Technology Intelligence: IGBTs/High-Power Silicon Switches

Prepared for the Department of Energy

Synthesis Partners, LLC

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Tasking

Synthesis Partners was tasked by the Department of Energy (DOE) to undertake research to address the following specific questions regarding IGBTs/high-power silicon switches.

1. Current US manufacturing capabilities/quantities being produced
2. Existing industry roadmaps
3. Near term plans to expand this manufacturing capability (i.e., over the next 10 years)
4. Limitations or constraints on manufacturing these devices in the US
5. Determine requirements for US industries to manufacture these devices that would include a timeline for production ramp-up if the aforementioned requirements were met

Sources and Methods

Our research covered a wide range of secondary and primary sources in a short period of time. Table 1 below provides information on the key sources searched during the March to July 2009 timeframe.

This work accessed and analyzed many targeted secondary sources, including 34 market research reports, 25 pre-screened corporate websites and thousands of web-pages for associations, academic institutions, consultancies and technology news sources. The market research reports surveyed revealed no new data on U.S. production or manufacturing capabilities specifically for IGBTs vis a vis the Phase 1 report information. While this work did identify numerous market research reports that mentioned IGBTs, these all either focused on other technologies and mentioned IGBTs as a component used in another item or were reports on companies that listed IGBTs as an example of a product sold by the company.

We checked all relevant sources and did not find that any of the authors of the key research reports referenced in the Phase 1 report have issued updates as of July 31st 2009.

Our primary source collection focused on the fifteen companies identified as being important players in the IGBT industry. Table 1 Research Summary Statistics provides an introduction to the companies and individuals contacted by telephone and email. We received replies from a large number of companies in this effort, as approximately 66% of the companies contacted responded to our queries. One company asked to provide proprietary information, and we are in the process of moving this request forward through the appropriate channels.

Table 1: Research Summary Statistics

Primary Source Contacts

Company	Name of Contact
ABB Semiconductor	Lukas Inderfurth
Delphi	Ralph Taylor
Dynex Semiconductor	Stuart Cox
Fairchild Semiconductor	Jim Gillberg
Freescale Semiconductor	Vivek Mohindra
Fuji Device Technology America	Leo Fick
International Rectifier	Dee Bunna
Intersil	David Bell
Microsemi Power Products Group	Chang Qian
Objective Analysis Semiconductor Market Research	Jim Handy
ON Semiconductor	Keith Jackson
Powerex	Scott Leslie
Semiconductor Industry Association	Darryl Hatano
Semitronics	Henrietta Rivman
Solitron	Shevach Saraf
Universal Semiconductor	Fred Garcia
Synthesis Partners, LLC (2009)	

Market Research Topics

Topic	Wind Power Generation	Other Power Generation	Automotive Industry	Semiconductor Industry	Other Topics
Reports Found	20	2	1	5	6
Synthesis Partners, LLC (2009)					

1. Current U.S. Manufacturing Capabilities/Quantities Being Produced

Due to the scarcity of new, detailed information in the secondary source literature, we focused on primary source contacts in this phase.

Jim Handy of Objective Analysis Semiconductor Market Research stated that the semiconductor industry in general is currently in the downswing of what tends to be a four-year cycle. When a new breakthrough technology hits the market, the top tier manufacturers invest in new production equipment, selling the equipment used to produce the previous generation of technology to second tier manufacturers. These in turn pass down the equipment they were using to those who produce "commodity" semiconductor devices such as IGBTs which are "not as sensitive to being manufactured on leading-edge equipment."

In 2006, manufacturers invested in new equipment to produce the latest generation of semiconductors. By 2008, this manufacturing capacity should have reached full volume production. However, the recession reduced demand dramatically. This exacerbated what would normally have been a slowing of production and "sucked profits." Normally, an upturn would be expected in 2009, but Mr. Handy sees this as delayed because of the recession.

Semiconductor Industry Association (SIA) (http://www.sia-online.org/) provides the following information on the overall U.S. semiconductor industry:

- U.S. 2008 Sales = $120 Billion
- Worldwide 2008 Sales = $249 Billion

- 2008 World Market Share = 48 percent of $249 Billion Market
- Percent of Sales Outside U.S. Market = 77 Percent
- Capital Equipment = $13 Billion, 11 Percent of Sales
- R&D Investment = $20 Billion, 17 Percent of Sales

