS

The Greater Portland region has a rich network of resources promoting and supporting the C&E industry. A complete list is provided in Appendix C.

- Legal assistance for regulatory compliance and exporting
- Capital access
- Business organizations
- Industry technical experts
- University R&D
- Government-supported research centers

C&E Industry Research & Advocacy Organizations

Key industry support organizations relevant to C&E include advanced manufacturing, clean technology and “high” technology such as semiconductors, electric vehicles and nanotechnology.

Infrastructure Assets

Oregon Best

Oregon Best collaborates with Oregon universities on photovoltaics and other clean technology innovations to help companies build capabilities, network, and find solutions to environmental challenges. Shared-user lab facilities offer businesses access to research, expertise and workforce development to help companies compete globally. www.oregonbest.org

Technology Association of Oregon

The largest professional technology association in the Northwest, TAO works with over 350 companies in Oregon and Southwest Washington in technology and software industries. www.techoregon.org

Oregon Nanotechnology &

Microtechnologies Institute

ONAMI accelerates innovation and commercialization of materials science and related device and systems technologies. www.onami.us

Oregon Innovation Council

Oregon InC supports the state’s signature research centers, connecting businesses and universities with research resources. www.oregon4biz.com

Oregon Metals Initiative

OMI is a consortium of metals industry research institutions and businesses pursuing research to improve Oregon’s competitiveness and industry infrastructure for metals material development and manufacturing, and to commercialize and patent technology advances. Metal and new light metals are key basic ingredients in the manufacture of semiconductors and other electronic products. www.oregonmetal.org

Pacific Northwest National Laboratory

Located in Richland, Washington and Portland, Oregon, PNNL provides basic research for and helps commercialize science and technology advancements. Current electronics efforts focus on sensors and systems monitoring. www.pnl.gov

Drive Oregon

Portland-based Drive Oregon connects innovators, entrepreneurs and industry leaders to grow the region’s electric mobility industry. www.driveoregon.org

SUPPLIER COMMODITIES

The chart below shows commodity supplies needed by C&E manufacturers and amounts procured locally.⁹⁰ Those highlighted in gold are necessary inputs that seem to be in relatively short supply regionally, indicating opportunities to be filled.

NAICS Code	Products	Local Purchase Percent	No. of Companies
3243	Semiconductors & Related Devices	68.52	61
3376	Scientific R&D Services	65.79	347
3170	Iron, Steel, Ferroalloy Products	59.43	4
3127	Plastics Materials and Resins	6.39	5
3177	Rolled, Drawn, Extruded, Alloyed Copper	35.74	1
3209	Semiconductor Machinery	32.94	20
3196	Turned Products and Screws, Nuts, and Bolts	28.68	27
3195	Machined Products	28.55	269
3143	Unlaminated Plastic Profile Shapes	25.71	6
3247	Other Electronic Components	20.39	25
3253	Electricity & Signal Testing Instruments	19.27	21
3244	Electronic Capacitors, Resistors, Coils, Transformers & Others	18.57	6
3181	All Other Forged, Stamped, and Sintered Metals	18.36	7
3236	Computer Terminals & Other Peripherals	16.06	16
3269	Relays & Industrial Controls	15.27	21
3121	Industrial Gas	13.70	7
3125	All Other Basic Inorganic Chemicals	13.02	7
3242	Bare Printed Circuit Boards	11.80	11
3246	Printed Circuit Assemblies	11.60	29
3268	Switch Gear & Switchboard Apparatus	11.29	7
3251	Industrial Process Variable Instruments	7.4	22
3141	All Other Chemicals & Preparations	6.68	10
3127	Plastic Materials & Resins	6.39	5
3211	Optical Instruments & Lenses	4.52	13
3267	Motors & Generators	4.34	3
3243	Electronic Computers	3.48	17
3176	Nonferrous Metals (except Copper and Aluminum)	0	0

Figure 14

Growth Opportunity for Successful Industry Suppliers

Only four commodities (highlighted in red on the chart above) are purchased locally by more than 50%. That leaves much still to be supplied within or near the region by existing and new suppliers. OEMs/ODMs are increasingly sourcing complete system-level solutions that integrate the functionality of multiple integrated circuits required to operate as a “system-on-a-chip.” This trend will benefit semiconductor companies, and it presents a significant opportunity for regional suppliers who have system-level expertise, software capabilities, and validation and testing competence.

90 Business Oregon and IMPLAN 2010.

The Greater Portland region is perfectly positioned for shipping nationally and internationally, with direct access north to Canada, south to Mexico, and west to Asia, as well as directly across to the U.S. East Coast. The infrastructure includes world-class Portland International Airport (PDX), marine and rail ports in Portland, Oregon and Vancouver, Washington, and a network of north/south and east/west interstate highways. A report detailing port access and logistics improvements has been prepared for the MEI.⁹¹

Computers & Electronics Regional Gap: The Workforce

While the Greater Portland area has a multitude of assets, there are challenges that prohibit the potential of regional economic growth. The regional educated workforce in C&E-related fields is at par or above the U.S. as a whole. But the need for educated and trained workers for C&E-related companies is predicted to grow over the next ten years.⁹²

Regional Workers with Bachelor’s Degrees, 25 and Older (2011)⁹³, Are on Par with the National Average

Profession	% Regional Degree Holders	U.S. Degree Holders
Science & Engineering Related Fields	48%	44%
Engineering	8.3%	7.8%
Science & Engineering	8%	9%
Physical Sciences	4.3%	3.5%
Computers, Math, Statistics	3.8%	4.2%

Figure 15

Portland regional employment is highly concentrated in STEM fields (science, technology, engineering and math), accounting for 7.2% of metropolitan regional jobs versus 5.8% nationwide. Though behind U.S. leaders like San Jose, California, Portland has a relatively high technology manufacturing sector – greater than Houston, Dallas, Pittsburgh or Atlanta.

The region also has a higher proportion of employees in electronics and related fields: engineers, technicians, web developers, “all other computer occupations,” and industrial and electronic engineers. However, the average regional STEM wage is 2.1% below the national average, at \$77,206 versus \$78,878.⁹⁴

91 Greater Portland Export Initiative, Regional Westside Freight Access and Logistics Analysis. DKS Associates, October 1, 2013.

92 Oregon Employment Department, Amy Vandervliet, September 2013.

93 U.S. Census Bureau, 2011 American Community Survey. Portland, Hillsboro, Vancouver MSA.

94 Oregon Employment Department, Workforce Analysis, Portland Trends. June 2013.

Relevant Occupations as a Portion of Regional Employment⁹⁵

In this analysis, the cluster is defined by the following four-digit North American Industrial Classification Codes (NAICS):

- 3332 Industrial Manufacturing
- 3344 Semiconductor and Other Electronic Component Manufacturing
- 3345 Navigational, Measuring, Electromedical, and Control Instruments
- 3341 Computer and Peripheral Equipment Manufacturing
- 3353 Electrical Equipment Manufacturing
- 3359 Other Electrical Equipment and Component Manufacturing

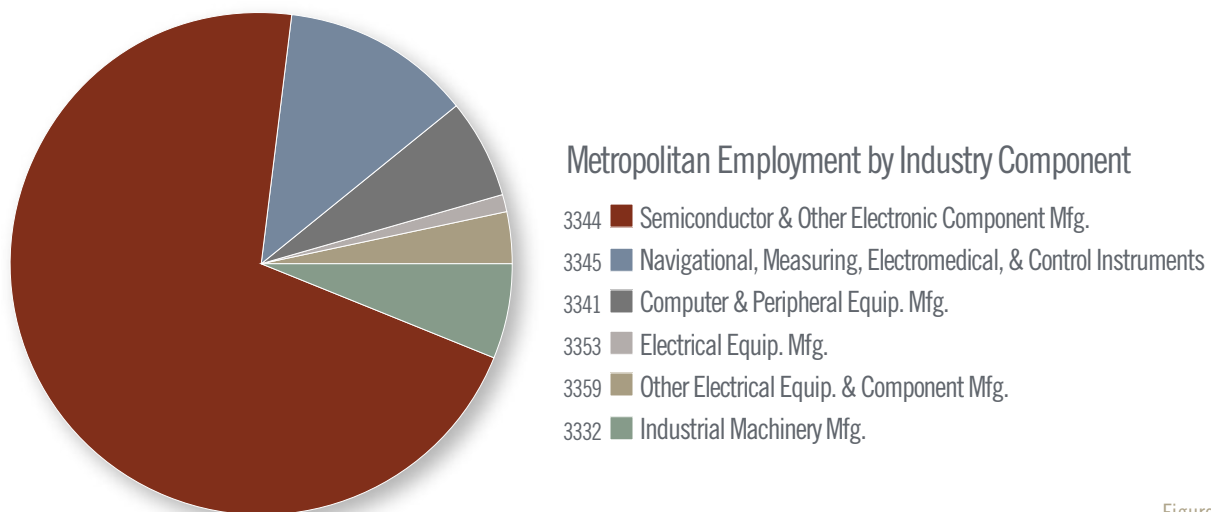


Figure 16

C&E jobs in each industry sector reflect a preponderance of jobs in semiconductor and electronic component manufacturing. C&E employment totaled 35,466 jobs in 2012.⁹⁶

Number of Regional C&E Related Jobs

Industrial Machinery Mfg.	(3332)	2,172
Semiconductor & Other Electronic Component Mfg.	(3344)	25,214
Navigational, Measuring, Electromedical, & Control Instruments	(3345)	4,330
Computer & Peripheral Equip. Mfg.	(3341)	2,244
Electrical Equip. Mfg.	(3353)	372
Other Electrical Equip. & Component Mfg.	(3359)	1,134

Figure 17

⁹⁵ WorkSource Oregon Labor Market Information.

⁹⁶ WorkSource Oregon, September 2013.

Components of this industry are part of advanced manufacturing and high technology clusters identified by WorkSystems Inc. and WICCO (Workforce Investment Council of Clackamas County) in their sector strategy efforts. Sector strategies are employer-driven partnerships aimed at addressing the workforce needs of key industries. Partners include business, economic development, and education and training providers. They are a key component of the Governor’s Ten-Year Plan and the Oregon Workforce Investment Board’s Strategic Plan.

The Portland Development Commission includes advanced manufacturing and high tech on their list of industries critical to the City’s current and future economic health. Greater Portland Inc., an organization that helps companies expand and locate in the greater metropolitan area, has also identified them as key sectors because of their economic contributions:

- **Well-paying jobs:** \$117,687 average annual wage in 2012
 - All components pay higher than average wages
 - Jobs in this industry pay over twice the all-industry average for the private sector
- 4.7% of total private sector employment accounts for 10.9% of total private sector payroll
- The region’s durable goods manufacturing accounts for 32.7% of the region’s employment
- Employment is nearly four times more concentrated in the Greater Portland region versus the nation (location quotient 3.94)

FAST FACTS Portland Metro Area (Oregon Portion): 2012⁹⁷

Business units: 283
Employment: 35,466
Payroll: \$4,173,894,106
Average Wage: \$117,687

Computers & Electronics Manufacturing Employment Forecast⁹⁸

Tri-County Area (Multnomah, Clackamas, Washington)⁹⁹

NAICS	Industry	2010	2020	% Change
3353	Electrical Equipment	300	380	26.7%
3332	Industrial Machinery	1840	2260	22.8%
3359	Other Electrical Equip't & Components	1000	1170	17.0%
3345	Navigation, Measuring, Electromedical & Control Instruments	4190	4880	16.5%
3341	Computer & Peripheral Equipment	2450	2810	14.7%
3344	Semiconductor & Electronic Components	23110	26100	12.9%
	TOTALS	32,890	37,600	17.84% avg
	All Industries	806540	972570	20.6%
	Durable Goods Manufacturing	67,660	79,460	17.4%

Figure 18

97 Ibid.

98 Oregon Employment Department, Workforce & Economic Research, September 2013.

99 **The Portland-Vancouver-Hillsboro, Ore. Metropolitan Statistical Area** includes Clackamas, Columbia, Multnomah, Washington, and Yamhill Counties of Oregon and Clark and Skamania Counties of Washington.

Job Specific Employment Forecast for Computer & Electronic Product Manufacturing* (Oregon Statewide)

NAICS 334

Computer & Electronics Manufacturing Employment Forecast	2012 Employment	Projected 2020	% Increase
Electrical & Electronics Repairers, Commercial & Industrial	993	1,075	15.2%
Electronics Engineers, Except Computer	1,781	2,034	14.2%
Electrical & Electronic Equipment Assemblers	4,519	4,833	7.0%
Electrical Engineers	1,324	1,550	17.1%
Electrical & Electronic Engineering Technicians	2,777	2,989	7.6%
Industrial Engineers	3,447	3,832	11.2%
Supervisors & Managers of Production/Ops Workers	6,960	7,757	11.5%
Inspectors, Testers, Sorters, Samplers, Weighers	5,146	5,941	15.5%
Engineering Technicians, Except Drafters, All Other	,668	1,786	7.1%
Software Developers, Applications	7,563	9,610	27.1%
Computer Hardware Engineers	3,445	3,993	15.9%
Semiconductor Processors	2,342	2,490	6.3%
Business Operations Specialists	48,498	56,115	15.7%
Engineers, All Other	2,244	2,533	12.9%
Engineering Managers	2,689	3,110	15.7%

*Oregon Employment Department, Workforce and Economic Research, April 2014

Figure 19

Regional Business Owners Express Concern about Finding the Workers They Need

While forecasts predict increased need, even now regional employers feel the pressure of a small qualified labor pool. The Portland Business Journal hosted a Manufacturing Roundtable in July 2013.¹⁰⁰ where participants expressed their struggle to find skilled employees. Companies want the public school system to focus more on skill-based training for manufacturing occupations and provide school-industry partnerships and apprenticeships where students learn industry-specific skills. Some companies have initiated in-house apprenticeship programs to address their need for workers. However, there are no sanctioned curricula on which they may rely. This is an opportunity for economic development and workforce support organizations to work with the private sector to develop and implement appropriate training courses.

In the Portland-Vancouver-Hillsboro MSA, above-average concentrations of employment were found in many of the occupations within the architecture and engineering group. For instance, electrical and electronics engineering technicians were employed at 2.4 times the national rate in Portland, and electronics engineers (except computer engineers) were employed at 2.2 times the U.S. average.¹⁰¹

100 Oregon Employment Department, WorkForce Research, October 2013.

101 Occupational Employment and Wages in Portland-Vancouver-Hillsboro, May 2012. U.S. Department of Labor Bureau of Labor Statistics, May 29, 2013.

