



Study on semiconductor design, embedded software and services industry

April 2011

Executive summary



Supported by the Department of Information Technology,
Ministry of Communications & Information Technology
Government of India



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India Semiconductor Association (ISA) is the premier trade body representing the Indian Electronic System Design and Manufacturing (ESDM) industry. It has represented this industry since 2005. ISA has around 150 members companies. ISA is committed towards building global awareness for the Indian ESDM industry and supporting its growth through focused initiatives in developing the ecosystem. This is through publishing credible data, networking events and alliances with other international associations. ISA works with the Government as a knowledge partner on the sector, both at the central and state levels. It has helped the Government of Karnataka in the formation of the first ever State Semiconductor Policy 2010. More information about ISA can be found at www.isaonline.org

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Study on semiconductor design, embedded software and services industry

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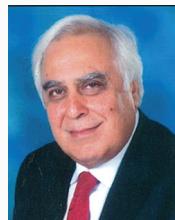


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MESSAGE

The semiconductor design, embedded software and services industry has witnessed considerable growth in India and has become a vehicle of economic growth and development. I am glad that this growth has made India a destination for high-end design. It is heartening to note that some of the top global semiconductor companies have their largest design centres, outside of US, operating in India. I have always believed that India has intrinsic strength to become a global leader in semiconductor design.

India Semiconductor Association (ISA) can play an important role in this endeavour. I am happy to note that ISA has set ambitious targets for the future and is working towards this vision. The success of this industry in the country should be a source of motivation to related verticals in the ecosystem.

I am glad that the study organized by ISA has focused on talent, innovation and done a benchmarking of India vis-à-vis other countries in the industry. The growth of the Electronic Systems, Design and Manufacturing (ESDM) ecosystem will throw up enormous opportunities for skilled manpower. I urge the industry to step up the base for skills and competencies, so that supply keeps pace with demand.

I congratulate ISA and the officers of the Department of Information Technology for their painstaking efforts in bringing out this report. I am sure that the recommendations will be examined by the constituents of the industry, academia and the Government.

Kapil Sibal
(KAPIL SIBAL)



R. Chandrashekhar



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MESSAGE

The Electronic Systems Design and Manufacturing (ESDM) ecosystem is knowledge driven. Over the past several years the electronics driven industry has grown into becoming an important contributor to the nation's economy. India Semiconductor Association (ISA) has played the role of a catalyst in the growth of semiconductor design, embedded software and services sector in India.

ISA is engaged in providing data through collaborative research and publications. I am extremely happy with ISA's endeavour in preparing this report. The report has collected and analysed the facts and figures of the Indian semiconductor design industry and has identified future opportunities which in turn will contribute to the existing design ecosystem. The well researched study will serve as a useful reference for various stakeholders such as the education segment, the industry segment and the Government. It will enhance the interest of the stakeholders in seeking business opportunities in India.

My best wishes to ISA and the industry on publication of this report. We look forward to periodic updates which will be valuable for stakeholders.

(R. Chandrashekhar)

New Delhi
Dated : April 1, 2011



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Dr. Ajay Kumar
Joint Secretary

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Message

At the outset, I wish to compliment the India Semiconductor Association (ISA) for its endeavor in undertaking the “Study on semiconductor design, embedded software and services industry”. Semiconductor technology lies at the heart of the amazing revolution across sectors and is one of the key drivers of growth. Semiconductor industry is Research and Development intensive in the design stage and capital intensive in the manufacturing stage.

The report has addressed several areas relating to the industry dynamics, key trends, growth drivers and impact on the semiconductor and electronics industry. The report is strategic as it will provide critical insights to key stakeholders; facilitate the ideation and innovation processes and identify customer needs. The comprehensive study will certainly enhance the interest of various stakeholders in seeking business opportunities in India.

My best wishes to ISA and trust they would continue to undertake such studies in future.

(Dr. Ajay Kumar)



Preface

Since its inception in 2004, the ISA has played an important role in facilitating the semiconductor and electronics ecosystem in the country.

Research has been one of the cornerstones of ISA's activities. ISA is now releasing a study on the Indian semiconductor design industry in collaboration with Ernst & Young India and with the active participation and support of Department of Information Technology, DIT, Government of India.

The current report is divided into three sections – the industry analysis, benchmarking of India; and recommendations. Industry analysis focuses on the Indian industry. It discusses the ecosystem for semiconductor design development in areas ranging from intellectual property, talent landscape to the key drivers and challenges.

The quantitative benchmarking compares various parameters such as industry dynamics, talent pool, infrastructure, operating costs, quality of business environment and innovation and intellectual property which are important for the development of semiconductor design sector in a country.

Finally, based on the findings of these two sections, key issues constraining the growth of the semiconductor design industry are

summarized based on which elaborate recommendations are articulated.

Government and industry need to reflect on these recommendations. Together, we can ensure that India continues to benefit, grow and prosper from a sector that is marked by innovation and a desire for world-class performance.

The concerted efforts of the EY team comprising Sunil Bhumralkar, Sunil Shenoy, Balasubramanian Gurunathan, N Kamalanand, Santosh Premdas, Swapnil Srivastava, Sachin Mehta and Amit Mahendru to meet the timelines of the study are greatly appreciated. The industry core committee has given their time and inputs for the study. Prof. Jamadagni (Indian Institute of Science) has also spared us his time for the report. Our thanks to these individuals. Rajiv Jain and Dr. Vidya Mulky from the Secretariat coordinated the process.

We would especially like to acknowledge the Department of IT (DIT), Ministry of Communication and Information Technology (MCIT), Government of India for supporting the report at every stage to conduct this initiative.

Poornima Shenoy
President, ISA

Dr. Pradip K Dutta
Chairman, ISA

Executive summary

Key excerpts from the three sections of the report are provided below

1) Industry analysis: The finding of the industry analysis demonstrates the growth of the Indian semiconductor industry, which comprises VLSI design, embedded software development and hardware/board design, and had an estimated value of US\$ 7.5 billion in 2010. Increasing consumer electronic goods sales, a burgeoning telecom/networking market and significant growth in the use of portable/wireless products is a trend being seen in India, which is driving the growth of the semiconductor design industry.

► **Overall semiconductor industry drivers and challenges:** Adequate availability of the talent pool, the maturity of the Indian semiconductor industry and stringent IP protection measures are driving this industry, but the lack of a semiconductor manufacturing ecosystem and of quality in specialized skills, competition from other Asian countries and eroding cost advantage are seen as major challenges. Venture capital activity, especially at the seed fund stage, is still not as mature as in the IT/ITeS industry.

► **India's talent scenario:** India's abundant talent pool continues to play a major role in the country's position in global semiconductor design vertical, which employed a workforce of 160,000 in 2010. The industry has a young workforce with close to 78% consisting of B.Tech graduates and close to 60% with less than eight years of work experience. However, the lack of product conceptualization and management as well as analog design skills are some talent-related challenges that need to be addressed.

► **VLSI design:** Almost 50% of the work conducted in VLSI design is in the gate range of 1M-10M, and more than 50% of the work is carried out in the digital design segment, but mixed signal design work is rapidly increasing. In terms of design, IP development and module design and verification garner the major share of projects. The main growth drivers include:

- The increasing maturity of the Indian design ecosystem
- The rising demand for electronics products globally, which is driving VLSI industry

Some of the notable challenges in this segment:

- Lack of scale at the leading node
- Lack of R&D funding in universities.

► **Embedded software design:** The embedded software industry contributes close to 80% to the Indian semiconductor industry's revenues, with the key consuming verticals being telecom/networking and consumer electronics products. Factors that provide an impetus to this segment include:

- Product customization due to localization and legislative requirements
- Lower entry barriers
- Adaption to open-source platforms

The main challenges faced in the embedded software segment include:

- Cost pressures due to constantly evolving platforms
- Skill-set availability for high-end programmers
- Preference for ADM services as a career option

► **Hardware/Board design:** The hardware/board segment is the smallest contributor to the semiconductor design industry in India. More than 50% of the work is conducted in the sub-10 layers range. Factors that aid in the growth of this segment include:

- Increased outsourcing by service providers
- Re-engineering opportunities
- Captives partnering third-party service providers and bringing in increased business

This segment is hindered in growth by the following:

- Compliance-related challenges
- Lack of semiconductor ecosystem

2) Benchmarking study: This study was conducted with the aim to quantitatively compare India with seven other countries, which are considered the pioneers in semiconductor design, on the parameters relevant for this industry. The representative set of countries chosen consists of the US, the UK, Germany, Sweden, China, Taiwan and Israel. The 20 benchmarking parameters that were considered for the study are important for the development of a country's semiconductor design sector. These parameters can be broadly classified under the following heads – industry dynamics, talent pool, innovation environment, operating cost, infrastructure and the quality of the business environment.

The following are the key findings from the benchmarking exercise:

- ▶ **Industry dynamics:** India has a fairly well-developed semiconductor design industry, with 120 design units. Several global integrated device manufacturers (IDMs) have established their captive design centers in the country, which ranks the second among the sample set of countries in terms of design revenues. The country's electronics market is growing rapidly and is expected to boost the demand for semiconductor components in the future.
- ▶ **Talent pool:** India is a strong performer on its talent parameters and features among the top three in the sample set in terms of the engineers employed in its semiconductor design sector. This is due to the required degree graduates being produced each year, who have the requisite skills to be employed in the country's design sector. India also has the highest number of engineering colleges among the sample set of countries.
- ▶ **Innovation environment:** India is seeing rapid evolution in its innovation environment due to the availability of its skilled talent pool and high-quality scientific research institutes. The country ranks favorably among the sample set countries in terms of the number of IEEE papers filed by it in the fields relevant for semiconductor design. India however lags behind other sample set countries in terms of company spending on R&D.
- ▶ **Operating cost:** India is highly competitive in terms of operating costs for businesses and ranks among the top few in the sample set in terms of the salaries of semiconductor design professionals and Grade A office space rentals, which form a major portion of a company's costs. In terms of the cost of raising debt and electricity costs, India ranks among last countries in the sample set, although both these parameters do not comprise a major portion of the operating costs of companies.
- ▶ **Infrastructure:** India ranks among the top countries in the sample set in terms of its future availability of office space. However, the country's economy is still power-deficient. On the positive side, in the last few years, India has overcome its internet bandwidth constraints and now has ample capacity to provide high-speed international connectivity to companies.
- ▶ **Quality of business environment:** India lags behind other countries in the sample set in terms of the overall quality of its business environment. There are innumerable procedures required to start a new business in the country. Corporate taxation rate in India is also among the highest in the sample set, but the country performs better than other developing countries in the sample set in terms of the efficiency of its legal framework.

3) Recommendations for the Indian semiconductor design industry:

Based on the findings of the industry analysis and benchmarking exercise, the key challenges constraining the growth of the semiconductor design industry are summarized below:

- i. Quality, availability and maturity of talent
- ii. Absence of a start-up and SME ecosystem
- iii. Lack of a semiconductor ecosystem
- iv. Lack of adequate infrastructure, policies and implementable incentives
- v. External issues affecting the Indian semiconductor industry

Each of these issues has been tackled in detail, with detailed recommendations in this report.

These recommendations require the concerted and coordinated effort of the Government, industry and the academia to help India reach the next level of growth and achieve the specific goals envisaged for the Indian semiconductor design industry, which include the following:

Goal 1	Maintain leadership in semiconductor design by incubating 50 fabless semiconductor companies, each with the potential to grow to US\$ 200 million in annual revenues by 2020
Goal 2	Build on India's favorable intellectual property protection image and make it among the top 5 destinations for intellectual property creation in the semiconductor design industry
Goal 3	Capitalize on indigenous demand in strategic sectors to provide impetus to the Indian fabless semiconductor industry
Goal 4	Sustain and nurture high-class semiconductor design manpower at a growth rate of 20% year-on-year to double its current output levels to reach a workforce size of 400,000 in the next five years



About this study

This study on the Indian semiconductor and embedded design services industry has been commissioned by the Department of Information Technology, Ministry of Communication and Information Technology, India, with the intention of providing a thorough and systematic analysis of the Industry. It highlights India's growth and positioning in the global semiconductor design industry to identify areas of improvement and frame recommendations for the Indian semiconductor design industry. This report is jointly prepared by the India Semiconductor Association and Ernst & Young Pvt. Ltd.

The output of the study is presented in three sections:

Section 1: Industry analysis

This section throws light on the global semiconductor design and embedded software industry with a focus on the Indian industry. It discusses the ecosystem for semiconductor design development, the status of intellectual property in the industry and the talent landscape. It also provides estimates of industry revenues, workforce demand and supply, demographics, trends in terms of technology nodes and business models, and highlights the key drivers of and the challenges faced across the following three segments of domestic industry:

- ▶ Very large scale integration (VLSI) design segment
- ▶ Embedded software design segment
- ▶ Board/hardware design segment

This section also discusses the nuances of the Electronic Design Automation (EDA) market in terms of global and Indian markets, their drivers, the challenges faced by them and their license models.

Section 2: Benchmarking

The objective of the benchmarking exercise is to provide a competitive assessment of India as compared to seven countries that are pioneers in semiconductor design. Quantitative benchmarking compares various parameters including industry dynamics, talent pools, infrastructure, operating costs, the quality of the business environment, innovation and IP, which are important for the development of a semiconductor design sector in a country. This analysis will elaborate on issues faced by India vis-à-vis its competitor countries, as well as the model that needs to be developed, based on best practices followed worldwide.

Section 3: Recommendations

Key issues relating to the growth of the semiconductor design industry are summarized, based on the findings of the Industry report. In the Benchmarking exercise, elaborate recommendations have been made to tackle the issues mentioned above. This will be a valuable source of data for the Government of India, the industry and academia, and can be used to plan and influence government policies for the domestic semiconductor design industry, building a strong ecosystem for the industry and bridging the gap in the talent scenario.

Section 1

Industry

analysis

Contents

Section 1: Industry analysis

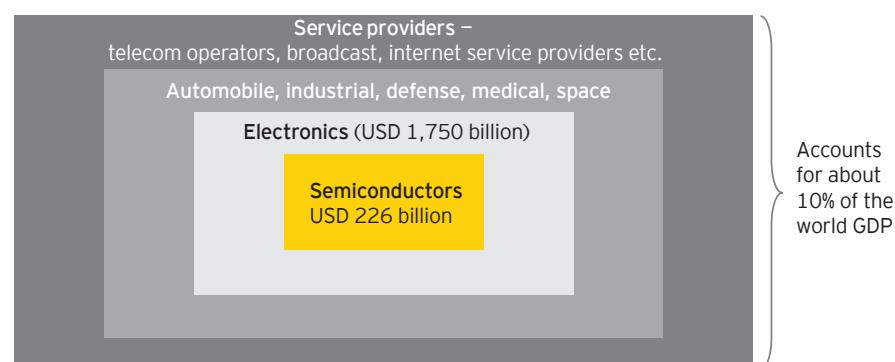
I. Introduction	14
II. Current global semiconductor industry	16
Industry segmentation by product category	17
Geographic distribution of global semiconductor market	18
Key end vertical consumption trends and demand evolution	18
Key drivers and challenges faced by global semiconductor industry	20
Global semiconductor industry projections	21
III. Indian semiconductor industry overview	23
Evolution of semiconductor design industry in India	23
Current and future semiconductor design industry size in India	24
Key consuming industry segments and demand evolution	25
Impact of Indian semiconductor design industry on India	25
Billing models	27
Indian semiconductor design industry drivers and challenges	27
Innovation landscape in India	29
India: talent analysis	34
IV. VLSI design industry	42
VLSI design flow/value chain	43
Key consuming industry segments for VLSI design	44
Indian VLSI design industry operations - quantitative analysis	45
Indian VLSI design industry workforce	47
VLSI design industry drivers and challenges	49

V. Embedded software industry	51
Embedded software layer	52
Key consuming industry segments for embedded software design	53
Indian embedded software development industry workforce	54
Embedded software industry drivers and challenges	56
VI. Board/hardware design industry	58
Hardware/board design flow	59
Key consuming industry segments and demand evolution of hardware/board design	60
Indian hardware/board design industry operations - quantitative analysis	61
Indian hardware/board design industry workforce	62
Hardware/board design industry: drivers and challenges	63
	
Annexure	66
Annexure I: EDA tools industry	66
Annexure II: definitions	70

Introduction

The semiconductor industry has entirely changed the outlook of the world we live in today. The industry is one of the key drivers of growth, not just for a few electronics appliances but of the entire electronics value chain. As illustrated below, from a worldwide base semiconductor market of US\$ 226 billion in 2009, the industry enables the generation of electronics systems and services, which account for about 10% of the total world GDP.

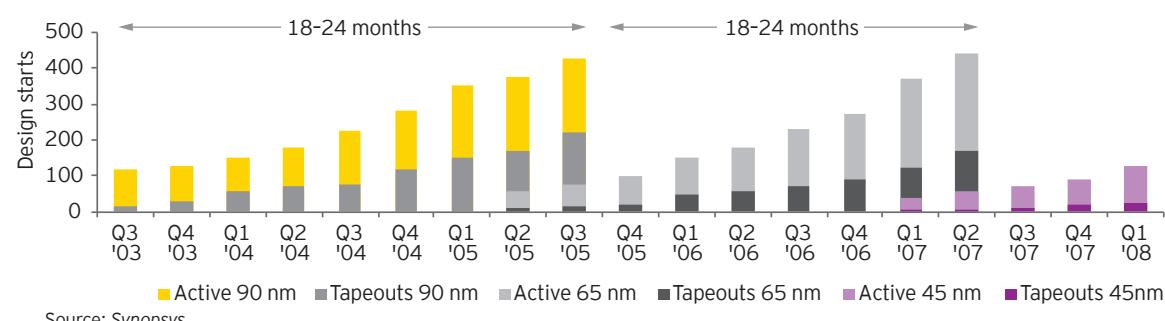
■ Exhibit 1: Global impact of semiconductor industry



Source: Worldwide Semiconductor Trade Statistics (WSTS), IMF, European Semiconductor Industry Association (ESIA) Competitiveness Report, 2009.

Moore's Law, based on the observation made by Intel Co-founder Gordon Moore in 1965, is a principle, which states that the number of transistors per square inch on Integrated Circuits (ICs) had doubled every year since ICs were first invented. Moore predicted that this trend would continue for the foreseeable future. Semiconductor designers shrink the transistors on chips so that electrons have less distance to travel, which expedite processing of data. This method is becoming harder to perform, as circuits are packed so closely that chips are heating up and their performance is beginning to suffer.

Exhibit 2: Illustration of Moore's Law

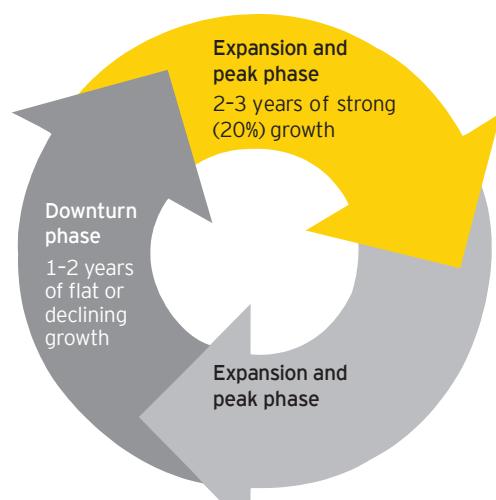




This is expected to play a significant role in the continued consolidation of the industry. While the market growth rate of the industry is slowing down, costs within it are not. Furthermore, continued technology convergence or integration is leading to an increase in the complexity of devices, which is escalating design costs. Additionally, it is predicted that continued integration is likely to cause certain standalone chip markets to become inconsequential as individual functions are fused into bigger chips, which is expected to result in a smaller number of chip types being produced by fewer vendors. This is likely to lead to further consolidation in the industry over the next few years.

The industry is research- and development-intensive at the design stage and capital-intensive during the manufacturing phase. This is accompanied by continuous growth in a cyclical pattern with high volatility. Generally, cycles include an expansion and peak period, followed by a slowdown phase, and eventually a downturn stage, as illustrated in the figure below. The industry has witnessed six major cycles since 1970, and there is good reason to believe that 2009 marked the end of the downturn phase of another cycle. These cycles and their volatility have meant that players in the industry are aware of the critical need for a high degree of flexibility and innovation to constantly adjust to the rapid pace of change in the market.

■ Exhibit 3: Cyclical nature of global semiconductor industry



Source: EY research 2010

Current global semiconductor industry

There has been a drastic fall in the year-on-year growth of the global semiconductor industry, beginning in 2008, with a maximum decline of 9.0% in 2009. Initial estimates indicated less significant revenues of US\$ 219.7 billion in 2009, but the industry had evolved since the earlier 2001 boom-bust period and was quick to adapt to prevailing conditions. Therefore, it witnessed higher-than-expected revenues of US\$ 226.3 billion in 2009.

Some factors that initially led to this decline over 2008-2009 included:

► **Fall in end-market demand**

Falling demand in almost all semiconductor end markets had a huge impact on industry revenues. While the communications industry saw less significant growth rates of 5.8%, as compared to 7.9% earlier, the automotives industry was not as fortunate and witnessed a fall of 14.9%. Almost all end markets saw a decline or lower growth rates, resulting in an overall fall in the demand for semiconductors as well

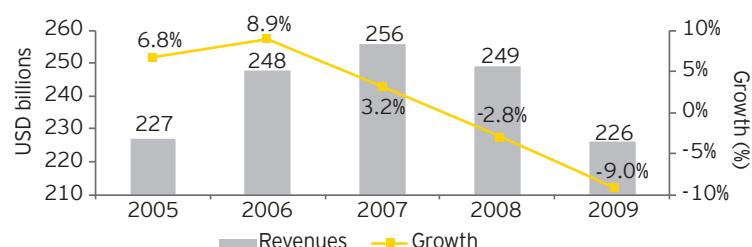
► **External macroeconomic factors**

Difficult macroeconomic conditions due to the recession led to lower disposable incomes, and hence, lower consumer consumption, which played a key role in falling semiconductor revenues. The global economic crisis had a profoundly negative impact on almost all industries, including the semiconductor industry

► **Cyclical behavior**

The cyclic nature of the industry may also have been responsible for the decline in 2008-2009. This would suggest that the last quarter of 2009 was leading into the upturn period that follows a dip in the semiconductor industry cycle. The dip may have been too short to be considered part of a regular cycle, but these cycles are getting shorter in length due to the rapid inventory re-adjustments that are now possible and the buffer that fab-less companies have when they outsource their manufacturing operation to third-party foundries.

■ Exhibit 4: Global semiconductor industry



Source: Worldwide Semiconductor Trade Statistics (WSTS), 2009

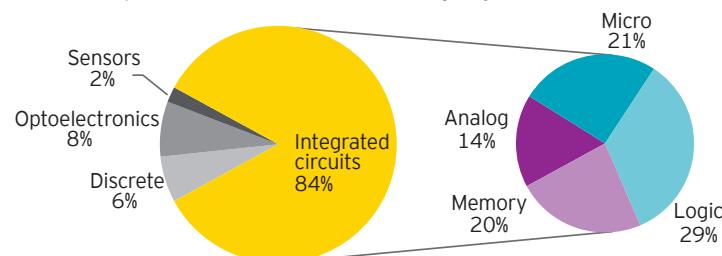
The recessionary impact is clearly seen in the graph above, indicating that there was decline of 2.8% in 2008 and a further decline of 9% in 2009.

Industry segmentation by product category

The overall semiconductor industry is fairly fragmented and each segment or sub-segment has its own group of key competitors. The following trends have been observed in the various segments of the industry:

- ▶ Discrete semiconductors – diodes, transistors, etc.
- ▶ These typically perform a single function in electronic circuits, the purpose of which is switching, amplifying or rectifying and transmitting electrical signals. The discrete segment is expected to grow from US\$ 14.2 billion to US\$ 21.6 billion during 2009-2012. The growth of the segment is usually quite stable, relative to the overall industry, due to its lower presence in computer applications
- ▶ Optoelectronics – electrical/ optical or optical/ electrical transducers
- ▶ This is a separate segment as different technology and processes are required to manufacture optoelectronics, as compared to integrated circuits or discrete semiconductors. The optoelectronics segment is expected to grow from US\$ 17.0 billion to US\$ 26.8 billion during 2009-2012. This growth is expected to be mainly driven by the use of optoelectronics in digital cameras, and especially in cameras in multimedia mobiles and handsets
- ▶ Sensors – sense physical quantity and convert it to electrical signals.
- ▶ Although a relatively small segment of the overall industry, sensors are expected to see a sizeable growth from US\$ 4.8 billion in 2009 to US\$ 7.9 billion in 2012. The increasing need for sensors in digital applications, which may have previously been analog, should be a strong driver of growth for the segment.
- ▶ Integrated circuits (ICs) – miniaturize electronic circuits, integrating a large numbers of tiny transistors into a small chip
- ▶ Integrated circuits comprise the bulk of the semiconductor industry, accounting for around 84% of the industry in 2009. The discrete segment has become a smaller segment as an increasing number of integrated circuits can perform the functions carried out by Integrated circuits. The segment has sub-segments including analog, memory, micro and logic components. It is expected to grow from US\$ 190.3 billion in 2009 to US\$ 275.0 billion in 2012.

Exhibit 5: Split of semiconductor revenues by segment, 2009

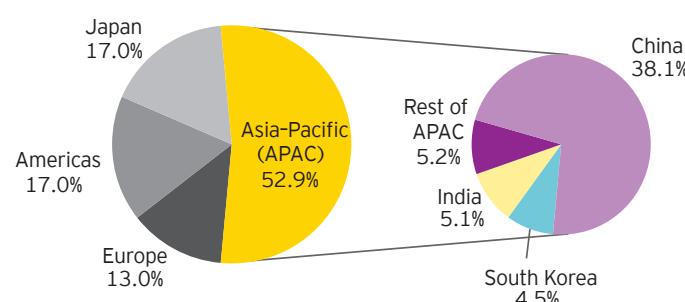


Source: Worldwide Semiconductor Trade Statistics (WSTS)

Geographic distribution of global semiconductor market

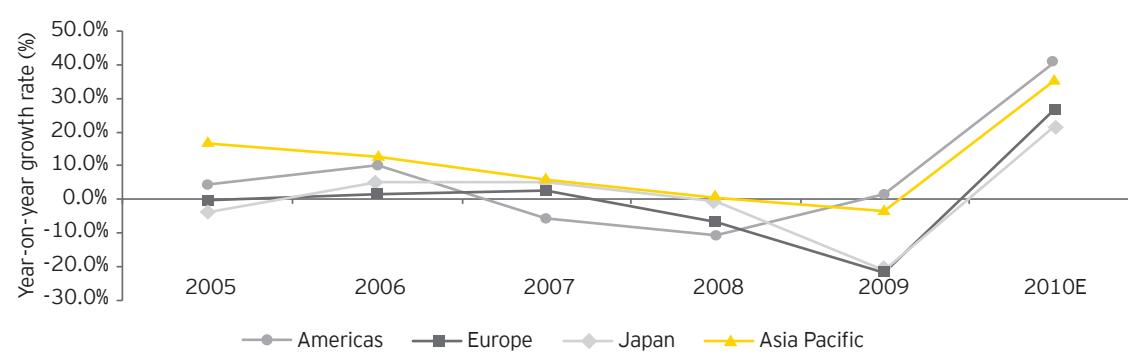
The Asia Pacific continues to be the largest market for semiconductors, garnering almost half the global semiconductor market. During the global recession, sales in the Asia Pacific remained flat, whereas that in the Americas and Europe witnessed a steep decline. Worldwide semiconductor growth in recent years has been largely driven by the increasing demand for consumer electronics such as portable music players, mobile phones and flat screen televisions. With many of these products being manufactured in Asia, along with growing consumption electronics in these countries, explains why sales to this region are so large. The Asia-Pacific region surpassed the Americas to become the world's largest region for semiconductor sales in 2001, and since then, its lead has increased every year.

■ Exhibit 6: Geographic split of global semiconductor market, 2009



Source: Worldwide Semiconductor Trade Statistics (WSTS)

■ Exhibit 7: Geographic growth trends of the global semiconductor market, 2005-2010E



Source: Worldwide Semiconductor Trade Statistics (WSTS)

Key end vertical consumption trends and demand evolution

These various segments of the semiconductor industry lead to their various applications in end markets ranging from consumer electronics to communications.

The following are the key end market growth drivers:



► **Data processing market**

This market has seen strong demand from emerging countries while witnessing a recovery in sales in enterprise sector through new products. The benefits of these new products are driving hardware upgrades among enterprises. However, the main growth driver in the computing market is expected to be mobile computing platforms. The growth of the cloud computing and data center segments may also play a significant role

► **Consumer electronics market**

Key products such as LCD TVs and blu-ray players are also a major driver of revenue, even with their low margins. These margins are the result of aggressive pricing due to the intense competition in the market. The Consumer Electronics Association (CEA) has indicated that the fall in revenue in 2009 was the result of weak pricing as actual unit volumes of consumer goods increased. There is also expected to be a general global trend of switching from analogue to digital broadcasting of TV signals, driving the growth in high-resolution TVs and digital set top boxes

► **Automotive industry**

The increased need for, e.g., navigation and fuel efficiency for vehicles in the automotive industry, is driving the growth for electronic content per vehicle. As automobiles have a longer lifespan than consumer goods, semiconductors for automobiles tend to generate revenue for a number of years, realizing a stable business model with a strong growth profile for the future

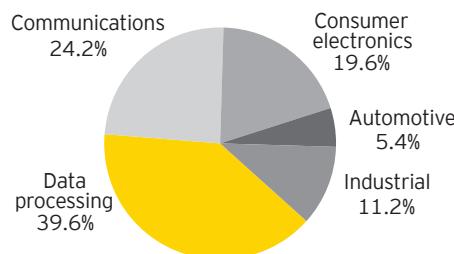
► **Communications**

The growth in cell phone sales has led to that of semiconductors such as analog chips and microcontrollers, which are used in wireless communication. According to International Data Corporation (IDC), the key drivers in this segment include higher connectivity, increased storage and multimedia-enabled handsets and smartphones.

► **Industrial**

Environmental-friendly technology, as well as energy-efficient technologies such as smart meters and smart grid, is driving the growth of the industrial segment. Semiconductors in this segment are mainly focused in the areas of control and power, and the largest number of installed components include logic, MCUs and DSPs.

■ **Exhibit 8: End-vertical consumption, global semiconductor market, 2009**



Source: ISA-EY research 2010



Key drivers of and challenges faced by global semiconductor industry

Drivers

Although consumer electronics and computers were the drivers of industry growth during the earlier part of this decade, they have now paved the way for other key drivers of growth.

► Key products and applications

► Portable mobile devices and smart-phones

As various applications of mobile devices increase, the communications end market is the most likely to replace consumer electronics and computers in furthering the industry's growth.

► Electric cars

The production of electric cars is on the rise, and the global focus on energy efficiency should lead to rising production levels. Semiconductors, which enhance the practicality of these cars, e.g., increased battery efficiency, are expected to lead the way.

► Medical and healthcare applications

With an augmented healthcare applications industry and personal home healthcare applications, there should be a significant increase in the need for semiconductors in these applications as well.

► Key areas

► Energy efficiency

Renewable energy in the form of solar panels, etc., is expected to be at the forefront with increasing global awareness of the need to conserve energy. Semiconductors are likely to play a big role in electrical energy creation by enhancing the design of solar panels.

► Embedded intelligence

While driving consumer growth, these are also critical for generating opportunities for convergence.

► Sensors and detectors

The need for security and related applications in the modern world, as well as its requirement for sensors and detectors, should be the growth driver for semiconductors as well.



Challenges

Although the semiconductor industry is being driven by so many different factors, there are still some major issues faced by the industry. Some of these include:

► **Timing of delivery of products**

The timing of delivery in some segments such as consumer electronics and mobile devices is crucial because of the fast-changing nature of the demand for these products – the demand for a current chip may begin to dip rapidly and delays in delivery would mean substantial loss of profits as well as market reputation.

► **Technology changes**

Rapid technology changes, increasing complexity and the increasingly complex equipment required to cope with these changes result in high costs.

► **Prices**

Falling prices due to fierce competition, commoditization and rising pressures from OEMs for lower prices have led to declining profit margins.

► **Macroeconomic conditions**

A weak economy or end market conditions may result in falling demand.

Global semiconductor industry projections

Although the industry was heavily impacted by the recession in 2009, the sharpest decline it has seen since 2001, forecasts for 2010 were very encouraging, with a year-on-year growth of 28.6% and projected revenues of US\$291 billion. According to reports, these forecasts are on track with semiconductor sales exceeding expectations. Some of the key factors that are driving this growth include:

► **Production cuts**

Semiconductor manufacturers are increasingly aware of the risk of excess stock after the boom bust of 2001. As soon as the recession began taking effect in late 2008, manufacturers responded by drastically cutting their production levels instead of running their production lines at full capacity with the hope of maintaining their margins when the recession died down. Consequently, there was no excess stock; in some cases a shortage was seen, which, in turn, led to higher pricing.

► **Consumer electronics and PC markets**

The return to strength in consumer electronics and PC markets toward the end of the year accounts for around 60% of global semiconductors sales. New product launches, e.g., of netbooks and more complex chip content in products such as LCD TVs, contributed to the process.

► **Increasingly diverse end markets**

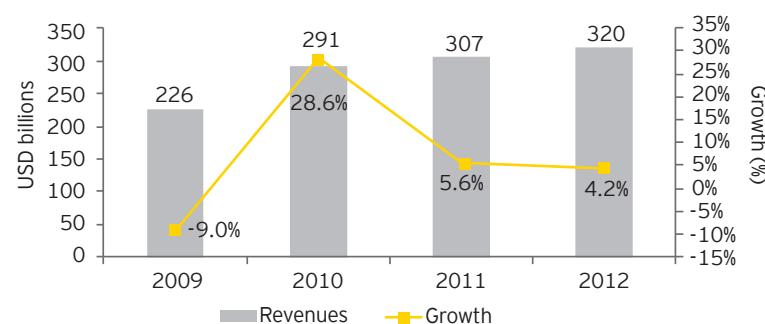
The global shift toward energy efficiency and alternative energy is driving and creating semiconductor sales in emerging markets (as well as in medical equipment).

► **Pricing**

Effective inventory management during the recession meant that there was a supply shortage, given the demand. This created an upward pressure on prices, which rose significantly.

It is also important to note that the phenomenal industry growth of 28.6% was just a return to normal growth in 2010, but seems inflated in comparison with recession-impacted 2009 figures. If compared to 2007 revenues of US\$ 256 billion, 2010 figures represent a more standard growth of 13.7%.

■ **Exhibit 9: Global semiconductor industry projections**



Source: Worldwide Semiconductor Trade Statistics (WSTS), 2009



Indian semiconductor industry overview

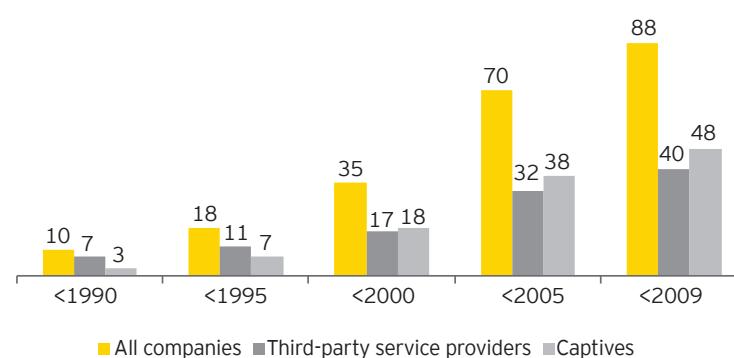
Evolution of semiconductor design industry in India

The semiconductor industry was initiated in India in the late sixties with the establishment of discrete semiconductor device R&D and manufacturing in the Germanium and Silicon technologies, and the first saleable integrated circuits (both digital and analog) were made and marketed. This marked the country's first step toward semiconductor R&D and led to the establishment of global incumbent semiconductor companies such as Texas Instruments (1985) and Arcus (acquired by Cypress Semiconductor). The evolution of the domestic semiconductor design industry can be classified into four phases.

- a. **The exploratory phase (Pre1995):** This phase saw the initiation of semiconductor design in India with the establishment of state-run companies, which produced discrete Germanium semiconductors and some multi-national companies such as Texas Instruments, which were looking to test the Indian waters and were the first movers in tapping the Indian opportunity.
- b. **The IT industry-led growth phase (1995 -2000):** With the growth of the domestic IT industry in India, coupled with the increasing number of English-speaking engineers,, an ecosystem developed, which led to the entry of an increasing number of domestic and MNC companies such as Analog Devices, National Semiconductor, Delphi Automotive Systems and Synopsys.
- c. **Explosive growth phase (2000 -2005):** This phase marked the highest growth of semiconductor design companies in India, which led to the establishment/entry of about 42% of the companies currently operating in the country. This was primarily driven by strong government support and rapidly evolving educational institutions, which began offering advanced courses in semiconductor design.
- d. **Innovation phase (2005 onwards):** With the top 10 global cable companies and the top 25 semiconductor companies present in India, the ecosystem is gradually orienting toward product/ design innovation. Both captives and non-captives are gradually orienting themselves to execute projects of enhanced strategic value (toward spec-to-tape out/ product ownership).

By 2005, a large number of global semiconductor companies had set up captive design units in India, which explains the peak in the number of companies established before 2005 as shown below.

Exhibit 10: Evolution of Semiconductor Design Companies in India by number of companies and year of incorporation (cumulative growth)

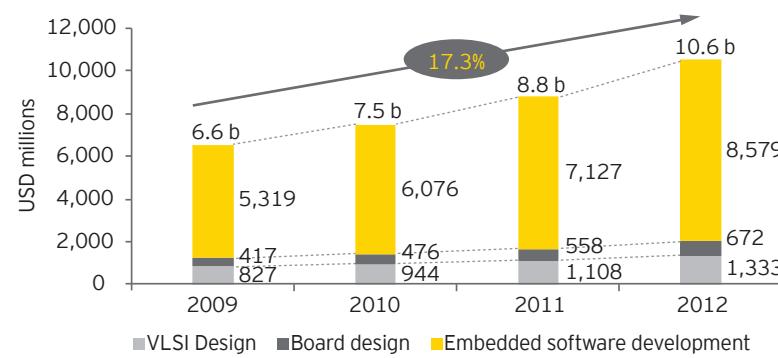


Source: ISA-EY research 2010

Current and future semiconductor design industry size in India

The semiconductor design industry in India, consisting of VLSI design, board/hardware design and embedded software development, was estimated to be US\$ 6.5 billion in 2009 and is expected to log a compound annual growth rate of 17.3% over the next three years to reach US\$ 10.6 billion in 2012. The major contributor to these revenues is embedded software development, followed by VLSI and board design. The increasing availability of a capable talent pool, coupled with the emergence of India as a consumer market for electronic goods, has led to the increase in work being done to India.

Exhibit 11: Semiconductor design industry in India, 2009-12



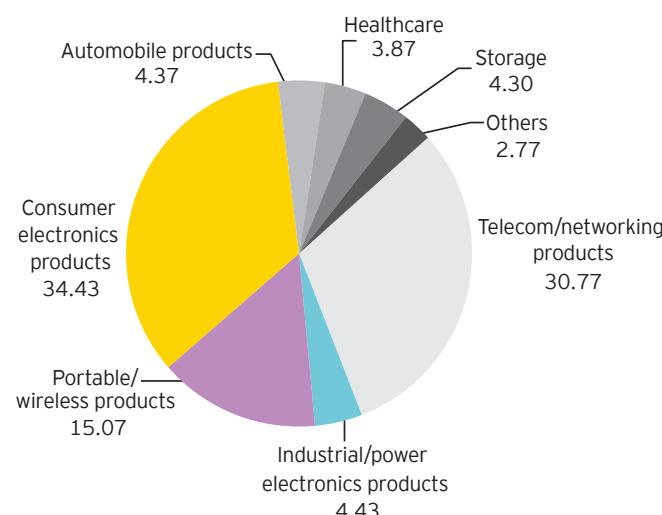
Source: ISA

Key consuming industry segments and demand evolution

The increasing sale of consumer electronic good, a burgeoning telecom/networking market and the growth in the use of portable/ wireless products globally, a trend which is also being seen in India, is driving the growth of the semiconductor design industry in the country. Today, end users demand a lot more from a particular electronic product in terms of its stand-alone functionality, cross product integration, connectivity and emergence of new technologies such as LED screens, 3G and Wi-Max. This translates into an increased demand for semiconductor design. Increasing markets for such products in India has given rise to an emergent trend, with companies looking at domestic companies for semiconductor design services, since these have better market knowledge and understanding.