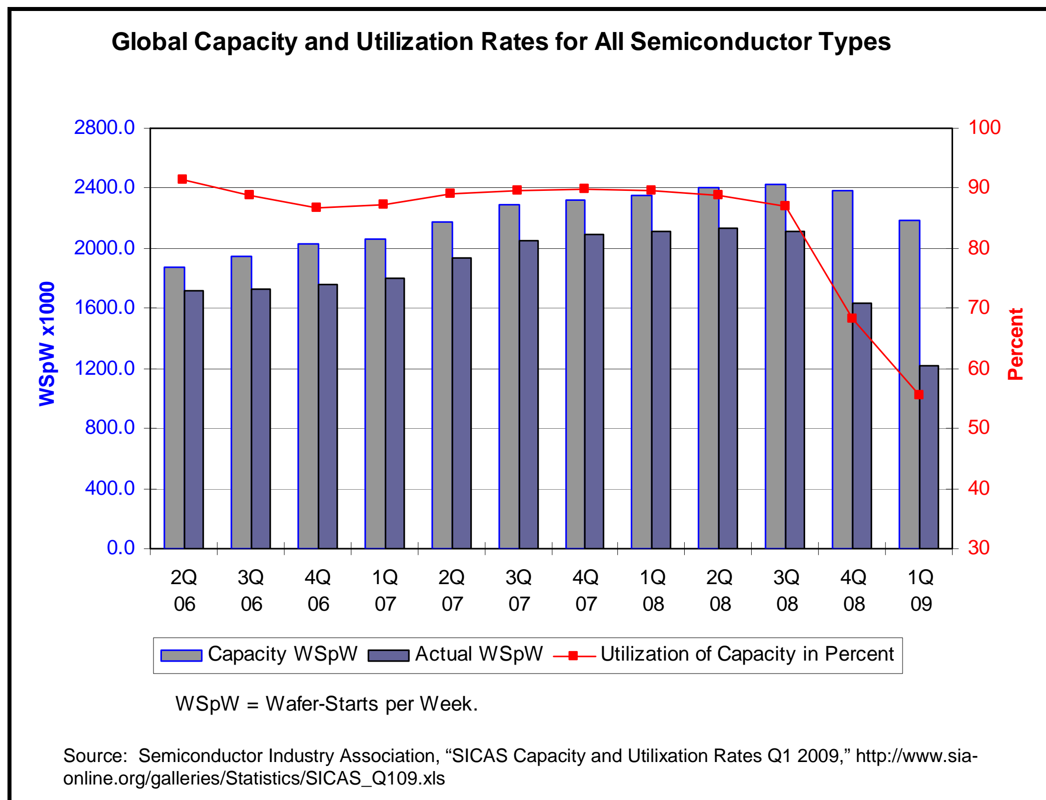
Analysis of the annual reports and recent SEC filings for the IGBT and semiconductor producers listed in Table 1 shows that several US companies maintain between 13 and 15 weeks of net sales in inventory. This amounts to $152m for smaller producers (i.e., Delphi), and $775m for the larger producers, (i.e., Freescale Semiconductor). While the publicly-available inventory data covers all types of semiconductors produced, we discovered no data on IGBT inventories specifically.

To put this inventory data into context, Gartner Group's Dataquest Semiconductor Inventory Index (DASI) dropped from 1.54 in the fourth quarter of 2008 to 1.31 in the first quarter of 2009. This occurred even as demand continued to shrink. The Dataquest Semiconductor Inventory (DASI) index is a single number that measures the status of the semiconductor industry throughout the supply chain. As Gartner reports, an index of 1.0 indicates that, on average, semiconductor inventory in the supply chain is at an ideal level. Above 1.0, and inventories are inflated and there will likely be downward pressure on average selling prices. Below 1.0, and inventories are low and components may be on allocation. Greater than 1.20 represents "severe excess inventory."

Status of Global Semiconductor Manufacturing Capacity

The SIA also publishes information on industry-wide production, production capacity, and overall utilization of capacity for the manufacture of semiconductor wafers.