However, relevant electronics industry occupations are reported as difficult to fill by employers. They include:¹⁰²

- Cutters, Trimmers, Electricians
- Welders, Cutters, Solderers and Brazers
- Computer Controlled Machine Tool Operators
- Software Developers, Applications
- First-line Supervisors of Production and Operations Workers
- Production Workers

Reasons they are difficult to fill, ranked in order of difficulty, include:

1. Lack of qualified candidates	18%
2. Unfavorable working conditions	18%
3. Lack of job applicants	15%
4. Lack of work experience	13%
5. Other	7%
6. Lack of technical skills	6%
7. Lack of certification	5%
8. Lack of soft skills	5%
9. Location	4%
10. Low wages	4%
11. Lack of training	3%
12. High education requirements	2%

At the graduate degree level, reasons for hard-to-fill vacancies are different:

1. Lack of job applicants	47%
2. High education requirements	18%
3. Lack of qualified candidates	15%
4. Other	7%
5. Location	4%
6. Low wages	3%
7. Lack of work experience	3%
8. Lack of technical skills	2%
9. Lack of training	1%

While both categories – relevant occupations and professional/management careers – reflect difficulty finding qualified, experienced applicants, more than 33% of occupations and nearly half of graduate-level jobs have no qualified applicants. The latter category includes engineers, scientists and other technical experts.

There is a smaller pool of applicants at that level nationally as well as regionally. To attract the best candidates, regions need more than just quality of life and cost-of-living benefits. They need an attractive, competitive assortment of industry and career-related options: R&D organizations engaged in industry innovation, competing companies for growth opportunities, and world-class universities engaging in industry research and public-private business partnerships.

102 Oregon Employment Department, Two-Fifths of Oregon's Job Vacancies are Difficult to Fill. July 2013.

INTERNATIONAL TRADE

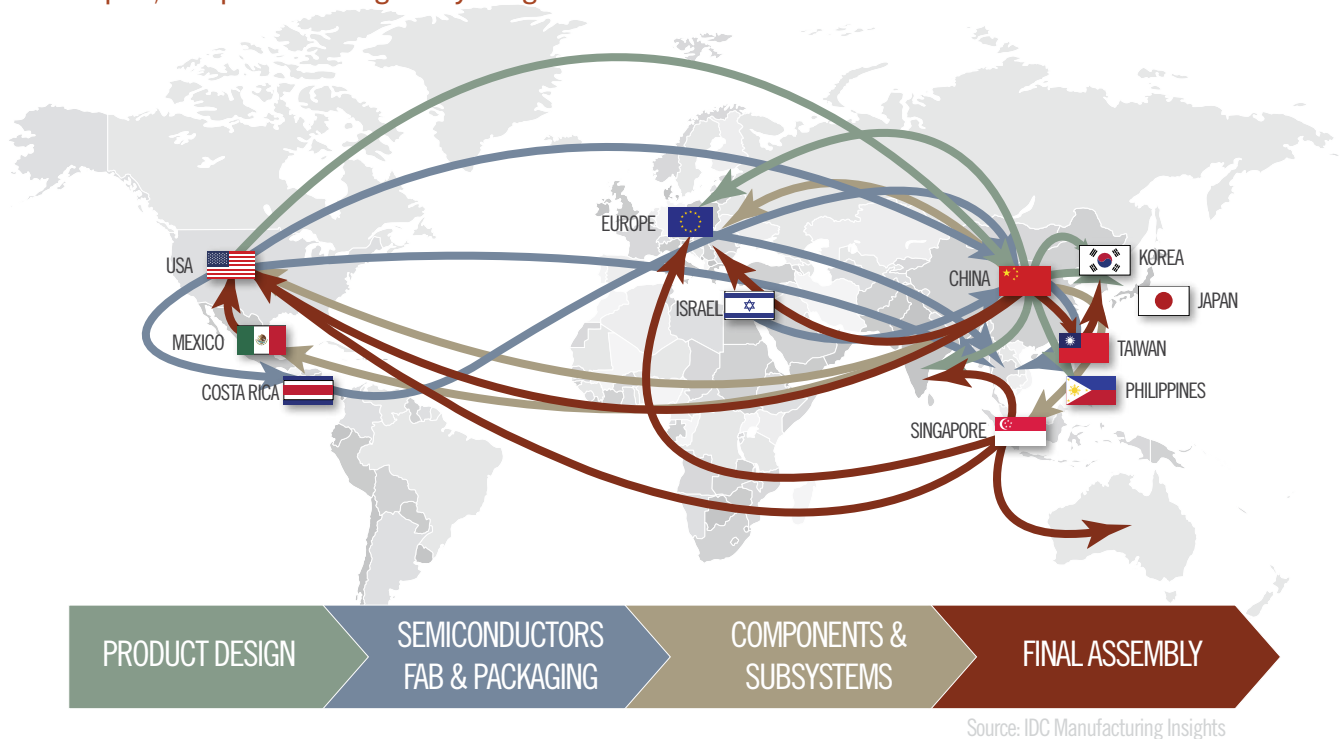
A Market Expansion Opportunity in Support of the Greater Portland Export Initiative

Instead of exporting directly, many American small and medium businesses export indirectly by selling goods to large U.S. companies that export. Those companies account for nearly 25% of the value of purchases by large companies that export finished goods to customers around the world.¹⁰³ Large companies are constantly looking for product suppliers that can meet strict quality, certification and quantity requirements, but capacity issues can be a challenge for small firms.

Foreign-owned companies, such as Switzerland-based STMicroelectronics Inc., one of the world's largest semiconductor companies, rely on regional companies such as Ash Ware Inc. of Beaverton, Oregon, to provide products like timing processors for aerospace, industrial controls, and commercial electronics.¹⁰⁴

The global supply chain for semiconductor products is complex and sometimes circular. A chip made in Oregon or Washington can be shipped to Vietnam, Malaysia or other points east to be assembled into components that end up in electronic devices and products shipped back to the U.S. or to Europe for distribution and resale.

The global supply chain for semiconductors and electronic devices is complex, competitive and globally integrated.



103 Business Roundtable, David Thomas, www.brt.org/trade.
104 www.st.com.

Figure 20

Top 10 U.S. Imports¹⁰⁵

As indicated in the following chart, C&E accounts for nearly 20% of U.S. imports.

Products (top 10 total = 78%)	\$ Value Millions	Percent of Total Imports
Computer & Electronic Products	342,594	15.7
Oil & Gas	279,778	12.8
Transportation Equipment	267,865	12.2
Chemicals	216,035	9.9
Petroleum & Coal Products	141,244	6.5
Machinery, except Electrical	133,770	6.1
Miscellaneous Manufactured Commodities	104,174	4.8
Primary Metal Manufacturing	102,992	4.7
Electrical Equipment, Components & Appliances	75,761	3.5

Figure 21

The largest source of semiconductor and related device *imports* to the U.S. are from the countries shown in the following chart:¹⁰⁶

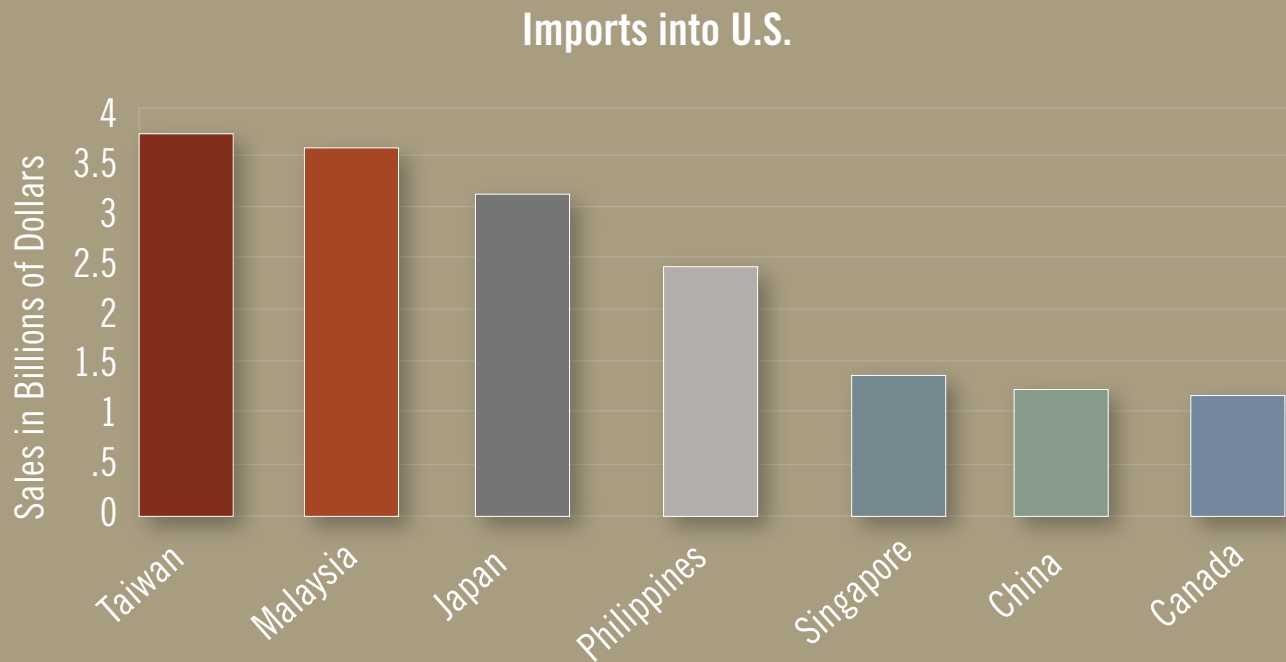


Figure 22

¹⁰⁵ U.S. Census.gov, foreign trade information.

¹⁰⁶ www.nationmaster.com, economic trade information.

U.S. Exports

C&E is a global industry with heavy competition from established technology countries such as Taiwan and South Korea and rapidly advancing countries such as China. However, the U.S. still maintains a slight advantage with the best worldwide reputation for quality and innovation. Holding on to those high-value, high-margin parts of the industry and exporting components and systems to branded manufacturers in other countries can be a profitable route to success.

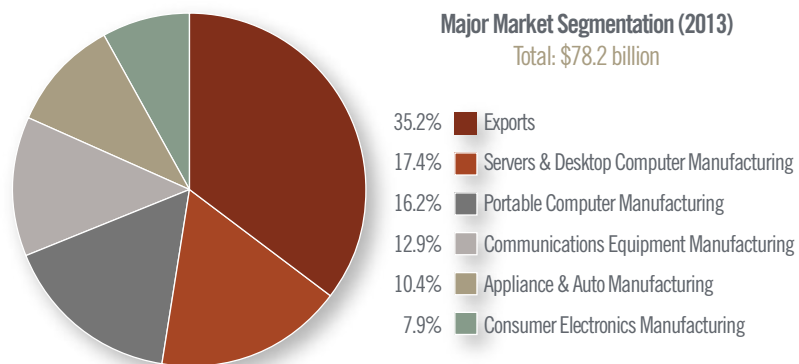
One-third of all U.S. exports are capital goods worth \$527 billion. The largest categories are industrial machines, commercial aircraft, semiconductors, medical equipment, telecommunications and *computer equipment*.¹⁰⁷ China in particular is interested in environmental monitoring, measuring, and cleaning equipment, given its problems with air and water pollution.

Electrical equipment leads the list of the top ten manufactured products in America's \$2 trillion export industry.¹⁰⁸ It has a 3.4% share of manufacturing exports, a 3.4% share of export growth, and is growing at a rate of 14.7% annually.

C&E products are number seven on the list of top U.S. exports, with 12.8% of U.S. manufacturing exports, 13% of manufacturing export growth, and an annual growth rate of 14.8%. Semiconductors are the number one U.S. high tech export;¹⁰⁹ nearly 75% of U.S. chip industry revenue is the result of export sales.¹¹⁰

The revenues of U.S.-based chip companies account for nearly half of global semiconductor sales, and more than three-quarters of U.S.-owned chip manufacturing capacity is located in the U.S. The chip industry enables related industries across the country, such as telecommunications, software, and consumer electronics. The largest portion of industry revenue (35.2%) came from exports in 2013; that's a decline from 55.6% in 2008.¹¹¹

Revenue percentages from major market product segments are shown in this chart.¹¹² The largest segment is from exports, which accounted for 35.2% of industry revenue in 2013. In the past five years, this segment has declined from 55.6% of industry revenue in 2008 due to heavy global competition and increased offshoring of production among industry firms. However, exports have remained the largest segment of industry revenue due to U.S.-based Intel and Broadcom, who do most of the R&D for semiconductor technology.



SOURCE: www.Ibisworld.com

Figure 23

107 USEconomy.about.com.

108 Business Insider.com: Top 10 Manufactured Products in America's export Industry. March 8, 2012.

109 Semiconductor Industry Association.

110 US Semiconductor Association.

111 IBISWorld, July 2013.

112 IBISWorld, December 2013.

Fxports are expected to decline over the next five years as imports increase due to cheaper production costs abroad. Companies are also going overseas to improve efficiency by being in geographical proximity to key buying industries in Asia, such as computer manufacturing.¹¹³ Growth is contingent on the computer manufacturing industry, a key driver of demand for microprocessors and CPUs, and their sales are expected to decline over the next five years due to shifts in mobile technology and cloud data storage.

Global competition, lower prices, and the trend toward automation indicate further U.S. industry consolidation, along with reduced employment, which is projected to decline more than 2% annually over the next five years. Greater use of automation is expected to lower costs and help support increased production, but it will not help employment.

Manufacturing consolidation is also increasing, eroding U.S. production capacity as foreign producers invest in fabrication facilities with capabilities similar to U.S. firms. Asian companies are geographically closer to key parts of the supply chain in South Korea, Taiwan and China. Contract manufacturers in those countries have now become fully operating semiconductor designers.

Technological innovation, the trait that led the U.S. to become the world's leader in C&E, is a major asset for increasing U.S. exports. Product trends in every industry are grounded in the sciences of advanced electronics and advanced materials. The Portland region has exceptional strengths in those areas. This is a tremendous asset, as the following chart illustrates that manufacturing industries, and in particular the C&E industry, drive export growth.