Automobile electronics is another key growth area, since passenger and industrial vehicles are both getting increasingly "smarter" with on-board computer systems, used to enhance safety and the customer experience.

Exhibit 12: Semiconductor Design Projects Split by Consuming Industry Segment, 2009



Source: ISA

Impact of Indian semiconductor design industry on India

The semiconductor design industry has contributed significantly to the country's economy. In addition to fueling India's economy, this industry is also positively influencing the lives of its people through its active direct and indirect contribution to various socio-economic parameters such as employment, standard of living, education and diversity, among others.

The impact can be assessed for some of the parameters provided below:

Contribution to the economy

The ratio of the industry's output to India's GDP is an important indicator of its impact on the country's economy. The semiconductor design industry contributes around 0.5% to India's economy and this is expected to increase further.

Generation of employment platform

The growth of the Indian semiconductor design industry has contributed to the employment of close to 1,35,000 employees in 2009.

The design industry also generates employment to support ancillary semiconductor segments such as PCB design, packaging and testing.

The semiconductor design industry also impacts the lives of indirect employees. The establishment of a semiconductor design unit provides employment to numerous people involved in ancillary activities such as catering, security, transportation and house-keeping.

Other economic impact

Other economic contributions include growing exports boosting foreign exchange earnings, strong tax contributions, attracting PE/VC investments and development of tier 1 cities.

Bridging the gender divide

The semiconductor design industry has helped to bridge the gender divide in the Indian workforce by ensuring a healthy ratio of women candidates, with close to 20% of the workforce consisting of women (excluding the board industry, which has a relatively larger proportion of men to women).

Investment in R&D

The top 25 global semiconductor companies now have a presence in India through their captive centers, working in cutting edge technology nodes. Out of the total India engineering R&D spend of US\$7.9 billion, investment in the semiconductor space is estimated at nearly 19% of the total.

Billing models

Billing models are undergoing changes with established standard models giving way to more customized ones in a dynamically growing industry. The various models being used include the following:

► **Time and material model**

This is the standard time-and-materials method of work, based on actuals.

- A variant of this model is the time and material model with a “not-to-exceed clause” - this is a standard time-and-materials method, with an additional clause that the price paid will not exceed a certain amount

► **Fixed price model**

This model involves fixing the deliverable, project duration, platform, tools required for design and resources. Most of the time, the cost is decided by calculating the person-months required to execute the project, and any additional features requested during the course of the project are mutually agreed on by a change request.

► **Joint go-to-market models**

There are two widely used models under this category, wherein captives involve third-party service providers and Indian design companies at the following phases:

- The design phase wherein service providers invest in the design phase and are paid for it in the form of royalty from the end sales of the product
- Sales phase, in addition to the design phase, through three channels - sell-to, sell-through and sell-with

Indian semiconductor design industry drivers and challenges

Drivers

i. **Availability of talent pool**

With the Indian Government focusing on improving access to higher education and the increasing number of colleges and universities in the country, India adds a significantly large number of engineers to the talent pool every year.

ii. **Maturity of the semiconductor industry**

With their having gained considerable experience, Indian semiconductor design companies are seeing an increasing number of projects in chip development as compared to derivative chip design earlier. The complexity of work is also increasing with more designs being worked on for the current technology node.

iii. **Cost competitiveness**

Although cost structures are gradually increasing in India on an absolute level, India still has a considerably significant overall cost advantage as compared to the US, Europe or Japan.

iv. Stringent IP protection measures

The Government of India and Indian design companies have strict policies on IP protection as compared to other competing Asian countries. There have been instances when companies have sent work to India, even though design turnaround times are considerably higher in the country, as compared to the countries mentioned above, because of the more stringent IP protection measures in India.

v. Proximity to growing APAC customers

Semiconductor design companies in India are getting an increased amount of design work due to the fact that the country is closer in terms of distance and time zone difference for Asia-Pacific customers.

vi. Reverse brain drain

Repats, as they are known, are drawn by India's booming economic growth, the chance to wrestle with complex problems and the opportunity to learn more about their heritage. They are joining multinational companies or investing in start-ups, which augurs well for the industry. This trend has not only raised the technological sophistication of VLSI design services, but has also assured the industry of abundant outsourcing projects.

Challenges

i. Lack of semiconductor manufacturing ecosystem

- ▶ The lack of foundries implies insufficient experience in foundry interactions and a longer time-to-market, which has inhibited the growth of the domestic semiconductor design industry to a certain extent. Unless this gap is plugged, the ecosystem cannot mature or develop at a rapid pace.
- ▶ The lack of local ODM/ OEM companies that cater to the huge demand generated in the country has hindered the rapid growth of the Indian ecosystem.

ii. People-related challenges

a. Quality of talent

- ▶ **Fresh talent supply:** The difference in expectations between the industry and the Indian education system results in low skill-sets in the talent pool graduating from non-premier institutes. This implies higher training costs and a considerably large gestation period before an engineer is productive.
- ▶ **Lack of experience:** Companies have cited instances of lack of experienced talent in terms of breadth and depth of experience – breadth indicates knowledge of all the aspects of design flow and depth an extensive knowledge of a particular aspect of the design flow.
- ▶ **Digital vs. analog:** Although India has strong capabilities in digital technologies, it lacks the requisite number of engineering graduates who are capable of handling analog technologies.
- ▶ **Lack of product know-how:** There is a lack of talent for product conceptualization and management for emerging markets. Systems management for captives continues to be driven by the headquarters of companies – qualified and experienced talent need to be nurtured to fill this gap.



b. Lack of awareness of technical career path

The workforce in India values management leadership as compared to technical leadership, unlike in the Silicon Valley region. This is aggravated by substantial salary differences between technical and management personnel with the same work experience. In the Silicon Valley, technically inclined people are promoted to the position of a fellow, which is the equivalent of a Vice-President and salary differences are not significant.

c. Attrition

Given that the current workforce in the semiconductor design industry in India is quite small, attrition due to competitive pressures on people or their moving on for higher studies can adversely impact the design ecosystem.

Another reason for high attrition can be attributed to high recruitment by large third-party service providers, who were traditionally in the enterprise application space, but are now forming large teams to tap the next growth area in VLSI and embedded design.

iii. Competition from China, Taiwan and other South East Asian countries

The countries mentioned above have had a complete and mature ecosystem, which has been built over the past 30 years, with the presence of OEM/ODM players, strong government support, infrastructure, uninterrupted power. Therefore, these countries are often preferred over India, even in the areas of design-related activities.

iv. Eroding cost advantage

Both the captives and the non-captives face this challenge in terms of rapidly increasing cost structures and the pressure on billing rates, which lead to the loss of competitive advantage as compared to other low-cost Asian or eastern European countries.

v. Adoption of protectionist policies by other countries

The rising insecurity of foreign governments and companies in offshoring activities to India (or other offshore destinations) could become a challenge to attract more work to India, going forward.

Innovation landscape in India

Recessionary impact on Innovation in India

Recession did not mean a major setback for India with regard to filing of patents. Statistics indicate a minor decrease in filing and grants of patents during the period of the economic downturn. It is important to know that many commercially successful innovations were made during this period. Many semiconductor companies undertook IP audits to take stock of their IP portfolios and determine alternative paths of funding during the crisis, e.g., licensing, franchising, etc. Of the companies interviewed, many indicated that recession was a good time to invest in R&D, so that they were in a better position when the economy improved.

Measurement of innovation

No country currently includes a comprehensive estimate of business investment in intangible assets in their official accounts. Most economists agree, however, that intangible assets – which represent an important input in the innovative process–are critical components of a modern economy.

Among tangible assets, several quantitative measures pertaining to innovation are possible, including patents, trademarks and designs. A review of such measures leads to the conclusion that each of these has some validity, but none can act as a stand-alone measure of innovation. This is the reason why such measures are called “indicators.” Such indicators can be combined to form an overall measure of innovation. This section attempts to study some of the following indicators of innovation activity in India:

- ▶ Research labs
- ▶ IEEE papers
- ▶ Venture capital activity

Research labs

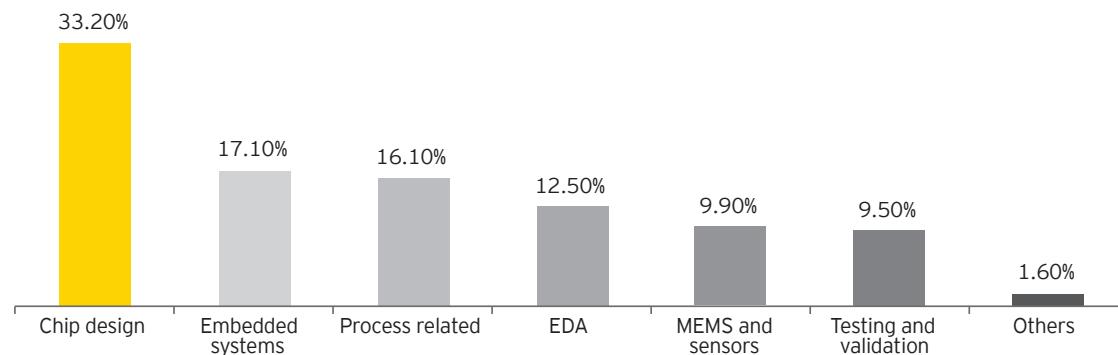
Most of the R&D labs present in India, which are concentrated on the semiconductor domain, are located in premier technical institutes in the country. These institutes have access to funding, experienced faculty, infrastructure as well as the availability of a large talent pool.

According to the ISA-Evalueserve study 2008, 70-75% of semiconductor research activities are concentrated in the IITs, IISc and in BITS, Pilani.

Research fields

In view of research activity that is proportionate to the percentage breakup of faculty members in the field, almost 43% of research activities undertaken in Indian institutes are in the area of chip design.

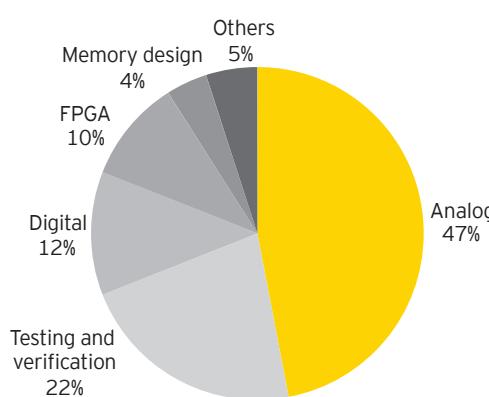
■ Exhibit 13: Breakup of research related activities in Indian institutes



Source: ISA-Evalueserve Study 2008

Nearly 78% of the projects are related to chip design and 22% are in the fields of testing and verification. Around 47% of the projects are in the areas of analog and mixed signals. Fabrication facilities that are not available in India are seen as a challenge for research, and designs have to be sent abroad to be tested. This results in delay in time and increases the cost of research.

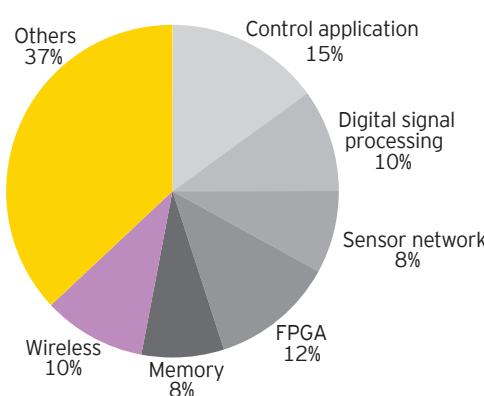
Exhibit 14: Percentage breakup of projects in chip design and testing



Source: ISA-Evalueserve Study 2008

The embedded segment forms the second-largest field of research in Indian institutes. Research is conducted across the areas of control application, sensor network, FPGA, memory and wireless.

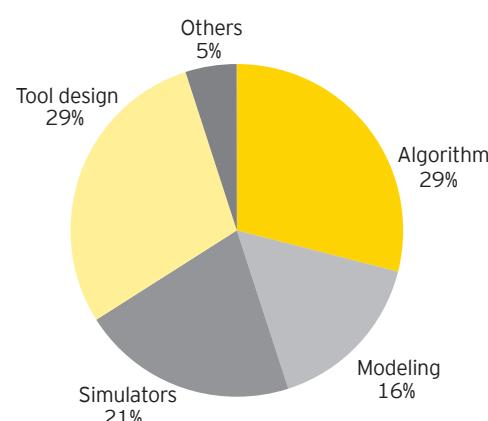
Exhibit 15: Percentage breakup of projects in embedded systems



Source: ISA-Evalueserve Study 2008

Research in EDA is limited to optimization techniques, algorithms, simulators and simple design tools.

Exhibit 16: Percentage breakup of projects in EDA

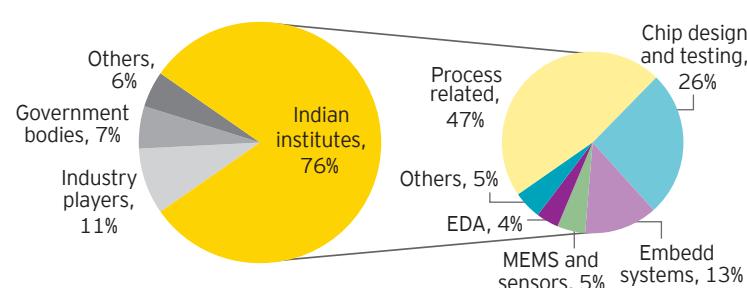


Source: ISA-Evalueserve Study 2008

Research output

Of the IEEE papers published between 2003 and 2007, Indian institutes show maximum activity in terms of publishing research papers due to the greater importance given to knowledge sharing in these institutes. Papers that are published may not have commercial viability, resulting in a low percentage of publications from the industry. Among the papers published by the institutes, almost half are in the process/manufacturing segment, followed by chip design and embedded software.

Exhibit 17: Research output



Source: ISA-Evalueserve Study 2008

Industry-academia tie-ups

In India, industry plays a key role in promoting research-related activities. Various forums of industry-academia tie-ups exist such as the following:

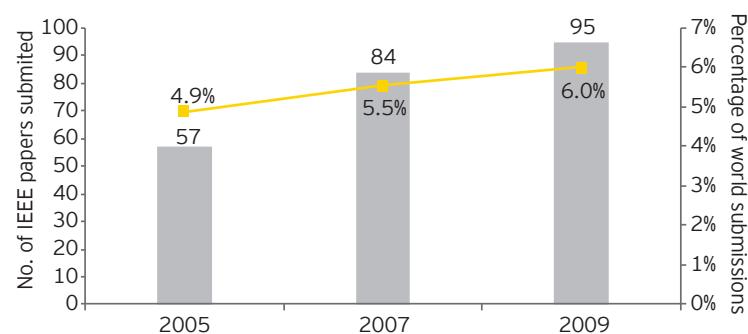
- ▶ **Consultancy** – The faculty at institutes work as consultants on industry projects.
 - ▶ Research-based industrial consultancy: The faculty conducts research at these institutes.
 - ▶ On-site industrial consultancy: The faculty conducts research at the facility provided by industry.
- ▶ **One-on-one** – These are tie-ups between academic institutes and industry players, resulting in focused and customized research.
- ▶ **Consortium** – This is a tie-up between an academic institute and multiple industry players. Funding is provided by all the players to enable the institute to conduct research on specific topics.
- ▶ **Collaboration with overseas institutes** – Indian institutes working in collaboration with overseas universities in the more developed countries provide the latter access to the latest technologies and sharing of knowledge.

IEEE papers

IEEE papers submitted, 2005-2009

The number of IEEE papers submitted in India has shown a growing trend as compared to other countries such as China. The number of papers submitted from India has grown from 57 in 2005 to 95 in 2009, garnering 6% of global submission of IEEE papers.

■ Exhibit 18: IEEE papers submitted, 2005-2009



Source: IEEE

Although the figures above indicate submission of IEEE papers, the overall number of papers published in India in 2010 is quite low with an acceptance ratio of only 4.48%, as compared to acceptance rates in the US and the UK, which had acceptance rates of at 38% and 34%, respectively and 15%, for China. This reveals a relative lack of quality in research work carried out in India.

Statistics on IEEE papers are sourced from the IEEE societies of computer, software, design and testing of computers, transaction on computers and software engineering.

Venture capital activity

Although venture capital (VC) companies are keen on investing in the Indian semiconductor design industry, currently, there is very little activity seen by these players. The focus of VCs on India is more on IT/ITeS service companies.

Startups in the design industry are very small players, which do not grow in scale quickly, due to the nature of the industry, which is quite unlike the trend seen in the IT/ITeS industry. Hence, these startups are mainly funded by Angel funds, which are difficult to track.

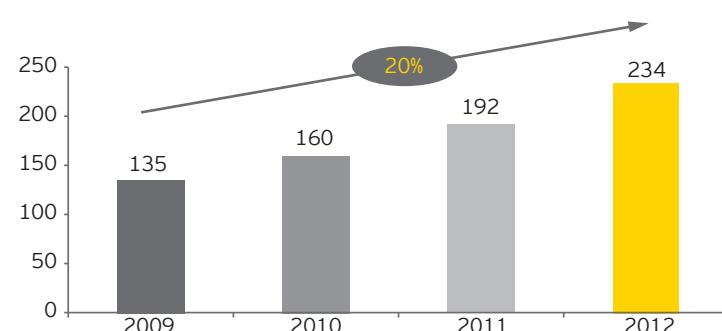
The other reasons why VCs may be staying away from the Indian semiconductor industry can also be the absence of semiconductor-manufacturing units in the country, the volatile cyclical nature of the industry and the difficulty in getting valuations for design companies.

India: talent analysis

Installed talent pool

The strong growth in the Indian semiconductor design industry has resulted in employment opportunities for the engineering workforce in the respective segments. The current workforce in the semiconductor design industry in India was estimated at around 135,000 in 2009 and is expected to grow at a compounded annual growth rate (CAGR) of 20% to reach 230,000 by 2012.

■ Exhibit 19: Installed talent pool, 2009-2012 (in '000s)

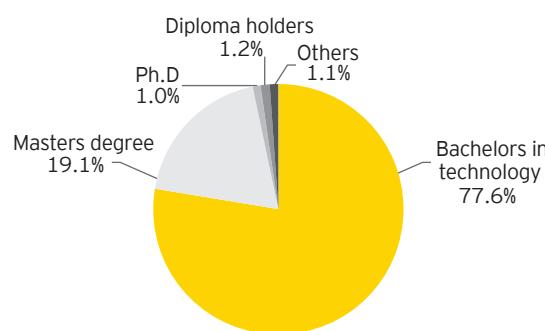


Source: ISA

Breakup by educational qualifications

The semiconductor design industry is dominated by engineering graduates, who comprise two-thirds of the entire workforce, followed by Master's degree holders. The industry cites six months to a year for talent graduating from colleges to become deployable and industry-ready. The diploma holders are mainly recruited in the board segment.

■ Exhibit 20: Semiconductor design industry split by educational qualification, 2009

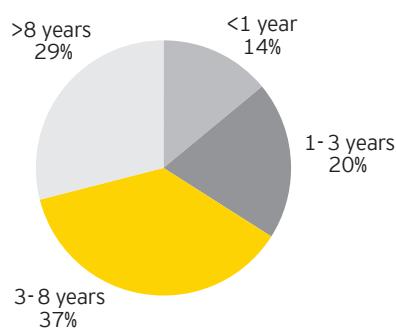


Source: ISA-EY research 2010

Experience-wise and diversity ratio distribution of employees

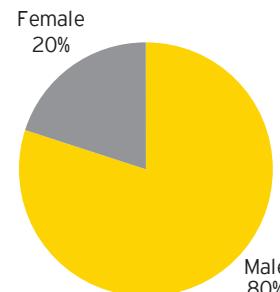
The semiconductor design industry consists mainly of a young workforce, with close to 60% with experience of one to eight years. The industry in India primarily constitutes men, with women comprising 20% of the workforce. The VLSI and embedded segments comprise of a high ratio of women as compared to the board segment.

■ Exhibit 21: Semiconductor design industry headcount split by experience, 2009



Source: ISA

■ Exhibit 22: Semiconductor design industry split by gender, 2009



Source: ISA

Special Manpower Development Programme - Phase II

During the Ninth Plan, the Department of Information Technology (DIT) aimed to increase India's share of the global VLSI design market from around 0.5% to around 5.0%. In view of the availability of quality human resources for achieving this target as the key catalyst, The DIT initiated a "Special Manpower Development Programme in the area of VLSI Design and related Software," which comprised 19 institutions (7 resource centers (RCs) and 12 participating institutions (PIs) in 1998.

The objective of this program was to carry out research and guidance in VLSI-related areas with the establishment of VLSI Design Labs at resource centers and participating institutions by training graduates, post graduates and at the doctoral level.

SMDP II, which started in the year 2006, is currently present across the country and of 32 institutions, consisting of 7 resource centers and 25 participating institutes, participate in it.

The talent pool generated from SMDP II of DIT, in terms of the number of students for the academic year 2009-2010, according to our estimates from discussions with resource centers and participating institutes, is a total of 5471. The individual breakup comprises:

- ▶ Type I - 58
- ▶ Type II - 672
- ▶ Type III - 892
- ▶ Type IV - 3849

Fresh graduate talent supply

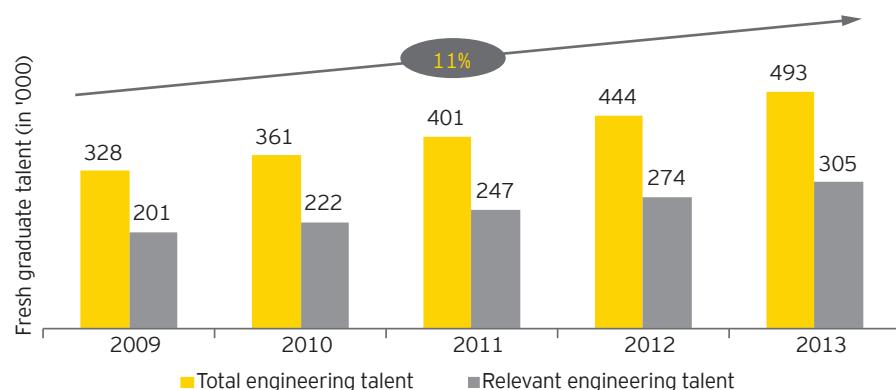
Engineering is the preferred educational stream for Indian youth, as a result of which India produces around 361,000 engineering graduates every year. This includes graduates as well as post graduate degree holders.

- ▶ Relevant engineering talent for the semiconductor design industry:
- ▶ Computer science
- ▶ Software
- ▶ Electronics and communications
- ▶ Electrical and electronics
- ▶ Information Technology (IT)

India produced around 222,000 fresh engineering graduates in these streams, comprising nearly 62% of the total engineering turnout, in 2009.

Exhibit 23 showcases the growth of fresh engineering talent over five years.

Exhibit 23: Fresh graduate supply in India



Source: NASSCOM Strategic Review, 2010, EY research

The fresh graduating population relevant for the semiconductor design industry is set to grow at a CAGR of around 11% to more than 300,000 by 2013. This growth is expected as a result of the following policies and measures implemented the Indian Government.

Grants program: To motivate students to opt for higher education at the doctorate level, the Government has launched a couple of grants programs. UGC selects 50 candidates each year for Junior Research Fellowships.

Inclusion program: To promote technical education for women, handicapped and the weaker sections of the society, All India Council for Technical Education (AICTE) has introduced its Tuition Waiver Scheme for women, economically backward and physically handicapped meritorious students in technical institutions.

Improvement in quality of education: The percentage of fresh talent from tier 1 institutes such as the IITs and the NITs is geared to increase due to the proposed increase in the number of these institutes. Hence, the quality of talent available that is to be deployed in the semiconductor design industry is also set to improve.

Split of talent supply by type of degree

The type of degree (B.Tech or M.Tech) is an important parameter to determine the proportion of specialized talent available. India has a significant number of post graduates graduating every year and the number has grown substantially in the last one year. However, the number of graduates is still much larger due to the Government's focus on the first level of higher education.

Exhibit 24: Split of fresh talent by type of degree (percentage split of the relevant talent pool)

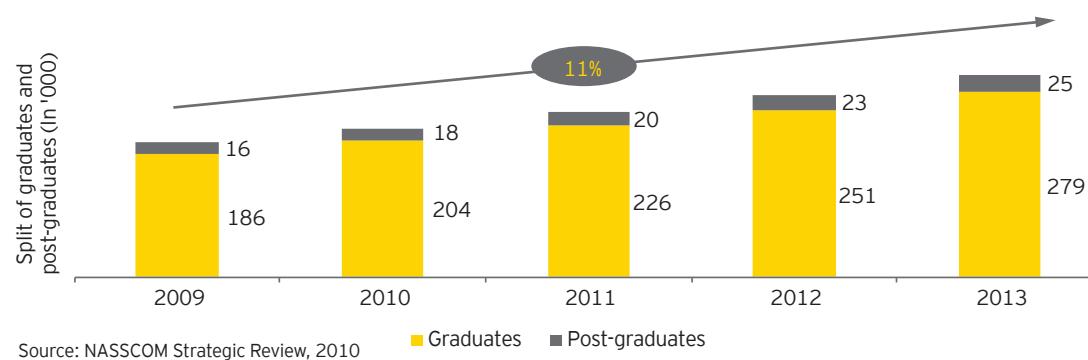


Exhibit 25: Split of relevant under graduate in-take by fields of specialization, 2010

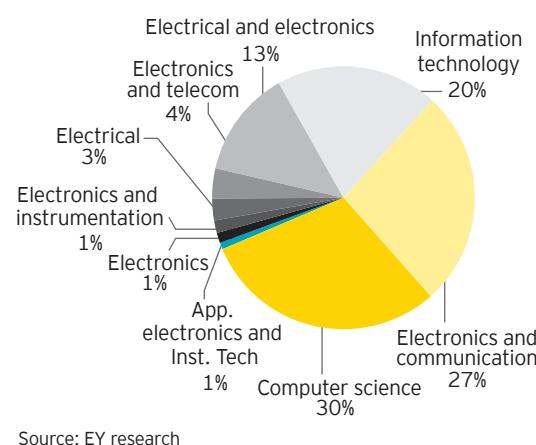
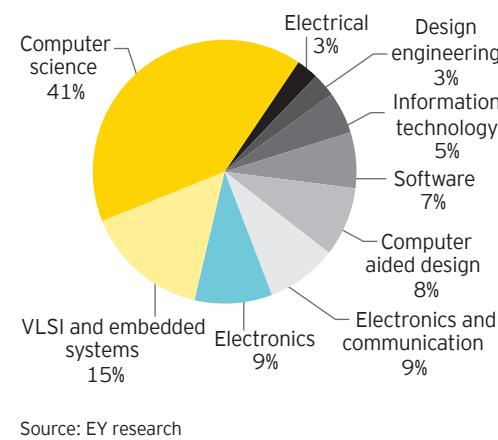


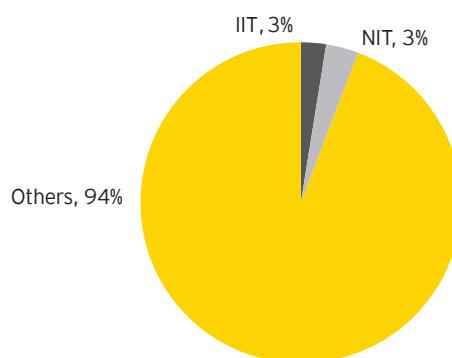
Exhibit 26: Split of relevant post-graduate in-take by fields of specialization, 2010



Split of talent supply by university tier

The split of talent supply by university tier is an important parameter to determine the quality of talent. Institutes such as the IITs and NITs have tough entry criteria, excellent faculty and renowned alumni. Around 6% (approx. 13,000) of the graduates, who may be relevant for the semiconductor design industry, graduate from tier 1 institutes such as the IITs and NITs.

■ Exhibit 27: Split of fresh talent by university tier (percentage split of the relevant talent pool), 2010



Source: HRD Ministry's Annual Report 2009-2010, Admission boards of IITs and NITs

Location split of universities offering relevant degrees

The location split of engineering colleges and universities is an important parameter to define the catchment area of relevant talent for semiconductor companies.

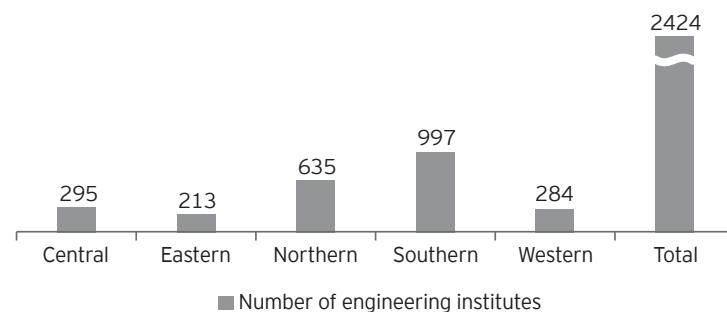
India can be divided into five geographical regions – northern, eastern, western, southern and central. The split of states is as follows:

■ Exhibit 28: Location split of universities offering relevant degrees

Region	States
Northern	Jammu and Kashmir, Himachal Pradesh, Punjab, Haryana, Delhi, Rajasthan, Bihar, Uttarakhand and Uttar Pradesh
Eastern	Arunachal Pradesh, Assam, Meghalaya, Mizoram, Manipur, Tripura, Jharkhand, Nagaland, Orissa and West Bengal
Western	Maharashtra and Goa
Southern	Andhra Pradesh, Karnataka, Kerala and Tamil Nadu
Central	Gujarat and Madhya Pradesh

Source: AICTE

■ Exhibit 29: Geographic split of universities offering relevant degrees, 2010



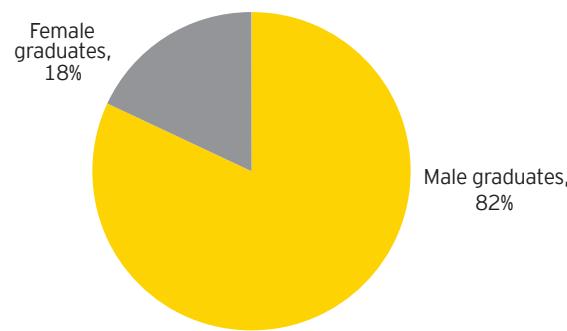
Source: AICTE

Most of the universities are based in the southern region. Andhra Pradesh accounts for a major portion of the chunk. The second highest is the northern region constituting the states of Bihar, Uttarakhand and Uttar Pradesh.

Gender ratio of fresh talent supply

Gender ratio is an important parameter to gauge the extent of diversity in the talent pool of a particular region.

■ Exhibit 30: Gender ratio of fresh talent supply (% split of the relevant talent pool), 2010



Source: HRD Ministry's Annual Report 2009-2010

India's talent pool is still skewed toward the male population. Around 18% of fresh engineering graduates in 2009-10 were women. However, the Government has put several programs in place to ensure inclusion of women.

- ▶ Around 85% of the target beneficiaries of the SAAKSHAR BHARAT (the national literacy mission) will be women.
- ▶ Mahila Samakhya is an ongoing scheme for education and empowerment of women in rural areas.



India's talent analysis summary

The current workforce in the semiconductor design industry in India was estimated at around 135,000 in 2009 and is expected to grow at 20% to reach 230,000 by 2012. Around 70% of the installed workforce has experience of more than three years. Women constitute around 22% of this workforce, with a the majority of them working in the VLSI and embedded segments.

- ▶ India produces around 222,000 fresh engineering graduates every year and this is expected to grow at the rate of 11% over the next two to three years. The majority of these students come from the southern part of the country, since the south Indian states (Andhra Pradesh, Tamil Nadu, Karnataka and Kerala) have the maximum density of engineering colleges.
- ▶ This pool of engineers consists of 8% (around 18,000) post graduates.
- ▶ Around 6% of graduates, who are relevant to the semiconductor industry, come from tier 1 institutes such as the IITs and NITs.

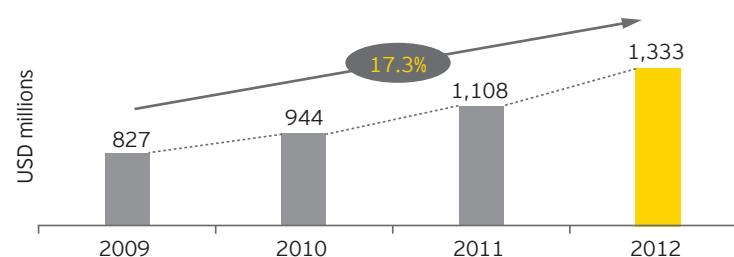
IV.

VLSI design industry

VLSI design is the process of designing integrated circuits by combining thousands of transistors into a single chip, and involves various design activities ranging from specification to tape-out of the chip, as described in the next section.

The total revenue from VLSI design in India was estimated at US\$ 826.7 million in 2009 and is expected to log a compound annual growth rate of 17.3% over the next three years.

■ Exhibit 31: VLSI Design Industry in India by Revenue, 2009-12



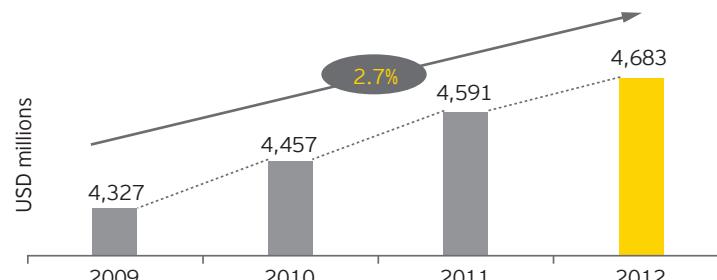
Source: ISA

The blended and fully-loaded cost per Full Time Employee (FTE) per month is close to US\$ 4,300 currently and is expected to rise at a CAGR of 2.7% over the next three years to reach US\$ 4700 in 2012. This increase in costs balances the increasing wage inflation and facility costs with scale benefits.

These rates saw a bit of correction to 2007 rates due to the impact of the recession. One way in which the recession was managed was to change the skill-set mix by increasing the number of "freshers" to the lateral hiring ratio to lower average fully-loaded costs.

VLSI still commands premium rates over the board and embedded segments, mainly due to the complexity of the work involved and market competition for available talent.

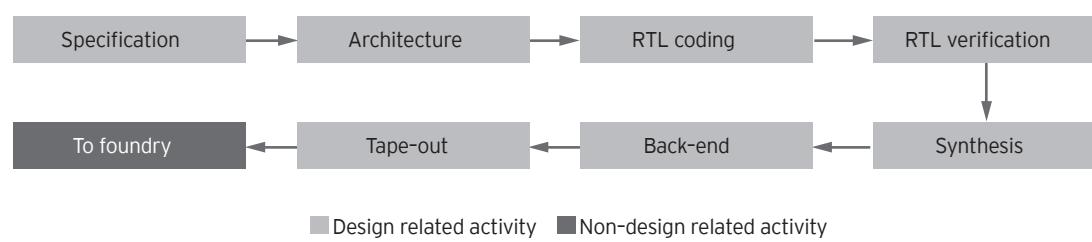
■ Exhibit 32: VLSI design industry in India – average blended and fully-loaded cost per FTE per month, 2009-12



Source: ISA

VLSI design flow/value chain

Exhibit 33: Activities in the VLSI design flow



Source: ISA-EY research 2010

Most of the VLSI design business in India originates from the United States with European companies contributing in the next place. Although Japan is home to a very large number of electronic product companies requiring design services, various challenges such as language, culture, etc., have hindered VLSI requests for design business from Japan. Of late, many companies are targeting Japan, and it is widely expected to become a major revenue source in the future.

End-to-end product ownership seldom occurs in India, since it is solely a function of being proximal to the customer, although we are beginning to see a change in this, with captives as well as some third-party service providers building capability to provide services in the entire value chain. Since India currently does not play host to customers of semiconductor companies (OEMs, ODMs, etc.), higher end activities in the design flow, such as specification definition and architecture design, are restricted to the global or regional head quarters of companies, which directly interact with their customers.

Additionally, another reason why total product ownership does not occur in India is that most global semiconductor companies follow a distributed and collaborative development methodology across various countries in multiple geographies. Hence, no single center has total ownership of a product or product-related decisions.

In the case of third-party service providers, captives are comfortable outsourcing total design-related activities from RTL coding or verification to tape-out for derivative products, but have restricted design outsourcing of current generation products to lower complexity activities in the design flow.

Recessionary impact on VLSI design industry in India

Of the companies interviewed, several indicated that the economic downturn of 2008-2009 had not had a major impact on the VLSI design industry in India. During this time, the majority of global semiconductor companies stalled their new products and aggressively focused on derivative product development and design, which resulted in the offshore Indian captive centers of these semiconductor companies getting additional work.

Third-party service providers also indicated that they had been relatively immune to the recession due to two major reasons:

- ▶ Since most of the product development was on derivative chips, they were able to secure a significant number of customer wins.
- ▶ The recession also led them to explore alternative local revenue streams, which opened up new markets such as defense and avionics in India.

However, there is an overall semiconductor design industry consensus that the impact of the recession was felt in India with growth getting delayed, increased cost pressures, a significant number of programs getting canceled, an increased percentage of employees on the bench and potential hiring plans put on hold. Furthermore, the industry indicated that the positive outlook provided in interviews was due to hindsight while looking at the recession and the sharp slap-back effect with which the recession bounced back.

Every recession brings in its wake higher quality of work, and this one also forced third-party service providers to look at new business models, which complimented their current service portfolios with IP-based solutions or a reusable framework for better revenue realization.

Key consuming industry segments for VLSI design

With the increasing global demand for communications and consumer products, consumer electronics products consist of the bulk of the VLSI design industry pie. Although the PC market is still the largest for chips, the demand for mobile phones and digital TVs is expected to spur the design industry again as the economy has begun to recover. New drivers of growth, such as increasing digitization of products and anytime/anywhere connectivity, have caused vendors to expand the application of existing products to alternative end markets and develop new applications for biometric security markets, digital power supplies and gaming devices.

The telecom sector is expected to continue its dominance as compared to 2007 levels, although it is expected to hit a plateau in terms of growth. The portable/wireless industry is also driving growth with applications in connectivity technologies such as Bluetooth, Wi-Fi, GPS, UWB, WiMax, NFC and the automobile electronics and healthcare segments expected to see a small amount of traction.

Exhibit 34: VLSI design projects split by consuming industry segment, 2009-2011

	2009	2010	2011
Telecom/Networking products	31%	30.40%	30.00%
Industrial/Power electronics products	4.50%	4.00%	3.80%
Portable/Wireless products	14.80%	15.20%	15.40%
Consumer electronics products	34.50%	34.80%	35.00%
Automobile products	4.30%	4.50%	5.00%
Healthcare	3.90%	4.00%	4.00%
Storage	4.40%	4.50%	4.20%
Others	2.60%	2.60%	2.60%

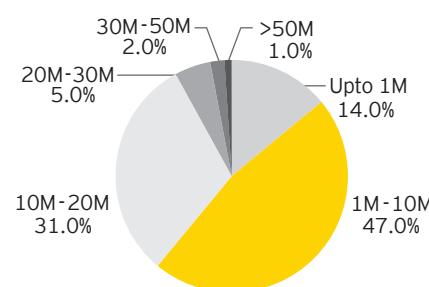
Source: ISA

Indian VLSI design industry operations - quantitative analysis

Distribution of total projects carried out in India by gate count (complexity)

The industry continues to see large traction with almost 50% of its projects in the 1M-10M gate range, although with technology nodes moving to 65nm and below range, there is increased activity in projects in the 10M-20M gate range. As the number of gate counts are increasing and technology nodes are moving into lower sub-micron ranges, various challenges are beginning to surface, some of these including the quantum-mechanics phenomenon, thinner wires offering larger resistance, parasitics such as capacitive and inductive coupling between parallel wires and electro-migration.