Figure 1: Global Capacity and Utilization Rates for All Semiconductor Types

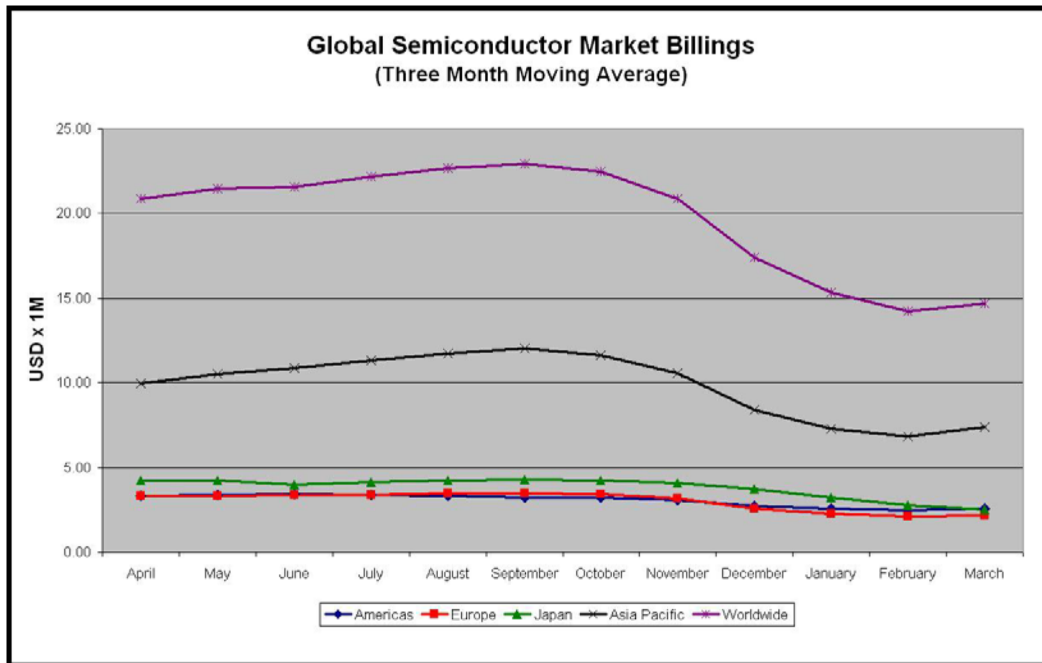


Source: Semiconductor Industry Association, "SICAS Capacity and Utilixation Rates Q1 2009," http://www.sia-online.org/galleries/Statistics/SICAS_Q109.xls

Currently, the industry-wide capacity utilization rate is 55.6 percent. This utilization rate is the lowest found in available records. A recent history shows that, in the third quarter of 2000, utilization hit 96.4 percent then dropped to 64.2 percent by the third quarter of 2001. It rebounded to 87 percent in the second quarter of 2002, and was back up to 95.4 percent by the second quarter of 2004. It fell to 84.8 percent in the first quarter of 2005 and hit 91.2 percent in the second quarter of 2006, the highest it has been since. As the figure above shows, utilization fell gradually until the third quarter of 2008, where it dropped below 70 percent for the first time since 2001. This historical view underscores the impact of the current recession.

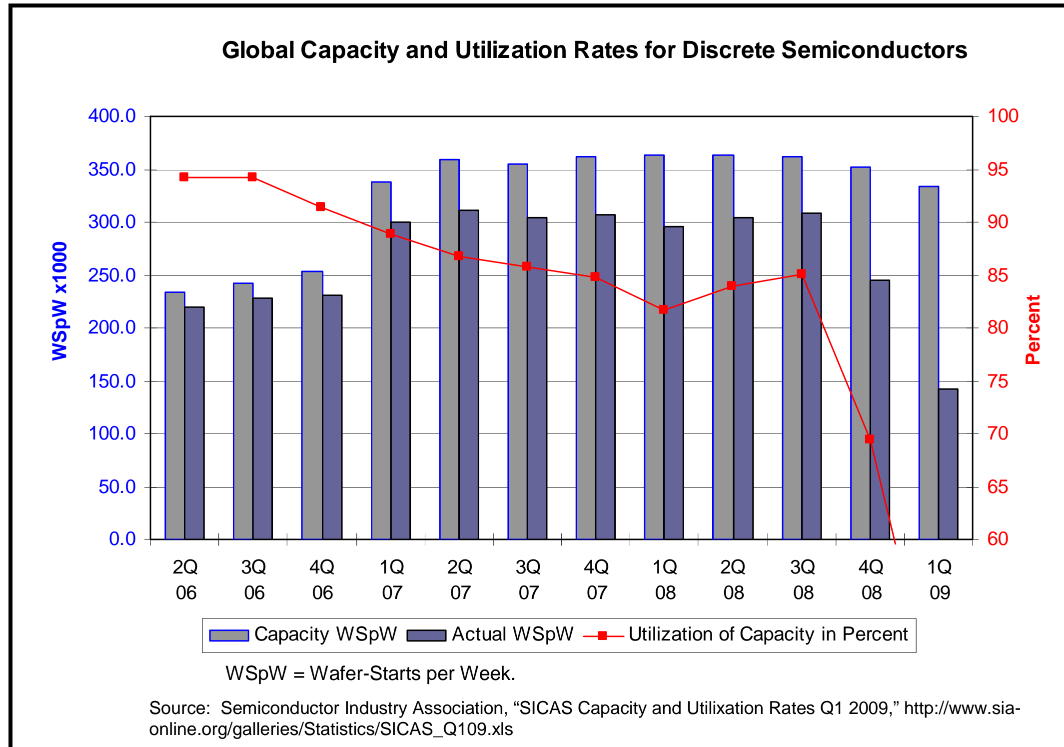
Across the industry, monthly billings – the dollar values of shipments – show how the economic situation has affected the semiconductor industry.