Manufacturing Industries Drive Top 100 Metro Export Growth

2009 - 2010			2010 - 2012		
Industry	Export Growth \$mil 2012	Share of Total Export Growth Top 100 Metros	Industry	Export Growth \$mil 2012	Share of Total Export Growth Top 100 Metros
Computers & Electronics	24,933.26	21.5%	Transportation Equipment	29,857.28	22.6%
Machinery	14,317.64	12.4%	Petroleum & Coal Products		13.9%
Chemicals	13,067.45	11.3%	Computers & Electronics		11.4%
Transport'n Equipment	6,179.23	5.3%	Primary Metals		9.7%
Medical Equipment, Sporting Goods	5,894.84	5.1%	Machinery		7.7%
Primary Metal	3,703.36	3.2%	Medical Eqpt Sport Goods		4.1%
Petroleum & Coal Products	3,417.28	3.0%	Electrical Equipment		3.0%
Fabricated Metal Prods	3,322.09	2.9%	Fabricated Metal Prods		2.9%
Electrical Equipment	3,072.97	2.7%	Food Products		1.6%
Food Products	2,632.71	2.3%	Plastics & Rubber Prods		0.9%

Figure 24

C&E exporting is a pillar of the Northwest Oregon and Southwest Washington regional economy

- Nearly 20% of the Greater Portland region's economy is generated by exports
- Greater Portland's exports support nearly 145,000 jobs
- For every \$1 billion in exports, an average of 5400 new jobs are created

While manufacturing exports from the top 100 U.S. MSAs grew 66%, the Greater Portland region grew its exports 85.2%. Additionally, 85.6% of the region's export jobs are related to manufactured products, not services.

Export-Intensive U.S. Metropolitan Statistical Areas

Portland ranked number four among the most export-intensive MSAs in 2012¹¹⁴

Metro Area	Export Volume (\$mil)	Export Intensity	Largest Industry	Industry Share of Total Metro Exports
Baton Rouge, Louisiana	14,557.25	30.5%	Chemicals	53%
Ogden, Utah	6,005,446	29.2%	Primary Metals	51%
Wichita, Kansas	7,673.165	27.7%	Transportation Equip't	60%
Portland Oregon/Washington	33,941.46	24.4%	Comps & Electronics	67%
San Jose, California	34,641.22	23.8%	Comps & Electronics	62%
Youngstown, Ohio	4,667.692	23.0%	Primary Metals	42%
Salt Lake City, Utah	15,699.50	22.1%	Primary Metals	53%
Detroit, Michigan	37,996.94	20.8%	Transportation Equip't	60%
New Orleans, Louisiana	14,636.04	20.5%	Petroleum/Coal	47%
Seattle, Washington	47,103.72	20.3%	Transportation Equip't	59%
Greenville, Sout Carolina	5,596.87	20.2%	Machinery	34%

Figure 25

Top U.S. Computer & Electronics Export Metros

The Greater Portland region is number one of the top 100 U.S. MSAs, with more than half of total exports coming from one industry: Computers & Electronics.

METRO	Largest Industry 2012	Indus Export Volume 2012 \$Mil	Share of Total Metro Exports	Metro Export Growth 2003-2012
Portland OR/WA	Computers & Electronics	22,753.37	67%	12.8%
San Jose, California	Computers & Electronics	21,480.47	62%	7.2%
Detroit, Michigan	Transportation Equip't	22,645.07	60%	3.6%
Wichita, Kansas	Transportation Equip't	4,566.835	60%	3.4%
Seattle, Washington	Transportation Equip't	27,926.32	59%	9.5%
Las Vegas, Nevada	Travel/Tourism	5,305.755	53%	8.5%
Baton Rouge, Louisiana	Chemicals	7,722.084	53%	9.4%
Salt Lake City, Utah	Primary Metals	8,2289.773	53%	16.3%
Ogden, Utah	Primary Metals	3,057.106	51%	14.4%
Palm Bay, Florida	Computers & Electronics	1,535.947	50%	6.0%
Boise City, Idaho	Computers & Electronics	1,955.097	50%	5.7%

Figure 26

C&E represents 67% of regional exports (\$22.8M) and grew 12.8% from 2003 to 2012. That compares with #2 San Jose, CA (Silicon Valley) at 62% of total area exports (\$21.4M) and 7.2% growth.¹¹⁵ Regional C&E industry exports represent 11,163 jobs (direct, Indirect and Induced.)¹¹⁶

114 Export Nation 2013: U.S. Growth Post-Recession. Brookings Global Cities Initiative.

115 Brookings Export Nation 2013.

116 Implementing the Greater Portland Export Initiative Through Regional Clusters: How effective is it? Page 7, Table 2, October 2012.

Oregon Electronics Related Exports 2012¹¹⁷

Commodity	2012 Export Value \$Millions	Change vs. Prior Year
Insulated Wire, Cable, Optical Sheaths, Fiber Cables	55,445,041	98.0%
Compass & Navigation Instruments	5,014,505	92.0%
Automatic Data Processing Machines, Magnetic Readers	722,031,832	46.8%
Electronic Integrated Circuits, Micro-assemblies & Parts	16,863,651,501	37.0%
Electrical Switching Apparatus	51,928,854	36.7%
Semiconductors, Light Emitting Diodes, Parts	272,035,166	18.9%
Semiconductor Boule Machinery & Applications, Parts	428,919,279	17.7%
Printed Circuits	32,046,224	13.0%
Automatic Regulating & Control Instruments	7,661,515	5.2%
Liquid Crystal Devices, Lasers, Optical Devices	125,493,969	3.5%
Electronic Transformers, Converters, Inductors, Adaptors, power supply parts	37,656,507	1.8%
Electrical Resistors	6,195,152	.10%
Electric Storage Batteries and Parts	36,125,579	-(3.7)
Oscilloscopes, Spectrum Analyzers, Parts	201,815,529	-(5.9)
Chemical Elements for Electronics, Analyzers, Parts	177,675,486	-(7.6)
Electrical Machines with Industrial Functions	36,369,577	-(10.5)

Figure 27

While the highlighted categories above show significant growth, the last five categories indicate opportunities for growth. Batteries and oscilloscopes are both areas where this region can excel. Electric vehicles will drive demand for longer-life batteries. Oscilloscopes, which measure voltage, time, and frequency of electronic signals to test circuits, are used in science, medicine and engineering. Both are comprised of electronic integrated circuits, which represent 70% of regional exports.

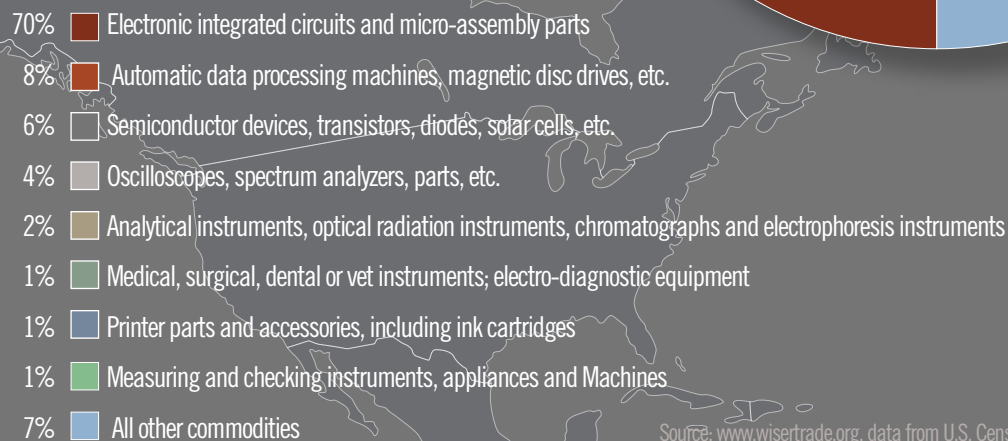
117 WiserTrade data provided by Business Oregon: State HS Database. Source: U.S. Census Bureau, Foreign Trade Division. \$\$ through November 2012.

Oregon Electronic Exports

A small number of companies and industries dominate the region's exports. The largest is the C&E products industry, thanks to Intel, TriQuint and Tektronix, which account for 57% of total exports and 63.4% of export growth.¹¹⁸ However, nearly 30% of the region's total exports, worth \$60 million, are from small and medium companies.

Oregon Computer & Electronics Exports 2012

Electronic Integrated Circuits (Microchips) Made Up 70% of All Oregon Computer & Electronic Product Exports in 2011



Source: www.wisertrade.org, data from U.S. Census Bureau, Foreign Trade Division

Figure 28

118 Ibid.

Of the top ten countries importing from the U.S., only three import computers and electronics. All are in Asia.¹¹⁹

1. Canada, \$228 billion – Mostly automotive related parts and accessories
2. Mexico, \$149 billion – Mostly automotive related
3. China, \$82 billion – *Computer accessories, parts and peripherals for the computer assembly industry, as well as Chinese retailers and end-users*
4. Japan, \$55 billion – Agriculture, aviation and aircraft
5. United Kingdom, \$44 billion – Civilian aircraft, chemicals and primary metals
6. Germany, \$44 billion – Pharmaceutical related drug preparation chemicals
7. South Korea, \$35 billion – *Semiconductors, and products for chemical manufacturing*
8. Brazil, \$32 billion – Chemical manufacturing related to extraction of natural resources
9. The Netherlands, \$31 billion – Pharmaceutical preparations
10. Singapore, \$26 billion – *Computer and electronics products*



On a national basis, the Greater Portland region is a relatively small but very mighty exporter. Total goods exported in 2012 were valued at \$18.3 billion. C&E were \$6.4 billion of that – the region’s number one merchandise export category. Semiconductors and components were \$4.8 billion, and computer equipment was \$917 million.¹²⁰

The region’s top export destinations are Japan and Canada. Others include China, Malaysia, Costa Rica and South Korea. Tokyo is Greater Portland’s number one export market, mainly for agricultural products as well as C&E. Brazil is number two and Israel is number three.¹²¹

Fast growing export destinations for regional goods include Vietnam, which has grown 54% per year since 2002; Brazil, which grew 51% per year; and Turkey, which grew 29% per year.¹²² Other countries rapidly expanding their imports from Oregon include Mexico, Chile and Australia.

Despite the opportunities for increased revenue, small and medium companies often hesitate to export.

This region has many small and mid-sized companies with opportunity to enter the global export market through existing supply chains. However, they are hesitant to do so and mostly unaware of the many services available to help them get started with limited risk. As part of the Greater Portland Export Initiative, regional companies were surveyed to assess their interest.

Companies expressed concern about many aspects of exporting:

- Limited knowledge of how and where to go
- Fear of the unknown
- Hassles with global marketing, logistics, regulatory requirements and unfair trade practices
- Concerns about financing and about getting paid
- Connecting with trustworthy international partners and foreign distributors

They also face real “running-as-fast-as-I-can” issues, with little time and few financial resources to dedicate to exporting.

Many companies are also under the misconception that the U.S. “. . . was, and still is, the biggest market and there is no need to export.”¹²³ That is fundamentally wrong for two key reasons:

- 90% of consumers are outside of U.S. borders
- Foreign governments and companies are major buyers of U.S. products

Other companies want to expand their business in the U.S. first, which is a good growth strategy if the U.S. market is accessible and lucrative enough. Still more say they have enough business locally – a satisfying short-term plan, but it leaves money on the table today, and can be risky if it makes you uncompetitive in the future.

120 Ibid.

121 Japan America Society of Oregon presentation, May 2013.

122 Business Roundtable, David Thomas, www.brt.org/trade.

123 Confidential interview.

If a company finds itself among those not interested in or worried about exporting, consider these comments from businesses that do well selling into other countries.

“We have been exporting for years and have an active sales effort to expand international markets.”

“We don’t think about markets by country; we think about them by customers.”

“Our export markets are wherever our large customers are located.”

“The (real) obstacles are payment, contracts and foreign regulations. Internally, obstacles relate to company capacity building.”

While exporting may seem intimidating to small and medium businesses that have not yet tried it, it is definitely a way to grow rapidly. Lack of awareness of the technical and financial assistance available hampers companies who want to export. Businesses in the Greater Portland region have access to a rich network of commercial and technical exporting expertise. It ranges from research about which countries might offer the best opportunities, to support for attending overseas trades shows and direct connections with in-country resources, as well as connections to legal and regulatory advice. Eighty-nine percent of survey respondents had not received export assistance; yet of those who did, 81% rated the services “good to excellent.” A list of exporting resources is included in Appendix D.



Places to Target: Close to Home or Culturally Similar

Oregon State defines “traded sector” opportunities as “industries in which member firms sell their goods or services into markets for which national or international competition exists.”¹²⁴ With many OEMs and branded companies manufacturing in the U.S. or seeking U.S. suppliers to provide components, assemblies and finished products, regional small and medium companies can look outside their own area but still within the U.S. to “export.”

Portland-Vancouver Metropolitan Region’s Top Export Markets¹²⁵



CANADA



CHINA



UNITED KINGDOM



AUSTRALIA



GERMANY



JAPAN



MEXICO



FRANCE



SOUTH KOREA



MALAYSIA

The easiest way to start is by considering exports to Canada, which is the largest U.S. export market and Oregon’s largest export market. Thirty two million Canadians buy more from the U.S. than 1.335 billion Chinese. Canada is close, has the same language, culture, high financial transparency and low corruption, and a similar legal system. All of that adds up to lower risk. Canadian customs regulations are compatible, and it is acceptable for U.S. companies to compete with Canadian companies. NAFTA makes it 98% duty free with no residency requirement. Help is available at www.export.gov/FTA.nafta.index.asp for statistics, trends, and opportunities to export products and services.

Places to avoid because of political and economic risk or social turbulence include:



RUSSIA



YEMEN



SOMALIA



LEBANON



LIBYA



NIGERIA



PAKISTAN



MALI



NICARAGUA



HAITI



CENTRAL
AFRICAN REPUBLIC



MAURITANIA



AFGHANISTAN



VENEZUELA

124 www.oregonlaws.org/: Vol. 7, Chapter 285A.010.

125 Brookings Metropolitan Export Initiative 2012.

High-Potential International Product Markets for C&E Suppliers¹²⁶

1. Electronic integrated circuits, micro-assembly and component parts; total export value \$4,590,915,294:

- Japan
- Germany
- Mexico
- Brazil

5. Oscilloscopes, spectrum analyzers and component parts; total export value \$235,867,568:¹²¹

- United Kingdom
- Canada
- Latin America

2. Automatic data processing machines, magnetic readers and components; total export value \$541,085,339:

- Hong Kong, China
- United Kingdom
- France

6. Chemical elements used in electronics, discs and wafers; total export value \$205,220,886:

- South Korea
- France
- Hong Kong, China

3. Machining and applications for semiconductor manufacturers: boules and component parts; total export value \$382,974,819:

- Hong Kong, China
- Malaysia

7. Liquid crystal devices, lasers, optics, applications and component parts; total export value \$143,014,188:

- China
- Hong Kong, China
- Mexico
- South Korea

4. Semiconductor devices, light-emitting diodes and component parts; total export value \$357,942,433:

- Italy
- Netherlands
- South Korea
- France

126 WISERTrade: State HS Database. Source: <http://www.wisertrade.org>.data from U.S. Census Bureau, Foreign Trade Division. Data supplied by Business Oregon.