Exhibit 35: VLSI design industry split of projects by gate count, 2009



Source: ISA-EY research 2010

Distribution of total projects carried out in India by technology

Although the digital design industry still garners the majority of projects in India, the mixed signal design industry is showing significant momentum and is on an upward curve. Digital signal designs are more standardized, use simplified device models, work with easily available EDA tools and there is an abundant supply of talent in India. However, the percentage of work carried out in the analog industry is expected to remain constant due to the dominance of eastern European countries in the industry. Other reasons for this include the need for customizable synthesis tools, difficulty in testing designs and shortage of talent due to lack of training focus and the need for specialized analog lab infrastructure, resulting in competition for already available talent.

■ Exhibit 36: VLSI design industry split of projects by technology, 2009

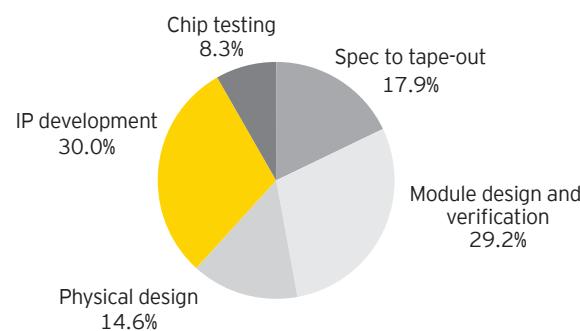
	2009	2010	2011	2012
Digital	62%	57%	53%	51%
Analog	19%	21%	21%	22%
Mixed	19%	22%	26%	27%

Source: ISA

Distribution of total projects carried out in India by type of design

As the industry is maturing, companies have confidently begun developing their IP and investing in it. This is in line with the trend of captives partnering with third-party service providers by participating in early chip development programs and providing modular IPs to reduce their time-to-market. The share of projects in the module design and verification space has gradually declined over the last two years.

■ Exhibit 37: VLSI design industry split of projects by type of projects, 2009



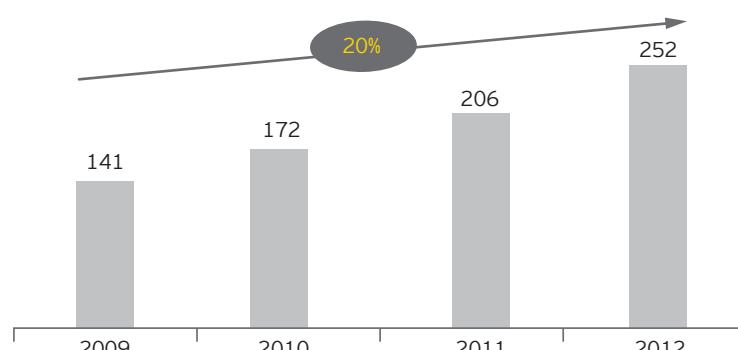
Source: ISA-EY research 2010

Indian VLSI design industry workforce

Breakup by total workforce size

The VLSI industry in India currently employs about 14,578 people and total employment is expected to grow at a CAGR of 20% for the next three years.

■ Exhibit 38: VLSI design industry workforce in India, 2009-12 (in '00s)

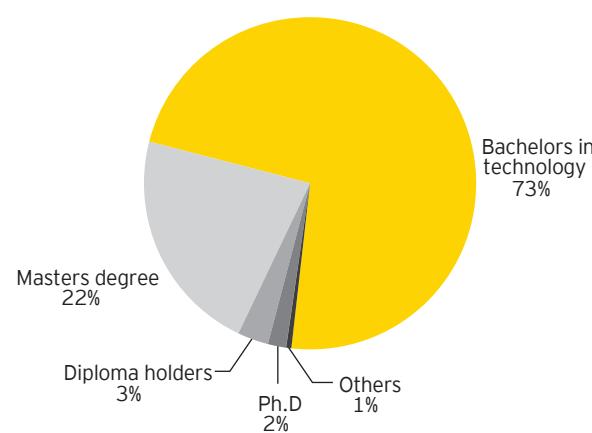


Source: ISA-EY research 2010

Breakup by educational qualifications

The industry is dominated by engineering graduates, who constitute nearly two-thirds of the entire workforce. VLSI design requires specialized skill-sets, and hence, the presence of a large number of postgraduates, as compared to the other two segments, particularly the board/hardware segment.

■ Exhibit 39: VLSI design industry split by educational qualification, 2009

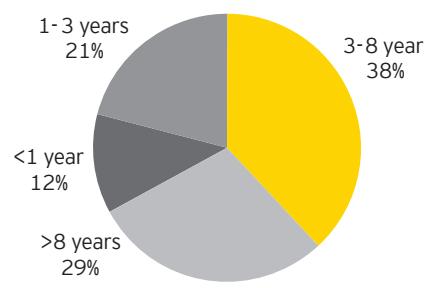


Source: ISA-EY research 2010

Experience-wise and diversity ratio distribution of employees

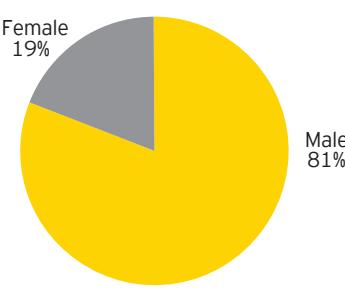
The distribution of the workforce is rather skewed toward more experience, mainly due to the presence of an older and mature VLSI industry workforce in India and a substantial number of VLSI designers, who are returning to India from abroad to join captives or service provider firms. Employees with more than three years of work experience account for close to 60% of the entire workforce in the country. Although the VLSI industry largely comprises men, the percentage of women in this sector has grown slightly year-on-year.

■ Exhibit 40: VLSI design industry headcount split by experience, 2009



Source: ISA

■ Exhibit 41: VLSI design industry split by gender, 2009

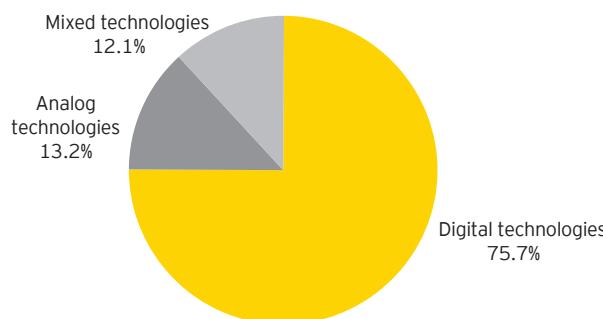


Source: ISA-EY research 2010

Distribution of employees by technology

While digital technology attracts an abundance of talent to the Indian VLSI industry, companies are moving up the value chain, which is evident in increased availability of talent in the analog and mixed signals space. Analog designs are becoming more intuitive and come with quite a few years of experience. These designs cannot be automated as easily as digital signals, making tools of little or no use. The crucial point is the requirement for specific analog-related skill-sets, which are still scarce, and the availability of talent does not meet the requirements. On the other hand, data converters and wireless networks are driving the demand for mixed signal engineers.

■ Exhibit 42: VLSI design workforce split by technology, 2009



Source: ISA-EY research 2010

VLSI design industry drivers and challenges

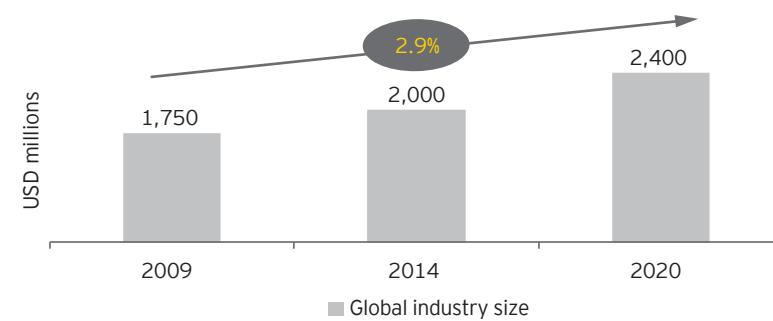
Drivers

A multitude of factors have made the semiconductor design ecosystem in India extremely conducive for growth. The key drivers of the country's VLSI design industry include:

i. Rising demand for electronic products worldwide

The increase in the global demand for electronic products, particularly consumer electronics and computer hardware, and the need for enhanced functionality in electronic products is creating a strong demand for product innovation. This global demand is creating an industry for design services in India.

Exhibit 43: Increasing demand for electronic products globally, USD billions, 2009-2020



Source: EY report on electronics systems design and manufacturing ecosystem, 2009

ii. Increasing maturity of the Indian design ecosystem

With the presence of the top 25 semiconductor companies and 10 fab-less companies in India, more complex work, in terms of current technology nodes, is being carried out in Indian centers.

Companies that have been in existence for more than 10 years in the country are slowly moving toward complete engineering ownership (including end-customer support), which has been one the key factors driving maturity in the VLSI segment

Challenges

Though there are signs that indicate a positive outlook for the VLSI design industry in India, there are a few challenges which hinder its progress, among which a few need to be addressed soon.

i. Lack of scale at leading node

With technology transforming at a rapid pace (Moore's Law), India's deficit of relevant talent is increasing. Although expertise does exist in handling geometries of 45nm or 32nm, there is an absence of scale, with most of the engineers in India handling geometries of 65nm and 90nm. Design and validation of complex system on chips (SoCs) and getting the silicon to work the first time is the biggest challenge. Furthermore, verification or validation of such complex systems is one of the biggest challenges, which requires the use of methodologies such as OVM, VMM and UVM.

ii. Lack of R&D funding in universities

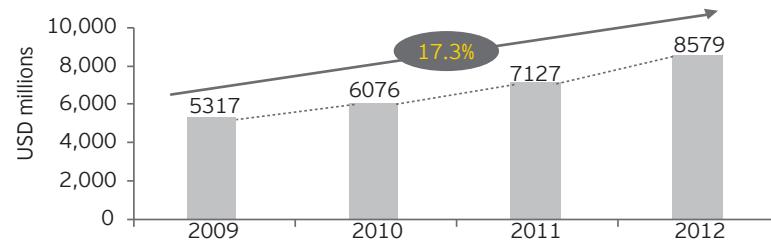
Universities in mature markets such as in the US or in Europe work on cutting edge chip technologies and design, which materialize into products a few years later. But this phenomenon is absent in India, which leads to fresh talent not being readily deployable and requiring a lead time to come to speed. Challenges present themselves in inadequate research infrastructure facilities to facilitate research toward device shrinkage beyond 45/32nm semiconductor process technology.

Embedded software industry

Embedded software is any computer software which plays an integral role in the electronics with which it is supplied. It can be any code, which interacts with the hardware layer, ranging from the hardware abstraction layer, device drivers, kernel programming to application programming.

The total embedded software industry in India was estimated at US\$ 5.3 billion in 2009 and is projected to grow at a CAGR of 17.3% to reach US\$8.6 billion in 2012. This industry accounts for the bulk of semiconductor design activities in India, with a share of 80% in the Indian semiconductor design industry's revenues.

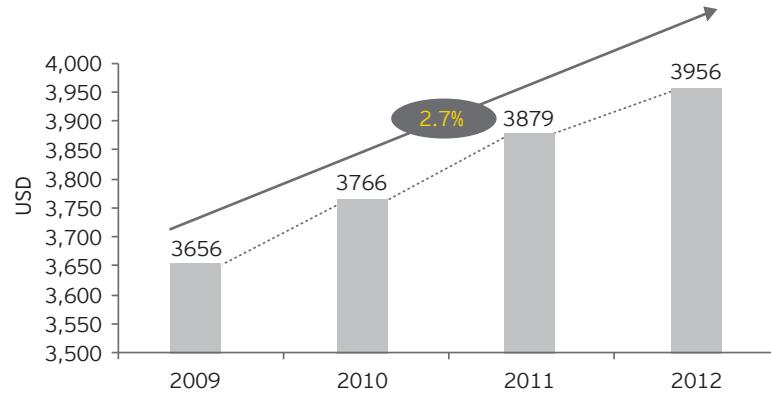
Exhibit 44: Embedded software industry in India by revenues, 2009-12



Source: ISA

The industry estimate of the fully-loaded cost per FTE per month is US\$ 3,656 and is expected to rise at a CAGR of 2.7% to reach close to US\$ 4,000 in 2012. This growth can be attributed to the embedded software industry tiding over the recession and third-party service providers recruiting in bulk.

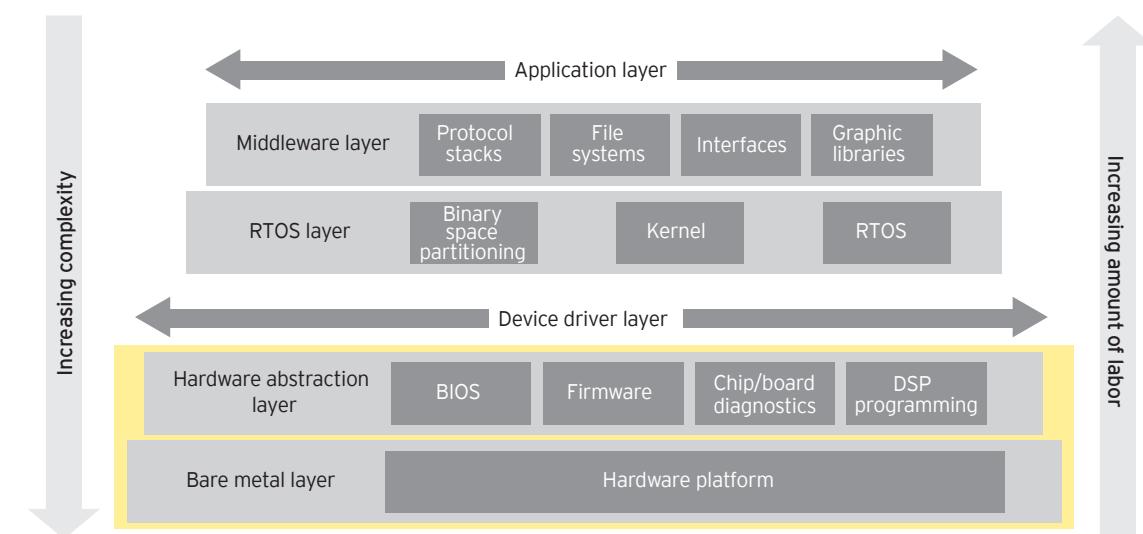
Exhibit 45: Embedded software design industry in India - average blended and fully-loaded cost per FTE per month, 2009-12



Source: ISA

Embedded software layer

Exhibit 46: Embedded software layer



Source: ISA-EY research 2010

While in terms of amount of labor, more embedded software programmers are required for movement away from the hardware abstraction layer to the application layer, in terms of complexity, multiple skill-sets are required on movement from the application layer to the hardware abstraction layer.

The embedded software industry is expanding as third-party service providers are moving up the value chain to offer more high-value activities relating to middleware, driver design and associated applications.

Captives largely work on the hardware abstraction layer and the device driver layer. While many captives outsource application-related work to third-party service providers and Indian design companies to shorten their time-to-market, others prefer to grow their domain-specific embedded application expertise in-house.

Other reasons for increased adoption of embedded software is its utilization by electronic companies in the face of immense pressure for innovation from end customers in terms of increased functionality, reduced time-to-market and reduction in costs.



Key consuming industry segments for embedded software design

Telecom, portable or wireless products and consumer electronics products continue to be the major verticals in terms of revenue, accounting for three-fourths of the embedded software industry. Telephones and handheld devices in the telecom segment and home multimedia and security systems in the consumer electronics segments are driving growth in the industry.

While Indian vendors have been growing in these verticals, players have begun building competencies around new verticals such as automobile, healthcare and storage, and the automobile sector is expected to grow considerably over the next two years.

■ Exhibit 47: Embedded software design projects split by consuming industry segment, 2009-2011

	2009	2010	2011
Telecom/Networking products	30.7%	30.1%	30.0%
Industrial/Power electronics products	4.3%	3.8%	3.7%
Portable/Wireless products	15.2%	15.3%	15.2%
Consumer electronics products	34.5%	34.6%	34.8%
Automobile products	4.4%	4.8%	5.0%
Healthcare	3.9%	4.0%	4.0%
Storage	4.2%	4.4%	4.3%
Others	2.8%	3.0%	3.0%

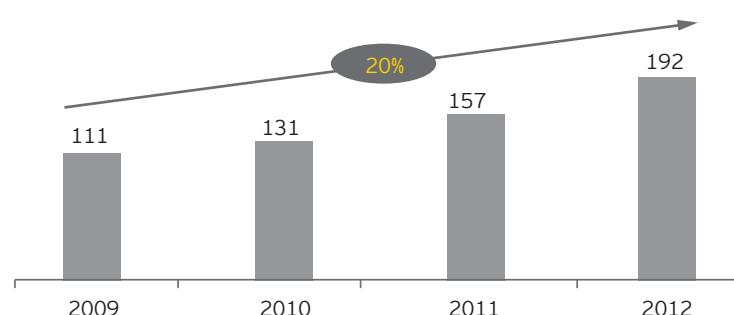
Source: ISA

Indian embedded software development industry workforce

Breakup by total workforce size

More than 50% of the projects in board/hardware design are between six to eight layers, which are used for consumer electronics, computing products, in the automotive space and for industrial automation. The projects in >10 layers are mostly related to telecom/network gigabit ethernet switches.

■ Exhibit 48: Embedded software design industry workforce in India, 2009-12 (in '000s)

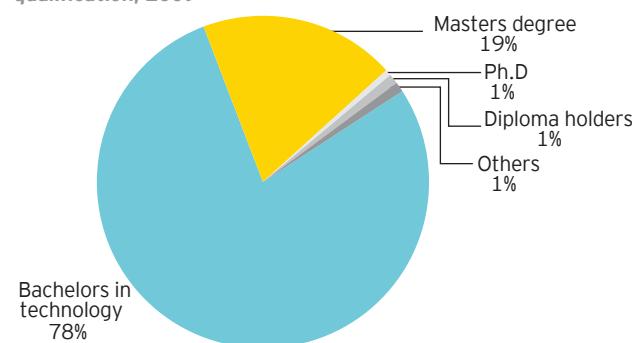


Source: ISA

Breakup by educational qualifications

Although the segment draws heavily from engineering graduates, the concentration of the workforce with Master's degrees is relatively lower than in the VLSI segment. This could be due to the large requirement for fresh talent, year-on-year, by this industry.

■ Exhibit 49: Embedded software industry headcount split by educational qualification, 2009

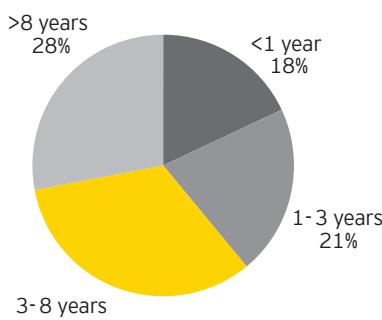


Source: ISA-EY research 2010

Experience-wise and diversity ratio distribution of employees

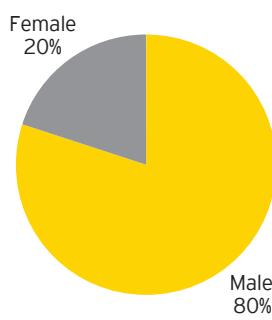
Due to the nature of the job profile being similar to software development, this segment employs a higher number of freshers out of college, as compared to the VLSI industry. It has not seen any significant change in the ratio of women to men employed in the industry, as compared to 2007 levels.

■ Exhibit 50: Embedded software design industry headcount split by experience, 2009



Source: ISA

■ Exhibit 51: Embedded software design industry split by gender, 2009

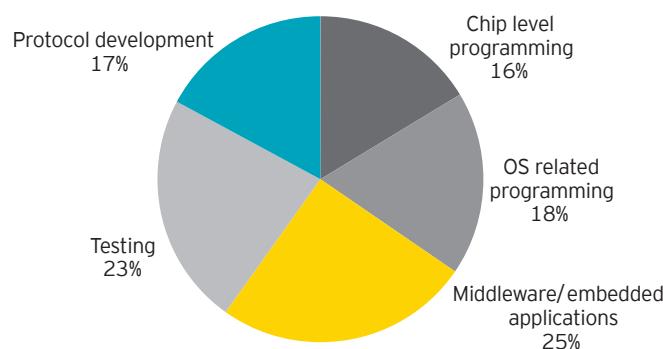


Source: ISA-EY research 2010

Distribution of employees by activity

The segment draws heavily from engineering graduates, although this industry employs a larger number of diploma degree holders as compared to the other two segments. The presence of a large number of diploma holders helps to maintain lower average fully-loaded cost per FTE in the industry.

■ Exhibit 52: Embedded software headcount split by activity, 2009



Source: ISA-EY research 2010

Embedded software industry drivers and challenges

Drivers

i. **Product customization due to localization**

The growing consumer market is creating a need for localized product features, resulting in increasing activity in the embedded software development domain, especially in the consumer electronics, defense, telecom and automotives segments.

ii. **Greater requirement for flexibility and functionality**

Growing affluence is redefining lifestyle aspirations, influenced by growing self-confidence, expanding consumerism, increased spending power and greater access to lifestyle goods and services, e.g., in the field of automobiles, embedded software being used in features such as power steering and windows.

iii. **Legislative requirements**

Country specific legislations, such as Bharat Stage -IV norms, require customization of certain features/functionality. Other instances are in the field of green energy (emission control), safety innovations (anti-lock brakes and air bags), etc.

iv. **Increasing capability of third-party service providers and Indian design companies**

The increasing capability of third-party service providers and Indian design companies, which are moving up the value chain to offer high-value activities relating to middleware and OS programming, is driving the expansion of the embedded software industry in India.

v. **Lower entry barrier for service providers**

Embedded software development does not require costly tools and solutions such as EDA, and the presence of a large talent pool has resulted in the establishment of a large number of small and niche service providers in this space.

vi. **Adaption of open-source platforms**

With chip design companies adapting open-source platforms such as Linux and Google's Android, there is an increased amount of embedded software required to support a chip's functionality, in which has given a boost to the embedded software industry



Challenges

i. Cost pressures due to constantly evolving platforms

One of the key challenges in the embedded software industry is to keep pace with the current technology node, which changes every 18-24 months, while providing increased functionality at the same or lower cost.

ii. Integration and testing of software and hardware

Semiconductor design companies face issues relating to integration and testing of software procured from IP providers. Although many captives have invested in home-grown integration and testing platforms or frameworks, this increases cost pressures on IP developers and causes performance issues with the integration of multiple IPs. No standard methodology is evolving, even with the use of various traditional methods such as co-simulation, simulation acceleration, emulation, and FPGA testing.

iii. Skill-set availability of high-end programmers

Multiple embedded processors in SoCs / MCUs with independent functions are being adopted in electronic devices due to higher power consumption from single core processors. Building these reliable and high-performance systems requires parallel software development, called symmetric multi processing, which is leading to an increased requirement of expert parallel programmers. There are also challenges in finding software programmers, who can balance power and tight optimization in limited hardware memory.

iv. Preference for ADM services as a career option

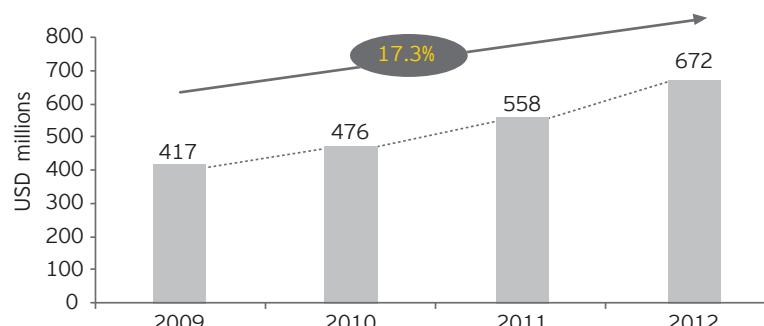
In terms of complexity, embedded programmers have to work within a limited memory that comes with the hardware, balance power, cost, size and simplicity of the design. However, even in the case of those with these complex skill-sets, Application, Development and Maintenance (ADM) services are perceived as an uncomplicated career option.

VI.

Board/hardware design industry

The hardware/board design Industry in India was estimated at around US \$ 417 million in 2009 and is expected to rise at a CAGR of 17.3% to reach US\$ 672 million in 2012. This industry is the smallest segment in the Indian semiconductor design industry, accounting for only 6.3% of the design industry's revenues. Its growth can be attributed to captives concentrating on pure-play VLSI activities and preferring to outsource reference and new board design activities to third-party service providers and to set up home-grown companies that only concentrate on board/hardware design activities.

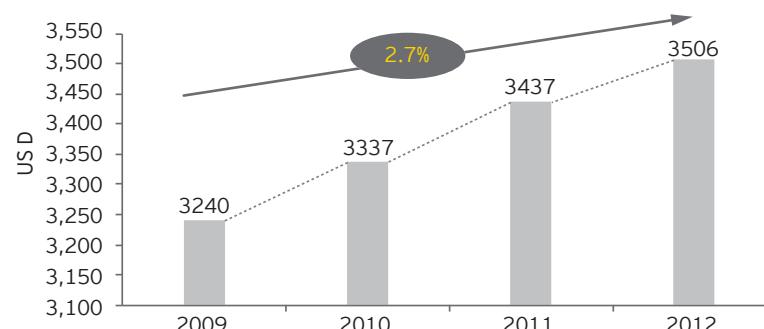
■ Exhibit 53: Hardware/board design industry in India by revenues, 2009-12



Source: ISA

The industry estimate for the average fully loaded cost per FTE per month is US\$ 3,240 and is expected to rise at a CAGR of 2.7% to reach US\$ 3,506 in 2012. These rates are comparatively lower than that commanded by the embedded software industry and considerably lower than the VLSI design industry's. One reason could be the presence of a larger percentage of diploma holders in the industry, as is seen later in Exhibit 78, which helps to bring down the average fully-loaded cost per FTE.

■ Exhibit 54: Hardware/board design industry - average blended and fully-loaded cost per FTE per month, 2009-2012



Source: ISA

This segment broadly consists of the following categories:

- ▶ Reference board design
- ▶ New board design
- ▶ Board design derivatives and modifications on existing boards

Most captives only make reference boards that are used to validate the capabilities of silicon chips designed in-house. Captives are not yet providing reference board designs as a service to other companies. Some captives are outsourcing reference board design work to third-party service providers and Indian design companies, in which the schematic layout is designed by the captives and the rest of the activities are outsourced, which decreases the time-to-market of the chip. These service providers have a significant presence in the new and derivative board design space for product development companies

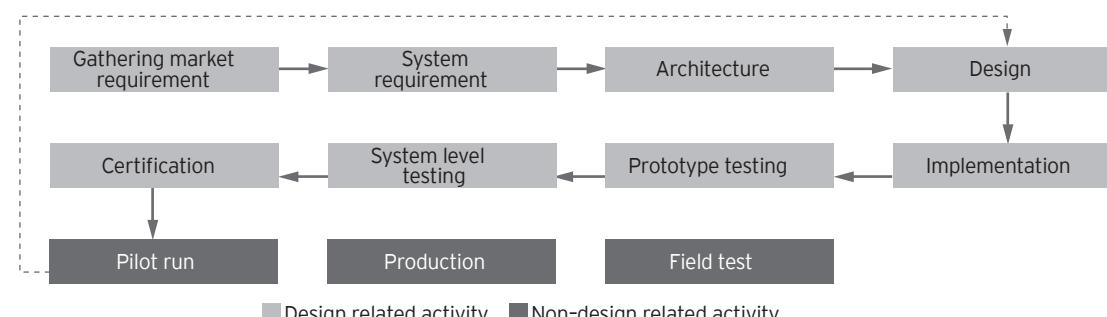
There is significant opportunity for hardware/ board design services in India. Some of the factors contributing to this include:

- ▶ As compared to the VLSI segment, proximity to local/ end-use markets has a pronounced effect on hardware/ board design, since customer requirements and local nuances need to be considered. With most global electronic product majors focusing on creating emerging market-specific products, this leads to significant traction in the segment
- ▶ Indian service providers are taking strong IP measures to drive India's USP, as compared to competition from countries such as China and Taiwan. Some of the measures undertaken include:
 - ▶ Conducting IP protection sessions regularly for all employees to reinforce IP protection principles
 - ▶ Conducting IP audits for every project to ensure that no open source codecs or other companies code is used
 - ▶ Providing cool-off period for designers before they work on a competitor customer product

Hardware/board design flow

In terms of design-related activities, captives are collaborating with third-party service providers during the chip design stage. This is due to their increased confidence on Indian board designers and their competence in the areas of IP development and integration.

■ Exhibit 55: Hardware/board design flow



Source: ISA-EY research 2010



There is an attractive business opportunity for third-party service providers in the product white-label manufacturing space, primarily driven by three factors:

- ▶ Movement up the value chain due to India slowly losing the cost arbitrage advantage
- ▶ Customers looking to involve third-party service providers in an end-to-end ownership model
- ▶ Increased profitability by customizing a single product according to different customers' requirements

Third-party service providers are refraining from getting into the selling space directly as they lack the required sales and marketing infrastructure, post sales support and logistics to support this.

Key consuming industry segments and demand evolution of hardware/board design

Consumer electronics, telecom/ networking products and portable wireless are the key growth contributors to the hardware/ board design industry. With India-specific products emerging as a major consumer segment for these product categories, the demand for hardware/ board design in India is pronounced.

■ Exhibit 56: Hardware/board design projects split by consuming industry segment, 2009 -2011

	2009	2010	2011
Telecom/Networking products	30.6%	30.0%	29.8%
Industrial/Power electronics products	4.5%	4.1%	3.8%
Portable/Wireless products	15.2%	15.4%	15.5%
Consumer electronics products	34.3%	34.5%	34.9%
Automobile products	4.4%	4.7%	4.8%
Healthcare	3.8%	3.9%	3.9%
Storage	4.3%	4.5%	4.3%
Others	2.9%	2.9%	3.0%

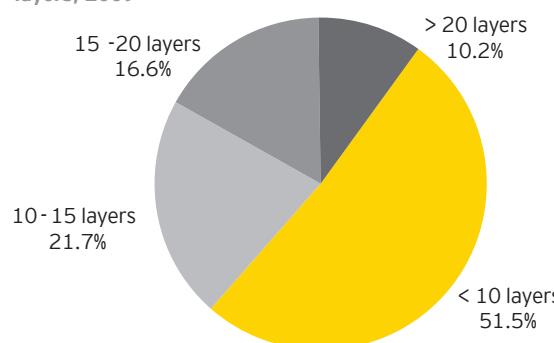
Source: ISA

Indian hardware/board design industry operations – quantitative analysis

Distribution of total projects carried out in India by number of layers (complexity)

More than 50% of the projects in board/hardware design are between six to eight layers, which are used for consumer electronics, computing products, in the automotive space and for industrial automation. The projects in >10 layers are mostly related to telecom/network gigabit ethernet switches.

■ Exhibit 57: Hardware/board design industry split of projects by number of layers, 2009

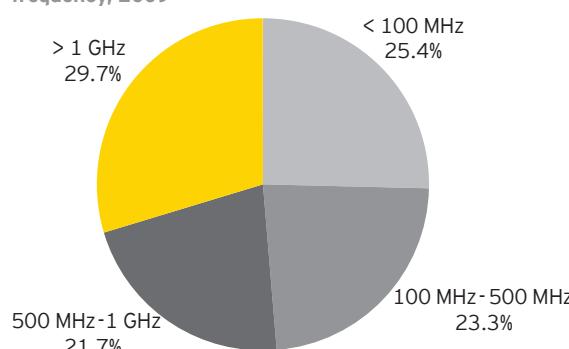


Source: ISA-EY research 2010

Distribution of total projects carried out in India by frequency

Most board designs in the frequency of 100-500 MHz are for wireless, telecom and consumer products. The 1 GHz range mentioned above has the major presence of computing products as well as of maintenance and testing projects. Automotive and industrial automation projects are in the <500 MHz category and RF-related projects are between 500 MHz-1 GHz.

■ Exhibit 58: Hardware/board design industry split of projects by frequency, 2009

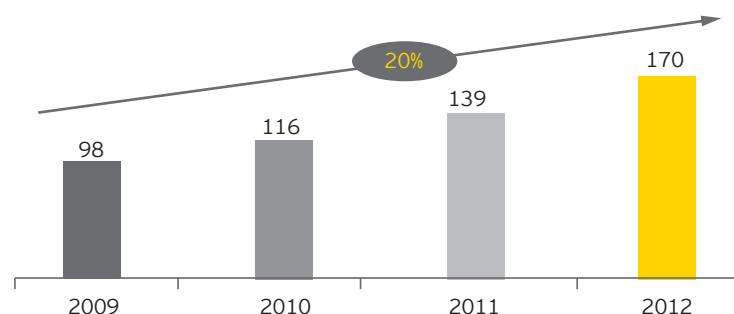


Source: ISA-EY research 2010

Indian hardware/board design industry workforce

The hardware/ board design industry in India currently employs around 9,800 FTEs and total employment in the industry is expected to grow at a CAGR of 20% to reach close to 17,000 FTEs in 2012. This growth in the workforce is primarily driven by increasing business volumes generated by third-party service providers from captive centers as well as VLSI design captives offering hardware/ board design services to the parent company. However, the key challenge the country's workforce faces is the inadequate supply of qualified design engineers, who are capable of handling ever-increasing board design complexity.

■ Exhibit 59: Hardware/board design industry workforce in India, 2009-12 ('00s)

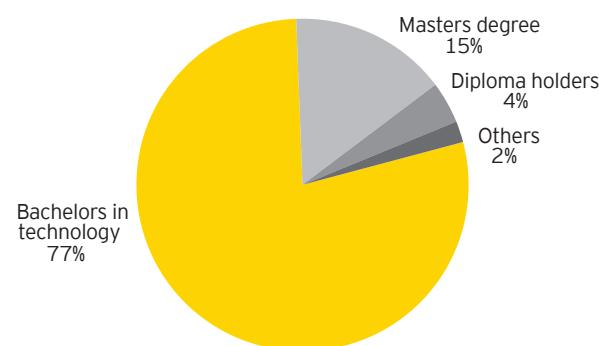


Source: ISA

Breakup by educational qualifications

The segment draws heavily from engineering graduates, although this industry employs a larger number of diploma degree holders as compared to the other two segments. The presence of a large number of diploma holders helps to maintain lower average fully-loaded cost per FTE in the industry.

■ Exhibit 60: Hardware/board design industry headcount split by educational qualification, 2009

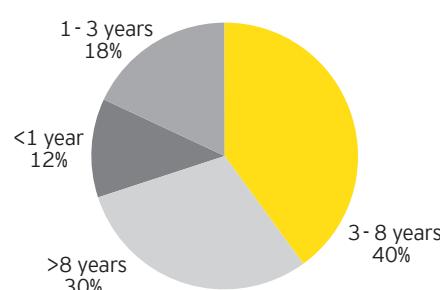


Source: ISA-EY research 2010

Experience-wise and diversity ratio distribution of employees

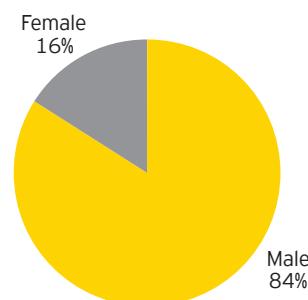
This segment employs the maximum workforce with above three years of work experience. On an average, the industry estimates around four to five years for an employee to become a world-class board designer. The hardware/ board segment is largely constituted of men with only a minute percentage of women – this trend is quite dissimilar to that in the other two segments.

■ Exhibit 61: Board/hardware design industry headcount split by experience, 2009



Source: ISA

■ Exhibit 62: Board/hardware design industry split by gender, 2009



Source: ISA-EY research 2010

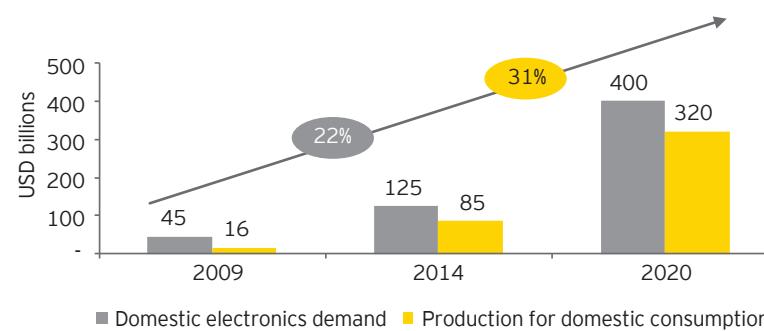
Hardware/Board design industry: drivers and challenges

Drivers

i. Emergence of India as a consumer market

The rising discretionary spending of consumers has positively affected the consumer electronics and automobile segments, creating new opportunities in India, as is the trend seen in more mature markets.

■ Exhibit 63: Increasing demand for electronic products in India, 2009-2020



Source: EY report on electronics systems design and manufacturing ecosystem, 2009

ii. Increased outsourcing by OEMs and emergence of EMS companies

India is beginning to mirror the global trend in terms of EMS companies gaining popularity and setting up their captive design centers to support their global and APAC customers and also tap into the local market opportunity. OEMs are also increasingly outsourcing their system designs to Indian design companies.

iii. Product localization

An increasing number of companies are re-engineering their products to suit domestic market requirements to lower costs, enhance functionality and provide a competitive advantage over other products, especially in the market for mobile telephony, consumer products, automotives, indigenized defense and avionics.

iv. Re-engineering opportunities

Multiple re-engineering opportunities are available within the Indian ecosystem to provide benefits such as reduced system costs, effective risk management and prevention of health hazards.

- ▶ Augmenting existing designs with additional features
- ▶ Obsolescence - frequent changes in semiconductor components (Moore's law) and other re-design related changes such as changing power designs, more mobile and portable systems and reducing capacity loads
- ▶ Compliance - changing environmental legislation, giving rise to RoHS and WEEE laws and regulations with which to comply

v. Captives partnering third-party service providers

Captives are exploring various possibilities of partnering with third-party service providers. Some of these include the following:

- ▶ The introduction of early access programs to design reference boards and verification platforms in parallel with chip design to reduce time-to-market
- ▶ Chip usage promotion during board/ hardware design
- ▶ Setting up design labs in campuses of third-party service providers to increase marketability of captive products, thereby bringing in more work to the segment

Challenges

i. Compliance-related challenges

Lab testing and certification services are offered by a few companies in India and issues arise in the following:

- ▶ Potential delay in products reaching the market due to the time required for certification
- ▶ Timely availability of testing slots

Having in-house certification labs is not feasible due to the vast number of certifications as well as the expense factor in setting up such labs. Another challenge is the absence of standardized frameworks for pre-qualification testing in-house to save time and reduce the number of design iterations.