Figure 2: Global Semiconductor Market Billings



With regard to discrete semiconductor devices, which include IGBTs, the capacity utilization for production of wafers is even lower, at 42.7 percent for the first quarter of 2009.

Figure 3: Global Capacity and Utilization Rates for Discrete Semiconductors



The 2008 drop-off in discrete semiconductor capacity utilization rates is significant, and largely similar to the drop-off in utilization rates for all semiconductors. As is the case with all semiconductors, the available discrete semiconductor capacity has exceeded utilization rates since at least 2006, if not before.

There is no indication that the current slow-moving economic recovery, or indeed a return to the robust growth period of 2006 and early 2007, will lead to any significant pressure on the discrete semiconductor and IGBT manufacturing capacity in the next five years.

Given that the equipment overinvestment from the 2006 period has yet to be utilized, and capacity utilization rates are at historic lows, we assess that IGBT production rates will remain below capacity for at least five years or more.

Several sources provided good anecdotal understanding as to the impact of recession and added context regarding the state of the IGBT industry:

- As Mr. Handy points out, the industry moves in a cyclic manner and is currently in the downswing of the cycle. Because of this, it is difficult to quantify the impact the current recession is having on the industry. He feels the market will slowly return to normal by 2010.

- Chang Qian from Microsemi Power Products reports revenue in the semiconductor industry is down about 30 percent and doesn't see any "solid proof" it will change in the short term. He also indicates there is excess production capacity in the IGBT industry but he would not quantify it. However, he states due to the IGBT's role in "green" technology, the production of IGBTs has not fallen as drastically as semiconductors used in consumer electronics and, in fact, he sees the excess capacity diminishing as demand for green technology grows.

- Jim Gillberg from Fairchild Semiconductor painted a bleaker picture. He stated that there's been a 30 percent drop in production on the automotive side "across the board" – not just in higher-line

semiconductors but also in IGBTs and MOSFETs. He estimates it will take at least two years of growth to get the industry back to the "normal" level they had expected for 2009; he does not expect a recovery until at least 2011.

While Fairchild hasn't lost any existing projects, Mr. Gillberg notes they have had fewer new projects starting this year, and those have started much more slowly than normally. He also cites a distinct decline in the number of new engineering programs they are undertaking as an indicator that it will take several years to recover.

Capacity Transfer from the US to Overseas Location

Mr. Gillberg related that Fairchild is closing their 8-inch wafer fab plant in Mountaintop, Pennsylvania, and transferring IGBT production to a plant in Korea (MOSFET production will move to a plant in Salt Lake City, Utah). He estimates the plant in Pennsylvania will be shut down completely by June 2010. When asked if the plant would reopen should there be a surge in demand for IGBTs, he stated that it would not, and that they'd most likely expand production in Asia to meet any new demand.

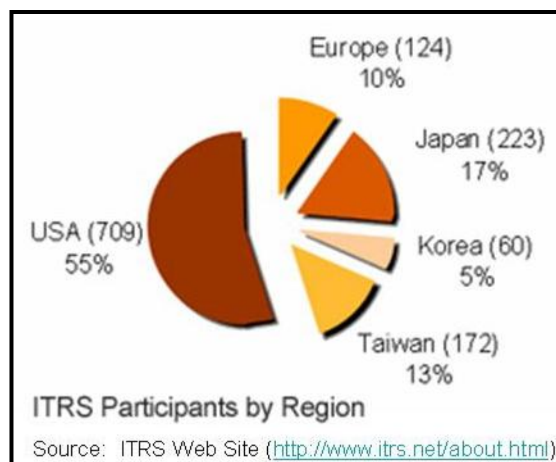
Synthesis assesses that absent an (unexpected) sharp increase in demand for certain advanced technology automotive IGBTs for which US manufacturers have some competitive advantage, it is difficult to see a business model to support sourcing 8"-plus IGBT wafers in the US. Fairchild's decision to relocate its Mountaintop facility to Korea demonstrates the real-world constraints facing U.S. manufacturing concerns.

