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Catalyzing the Growth of the Semiconductor Ecosystem in India

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भारत सरकार के प्रमुख वैज्ञानिक सलाहकार
एवम्
डी.ए.इ. - होमी भाभा प्रोफेसर

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सत्यमेव जयते

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FOREWORD

India was one of the first countries in Asia after Japan to start the production of semiconductor devices. Despite the initial head start for the semiconductor industry in the country, the pace of development has not been as fast as it could have been and needs to be accelerated. In this context, Government as well as industry have recently taken many initiatives. One of them is from our Office, which is leading to the setting up of two Centres of Excellence on Microelectronics and Nanoelectronics – one each in the Indian Institute of Technology, Bombay (IITB), Mumbai and the Indian Institute of Science (IISc), Bangalore at a total approximate cost of Rs. 100.00 crores under a common project sanctioned by the Department of Information Technology (DIT), Government of India. This led to the forging of a unique partnership between two leading academic institutes i.e. the IITB and IISc and the establishment of a nationally-spread user community.

Keeping all this in view, the Scientific Advisory Committee to the Cabinet (SAC-C) in its 15th meeting held on 13th August, 2008 recommended that a Committee be formed to evolve an approach plan for catalysing the growth of the Semiconductor Ecosystem in India. The Committee submitted the present Report in May, 2009, recommending a number of steps to be taken to promote India as a hub of production for semiconductor devices in general. SAC-C in its 18th Meeting held on 27th August 2009 endorsed the recommendations made in the Report.

I am sure that the Report will give a new momentum for the creation of an ecosystem for the sustained growth of this industry.

(R. Chidambaram)

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2.	Shri N. K. Sinha Joint Secretary Ministry of Human Resource Development, New Delhi	Member
3.	Dr. Chandra Shekhar Director Central Electronics Engineering Research Institute, Pilani	Member
4.	Dr. Navakanta Bhat Associate Professor Department of Electrical Communication Engineering, Indian Institute of Science, Bangalore	Member
5.	Dr. Debasis Dutta Scientist 'G' Department of Information Technology, New Delhi	Member
6.	Dr. Madhusudan V. Atre President Applied Materials India Pvt. Ltd., Bangalore	Member
7.	Dr. B. M. Arora Former Professor Tata Institute of Fundamental Research, Mumbai	Co-opted Member
8.	Dr. R. K. Bhogra Additional General Manager and Head Amorphous Silicon Solar Cell Plant, BHEL, Gurgaon	Co-opted Member
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Preamble

At its 15th meeting held on 13th August, 2008, the Scientific Advisory Committee to the Cabinet (SAC-C) under the Chairmanship of Dr. R. Chidambaram, the Principal Scientific Adviser to the Government of India, recommended that a Committee be formed to look at the future of the semiconductor industry in India. A Committee was, accordingly, formed and notified on 26th November, 2008.

The terms of reference of the Committee were:

(i) To look into various aspects for exploring the possibilities of semiconductor industries in India.
(ii) To assess the impact of the SIPS (Special Incentive Package Scheme), also sometimes referred to as the Semiconductor Policy, announced by the Government of India, and to make suitable recommendations to achieve maximum benefits from this policy.
(iii) To assess the requirements of manpower and R&D for existing and future semiconductor industries in India.

The Committee met on two occasions, 2nd February 2009 and 13th May 2009. In addition, a "brainstorming session" was held on 6th March 2009, chaired by the Principal Scientific Adviser to the Government of India and attended by many invitees from government, academia, private and public sector industry, national laboratories and industry associations. The attendees at this brainstorming session included, besides the members of the Committee, the following: Shri Rajesh Bhat, Reliance Industries Limited; Shri Ajai Chowdhry, HCL Infosystems; Dr. B.K. Gairola, National Informatics Centre; Shri Rajiv Jain, ISA; Shri Naveen Mandhana, Videocon Industries Limited; Dr. R. K. Nahar, CEERI; Dr. K. D. Nayak, ANURAG; Shri Keshav Prasad, Tata BP Solar; Dr. S.C. Sabharwal, BARC; Shri V.V.R. Sastry, BEL; Ms. Poornima Shenoy, ISA; and Dr. M. J. Zarabi, INAE. Very useful inputs were received from the participants both during the meeting as well as later in writing and particularly apex organisations like DIT and ISA, which are also responsible for promoting domestic semiconductor industry.

Two sub-committees were appointed to look at the status of semiconductor industry in India, and at the requirements of education and manpower training, respectively. These sub-committees met on 6th March, 26th March and 21st April 2009. The former sub-committee visited several semiconductor industries in Delhi, Bangalore and Hyderabad.

In addition to the in-person meetings, the committee members exchanged views and information via email and telephone.

This report, *Catalyzing the Growth of the Semiconductor Ecosystem in India*, presents the Committee's analysis of the current scenario in India, and provides recommendations for promoting the development and growth of the semiconductor fabrication ecosystem in India, which includes the manufacturing industry as well as relevant aspects of research and manpower training for this area.

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1. Historical Introduction and Background

1.1 Historical Introduction

The semiconductor industry is one of the major global economy drivers. After the invention of the transistor in 1947 and the invention of the integrated circuit in 1958, the industry grew rapidly, fed by R&D from major corporations, academia and research laboratories. The growth of semiconductors is epitomized by Moore's Law which states that the density of chips doubles every 18 months a law which, though propounded in 1960's, continues to hold into the new millennium. Semiconductor products fed into computers, communications, automobiles, entertainment, defence and consumer industry, and revolutionized them all. The semiconductor industry today is an approximate US$ 260 billion industry worldwide (as of end 2008).