There is also the absence of a testing equipment ecosystem for rent, unlike that available in Taiwan and China

ii. Lack of component ecosystem development

Unavailability of component-manufacturing setups in India, especially of type C components, leads to:

- ▶ Delays in sourcing components at the required time
- ▶ Excess buildup of inventories due to placement of minimum order quantity orders only

There is a need for either electronics system-manufacturing companies setting up shop in India or the component supply chain strengthening.

iii. Adoption of de-risking business models by customers

Product companies are seeking longer warranty periods and engaging design teams in a joint ownership model, thereby ensuring that they work as partners to share risks by incorporating sufficient input received from adequate pilot runs and field tests into the design cycle, to produce a better, complete and successful product.

iv. Official policies

- ▶ Movement of hardware products/goods between STPI units and SEZs as well as different STPIs is not permissible by the law today, causing inconvenience to companies, which are a part of these units and have a presence in STPIs and SEZs.
- ▶ Import procedures are time-consuming and there is a dire need to streamline them, especially in the area of classification of items

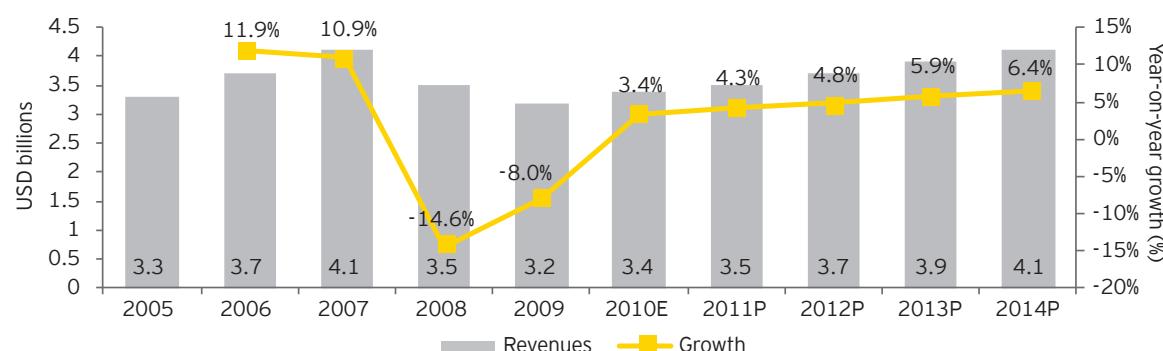
Annexure

Annexure I: EDA tools industry

Global EDA industry overview

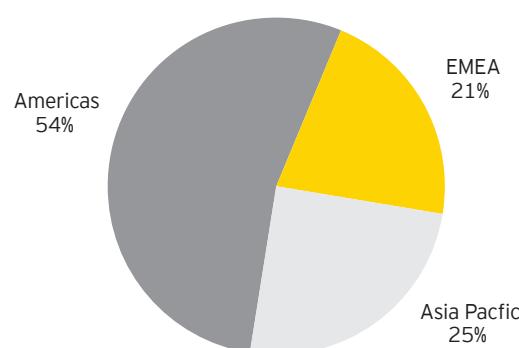
The global electronic design automation industry has been hit hard by the recession, primarily due to the falling demand for electronic products resulting in reduced sales of semiconductor devices. The global EDA industry witnessed a decline of 8% from US\$ 3.5 billion in 2008 to US\$ 3.2 billion in 2009. As the economic situation stabilizes and brings back electronic products and semiconductor consumption levels to normalcy, the industry is expected to grow at a CAGR of 5% to reach US\$ 4.1 billion in 2014. Most of the end-markets for semiconductor devices continue to be highly competitive and use design as an enabler to achieve cost reduction and product differentiation through feature enhancement. Going forward, this is expected to be the key driver to aid the growth of the EDA industry.

Exhibit 64: Global EDA industry



Source: IDC

Exhibit 65: Geographic split of the global EDA industry, 2009



Source: IDC



Overview of Indian EDA industry

EDA is a very important enabler for semiconductor design and a niche industry with global revenues of around US\$ 3.2 billion. The development of such products requires diverse skill-sets spanning electronics and electrical engineering, computer science and programming, and advanced mathematics. India has traditionally been very attractive to global EDA for product development due to the country's high graduate turnout in relevant fields.

There are an increasing number of companies operating in the semiconductor design space, both captives and non-captives (including India-based semiconductor product companies). These companies are moving up the value chain to take up higher complexity design work, which creates a huge demand for EDA tool usage.

It is quite impossible to estimate the revenues of individual countries, where a large number of captive centers are located, since license sale happens at their headquarters and these licenses are utilized in unique ways across time zones to optimize costs.

Drivers of the Indian EDA industry

i. Rapidly evolving semiconductor design ecosystem in India

Companies operating in the semiconductor design space in India are moving up the value chain to take up higher complexity projects and are operating in an engineering product ownership mode, which is resulting in increased design services being performed in India. This is driving increased EDA tool license sales in India.

ii. Increasing design complexity

Decreasing technology nodes and an increasing number of architectural decisions, driven by Indian design centers, are creating a strong need for the adoption of additional EDA tools, to keep up with the rapid pace of the semiconductor industry.

iii. Strategic acquisitions by Indian design services companies

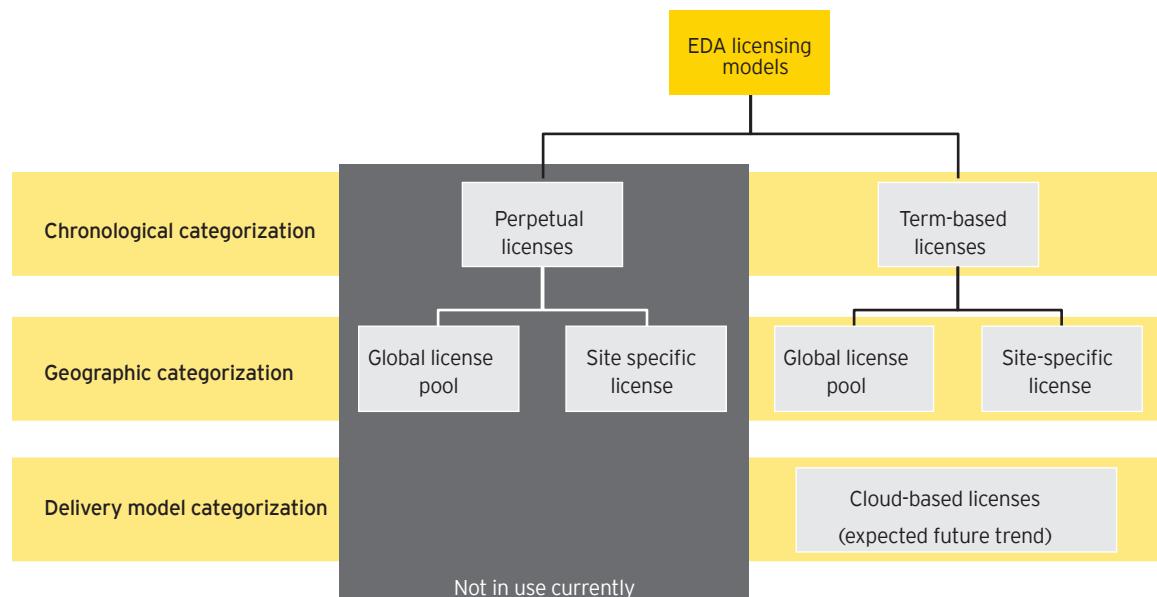
Indian design services companies have acquired captive design centers to enhance their design service offerings, which emphasizes their commitment to the Indian semiconductor scenario and is an indication of the burgeoning growth of this industry in the country, e.g., MindTree's acquisition of TES PV.

Challenges for the Indian EDA industry

The EDA companies operating in India do not face any India-specific challenges, since there are no India-specific EDA tools or chips designs. The majority of the challenges faced by EDA companies are technical, and are caused due to rapid advancement in chip and chip-manufacturing technologies. The rapid innovation cycles of semiconductor companies force EDA companies to develop new products to keep pace with market requirements, e.g., low power (from the system level through physical layout), functional verification challenges and manufacturing variability (through the application of design-for-manufacturing techniques to design).

Licensing models

Exhibit 66: The various licensing models for EDA tools, 2009



Source: EY research

i. Perpetual license model

This is the more traditional model, which is seldom used. The license, once procured for this model, is typically effective for 99 years. Maintenance, which includes technical support, product updates, bug fixes, etc., is typically purchased separately on a year-on-year basis and is typically around 10 -15% of the perpetual license cost.

ii. Term-based models

Term-based models allow the lease of the EDA tool license for a fixed duration (in weeks/months/ years) and typically includes maintenance. This is the model preferred by most companies engaging in semiconductor design in India as it offers flexibility on a client-to-client and a project-to-project basis. The annual pricing of a time-based license is generally around 20 -40% of the price of the perpetual license.

a. Captives

The captive centers of global companies typically use a global pool of licenses hosted in one or more locations, which can be accessed by their employees worldwide across time zones. These allow the flexibility of one license being utilized by more than one designer in a complimentary time zone. Less than 5% of the captive centers have opted for a site-specific/ India-specific license. A global license typically costs more than a site-specific one due to the flexibility it offers.

b. Third-party service providers

In the case of third-party service providers, who have fixed delivery centers across the world, the site-specific license is the preferred model (c. 80–90%) over a global one.

However, utilization of the license depends on the customer's budget and infrastructure. In the case of small customer budgets, service providers use their own licenses. In the case of a larger customer budgets, third-party service providers typically use the customers' licenses, either onsite or offsite for client servicing.

iii. Cloud-based licenses

None of the companies currently offer this type of a delivery model, in which the purchaser is charged on a pay-per-use basis. However, this is slated to be a key trend in the industry as it opens up opportunities for EDA tool vendors to tap into a larger section of the market, which cannot afford to pay huge upfront license costs.

EDA tool-buying behavior

The purchase of an EDA tool depends on a multitude of factors including costs, capabilities, features, the maturity of the team that will be using it, etc. Based on discussions with industry players, companies headquartered in the Americas have typically preferred a global pool of licenses, as compared to companies in Europe that have site-specific license allocation for specific projects/ products.

The maturity and capability of the global design center of an MNC firm typically defines the types of EDA tools and license models. The head of a relatively mature design center (implying local engineering ownership and governance) has a significant say in purchase decisions related to that center, as compared to a newly established center, which is globally governed and monitored.

Companies with lower EDA budgets have limited themselves to a single EDA tool across their organizations, but those with larger budgets typically use a diverse set of tools from multiple tool vendors for various applications in their global location.

Annexure II: definitions

Captive unit

A captive unit is a company that develops a total product or a module, which it brands and markets as part of its (own) product development. The India unit carries out the work for the global organization.

Non-captive unit

This is a unit that provides third-party services/ IP design and development services in the areas of interest mentioned below for a fee, and the activity undertaken is not for its own use.

Revenue

The year 2009 was taken as the base year for estimating revenues for this study.

Service

The service includes VLSI design, hardware/ board design and embedded software development offered by captive and non-captive companies.

Average blended and fully-loaded cost per FTE per month

The average fully-loaded cost per FTE per month is the simple average of the per month per engineer rate, which includes

other elements of the costs to the company, such as the facility, administration and other infrastructure-related costs of VLSI, hardware/ board design and embedded software development activity in the semiconductor and embedded design industry in India. Hence, this is different from the average salary drawn per FTE. However, it excludes EDA tools license costs.

VLSI design

VLSI circuit design refers to technology by which it is possible to design and implement large circuits on silicon. These circuits have more than one million transistors. VLSI technology has been successfully used to build microprocessors, signal processors, systolic arrays, large capacity memories, memory controllers, I/O controllers and inter connection networks.

Revenue from VLSI

The base year for which revenue estimates for the VLSI industry are provided is 2009. This is the total engineering month cost incurred through VLSI design work executed by the offshore centers of captive and non-captive companies.

VLSI services

VLSI design

This includes the services provided by captive companies to their parent companies as an offshore center and by non-captive companies as part of their service model.

Digital

This includes all the services offered for a digital chip from specifications till tape-out.

Analog

This includes all the services offered for an analog chip from specification till tape-out.

Mixed signal

This includes all the services offered for a mixed signals chip from specification till tape-out.

Hardware/Board design

Hardware/Board design refers to the reference board for semiconductors and also includes boards designed as a part of new product development.

Revenue from hardware/board

The base year for which revenue estimates for the hardware/board industry are provided is 2009. This is the total engineering month costs incurred on account of hardware/board design work executed by the offshore centers of captive and non-captive companies.

Services

The services offered by hardware/board design industry participants include digital and analog design, board layout and routing, the design for manufacturability, system/ board testing and system productivization.

Board design

This includes low and medium complexity boards in embedded technologies, x86, Ethernet switches, digital video boards, field programmable gate array (FPGA) validation boards and standard form-factor boards.

PCB design

This includes library services, board component placement, manual routing, Gerber processing and CAM services.

Embedded software

This can be as simple as a microcode instruction set of microprocessor or as complex as security software. Embedded software performs a specific function, which is not under the control of the primary user.

Revenue from embedded software

The base year for which revenue estimates for the embedded software industry are provided is 2009. This is the total engineering month costs incurred by embedded software work executed by the offshore centers of captive and non-captive companies.

Services: The services offered by embedded software development market participants include developing software for integrated circuits, boards and systems.

Section 2

Benchmark

arking

About this study

This study on the Indian semiconductor and embedded design services industry has been commissioned by the Department of Information Technology, Ministry of Communication and Information Technology, India, with the intention of providing a thorough and systematic analysis of the Industry. It highlights India's growth and positioning in the global semiconductor design industry to identify areas of improvement and frame recommendations for the Indian semiconductor design industry. This report is jointly prepared by the India Semiconductor Association and Ernst & Young Pvt. Ltd.

The output of the study is presented in three sections:

Section 1: Industry analysis

This section throws light on the global semiconductor design and embedded software industry with a focus on the Indian industry. It discusses the ecosystem for semiconductor design development, the status of intellectual property in the industry and the talent landscape. It also provides estimates of industry revenues, workforce demand and supply, demographics, trends in terms of technology nodes and business models, and highlights the key drivers of and the challenges faced across the following three segments of domestic industry:

- ▶ Very large scale integration (VLSI) design segment
- ▶ Embedded software design segment
- ▶ Board/hardware design segment

This section also discusses the nuances of the Electronic Design Automation (EDA) market in terms of global and Indian markets, their drivers, the challenges faced by them and their license models.

Section 2: Benchmarking

The objective of the benchmarking exercise is to provide a competitive assessment of India against seven countries considered pioneers of semiconductor design. Quantitative benchmarking compares various parameters such as industry dynamics, talent pool, infrastructure, operating costs, quality of the business environment, and innovation and IP, which are all pivotal to the development of a country's semiconductor design sector. This analysis aims to highlight the challenges India faces vis-à-vis its competitors and the model to develop based on best practices adopted worldwide.

Section 3: Recommendations

Key issues relating to the growth of the semiconductor design industry are summarized, based on the findings of the Industry report. In the Benchmarking exercise, elaborate recommendations have been made to tackle the issues mentioned above. This will be a valuable source of data for the Government of India, the industry and academia, and can be used to plan and influence government policies for the domestic semiconductor design industry, building a strong ecosystem for the industry and bridging the gap in the talent scenario.

Contents

Section 2: Benchmarking

I. The benchmarking study: overview	76
II. Quantitative country benchmarking	78
1. Industry dynamics	79
2. Talent pool	88
3. Innovation environment	93
4. Operating costs	98
5. Infrastructure	105
6. Quality of the business environment	110
III. Government policies and support	117
Taiwan	117
China	118
India	119
Israel	120
US	120
UK	120
Germany	121
Sweden	121
IV. Summary	122
.....	
Annexure	123
Definitions	123
References	124

The benchmarking study: overview

The objective of this benchmarking study is to explain the current state of the Indian semiconductor design sector and overall business environment. The study explains various parameters that are important for the development of a country's semiconductor design sector. Quantitative benchmarking for India has been done on these parameters vis-à-vis other countries, which are considered pioneers of semiconductor design.

The countries selected for this study constitute a representative sample of semiconductor design activity. India's benchmarking has been done with the following countries:

- ▶ The US
- ▶ The UK
- ▶ Germany
- ▶ Sweden
- ▶ China
- ▶ Taiwan
- ▶ Israel

We conducted the study through publicly available secondary sources. Other countries such as Japan and South Korea, which are considered pioneers in semiconductor design, were not included in the sample set because of associated difficulties in obtaining information from public sources due to language constraints. The parameters for this study are industry dynamics, talent pool, innovation environment, operating costs, infrastructure and quality of the business environment.

The section on industry dynamics consists of parameters that explain the development of the semiconductor ecosystem in a country. It comprises a number of design houses, electronics production, design industry revenues and the geographic concentration or fragmentation of the industry.



Semiconductor design requires a highly skilled labor force. The talent pool section focuses on the number of engineers currently working in the semiconductor design sector and the annual addition of engineers qualified in disciplines relevant to the semiconductor design sector. The number of engineering colleges covered in this section is an indicator of the future scalability of talent.

The design sector involves a high degree of creation of IP. The innovation environment deals with the innovation capabilities of a country as a whole. The comparison on innovation environment has been made based on the quality of scientific research institutes and spending on R&D by companies. Countries have also been benchmarked on the number of IEEE papers filed from the country for disciplines relevant for semiconductor industry.

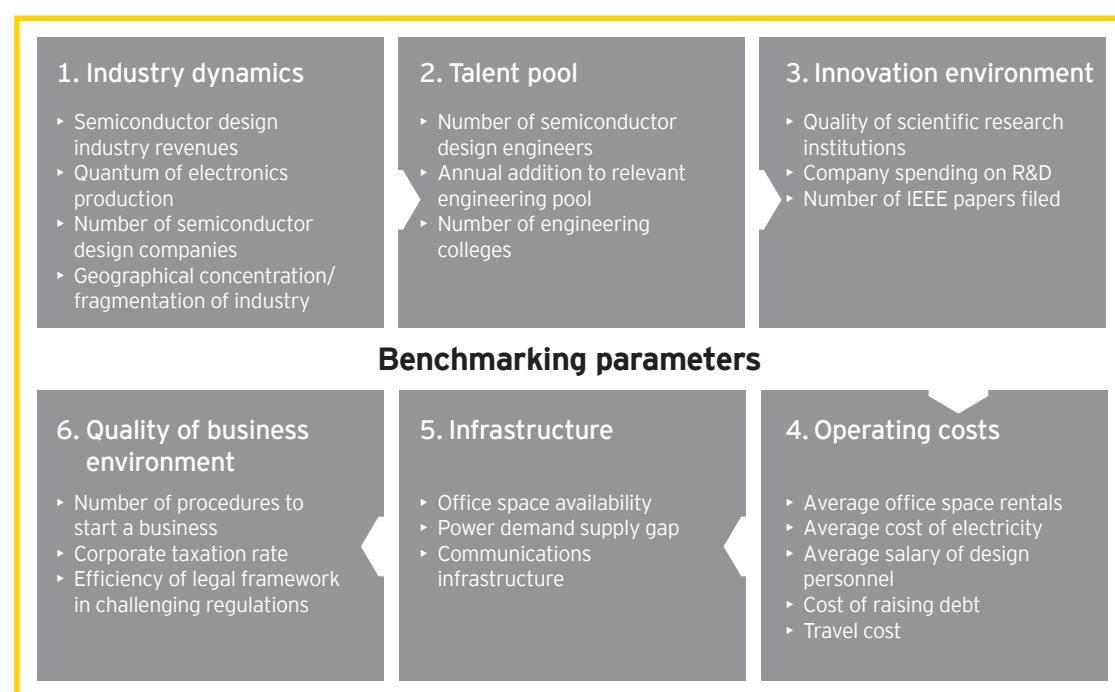
Operating cost is an important parameter, as it impacts the overall profitability of running a business in a country. The major costs of operating in a country include manpower cost, office space rentals, electricity cost, interest cost and travel cost. High costs reduce profitability and, therefore, companies do not consider countries with high operational costs to be favorable business destinations.

The quality of physical infrastructure available in a country is a major factor that attracts new players, both domestic and foreign, for business. The study focuses on comparing countries on the basis of communication infrastructure, the availability of high-quality Grade A office space and the power demand-supply scenario.

The section on the quality of business environment describes parameters that depict the ease of doing business in a country. A country's business environment is measured by the complexity involved in starting a new business in terms of number of procedures and taxation rates. Prevalence of an efficient legal framework is important for the protection of IP rights for that country's semiconductor design industry. Efficiency of legal framework in challenging regulations has been used as benchmarking parameter to study the legal environment in a country.

Quantitative country benchmarking

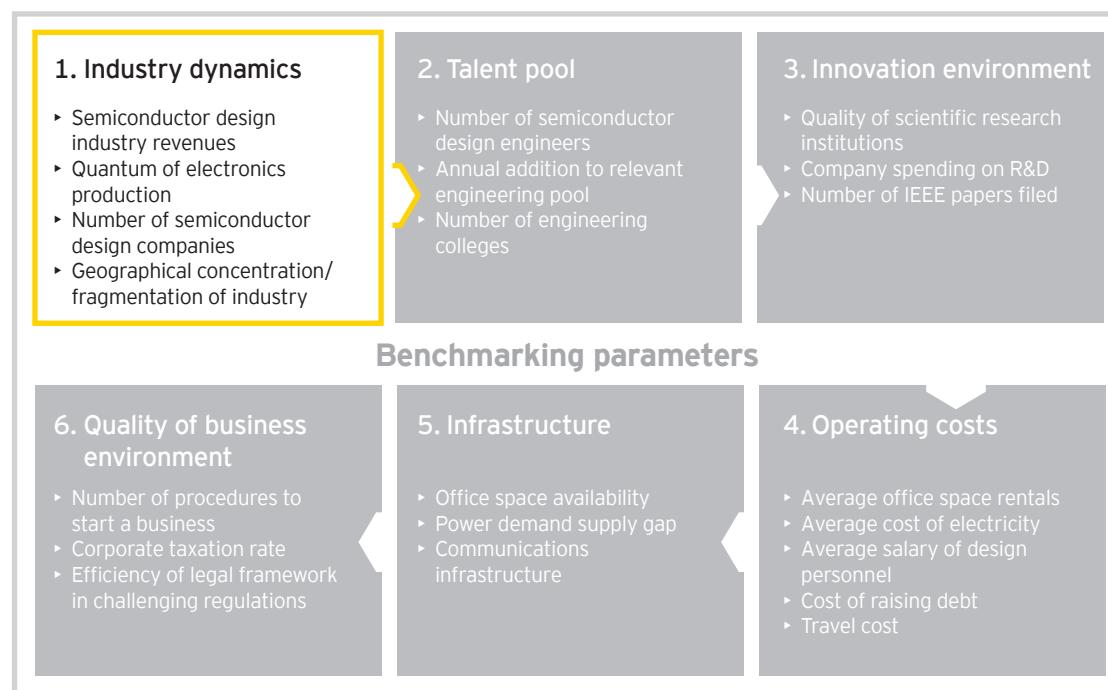
Exhibit 1





1. Industry dynamics

Exhibit 2



Industry dynamics comprises factors that explain the semiconductor design ecosystem of a particular country. These factors include semiconductor design industry revenues, quantum of electronics production, number of semiconductor design companies operating in the country, and geographical concentration or fragmentation of the industry. Such factors help explain the maturity of a particular country's semiconductor design industry.

The benchmarking parameters considered in this category are:

- Industry revenues
- Quantum of electronics production
- Number of semiconductor design companies
- Geographically concentrated/fragmented industry

The quantum of electronics production sheds some light on the maturity of the semiconductor ecosystem, since the electronics sector is a major consumer of semiconductors. So, an increase in electronics production will indicate a better market potential for the semiconductor industry.

Electronics production data has been obtained from the *OECD Information Technology Outlook: 2010*, an Organization for European Economic Co-operation and Development (OECD) publication.

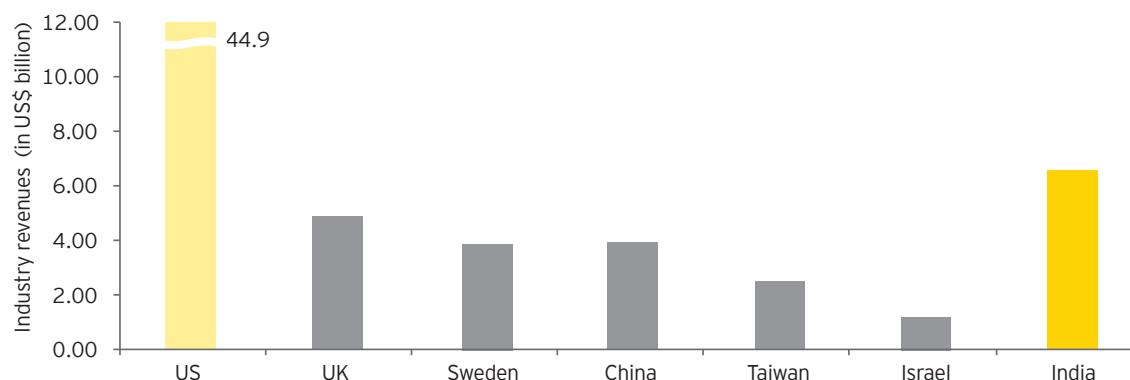


1.a. Industry revenues

Industry revenues reflect the level of semiconductor design activity taking place in a particular country. The numbers for revenues have been estimated using the number of design engineers working in a particular country, fully loaded cost (including tools and infrastructure) per full-time employee (FTE) and profit margin.

Exhibit 3 compares the countries on the value of semiconductor design industry revenues in 2009.

■ Exhibit 3: Semiconductor design industry revenues



Source: Multiple; refer references on page 124

*Data not available for Germany

Key observations

- ▶ Among the sample set of countries, the US has the highest semiconductor design revenues.
- ▶ With design revenues of US\$1.23 billion, Israel ranks last among the sample set of countries.
- ▶ India ranks second among the sample set of countries, with revenues of US\$6.6 billion.

Takeaways for India

- ▶ Since the US leads the sample set in terms of number of design engineers and average salary cost of an FTE, design revenues in the US are the highest. Benchmarking on the number of design engineers has been done in Chapter 2.a., while salary cost has been benchmarked in Chapter 4.c.
- ▶ Based on the steady increase in the number of design engineers in India in the past few years, design revenues are expected to grow at a CAGR of 17.3% until 2012.

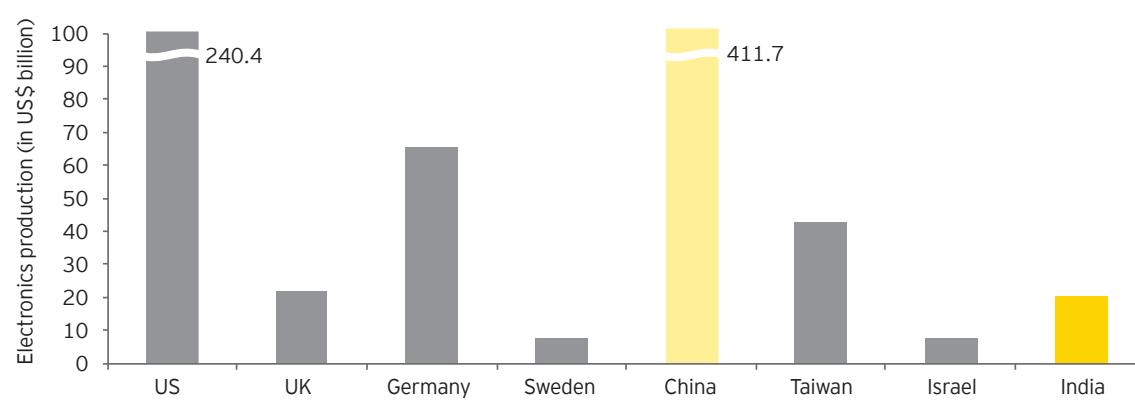


1.b. Quantum of electronics production

Semiconductors constitute an integral part of electronic products. Therefore, a high amount of electronics production boosts growth in a country's semiconductor industry.

Exhibit 4 compares countries on the value of electronics production in 2009.

Exhibit 4: Quantum of electronics production



Source: Multiple; refer references on page 124

Key observations

- ▶ China leads the sample set of countries in terms of value of electronics components and equipment manufactured with revenues of more than US\$411.7 billion from electronics production.
- ▶ Sweden has the lowest value of annual electronics production in the sample set, at approximately US\$7.5 billion.
- ▶ Electronics production in India was valued at US\$20.3 billion in 2009, and ranks sixth among sample set countries on this parameter.
- ▶ While India is ahead of Sweden and Israel, it lags behind China, the US, Germany, Taiwan and the UK.



The Indian electronics industry

The demand for electronics in the Indian market stood at US\$45 billion in 2009 and is projected to grow at a CAGR of 22% to reach US\$125 billion by 2014 and to US\$400 billion by 2020. India meets a large portion of its domestic demand of electronics items through imports from countries such as China, Taiwan, Korea and Malaysia. Exports, which constituted a small portion (approximately 21%) of production in 2009, are expected to increase from US\$4.4 billion in 2009 to US\$15 billion by 2014 and US\$80 billion by 2020, growing at a CAGR of approximately 31%.

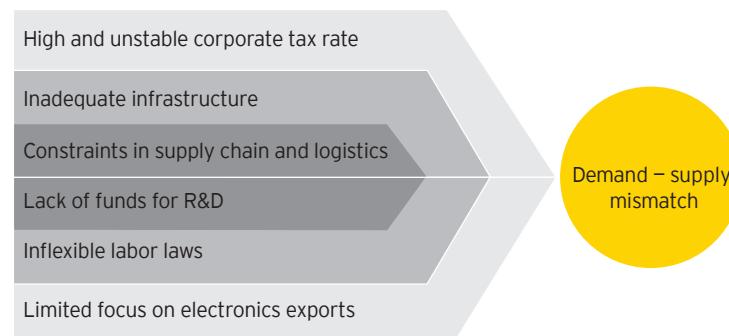
Growth in per-capita income has been a major trend driving this market. Nearly 10 million households are estimated to have income levels above US\$10,000 per annum. With an annual growth rate of 20%, this household segment offers opportunities for electronics products. The rising Indian middle class has generated more demand for mobile handsets, televisions, retail, and automotive and other consumer electronics products.

Electronics production between 2005 and 2009 grew at a CAGR of approximately 17%. At this rate, electronics production is expected to increase to US\$114 billion in 2020. This, in turn, is likely to lead to a significant increase in the demand-supply gap, which will rise to US\$286 billion in 2020. Therefore, it is essential to increase the pace of growth. The targeted growth rate in electronics production is around 31% annually between 2009 and 2020 and is expected to reach a value of US\$400 billion. Of this, while US\$80 billion is expected to be exported, US\$320 billion will meet domestic demand.

Takeaways for India

- ▶ The rapidly growing electronics market is likely to serve as an important growth driver for the Indian semiconductor industry.
- ▶ Despite the rising demand for electronics in India, certain challenges tend to lead to a significant demand-supply gap.

■ **Exhibit 5: Factors resulting in relatively low electronics production**





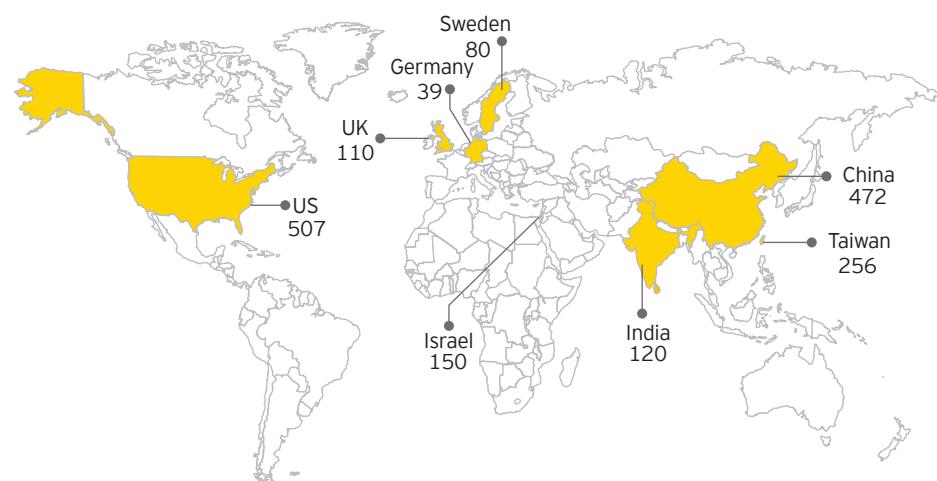
- ▶ India's corporate taxation rate is higher than that of the sample set of countries, which makes the final product less competitive than low-cost destinations such as China and Taiwan. Tax-rate benchmarking of all sample countries has been done in Chapter 6.b.
- ▶ The GoI also needs to ramp up infrastructure development in the country. Chapter 5 of this report details the benchmarking of several infrastructure-related parameters.
- ▶ Supply chain and logistics constraints, inflexible labor laws and limited focus on exports are others issues that need to be addressed to boost electronics manufacturing in the country.
- ▶ India is one of the leaders among the sample set of countries in producing engineers equipped with the requisite skills for electronics production. The country's abundant talent pool and resources can be utilized to produce high-value products; thus, domestic value addition may be encouraged and incentivized. Talent-pool benchmarking has been detailed in Chapter 2.
- ▶ The GoI should encourage products specifically designed for India. The developmental sector can benefit from biometric readers, smart meters, micro-payment devices, and low-cost medical devices.
- ▶ Improvements in these factors are likely to help local manufacturers compete with the prices of imported finished goods.

1.c. Semiconductor design companies

The number of fabless semiconductor design units is a direct indicator of a semiconductor design sector's maturity in any given country.

Exhibit 6 depicts the number of semiconductor design units in various countries.

Exhibit 6: Semiconductor design companies



Source: Multiple; refer references on page 124

Key observations

- ▶ The US leads the sample set with the highest number of design units. The country has 507 design units.
- ▶ China is a close second with 472 design units.
- ▶ India ranks fifth among the sample set countries, with around 120 design units in operation.

Takeaways for India

- ▶ Taiwan, which has adopted a cluster-based approach, is home to more design companies than India, as it has a well-developed semiconductor ecosystem with fabrication, assembly testing and packaging (ATP) units, along with design units. The section on geographic concentration or fragmentation of the semiconductor industry discusses semiconductor clusters in the sample set of countries.
- ▶ Several global integrated device manufacturers (IDMs) have set up captive design centers in India in the past decade. Several IDMs have also started outsourcing projects to third-party design houses in India. This has led to the establishment of a large number of independent design houses in India in the past decade.
- ▶ India needs to encourage the establishment of fabrication units and ATP companies, since the development of an entire semiconductor ecosystem may also give an impetus to the establishment of design units in the country.



1.d. Geographic concentration/fragmentation of design industry

Geographic concentration/fragmentation is an indicator of how semiconductor design activities across the country are distributed. High fragmentation implies that design centers are dispersed throughout the country. A cluster-based approach tends to be more successful, as it focuses on linkages and interdependence between companies while producing products and services and creating innovations.

Cluster formation captures interdependencies as well as economies of scale and scope. It reduces transaction costs, results in the development of new skills and speeds up learning processes.

Some countries in the sample set have well-defined semiconductor clusters, which include integrated circuit (IC) design companies, fabrication units, and packaging and testing companies, all under one roof. This allows for competition as well as cooperation and integration, which facilitate the overall development of the industry.

Exhibit 7 lists the regions where the majority of semiconductor design activity in each country is conducted.

Exhibit 7

Country	Semiconductor design activity in cities/clusters
India	The majority of semiconductor design centers are spread across Bengaluru, the National Capital Region (NCR), Hyderabad and Pune.
China	China has more than 100 "high-technology parks" scattered throughout the country. Relatively large and more concentrated clusters are emerging in Zhangjiang, Suzhou and Beijing.
Taiwan	The country's semiconductor cluster is located in Hsinchu Science Park near Taipei. Nankang Software Park also has an IC design park.
UK	Several fabless semiconductor players, especially start-ups, have a presence in Southwest England – Bristol, Bath, Plymouth and Gloucester. Oxford, Southampton and Surrey in Southeast England are focused on application engineering and hardware design in the semiconductor ecosystem. Cambridge in East England has a healthy number of semiconductor design companies focused on device- and application-based markets.
Sweden	Stockholm, Lund, Göteborg and Linköping are four clusters in Sweden with the highest concentration of the semiconductor industry.
US	Semiconductor clusters in the US are located in Silicon Valley, Texas, New Mexico and Arizona.
Israel	Semiconductor design units can be found in Tel Aviv, Haifa, Herzliya, Migdal Ha'emeq, Holon, Beer Sheva and Dimona.
Germany	Semiconductor clusters in Germany are located in Dresden, Dortmund, Munich, Berlin and Hamburg.

Source: Multiple; refer references on page 124



Case study: the Cambridge cluster

"Silicon Fen," as the cluster is popularly known as, is located in the Cambridge region in East England. High-technology companies engaged in electronics and software have a strong presence in this cluster. Silicon Fen has several semiconductor design companies that focus on device- and application-based markets. The cluster came into existence in 1970s, when a large number of high-technology spin-offs from the University of Cambridge established businesses to meet the growing international demand for high-tech output. In the 1980s, this cluster produced more patents per capita than the UK average. Subsequently, the cluster grew rapidly along with the emergence of computer services firms and companies involved in R&D.

Its proximity to the University of Cambridge has been cited as the prime reason behind its development. The university is a major source of highly skilled and qualified manpower. The availability of competitive manpower addresses the need of the semiconductor sector, which is highly knowledge-intensive. High-technology companies located in the cluster collaborate with related departments at the University of Cambridge for R&D activities by setting up research laboratories on campus. Easy access to finance is another important factor. Venture capital firms and local intermediaries provide financial assistance to firms situated in the cluster. The university remains a breeding ground for several technology start-ups, which set up their operations in the cluster. A combination of all these reasons has led to the formation of a well-established semiconductor industry in this part of the UK.

Takeaways for India

- ▶ India can learn from China and Taiwan, where the respective governments have promoted the formation of a semiconductor ecosystem through a cluster-based approach. This has led to the rapid development of captive and independent design centers in these countries, due to which they are ahead of India in terms of number of design units.
- ▶ The GoI needs to take steps to develop fabrication and ATP units in the country. The creation of clusters hosting the entire value chain of the semiconductor sector needs to be promoted in order to facilitate consolidation and overall industry development.



Industry dynamics: summary

The Indian semiconductor design sector is fairly developed, with around 120 design units. The country is ranked second among the sample set of countries in terms of design revenues. Several global integrated device manufacturers (IDMs) have set up captive design centers in India in the past decade.

Bengaluru, Hyderabad, Pune and the NCR collectively account for the majority of semiconductor design activity in India. India can give further impetus to this industry by drawing from industry experience in Taiwan and China, countries that have adopted a cluster-based approach and developed a mature semiconductor ecosystem with fabrication and ATP units to complement design units.

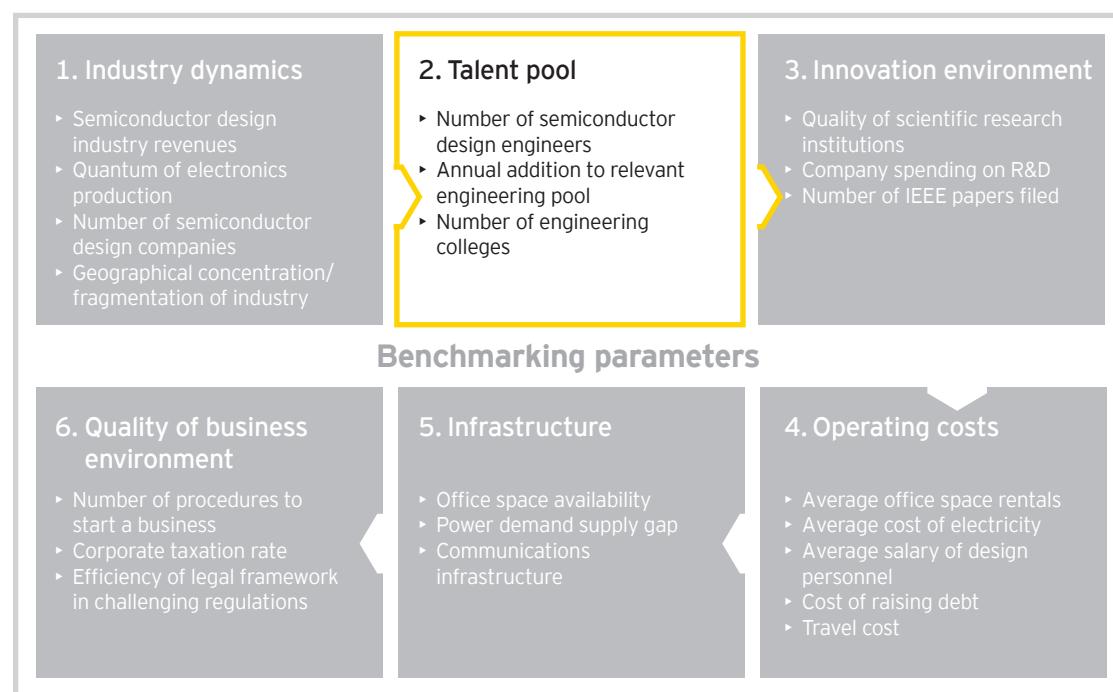
The rapidly growing electronics market in India has resulted in increased demand for semiconductor components. As such, the electronics industry is expected to serve as one of the primary growth drivers of the country's semiconductor industry in future.