127 <http://tse.export.gov/NAICs> 334.

SUCCESS STORIES¹²⁸

Met One Instruments | Grants Pass, Oregon

Founded in 1976, Met One designs, engineers and manufactures in Oregon, Texas and New York. They are ISO 9001-2008 certified. Products include air quality measurement and meteorological sensors; weather stations; air particulate measuring devices; and calibration and testing equipment, including optical particulate sensors as well as wind sensors located at sea. Acquiring Northwest Technologies in 1991 allowed the company to fabricate for semiconductor and aircraft companies and engage in robotics to enhance their instrumentation manufacturing. Met One employs 100 people, from engineers to machinists.

Met One technologies incorporate hardware, software and electronics – the complete “mechatronics” package so vital to modern manufacturing. They invest in internal R&D and provide after-sales service in countries around the world. Met One participates in international trade shows, including the Meteorological Technology World Expo that was held in Belgium in October 2013. Met One exports to France, the United Kingdom, Tunisia, Croatia, Serbia, Bosnia, Kazakhstan, the United Arab Republic, Australia, Indonesia, the Philippines, Costa Rica, China, Colombia, Taiwan, Malaysia, Chile, and India. They even have a system monitoring weather effects on the Sphinx in Egypt.

Met One is a good example of a company offering high tech electronic components that provide in-demand product solutions. While they have a singular focus on monitoring and instrumentation, they have diversified their offerings to serve a variety of U.S. and international markets.

Cascade Microtech | Beaverton, Oregon

Founded in 1983, Cascade Microtech designs, develops and manufactures semiconductor and electronics measurement and testing devices for integrated circuits and chips. The company employs 400 people worldwide and has customer operations in Taiwan, Singapore, China, Japan and Germany.

Cascade’s probe stations and analytical probes are used in R&D to perform precise electrical measurements on complex high-speed chips for digital signal processors, telecommunications, optical devices and radio frequency integrated circuits.

The company’s products help ensure quality and reliability, reduce costly redesigns, accelerate time to market, and improve chip fabrication processes. Cascade Microtech has 1700 customers, including world leaders such as Agilent Technologies, IBM, Intel, Micron Technology, NEC, Samsung, Sony, TSMC (WaferTech), and Texas Instruments.

Cascade Microtech has grown through inventions and acquisitions. Its global service organizations provide comprehensive product knowledge and applications expertise. It maintains a significant industry presence by participating in industry events such as SEMI’s¹²⁹ Pacific Northwest Professional Development Seminars and sponsoring the Compass Annual User Conference.

128 Companies were randomly selected to represent diverse C&E products. Information provided is from companies’ websites. December 2013.

129 Semi is the world-wide Semiconductor Industry professional association.

Biamp Systems, Inc. | Beaverton, Oregon

Launched in 1989, Biamp manufactures and installs custom-designed commercial electronic audio, teleconferencing and sound management systems, including hardware, software and firmware. Their diverse markets include government, healthcare, recreation, business, education, transportation, and houses of worship. Diverse clients include cathedrals, airports, museums, sports bars, stadiums and judicial court systems. Products include distance conferencing, distance court interpretation, networked paging systems and voice evacuation systems. Its networked systems offer customers cost savings via efficient, flexible, scalable and sustainable solutions. The company is ISO 9001:2008 and EN54-16 certified.

Biamp Systems exports to and has distributors in countries as diverse as China, India, Brazil and Australia, where it has manufacturing operations in Brisbane. Its value-added customer services include:

- Comprehensive user and installer training programs (in-person and on-line) for audio industry professionals around the world
- Troubleshooting and design reviews of proposed custom systems
- In-house engineering and technical support (on-line and in-person)
- Downloadable document library
- Developer partnerships with Cisco Systems and Avaya for seamless integration and compatibility

Biamp Systems learns from and contributes to its industry through participation in trade organizations such as The American Institute of Architects, the AVnu Alliance, and BICSI, as well as CompTIA, HiMSS, infoCom International, and the National Systems Contractors Association.

Silicon Forest Electronics | Vancouver, Washington

Founded in 1999, Silicon Forest is a contract manufacturer providing complex products to meet customer standards and regulatory requirements. It designs and manufactures high-quality electronics solutions for diverse industries including Aerospace, Defense, Medical Equipment, Instrumentation and Unmanned Systems. Competencies include machine placement and automated assembly, hand assembly and specialty processes such as coating, flex assembly and quick-turn manufacturing via flexible production lines.

The company provides testing capabilities for analog and digital signals and systems, and inspection and process controls via 3D solder paste inspection, automated optical inspection, and x-ray.

Value-added services include design and rapid prototyping capabilities, printed circuit board layouts, design-for-manufacturability reviews, design-for-test reviews and test development. The company helps customers meet design needs and supplement engineering resources during peak workload times in order to meet market demands and short lead times. They also help with inventory and supply chain solutions, such as strategic sourcing of long-lead components, determining the amount of finished goods to have on hand, and obsolescence management. Customer support is provided from prototyping through the product life cycle, and turnkey program management is available. The company is AS 9100C certified for aerospace and military products, AS 13485 certified for medical products, and ISO 9001 certified for industrial products.

FINDINGS & IMPLICATIONS

Expanding the Greater Portland region's C&E supply chain, along with extending its global reach by doubling exports over the next five years, is crucial for leveraging economic potential and ensuring a prosperous future.

Opportunities for accomplishing that ambitious goal exist for small and medium companies ready to grow. Strategically, the optimal place to start is by using the assets and resources provided by the JIAC IAM² grant to support business expansion through product, market and geographic diversity.

U.S. business history is weighted with cautionary tales of regions that failed to anticipate technological change and economic disruption not even related to the recent recession. The collapse of the textile industry in the South, failing Fortune 500s in Cleveland,¹³⁰ falling infrastructure in Minneapolis,¹³¹ and the demise of the auto industry in Detroit are just a few examples of what happens when regions don't invest in their future.

Regions that succeed will invest in infrastructure, education and R&D, thereby creating a healthy entrepreneurial ecosystem that helps companies thrive and grow. In turn, companies that prosper will invest in product development, manufacturing and training to increase regional economic output and employment.

Implications for Supply Chain Companies

Successful companies provide more than commodities. They invest in themselves, provide value-added services for customers, and share their wealth by exporting.

Upgrade Processes, Equipment, Materials & Customer Service

- Technology changes rapidly. Be prepared to accommodate new materials such as graphene and to deal in a world of new processes such as 3D printing and “skyscraper chips.”
- Work with organizations such as state manufacturing extension partnerships to improve process flow, and implement lean manufacturing and lean product development.
- As more production moves overseas, the supply chain moves with it. Companies must upgrade their capabilities and capacities or they will be bypassed. This is difficult to do, given margin constraints and competitive pricing overseas, so lean techniques are crucial.
- Major suppliers link electronically with customers to anticipate demand and provide inventory management.
- Buyers are reluctant to change suppliers when quality and performance are crucial to their own brand image; value-added services are needed to retain good customers.
- Suppliers must keep up with customers' ongoing need to innovate and improve product performance and be able to meet demand for leading edge technology amid severe price competition, a weak economy, and hard-to-predict market volatility.
- Companies must have reliable relationships among their own supply chain so they can respond to just-in-time demand, especially for crucial commodities.

130 Cleveland had 21 Fortune 500 Corporations in 1995, ranking fourth behind New York, Chicago and Houston. As of this publication, it has only five.

131 I-35 Mississippi Bridge collapse, August 1, 2007.

Plug in to the Global Supply Chain

- Take advantage of state and regional export resources to learn how to export products, either directly or through distributors.
- Attend conferences and seminars sponsored by industry associations and organizations.
- Investigate resources available for companies wanting to participate in international trade fairs.
- Learn about other countries and cultures, and their needs for the products your company manufactures.
- Partner with other companies to leverage assistance in taking on new markets or new projects. Many customers are looking for complete systems and turnkey solutions. Companies can share the investment and the risk if they work together to add competencies that complement what each other offers.
- Participate in exporting conferences sponsored by Business Oregon and the Columbia River Economic Development Council.

Invest in Employee Training

Employees are an investment, not an expense. Helping them learn new tools and techniques makes them more efficient, which saves time and money.

- Explore training options with local workforce development organizations. Many provide free or low-cost programs for incumbent and new workers; some will even help pay salaries while employees learn.
- Be sure front-line workers, such as sales and customer service employees, have the organizational and interpersonal skills they need.
- Pay for training seminars that improve productivity and quality.
- Ensure roles, responsibilities and internal communications are clear.
- Recognize and appreciate employee contributions.

Understand the Regulatory Environment

- The C&E industry has a moderate level of regulation. The U.S. federal government regulates exports and some uses because of their potential in military applications, and restricts export of some high-capacity chips to protect national security.
- Country exporting and customs requirements are usually different from those of the U.S. Even Canadian air regulations differ from those of the FAA. Get expert advice on rules and documentation.
- Know what certifications are required to participate in particular industries: ITAR, ISO, etc.

Invest in R&D

Even if a company can't afford a laboratory or a Ph.D. scientist, most can afford subscriptions to trade magazines providing new technical information and attendance at conferences for networking with industry experts. Other ways to monitor an industry and stay abreast of product, technology and competitive trends include proactive involvement in the industry.

- Assign a market information topic to a particular employee who will enjoy the research and will share findings.
- Network with suppliers to ask what's new in their realm.
- Learn about relevant activities at state-supported R&D organizations such as ONAMI, Oregon Best, the Technology Association of Oregon and the Pacific Northwest Defense Coalition.
- Participate in manufacturing conferences sponsored by the Portland Development Commission and the Columbia River Economic Development Council.

Implications for Regional Economic Development

Helping small and medium companies grow in capacity and capabilities enables them to serve higher tiers in their supply chain and strengthens the regional economy.

Convene and Educate Small and Medium Suppliers to Build from Within

- Connect suppliers with industry and manufacturing expertise available from world-class regional organizations such as:
 - Oregon Manufacturing Extension Partnership
 - Impact Washington
 - Pacific Northwest Defense Council
- Network regional suppliers to buy from each other, share leads, and collaborate on large projects they cannot undertake alone.

Attract New Businesses to Fill Gaps and Expand Capabilities

- Recruit new supplier companies that fill regional supply chain gaps:
 - Optoelectronics
 - Robotics
 - Chemicals and specialty chemicals
 - Circuit boards
- Address underserved, high-opportunity market segments:
 - Cable and wire
 - Copper, aluminum, other nonferrous metals
 - Lithium storage batteries

Invest in Infrastructure Investments

- Maintain and build new roadways, rail transport and marine facilities to facilitate logistics and enable regional, national and global trade via regional ports.
- Protect and promote the region's abundant and affordable clean water and hydroelectric power. One semiconductor foundry can use millions of gallons of water a day and enough electricity in one year to power 225 homes.¹³²

Encourage Participation in International Trade

The C&E industry is global and highly competitive. Computer manufacturing and assembly is almost entirely in Asia and supported by local suppliers there, so U.S. exports of C&E continue to shrink. Strengthening the regional C&E supply chain by diversifying its export base is key to achieving the region's goal to double exports over the next five years. This research highlights opportunities for accomplishing that ambitious goal:

- Increase awareness of the myriad state and regional export assistance programs among businesses and economic development agencies. For a list, see Appendix D.
- Upgrade the logistics and transportation infrastructure to support increased access to marine, rail, and airports, as well as the roadways and bridges used for freight trucking.
- Provide training and support resources for businesses and economic development professionals about trade barriers such as tariffs, government regulations and currency exchange challenges.
- Continue to invest in financial and country-expert support for attendance at national and international industry trade shows.
- Be aware of policy issues affecting exports that make it difficult for companies to engage in international trade. For example:
 - The federal government should consider negotiating common standards with Canada, as the U.S. FAA and Transport Canada have different requirements.
 - Current tax laws require depreciation of semiconductor manufacturing over a five-year period, although the life of the equipment is only three years. Europe and Japan allow more rapid depreciation and therefore have a competitive advantage over the U.S. for attracting companies.

Support Regional Research & Development

U.S. OEMs and ODMs have a slight edge given their reputation for innovation and quality. However, for the U.S. C&E industry to retain that status, companies and regions must invest in R&D that leads to increased product effectiveness and breakthrough technology innovations.

- Invest in regional and state signature research & development centers:
 - Oregon Nanoscience and Microtechnologies Institute | www.onami.us
 - Technology Association of Oregon | www.techoregon.org
 - Oregon Best | www.oregonbest.org
 - Drive Oregon | www.driveoregon.org
 - Oregon Metals Initiative | www.oregonmetal.org
 - Washington State Technology Investment Association (WTIA), Seattle | www.washingtontechnology.org

132 Estimate, Clark Public Utilities, October 2013.

- Support state university R&D and commercialization efforts to increase their access to grants from DARPA (Defense Advanced Research Projects Agency), the National Science Foundation, and the National Institutes of Health.
- Support high-potential, high-technology companies with more access to Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) research grants.
- Strengthen ties between universities, R&D centers, and the private sector to promote commercialization of advanced technologies.

Strengthen the Workforce

- Increase the technically skilled workforce: technicians, machine operators, specialty welders, CAD-CAM designers.
- Educate and retain more software designers and computer programmers for electronics manufacturing, not just mobile applications; connect university student software designers and programmers with industry needs and opportunities.
- Help attract and retain the highly educated workforce: electrical, mechanical and process engineers, chemists, metallurgists, and physicists.
- Ensure adequate resources for organizations providing manufacturing technical assistance and workforce training and certification support:
 - Impact Washington | www.impactwashington.org
 - Oregon Manufacturing Extension Partnership | www.omep.org
 - Southwest Washington Workforce Development Council | www.swwdc.org
 - WorkSource Oregon | www.worksourceoregon.org
- Support apprenticeships as well as internships.
- Support innovative community college programs such as Clark College's Mechatronics Lab.
- Encourage companies to work with governments and schools to develop the workforce they need.
- Provide curricula to improve the interpersonal skills of all workers: communications, teamwork, leadership potential.