2. Existing Industry Roadmaps

The International Technology Roadmap for Semiconductors (ITRS) is a "fifteen-year assessment of the semiconductor industry's future technology requirements" (http://www.itrs.net). Its sponsoring organizations are the European Semiconductor Industry Association (ESIA), the Japan Electronics and Information Technology Industries Association (JEITA), the Korean Semiconductor Industry Association (KSIA), the Taiwan Semiconductor Industry Association (TSIA), and the United States Semiconductor Industry Association (SIA).

The U.S. industry is well represented in this effort. As the graph below shows, 55 percent of the participants in the effort are from the U.S.

Figure 4: IRTS Participants by Region



The Roadmap is a complex document that is updated in even-numbered years and fully revised in odd-numbered years. The last revision (2007) consists of a series of PDF documents

(http://www.itrs.net/Links/2007ITRS/Home2007.htm) and Excel data tables with key technology driver data. It covers the following topics:

Executive Summary
System Drivers
Design
Test & Test Equipment
Process Integration, Devices & Structures
RF and A/MS Technologies for Wireless Communications
Emerging Research Devices
Emerging Research Materials
Front End Processes
Lithography
Interconnect
Factory Integration
Assembly & Packaging
Environment, Safety & Health
Yield Enhancement
Metrology
Modeling & Simulation

The 2008 update consists of an overview document (http://www.itrs.net/Links/2008ITRS/Update/2008_Update.pdf) and updated interlinked Excel spreadsheets with data projected through 2022.

Table 2: 2008 ITRS Data Update

File	2008Tables_FOCUS_A.xls	2008Tables_FOCUS_B.xls	2008Tables_CROSSCUT.xls
Tables	ORTC (Overall Roadmap Technology Characteristics)	ORTC	ORTC
	System Drivers	Front End Processes (FEP)	Environment, Safety, and Health (ESH)
	Design	Lithography	Yield Enhancement
	Test and Test Equipment	Interconnect	Metrology
	Process Integration, Devices, and Structures (PIDS)	Factory Integration	Modeling and Simulation
	RF and Analog/Mixed-signal Technologies for Wireless Communications	Assembly and Packaging	
Source: ITRS Web Site (http://www.itrs.net/Links/2008ITRS/Home2008.htm)			

A complete list of the data tables in the 2008 update is at Appendix A.

IGBTs are not specifically mentioned in the Roadmap. There are references to MOSFETS, primarily in the context of discussing scaling trends such as how carbon nanotubes and graphene nanoribbons will allow making them much smaller. While IGBTs are not discussed in particular, we assess that the general industry trends described in the roadmap (higher performance, better yield, more efficient production) will apply to IGBTs as well as other semiconductors as the roadmap is implemented.

The primary semiconductors discussed in the update are memory chips and processors. The primary trend the Roadmap assesses and tracks is “decreasing cost-per-function, which has led to significant improvements in economic productivity and overall quality of life through proliferation of computers, communication, and other industrial and consumer electronics.”

The Roadmap does not yet address specific semiconductors for use in hybrid or electric vehicles. The 2008 Roadmap states, "The rapid growth in hybrid and electric vehicles brings an additional class of electronics and a new subset of environmental conditions that will be addressed in the 2009 rewrite of the ITRS Roadmap." Synthesis studied the Roadmap and found very few references to automotive applications. However, the current Roadmap offers the following table of operating environment specifications for automotive semiconductors.

Table 3: Automotive Operating Environment Specifications

Automotive Operating Environment Specifications	
Metric	*Specification*
Automotive Maximum Temperatures (Ambient Temperatures)	
Passenger Compartment Dashboard, panel Hatrack	 +85°C +120°C
Chassis Isolated areas Exposed to heat source	 +85°C +125°C
Transmission Exposed to heat source Exposed to oil/hydraulics (today always bare die on ceramic substrate)	 +125°C +175°C
Engine Compartment Moderate areas Attached to Engine (today always bare die on ceramic substrate)	 +125°C +155°C
Storage Range	-55°C to 125 °C
Operating Range	-40°C to 150°C
Typical Mission Profile	-40 to - 20°C / 300h -20 to + 20°C / 600h 20 to +130°C / 4000h 130 to +140°C / 1000h +150°C / 100h
Vibration	40g / 10–1000Hz (depending on customer)
Mechanical Shock	50g / 11ms (depending on customer)
Source: ITRS Table AP21	

In addition, the ITRS mentions hybrid vehicles in the context of packaging and assembly of semiconductors for automotive applications. It states:

> Today the cost of electronic parts in cars is 15% for compact cars, 28% for luxury cars and 47% for hybrid cars (source: M. Hattori., Toyota, Semicon Japan 2006). Reducing size for automotive electronic systems is crucially important. The installation space that can be equipped with electronic systems is limited. The numbers of automotive electronic systems will rapidly increase during the next few years and thus minimum volume of the electronic systems is required.