2. Talent pool

This chapter focuses on the second benchmarking parameter – talent pool.

Exhibit 8



The talent pool parameter represents the number of engineers currently employed in semiconductor design. The category also includes the annual addition to the relevant engineering pool. Relevant engineers are those, who are qualified in electrical design, electronics, telecommunications, computer engineering or electronic design.

The benchmarking parameters considered in this category are:

- Current size of the relevant engineering talent in semiconductor design (Bachelor's degree and above)
- Number of relevant engineering degrees awarded per year (Bachelor's degree and above)
- Number of technical institutes that offer engineering degrees

These parameters are indicators of the current supply of talent for the semiconductor sector as well as of the potential for future scalability.

The majority of talent pool data has been collected from websites of government education departments and statistical databases of countries in the sample set.

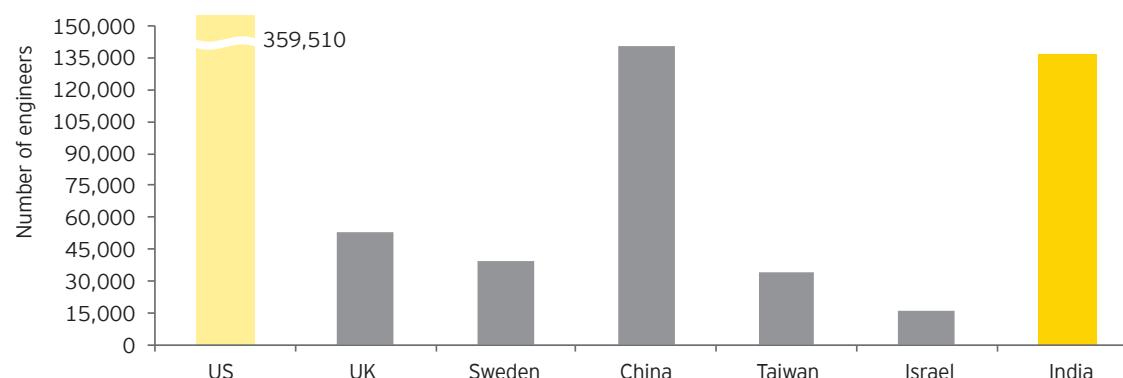
2.a. Size of the relevant engineering pool in semiconductor design

The number of engineers working in semiconductor design is an indicator of development of design sector in the country.

Exhibit 9 compares the sample set countries on the basis of number of engineers currently employed in semiconductor design sector in the country.

Key observations

Exhibit 9: Size of the relevant engineering pool in semiconductor design



Source: Multiple; refer references on page 125

- ▶ The US has the largest number of engineers employed in the semiconductor design sector among the sample set countries.
- ▶ Israel, with 15,343 engineers employed in the design sector, ranks last on this parameter in the sample set.
- ▶ With 135,404 engineers in its design sector, India ranks third among the sample set of countries.

Takeaways for India

- ▶ Around 5% of the total engineering pool in India is employed in semiconductor design, indicating a strong base of skilled design professionals in the country.
- ▶ The return of experienced expatriate Indian professionals to the country has resulted in strengthening of talent base in India, thus fortifying India's position in the global semiconductor design industry.

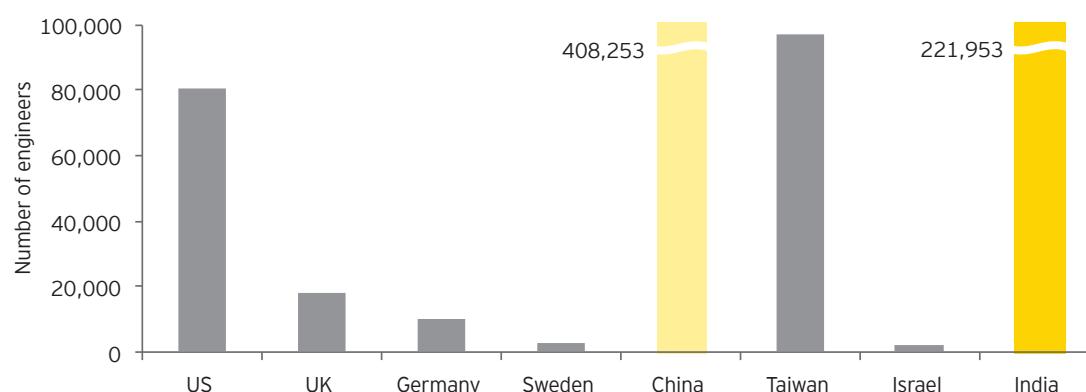


2.b. Supply of relevant engineers every year

Semiconductor design is a highly knowledge-intensive sector that requires skilled workforce. The supply of relevant engineers is an indicator of a country's ability to produce engineers with the requisite skill sets for the semiconductor design sector.

Exhibit 10 compares the sample set of countries on the basis of annual addition of engineers relevant to semiconductor design sector to the total pool in the country.

■ Exhibit 10: Supply of relevant engineers every year



Source: Multiple; refer references on page 125

Key observations

- ▶ China produces nearly 408,253 engineers with skills relevant for the semiconductor design sector. The country ranks first among the sample set countries on this parameter.
- ▶ Israel produces 2,367 engineers every year and ranks last in the sample set on this parameter.
- ▶ Producing around 221,953 engineers graduating each year with relevant degrees, India ranks second on this parameter.

Takeaways for India

- ▶ Exhibit 10 indicates that within the sample set, India is among the best-placed countries in terms of future scalability of relevant talent.
- ▶ India is also well-placed in terms of the proportion of relevant engineers with respect to total engineers, since close to 61% of engineers produced every year in the country are equipped with skills relevant for the semiconductor design sector. Only Taiwan is ahead of India in terms of this proportion, as approximately 79% of engineers graduating every year in this country are relevant for the design sector.
- ▶ Therefore, India is one of the leading countries in terms of the potential it offers through its supply of engineers equipped with relevant skills for the sector.

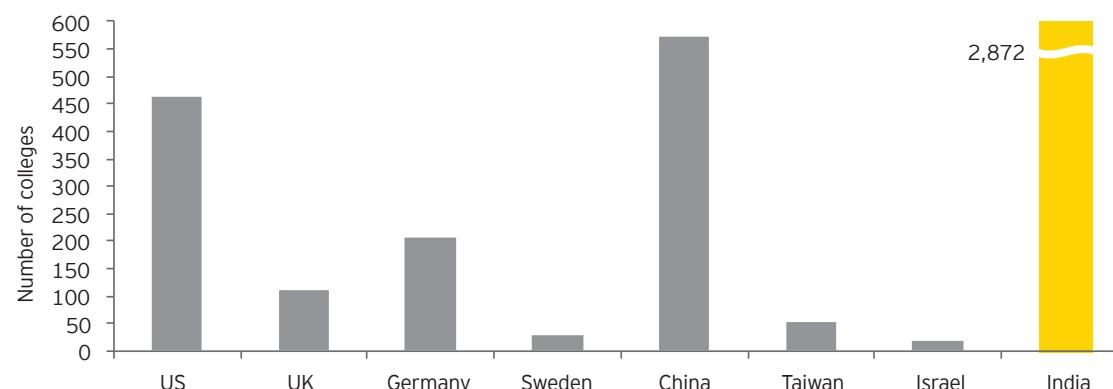


2.c. Number of technical institutes

The number of technical institutes in a country reflects the country's ability to produce engineering graduates each year. The higher the number of engineering colleges, the higher is the number of professionals produced every year, equipped with requisite skills for semiconductor design.

Exhibit 11 compares the sample set of countries on the basis of the number of institutions that provide engineering education.

■ Exhibit 11: Number of technical institutes per country



Source: Multiple; refer references on page 126

Key observations

- ▶ With 2,872 engineering colleges in the country, India scores the highest on this parameter in the sample set.
- ▶ Israel ranks last among the sample set of countries as it has only 17 universities and colleges that offer engineering degrees.

Takeaways for India

- ▶ India has the highest number of engineering colleges among the sample set of countries. The country produces the second-highest number of engineering graduates among the sample set.
- ▶ In India infrastructure for technical education is poised on unprecedented growth as a result of several initiatives. These include the recent establishment of 8 new Indian Institutes of Technology (IITs) and the Eleventh Five Year Plan's vision to set up 10 new National Institutes of Technology (NITs), 3 Indian Institutes of Science Education & Research (IISERs) and 20 Indian Institutes of Information Technology (IIITs).



Talent pool: summary

India is a strong performer on the parameters of current and future availability of engineering talent. The country features among the top three in the sample set in terms of engineers employed in the semiconductor design sector as well as relevant degree graduates being produced each year.

India also has the highest number of engineering colleges among the sample set of countries. Consequently, it is among the leading countries in the sample set in terms of the number of engineers that graduate in the country each year. The growing number of engineering colleges in India is expected to increase the number of skilled graduates. The country has the second-highest proportion of relevant engineers with respect to total engineers graduating annually.

Therefore, from the current availability and scalability perspective, and considering the strengthening of its talent pool following the return of expatriates, India is among the best-placed countries for semiconductor design.

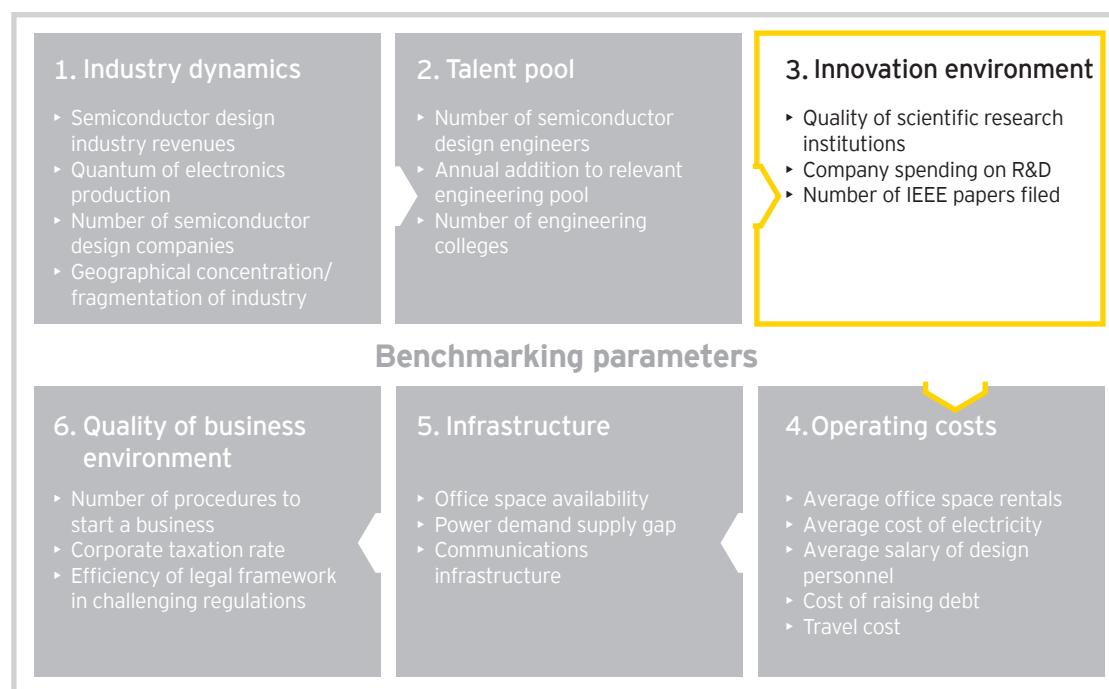




3. Innovation environment

This chapter focuses on the third benchmarking parameter – innovation environment.

■ Exhibit 12



The implementation of several innovative activities is a reflection of the innovative quality of a country's environment. This category deals with a country's innovation capabilities.

The benchmarking parameters used in this category are:

- Quality of scientific research institutions
- Company spending on R&D
- Number of IEEE papers submitted

The information on these parameters has been collected from the World Economic Forum (WEF)'s Global Competitiveness Report 2010-2011. The comparison on the parameters above reflects a country's overall innovation environment, and is not specific to the semiconductor design sector.

3.a. Research and development

Companies need to design and develop innovative products and processes to create and sustain competitive advantage. This requires investment in R&D and collaboration between universities and the industry for research.

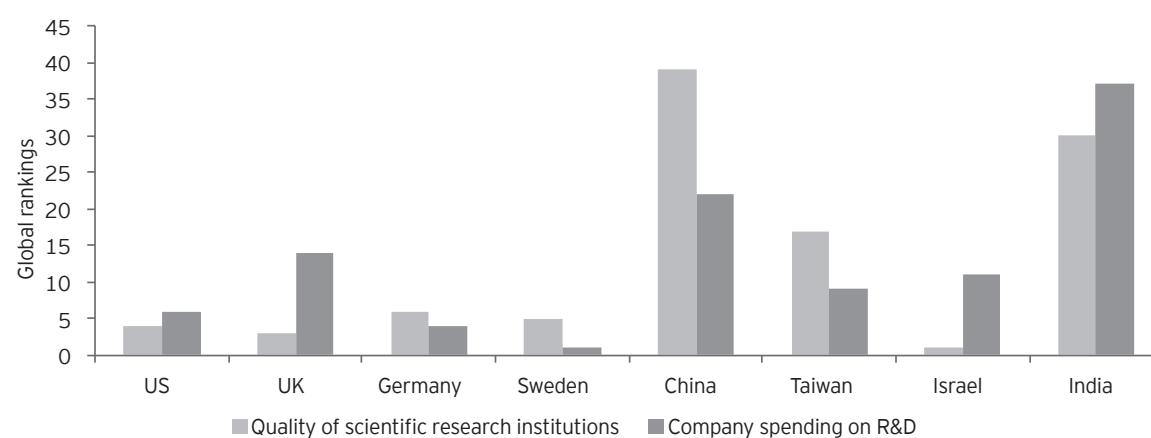
The presence of high-quality research institutes facilitates R&D activity in a country by making available the requisite resources for the development of new technologies.

The benchmarking of countries to indicate their research and development environment has been done on the following parameters:

- ▶ Quality of scientific research institutions
- ▶ Company spending on R&D

Exhibit 13 depicts the rankings of the countries on the parameters mentioned above.

Exhibit 13: Global rankings on research and development environment parameters



Source: Multiple; refer references on page 126

A high ranking on the quality of scientific research institutions parameter indicates that the institutes are regarded as best in their category internationally.

The countries where companies spend more money on R&D activities are ranked higher than others in the sample set.

Key observations

Quality of scientific research institutes:

- ▶ Israel is the best-ranked country in the sample set as well as globally in terms of quality of scientific research institutes.
- ▶ China, with a global rank of 39, ranks last among the sample set of countries.
- ▶ India, with a global rank of 30, ranks seventh in the sample set.



Company spending on R&D:

- ▶ Sweden ranks the highest among the sample set of countries as well as globally in terms of company spending on R&D.
- ▶ India, with a global rank of 37, ranks last among the sample set of countries.

Takeaways for India

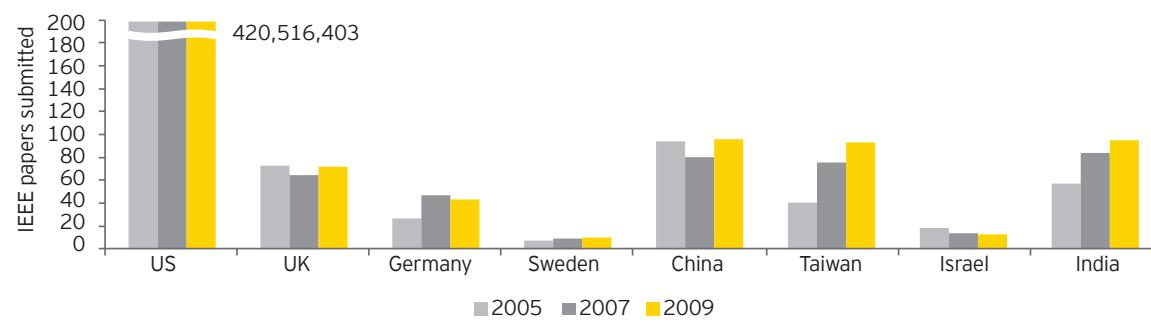
- ▶ India provides companies with a favorable environment in which to set up R&D facilities. Global MNCs such as General Electric (GE) have established their research centers in the country. GE's John F Welch Technology Centre, which was established in Bengaluru in 2000, is one of the company's first R&D facilities outside the US. Since its operational inception, the center has filed around 180 patents.
- ▶ Leading companies in the semiconductor industry have also set up their captive centers in the country to conduct R&D activities. The number of patents filed by India operations of companies such as Texas Instruments (TI), ST Microelectronics (STM), Intel and Broadcom Corporation between 2005 and 2009 is 181, 120, 54 and 51, respectively.
- ▶ The R&D talent pool of MNCs in India has also seen rapid growth in the past decade. The number of MNC employees working at their respective R&D centers in India has increased from 16,000 in 2000 to 180,000 in 2009, growing at a CAGR of 30.9%. This number is further expected to grow at a CAGR of 10% to reach 319,000 in 2015. On the other hand, China also had approximately 16,000 MNC personnel employed at R&D centers in 2000. This has increased to 130,000 in 2009, growing at a CAGR of approximately 26%. Thus, India is ahead of China in terms of the R&D initiatives that MNCs in the countries are adopting.
- ▶ India lags behind other countries in the sample set in terms of company spending on R&D activities. Although the GoI provides certain tax exemptions on R&D expenditure by companies, it needs to provide more incentives to encourage companies to spend more on R&D.
- ▶ India also needs to improve the quality of research institutions in order to remain an attractive destination for MNCs wanting to conduct R&D activities in the country.

3.b. Number of IEEE papers submitted

The number of IEEE papers submitted reflects the country's ability to conduct research and innovate new designs for the semiconductor industry. High number of IEEE papers filed from a country indicates a greater level of involvement in innovation activities.

Exhibit 14 compares the sample set of countries on the basis of the number of IEEE papers filed from a country. The statistics on IEEE papers are sourced from the IEEE societies of computer, software, design and test of computers, transaction on computers and software engineering.

■ Exhibit 14: Number of IEEE papers submitted



Source: IEEE

Key observations

- ▶ The US ranks first on this parameter with the highest number of IEEE papers submitted for 2005, 2007 and 2009, respectively.
- ▶ Number of IEEE papers filed from Sweden is 7, 9 and 10 for 2005, 2007 and 2009, respectively. The country ranks last on this parameter.
- ▶ In India, the number of IEEE papers is 57, 84 and 95 for 2005, 2007 and 2009, respectively. In terms of 2009 rankings among sample set countries, India is ranked third after the US and China.

Takeaways for India

- ▶ The number of papers submitted from India has grown from 57 in 2005 to 95 in 2009, indicating an absolute growth rate of 66.6% in four years. India is ranked higher than all the other countries except Taiwan in terms of this growth rate.
- ▶ India's share in terms of world submission of IEEE papers has also increased from 4.9% in 2005 to 6% in 2009 indicating a higher level of research activities being carried out in the country.
- ▶ Although the above figures indicate the submission of IEEE papers, India needs to improve the acceptance rates of papers submitted. In 2010, acceptance rate of India's papers was 4.5%, which is very low as compared to countries such as the US, the UK and Germany, which have acceptance rates of 37.6%, 34.2% and 21.7%, respectively. This indicates a relative lack of quality in research work carried out in India.



Innovation environment: summary

The innovation environment in India is evolving rapidly, and the country is becoming one of the prime destinations for companies seeking to establish R&D centers outside their home country. India's availability of skilled talent and high-quality scientific research institutes are primary reasons for its growing reputation as an attractive country for the establishment of R&D centers. A number of Indian captives of global semiconductor companies file patents every year, which indicates the level of IP being created.

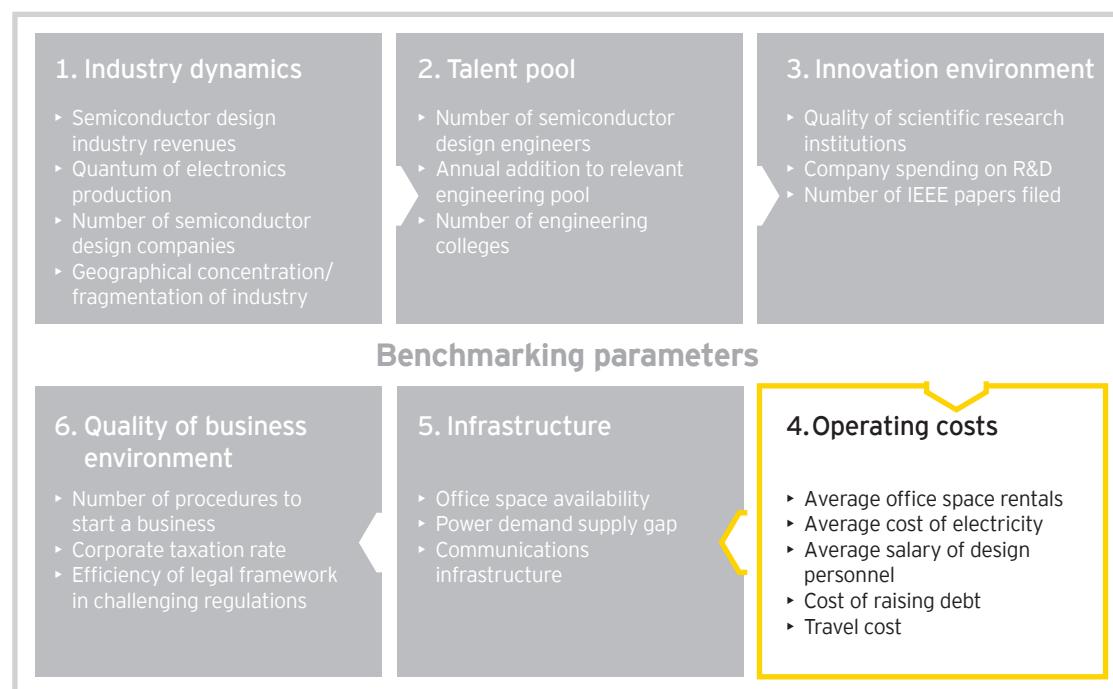
The country also ranks favorably in terms of the number of IEEE papers filed from the country in the fields relevant for semiconductor design. Since India lags behind other countries in the sample set in terms of company spending on R&D, the GoI needs to provide more incentives to encourage R&D activity in India.



4. Operating costs

This chapter focuses on the fourth benchmarking parameter – operating costs.

Exhibit 15



Operating costs for semiconductor design units include salaries of semiconductor design professionals, electricity costs, office space rent, the cost of bandwidth and design tools, and miscellaneous expenses. For the purpose of this benchmarking study, the cost of design tools has not been taken into account, since it is almost standard across the globe for a given multinational semiconductor company. This is because companies purchase global licenses for tools, which can be used by their design centers in different time zones. The benchmarking parameters analyzed in this category are:

- Average annual rentals of office space
- Average cost of electricity
- Average annual salary of semiconductor design personnel
- Cost of raising debt
- Travel costs

Information on office space rentals has been collected using research reports published by global real estate consulting majors such as Jones Lang Lasalle and CB Richard Ellis.

The majority of the data on electricity tariffs has been collected from websites of government energy departments and statistical databases of countries in the sample set.

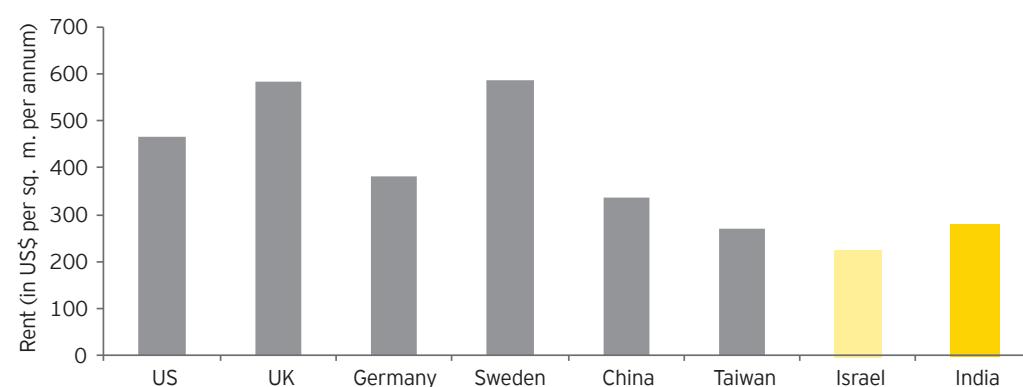
Data on prime lending rates for most of the countries has been obtained from the websites of central banks of the respective countries.

4.a. Annual average office space rentals

The amount of rent that companies pay for office space constitutes a major chunk of companies' operating costs. The countries that offer high-quality office space at relatively low rent are seen as favorable business destinations.

Exhibit 16 depicts the comparison between countries on the basis of average annual rentals of Grade A office space in terms of US\$ per sq. m. per annum. The rentals are for office space in central business districts (CBD) and suburban business districts (SBD) in important cities in each country. The average has been computed by providing 80% weight to rentals at low-cost locations and 20% weight to rentals at high-cost locations within a country.

Exhibit 16: Annual average office space rentals



Source: Multiple; refer references on page 126

Key observations

- ▶ Israel ranks the highest on this parameter, with average annual rentals of US\$224 per sq. m. per annum.
- ▶ With US\$587 per sq. m. per annum, Sweden is home to the costliest office spaces.
- ▶ Other developed countries such as the US and the UK also rank low on this parameter.
- ▶ India, with US\$278 average annual rentals for Grade A office space, has one of the lowest rentals among the sample set of countries. It ranks third on this parameter, closely following Taiwan, where rentals are US\$271 per sq. m. per annum.

Takeaways for India

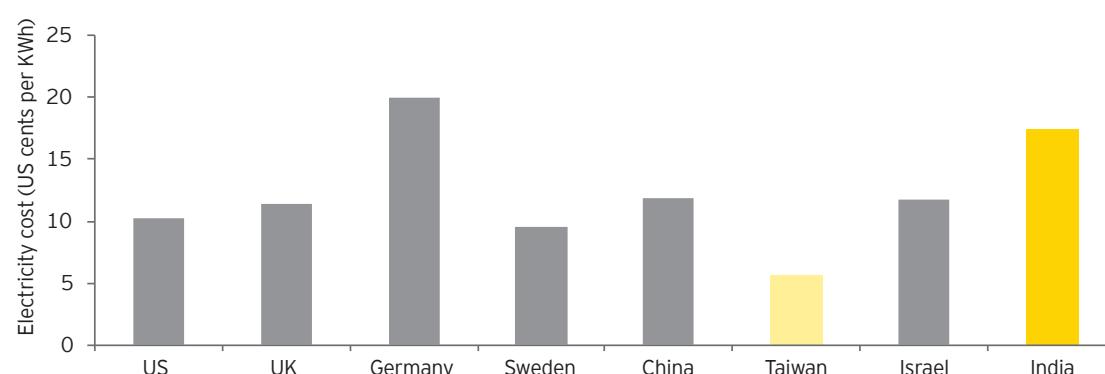
- ▶ India performs well on this parameter, and with nearly 21 million sq. ft. of Grade A office space expected to be developed in the next one year in major cities and a high current vacancy rate, average annual rentals in India are expected to remain low vis-à-vis other countries in the sample set. Chapter 5.a. details the benchmarking of countries on the availability of office space.

4.b. Average cost of electricity

Electricity costs constitute an important constituent of operational cost, but assume less significance, since semiconductor design is not power intensive.

Exhibit 17 represents average cost of electricity per unit (1 unit = 1 Kilowatt hour) in US cents for commercial consumers in a country.

■ Exhibit 17: Average cost of electricity



Source: Multiple; refer references on page 127

Key observations

- ▶ With the lowest per unit cost of electricity among the sample set of countries, Taiwan ranks first on this parameter.
- ▶ Germany, where commercial customers pay approximately US\$0.20 per unit for electricity ranks last.
- ▶ India ranks seventh on this parameter ahead of Germany. Commercial customers in India pay around US\$0.17 per unit of electricity.

Takeaways for India

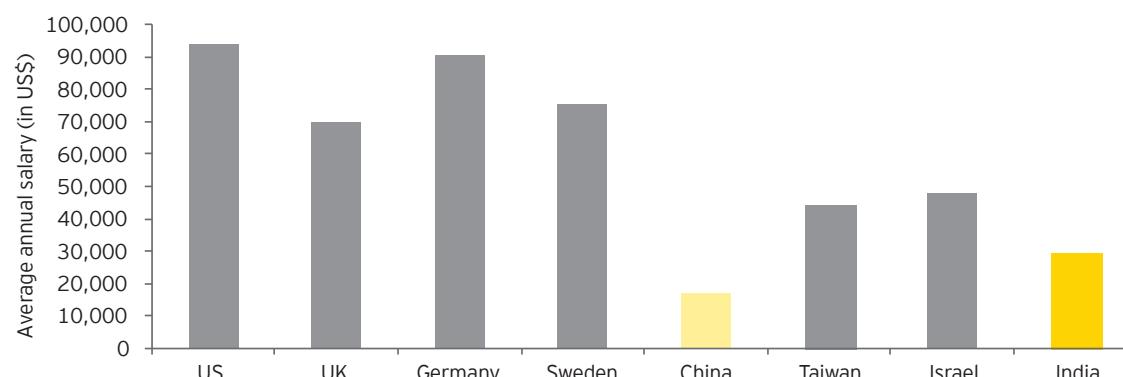
- ▶ Apart from being a power-deficit nation, India has one of the highest per unit costs among the sample set of countries.
- ▶ Although the semiconductor design sector is not power-intensive, low electricity costs help reduce overall operating costs for companies, therefore enhancing a country's cost-competitive edge.

4.c. Average annual salaries of semiconductor design personnel

The semiconductor design sector requires a highly skilled and trained workforce. Human resource costs, thus, constitute a major expense for semiconductor design companies, as skilled personnel come at relatively low salaries.

Exhibit 18 compares the countries on the basis of average salaries of semiconductor design professionals in terms of US\$ per annum.

■ **Exhibit 18: Average annual salary of semiconductor design personnel**



Source: Multiple; refer references on page 127

Key observations

- ▶ With annual compensation of around US\$16,900, semiconductor design professionals employed in China draw the lowest salaries among the sample set of countries.
- ▶ Average annual salaries of semiconductor design professionals working in the US are the highest. The estimated figure is around US\$93,669.
- ▶ Other developed countries also have much higher levels of salary as compared to developing countries.
- ▶ The average salary cost in India is US\$29,246, which places the country second among the sample set of countries.

Takeaways for India

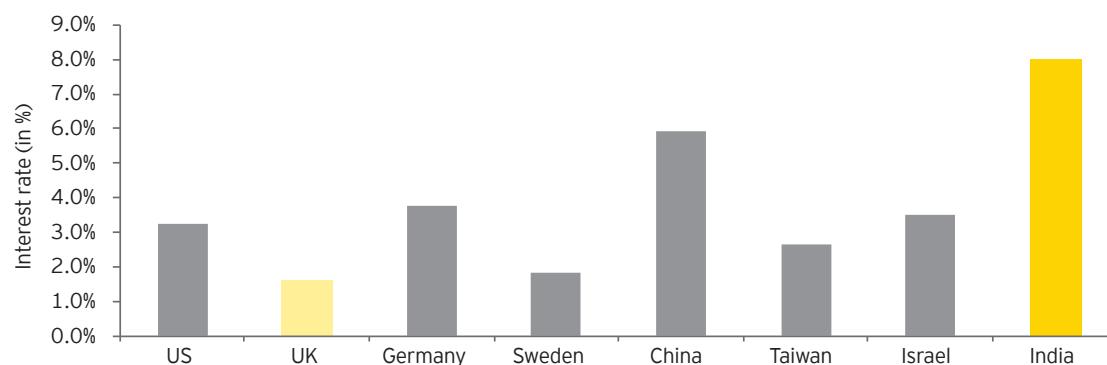
- ▶ India performs very well in terms of salaries of semiconductor design professionals. Average salaries in India are higher than in China but significantly lower than all the developed countries in the sample set.
- ▶ With a large number of skilled graduates being produced in India every year, the country is expected to maintain this talent cost advantage in future. Benchmarking on the number of relevant engineers produced in a country has been discussed in Chapter 2.b.

4.d. Cost of raising debt

New businesses require adequate funding from different sources to establish their operations. The cost of raising debt from banks affects the profitability of businesses, as interest costs may constitute one of the major cost components for startups. The higher the interest cost in a country, the lower is the incentive to set up a new business.

Exhibit 19 compares the sample set of countries on the basis of the prime lending rates offered by commercial banks in the country. Prime lending rate is the underlying index that banks use to determine the interest rate they offer to their customers on the basis of their credit rating.

■ Exhibit 19: Prime lending rates offered by commercial banks



Source: Multiple; refer references on page 127

Key observations

- ▶ The UK ranks first on this parameter, with the lowest interest cost in the sample set.
- ▶ Banks in India offer a base interest rate of around 8%, which is highest among the sample set of countries. Therefore, the country ranks last on this parameter.

Takeaways for India

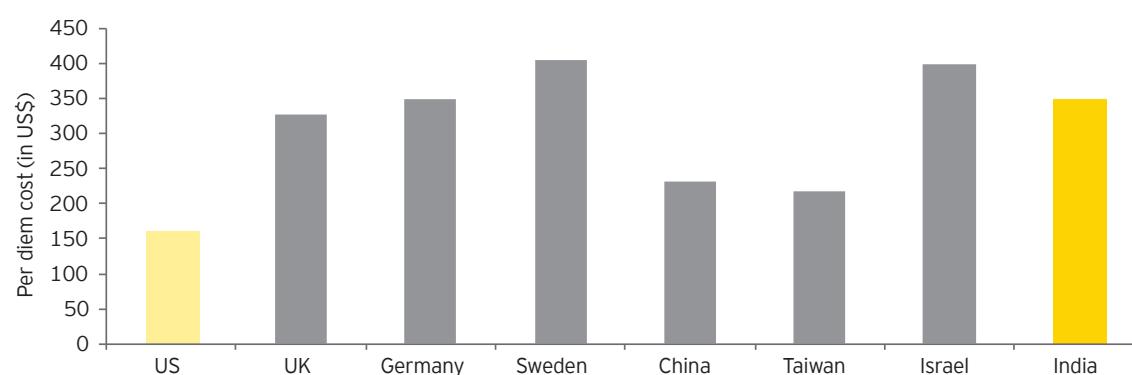
- ▶ High interest cost is a deterrent for new businesses seeking to initiate operations. Commercial banks in India should encourage start-ups by reducing the thrust on collateral security and offering loan on more liberal terms.
- ▶ Banks in India also need to streamline their credit-appraisal process to reduce the time to sanction loans and, thus, enhance the ease of obtaining loans.

4.e. Travel cost

Travel cost is an important parameter under consideration, because employees of multinational companies are required to travel to different countries across the world for business-related activities. Travel cost has been estimated by taking the average of per diem rates in major cities of a country. This rate covers lodging, meals and incidental expenses.

Exhibit 20 compares per diem rates across sample set countries.

■ Exhibit 20: Per diem rate



Source: Multiple; refer references on page 128

Key observations

- ▶ The US ranks first on this parameter, with the lowest per diem rate of US\$159 in the sample set of countries.
- ▶ Sweden, with the highest per diem rate of US\$404, ranks last among the sample set of countries.
- ▶ India ranks fourth on this parameter, closely behind Germany, with an average per diem rate of US\$349.

Takeaways for India

- ▶ India is an expensive business destination in terms of travel charges as compared to other developing countries such as China and Taiwan.
- ▶ The high charges of business hotels and costly local travel are major components leading to India's high value of per diem charges.



Operating costs: summary

India is highly competitive in terms of two major components of operating costs for businesses. Salary cost forms the major component of operating costs for design companies. Grade A office space rentals in India are among the lowest in the sample set of countries. A high ranking on these parameters makes India an attractive destination for the establishment of captive design units by companies in the US and Europe.

The cost of raising debt in India is the highest among the sample set of countries. Interest cost is not an important parameter from the perspective of captives, since these are generally cost centers; however, it is very important for new business start-ups. Travel costs in India are high as compared to developing nations such as China and Taiwan.

The cost of electricity is also high in India but it is not a major cause for concern, since the semiconductor design sector is not power-intensive.

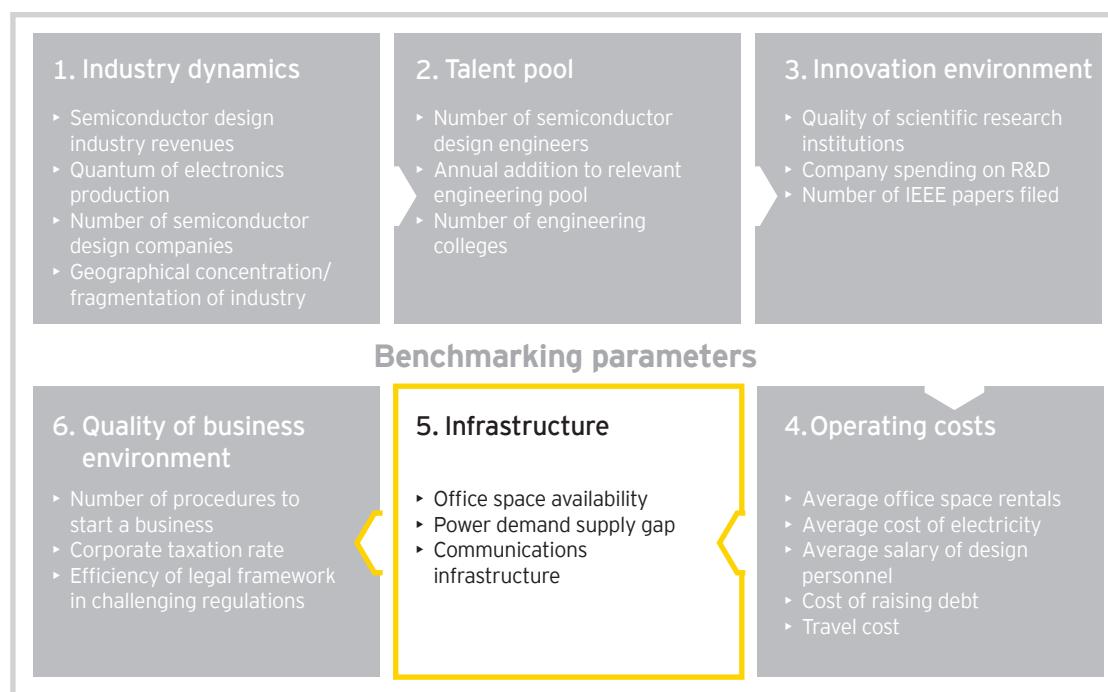




5. Infrastructure

This chapter focuses on the fifth benchmarking parameter – infrastructure.

■ Exhibit 21



The availability of quality physical infrastructure is important for the efficient working of any business in a country. It includes quality office space, adequate international internet bandwidth, reliable supply of electricity and sound connectivity with developed markets.

The benchmarking parameters in this category are:

- ▶ Future availability of Grade A-quality office space
- ▶ Demand-supply gap in power
- ▶ Availability of communications infrastructure

Data on office space has been collected using research reports published by global real estate consulting majors.

The majority of electricity statistics has been collected from the websites of government energy departments and statistical databases of countries in the sample set.

The quality of overall infrastructure rating has been obtained from the WEF's *Global Competitiveness Report 2010-2011*.