Invest in STEM* & Technical Education (*science, technology, engineering, math)

- Fund regional Washington and Oregon universities for more advanced technology research and increased Ph.D. programs.
- Promote STEM education for grades K-12, as well as at secondary and graduate school levels.
- Support technology-based scientific research at regional universities to help them gain nationally recognized reputations; when companies recruit in C&E, they want world-class Ph.Ds.
- Increase investment in applied materials sciences, engineering, and software development educations to grow, recruit and retain enough talent to support the growing advanced manufacturing base.
- Increase the strength and number of community college and university applied engineering and applied materials sciences degree programs.

Increase Access to Financial Resources and Incentives

Greater access to capital, from grants to loans to investment, is necessary for companies expanding their manufacturing capabilities. Assess tax policies and investment incentives that encourage companies to stay, expand in, or move to the Greater Portland region. The Oregon Capital Scan,¹³³ sponsored by Meyer Memorial Trust, the Oregon State Treasury, and others highlighted gaps in the regional investment ecosystem:

- Lack of working capital for small manufacturers seeking \$150,000 lines of credit
- Seed stage capital for companies needing \$100,000 to \$500,000
- Growth capital for bootstrapped companies with EBITDA¹³⁴ of \$500,000 to \$3,000,000
- Lack of sufficient capital for life sciences and clean technologies

As the report stated, “It’s not just about capital
... building more competitive entrepreneurs is vital to economic development
... increasing awareness of financing options may
go a long way to building small businesses.”¹³⁵

In conclusion,

companies that want to grow should look for opportunities in new technologies, especially at the intersection of manufacturing, electronics and software. They also need to reach beyond their current markets and their comfort zone and into new industries and new geographies.

While research is a rearview mirror – out of date as soon as it’s printed, especially where innovation is concerned – it is hoped that the insights shared in this research will provide motivation and information for regional small and medium companies to grow, diversify, and export, thereby contributing to the economic health and prosperity of the Greater Portland region.



133 Oregon Capital Scan: A Developing Ecosystem, Niels Zellers, pgs. 24-25, March 2012.

134 Earnings before Interest, Taxes, Depreciation & Amortization.

135 Ibid, pg. 25.

REFERENCES & RESOURCES

1. 12 Steps to a greener, more sustainable electronics supply chain. Global Electronics Industry. IBM, March 2010.
2. 2013 Employment Projections, Washington State Employment Security Department.
3. ASEAN: Regional Trends in Economic Integration, Export Competitiveness and Inbound Investment for Selected Industries. U.S. International Trade Commission, August 2010.
4. Brookings Institute Global Cities Initiative Export Nation, September 2013.
5. Business Oregon Computers & Electronics Export Data, 2013
 - Top Supplier Commodities to Computer & Electronic Product Manufacturing
 - Key Industry Group Definitions by NAICS
 - Computer & Electronics Product Manufacturing Export Breakdown
 - Possible Markets for Oregon's Largest Exports
6. Business Oregon High Technology Key Industry, www.oregon4biz.com. March 2013.
7. Business Roundtable, David Thomas. www.brt.org/trade.
8. Business Week, Smaller, faster, lighter, cheaper. Microbatteries. Technology, pg. 34, July 22-26, 2013.
9. Change of pace for the semiconductor industry? PriceWaterhouseCoopers, 2009.
10. CIA World Fact Book, Exports.
11. Computer and electronic product manufacturing, 2005-2014. Federal Reserve Economic Data, St. Louis, Missouri, August 2013.
12. Computer World, May 13, 2013.
13. Council of Supply Chain Professionals.
14. Corvallis Economic Development Strategy, 2012.
15. Creating New International Sales Opportunities, Business Oregon, 2012.
16. Creative Value in the Semiconductor Industry, McKinsey, Autumn 2011.
17. Cyber States 2013, Washington D.C. Based on U.S. Bureau of Labor Statistics.
18. Digikey Supply Chain HQ, July 2013. www.digikey.com.
19. Discover, Electronics, Yong and Ross, August 2, 2013.
20. Disruptive Technologies, McKinsey Global Institute, May 2013.
21. Economic Contribution of Computer & Electronic Product Manufacturing in Oregon, Preliminary Analysis (draft), Business Oregon, November 20, 2012.
22. Economist, Science and Technology, pg. 85, May 12, 2012.
23. Electronic exports: Identifying Asia's winners and losers. Credit Suisse, January 22, 2013.
24. <http://encyclopedia2.thefreedictionary.com/>
25. Encyclopedia Britannica, October 2013.
26. End of Moore's Law: Where to Next? Graeme Lipschitz, Memeburn, June 28, 2013.
27. Export.gov Market Reports: Turkey, October 2013.

28. Greater Portland Export Initiative Regional Westside Freight Access and Logistics Analysis, DKS Associates, October 1, 2013.
29. HP Memory Labs, R. Stanley Williams, Memeburn, June 2013.
30. IC Insights Strategic Review Database, 2013.
31. Intel Third Quarter Earnings Announcement, October 2013.
32. Investopedia Industry Handbook: Semiconductors, September 2013.
33. Israeli Electronic Components Leading Sector for U.S. Export, Israel Association of Electronics & Software Industries, January 30, 2013.
34. Jobs through Exports, Jim Lucchesi, Export-Import Bank of the U.S., 2012.
35. Lam Research at a Glance, 2013.
36. Lattice Corporate Strategy, July 2013.
37. Manufacturing Economic and Workforce Data at a Glance, Southwest Washington Workforce Development Council, August 2012.
38. Manufacturing Workforce Survey Report, Columbia-Willamette Collaborative, November, 2012.
39. McKinsey on Semiconductors, Fall 2011.
40. Memeburn, Steve Tieg, CTO and President, Tabula Inc., June 28, 2013.
41. Nanowire Electronic and Optoelectronic Devices, Materials Today, Vol. 9, No. 10, October 2006.
42. Occupational Employment and Wage Estimates, WA State Employment Security Department, June 2012.
43. Office of the U.S. Trade Representative.
44. Office of Technology & Electronic Commerce.
45. Oregon Capital Scan, Niels Zellers, Oregon Community Foundation, Meyer Memorial Trust, Oregon State Treasury.
46. Oregon Employment Department, September 2013.
47. Oregon History Project, <http://www.ohs.org/education/oregonhistory/>.
48. Oregon Tech Industry, TechAmerica Foundation, Cyberstates 15th Annual Ed., 2013.
49. Portland Business Alliance Check-up on the Portland-Region's Economic Health, 2013.
50. Portland Export Plan, Brookings Institute, 2012 and 2013.
51. Portland Oregon/Vancouver Washington Regional Comprehensive Economic Development Strategy (CEDS), 2012.
52. PR Newswire, February 4, 2013.
53. ProQuest Industry Reports, 2013.
54. <http://selectusa.commerce.gov/>, 2013.
55. Semiconductor Industry Association, January 31, 2010.
56. Semiconductor Investment Overview, www.investopedia.com, 2013.
57. www.semi.org.
58. Silicon Forest Overview: NAICS Spending on Semiconductors. Oregon Business Development Department, Business Oregon, 2012.

59. Solar Semiconductor Supply Chain. *www.semi.org*, January 24, 2013.
60. Systems Level Design Insights for Chip Architects and Engineers, Changing Supply Chain, *http://chipdesignmag.com*, August 2013.
61. Top 10 Manufactured Products in America's Export Industry, *www.businessinsider.com*, March 8, 2012.
62. Top 20 Semiconductor Suppliers, IC Insights Strategic Reviews Database, 2013.
63. Triquint Annual Report, 2012.
64. Triquint Semiconductor: Improving Supply Chain Collaboration Through Supplier Managed Inventory, 2010.
65. Triquint Company Overview, August 2013.
66. TSMC Annual Report 2012.
67. Twelve Steps to a Greener, More Sustainable Electronics Supply Chain, IBM, March 2010.
68. Used Electronic Products: An Examination of U.S. Exports, February 2013.
69. U.S. Census Bureau American Community Survey, 2011.
70. U.S. Census Bureau Business & Industry Statistics, July 2013.
71. U.S. Commercial Service.
72. U.S. International Trade: Trends and Forecasts, Congressional Research Service, October 19, 2012.
73. U.S. Mission to the European Union, Country Profiles, France, 2013.
74. U.S. Trade Summary, *www.ustr.gov*, Argentina, 2012.
75. Washington Tech Industry, TechAmerica Foundation, Cyberstates 15th Annual Ed., 2013.
76. We Create What's Next, Techlandia Portland. Portland Development Commission, Business Oregon, Greater Portland Inc., 2012.
77. World Semiconductor Trade Statistics Forecasts Semiconductor Market Recover in 2013 After Slight Decline in 2012, Cologne Germany, May 2013.
78. WorkSource Oregon Labor Market Information, 2013.
79. Zacks Investment Research: December 2012, January 2013.

APPENDIX A: Regional Computers & Electronics Business List

Computers and Electronics companies in the five county region representing NAICS codes 33591, 33451, 33531, 33441, 33411, 33592, 33142, 33593, 333242, 335999, 334613, 334310

Company Name	Location Address	City	ST	ZIP	Employees	Sales
Accelerant Networks	15268 NW Greenbrier Pkwy	Beaverton	OR	97006	5 to 9	\$2.5m to \$5m
Advanced Micro Devices Inc.	920 SW 6th Ave # Mezz	Portland	OR	97204	10 to 19	\$5m to \$10m
Alphatek Specialty Products	14200 SE 98th Ct # 300	Clackamas	OR	97015	1 to 4	\$2.5m to \$5m
American Tool Systems Inc.	PO Box 476	Troutdale	OR	97060	5 to 9	\$2.5m to \$5m
AMETEK, Inc. (TSE Location)	4755 SW Griffith Dr	Beaverton	OR	97005	5 to 9	\$1m to \$2.5m
Anthem Electronics	15115 SW Sequoia Pkwy # 160	Tigard	OR	97224	5 to 9	\$2.5m to \$5m
APCON Inc.	9255 SW Pioneer Ct	Wilsonville	OR	97070	50 to 99	\$50m to \$100m
Applied Laser Technology Inc.	14155 SW Brigadoon Ct # B	Beaverton	OR	97005	10 to 19	\$2.5m to \$5m
Aptic Semiconductor Inc.	3800 SW Cedar Hills Blvd # 224	Beaverton	OR	97005	1 to 4	\$1m to \$2.5m
ASM America	2500 NW 229th Ave # 400	Hillsboro	OR	97124	5 to 9	\$2.5m to \$5m
ASML US Inc.	7235 NW Evergreen Pkwy # 100	Hillsboro	OR	97124	50 to 99	\$5m to \$10m
ATMI - Beaverton	4900 SW Griffith Dr # 253	Beaverton	OR	97005	5 to 9	\$1m to \$2.5m
Axcelis Technologies	10260 SW Nimbus Ave # M1	Portland	OR	97223	5 to 9	\$1m to \$2.5m
Axiom Electronics	19545 NW Von Neumann Dr # 200	Beaverton	OR	97006	50 to 99	\$10m to \$20m
Baccini North America	30 SW 68th Ave	Portland	OR	97225	1 to 4	\$1m to \$2.5m
Besang Inc.	1915 NW Amberglen Pkwy # 400	Beaverton	OR	97006	5 to 9	\$2.5m to \$5m
Biamp Systems	9300 SW Gemini Dr	Beaverton	OR	97008	10 to 19	\$20m to \$50m
Cascade Microtech	9100 SW Gemini Dr	Beaverton	OR	97008	100 to 249	\$100m to \$500m
Cascade System Technology	23176 NW Bennett St	Hillsboro	OR	97124	20 to 49	\$2.5m to \$5m
Celestica	18870 NE Riverside Pkwy	Portland	OR	97230	250 to 499	\$1m to \$2.5m
Chen Instrument Design Inc.	4901 NW Camas Meadows Dr	Camas	WA	98607	10 to 19	\$2.5m to \$5m
Cirrus Logic Inc.	4500 Kruse Way	Lake Oswego	OR	97035	1 to 4	\$1m to \$2.5m
Coiltron Inc.	6755 SW Sandburg St	Portland	OR	97223	10 to 19	\$2.5m to \$5m
Compound Photonics US Corp.	PO Box 61482	Vancouver	WA	98666	20 to 49	\$10m to \$20m
Consolidated Electrical Distributors	8100 NE St Johns Rd # E101	Vancouver	WA	98665	10 to 19	\$5m to \$10m
ControlTek	3905 NE 112th Avenue	Vancouver	WA	98682	100 to 49	\$2.5m to \$5m
Cymer Inc.	3000 NW Stucki Pl # 140	Hillsboro	OR	97124	5 to 9	\$2.5m to \$5m
D & R Enterprises	3231 Fir Ridge Rd	Lake Oswego	OR	97035	1 to 4	\$1m to \$2.5m
Daitron Inc.	27750 SW 95th Ave # 100	Wilsonville	OR	97070	10 to 19	\$5m to \$10m