The Roadmap recognizes the challenges of economically packaging automotive electronics in the smallest space, with greatest energy efficiency and at the lowest operating temperature possible. Table 4 below compares System on a Chip (SoC) and System in a Package (SiP) architectures, and illustrates the relative

strengths and weaknesses of each. These data are typical of the detailed information the Roadmap contains.

Table 4: Comparison of SoC and SiP Architecture

Comparison of SoC and SiP Architecture		
Market and Financial Issues		
Item	**SiP**	**SoC**
Relative NRE cost	1×	4-10×
Time to Market	3–6 months	6–24 months
Relative Unit Cost	1×	0.2–0.8×

Technical Features PROs	
SiP	**SoC**
Different front end technologies; GaAs, Si, etc.	Better yields at maturity
Different device generations	Greater miniaturization
Re-use of common devices	Improved performance
Reduced size vs. conventional packaging	Lower cost in volume*
Active & passive devices can be embedded	CAD systems automate interconnect design
Individual components can be upgraded	Higher interconnect density
Better yields for smaller chip sets	Higher reliability (not true for very large die)
Individual chips can be redesigned cheaper	Simple logistics
Noise & crosstalk can be isolated better	
Faster time to market	
Technical Features CONs	
SiP	**SoC**
More complex assembly	Difficult to change
More complex procurement & logistics	Single source
Power density for stacked die may be too high	Product capabilities limited by chip technology selected
Design Tools may not be adequate	Yields limited in very complex, large chips
	High NRE cost
* The cost advantage is only applicable when the SoC has good yield	
Source: ITRS Table AP8	

3. Near-Term Plans to Expand Manufacturing Capability (Over Next 10 Years)

No evidence was uncovered which indicates any semiconductor companies have plans to expand their manufacturing capability in the US in the foreseeable future. The excess manufacturing capacity currently in the industry and decreased sales due to the current economic conditions undoubtedly argue against investments in capacity expansion at this time.

Microsemi's Qian indicated that IGBT production had not slowed as much as other semiconductors due to their use in "green" technology. However, he didn't know of any plans within the industry to expand manufacturing capacity. Instead he feels the current excess capacity will sustain the industry for the foreseeable future. He did state that eventually demand for IGBTs will exceed production capacity but didn't know when this might happen (assuming no replacement is found for IGBTs in green technology).

4. Limitations or Constraints on Manufacturing These Devices in the US

As with practically any industry, there are a number of factors which can limit or constrain IGBT manufacturing in the US. These include environmental compliance costs, the difference in labor costs between the US and other countries, the expense of restarting production lines that have been idled, and competition with other industries for raw materials.

However, these factors aren't the primary concerns identified by the industry. The SIA addresses other issues in a white paper titled "Maintaining America's Competitive Edge: Government Policies Affecting Semiconductor Industry R&D And Manufacturing Activity."
(http://www.sia-online.org/galleries/default-file/Competitiveness_White_Paper.pdf)

In this white paper, they address the matter "that an increasing number of the U.S. semiconductor industry's manufacturing and research facilities are being established outside the United States, giving rise to concerns that the United States is in danger of losing this critical aspect of its technological leadership" in the semiconductor industry. They look at "what needs to be done in order to be more competitive and attract critical domestic and foreign investment in the United States."

The paper offers four recommendations for improving the U.S. position in the semiconductor industry:
1. Tax and incentive policies to promote semiconductor manufacturing and R&D
2. Government research funding for science and technology
3. Building America's talent base in engineering and the physical sciences
4. Promoting energy research and energy-efficient manufacturing

However, they warn "there is no single public policy 'silver bullet' that drives company decisions for R&D and manufacturing investment.... The key to future U.S. innovation is to ensure that our policies are at least as competitive as those of our trading partners."

Darryl Hatano, the paper's author, stated he was not aware of any programs currently in place to implement any of these recommendations.

Jim Handy has a more pragmatic theory for why there aren't many IGBTs producers in the US. He explains that historically, American and Taiwanese manufactures have been interested in short-term profits, pure and simple. On the other hand, companies in Japan and Korea are focused on market share, feeling that profits will come once they establish market share. Because of this, few American companies want to manufacture low-profit commodity semiconductor like IGBTs. Instead, they focus on the more-profitable semiconductors used in computers and other logic devices and leave the "commodity" semiconductors to Asian companies.