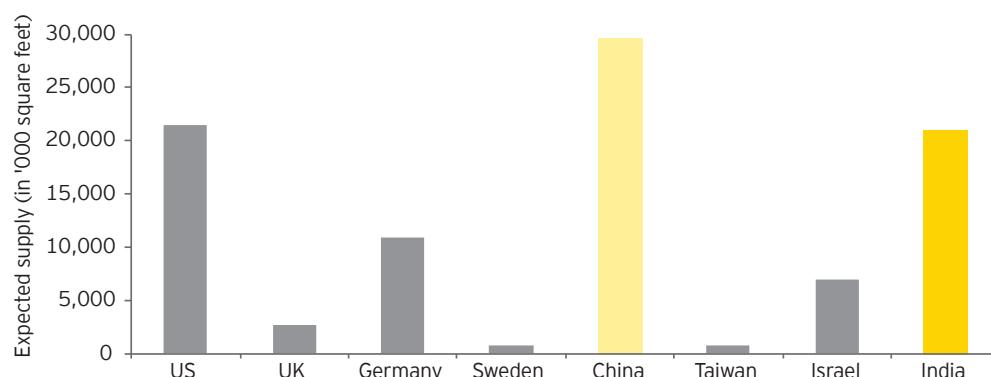
5.a. Future availability of Grade A office space

Companies looking to establish business in a country require quality office space with adequate facilities to conduct their operations.

Grade A office space consists of buildings that are newly constructed or recently redeveloped at prime locations in major cities. These offices boast of high-quality furnishings, the latest facilities, and excellent accessibility. Thus, these are the most sought-after locations for multinational companies looking to establish offices.

Exhibit 22 compares the future availability of Grade A-quality office space in each country across key cities. Expected supply takes into account new construction that is currently in progress and is expected to be completed in the next one year in major cities across the country.

■ Exhibit 22: Future availability of Grade A office space



Source: Multiple; refer references on page 128

Key observations

- ▶ In terms of future availability of office space, China and the US are the leading countries with a significant pipeline of upcoming office infrastructure.
- ▶ Taiwan, followed by Sweden, has the smallest pipeline of new office space.
- ▶ There is a major pipeline of Grade A office space planned for India, with around 21 million sq. ft. to be added in the next one year. The country ranks third after China and the US in terms of future availability of high-quality office space.

Takeaways for India

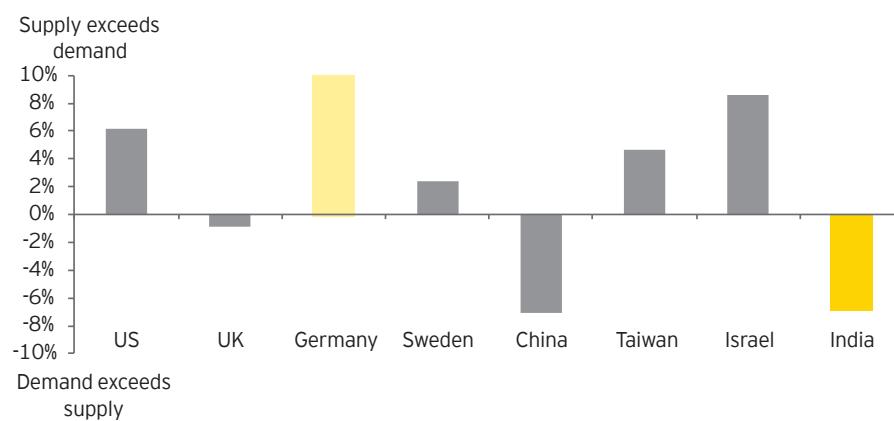
- ▶ The fast pace of economic development, leading to the establishment of new businesses and rapid expansion by existing companies, is a prime factor for such rapid development of office space infrastructure.
- ▶ Mumbai and Bengaluru are the leading cities in India in terms of current and future availability of Grade A office space.

5.b. Power demand-supply gap

Power is an important infrastructure parameter, as companies do not consider countries with power deficit as attractive investment locations to set up operations. Businesses operating in such countries have to invest in power backup infrastructure, which increases set-up and operating costs.

Exhibit 23 compares the power demand and supply situation between countries in the sample set.

■ Exhibit 23: Power demand-supply gap



Source: Multiple; refer references on page 128

Key observations

- ▶ Germany leads the sample set of countries in terms of the demand-supply scenario, with approximately 10% excess power generation as compared to demand.
- ▶ China ranks last on this parameter, with around 7% deficiency in supply.
- ▶ Among developed countries, the UK is the only country that is power deficient, and meets its demand through import of electricity.
- ▶ India faces a power deficit of 6.85% and features among the lowest ranks on this parameter. However, India performs slightly better than China, which faces a similar demand-supply gap.

Takeaways for India

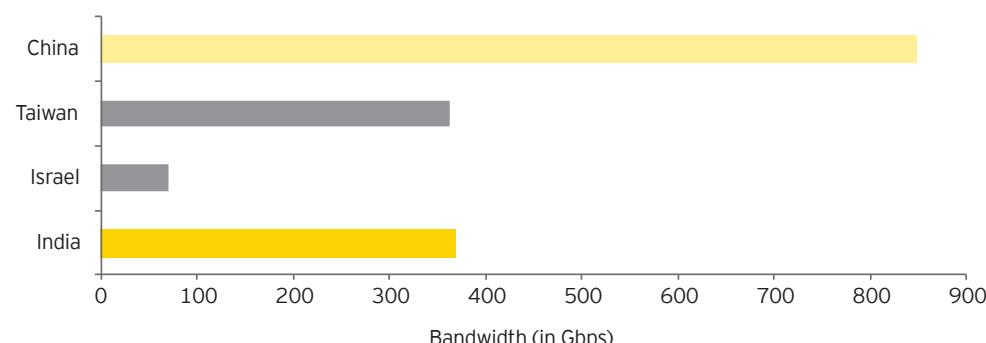
- ▶ The electricity supply situation has improved in India over the years due to enhanced power-generation capacity and the entry of several private players in the power generation sector.
- ▶ Power-generation capacity in India is currently around 162,367 MW.
- ▶ The power demand-supply gap is expected to reduce further in future on account of several power projects in the pipeline.
- ▶ Although the semiconductor design sector is not power-intensive, India still needs to tackle outages from time to time in major cities by improving power-distribution infrastructure.
- ▶ Assured and uninterrupted power supply is likely to reduce the cost of investing in back-up sources.

5.c. Availability of communications infrastructure

Communications infrastructure in a country is an indicator of the country's international connectivity. Developing nations are home to several captive design centers of US- and Europe-based companies. As a result, they require high-quality international connectivity. Further, developed nations possess quality infrastructure with sufficiently high bandwidth. Therefore, this parameter is more important from the perspective of developing nations as compared to developed nations.

Exhibit 24 compares developing nations on the basis of availability of communications infrastructure. This parameter has been measured using international internet bandwidth availability in each country. International internet bandwidth is the contracted capacity of international connections between countries for transmitting internet traffic.

Exhibit 24: Availability of communications infrastructure



Source: Multiple; refer references on page 129

Key observations

- ▶ China leads among the developing countries in the sample set with a bandwidth of 846 Gbps.
- ▶ Israel has the lowest bandwidth among the developing nations.
- ▶ India ranks second among the developing nations. Its bandwidth capacity of 368 Gbps is similar to that of Taiwan (363 Gbps).

Takeaways for India

- ▶ India has made rapid progress on this parameter over the years, and bandwidth is no longer a constraint.
- ▶ India now has ample bandwidth to provide companies with high-quality international connectivity.



Infrastructure: summary

Over the years, India has advanced rapidly in terms of quality infrastructure. The country's growing economy has led to the rapid expansion of businesses. This has resulted in the construction of new, high-quality office buildings and the development of special economic zones (SEZs) across the country. With a high vacancy rate, currently and a large number of constructions in the pipeline, India is well-poised to provide high-quality office space to companies that want to set up operations in India.

The power demand-supply gap in India has also improved over the years, although the country remains a power-deficient economy. With a number of private players entering the power-generation business, India's power-supply scenario is set to improve in future.

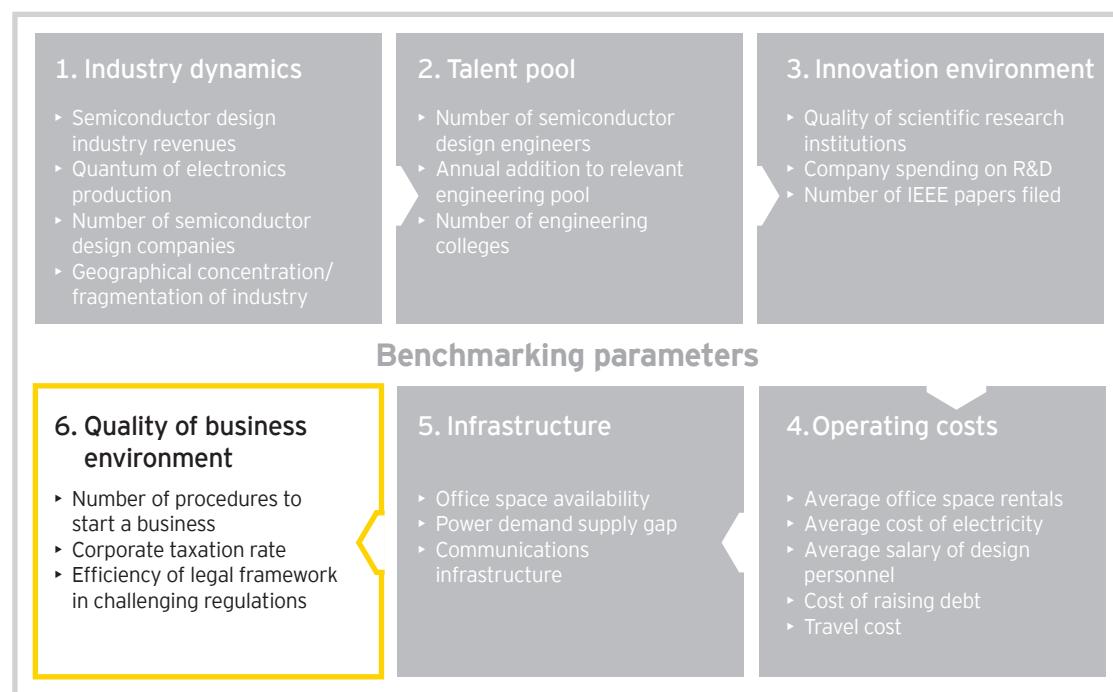
India has overcome its bandwidth constraints of the past and now has ample capacity to provide high-speed international connectivity to companies.



6. Quality of the business environment

This chapter focuses on the fourth benchmarking parameter – operating costs.

■ Exhibit 25



Quality of business environment determines the ease of doing business in a country.

Business environment includes factors such as the complexity involved in starting a new business and taxation rates in the country. IP rights protection is important to safeguard the rights and interests of businesses engaged in R&D. Since the semiconductor design industry involves substantial IP creation, it is very important that a country's legal framework is efficient enough to prevent IP-related thefts by implementing strict laws.

The benchmarking parameters used in this category are:

- ▶ Number of procedures required to start a business
- ▶ Corporate taxation rate
- ▶ Efficiency of the legal framework in challenging regulations

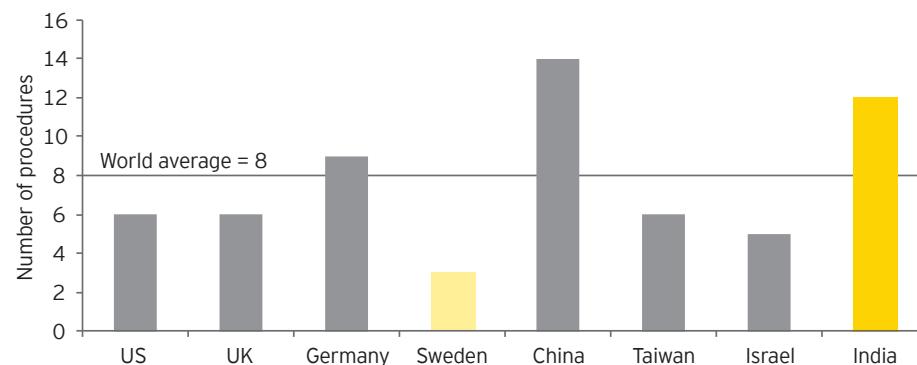
Information on these parameters has been collected from WEF's *Global Competitiveness Report 2010-2011* and the World Bank and International Finance Corporation (IFC)'s *Doing Business 2011* report by the World Bank. Information on the parameters and their comparison reflects the business environment in the countries as a whole, and is not specific to the semiconductor design sector.

6.a. Number of procedures to start a business

Legal regulations of a country require certain procedures to be completed to incorporate and register the new firm before it can start operations. Countries with efficient processes have a higher entry rate as they encourage entrepreneurs to set up businesses.

Exhibit 26 compares the countries in the sample set on the basis of number of procedures to start a business.

Exhibit 26: Number of procedures to start a business



Source: Doing Business 2011, World Bank, IFC and Palgrave MacMillan, October 2010

Key observations

- ▶ Sweden ranks the highest among the sample set of countries in terms of number of procedures to start a new business. Companies need to complete only three procedures to start a new business in Sweden.
- ▶ China requires 14 procedures to be completed before a new business can become operational. It ranks last on this parameter.
- ▶ India requires 12 procedures to be completed and, therefore, features among the lowest ranked on this parameter. It lags behind all countries in the sample set except China.
- ▶ According to Doing Business 2011, it takes 8 procedures on an average to start a business around the world. India lags behind the world average.

Takeaways for India

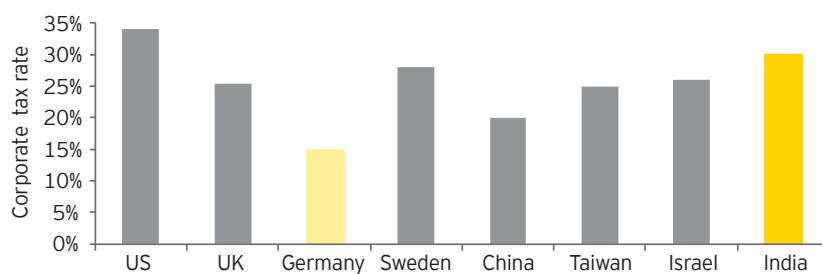
- ▶ Typical procedures in India include registering the company name with the Registrar of Companies (ROC), getting the company incorporated, making a seal, obtaining a permanent account number (PAN) and tax account number, and registering for Value Added Tax (VAT), professional tax, and employees provident fund organization (EPFO).
- ▶ India could improve on this parameter by implementing simpler and faster procedures. It can also work on transitioning some procedures online to decrease the time and complexities involved.

6.b. Corporate taxation rate

The competitiveness, investment and growth of businesses can be restricted by governments by imposing heavy taxes. High tax rates lower the profits of companies and are thus discouraging for businesses.

Exhibit 27 compares the statutory corporate taxation rate in each country.

■ Exhibit 27: Statutory corporate taxation rate



Source: Doing Business 2011, World Bank, IFC and Palgrave MacMillan, October 2010

Key observations

- ▶ Germany ranks the highest on this parameter, with a corporate taxation rate of 15%.
- ▶ The US, with a corporate taxation rate of 34%, ranks last on this parameter.
- ▶ With a 30% corporate tax rate, India has the highest rate among the developing countries in the sample set.



Takeaways for India

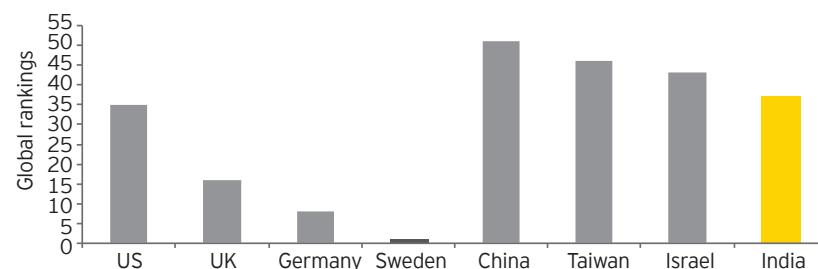
- ▶ Apart from corporate tax, companies are required to pay other taxes in all countries. These include turnover tax, labor taxes, personal income tax withheld by the company, VAT or sales tax, property tax, property transfer tax, dividend tax, capital gains tax, financial transactions tax, waste collection tax, vehicle and road taxes and other small taxes (such as stamp duty and local taxes).
- ▶ In India, the composition of other taxes is as follows (as % of gross profits):
 - ▶ Central Sales Tax (17.1%)
 - ▶ Social security contributions (13.5%)
 - ▶ Employee state insurance contribution (4.6%)
 - ▶ Property tax (3.3%)
 - ▶ Dividend tax (3.8%)
 - ▶ Fuel tax (0.4%)
 - ▶ Fringe benefit tax (0.1%)
 - ▶ Tax on insurance contracts (0.2%)
- ▶ In 2009–10, Israel and China reduced corporate income tax rates, thereby increasing their competitiveness by helping businesses to grow.
- ▶ Although corporate taxation in India is higher than that in other countries within the sample set, the GoI provides a number of tax incentives to companies setting up operations in SEZs and STPIs. As an example, companies engaged in the export of goods and services are eligible for 100% income tax exemption for the first five years of operations and 50% exemption for the next five years of operations.
- ▶ As discussed in Chapter 1 on industry dynamics, a stable tax structure needs to be in place in order to encourage companies to make long-term investments in the semiconductor design and electronics production sector.

6.c. Legal framework efficiency in challenging regulations

The legal framework of a country is important for the development of the country's innovation capabilities. Companies that possess IP are not likely to be willing to invest in innovation and R&D if their rights as IP owners are insecure. This requires a business environment that supports innovation. An efficient legal framework helps protect the companies' IP and settles disputes quickly and effectively. Therefore, it encourages companies to undertake more R&D activities.

Exhibit 28 depicts the rankings of the countries on the efficiency of the legal framework in challenging regulations. The more efficient is the country's legal framework for private businesses in challenging the legality of government actions and regulations, the higher is the country's ranking on this parameter.

Exhibit 28: Global rankings on efficiency of the legal framework in challenging regulations



Source: Global competitiveness report 2010-2011, The World Economic Forum

Key observations

- ▶ Sweden ranks best among the sample set of countries, as well as globally indicating a highly efficient framework in challenging regulations.
- ▶ China has a global rank of 51, and ranks last among the sample set of countries.
- ▶ With a global rank of 37, India ranks fifth in the sample set, ahead of China, Taiwan and Israel.



Takeaways for India

- ▶ India ranks higher than other developing countries in terms of its legal framework's efficiency in challenging government regulations.
- ▶ In terms of the IP protection scenario in India with respect to the semiconductor design sector, a discussion with semiconductor industry professionals in India indicates that companies largely consider the country to be ahead of China. IP protection laws for the semiconductor design sector are more stringent in India than in China.
- ▶ To be able to further drive innovation, India's IP protection regime needs improvement through the implementation of strict laws. The Semiconductor Integrated Circuits Layout Design (SICLD) Act, 2000 governs integrated circuit (IC) layout designs in India.
 - ▶ The act is aimed to protect IP rights for semiconductor IC design layouts.
 - ▶ Layout design shall be registered for a period of 10 years from the date of filing the application or from the date of first commercial use anywhere in India or in any country, whichever is earlier.
 - ▶ Layout design that is not commercially exploited for more than two years from its date of registration shall be treated as commercially exploited for the purpose of this act.
 - ▶ Reproducing, distributing, selling or importing the IC layout design for commercial purposes will lead to infringement of law.



Quality of business environment: summary

India lags behind developed nations in terms of overall quality of business environment. The number of procedures required to start a new business in India are on the higher side. It could improve on this aspect by simplifying the steps involved to set up a new business and enabling the online completion of some procedures.

Further, in terms of taxation, the GoI imposes several taxes, apart from corporate tax, which reduce profitability. To improve India's attractiveness as a business destination, the GoI should reduce the burden of taxes on startups.

The efficiency of the legal framework in India will play a major role in the development of the country's innovation capabilities in the near future. India already has a Semiconductor IC Design Layout Act in place to protect the interests of IP owners of semiconductor design. While India performs better than other developing countries in terms of efficiency of its legal framework in challenging government regulations, GoI needs to make the legal framework more efficient by resolving disputes more efficiently and timely.



Government policies and support

The semiconductor design sector involves a lot of expenditure on R&D. Government support in the form of R&D incentives, tax holidays and loan grants can help companies sustain research initiatives and remain profitable. Government support in developing fabrication, assembly testing and packaging units, and for other sectors related to semiconductors, such as electronics, help create an overall ecosystem in the country. These initiatives help a country become a favorable investment destination.

The countries in the sample set provide businesses engaged in the semiconductor and related sectors with different kinds of incentives. Prominent among these are:

Taiwan

The Government of Taiwan has taken several initiatives to reduce risks and enhance the competitiveness and innovation capability of businesses engaged in research activities.

The Government of Taiwan has developed the Hsin-chu Science-based Industrial Park (HSIP) following the model of Silicon Valley in the US to create an environment conducive to the development of a high-technology industry (including semiconductors). The park's proximity to two of Taiwan's oldest universities gives it the advantages of a skilled labor supply and low employee training costs, apart from the advantages an industrial cluster enjoys. The Government of Taiwan also provides for zero tax, exemption from import duties and certain other taxes on products manufactured for export in more such designated science parks.

In order to provide companies with technological and R&D support, the Government of Taiwan has established research institutions such as the Industrial Technology Research Institute (ITRI), which has several laboratories that collaborate with private-sector companies to build their research competitiveness. The National Science and Technology Projects (NSTP) provide financial stability to ITRI. Some of ITRI researchers join private sector companies, which increase R&D capabilities of the private sector.

The Government of Taiwan enacted the Statute for Upgrading Industries in 1990 and amended it in 2003. The statute encourages the hi-technology industry by providing a five-year holiday on corporate income tax, applicable to the entire income for the newly incorporated company, and on incremental income from new construction or expansion for pre-existing and qualifying companies.



A company in Taiwan is eligible for a 30% credit for R&D expenses against income tax payable for five years, starting from the year the company begins R&D activity. If this expenditure exceeds the average of the preceding two years, 50% of the excess amount may be offset against income tax payable that year. Equipment and machinery used for R&D can be depreciated completely over a two-year period.

The Government of Taiwan also offered a major incentive to the semiconductor design industry in 2002 through the launch of a Si-Soft project. The project aimed at developing resources to create a skilled workforce for the semiconductor design sector and the establishment of an IC design park. Under this project, the Nankang IC design science-park was initiated in July 2003. This collaborative effort with Hsinchu and Tainan science-based industrial parks and Nankang Software Park, aimed to increase the faculty count specializing in Very Large Scale Integration (VLSI) design at universities and introduce several new courses in semiconductor design as a part of the curriculum to produce more design engineers annually. The overall objective was to promote IP creation by IC design units in Taiwan.

China

Since 2000, the Government of China has been actively involved in implementing favorable tax policies and providing incentives to companies to develop a competitive semiconductor industry. After 2000, government policies saw major changes. Before 2000, semiconductor firms were mostly government-owned or joint ventures involving a government entity as the Chinese partner. FDI in the sector was highly restricted. After 2000, the Government of China started encouraging foreign investment in the sector while holding only a passive minority stake in enterprises. Tariffs on semiconductors, which were in the range of 6%-30% before 2000, were completely removed. Steps were also taken to promote the IC design industry. Earlier, the emphasis was on state-owned research institutes, while after 2000, the Government of China privatized these institutes and also provided financial assistance to private companies to conduct R&D activities.

Under the Tenth Five Year Plan, the semiconductor industry has been designated as an encouraged industry, and the Government of China laid down a number of policies to promote industry growth.

Since 2008, China's taxation laws for the semiconductor manufacturing sector, , have allowed for a five-year tax holiday involving full exemption from corporate income tax for the first five years, starting in the year in which the business becomes profitable. For the next five years, these businesses are required to pay half the applicable tax rate.

Another incentive is the R&D tax deduction. Companies engaged in R&D activity for the production of new technologies, products, or techniques can enjoy a 50% "super deduction" above the actual expense deduction.

IC manufacturers are exempt from paying import duties and 17% VAT on IC production equipment and machinery. They are also granted easy customs clearance.



Some local incentives are also available to the semiconductor industry. For example, under a “virtual fab” strategy adopted by some local governments, the construction of a fabrication plant is either completely or largely government-funded, but contracted private firms manage the process under a profit-sharing agreement.

As another example, for pre-approved R&D centers, The Pudong New Area in Shanghai refunds land-use fees and subsidizes property taxes under the Pudong Technology Development Fund.

India

The GoI provides several incentives and tax benefits to the semiconductor industry and related sectors for the overall development of the semiconductor ecosystem in India. The GoI offers a weighted deduction of 150% on any expenditure on in-house scientific research by companies engaged in electronic equipment manufacturing. Further, a 10-year tax deduction is offered for 100% of profits derived from the export of certain products by companies located in SEZs, an electronic hardware technology park, and free trade zones, among others.

The GoI introduced the National Semiconductor Policy in 2007 to encourage investments in the establishment of fabrication units. It covers production, assembly and testing of semiconductors, photovoltaics, LCDs, plasmas, storage devices, solar cells and nanotechnology products. For the implementation of the policy, the GoI launched the Special Incentives Package Scheme (SIPS). According to this scheme, businesses setting up qualifying wafer-fabrication facilities with a minimum investment of US\$581 million will be eligible for government grants. For units located inside SEZs, the GoI will provide 20% of the capital expenditure for the first 10 years of operations. For units outside SEZs, countervailing duty (CVD) on capital goods will be exempt, and the GoI will be responsible for 25% of the capital expenditure for the stated duration. The scheme limits the equity participation of the GoI in the project to a maximum of 26%, assuming a 1:1 debt equity ratio for the project. The rest will be in the form of interest-free loans, tax subsidies and concessions. The policy also provides state governments with the option to offer semiconductor companies additional benefits.

Some state governments also provide incentives for the development of the semiconductor industry. For example, the Government of Karnataka introduced a semiconductor policy in February 2010. The policy is aimed at providing financial assistance to start-up design units through Karnataka Information Technology Venture Capital (KITVEN) Fund. It will also provide financial assistance to firms for filing IP. The GoI plans to set up industrial parks and SEZs following the model of Hsinchu Park in Taiwan and Suzhou Park in China. These SEZs are expected to offer benefits such as low rentals on land, tax benefits, exemptions from certain tariffs and low-interest government loans.

Some of the fiscal incentives listed in the Karnataka Industrial Policy 2009–14 include exemption from stamp duty to micro, small and medium enterprises (MSME), large and mega projects, an investment promotion subsidy, interest free loan on VAT to large and mega projects, and interest subsidy to micro manufacturing enterprises.



Israel

The Government of Israel has entitled foreign investors to a 10% corporate income tax rate. If the business is set up in central Israel, investors are also eligible for a two-year exemption from that tax. A 10-year full tax exemption can be provided in case the company is located outside of central Israel.

Taxation laws allow for a full deduction of R&D expenses, including capital expenditures in the year in which the expenditures are made. Further, a qualified R&D plan makes the company eligible for grants ranging between 20% and 50% of R&D expenses. Grants depend upon the amount of local production and the contribution of R&D to Israeli research. Non-Israeli residents are eligible for full capital gain tax exemption for the sale of shares in an "intensive R&D company."

US

The US Government provides the semiconductor industry with several tax incentives through the American Jobs Creation Act of 2004. Since 2008, the Government of the US has been offering a 14% alternative credit for qualifying R&D expenditures above 50% of the average qualified research expenditures over the three years before the credit year. A major drawback is that this R&D incentive is on a temporary basis and lasts for one or two years. It is required to be renewed after the stated period. Companies enjoy certain state-level tax incentives, but there is no provision of tax holidays from the US federal corporate income tax. The US also offers 3.15% tax deduction for manufacturing activities in the domestic semiconductor sector.

UK

The Government of the UK offers incentives to companies involved in R&D. Such companies are entitled to claim a deduction on their taxable profits if they spend at least £10,000 in their accounting year on qualifying R&D activities. Small and medium enterprises (SMEs) can claim 175% of qualifying expenditure (incurred after 1 August 2008). Large companies can claim 130% of expenditure (incurred after 1 April 2008).

SMEs making losses are eligible to claim credit of 24% of qualifying expenditure. Further, SMEs are not required to own any IP attributable to their R&D expenditure as a condition of being able to claim.

Companies are allowed to claim R&D tax credits to incur costs on employing staff engaged in conducting R&D activities, material used, as well as power, water and computer software used directly in conducting R&D activities.



Germany

The Government of Germany provides a number of incentives for domestic and foreign investors in the electronics and micro-technology industry. The Government of Germany's investment incentives package provides cash incentives, loans at low interest rates and public guarantees to secure loan from private banks for companies looking to establish businesses in the country. Depending upon the size of the company, investment location and project scope, these incentives can amount to as much as 30% of expenditures for large enterprises and 50% for small enterprises.

The Government of Germany's operational incentives package is aimed at providing support to companies engaged in R&D. All R&D incentive programs are part of the Government of Germany's four-year high-technology strategy, under which an annual reserve of €3 billion has been provided for non-repayable project grants.

Sweden

The Government of Sweden does not provide any specific incentives for the semiconductor industry in particular, but supports R&D activities across industrial sectors in the country. Primary government support is in the form of grants for R&D projects. The Swedish Governmental Agency for Innovation Systems (VINNOVA) is one of the major agencies to which companies can apply for R&D grants. The agency's aim is to enhance the competitiveness of research activities in the country. The agency's annual budget to finance R&D activities is approximately SEK2 billion.

Other agencies in Sweden such as the Swedish Foundation for Strategic Research, Knowledge Foundation and Swedish Agency for Economic and Regional Growth also fund R&D projects in the country.

IV.

Summary

Exhibit 29 summarizes the findings of the benchmarking study.

Key to Exhibit 29

- India is ranked among top three in the sample set; implying best in the league
- India ranks between fourth and sixth among sample set countries; implying average standing among sample set countries
- India is ranked among last two in the sample set; indicating areas of improvement

Exhibit 29

Sr.no.	Section	Benchmarking parameters	India's standing
1	Industry dynamics	Industry revenues	
		Quantum of electronics production	
		Number of semiconductor design units	
2	Talent pool (quantitative)	Number of semiconductor design engineers	
		Relevant engineering graduates every year	
		Number of engineering colleges	
3	Innovation environment	Quality of scientific research institutions	
		Company spending on R&D	
		No. of IEEE papers filed	
4	Operating cost	Average office space rentals	
		Average cost of electricity	
		Average salary of semiconductor design & embedded software professionals	
		Cost of raising debt	
		Travel cost	
5	Infrastructure	Future availability of office space	
		Power demand supply gap	
		Availability of communication infrastructure	
6	Quality of business environment	Number of procedures to start a business	
		Corporate taxation rate	
		Efficiency of legal framework in challenging regulations	

Source: ISA-EY research 2010

Annexure

Definitions

Goi

Government of India

Business environment

Business environment constitutes the following factors – ease of setting up a business, taxation rates and procedures, and efficiency of legal framework.

EDA

Electronic design automation

Electronics

Electronics encompasses computing, industrial, communications and consumer electronics and electronic components.

Ernst & Young

Ernst & Young Pvt. Ltd., India

IDM

Integrated device manufacturer

Infrastructure

Infrastructure includes the following factors – Grade A-quality office space, electricity supply and international internet connectivity.

IP

Intellectual property

IPR

Intellectual property rights

IPC

International patent classification

ISA

India Semiconductor Association

Operating costs

Operating costs comprise office rentals, human resource costs, electricity costs, cost of raising debt and travel costs.

Relevant engineers/pool

This refers to engineers specialized in electrical, electronics, telecommunications, computer engineering, and electronic design.

References

Exhibit 3: Industry revenues

For all countries except China	Ernst & Young Analysis
China	"China's impact on the semiconductor industry: 2010 update," PricewaterhouseCoopers, November 2010, p. 30

Exhibit 4: Quantum of electronics production

For all countries except India	"OECD Information Technology Outlook: 2010," <i>OECD website</i> , www.oecd.org, accessed 20 December 2010.
India	"Department of Information Technology (DIT) 2009-10 annual report," <i>Department of IT website</i> , www.mit.gov.in/sites/upload_files/dit/files/annualreport2009-10_0.pdf, accessed 4 January 2011. <i>Electronic systems design and manufacturing ecosystem: Strategy for growth in India</i> , Ernst & Young, December 2009.

Exhibit 6: Semiconductor design companies

India	ISA
US	"Fabless semiconductor company directory," <i>Global Semiconductor Alliance website</i> , http://www.gsaglobal.org/login.asp?redirect=/directories/outsourcing/index.asp, accessed 20 December 2010.
UK	<i>The Future of Semiconductor IP blocks in Europe</i> , p. 58.
China	"China's impact on the semiconductor industry: 2010 update," PricewaterhouseCoopers, November 2010, p. 46.
Taiwan	"Overview on Taiwan semiconductor industry, 2009," <i>Taiwan Semiconductor Industry Association website</i> , www.tsia.org.tw/Eng/Files/Publication/200912317128.pdf, accessed 9 September 2010.
Sweden	<i>The Future of Semiconductor IP blocks in Europe</i> , p. 60.
Germany	<i>The Future of Semiconductor IP blocks in Europe</i> , p. 55.
Israel	"Semiconductor industry," <i>Invest in Israel website</i> , www.investinisrael.gov.il/NR/exeres/B52D66FB-60E9-46C8-B5D0-090E488793CB.htm, accessed 9 September 2010.

Exhibit 7: Geographic concentration/fragmentation

India	"The Indian Semiconductor Industry," <i>EuroAsia Semiconductor website</i> , www.euroasiasemiconductor.com/india_semiconductor.php, accessed 29 November 2010.
US	"The semiconductor industry in the 21st century: a global analysis using Michael Porter's industry related clusters," <i>Competitiveness Review</i> , 1998, p.27
UK	"India, UK set up chip shop," <i>IT Examiner website</i> , www.itexaminer.com/india-uk-set-up-chip-shop.aspx, accessed 14 November 2010; "Decline And Renewal Of High-Tech Clusters: The Cambridge Case"; "The Connected University, Driving Recovery and Growth in the UK Economy," National Endowment for Science, Technology and the Arts (NESTA), April 2009.
China	"Challenges to Foreign Investment in High-Tech Semiconductor Production in China," U.S. International Trade Commission, May 2009, p.4.
Taiwan	"Taiwan: Semiconductor Cluster," Harvard Business School Course Paper, 2 May 2007, p.13.
Sweden	Sweden embassy

Germany	"Fabless semiconductor company directory," <i>Global Semiconductor Alliance website</i> , www.gsaglobal.org , accessed 20 December 2010.
Israel	"Case study of several Israeli Start-Ups in the fabless semiconductor sector and niche sectors adjacent to the fables and the semiconductor sectors," September 2001, p.9.
Exhibit 9: Size of relevant engineering pool in semiconductor design	
India	ISA
US	"Occupational employment statistics," <i>US Bureau of Labor Statistics website</i> , www.bls.gov/oes , accessed 4 October 2010.
UK	"Skills Capability: Perception and Reality," <i>National Microelectronics Institute Yearbook 2009-10</i> , p. 30, © 2009 Regent Publications Ltd. and the National Microelectronics Institute.
China	Ernst & Young analysis
Taiwan	"Overview on Taiwan semiconductor industry, 2009," <i>Taiwan Semiconductor Industry Association website</i> , www.tsia.org.tw/Eng/Files/Publication/200912317128.pdf , accessed 9 September 2010.
Sweden	"Number of engineers employed, by discipline," <i>Statistics Sweden website</i> , www.scb.se , accessed 30 September 2010; Sweden Embassy
Israel	"Business research and development, 2006," <i>Central Bureau of Statistics website</i> , www.cbs.gov.il/webpub/pub/text_page_eng.html?publ=56&CYear=2006&CMonth=1 , accessed 20 September 2010.
Exhibit 10: Supply of relevant engineers every year	
India	"The IT-BPO Sector in India - Strategic Review 2010," <i>NASSCOM website</i> , www.nasscom.in/Nasscom/templates/NormalPage.aspx?id=58654 , accessed 16 August 2010.
US	"Degrees in computer and information sciences conferred by degree-granting institutions, by level of degree and sex of student: 1970-71 through 2007-08," <i>National Center for Education Statistics website</i> , http://nces.ed.gov/programs/digest/d09/tables/dt09_303.asp , accessed 1 December 2010. "Degrees in chemical, civil, electrical, and mechanical engineering conferred by degree-granting institutions, by level of degree: 1970-71 through 2007-08," <i>National Center for Education Statistics website</i> , http://nces.ed.gov/programs/digest/d09/tables/dt09_306.asp , accessed 1 December 2010.
UK	"Higher education statistics," <i>Higher Education Statistics Agency website</i> , www.hesa.ac.uk , accessed 16 November 2010, © Higher Education Statistics Agency Limited 2010.
China	"Breakdown of Engineering Students by Subfield of Study in Regular Higher Educational," <i>Ministry of Education, China website</i> , http://www.moe.edu.cn/publicfiles/business/htmlfiles/moe/s4971/201012/113575.html , accessed 4 January 2011; Ernst & Young analysis
Taiwan	Ernst & Young Analysis
Sweden	"Number of engineering graduates in 2008/09, by discipline," <i>Statistics Sweden website</i> , www.scb.se , accessed 30 September 2010; Sweden Embassy
Germany	"Studierende und Studienanfänger/-innen - Fächergruppe," <i>VDI website</i> , www.vdi-monitoring.de/pdf4.php , accessed 4 January 2011; Ernst & Young Germany research.
Israel	"Recipients of Degrees from Institutions of Higher Education 2007/08," <i>Central Bureau of Statistics website</i> , http://www.cbs.gov.il/webpub/pub/text_page_eng.html?publ=71&CYear=2008&CMonth=1 , accessed 17 December 2010.



Exhibit 11: Number of engineering colleges

India	"Mid-Term Appraisal of the Eleventh Five Year Plan," <i>Planning Commission website</i> , http://www.planningcommission.nic.in/plans/mta/11th_mta/pdf/MTA_comp11th.pdf , accessed 20 December 2010.
US	"Number of degree-granting institutions conferring degrees, by control, level of degree, and field of study: 2007-08," <i>National Center for Education Statistics website</i> , http://nces.ed.gov/programs/digest/d09/tables/dt09_278.asp , accessed 1 December 2010.
UK	"Qualifications obtained - higher degrees by subject of study at each institution 2003/04," <i>Higher Education Statistics Agency website</i> , http://www.hesa.ac.uk/index.php/content/view/1906/251/ , accessed 16 November 2010, © Higher Education Statistics Agency Limited 2010.
China	"Number of Regular Higher Educational Institutions," <i>Ministry of Education, China website</i> , http://www.moe.edu.cn/publicfiles/business/htmlfiles/moe/s4971/201012/113594.html , accessed 4 January 2011.
Taiwan	"Basic Information about Taiwan's Colleges and Universities of Technology, 2006," <i>Taiwan Education Center website</i> , www.tw.org/education/Taiwan_Colleges%20&%20Universities%20of%20Technology.pdf , accessed 1 December 2010.
Sweden	"Number of engineering colleges," <i>Swedish National Agency of Higher Studies website</i> , www.hsv.se , accessed 30 September 2010; Sweden Embassy
Germany	"Number of engineering colleges," <i>Gate4engineers website</i> , http://www.gate4engineers.de/ingenieur-studium.html , accessed 24 September 2010; Ernst & Young Germany research.
Israel	"Recipients of Degrees from Institutions of Higher Education 2007/08," <i>Central Bureau of Statistics website</i> , http://www.cbs.gov.il/webpub/pub/text_page_eng.html?publ=71&CYear=2008&CMonth=1 , accessed 17 December 2010.