Company Name	Location Address	City	ST	ZIP	Employees	Sales
Delta Computer Systems	1818 SE 17th Street	Battle Ground	WA	98604	20 to 49	\$5m to \$10m
DH Sutherland Co.	5600 SW Arctic Drive, Suite 110	Beaverton	OR	97005	20 to 49	\$5m to \$10m
DISCO Hi-Tec America, Inc.	20811 NW Cornell Rd # 700	Hillsboro	OR	97124	10 to 19	\$5m to \$10m
Dow Electronic Materials	1325 NW Slocum Way	Portland	OR	97229	1 to 4	<\$500k
Dupont Photomasks Inc.	23932 NE Glisan St	Gresham	OR	97030	1 to 4	\$1m to \$2.5m
East Penn Manufacturing Co, Inc.	13017 NE Airport Way	Portland	OR	97230	5 to 9	\$1m to \$2.5m
EBARA Technologies, Inc.	6199 NW Casper Pl	Hillsboro	OR	97124	20 to 49	\$10m to \$20m
Electro Scientific Industries (ESI)	13900 NW Science Park Dr	Portland	OR	97229	500 to 999	\$100m to \$500m
Electronic Controls	4287 SE International Way # B	Milwaukie	OR	97222	20 to 49	\$20m to \$50m
Electronic Manufacturing Service	10950 SW 5th St # 180	Beaverton	OR	97005	5 to 9	\$1m to \$2.5m
Engineering Design Team Inc.	1400 NW Compton Dr # 315	Beaverton	OR	97006	20 to 49	\$5m to \$10m
EO Technical Solutions LLC	2501 SE Columbia Way # 150	Vancouver	WA	98661	5 to 9	\$2.5m to \$5m
Equipment Technologies West	756 California Way	Longview	WA	98632	1 to 4	<\$500k
Exide Technologies	13802 NE Airport Way	Portland	OR	97230	20 to 49	\$10m to \$20m
FEI	5350 NE Dawson Creek Drive	Hillsboro	OR	97124	250 to 499	\$500m to \$1b
FLIR Systems	27700 SW Parkway Ave	Wilsonville	OR	97070	250 to 499	>\$1 billion
Foxconn Electronics	5920 NE Ray Cir # 150	Hillsboro	OR	97124	5 to 9	\$1m to \$2.5m
Fresco Logic, Inc.	17933 NW Evergreen Pkwy # 315	Beaverton	OR	97006	5 to 9	\$2.5m to \$5m
Green Light Studios	7615 NW 11th Ave	Vancouver	WA	98665	1 to 4	\$1m to \$2.5m
Hitachi High Technologies America, Inc.	2900 NW 229th Ave # 200	Hillsboro	OR	97124	20 to 49	\$10m to \$20m
Hitachi Kokusai Electric America	1211 SE Cardinal Ct	Vancouver	WA	98683	20 to 49	\$10m to \$20m
Honeywell	12503 SE Mill Plain Blvd # 150	Vancouver	WA	98684	500 to 999	\$100m to \$500m
HORIBA STEC Inc.	10110 SW Nimbus Ave # B11	Tigard	OR	97223	1 to 4	\$1m to \$2.5m
Heraeus Shin-Etsu America Inc.	4600 NW Pacific Rim Blvd	Camas	WA	98607	20 to 49	\$5m to \$10m
IMS Electronics Recycling	2401 St Francis Ln	Vancouver	WA	98660	1 to 4	\$5m to \$10m
Inday	1818 NE 140th Ave	Portland	OR	97230	1 to 4	\$500k to \$1m
Insulectro	1523 Poplar St	Forest Grove	OR	97116	5 to 9	\$500k to \$1m
Intel Corp.	2111 NE 25th Ave	Hillsboro	OR	97124	1000 to 4999	>\$1b
Intel Corp.	2501 NW 229th Ave	Hillsboro	OR	97124	100 to 249	\$100m to \$500m
Intel Corp.	5200 NE Elam Young Pkwy	Hillsboro	OR	97124	5000 to 9999	\$500m to \$1b
Interface Studies Inc.	2136 SW 5th Ave	Portland	OR	97201	1 to 4	\$500k to \$1m
International Rectifier Corp.	3000 NW Stucki Pl # 230	Hillsboro	OR	97124	1 to 4	\$1m to \$2.5m
Jamac Products Co.	8600 NE Sandy Blvd	Portland	OR	97220	1 to 4	\$1m to \$2.5m

Company Name	Location Address	City	ST	ZIP	Employees	Sales
JAE OR Inc.	11555 SW Leveton Dr	Tualatin	OR	97062	100 to 249	\$10m to \$20m
Jireh Semiconductor/ Alpha and Omega Semiconductor	3131 NE Brookwood Pkwy	Hillsboro	OR	97124	250 to 499	\$500k to \$1m
Johnson Controls Inc.	800 NW 3rd Ave	Canby	OR	97013	250 to 499	\$500k to \$1m
Joint Way International	1645 NE 72nd Ave	Portland	OR	97213	5 to 9	\$1m to \$2.5m
KEMET Electronics Corp.	14115 NE 45th Ct	Vancouver	WA	98686	1 to 4	<\$500k
Kustom Electronics	13988 SW Lambert Ln	Gaston	OR	97119	1 to 4	<\$500k
Kyocera International Inc.	15211 NE Bonanza Rd	Brush Prairie	WA	98606	10 to 19	\$5m to \$10m
Kyocera Tycom	8050 SW Cirrus Dr	Beaverton	OR	97008	20 to 49	\$50m to \$100m
Lam Research Corp.	11155 SW Leveton Dr	Tualatin	OR	97062	5 to 9	\$2.5m to \$5m
Lam Research Corp.	201 NE Park Plaza Dr # 295	Vancouver	WA	98684	5 to 9	\$2.5m to \$5m
Lam Research Corp.	222 NE Park Plaza Dr # 112	Vancouver	WA	98684	50 to 99	\$20m to \$50m
Lattice Semiconductor Corp.	5555 NE Moore Ct	Hillsboro	OR	97124	100 to 249	\$100m to \$500m
Leviton LES	20497 SW Teton Ave	Tualatin	OR	97062	100 to 249	\$20m to \$50m
Lexica Inc.	15075 SW Koll Pkwy # B	Beaverton	OR	97006	1 to 4	<\$500,000
Lightspeed Technologies Inc.	11509 SW Herman Rd	Tualatin	OR	97062	20 to 49	\$10m to \$20m
Linear Technology Corp.	6700 SW 105th Ave # 207	Beaverton	OR	97008	5 to 9	\$2.5m to \$5m
Linear Technology Corp.	5005 Meadows Rd # 410	Lake Oswego	OR	97035	5 to 9	\$1m to \$2.5m
Linear Technology Corp.	16000 SE Norma Rd	Milwaukie	OR	97267	20 to 49	\$2.5m to \$5m
Linear Technology Corp.	4200 NW Pacific Rim Blvd	Camas	WA	98607	250 to 499	\$100m to \$500m
Lockheed Martin	1220 SW 3rd Ave	Portland	OR	97204	5 to 9	\$1m to \$2.5m
LTX-Credence Corp.	20575 NW Von Neumann Dr # 150	Beaverton	OR	97006	10 to 19	\$5m to \$10m
MagneLink, Inc.	1060 NE 25th Ave # C	Hillsboro	OR	97124	5 to 9	\$1m to \$2.5m
Marcus Electronics	2264 SE Singing Woods Dr	Hillsboro	OR	97123	1 to 4	\$500k to \$1m
Maxim Integrated	14320 SW Jenkins Rd	Beaverton	OR	97005	10 to 19	\$5m to \$10m
MEC Northwest	1140 NW 3rd Ave	Canby	OR	97013	100 to 249	\$10m to \$20m
Mentor Graphics Corp.	8005 SW Boeckman Road	Wilsonville	OR	97070	500 to 999	>\$1b
MIControls Inc.	1617 E Burnside St	Portland	OR	97214	10 to 19	\$5m to \$10m
Microchip Technology Inc.	21015 SE Stark St	Gresham	OR	97030	10 to 19	\$5m to \$10m
Micron Semiconductor Products	10445 SW Canyon Rd # 240a	Beaverton	OR	97005	1 to 4	\$1m to \$2.5m
Micron Semiconductor Products	7245 NW Evergreen Pkwy # 150	Hillsboro	OR	97124	20 to 49	\$20m to \$50m
Microsystems Engineering Inc.	6024 Jean Rd # B	Lake Oswego	OR	97035	250 to 499	\$100m to \$500m
MixSignal Design, LLC	3255 NE Henderson Rd	Corbett	OR	97019	1 to 4	\$500k to \$1m
Nanometrics Inc.	2925 NE Aloclek Drive	Hillsboro	OR	97124	5 to 9	\$2.5m to \$5m

Company Name	Location Address	City	ST	ZIP	Employees	Sales
National Marketing Group	11855 SW Ridgecrest Dr # 205	Beaverton	OR	97008	1 to 4	\$10m to \$20m
NexPlanar Corp.	7175 NW Evergreen Pkwy # 200	Hillsboro	OR	97124	5 to 9	\$2.5m to \$5m
Noah Precision LLC	2501 SE Columbia Way	Vancouver	WA	98661	20 to 49	\$10m to \$20m
North Pacific Communications	5605 NE Lessard Rd	Camas	WA	98607	1 to 4	\$5m to \$10m
Northwest Circuit Board	2900 SW Cornelius Pass Rd #864	Hillsboro	OR	97123	1 to 4	\$500k to \$1m
Northwest Power Integrations	4211 SE International Way # F	Milwaukie	OR	97222	5 to 9	\$1m to \$2.5m
Novellus Systems, Inc.	11355 SW Leveton Dr	Tualatin	OR	97062	10 to 19	\$5m to \$10m
OECO LLC (Pacific Scientific-OECO)	4607 SE International Way	Portland	OR	97222	250 to 499	\$50m to \$100m
ON Semiconductor	23400 NE Glisan St	Gresham	OR	97030	1 to 4	\$5m to \$10m
OR Screw Machine Products	9291 SE 64th Ave	Portland	OR	97206	20 to 49	\$2.5m to \$5m
Parks Circuit Boards	19478 SW Shaw St # A	Beaverton	OR	97007	1 to 4	\$500k to \$1m
PCB International LLC	1503 SE Morgan Rd	Vancouver	WA	98664	1 to 4	<\$500k
PCB Unlimited	4749 Hastings Pl	Lake Oswego	OR	97035	20 to 49	\$5m to \$10m
Pico Machines	4779 NW 138th Pl	Portland	OR	97229	1 to 4	\$500k to \$1m
Pixelworks Inc.	16760 SW Upper Boones Fry #101	Portland	OR	97224	10 to 19	\$5m to \$10m
Pixelworks Inc.	8100 SW Nyberg St # 107	Tualatin	OR	97062	5 to 9	\$2.5m to \$5m
Planar Systems Inc.	1195 NW Compton Way	Beaverton	OR	97006	100 to 249	\$100m to \$500m
PMC-Sierra Inc.	8705 SW Nimbus Ave # 100	Beaverton	OR	97008	20 to 49	\$10m to \$20m
PNE International, LLC	4888 NW Bethany Blvd # K5-375	Portland	OR	97229	20 to 49	\$5m to \$10m
Polar Instruments Inc.	18649 SW Farmington Rd	Aloha	OR	97007	1 to 4	\$500k to \$1m
Precision Cable & Connector	3255 NW 29th Ave	Portland	OR	97210	1 to 4	\$1m to \$2.5m
Pro Circuit Inc.	6623 NE 78th Ct # B3	Portland	OR	97218	1 to 4	<\$500k
Quartz Scientific Inc.	700 NE 117th St	Vancouver	WA	98685	1 to 4	\$500k to \$1m
Ran-Tech Engineering & Aerospace	5516 SE International Way	Portland	OR	97222	10 to 19	\$2.5m to \$5m
Raytex Corp.	7337 SW Tech Center Dr	Portland	OR	97223	1 to 4	\$2.5m to \$5m
Relcom Inc.	2221 Yew St	Forest Grove	OR	97116	10 to 19	\$2.5m to \$5m
Renesas Electronics America	9020 SW Washington Square #400	Tigard	OR	97223	20 to 49	\$10m to \$20m
Rexel	1624 SE Grand Ave	Portland	OR	97214	1 to 4	\$1m to \$2.5m
Sanmina-SCI Corp.	16534 NW Audrey Dr	Beaverton	OR	97006	20 to 49	\$2.5m to \$5m
Sanmina-SCI Corp.	1301 Officers Row	Vancouver	WA	98661	250 to 499	\$50m to \$100m
SEH America	4111 NE 112th Ave	Vancouver	WA	98682	100 to 249	\$100m to \$500m
Sekidenko Inc.	2501 SE Columbia Way # 230	Vancouver	WA	98661	20 to 49	\$20m to \$50m
Semiconductor Components	23400 NE Glisan St	Gresham	OR	97030	5 to 9	\$1m to \$2.5m

Company Name	Location Address	City	ST	ZIP	Employees	Sales
Sensoray Co., Inc.	7313 SW Tech Center Dr	Portland	OR	97223	20 to 49	\$5m to \$10m
Silicon Forest Electronics Inc.	6204 E 18th St	Vancouver	WA	98661	50 to 99	\$100m to \$500m
Siltronic Corporation (Wacker)	7200 NW Front Ave	Portland	OR	97210	250 to 499	\$100m to \$500m
Simplicity Tool Co.	10330 NE Marx St	Portland	OR	97220	10 to 19	\$2.5m to \$5m
SMSC	4800 Meadows Rd	Lake Oswego	OR	97035	10 to 19	\$5m to \$10m
Spectrum Systems Design	937 SW 14th Ave # 101	Portland	OR	97205	5 to 9	\$2.5m to \$5m
Sputter Tech Inc.	12121 NE 99th St # 2170	Vancouver	WA	98682	1 to 4	\$5m to \$10m
Summit Semiconductor	22867 NW Bennett St # 200	Hillsboro	OR	97124	20 to 49	\$5m to \$10m
SunEdison	7832 N Leadbetter Rd	Portland	OR	97203	5 to 9	\$1m to \$2.5m
Sun Up Software	245 SW Lincoln St # 120	Portland	OR	97201	1 to 4	<\$500k
Sunset Transformers	10535 NW Groveland Rd	Hillsboro	OR	97124	10 to 19	\$1m to \$2.5m
Sunstone Circuits	13626 S Freeman Rd	Mulino	OR	97042	100 to 249	\$20m to \$50m
Tektronix Component Solutions	13975 SW Karl Braun Dr	Beaverton	OR	97005	5 to 9	\$2.5m to \$5m
Tinitron Inc.	6501 NW Croeni Rd	Hillsboro	OR	97124	10 to 19	\$5m to \$10m
Tokyo Electron America, Inc.	20175 NW Amberglen Ct # 140	Beaverton	OR	97006	100 to 249	\$100m to \$500m
Tosoh Quartz	14380 NW Science Park Dr	Portland	OR	97229	100 to 249	\$20m to \$50m
TriQuint Semiconductor Inc.	2300 NE Brookwood Pkwy	Hillsboro	OR	97124	500 to 999	\$500m to \$1b
Triad Speakers Inc.	15835 NE Cameron Blvd	Portland	OR	97230	50 to 99	\$100m to \$500m
Ultra Clean Technologies Corp.	5350 NE Dawson Creek Dr	Hillsboro	OR	97124	5 to 9	\$2.5m to \$5m
Vanguard EMS	9825 SW Sunshine Ct	Beaverton	OR	97005	250 to 499	\$20m to \$50m
Viasystems Technologies Corp., LLC	15725 SW Greystone Ct # 200	Beaverton	OR	97006	1000 to 4999	\$100m to \$500m
Viasystems Group Inc.	1521 Poplar St	Forest Grove	OR	97116	10 to 19	\$2.5m to \$5m
Vishay HiRel Systems LLC	2350 NE Griffin Oaks St # 1500	Hillsboro	OR	97124	100 to 249	\$50m to \$100m
Vitesse Semiconductor Corp.	4550 Kruse Way # 275	Lake Oswego	OR	97035	1 to 4	\$1m to \$2.5m
WaferTech, LLC	5509 NW Parker St	Camas	WA	98607	500 to 999	\$500m to \$1b
Westak International	2329 Yew St # C1	Forest Grove	OR	97116	10 to 19	\$2.5m to \$5m
Westak OR	3941 24th Ave	Forest Grove	OR	97116	5 to 9	\$1m to \$2.5m
WRS Materials	12001 NE 60th Way # B	Vancouver	WA	98682	10 to 19	\$10m to \$20m
Xilinx Inc.	8625 SW Cascade Ave	Beaverton	OR	97008	5 to 9	\$2.5m to \$5m
Z Technology, Inc.	14950 NW Greenbrier Pkwy	Beaverton	OR	97006	5 to 9	\$10m to \$20m
Zmag America LTD	10260 SW Greenburg Rd # 400	Portland	OR	97223	5 to 9	\$1m to \$2.5m

APPENDIX B: Major Global Manufacturers & Their Suppliers

NOTE: Most major manufacturers are private about their supplier base.