5. Requirements for U.S. Industries to Manufacture These Devices

Determining industry requirements for increasing manufacturing levels implies some expectation among industry players that this scenario will occur. Synthesis did not uncover any information to support this view and therefore no information about related growth plans or activities.

Perhaps more realistic for IGBT manufacturers in the current environment is the question of under what circumstances an overseas IGBT fab would be moved back to the U.S. When asked what circumstances could lead to moving technology back to the US from an overseas site, Jim Gillberg of Fairchild offered the following scenarios:
- A man-made or natural disaster at the off-shore site
- Significant long-term political unrest that affects the revenue stream
- IP/trade secret protection issues overseas
- Automation and economy of scale to a point where manufacturing costs in the U.S. would be less than off-shore

He then stated "Labor is our largest expense. Power is going up in 2010 in [Mountaintop] Pennsylvania as rate caps come off. The real drivers are cost, perceived value, and corresponding margin. [I'm] not sure what it would take for [Fairchild Semiconductor] to bring back a technology from offshore, but there

is always someone willing to take a risk for [a] sweet deal, [w]hether it be long term tax waivers, grants, low interest loans, etc.”

Synthesis assesses that the door is not completely closed to US industries expanding manufacturing capacity in the US, but it does appear that such a scenario is unlikely.

Appendix A
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Table AP18	MEMS Packaging Examples
Table AP19	Materials Challenges

Table AP20	Package Substrate Physical Properties
Table AP21	Automotive Operating Environment Specifications

Appendix B
U.S. Semiconductor (IGBT) Manufacturers

Name	URL	Contact	Title	Address	Phone	Email	Product(s)	Manufacturing Capacity
Delphi	http://delphi.com/manufacturers/auto/micro/	Ralph Taylor		2705 S. Goyer Road Kokomo, IN 46904	765-451-3884	Ralph.S.Taylor@delphi.com	Semiconductors including IGBTs	One plant manufacturing 4,400 5" wafers/week. No overseas sites manufacturing IGBTs
Fairchild Semiconductor	http://www.fairchildsemi.com/index.html	Jim Gillberg	Director of Automotive Development	3001 Orchard Parkway, San Jose California 95134	908-655-1004	Jim.Gillberg@fairchildsemi.com	Automotive semiconductors including IGBTs	Production capacity is proprietary information, IGBT production at Mountaintop is being moved to 6" fab plant in Bucheon, Korea
Freescale	https://www.freescale.com/	Vivek Mohindra	SVP Strategy & Business Transformation	6501 William Cannon Drive West Austin, Texas 78735	480-413-7400	vivek.mohindra@freescale.com	IGBTs and other semiconductors	Capacity unknown; suggested opening up service request on web site. Got no response. Web site shows wafer fabs in Austin TX, Chandler AZ, Scotland, Japan and France. Assembly plants in Malaysia and China
Fuji Device Technology America, Inc	http://fujidevicetech.com/	Leo Fick		240 Circle Dr. North Piscataway, NJ 08854	972.733.1700	lfick@fujidevicetech.com	Semiconductors; may include IGBTs	Does not manufacture IGBTs for automotive applications
International Rectifier	http://www.irf.com/indexsw.html	Alan Choy Dee Bunna	Director, Worldwide Strategic Planning Systems Automotive Products Program Management	233 Kansas St. El Segundo, CA 90245	310-726-8334 951.375.4104	achoy1@irf.com dbunna1@irf.com	Semiconductors; may include IGBTs	Email and followed up with call and got name for POC in the automotive division; emailed and got no response. Web site shows wafer fab and assembly plants in Santa Clara CA, El Segundo CA, Leominster MA, Temecula CA, Mesa, AZ. Also in Newport, Wales and Tijuana, Mexico
Intersil	http://www.intersil.com/cda/home/	David B. Bell	President/ CEO	1001 Murphy Ranch Road Milpitas, CA 95035	408-432-8888	dbell@intersil.com	Semiconductors; may include IGBTs	Does not make IGBTs. Web site shows wafer fab plant in Palm Bay FL. Annual report shows they produce 20% of their wafers and purchase 80% from external sources, primarily from plants in Taiwan.
Microsemi Power Products Group	http://www.microsemi.com/	Chang Qian	Applications Engineering Manager	405 S.W. Columbia St. Bend, OR 97702	(541) 382-8028	CQian@microsemi.com	IGBTs	Plants are located overseas; no manufacturing capacity provided. Wafers sourced from other companies in 4- and 6-inch sizes.