Exhibit 13: Quality of scientific research institutes; Company spending on R&D

For all countries	<i>Global competitiveness report 2010-2011</i> , The World Economic Forum, September 2010, p.371, 375, 376.
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Exhibit 14: Number of IEEE papers submitted

For all countries	IEEE
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Exhibit 16: Annual average office space rentals

India, China, Taiwan	<i>On Point, Asia Pacific Property Digest</i> , Jones Lang LaSalle, 3Q10, p.21, 22, 23, 25, 32, 33, 34, 35.
US	"North America Highlights," Colliers International, 3Q10, p. 1.
UK	"Office market conditions across the UK," Jones Lang LaSalle, 3Q10, p. 2, 3. "Central London Offices," Colliers International, 3Q10, p.2, 3. "Central Leeds Offices," Colliers International, 3Q10, p.2, 3 "Glasgow Offices," Colliers International, 3Q10, p.2,3
Sweden	<i>Property Times, Stockholm-Q3 2010</i> " DTZ Research, 11 October 2010, p.1, 5, 6, 7.
Germany	"Marketview, office market: Berlin," CB Richard Ellis, 3Q10, p.1, 2, 3, 4, 5, 6. "Marketview, office market: Hamburg," CB Richard Ellis, 3Q10, p.1, 2, 3, 4, 5, 6. "Marketview, office market: Frankfurt," CB Richard Ellis, 3Q10, p.1, 2, 3, 4, 5, 6. " Marketview, office market: Munich," CB Richard Ellis, 3Q10, p.1, 2, 3, 4, 5, 6.
Israel	"Man index of income-producing property in Israel," Man Properties, 3Q10, p.1, 2, 3, 4; "CBS, Statistical Abstract of Israel 2010," <i>Central Bureau of Statistics website</i> , www1.cbs.gov.il , accessed 1 December 2010.



Exhibit 17: Average cost of electricity

India	"MERC Tariff Order for MSEBCL for FY 2009-10," Maharashtra Electricity Regulatory Commission press release, www.mercindia.org.in , 16 August 2010.
US	"Annual Energy Review", <i>U.S. Energy Information Administration website</i> , www.eia.doe.gov , accessed 16 August 2010.
UK	"Quarterly energy prices," <i>Department of Energy and Climate Change website</i> , www.decc.gov.uk/en/content/cms/statistics/publications/prices/prices.aspx , June 2010.
China	Zhang Zhengfu, "China considers charging residential use of electricity on tiered basis," Xinhua's China Economic Information Service, 11 October 2010, via Dow Jones Factiva, © 2010 Xinhua News Agency.
Taiwan	"Tariff book," <i>Taiwan Power Company website</i> , www.taipower.com.tw , accessed 16 August 2010.
Sweden	"Industrial electricity prices," <i>Europe's energy portal website</i> , www.energy.eu , accessed 16 August 2010
Germany	"Industrial electricity prices," <i>Europe's energy portal website</i> , www.energy.eu , accessed 16 August 2010
Israel	Ehud Zion Waldoks, "Electricity prices to drop by 9.6 percent on February 15. Environment Ministry and Energy Forum warn: Lower costs will increase consumption," <i>The Jerusalem Post</i> , 2 February 2010, via Dow Jones Factiva, © 2010, <i>The Jerusalem Post</i>

Exhibit 18: Average annual salary of semiconductor design personnel

India	Ernst & Young analysis
US	"Occupational employment statistics," <i>US Bureau of Labor Statistics website</i> , www.bls.gov , accessed 4 October 2010.
UK	"Understanding UK's design capabilities," <i>National Microelectronics Institute Yearbook 2009-10</i> , p. 15, © 2009 Regent Publications Ltd. and the National Microelectronics Institute.
China	"2010 EE Times Global Salary and Opinion Survey," <i>EETimes website</i> , http://www.eetimes.com/electronics-news/4211059/2010-EE-Times-Global-Salary-and-Opinion-Survey , accessed 1 December 2010
Taiwan	"Salary survey," <i>EDN website</i> , http://www.edn.com/info/2232-EDN_Global_Electronics_Engineering_Salary_Survey.php , accessed 1 December 2010
Sweden	Sweden embassy
Germany	Ernst & Young Germany research
Israel	"CBS, Statistical Abstract of Israel 2010," <i>Central Bureau of Statistics website</i> , www1.cbs.gov.il , accessed 1 December 2010.

Exhibit 19: Prime lending rates offered by commercial banks

India	"Lending/Deposit rates," <i>RBI website</i> , http://www.rbi.org.in/home.aspx# , accessed 17 January 2011
US	"Prime rate, fed funds, COFI," <i>Bankrate website</i> , http://www.bankrate.com/rates/interest-rates/prime-rate.aspx , accessed 17 January 2011
UK	"Effective Interest Rates," <i>Bank of England website</i> , http://www.bankofengland.co.uk/mfsd/iadb/index.asp?Travel=N1xRx&levels=2&XNotes=Y&Nodes=&SectionRequired=1&HideNums=-1&ExtraInfo=true&A41513XNode41513.x=8&A41513XNode41513.y=7 , accessed 17 January 2011
China	"PBC Decides to Raise RMB Benchmark Deposit and Loan Rates," <i>The People's Bank of China website</i> , http://www.pbc.gov.cn/publish/english/955/2010/20101228160506528786054/20101228160506528786054_.html , accessed 17 January 2011
Taiwan	"Statistics," <i>Central Bank of Taiwan website</i> , http://www.cbc.gov.tw/np.asp?ctNode=507&mp=2 , accessed 17 January 2011



Sweden	"Riksbank key interest rates," <i>Riksbank website</i> , www.riksbank.com/templates/stat.aspx?id=17184 , accessed 17 January 2011
Germany	"Interest rate statistics January 2011," <i>Deutsche Bundesbank website</i> , http://www.bundesbank.de/statistik/statistik_zeitreihen.en.php , accessed 17 January 2011
Israel	"Quoted basic interest rate," <i>Bank of Israel website</i> , http://www.bankisrael.gov.il/deptdata/pikuah/ribit/ribhahde.htm , accessed 17 January 2011

Exhibit 20: Per diem rate

For all countries	"Per Diem Rates," <i>US General Services Administration website</i> , http://www.gsa.gov/portal/category/21287 , accessed 17 January 2011
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Exhibit 22: Future availability of Grade A office space

India, China, Taiwan	<i>On Point, Asia Pacific Property Digest</i> , Jones Lang LaSalle, 3Q10, p.21, 22, 23, 25, 32, 33, 34, 35.
US	"North America Highlights," Colliers International, 3Q10, p.1.
UK	"Office market conditions across the UK," Jones Lang LaSalle, 3Q10, p.2, 3. "Central London Offices," Colliers International, 3Q10, p.2, 3. "Central Leeds Offices," Colliers International, 3Q10, p.2, 3. "Glasgow Offices," Colliers International, 3Q10, p.2, 3.
Sweden	<i>Property Times, Stockholm-Q3 2010</i> , DTZ Research, 11 October 2010, p.1, 5, 6, 7.
Germany	"Marketview, office market: Berlin," CB Richard Ellis, 3Q10, p.1, 2, 3, 4, 5, 6. "Marketview, office market: Hamburg," CB Richard Ellis, 3Q10, p.1, 2, 3, 4, 5, 6. "Marketview, office market: Frankfurt," CB Richard Ellis, 3Q10, p.1, 2, 3, 4, 5, 6. "Marketview, office market: Munich," CB Richard Ellis, 3Q10, p.1, 2, 3, 4, 5, 6.
Israel	"Man index of income-producing property in Israel," Man Properties, 3Q10, p.1, 2, 3, 4; "CBS, Statistical Abstract of Israel 2010," <i>Central Bureau of Statistics website</i> , www1.cbs.gov.il , accessed 1 December 2010.

Exhibit 23: Power demand-supply gap

India	"Annual report 2009-2010," <i>Ministry of Power, Government of India website</i> , www.powermin.nic.in , in "Power sector at a glance," <i>Ministry of Power, Government of India website</i> , www.powermin.nic.in , accessed 1 September 2010
US	"Annual Energy Review," <i>U.S. Energy Information Administration website</i> , www.eia.doe.gov , accessed 1 September 2010.
UK	"Electricity statistics," <i>Department of Energy and Climate Change website</i> , www.decc.gov.uk/en/content/cms/statistics/source/electricity/electricity.aspx , accessed 1 September 2010.
China	"China energy profile," <i>U.S. Energy Information Administration website</i> , www.eia.doe.gov , accessed 1 September 2010.
Taiwan	"Taiwan energy profile," <i>U.S. Energy Information Administration website</i> , www.eia.doe.gov , accessed 1 September 2010.
Sweden	"Energy," <i>Statistics Sweden website</i> , www.ssd.scb.se , accessed 1 September 2010.
Germany	Federal Statistical Office, Germany; "Germany energy profile," <i>U.S. Energy Information Administration website</i> , www.eia.doe.gov , accessed 1 September 2010; Ernst & Young analysis.
Israel	"CBS, Statistical Abstract of Israel 2009," <i>Central Bureau of Statistics website</i> , www.cbs.gov.il/reader/shnatonenew_site.htm , accessed 1 September 2010.



Exhibit 24: Availability of communications infrastructure

India	"The Indian Telecom Services Performance Indicators", Telecom Regulatory Authority of India, 22 July 2010, p.25.
China	"Statistical survey report on internet development in China," China Internet Network Information Center, January 2010, p.27.
Taiwan	"Taiwan's international bandwidth hits 363.077 Gbps," <i>Telecompaper Asia</i> , 26 April 2010, via Dow Jones Factiva, © 2010 <i>Telecompaper</i> .
Israel	Ernst & Young analysis.

Exhibit 26,27: Number of procedures to start a business; Corporate taxation rate

For all countries	Doing Business 2011, World Bank, IFC and Palgrave MacMillan, October 2010, p. 156, 165, 169, 171, 197, 198, 202; <i>Doing Business 2011, India</i> , World Bank, IFC and Palgrave MacMillan, October 2010, p.60, 61
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Exhibit 28: Efficiency of legal framework in challenging regulations

For all countries	Global competitiveness report 2010-2011 The World Economic Forum, September 2010, p.466, 489, 490
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Government policies and support

India	"National semiconductor policy 2007,;" "Karnataka semiconductor policy 2010," Department of IT, BT and S & T, <i>Government of Karnataka website</i> , www.bangaloreitbt.in , accessed 29 November 2010.
US	"Maintaining America's competitive edge: government policies affecting semiconductor industry R&D and manufacturing activity," <i>Semiconductor Industry Association whitepaper</i> , March 2009.
UK	"About R&D tax credits," <i>Department for Business Innovation and Skills website</i> , www.bis.gov.uk , accessed 20 October 2010.
China	"Challenges to Foreign Investment in High-Tech Semiconductor Production in China," U.S. International Trade Commission, May 2009, p.6,7,8; "Maintaining America's competitive edge: government policies affecting semiconductor industry R&D and manufacturing activity," <i>Semiconductor Industry Association whitepaper</i> , March 2009; "Semiconductor chips and automobile parts," <i>Institute for International Economics website</i> , www.iie.com , accessed 20 October 2010.
Taiwan	"The Innovation Policy and Performance of Innovation in Taiwan's Technology- Intensive Industries," <i>Business Perspectives website</i> , www.businessperspectives.org/journals_free/ppm/2004/PPM_EN_2004_01_Tsai.pdf , accessed 1 November 2010; "Maintaining America's competitive edge: government policies affecting semiconductor industry R&D and manufacturing activity," <i>Semiconductor Industry Association whitepaper</i> , March 2009; "2009 Industrial Development in Taiwan, R.O.C," <i>Industrial Development Bureau, Ministry of Economic Affairs website</i> , www.moeaidb.gov.tw , accessed 20 October 2010
Israel	"Maintaining America's competitive edge: government policies affecting semiconductor industry R&D and manufacturing activity," <i>Semiconductor Industry Association whitepaper</i> , March 2009; "Support for R&D Centers of Foreign Companies," <i>Invest in Israel website</i> , www.investinisrael.gov.il , accessed 20 October 2010.
Germany	"Electronics and Microtechnology in Germany," <i>Germany Trade and Invest website</i> , http://www.gtai.com/fileadmin/user_upload/Downloads/Industries/Electronics/1_Englisch/IndustryOverview_Electronics_Oktober2009_GTAI.pdf , accessed 1 December 2010.
Sweden	Sweden embassy

Section
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Recomm

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About this study

This study on the Indian semiconductor and embedded design services industry has been commissioned by the Department of Information Technology, Ministry of Communication and Information Technology, India, with the intention of providing a thorough and systematic analysis of the Industry. It highlights India's growth and positioning in the global semiconductor design industry to identify areas of improvement and frame recommendations for the Indian semiconductor design industry. This report is jointly prepared by the India Semiconductor Association and Ernst & Young Pvt. Ltd.

The output of the study is presented in three sections:

Section 1: Industry analysis

This section throws light on the global semiconductor design and embedded software industry with a focus on the Indian industry. It discusses the ecosystem for semiconductor design development, the status of intellectual property in the industry and the talent landscape. It also provides estimates of industry revenues, workforce demand and supply, demographics, trends in terms of technology nodes and business models, and highlights the key drivers of and the challenges faced across the following three segments of domestic industry:

- ▶ Very large scale integration (VLSI) design segment
- ▶ Embedded software design segment
- ▶ Board/hardware design segment

This section also discusses the nuances of the Electronic Design Automation (EDA) market in terms of global and Indian markets, their drivers, the challenges faced by them and their license models.

Section 2: Benchmarking

The objective of the benchmarking exercise is to provide a competitive assessment of India against seven countries considered pioneers of semiconductor design. Quantitative benchmarking compares various parameters such as industry dynamics, talent pool, infrastructure, operating costs, quality of the business environment, and innovation and IP, which are all pivotal to the development of a country's semiconductor design sector. This analysis aims to highlight the challenges India faces vis-à-vis its competitors and the model to develop based on best practices adopted worldwide.

Section 3: Recommendations

Key issues relating to the growth of the semiconductor design industry are summarized, based on the findings of the Industry report. In the Benchmarking exercise, elaborate recommendations have been made to tackle the issues mentioned above. This will be a valuable source of data for the Government of India, the industry and academia, and can be used to plan and influence government policies for the domestic semiconductor design industry, building a strong ecosystem for the industry and bridging the gap in the talent scenario.

Contents

Section 3: Recommendations

Recommendations	134
Synopsis of challenges	134
Details of issues and actionable recommendations	136
Roadmap for recommendations implementation	162
Addressal of challenges with stakeholder responsibility	164

Recommendations

The Indian semiconductor design industry is estimated to have contributed US\$6.6 billion as revenues in 2009 and employs close to 135,000 people in semiconductor design besides providing employment to numerous people by means of indirect labor. The central and state governments in India recognize the strategic value of the semiconductor industry and have proactively made attempts to support the industry by unveiling policies aimed at growing the semiconductor footprint in the country.

In spite of the efforts made by the government, the Indian semiconductor industry faces challenges on numerous fronts in terms of competition from other countries, fast changing technology and increasing cost pressures. To help the Indian semiconductor industry reach its potential, government, academia, industry players and industry associations need to work together to improve India's business environment. In the absence of such a concentrated effort, the industry will fall significantly short of capturing its potential.

This section attempts to provide actionable recommendations to the challenges identified in the industry study and benchmarking exercise, which involved detailed discussions with industry experts coupled with intensive secondary research. This will be a valuable source of data for the Government of India, industry and academia to be used for planning and influencing government policies toward the semiconductor design industry, bridging the gap in the talent scenario and building a strong ecosystem for the semiconductor design industry.

The section is studied under the following sub-sections:

- ▶ Synopsis of challenges
- ▶ Details of issues and actionable recommendations
- ▶ Roadmap for recommendations
- ▶ Addressing of challenges and stakeholder responsibility

Synopsis of challenges

Based on the findings observed during the industry report and the benchmarking exercise, we have identified a set of 20 challenges faced by the Indian semiconductor industry today. These challenges are presented in Exhibit 1 below.

Exhibit 1: Complete set of challenges faced

Section	Sub-section	Challenges
Section 1: Industry analysis	India industry overview	<ul style="list-style-type: none"> ▶ People-related challenges <ul style="list-style-type: none"> ▶ Quality of talent ▶ Lack of technical career path ▶ Attrition ▶ Eroding cost advantage ▶ Lack of semiconductor manufacturing ecosystem ▶ Competition from China, Taiwan and other South-East Asian Countries ▶ Protectionist policies adopted by other nations
	VLSI design industry	<ul style="list-style-type: none"> ▶ Lack of R&D funding in universities ▶ Lack of scale at the leading node
	Embedded software industry	<ul style="list-style-type: none"> ▶ Cost pressures due to constantly evolving hardware ▶ Integration and testing of software and hardware ▶ Skill-set availability for high-end programmers ▶ Preference of ADM services as a career option
	Board/hardware design industry	<ul style="list-style-type: none"> ▶ Compliance related challenges ▶ Lack of component ecosystem development ▶ Adoption of de-risking business models by customers ▶ Official policies
Section 2: Benchmarking	Infrastructure	<ul style="list-style-type: none"> ▶ Deficient power supply ▶ Inadequate logistics infrastructure
	Cost	<ul style="list-style-type: none"> ▶ High electricity cost
	Business environment	<ul style="list-style-type: none"> ▶ High and unstable corporate tax structure ▶ Low efficiency of legal framework
	Government support	<ul style="list-style-type: none"> ▶ Expiry of the national level semiconductor policy
	Industry dynamics	<ul style="list-style-type: none"> ▶ Inadequate electronics production

Source: ISA-EY research 2010

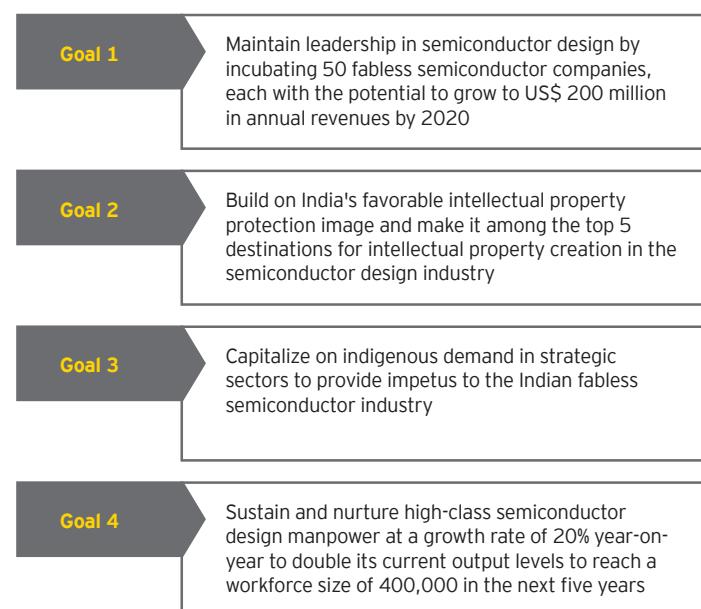
This entire set of challenges can be summarized under four main issues:

- ▶ Issue 1 - Quality, availability and maturity of talent
- ▶ Issue 2 - Building a startup and SME ecosystem
- ▶ Issue 3 - Absence of a semiconductor ecosystem
- ▶ Issue 4 - Lack of adequate infrastructure, policies and implementable incentives
- ▶ Issue 5 - External issues affecting the Indian semiconductor industry

Goals envisaged for the Indian semiconductor design industry

While the issues need to be addressed by actionable recommendations, specific goals are envisaged for the Indian semiconductor industry to provide a general direction to the recommendations. The four specific goals envisaged are:

Exhibit 2



Source: ISA-EY research 2010

Details of issues and actionable recommendations

This section takes up each one of four issues identified above and discusses them in detail. Elaborate potential recommendations to tackle these issues are articulated to enable the Indian semiconductor industry reach its complete potential.

Issue 1: Quality, availability and maturity of talent

Results from the industry analysis and benchmarking study shows that India scores well on current and future availability of talent with 61% of engineers graduating every year belonging to disciplines relevant for semiconductor design. However, this available talent is not readily deployable. As the semiconductor design sector is highly knowledge intensive, quality of talent produced is a very big challenge. The launch of the Special Manpower Development Programme (SMDP) by the Indian government is a welcome step in this direction.



Recommendations:

The detailed recommendations toward facilitating better quality of talent can be summarized as under:

Goal No. Addressed	Improvement area	In-depth recommendations elaborated
4	Talent	1A) Feedback on the Special Manpower Development Programme II (SMDP II) 1B) Set up specialized institutes for semiconductor design

Each of these recommendations is discussed below in detail:

Recommendation 1A: Feedback on the SMDP II

After discussions with SMDP coordinators, faculty members and Head of Departments at Resource Centers (RCs) and Participating Institutes (PIs), the following observations were made:

Objective: Involvement of more PIs in SMDP III

SMDP III needs enlargement in its scope to reach out and include more institutions as PIs in line with its vision. While SMDP II was a step in this direction with the number of PIs increasing from 12 to 25 from SMDP I, this trend needs to continue with SMDP III.

- ▶ SMDP III, if initiated, should focus largely on targeted system deliverables, such as SoCs
- ▶ These system deliverables should be designed by multiple institutions
- ▶ For the implementation of this program, it should be a collaborative program run on a public-private mode
- ▶ To achieve this program, SMDP III needs enlargement in scope to reach out and include more institutions as PIs
 - ▶ According to our estimates provided below, 11-14 more colleges must be introduced as PIs to bridge the demand supply gap by 2012.
 - ▶ The existing PIs can be evaluated and those which have become self-sufficient and graduated to the level of RCs can be promoted, which will ultimately help to expand to include the 11-14 additional PIs.

Type I Manpower	58	Manpower demand required by 2012 7,700 Hence, to bridge the demand-supply gap (7700 - 5471), about 11 - 14 more colleges need to be introduced as PIs
Type II Manpower	672	
Type III Manpower	892	
Type IV Manpower	3849	
Total	5471	

Source: ISA-EY research 2010

Leverage National Knowledge Network (NKN) for SMDP III:

NKN aims to connect more than 1,500 knowledge and research institutes in the country using a high-bandwidth network. As R&D activities and innovation in semiconductor design industry require multidisciplinary knowledge, NKN can be leveraged to connect geographically separated high-quality semiconductor design research centers and engineering colleges providing education in fields related to semiconductor design.

The SMDP module can gain significantly from NKN if all RCs and PIs under it gets connected. The network will facilitate data and resource sharing among all colleges. The workshops conducted under instruction enhancement programme (IEP) can take place online, which will increase faculty participation as they are not likely to require leaves to travel to other engineering colleges.

A lot of learning material can be provided online to students, which can be updated by institutes regularly to include latest technology. The students can leverage the expertise of faculties across engineering colleges and can take up projects under professors in their area of interest. The infrastructure provided by NKN can also lead to inclusion of more institutes under the umbrella of the SMDP program. This can prove to be very useful in creating world class semiconductor research institutions producing a pool of high quality design professionals.

Recommendation 1B: Setup specialized institutes for semiconductor design

India does not have specialized semiconductor design institutes, which focus on training students and carrying out research activities.

Recommendation: Set up four technology institutes specific to semiconductor design with government and industry players as key stakeholders. To begin with, one institute can be setup and based on its success, the other three can be initiated. While providing this recommendation, best practices have been taken from specialized institutes such as Interuniversity Microelectronics Center (IMEC) in Belgium, VLSI Design and Education Center (VDEC) in Japan and the nano-centers setup in IIT Bombay and IISC.

Objective: The proposed institutes should be set up with an aim to bridge the gap between fundamental research taking place in universities and colleges and technology development happening in industry.

IMEC Belgium

IMEC is an independent research center carrying out high-level innovative research in the field of microelectronics and nanotechnology in Leuven, Belgium. This was set up as a non-profit organization in 1984. The center has state of art fabrication tools with 200 mm processing facility, advanced laboratories for microelectronics research and a training program for VLSI design engineers. The current development at the center is toward 32 nm technology node. The organization has approximately 1,750 employees including 550 guest researchers and industrial residents. Revenues for 2009 were €275 million.



VDEC Japan

VDEC has been set up in the University of Tokyo and is shared by researchers all over Japan. The institute works for the improvement of instruction methods for VLSI design, distributes updated VLSI design-related information, provides CAD software and licenses and supports chip fabrications for universities and colleges in Japan. More than 600 research groups and 150 universities in Japan are using services of VDEC.

Model: Following is the model based on which the proposed institutes should be set up:

Working model	<ul style="list-style-type: none"> ▶ Institutes as education centers The institutes will act as education centers and will: <ul style="list-style-type: none"> ▶ Invite graduate engineers to pursue their M.Tech in areas specific to semiconductor design ▶ Offer post graduates in semiconductor design to carry out their doctorate thesis. ▶ Offer one-year Executive MBA program for development of project management skills ▶ Institutes as independent research hubs <ul style="list-style-type: none"> ▶ Will double up as independent research hubs and will aim to become nodal points for the majority of semiconductor research taking place in the country. ▶ Will employ design professionals to carry out high level research that will run three to five years ahead of industrial needs. ▶ Will invite guest researchers from academia as well as industry experts to carry out design research as industrial residents in the campus. ▶ Will also aim to attract foreign nationals to carry out research at the campus. ▶ State of art infrastructure The institutes should have highly experienced and well qualified faculty and should be well equipped with state-of-the-art laboratories and latest public domain and propriety design tools.
Funding and revenues	<ul style="list-style-type: none"> ▶ Initial funding <ul style="list-style-type: none"> ▶ Initially, the government should fund 50% of the set-up cost, of these institutes; the rest can be raised from the industry and other investors. ▶ EDA tool companies should be invited to contribute in laboratory infrastructure development by providing design tools at a highly subsidized cost ▶ Ongoing funding <ul style="list-style-type: none"> ▶ These will be set up as non-profit organizations and will earn revenues by providing industry-relevant technology solutions to companies and academia. ▶ The revenues will be utilized for paying salaries to employees and faculty, stipend to researchers and development of state-of-art infrastructure.
Sector and technology focus	<ul style="list-style-type: none"> ▶ Sector focus <ul style="list-style-type: none"> ▶ In the first phase, these institutes should focus on research activities specific to sectors of national importance such as defense, healthcare and infrastructure for developing high-level design methodologies and new process technologies for next generation of chips. ▶ In the second phase, they can extend their research to sectors such as multimedia, telecommunications, energy and transport. ▶ Technology focus The process development at the research level should be aimed at 45 nm and below devices.



Location	<ul style="list-style-type: none">▶ Locations The institutes should be set-up near the four major clusters of semiconductor design – Bengaluru, NCR, Pune and Hyderabad.▶ Location advantages<ul style="list-style-type: none">▶ These locations will help students obtain live projects and take up internships in nearby design units from semiconductor design companies to gain hands-on experience.▶ The institutes can also invite experienced design professionals from industry for guest lectures as it will be easier for them to travel to nearby places.
Board of Directors	<ul style="list-style-type: none">▶ Board of Directors should consist of delegates from industry, IITs, IISc, government and distinguished faculty from well established foreign institutes.
Courses offered	<ul style="list-style-type: none">▶ M.Tech▶ Ph.D.▶ Executive MBA▶ Short-term industry relevant courses
Faculty	<ul style="list-style-type: none">▶ Collaboration with IITs/IISc for faculty exchange▶ Collaboration with industry for guest lectures from industry experts.▶ Faculty student ratio should not exceed 1:2 for post graduation courses.
Curriculum and labs	<ul style="list-style-type: none">▶ Refer to Annexure 1 for details
Industry and academic collaboration	<ul style="list-style-type: none">▶ Industry collaboration<ul style="list-style-type: none">▶ Further collaboration with industry can be achieved by inviting companies to jointly conduct research on projects. This will allow these institutes to share cost, risk and expertise and IP with companies.▶ The patents can also be filed and co-owned by the company and institute's research team.▶ Academic collaboration Collaboration should be done with universities/colleges, which teach advanced courses in semiconductor design such as IMEC-Belgium, VDEC-Japan and Cambridge University for student and faculty exchange programs. The institutes can also invite eminent professors from abroad especially of Indian origin who can act as mentors for students willing to do Ph.Ds in areas of their expertise.
Learning and development activities	<ul style="list-style-type: none">▶ Employee training Training programs will be organized from time to time to equip employees with technical and management skills.▶ Short-term courses The institutes will organize seminars/workshops and offer short-term courses for skill development of academia and industry, which will be relevant for different levels of expertise.
Management development program	<ul style="list-style-type: none">▶ Objective The program will equip design engineers with project management skills essential to manage the research projects efficiently and effectively.▶ Program<ul style="list-style-type: none">▶ The institutes will offer a one-year executive Masters of Business Administration (MBA) on similar lines as "Visionary Leadership Program in Manufacturing" jointly offered by IIM Calcutta, IIT Kanpur and IIT Chennai.▶ The program will run with an aim to impart leadership and management skills together with cutting edge technology awareness to design professionals to produce next generation of techno-managerial leaders.▶ The program will be targeted to junior and middle-level management professionals of semiconductor design companies in India.

Management development program (cont'd.)

► Program (cont'd.)

- ▶ It will provide a right balance between theoretical inputs and practical training to develop high degree leadership skills. The program will offer professionals an international internship opportunity where they will work closely with industry leaders to gain hands-on experience at project management.
- ▶ The institutes will collaborate with semiconductor industry associations of leading countries in semiconductor design such as the US, the UK, Germany and Taiwan to invite top management professionals from semiconductor companies of these countries to impart project management knowledge to Indian design professionals.

Source: ISA-EY research 2010

KarMic Training Center – a rural semiconductor initiative serving a social cause

Semiconductor design for senior secondary graduates

KarMic Training Center, located in Nesargi village, around 40 kilometers from Belgaum, Karnataka is a VLSI training institute started by Dr. Shivaling S Mahant Shetty in June 1999. The institute has been set up with an objective to offer specialized semiconductor design training to graduate engineers to make them industry-ready for the design sector. This center also provides similar training to senior secondary graduates from rural areas of Karnataka who may have not been able to pursue higher education due to financial constraints.

The students are given a specialist training for a period of three years as a part of the "VLSI Junior Engineer" course. Major emphasis is on teaching students subjects specific to semiconductor design with a special focus on analog design. These students are given a practical exposure to design circuits on public domain tools available in computer laboratories. They learn to design chips used in mobile phones and other electronic gadgets. They also work on the projects obtained from semiconductor companies.

The annual intake of the institute is 20 students. The students are selected from the academic institutes of the state after an elaborate selection process. They are paid a stipend of INR500 per month, half of which goes to their parents with the understanding that this money will be paid back by the students once they get employed.

The first batch of the students will graduate next year. The model proposes the absorption of these graduates by the Karnataka Microelectronic Design Centre Pvt. Ltd., a company founded by Dr. Shetty.

The success of this initiative has not just brought about a rural revolution by unearthing the potential of rural students in becoming future design engineers; it is also an excellent example of fulfillment of an individual's social obligations by paying back what one has learnt from the society.

Recommendation

The government can attempt to achieve rural inclusion in the semiconductor revolution in India by replicating this kind of model and aid in enabling such set ups in tier-III cities and rural areas to encourage senior secondary and higher secondary graduates to take up a career in semiconductor design industry. Faculty can be encouraged to take up part-time/weekend courses in these setups.

Create a pool of skilled labor for semiconductor design industry

Apart from design engineers who are involved in R&D activities, semiconductor industry also needs skilled workforce to assist in areas related to VLSI testing activities, embedded services and hardware board design services.

The government should consider setting up a for-profit organization through public private partnership (PPP) route on similar lines as National Skill Development Corporation (NSDC) to fund development of skilled workforce for the semiconductor industry. This will be set up with an aim to bridge the existing gap between the demand and supply of skilled labor in the semiconductor industry.

Both government and private players will be stakeholders in this venture and the funds will be contributed by both of them. The organization will work to establish vocational training centers to produce a skilled workforce. It will also provide funding to other companies that provide skills training. Alternatively, the government should include semiconductor as one of the sectors in its list of 21 identified sectors, which face a shortage of skilled workforce under NSDC.

Other recommendations toward facilitating better quality of talent apply to the components of education and career advancement:

Improvement area	In-depth recommendations elaborated
Education	1C) Cultivate student interest 1D) Faculty development
Career advancement	1E) Plan employee advancement

Each one of these recommendations is discussed in detail below:

Recommendation 1C - Cultivate student interest

Area of concern: The semiconductor industry requires specialized skill sets preferably post graduates. However, the number of people pursuing post graduate degrees in India is a mere 8% of the total relevant engineering talent output in India. The average monthly stipend paid to an MTech student is INR 5,000 and that to a PhD student is about INR 9,500, which is far less than what a graduate earns in the industry.

Recommendation: There should be an increased focus on promoting higher education at this level by ensuring that students and research fellows get better stipend and other performance-based incentives. This recommendation applies to students following the completion of higher studies. Post-graduate students, not just from tier-I colleges, should be offered attractive packages by the industry as compared to those offered to graduates. Awareness of semiconductor design as a good career option should be provided to the students by the academia. The GoI should provide incentives to companies willing to sponsor students for higher education.

Area of concern: Lack of readily deployable talent in the industry is seen as a big challenge. Generally, the industry provides support by donating EDA tools and equipment. However, there are only a few programs aimed at training the students on this software.

Recommendation: Companies can help to bridge the gap by providing internships, organizing training programs and competitions in order to motivate students to use these tools. For example, some companies have introduced Analog Design contest in the past to encourage analog system design.

Recommendation 1D - Faculty development

Area of concern: The teaching profession in India does not necessarily attract good talent because of low remuneration, incentives and unattractive working conditions as compared to their counterparts in the industry or teachers abroad

Recommendations:

- ▶ Measures should be taken to increase salary bands and other benefits for faculty in order to attract quality talent.
- ▶ New cadres of professors with more than 15 years of work experience in corporate or organization experience should be introduced on the lines of clinical professorship offered at some ivy league institutes abroad
- ▶ Faculty should be provided incentives such as establishment/endowment of research chairs and provision of fast track promotion schemes.

Area of concern: Lack of continuous training opportunities for the Indian faculty to advance their own learning process

Recommendations:

- ▶ Engineering colleges should invest in providing training to its faculty in order to improve the quality of teaching especially in the areas of analog and mixed signal design as this is where lack of teaching expertise is cited.
- ▶ Colleges can provide sabbaticals to their faculty members for higher education or to work on industry projects.
- ▶ Educational institutions should forge collaborative ties for research with several leading international institutions, which are considered authorities on semiconductor design.
- ▶ Companies should take initiatives such as organizing faculty development programs by inviting faculty members to work on live industry projects with a view to foster design skills and latest technology know-how among Indian faculty.

Recommendation 1E - Plan employee advancement

Area of concern: Fresh engineering graduates exhibit an increased attraction towards higher education as opposed to working during the initial years of their career and due to lack of opportunities provided by industry, it leads to unnecessary attrition.

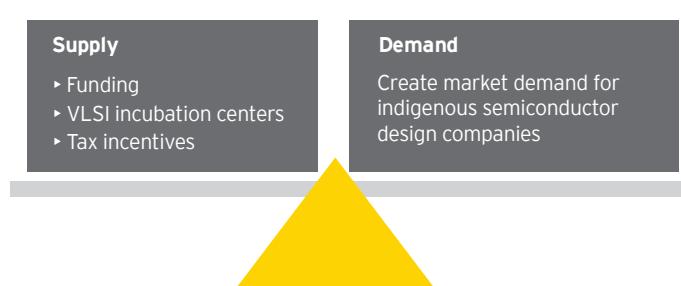
Recommendation: Companies can attract research-oriented talent by providing benefits such as sponsoring higher technical education (M.Tech, M.S., Ph.D etc.) and providing study leaves/sabbaticals to their employees to retain talent.

Area of concern: Employees have a tendency to advance their career by moving away from the technical career toward management positions.

Recommendation: Companies need to properly define the technical ladder in order to retain good talent in technical roles. Technically inclined people should be promoted to the position of a Fellow, which is equivalent to a Vice-President and the salary differences are not significant.

Issue 2: Absence of a startup and SMEs ecosystem

Goal No. Addressed	Improvement area	In-depth recommendations elaborated
1, 3	Absence of a startup and SMEs ecosystem	<p>Demand side: Keep aside share of indigenous products in sectors of national importance</p> <p>Supply side:</p> <ul style="list-style-type: none"> a. Provide avenues for seed and VC funding (Government and private) b. Setup VLSI specific incubation centers for incubation of startups and SMEs <ul style="list-style-type: none"> i. Incubation centers in STPI units ii. Incubation centers accessible to Tier-II engineering colleges c. Tax incentives



There is a need to manage/balance both the supply and demand side and it is imperative that there are interventions on both sides, in any market, to enable an industry to flourish. Much of the current policies in India emphasize on the supply side and hence, only providing supply side initiatives will not yield results as desired if there is no substantial market presence.

As illustrated above, the government, industry and academia can come together to create a market demand for indigenous semiconductor design and products and on the other hand strengthen the supply side to encourage startups to be incubated in order to satisfy this created demand.

In this section, recommendations have been provided to encourage more entrepreneurship activity and incubating semiconductor design startups.

Demand side

Keep aside share of indigenous products in sectors of national importance

Recommendation: GoI should consider creating market demand, which will complement the supply side initiatives provided by them in order to encourage fabless companies to set shop. Three key areas of national importance need to be identified where indigenous preference can be given to sourcing of Indian semiconductor products.

To begin with, 20% of IC content in these sectors, where GoI is the direct buyer, can be kept aside for products designed in India and this percentage can go up to 40% at a later stage for sectors such as Defense and Infrastructure. Some factors on which these sectors can be identified are the scale of potential demand, rapid pace of technology evolution, etc.

Special tax initiatives can be unveiled for fabless companies who meet the market demand created. This will have the added advantage of giving rise to other ancillary areas of research in this space.

Governments are themselves important buyers and suppliers of goods and services. However, only a handful of countries have signed on to WTO's Government Procurement Agreement, notably, major emerging markets such as Brazil and China are not signatories, so their government purchases do not have to be open to foreign firms.

Some suggested sectors that could be considered are (in alphabetical order):

- ▶ Agriculture
- ▶ Avionics
- ▶ Clean energy
- ▶ Defense
- ▶ Education
- ▶ Healthcare
- ▶ Infrastructure

India-specific products can be encouraged such as smart-meters used in energy, low-cost laptops, low-cost healthcare equipment, etc.

Supply side

A. Provide avenues for seed and VC funding

Though the venture capital firms are keen on investing in the Indian semiconductor design industry, currently there is very less investment activity seen by these players to the extent that investments in this space are not even tracked by any companies. Technology focus of VCs in India is more on the IT/ITeS service companies. Various reasons exist, some of them being – inability of the semiconductor companies to quickly grow in scale as compared to the IT/ITeS service companies, longer revenue realization period, higher initial investment, uncertainty over success of companies, etc.

The semiconductor sector needs heavy investment and the cost of capital per employee is much higher compared to IT start-ups. It is estimated that the minimum funding requirement for a design startup firm with 15 employees is approximately INR30 million in the first year, going up to INR100 million in three years. The short-term value proposition brought onto the table by these start-ups is not attractive enough to draw investors. Hence these start-ups are mostly funded by angel investors.

Suggested model and seed/VC investment required for that is:

Funding required for one design tape-out	US\$3-5 million per tape-out
Total no. of companies to be targeted for incubation	50
Average hit-ratio for a semiconductor design company to succeed	1:5
Number of companies with the potential to succeed and grow to US\$200 million revenues	10 companies
Total investment required for incubating 50 companies	US\$150 -250 million
Total investment required from government @50% of investment (with the rest 50% to be raised from VC firms)	US\$75 -125 million

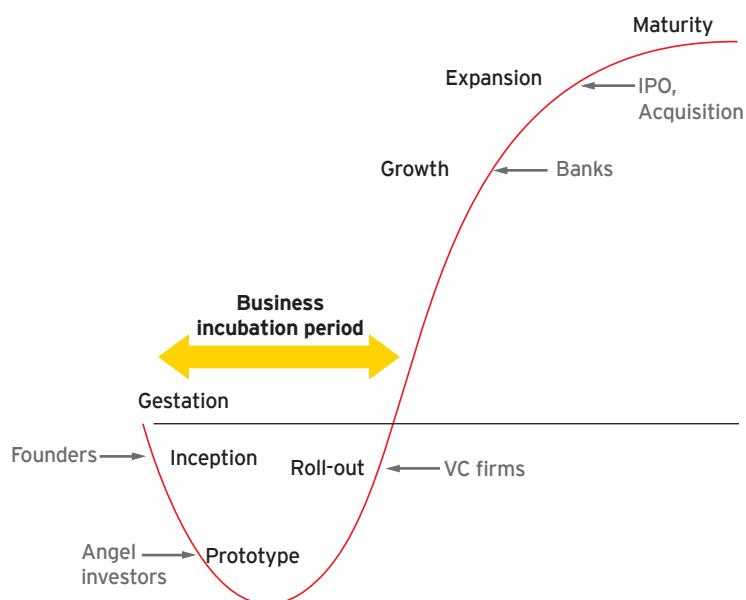
Source: ISA-EY research 2010

This makes a strong case for a government venture capital funding to encourage growth in this sector.