When suppliers could be identified from company websites, they are included in the following information.

INTEL CORPORATION

Santa Clara, California; Hillsboro, Oregon; Arizona; Texas; New Mexico; Massachusetts, and international operations

- 13.4% market share
- Revenue \$57 billion
- 100,000 employees worldwide
- Brands: Core i7/Extreme, Core i5, Core i3, Xeon, Atom, Itanium, McAfee

Founded in 1968, INTEL is the world's largest semiconductor chipmaker. It manufactures integrated circuits, memory and chips, embedded processors and other devices for computing and communications, including:

- Mobile phone communication components such as baseband processors, radio frequency transceivers, and power management chips. It recently acquired Infineon to grow this segment of its business.
- Microprocessors and related chipsets and chip routers for embedded applications in "Intelligent Systems" (non-PCs such as the Xeon chip in workstations and servers).
- Microprocessors and related chipsets for netbooks and tablets.
- Architecture-based products for next-generation consumer electronic devices like smart TV and digital health products.
- Low-power, architecture-based products for the handheld market.
- Software and services (via McAfee acquisition).

Growth in the developed West is slowing.¹³⁶ Intel's strength is in emerging markets, where growth is strong. It has strategic relationships with Motorola, Lenovo and Google. Its customers include Hewlett-Packard, Dell, Samsung, Apple, Microsoft, IBM, Altera, and Cisco Systems. It should be noted that Samsung is both a customer and a competitor. Intel's only major competitor in the x86 processor market is Advanced Micro Devices (AMD).

Intel "anchors Oregon's economy."¹³⁷ Its operations in Oregon stretch across six campuses west of Portland in Hillsboro, Washington County. These campuses comprise Intel's largest and most comprehensive site in the world – a global center of semiconductor research and manufacturing. The company has more than 16,000 employees in Oregon, making it the state's largest private employer.

Since 1974 when Intel acquired its first property in Oregon, the company's capital investments in the state have topped \$25 billion. That amount will increase significantly with the 2014 completion of a new \$5 billion development and fabrication facility, D1X, at the Ronler Acres campus. Intel is the largest property taxpayer in Washington County, paying approximately \$30 million a year.¹³⁸

Intel's Tri-Gate transistor, developed in Oregon, was named the "most innovative product" of the year, and Intel was recognized, for the fourth time, as the "most philanthropic company" in Oregon. The company donated \$2.4 million to Oregon schools and made \$6.8 million in contributions to local nonprofit organizations in 2012.

136 International Monetary Fund and Organization For Economic Cooperation & Development, 2011.

137 Intel interview, June 2013.

138 Intel website: www.intel.com.

Preferred Intel Suppliers in Oregon:

Supplier	HQ Location	OR/WA Presence?	Manufacturing in OR/WA?
ASML	Netherlands	Hillsboro, Oregon	No
KLA-Tencor Corp	Beaverton, Oregon	Beaverton, Oregon	Yes
TAIYO YUDEN CO., LTD	Tokyo, Japan	Distribution centers in Beaverton and Portland, Oregon	No
Tosoh Quartz Inc.	Portland, Oregon	Portland, Oregon	Yes
Marvell Semiconductor	Santa Clara, California	Corvallis and Beaverton, Oregon	Yes
DISCO Corp	Tokyo, Japan	Hillsboro, Oregon	No

Intel Suppliers Around the World

- Advantest Corporation supplies testers, test handlers, and test interface products. Advantest America, Inc. is located at 3061 Zanker Road, San Jose, California 95134. Also located in Japan, Europe, Taiwan, Singapore, Korea, and China.
- Applied Materials, Inc. supplies semiconductor manufacturing equipment, software and support services. Located at 2821 Scott Boulevard, P.O. Box 58039, Santa Clara, California 95050. Also has offices located around the world.
- Cabot Microelectronics Corporation supplies chemical mechanical polishing slurries. U.S. headquarters is in Illinois; manufacturing and R&D are in Illinois and in Asia.
- Daewon Semiconductor Packaging Industrial Co., Ltd. supplies plastic injected molded trays. Located in Hanam, South Korea.
- DuPont AirProducts NanoMaterials LLC supplies chemical mechanical planarization slurries. Headquartered in Pennsylvania and has offices around the world.
- Ebara Corporation supplies electroplaters, chemical mechanical polishers, and pumps and abatement systems. Main office is located in Tokyo, Japan, with U.S. offices in California, Pennsylvania and Nevada.
- FUJIFILM Electronic Materials supplies formulated chemicals, developers, precursors, slurries and advanced photoresists. Regional office is located in Seattle.
- Mitsubishi Gas Chemical Company, Inc. supplies chemicals for semiconductor device manufacturing. Located in Tokyo, Japan.
- Murata Manufacturing Co., Ltd. supplies multi-layer ceramic capacitors. The head office is located in Kyoto, Japan, and the main U.S. office is in Georgia.
- Rofin-Baasel supplies laser mark equipment. It is headquartered in Germany, and it has U.S. offices in the Southwest, Midwest and Northeast.
- Samsung Electro-Mechanics Co., Ltd. supplies flip chip substrates. The headquarters is located in Korea. The U.S. headquarters is in New Jersey.
- Siliconware Precision Industries Co., Ltd. supplies semiconductor assembly and test services. The headquarters is located in Taiwan. The U.S. offices are located in California, Arizona, and Texas, with manufacturing in China.
- STATS ChipPAC Ltd. supplies full turnkey packaging and test services. The headquarters is located in Singapore. The U.S. headquarters is in Fremont, California; sales offices are located in California, Massachusetts, Texas and Arizona.
- Nikon Corporation is the Intel achievement award winner for velocity. The headquarters is located in Tokyo, Japan.
- Powertech Technology Inc. is the Intel achievement award winner for customer orientation and cycle time reduction. Locations are in Taiwan and China.

SAMSUNG

Seoul, South Korea and Ridgefield Park, New Jersey

- Market share 12.6%
- Revenue \$213.4 billion; U.S. revenue \$9.8 billion
- 150,000 employees worldwide
- Brands: moviNAND, OneNAND, and OneDRAM

Samsung's U.S. semiconductor headquarters are in San Jose, California. Founded in 1969, the company manufactures semiconductors, digital appliances, telecom equipment, memory and digital media. A global leader in memory, logic, semiconductors and hard drive storage systems, Samsung's semiconductor sales represent 45% of company income, with the largest portion of its sales coming from the U.S. It has semiconductor research and fabrication facilities in Austin, Texas. Like Intel, Samsung invests heavily in R&D and state-of-the-art production facilities. It has registered nearly 5,000 patents in the U.S.

QUALCOMM

San Diego, California

- Revenue \$25 billion
- 31,000 employees worldwide

Qualcom was founded in 1985. Stating its intention to move from a semiconductor company to a major player in the consumer electronics market, Qualcomm in 2013 introduced the Toq (pronounced 'talk') Smartwatch that sends emails directly to the wearer's wrist. Other new products include the Snapdragon chipset for cameras with 3D sensors and chips that enhance graphics efficiency. Market share is 53% in smart phone applications and 97% in 4G LTE baseband chips.¹³⁹ *Preferred suppliers are not available on Qualcomm's website.*

ADVANCED MICRO DEVICES, INC.

Sunnyvale, California

- Market share 1.5%
- Revenue \$1.1 billion
- 8,600 employees

AMD designs and markets microprocessors for computers, graphics, and video games while outsourcing all of its production to Asia. Although much smaller, AMD is the only U.S. competitor to Intel for CPUs. The company's microprocessors are not compatible with Intel motherboards and other processors due to licensing restrictions; therefore, AMD depends on third parties to design and manufacture core logic chipsets, graphics cards, and other components for AMD's microprocessors. In 2009, AMD founded a joint venture partnership with the Saudi Arabian government to spin off GLOBALFOUNDRIES, which is building a fab in New York State.



139 <http://seekingalpha.com/>.

AMD Preferred Suppliers for 2012

Supplier	HQ Location	OR/WA Presence?	Manufacturing in OR/WA?
Unimicron Technology	Taiwan	No	Yes – California & Canada
AT&T	Texas	Yes	Yes
ModusLink Global Solutions	Massachusetts, Utah, California	No	Supply Chain & Logistics Services
Murata Mfg. Co., Ltd.	Kyoto, Japan; Georgia, Texas, Massachusetts, Colorado	No	Yes
Shinko Electric Industries Co.	Nagano, Japan; California, Arizona, Vermont, Texas	Redmond WA	Yes
Siliconware Precision Industries Co.	Taiwan; California, Arizona, Texas	No	Packaging, Assembly, Testing
Volt Workforce Solutions ¹⁴⁰	Beaverton, Oregon	Yes	Temp workers

TSMC (owns WaferTech LLC in Camas, Washington)

Taiwan

Established in 1987, TSMC is a dedicated semiconductor foundry. It manufactures wafers for other companies.

TSMC Outstanding Suppliers 2012

Supplier	HQ Location	OR/WA Presence	OR/WA Manufacturing
ASML Holding N.V.	Veldhoven, Netherlands	Hillsboro, Oregon	Yes
Applied Materials, Inc.	Santa Clara, California	No	Yes
Ebara Corporation	Tokyo, Japan; Nevada, Pennsylvania, California	No	Yes
Universal Scientific Industries	California, North Carolina, New York, Massachusetts	No	Yes
MEMC Electronic Materials (SunEdison)	Missouri, Texas	Portland, Oregon (was Solaicx)	Yes
Linde Lien Hwa	China	No	Yes
FUJIFILM Planar Solutions	Arizona, New York, Massachusetts, Connecticut, South Carolina, Rhode Island	Bothell, Washington	Yes
JSR Corporation	Japan; Ohio	No	Yes - materials

Other 'fabless' companies that design and supply semiconductors include Qualcomm and Nvidia. They outsource production to Renesas Electronics Corp. (Japan) and GlobalFoundries, which have U.S. presence.

¹⁴⁰ <http://www.amd.com/us/press-releases/Pages/amd-seven-suppliers-2013may14.aspx>.

GLOBALFOUNDRIES

- Estimated revenue \$4.56 billion in 2012 (privately held; does not release revenue numbers)
- 13,000 employees

GLOBALFOUNDRIES is the former manufacturing arm of AMD (Abu Dhabi). Founded in 2009, it manufactures on three continents and has more than 150 customers. Its headquarters are in Silicon Valley; manufacturing centers are located in Germany, Singapore and New York, where its new 300mm fabrication facility No. 8 in Saratoga, New York is one of the largest capital expansion projects in the U.S.¹⁴¹

Other “fabless” companies that design and supply semiconductors include Qualcomm and Nvidia. They outsource production to Renesas Electronics (Japan) and GLOBALFOUNDRIES, both of which have a U.S. presence.

BROADCOM

Irvine, California

- Market share 3.5%
- Revenue \$2.7 billion
- 10,000 employees worldwide
- Brands: moviNAND, OneNAND, and OneDRAM

With a presence in Seattle, Washington (none in Oregon), Broadcom is a “fabless” designer of semiconductors, focused on computing, telecom chips and systems-on-a-chip for digital video recorders and set-top boxes, including Apple’s iPhone and Nintendo’s Wii. Recognized supplier is Winonics in California.



141 <http://www.bizjournals.com/albany/morning-call/2012/05/abc-news-story-on-globalfoundries.html>.

TEXAS INSTRUMENTS

Dallas, Texas

- Market share 2%
- U.S. revenue \$1.7 billion
- 10,000 employees worldwide

TI designs and makes semiconductors, embedded digital processors and microcontrollers, microprocessors, calculators and digital displays. It is the world’s leading maker of analog chips, and its products are used in computers, medical equipment, industrial applications and consumer electronics. TI serves a large number of customers across a wide range of equipment areas with innovative semiconductor devices – from custom analog products to wireless and embedded processing products such as digital signal processors (DSPs) and microcontrollers. Major suppliers include Honeywell for sensors, controls and switches, and All Sensors for pressure sensors used in medical and industrial applications.

TRIQUINT

Hillsboro, Oregon

- Revenue \$900 million
- 2,720 employees (includes part time)

A spin-off from Tektronix, TriQuint manufactures high-performance radio frequency solutions for mobile devices, network infrastructure, defense and aerospace.

Award winning TriQuint suppliers include:

- Subtron Technology Co. Ltd, Taiwan – manufacturer of high quality integrated circuit package substrates.
- Kinsus Interconnect Technology Corp, Taiwan – IC package substrates.
- Okmetric, Finland – world’s leading supplier of silicon wafers for MEMS manufacturing.
- NTK Technologies Inc., Santa Clara, California – innovative semiconductor packaging materials.
- Hitachi Cable, Japan – manufacturer of single crystal wafers, epitaxial wafers, applied products made of gallium arsenide, and wafers made of gallium nitride. U.S. offices: New York, California, Michigan, New Hampshire, Indiana, and Florida.
- Unisem, Wales, United Kingdom – provider of semiconductor assembly and test services. U.S. office in Sunnyvale, California.

APPENDIX C: National & Regional Assets: Industry Organizations, Professional Associations, Publications & Conferences

State and local governments offer tax abatements and subsidies to attract semiconductor investment. In 2009, GLOBALFOUNDRIES received grants, tax credits and enterprise zone benefits for building their \$4.2 billion manufacturing facility in New York State. Intel and other regional companies have enjoyed similar incentives.

The National Science Foundation (NSF) supports research to expand science and educate future scientists and engineers, and it supports partnership programs between the federal government and 23 reputable U.S. universities. The International Technology Roadmap for Semiconductors (ITRS) provides expert forums to identify trends and issues affecting the industry.

SEMI is the global industry association serving the manufacturing supply chain for the microelectronic and nanoelectronic industries.