ON Semiconductor	http://www.onsemi.com	Keith Jackson	President	5005 E McDowell Rd Phoenix, AZ 85008-4229	1 602 244 6600	keith.jackson@onsemi.com	Semiconductors including IGBTs	Was told was told "our executive staff is too busy to participate in surveys." Web site shows manufacturing facilities in Phoenix AZ and wafer fab in Pocatello ID and Gresham OR. Also has plants Czech Republic, Slovak Republic, China, Japan, Philippines, Malaysia, Belgium, and Thailand.
Powerex	http://www.pwrx.com	Scott Leslie	Chief Technologist	173 Pavilion Ln Youngwood, PA 15697-1814	408-382-7500	sleslie@pwrx.com	Semiconductors	Declined via email to participate
Semitronics	http://semitronics.com/	Henrietta Rivman	President	80 Commercial St. Freeport, NY 11520	516-223-0200	hrivman@semitronics.com	Semiconductors including IGBTs	Emailed, called and faxed with no response. Capacity unknown.
Sensitron Semiconductor	http://www.sensitron.com/			221 W Industry Ct Deer Park, NY 11729-4605	(631) 586-7600	sales@sensitron.com	Semiconductors including IGBTs	Unknown; left voice mail twice; no response
Solid State Devices	http://www.ssdi-power.com	Sharon Pfifer	Director of Sales and Marketing	14701 Firestone Blvd La Mirada, CA 90638-5918	562.404.4474	Email contact via web form at http://www.ssdi-power.com/Contact.aspx	Semiconductors including IGBTs	Unknown; left voice mail twice; no response
Solitron	http://www.solitrondevices.com/index.htm	Shevach Saraf	President/CEO COO	3301 Electronics Way West Palm Beach, FL 33407	561-848-4311	ssaraf@solitrondevices.com	Semiconductors including IGBTs but only for defense and aerospace sectors.	Web site indicates may have manufacturing facility in FL but manufactures only for defense and aerospace sector. "Would not be competitive" in other sectors.
Toshiba America Electronic Components, Inc.	http://www.toshiba.com/taec/adinfo/transform/index.jsp			19900 MacArthur Boulevard, Suite 400 Irvine, CA 92612	949-623-2900	Email contact via web form at http://www.toshiba.com/taec/support/techquestions/index.html	Semiconductors including IGBTs	Declined via email to participate
Universal Semiconductor	www.universalsemiconductor.com	Fred Garcia		1925 Zanker Road San Jose, CA 95112	408 436-1906 X43	fgarciausi@sbcglobal.net	IGBTs	Capacity unknown; was told to "see web site" via email. No useful info there. Did not respond to follow-up emails. Web site indicates they have a wafer fab plant in San Jose CA. Further attempts to find information on the company or its management via Nexis were unsuccessful.
Other Countries								
ABB Semiconductor	http://www.abb.com/	Lukas Inderfurth	Head of Media Relations	Affolternstrasse 44 P.O. Box 8131 CH-8050 Zurich Switzerland +41 (0)43 317 7111	+41 58 585 47 07	lukas.inderfurth@ch.abb.com	Semiconductors including IGBTs	Provided information on industry in general but did not give any information on production capacity
Dynex Semiconductor	http://www.dynexsemi.com/	Stuart Cox		Doddington Road Lincoln. LN6 3LF	+44 (0)1522 502901	melanie_mayne@dynexsemi.com	Semiconductors; may include IGBTs	Asked for emailed questions; never responded to email or follow-up email

NXP	http://www.nxp.com/	Mr. Pang	High Tech Campus 60 Eindhoven 5656 AG The Netherlands	+ 31 40 27 29999	Email contact via web form at http://www.nxp.com/support/form.php?QTypeID=8&lang=3	Semiconductors; may include IGBTs	No answer after four attempts; left voicemail, no response
Semelab	http://www.semelab.com/		Coventry Road Lutterworth Leicestershire LE17 4JB	+44 (0) 1455 556565	sales@semelab.co.uk	Semiconductors; may include IGBTs	Called three times; got busy signal every time
STMicroelectronics	http://www.st.com/stonline/index.htm		STMicroelectronics 39, Chemin du Champ des Filles C. P. 21 CH 1228 Plan-Les-Ouates GENEVA, Switzerland	+41 22 929 29 29		IGBTs	Got recording "operator is not available, leave message…" No callback.

Appendix C

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