Recommendations for the Indian scenario

As shown in the exhibit below, start-ups require support in the business incubation period. In the Indian scenario, semiconductor startups are currently being funded mostly by angel investors and VC firms have adopted a more cautious approach. Hence there is a gap, which needs to be bridged by government support.

Exhibit 3: Recommendations for the Indian scenario



Source: ISA-EY research 2010

i) Government of India to collaborate with VC firms to provide early stage (pre-revenue) funding

Considering that start-ups have a dependence on the government for early-stage financing, the GoI should invite large international VC firms and those which specialize particularly in seed funding to invest in the Indian semiconductor industry, in various focused sectors, as is the case seen in China and Singapore.

The funds for this can be partly provided up to (50%) by the GoI and rest by private VCs and should be administered by private VCs. Private VCs are well-equipped to administer these funds as they bring in a wealth of technical and business expertise in dealing with semiconductor companies and also have good market connects, which are essentially very valuable for start-ups.

The investment size should be kept relatively high keeping in view the higher funding requirements for a semiconductor design company.

To understand the requirements and concerns of VCs, angel investors and term lenders toward providing seed funds, workshops/ road-shows need to be facilitated by the government where even semiconductor design startups can be invited.

Some famous established funds instituted by governments worldwide

The Israeli venture community was instrumental in advising the Chinese to set up guidance funds, similar to Israel's Yozma program in the early 1990s, in which the government invests as a limited partner in the local and foreign VC firms along with other institutional investors. It offered attractive tax incentives to any foreign venture capital investments in Israel and also offered to double any investment with funds from the government. As a result between 1991 and 2000, Israel's annual venture capital outlays, nearly all private, rose nearly 60-fold, from US\$58 million to US\$3.3 billion; companies launched by Israeli venture funds went up from 100 to 800; and Israel's information-technology revenues rose from US\$1.6 billion to US\$12.5 billion.

The recently established Russian Venture Company (RVC) is doing the same to attract international brand name VC firms to Russia.

ii) Government of India to collaborate with state VC funds

Contribution to state VC funds	<ul style="list-style-type: none"> ▶ Some states such as Karnataka have instituted a fund where the Karnataka government is expected to provide an amount of INR250 million, toward a 26% contribution to the KITVEN IT fund to assist start up semi-conductor units engaged in design and embedded software. The remaining funds are expected to come from the industry or mobilized through the PPP business model. ▶ Discussion with international VC funds suggest that governments in other competitive countries invest a larger percentage of the fund and then invite international VC firms to fill in the rest of the lacunae. The GoI can play a role here by providing the additional amount or some part of it and raise the rest of it through industry. In this way other states can also be encouraged to form funds.
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iii) Provide cluster-specific funds

- ▶ In order to mitigate risks, GoI should invest its available funds in the ratio of success of individual semiconductor clusters spread across India, such as Bangalore, NCR, Hyderabad, Pune and Chennai, since companies in these clusters already have proven capability in semiconductor design and have taken a lead in the Indian semiconductor story.
The split of funds can be based on a similar ratio of success of various individual semiconductor clusters in terms of revenue/employment generated, in order to ensure replication of success due to availability of talent and knowledge know-how in these clusters.
- ▶ Another criterion for distribution of funds can be to the companies focusing on sectors, which have evolved considerably in these clusters. For example, the aerospace sector in Bangalore or the automobile sector in Chennai.

B. Setup VLSI specific incubation centers

Two types of incubation center models are proposed:

- i. Incubation centers in STPI units
- ii. Incubation centers accessible to engineering colleges in Tier-II cities

Criteria of selection of companies for incubation: Such companies can be identified by a neutral body after judging the research and commercial potential of the ventures, focusing on different market verticals proposed to be served by the startups and SMEs looking for incubation.

Government's support required for tool procurement:

- ▶ To form an Incubation Center Committee (ICC) under the aegis of DIT to overlook the implementation of this program
- ▶ To procure tools from tool vendors at highly subsidized costs and provide them to the start-ups and SMEs, which are incubated. In order to incentivize EDA tool companies, the government can make proceeds from tools as tax-free.

Each of these incubation center models are further explained in detail below.

i) Incubation centers in STPI units

Recommendation: To build an ecosystem of semiconductor design start-ups and SMEs, governments should setup VLSI specific incubation centers in the four large semiconductor design clusters in India, in the cities of Bangalore, NCR, Hyderabad and Pune. Whereas existing incubation centers, which are present currently in STPI units/ academic institutions provide for basic physical infrastructure and connectivity, the VLSI specific incubation centers will provide physical infrastructure, connectivity and tools.

The key characteristics of the incubation centers in STPI units are as follows:

Size of centers	The incubation centers should have a seating facility for 150 people and should not incubate more than 8-10 companies.
Access to funds	The STPI-region specific branches should be empowered to provide a single-window access for clearance to facilitate hassle-free and timely access to funds to companies looking to be incubated.
VLSI-specific facilities required	In addition to the usual incubation center facilities, these VLSI-specific centers will require the presence of VLSI design labs and access to various design tools.
Payback of funds	Instead of charging the incubated companies the full cost for the facilities provided, a nominal charge plus an equity share of the incubated company should be provided to the incubation center.
Promotion of fabless companies	A central facility with the presence of characterization, failure analysis or qualification lab facilities should be provided by the government, which can be utilized by all the companies present in the incubation centers.

Source: ISA-EY research 2010

ii) Incubation centers accessible to engineering colleges in Tier-II cities

Government should consider setting up incubation centers accessible to engineering colleges in Tier-II cities. These centers will provide a symbiotic ecosystem for design start-ups and SMEs, faculty and students. These will provide start-ups with necessary infrastructure facilities and ready access to talent, giving them a platform to launch their operations. The start-ups will contribute in terms of training students and faculty on latest design tools.

Identification of engineering colleges in Tier-II cities: The colleges can be shortlisted on the basis of:

- ▶ One way is to adopt the participating colleges in Tier-II cities as mentioned in the SMDP
- ▶ Existing level of industry interaction with the college. This would help in selection of those colleges, which are above a minimum level in terms of inviting companies to the campus for placements, delivering guest lectures and conducting workshops.
- ▶ Quality of faculty in these colleges, judged on the basis of experience in teaching semiconductor design and number of research papers published

Setting up incubation center facilities can be quite a complex operation involving multiple stakeholders working together. Following are the key stakeholders identified for this initiative:

- ▶ Start-up and SME design companies
- ▶ Students
- ▶ Faculty
- ▶ Government

Following table lists the roles and benefits available to all the stakeholders.

Stakeholder	Roles	Benefits
Start-up companies and SMEs	<ul style="list-style-type: none"> ▶ To train students and faculty on latest design tools. ▶ To provide students and faculty with an opportunity to work on live projects and take up internships with them. 	<ul style="list-style-type: none"> ▶ Incubation facilities: Due to lack in availability of funds from venture capitals, start-ups require an atmosphere for incubation. These incubation centers will provide the necessary infrastructure such as office and laboratory space as well as power at a highly subsidized rate, which will lower their initial set-up cost. They will also get access to latest design tools procured by the government at highly subsidized costs.

		<ul style="list-style-type: none"> ▶ Access to talent: Design start-ups face challenge in hiring engineering graduates from colleges in tier-I colleges as majority of design talent opt for well-established MNCs in design space. This model will help them to attract quality talent from engineering colleges in Tier-II cities where they are likely to establish their operations. ▶ Reduction of deployment time: There will be a substantial reduction in their training costs for the fresh engineers as the students will receive training during their engineering tenure making them ready for the industry. ▶ Leverage on faculty: Companies can leverage the skills of the faculty in these colleges by engaging in long-term R&D projects with them. ▶ Employee satisfaction: As these incubation centers will be set up in the vicinity of engineering colleges in different parts of the country, the design engineers can opt for working for these companies established near their hometowns. This will help start-ups in attracting quality design professionals and reducing attrition rate.
Students	<ul style="list-style-type: none"> ▶ Involvement in design-related research activities ▶ Internship with design start-ups. ▶ To work on live projects with design companies 	<ul style="list-style-type: none"> ▶ The students will get hands-on experience on live projects by working with latest design tools used in the industry. ▶ Creation of an opportunity to get employed with the start-ups and SMEs after undergoing an extensive training during and after their graduation.
Faculty	<ul style="list-style-type: none"> ▶ To work closely with start-ups to conduct research. 	<ul style="list-style-type: none"> ▶ Faculty will benefit from the industry interaction by working closely with design start-ups and SMEs on various projects. This will result in a continuing education opportunity for them as they will get to refresh their skills and update their knowledge while working on latest design tools. ▶ Opportunity for faculty to obtain paid consulting projects from start-ups and SMEs.
Government	<ul style="list-style-type: none"> ▶ To identify potential engineering colleges in tier-2 cities for setting up incubation centers. 	<ul style="list-style-type: none"> ▶ Talent growth: The colleges in the vicinity of incubation centers will produce highly trained and design industry-ready manpower equipped with all the relevant skills. Thus the government will have to spend less amount of money to set-up facilities in colleges such as under SMDP to produce skilled design engineers. ▶ Equity stake: Government may consider having equity stake in some of these start-ups, which can later be sold and the profits obtained can be used to fund other start-ups.

Source: ISA-EY research 2010

C. Tax incentives

Direct tax benefits

- ▶ Tax deduction for R&D companies could be on a graded scale, based on the percentage of revenues that they spend on R&D. A higher percentage will mean that the complexity of the product R&D is higher and hence, it is expected to have higher value-addition and also a longer gestation period
- ▶ Exemption from levy of minimum alternate tax (MAT) for a period of five years, so that they can use the extra cash generated from tax savings to reinvest in R&D.

Indirect tax benefits

- ▶ Extension of service tax exemption to STPI and EOU units similar to that for SEZ units
- ▶ Abolition of Special Additional Duty (SAD) on all electronic products and components used by the semiconductor industry for a period of 5 years – similar to the present concession for the parts/components/accessories to manufacture mobile handsets, including cellular phones, introduced in the Union Budget 2011
- ▶ The GoI could consider exempting semiconductor units set up outside SEZs from the levy of countervailing duties (CVD).

Others incentives

- ▶ **Stamp duties:** Exemption from stamp duties paid with respect to loan agreements, credit deeds, mortgage and hypothecation deeds executed for availing term loans from financial institutions notified by the GoI for an initial period of five years. Further, exemption from payment of stamp duties could also be granted for lease deeds, lease-cum-sale deeds for units set up in areas notified by the central /state government for an initial period of five years. Registration charges could also be lowered for loan documents, sale deeds, etc.;
- ▶ **Entry tax:** State governments could consider exempting entry tax on plant and machinery and capital goods for an initial period of five years from the date of commencement of projects. Further, entry tax should also be exempt for raw materials, components and consumables (apart from petroleum products) for an initial period of 5 years from the date of commencement of commercial production;
- ▶ **Interest free loan on VAT:** Interest free loan on VAT could be provided by state governments depending on the quantum of investments and strength of work force in the units.

Issue 3: Lack of a semiconductor ecosystem

Competitive countries in the semiconductor industry have a mature and very well-developed semiconductor ecosystem, which in turn, enables growth of the semiconductor industry. Discussions with industry players also suggest that the cost arbitrage advantage enjoyed by India today, may not always last and the growth of the semiconductor industry in India may be muted if the other areas of the semiconductor value-chain such as ATMP and semiconductor manufacturing are not tapped into.

Recommendations:

Goal No. Addressed	Improvement area	In-depth recommendations elaborated
1	Ecosystem development	3A) Promote fabless semiconductor model - <i>build on expertise achieved in the services industry to promote semiconductor products designed in India</i>

The detailed recommendation for a strong ecosystem development is:

Recommendation 3A: Promote fabless semiconductor model

Fabless refers to the business methodology of outsourcing the manufacturing of silicon wafers, whereas they focus on the design, development and marketing of their products and form alliances with silicon wafer manufacturers, or foundries.

With process technology being viewed as commoditized and unable to provide a competitive advantage with the exception of memory, continuing down the integrated device manufacturer path was proving to be filled with challenges for many companies and hence, the shift over the last decade was seen toward fabless companies worldwide. There is now a trend seen toward fabless companies moving gradually toward Asia, due to large sustainable markets as well as the presence of foundries in this region.

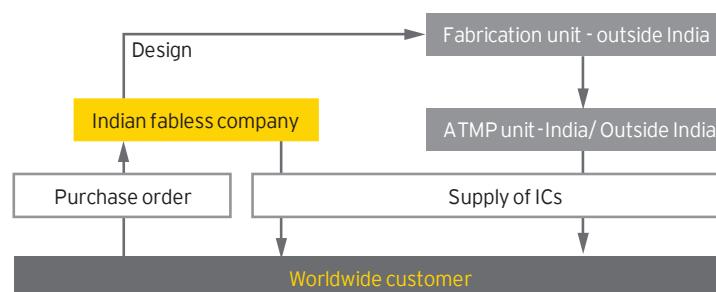
Area of concern: India with its large availability of talent pool in the design industry, presence of a market for region-specific products in the clean energy, rural and healthcare sectors and Indian companies are being better equipped to provide high-quality software as compared to its Asian competitors, make a strong case for the rise of the fabless industry. But the growth in the number of indigenous fabless semiconductor companies in India is not as expected. Apart from a very handful number of players, rest of the industry is heavily skewed toward design, resulting in government policies aimed to provide investments and incentives to the design industry.

Indian fabless companies can be defined as, companies with a combination of both, parent entity registered in India and with more than 75% of its design workforce operating out of India. This can be further debated and defined by the government.

Recommendations:

- ▶ Unveiling policy similar to STPI policy for incubating fabless semiconductor companies

■ Exhibit 4: Fabless industry model



Source: ISA-EY research 2010

Fabless companies selling ICs avail tax benefits in India under EHTP and not STPI. But these benefits are availed only if there is any further value-add from India, post manufacturing. Since these companies ship ICs, manufactured abroad, directly to the end customer, they are not provided exemption.

Recommendations:

Either of the following initiatives can be taken:

- ▶ Design should be conceived as the value-add and likewise STPI policy can be updated to reflect this
 - ▶ Fabless companies should be extended STPI such as benefits following the potential STPI policy expiry this year as moving into a SEZ may not be financially viable for a fabless semiconductor company, which is less people intensive.
- ▶ **Setting up of characterization, failure analysis and qualification lab**

Fabless companies in the startup phase are not able to setup these labs in-house as they are very cost intensive and hence these ICs need to be sent abroad, which is time consuming and hence a big disadvantage for Indian fabless companies. The cost of setting up a characterization lab alone can be more than US\$ 1.5 million plus maintenance costs.

Lab type	Services rendered
Qualification lab	<ul style="list-style-type: none">▶ ESD and Latch-up Testing and Certification▶ Military and Space Grade Qualification
Failure analysis lab	<ul style="list-style-type: none">▶ Focused Ion Beam (FIB)▶ Emission Microscopy (EMMI)▶ Package de-capsulation and encapsulation
Characterization lab	<ul style="list-style-type: none">▶ Phase noise measurement▶ RMS jitter

Source: ISA-EY research 2010

Recommendation: Fabless need an ecosystem similar to that present in other countries where private labs are setup locally. Since the fabless industry itself is in a nascent stage in India, there are not many good quality labs unlike other countries. Hence the government needs to provide 50% of the total cost towards purchase of proposed equipment while setting up the following labs. The remaining funds can come from the industry or mobilized through the PPP business model.

Other recommendations towards building an ecosystem which is conducive for the growth of the Indian semiconductor industry are:

Improvement area	In-depth recommendations elaborated
Absence of a startup and SMEs ecosystem	3B) Promote currently existing semiconductor clusters and develop new clusters
Tapping other components of the ecosystem	3C) Encourage and promote ATMP 3D) Support dedicated foundries to create devices meeting local demand

Each one of these recommendations is discussed in detail below.

Recommendation 3B - Promote currently existing semiconductor clusters and develop new clusters

According to CII, 60% of India's overall exports come from units in clusters, making it one of the key drivers of economic growth. With close to 80% of the companies in the semiconductor space having a presence in Bangalore, NCR, Pune and Hyderabad regions, there is a case for the region around these cities to be promoted as hubs of leading-edge semiconductor capabilities, research and development. Promoting clusters has various advantages – increasing competitiveness, sharing of semiconductor knowledge, ease of sourcing of components and ready availability of funding.

The concept of semiconductor clusters worldwide is slightly different in the context of India as India lacks the manufacturing foundries, which are an integral part of worldwide semiconductor clusters. The foundries are replaced by semiconductor design companies in India. Globally also the definition of semiconductor clusters has expanded to include the ecosystem, which is present within the periphery of hundreds of miles instead of a single campus.

Recommendations

- ▶ The government should establish institutes specialized in semiconductor research similar to the Indian Institute of Nano Science (IINS) being setup in Bangalore, Mohali and Kolkata and other colleges with specialization in semiconductor related engineering streams in proximity to the clusters in order to facilitate the industry academia interaction and collaboration. Taiwanese government developed Hsinchu park is close to two of Taiwan's oldest universities giving it the advantage of skilled labor supply and low employee training costs.

- ▶ Semiconductor companies need a strong supply of components and hence component sourcing companies should be encouraged to setup shop in these clusters to ease sourcing required for board/ hardware design in required quantities and time
- ▶ To increase collaboration and business opportunities, there needs to be increased cooperation with industry clusters which source semiconductors, like electronic clusters
- ▶ New clusters can be developed around a port city such as Chennai or Vizag. The advantage of a port city is vast availability of water and treatment plants. Sourcing of components and logistics are also a non-issue due to the presence of ports. Power plants can be setup within the vicinity of these clusters and these clusters can be given SEZ status to encourage investments in them.

Famous semiconductor cluster examples

“Silicon Fen”, as the cluster is popularly known as, is located in the Cambridge region of East England. In 1980s, this cluster produced more patents per capita than the UK average. Proximity to the University of Cambridge has been a major reason for the development of this cluster. High-tech companies located in the cluster collaborate with related departments in the university for R&D activities by setting up research laboratories there. Easy access to finance is another important factor for development of this cluster. Venture capital firms and local intermediaries provide financial assistance to the firms in the cluster.

Another case in point is Hsinchu park – a technology park that houses research centers, companies and universities within a single campus to promote for a healthy interaction.

Recommendation 3C - Encourage and promote ATMP

The ATMP stage completes the last link of the semiconductor value chain. Though currently this industry is very small and in its nascent state in India, with more captives outsourcing ATMP activities to ATMP units in India and the setting up of domestic testing and packaging companies, this industry has a vast potential to grow.

Recommendations

- ▶ Testing being a logical extension to design services and considered to be an industry worth multi- billion US dollars, governments should make additional provisions to encourage and incentivize companies to set up testing units in India. Labs involved in testing and certifications should be incentivized by government to set shop or companies can join hands to fund setting up of more common testing and certification facilities to service all their needs.
- ▶ Revision of the tax structure and allocation of special ATMP zones in the proximity of ports will also aid in building this ecosystem.
- ▶ The threshold limit for availing incentives for ATMP units of US\$ 250 million under the Semiconductor Policy of Government of India, 2007, appears to be very high for ATMPs and merits a review to reduce this threshold to above US\$ 100 million and up to US\$ 250 million as proposed in the Karnataka state policy.



Recommendation 3D - Support dedicated foundries to create devices meeting local demand

Area of concern: India cannot compete with Taiwan or China on the leading node since it involves significant investments to the tune of multi-billion US\$ and technical know-how, which these countries have gained over the past 20 years. India also faces issues in supporting foundry operations since there are infrastructural challenges such as uninterrupted water and power supply, easy access to ports etc.

Recommendations

- ▶ The options that can be explored are, creating foundries at “second-to-last” or “third-to-last” technology nodes probably at 90 nm or 120 nm, which require far less investment and can cater to local demand in select verticals such as industrial automation, consumer segment, etc. The large local demand, as well as proximity to customers, will ensure growth of such foundries and make movement of such units to other geographies less likely.
- ▶ Another option, which can be explored is creating foundries for analog and mixed signal technology. These foundries at 180 nm/130 nm are contemporary to worldwide analog and mixed signal foundries, cost-effective and meet global demands. An added advantage to this, considering that design is the mainstay of the Indian semiconductor industry, is that it may fuel the growth of analog and mixed design industry in India as the design content in these technologies is of higher value than digital technology.

Issue 4: Lack of adequate infrastructure, implementable incentives and policies, including IP protection and R&D ecosystem

The investors look up to the government for commitment to the development of the industry through equity participation, fiscal incentives and support infrastructure development.

Recommendations:

Recommendations to address the issue of lack of adequate infrastructure, policies and implementable incentives are:

Goal No. Addressed	Improvement area	In-depth recommendations elaborated
2, 4	Providing direct assistance	4A) Protect and promote intellectual property 4B) Provision of R&D funding initiatives for academia and industry
1	Providing indirect assistance	4C) Provide infrastructure support

Each one of these recommendations is discussed in detail below.

Recommendation 4A - Protect and promote intellectual property

IP offences such as trade secret theft, patent infringement and counterfeiting in the semiconductor space in India are lower as compared to its Asian counterparts such as China, Taiwan and Korea. The GoI has adopted a unique and exhaustive set of legislations for intellectual property in India in line with its prevailing socio-economic and political factors. Customers favor India for its relatively strong IP protection policies as compared to other Asian countries. The favorable opinion of customers of semiconductor companies toward IP protection in India can be further leveraged by the GoI and industry adopting some best practices and creating/possessing intellectual property. The focus now needs to shift to the next level where concentrated attention on promotion of innovation. These recommendations call for the government, industry and researchers to work together to improve the quality and standard of innovation and its application in India.

The following table describes various opportunities to foster innovation in the semiconductor space:

Create	<ul style="list-style-type: none"> ▶ Encourage Indian entities to develop IP Entities involved: Companies, government research labs etc <p>Recommendation:</p> <ul style="list-style-type: none"> ▶ Created in India: The GoI can continue with its program for financial assistance of 50% of patent costs instituted through DIT, through a few changes to the policy to facilitate better access to funds: <ul style="list-style-type: none"> ▶ Grants can be forwarded not just to SMEs or start-ups, but to large companies also based on the merit of innovation ▶ Filing procedures <ul style="list-style-type: none"> ▶ Reduce the high cycle time for processing patent reimbursement applications applied currently ▶ Set up monthly/quarterly sessions for application hearings ▶ Set up local/zone-wise offices instead of only a centralized office in Delhi, to reduce travel costs and time for applicants ▶ Encourage companies to present more than one application, if it is the case, per meeting <p>Criteria: An exclusive project funding process to be established and administered by the GoI. These can be granted to government or private companies based on the application's merit and valuation by an approved IP valuation committee. Some part of this fund should be expected to come back to the government, based on the success of the venture, in the case of for-profit ventures.</p>
2. Buy	<ul style="list-style-type: none"> ▶ Encourage IP ownership by Indian entities Entities involved: Companies, government research labs etc. <p>Recommendation: Owning IP is more important to creating value for businesses than just motivating innovation. Incentives need to be given to Indian entities to acquire intellectual property via different means:</p> <ul style="list-style-type: none"> ▶ Foreign company acquisition ▶ Foreign patent acquisition <p>Criteria: Government incentives will be based on business case justification approved by IP experts. <i>An Ideal situation is when the applicant is able to establish relevance of the patent to a product that the applicant exports to the said foreign country or the product has a large market in India.</i></p>

**3.
Encourage
academic
R&D**

► **Encourage Indian Universities to do international quality research**

Recommendations:

- ▶ Incentivize academic researchers to obtain publications in international journals such as IEEE and conference participation as part of the PhD evaluation process in India.
- ▶ Provide special incentives to support researchers and research students for patent applications as per criteria given in #1 above.
- ▶ Provide special tax incentives to companies willing to set up lab facilities at research institutions

Source: ISA-EY research 2010

Other recommendations towards protecting and promoting intellectual property are provided below:

Protecting intellectual property

Area of concern: Generate awareness about India's legislative and administrative framework amongst holders about protecting their rights and amongst industry about deceiving others of their intellectual property rights and the consequences.

Recommendations:

- ▶ Industry along with the various forms of government should conduct series of workshops/awareness programs, on line of those conducted by CII in collaboration with state governments, to discuss challenges/issues faced by the IP right holders, due consideration can then be given while framing new laws
- ▶ Companies should conduct regular training sessions for employees to improve awareness and imbibe strong IP protection measures, provide for a 'cool-off' period between projects of similar nature for different competitors and conduct audits for all projects to ensure uniqueness of design and patent protection

Promoting intellectual property

Area of concern: One of the key challenges in the embedded software industry is to keep pace with the current technology node which changes every 18-24 months while providing increased functionality at the same or lower cost.

Recommendations:

- ▶ Companies need to start investing in building libraries, so as to modularize code which can then be reused at a later stage for providing similar functionality. Thus with rapid hardware changes, costs can be controlled by utilizing lesser effort due to reusable code to provide increased functionality by the software. The advantage of investing to convert this reusable code to IP is to unlock and generate another revenue stream for the company by offering IP-based solutions.
- ▶ Industry should collaborate with academia for conducting research in the development of common testing platforms and frameworks to enable easy integration of third-party software IPs into custom chip development

Recommendation 4B - Provision of R&D funding initiatives for academia and industry

Semiconductor technology is growing at a rapid pace and to keep pace with it, the Indian semiconductor industry R&D system should be improved.

A. R&D funding initiatives for academia

The government should consider setting up an R&D fund for the following academia related activities:

Improvement of laboratory infrastructure in top 45 engineering colleges	<ul style="list-style-type: none"> ▶ SMDP covers 7 Resource Centers and 25 PIs. ▶ In order to enhance the output of engineers relevant for semiconductor design, laboratory infrastructure for other top engineering colleges, which fall outside the ambit of SMDP, needs to be improved. ▶ This program needs to be extended to 11-13 more engineering colleges by 2012 by equipping them with faculty and infrastructure to meet the demand for semiconductor design engineers by 2012.
Participation assistance for international conferences/ workshops	<ul style="list-style-type: none"> ▶ Grant The government should continue to encourage participation of semiconductor design faculty across engineering colleges in international conferences and workshops. The government should sponsor up to 75% of their travel expenses and 50% of the conference registration fee (if any). <p>Criteria for grant</p> <ul style="list-style-type: none"> ▶ This incentive should be made available to all the faculty members who have published at least two papers in the preceding two years in area of semiconductor design in referred magazines/journals of international reputation such as IEEE. ▶ In exceptional cases, where the research work has the potential to be filed as a patent, 100% of travel and registration fee exemption is proposed.
Funding for research projects undertaken by students and institutes	<ul style="list-style-type: none"> ▶ A council should be set-up by the DIT to identify good individual research projects undertaken by MTech/ PhD scholars and projects undertaken at institute level. Depending upon the complexity of the project and the potential idea, the funding should range from INR0.1 million to INR2 million. This funding can be partly provided by the DIT and partly sponsored by the industry

Source: ISA-EY research 2010

B. R&D funding initiatives for industry

The government should consider setting up an R&D fund for the following industry related activities:

R&D fund	<ul style="list-style-type: none"> ▶ The GoI should setup a semiconductor fund of excellence to provide funds to encourage private companies, who undertake R&D activities for India-specific products designed in India. ▶ The fund should cover 50% of R&D costs, including people-related costs, toward R&D activities. ▶ The effort made toward R&D by companies should be evaluated by an expert panel of academicians, top Indian leaders from Indian firms and MNCs, as well as invited talent from abroad to oversee policy implementation. ▶ Based on the evaluations, an award can be constituted for the best R&D project undertaken by companies in the semiconductor design space.
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Source: ISA-EY research 2010

Recommendation 4C - Provide infrastructure support

Unavailability of adequate infrastructure reduces the attractiveness of India as a manufacturing destination. As compared to China, India's infrastructure is in a poor condition. The gap between the two countries is widening every year with China investing 20% of its GDP in infrastructure as compared with India's 6%. These infrastructural challenges make doing business in India difficult.

Area of concern: India is a power-deficient nation and demand-supply mismatch is around 7%. Cost of electricity in India is high as compared to other countries in the benchmarking study except Germany.

Recommendations:

- ▶ The GoI should invest in developing more power plants and should encourage and incentivize more private players to enter this sector and set-up power projects. Power generation set-ups and distribution networks need to be improved in order to minimize losses.
- ▶ The quality of power to be supplied to manufacturing units should be uninterrupted and of a steady frequency and voltage
- ▶ The government should provide subsidies in electricity prices similar to those provided in the Karnataka Semiconductor policy to new business set-ups to help them reduce their operational costs and become profitable soon. These subsidies can be removed after the businesses become profitable.

Area of concern: The semiconductor industry requires world-class logistics infrastructure for inbound material and outbound finished products to be shipped globally. India's ports today are already at saturation point and container capacities are almost completely utilized.

Recommendations:

- ▶ This requires upgrading of Indian ports and setting up of a clean room supply chain to handle high-tech electronic components and raw material.
- ▶ The government needs to make public investment in additional capacities, invite privatization of operations and further reduce customs clearance times to one or two days (as has China) from the current one or two weeks.

In addition to the above recommendations, some other infrastructure incentives which can be adopted as best practices from China are:

- ▶ Under a "virtual fab" strategy adopted by some local governments, construction of a fabrication plant is fully or largely funded by the government but is managed by contracted private firms under a profit-sharing agreement.
- ▶ Another instance is, that of The Pudong New Area in Shanghai, which refunds land use fees and subsidizes property taxes for pre-approved R&D centers, under the Pudong technology development fund

Issue 5: External issues affecting the Indian semiconductor industry

Area of concern: Sustenance of India's growth momentum against increased competition from low-cost Asian countries

Recommendations:

- ▶ Unveil new India-specific policies aimed at other industries, which utilize semiconductors as sub-components. This will encourage more R&D in the semiconductor space in India in order to adhere to these policies, thereby converting them into local market opportunities. An example is the environmental protection policy in the form of Bharat norms introduced by the government for the automobile industry in India.
- ▶ The industry should begin to move away from the standard fixed FTE-based or time and material business models and adopt innovative non-linear business models (outcome-based). Output is not directly proportional to inputs in these models and pricing is not calculated based on costs rather on the markets appetite. The industry should also invest in more automation and reusability of code as well as develop IP-based solutions. These steps can aid in reducing costs, improve efficiency and increase revenues to help maintain India's position vis-à-vis competition.

Roadmap for recommendations implementation

Provided in Exhibit 5 below is an indicative roadmap for all the articulated recommendations to be implemented in order to aid the Indian semiconductor industry tap into its complete potential. The timeline for recommendations is to be read as:

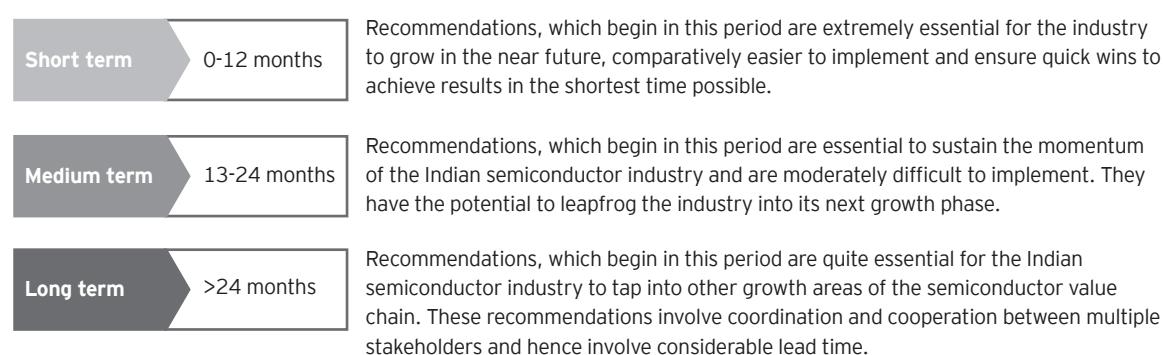
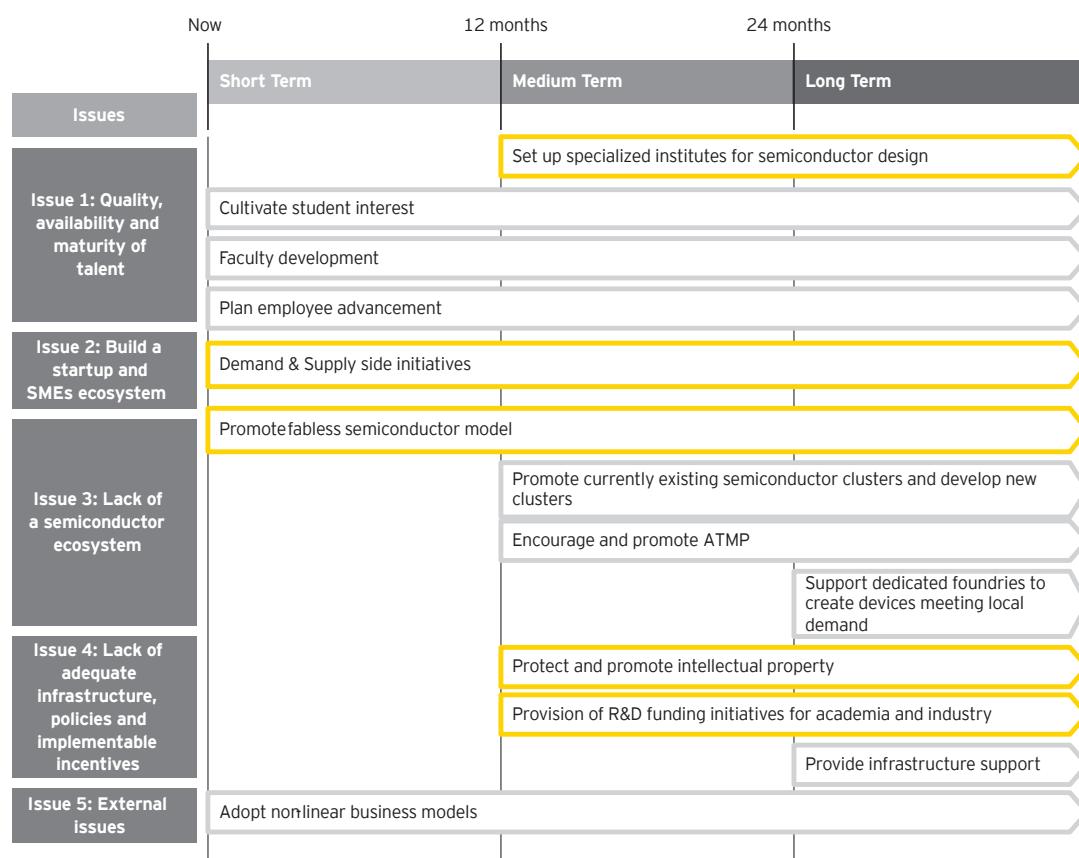


Exhibit 5: Roadmap of recommendations



Source: ISA-EY research 2010

*Highlighted recommendations are detailed recommendations

A point to be noted is that all the recommendations proposed are activities which are to be ongoing and continuous and hence extend beyond the period of their respective terms.



Addressal of challenges with stakeholder responsibility

In conclusion, Exhibit 6 below summarizes the main issues that the Indian semiconductor industry faces, the key challenges associated with each issue and the corresponding recommendation proposed for each issue.

Also provided is the indicative group of stakeholders who will be involved in shaping these recommendations to convert them into specific action items which can then be implemented as per the suggested roadmap in Exhibit 5.

Exhibit 6: Addressal of challenges with stakeholder responsibility

Issue no.	Main Issue	Challenges to be addressed	Recommendations	Challenges		
				Government	Industry	Academia
1.	Quality of talent	► People-related challenges	► Feedback on the SMDP II	√	X	√
		► Quality of talent				
		► Lack of technical career path				
		► Attrition				
		► Lack of scale at the leading node				
		► Increasing requirement of expert parallel programmers				
		► Lack of R&D Funding in universities				
		► Preference of ADM services as a career option				
		► Set up specialized institutes for semiconductor design	√	√	√	
		► Cultivate student interest				
		► Faculty development				
		► Plan employee advancement	X	√	X	



Issue no.	Main Issue	Challenges to be addressed	Recommendations	Challenges		
				Government	Industry	Academia
2	Absence of a start up and SME ecosystem	<ul style="list-style-type: none"> ▶ Lack of encouragement for startups and SMEs in semiconductor design 	<ul style="list-style-type: none"> ▶ Demand side: keep aside share of indigenous products in sectors of national importance ▶ Supply side: <ul style="list-style-type: none"> a. Provide avenues for seed and VC funding (Government and private) b. Set up VLSI-specific incubation centers for incubation of startups and SMEs <ul style="list-style-type: none"> i. Incubation centers in STPI units ii. Incubation centers accessible to tier-II engineering colleges ▶ Tax incentives 	√	√	√
3.	Lack of a semiconductor ecosystem	<ul style="list-style-type: none"> ▶ Lack of semiconductor manufacturing ecosystem ▶ Compliance-related challenges ▶ Integration and testing of software and hardware ▶ Need for ecosystem development 	<ul style="list-style-type: none"> ▶ Promote fabless semiconductor model ▶ Promote currently existing semiconductor clusters and develop new clusters ▶ Encourage and promote ATMP ▶ Support dedicated foundries to create devices meeting local demand 	√	√	√

Issue no.	Main Issue	Challenges to be addressed	Recommendations	Challenges		
				Government	Industry	Academia
4.	Lack of adequate infrastructure, policies and implementable incentives	<ul style="list-style-type: none"> ▶ High and unstable corporate tax structure ▶ Expiry of the national level semiconductor policy ▶ Cost pressures due to constantly evolving hardware ▶ Deficient power supply ▶ High electricity cost ▶ Inadequate logistics infrastructure 	<ul style="list-style-type: none"> ▶ Protect and promote intellectual property ▶ Provision of R&D funding initiatives for academia and industry ▶ Provide infrastructure support 	√	√	√
5.	External issues affecting the Indian semiconductor industry	<ul style="list-style-type: none"> ▶ Competition from China, Taiwan and other South-East Asian Countries ▶ Adoption of de-risking business models by customers ▶ Protectionist policies adopted by other nations 	<ul style="list-style-type: none"> ▶ Introduce India-specific policies ▶ Adopt non-linear business models 	√	√	X

Source: ISA-EY research 2010

Annexure I

Indicative list of subjects which should be offered in proposed semiconductor institutes

Semiconductor Devices and Modeling	Semiconductor Physics
VLSI Design	VLSI Layout
VLSI Fabrication Technology	VLSI System & Architecture
VLSI Testing & Testability	VLSI Interconnect Analysis
Analog Design	Digital IC Design
System Design	Hardware Software Co-design
RF Design	Low Power Design
Mixed Signal IC Design Analysis	Circuit Simulation & Timing Analysis
Hardware Description Language	Reconfigurable Computing
Embedded Systems	Combinatorial Algorithms for VLSI CAD
Test and Verification	Digital Signal Processing
CAD for VLSI	Device Modeling and Simulation
Advanced System Architecture	FPGA/CPLD

Indicative list of laboratories which should be set up in proposed semiconductor institutes

VLSI Design lab	Analog Design lab
VHDL-based Design lab	Verilog-based Design lab
Systems Simulation laboratory	Chip Applications laboratory
Process Technology lab	Integrated Circuits Design laboratory
RF Measurements and RFID laboratory	Multimedia Application laboratory
DSP laboratory	FPGA laboratory
Interface Circuits/Video System laboratory	Microcomputer lab
Device Modeling lab	PC Interface lab
LED Process laboratory	TFT-LCD Process laboratory
White Light LED lab	SoC Design
SoC Testing	

Notes



Notes





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