SEMICON is the industry's international trade show, produced by SEMI and sponsored by major industry players including Intel. The trade show includes:

- Semiconductors
- Photovoltaics
- High brightness light-emitting diodes (LEDs)
- Flat panel displays
- Micro-electromechanical systems (MEMS)
- Printed and flexible electronics
- Related microelectronics

The Semiconductor Research Corporation (SRC) in North Carolina manages the Nanoelectronics Research Initiative (NRI). This U.S. semiconductor R&D program supports university research to ensure that the U.S., the country that developed microelectronics 50 years ago, will also be the leader in nanoelectronics. SRC works with the federal Defense Advanced Research Projects Agency (DARPA, part of the Department of Defense) to fund research in microelectronics.

SRC has more than 125 participating international universities, including Oregon State University, Portland State University and Washington State University. OSU participates on the SONIC academic team hosted at the University of Illinois; it focuses on nanoscale image processing and communications. The University of Washington participates in the Center for Future Architectures Research (C-FAR) based at the University of Michigan. It investigates parallel computing using integrated circuit technology. The TerraSwarm project, hosted at the University of California, Berkeley (UC Berkeley), focuses on distributed applications on shared platforms. www.src.org

Institute of Electrical and Electronics Engineers (IEEE) is the world's largest professional association supporting the advancement of technology in computers and electronics. U.S. headquarters are in Washington D.C. www.ieeeusa.org

Association for Computing Machinery (ACM) is an international organization providing resources to advance computing as a science and a profession. It provides publications, conferences and career resources. There is no local chapter in Oregon or Washington. www.acm.org

Electronics Technicians International Association (ETIA) is an international association providing training, certifications and support for electronics professionals in electronics-related fields. www.eta-i.org

- Avionics
- Data Cabling
- Electronics
- Fiber Optics
- Industrial Electronics
- Photonics
- Precision Optics
- Radar
- Security Surveillance
- Smart Home Technology
- Wireless Communications

Electronic Components Industry Association (ETI) is a manufacturer and distributor organization providing standards and industry guidelines, trade shows and reports. www.eciaonline.org

National Electrical Manufacturers Association (NEMA) is a membership organization for electrical equipment and medical imaging manufacturers. It provides information about electronics, emerging technologies, industrial automation, insulating systems and lighting systems. www.nema.org

Semiconductor Industry Association (SEMI). The microelectronics industry began in 1947 with the invention of the transistor at Bell Labs. SEMI was formed in 1977 as an international support group for developing new semiconductor and electronics technology, providing public policy in support of the industry, researching and publishing findings, providing industry statistics and organizing industry events. www.semi.org

Wireless Communications Alliance (WCA) was founded in 1994. It provides education along with connection and advocacy for companies, organizations and individuals involved with electrically enabled wireless technologies, including semiconductors used in wireless applications. www.wca.org

Universities & Labs

Oregon State University (OSU) offers an innovative, hands-on electrical and computer engineering undergraduate degree (Electrical & Computer Engineering). Its core curriculum includes:

- Electrical Fundamentals
- Digital Logic
- Electronics
- Systems & Signals
- Computer Networks
- Transmission Lines
- Computer Organization
- Supporting disciplines: math, physical sciences, computer science

Washington State University School of Electrical Engineering and Computer Science has a research mission to develop technologies. Washington State University (WSU) School of Electrical Engineering and Computer Science has a research mission to develop technologies. Computer Science and Electrical Engineering degrees are available at the Vancouver, Washington, campus.

Faculty members engage in research for the C&E industry:

- Computer and Systems Engineering
- Bioinformatics and Computational Biology
- Control and Signal Processing
- Distributed and Networked Computing Systems
- Electrophysics
- Microelectronics
- Software engineering
- Smart Environments

The University of Oregon (U of O) has research centers relevant for computers and electronics sciences: Oregon Center for Optics (OCO) in physics and physical chemistry, and the Materials Science Institute (MSI) for the study of the structure and properties of materials.

Portland State University (PSU) has the Research Center for Electron Microscopy and Nanofabrication (CEMN).

Clark College in Vancouver, Washington has the West Coast's only mechatronics lab and offers two-year degrees.

Oregon Institute of Technology (OIT) offers both bachelor and master degrees in Manufacturing Engineering Technology and Technology and Management.

R&D Organizations

Oregon Nanoscience and Microtechnologies Institute (ONAMI) is an Oregon signature research center focused on materials science and related device and system technologies, including:

- Nanoelectronics, nanometrology and nanobiotechnology
- Sustainable materials chemistry
- Microtechnology-based energy and chemical systems
- Safer nanomaterials and nanotechnology

ONAMI works with companies to improve existing products and provides access to rapid prototyping, materials characterization, and fabrication equipment, as well as university laboratories and highly skilled workers. It also provides companies with access to matching grant programs. Members include:

- Corporate technology leaders such as Intel, IBM, and small and medium companies
- Universities
- Established technology executives and professionals
- Entrepreneurs, startup business owners and independent contractors
- Service companies supporting the technology community

Pacific Northwest National Lab (PNNL), located in Richmond, Washington, and Portland, Oregon, is a Department of Energy Office of Science National Laboratory operated by Battelle, the world's largest independent scientific research and technology development organization. PNNL provides unique laboratories and specialized equipment as well as the Environmental Sciences Laboratory. Work related to computers and electronics includes:

- Computational sciences
- Instrument development
- National security
- Visual analytics

Associations

Association for Computing Machinery

www.acm.org

Publications: Many online journals, magazines and other publications at www.acm.org/publications

Global Semiconductor Alliance

www.gsaglobal.org

Publications: GSA Forum (quarterly), IC Foundry Almanac

Consumer Electronics Manufacturing Association

www.cemacity.org

IPC: Association Connecting Electronics Industries

www.ipc.org

Electronic Components Industry Association

www.eciaonline.org

Publications: Market reports and surveys available on their website

National Electrical Manufacturers Association

www.nema.org

Publications: Electroindustry magazine and eiXtra bi-weekly e-newsletter

Semiconductor Equipment and Materials International (SEMI)
www.semi.org

Semiconductor Industry Association
www.semiconductors.org
Publications: Various issue papers and whitepapers

Sematech Manufacturing Technology Center
www.sematech.org
Technical Publications available online:
www.sematech.org/publications/technical.htm

Surface Mount Technology Association www.smta.org

World Semiconductor Trade Statistics www.wsts.org

Publications

EE Times
www.eetimes.com

Electronics Weekly
www.electronicweeky.com

Solid State Technology
www.electroiq.com

Trade Shows, Conferences & Seminars

Applied Power Electronics Conference and Exposition
www.apec-conf.org

Custom Integrated Circuits Conference
www.ieee-cicc.org

Del Mar Electronics Expo
www.vts.com/delmar

Design West Conference, EE Live
www.ubmdesign.com/sanjose

Design Con
www.designcon.com/santaclara

EDS – Electronics Distribution Show
www.edsconnects.com

Electronics New England Expo and Conference
www.canontradeshows.com/expo/ene13/index.html

Hot Chips: A Symposium on High Performance Chips
www.hotchips.org

IC China Semiconductor Expo
http://www.chinaexhibition.com/trade_events/3380-IC_China_2013_-_The_11th_China_International_Semiconductor_Expo.html

IEEE Conferences
www.ieee.org/conferences_events

IPC Apex Expo
<http://ipcapexexpo.org/html/main/default.htm>

Industry Strategy Symposium
www.semi.org/en/node/35136

International Technology Partners Conference
www.semi.org/ITPC

International Test Conference
www.itctestweek.org

Linley Tech Processor Conference
www.linleygroup.com/events/event.php?num=24

MEPTEC Semiconductor Symposium
<http://meptec.org/meptecevents.html>

Plastic Electronics Exhibition
www.plastic-electronics.org

SEMI
www.semi.org/en/EventsTradeshows

SEMI Professional Development Seminar Pacific Northwest
www.semi.org/en/node/46246

SEMICON West
www.semiconwest.org
Also, SEMICONs held in China, Europe, Taiwan, etc.

SMTA Symposium
www.smta.org

Strategic Materials Conference
www.semi.org/node/41386

APPENDIX D: Regional & National Exporting-Related Resources

Organizations

Impact Washington ExportTech Training Program
www.impactwashington.org

Washington State Export Resource Program
www.waexports.com

Portland Export Assistance Center
www.export.gov/oregon

Business Oregon International Export Assistance
www.oregon4biz.com

Export Council of Oregon
www.exportcounciloforegon.org

U.S. Export Assistance Center
www.sba.gov

U.S. Commercial Service, Oregon,
International Trade Administration
www.trade.gov/cs/states/or.asp

Websites

Trade Leads, Finding Customers, Distributors, Company Directories and Databases

FITA:Federation of Int'l Trade Associations
www.fita.org

Global eMarketplace
www.alibaba.com

Global Industrial Products and Company Database
www.solusource.com

Business Oregon Export Assistance
www.oregon4biz.org

Trade Counseling, Mentoring

Find your local Small Business Development Center
www.sba.gov/tools/local-assistance/sbdc

Find a local District Export Council that mentors exporters
<http://districtexportcouncil.org/local-dec-locator>

Find U.S. Export Assistance Center (U.S. Commercial Service, U.S / Dept. of Commerce)
www.export.gov

Foreign Market Data, Country Economic & Business Climate

US Gov't/US Commercial Service export portal
www.export.gov

Economist Economic Intelligence Unit, country market data and industry analysis
www.eiu.com

US Dept. of Agriculture, Foreign Agric. Service
www.fas.usda.gov

FITA Market Research
www.fita.org or www.internationaltrade.org

Global business web portal
www.globaledge.msu.edu

World Bank info re: foreign market regulatory environments
www.doingbusiness.org

Global market studies to purchase
www.marketresearch.com

Journal of Commerce
www.joc.com

Websites, continued

Trade Information Portals, Tutorials, Export Guides, Links to Other Sources

Basic guide to exporting

www.sba.gov/tools/local-assistance/sbdcwww.unzco.com

Links to 100 Trade websites

www.quazell.com/top100.html

US Gov't. Export Portal

www.export.gov

MSU Global Business portal

<http://globaledge.msu.edu>

FITA "Really Useful Links" trade info

www.fita.org or www.internationaltrade.org

Free on-line Export Training

www.export-u.com

International Trade Assoc.

www.ita.doc.gov

Business Culture

Foreign Business Culture

www.executiveplanet.com

See Country Commercial Guides

www.export.gov

Foreign Business Culture

www.worldbiz.com

Trade Data, Tariffs, Duties, HS (International Harmonized System) Codes

International Trade Administration

www.ita.doc.gov and <http://tse.export.gov>

U.S. Government Trade Data

www.usatradeonline.gov

UN Trade Database

<http://comtrade.un.org>

U.S. International Trade Commission

www.usitc.gov

USITC Interactive Trade Data Source

<http://dataweb.usitc.gov>

Tariff Info, HS Codes

<http://export.customsinfo.com/Default.aspx>

Census Bureau Trade Data

www.census.gov/foreign-trade

Tariff Info, HS Codes

http://www.fedex.com/GTM?cntry_code=us

Trade Finance

Export-Import Bank website

www.exim.gov/tradefinanceguide

US Gov't Trade Finance Guide

<http://export.gov/fradefinanceguide>

Websites, continued

Trade Shows, Events

Trade Show News Network Events Database
www.tsnn.com

See Trade Events section under “opportunities” menu
www.export.gov

Legal and Compliance

Legal Export Assistance Network
www.exportlegal.org

EBook: Three Common Global Trade Compliance
Deficiencies that affect your bottom line
http://info.amberroad.com/rl_wp_GTMDeficiencies.html

US Customs & Border Protection Trade Resources
www.cbp.gov/xp/cgov/trade/

Stanford Univ. Export Control Info & Tools
[http://doresearch.stanford.edu/research-scholarship/
export-controls](http://doresearch.stanford.edu/research-scholarship/export-controls)

Special 301 Report on Intellectual Property
protection by country
<http://www.ustr.gov/trade-topics/intellectual-property>

US Bureau of Industry & Security (US Export Controls)
www.bis.gov/doc

Export Council of Oregon
www.exportcounciloforegon.org

Acknowledgements

This report was prepared for the Columbia River Economic Development Council and Business Oregon by the MarketLink™ Market Research Department of the Oregon Microenterprise Network in support of the federal Jobs and Innovation Accelerator Challenge grant for Advanced Manufacturing & Materials, and the Greater Portland Export Initiative.



This report was researched in partnership with Impact Washington, the Oregon Manufacturing Extension Partnership, the Pacific Northwest Defense Coalition, the Southwest Washington Workforce Development Council, Oregon Worksystems Inc., Greater Portland Inc, and the Portland Development Commission.



Special gratitude for inspiration and invaluable insights goes to the numerous (confidential) business and industry leaders who provided the in-depth interviews that enriched this research and grounded it in real-world challenges faced by regional businesses.

Appreciation goes to the many who shared their data and expertise, including: Elizabeth Scott of CREDC; Max Woodbury of Oregon Metro; Jim Wehrs of Oregon Manufacturing Extension Partnership; Kristin Kautz of Impact Washington; Amy VanderVliet, Brenda Scott and Christian Kaylor of the Oregon Employment Department; Scott Bailey of Washington State University; Jo Oshiro of Oregon University Systems; Derrick Olsen of Greater Portland Inc; and Karen Goddin and Mike Meyers of Business Oregon.

Many thanks for collaboration and interview connections go to Bonnie Moore, and to Emily Leuning, Rachel Madewell, Marilyn Johnson-Hartzog, and Susan Pagel for editing and fact checking.

Researched and written by Dr. Beth Fitz Gibbon, founding principal of Fitz Gibbon Inc. Venture Development and senior research and policy advisor, Oregon Microenterprise Network.



Original artwork, #3-09 “In the Pulpit” and all derivative details were reproduced by permission of the artist and are copyrighted by Donna Steger of Steger Ink, LLC in Portland, Oregon. The artist, Donna Steger, has creative talents that carve a wide swath of artistic diversity with both theme and medium. As a specialty, Ms. Steger has developed a unique ability to find artistic intrigue within industrial environments and uses her artistic vision to create themes expressing the dignity and productivity of those who work in manufacturing: **THE ART OF WORK AS WORKS OF ART™**. For more information, visit her website at www.artbysteger.com or contact her at donna@artbysteger.com.

Report design by Patrick Hildreth, PDH Creative, LLC; Camas, Washington. www.pdhcreative.com

Published June 2014

Copyright © 2014 Columbia River Economic Development Council. All rights reserved.