Although the semiconductor revolution began in the USA, it spread within a few years to Japan and Europe, and within a couple of decades to many countries in the Pacific rim, like Taiwan, Korea and Singapore. Later, in the 2000's, it also took root in China with the setting up of major foundries in that country.

The history of semiconductors in India is checkered. India was one of the first countries in Asia after Japan to start production of semiconductor devices: Bharat Electronics Ltd. (BEL) manufactured Si and Ge transistors in the early 1960's, under license from RCA. TIFR in Mumbai developed versions of TTL integrated circuits in the late 1960's, and transferred the technology to BEL. BEL manufactured TTL chips in the early 1970's, and also metal-gate CMOS in the mid-1970's. Semiconductor Complex Ltd. (SCL) was envisaged as a Si-gate CMOS design and fabrication company in the mid 1970's, when this technology was yet in its infancy, with its great future still uncharted. All of these developments in India were only 3-5 years behind similar developments in USA and Japan, and far ahead of what was happening in most other countries.

Despite the initial head start for the semiconductor industry in India, the pace of development in integrated circuits faltered in the politically turbulent years of the late 1970's and early 1980's. SCL did not start production of its 5 µm CMOS circuits till 1983, and BEL continued to focus only on small-scale bipolar integrated circuits. Some other semiconductor manufacturing initiatives during the early years were the setting up of GAETEC, focusing on GaAs; a CMOS facility created at ITI Ltd; and several small private companies such as Continental Devices India Ltd. In addition, some companies were set up to focus on optoelectronics applications of semiconductors, such as Central Electronics Ltd., which fabricated solar cells, and, in the early years, LEDs. The public sector giant BHEL also ventured into the fabrication of discrete power devices and photovoltaic cells. During the 1990's, private companies started manufacturing photovoltaic cells under Joint Venture agreements.

A major boost to semiconductors in India came with the setting up of VLSI chip design companies in India. These companies utilized the engineering skills and training available in India. The first of the major multinational companies began to set up design centres in the mid-80s. This was followed by many others, and today over 150 international companies have their design centres in India, in addition to several Indian companies. 9 of the top 10 global fables companies and 23 of the top 25 global semiconductor companies have a presence in India. Though most of these companies have stayed in the field of chip design, some of them have diversified into related areas like semiconductor device and process modelling, testing, and reliability characterization. Recent developments include companies offering services in semiconductor chip testing and equipment manufacturing. However, no major international company ventured into semiconductor manufacturing.

In recent years, there have been some initiatives to target semiconductor manufacturing, including chips. Interest was shown by several entrepreneurs and technology companies. To capitalize on this nascent interest, and recognizing that semiconductor foundries in many other countries have received government support, the Department of Information Technology (DIT) of Ministry of Communication and Information Technology (MCIT) announced its "Special Incentive Package Scheme to encourage investments for setting up semiconductor fabrication and other micro and nano technology manufacture industries in India" (also called SIPS or Semiconductor Policy) in March 2007, and issued detailed guidelines for its operation in September 2007.

During the past two decades, India has made enormous strides in various areas of software, of which VLSI chip design is the one which is directly related to semiconductors. Indian chip designers are widely recognized to be outstanding. Though the VLSI chip design industry started in India to take advantage of salary differentials with respect to US and Europe, the growth in recent years has focused on the high level of skills and expertise available. Flagship chips of several major international companies have been fully designed, from concept to silicon, at their India centres.

1.2. Background

Despite the achievements on the VLSI chip design front, it was starting to be recognized that without the backup manufacturing prowess, India would always remain a small player in the global semiconductor and electronics arena. The arrival of potentially disruptive technologies like nanotechnology during the 2000's provided an incentive to target electronics manufacturing afresh.

Simultaneously, during the last decade, we have seen a remarkable resurgence of manufacturing in many areas in the country. This has been particularly visible in pharmaceuticals, chemicals, steel, automobiles and automobile accessories. Several state-of-the-art manufacturing facilities have been set up. Since cutting-edge manufacturing requires a highly skilled engineering workforce, India is well suited to exploit in this. The confluence of these three streams: the need to go into semiconductor manufacturing, the emergence of a disruptive nanomanufacturing technology, and the success in manufacturing in other areas, has provided a new opportunity for semiconductor manufacturing in India.

1.3. Organization of this Report

This report describes the status and future of semiconductor manufacturing in India. After the brief introduction provided in this chapter, the next chapter describes the Semiconductor Policy (SIPS) of 2007, and the industry response to it, including the response in semiconductor photovoltaic devices. Chapter 3 looks at the status of research and education in the area of semiconductors in India. Finally, the last chapter presents recommendations of the Committee which will enable us to capitalize on the unique opportunities available, and provides a vision for the way forward.

2. Indian Semiconductor Policy 2007 (SIPS)

2.1 Announcement of the Special Incentive Package Scheme (SIPS) 2007

In March 2007, the Department of Information Technology (Ministry of Communication and Information Technology), announced the Special Incentive Package Scheme (SIPS) for setting up semiconductor industries and ancillary units in India, and in September 2007 it laid down detailed guidelines for its implementation.

The incentives are intended to be for the manufacture of all semiconductors, displays including Liquid Crystal Displays (LCDs), Organic Light Emitting Diodes (OLEDs), Plasma Display Panels (PDPs) and any other emerging displays; storage devices; solar cells; photovoltaics; other advanced micro and nanotechnology products; as well as for the assembly and test of all of the above products. A brief notification of the Semiconductor Policy 2007 is given in Appendix 1.

According to the Policy, the industry would be given a subsidy of 20 % or 25 % of the capital expenditure (depending on whether it is set up in an SEZ or not), and the threshold of investment to qualify for the incentive is Rs. 2500 crore for Fab Units, and Rs. 1000 crore for Eco-System Units. Though "eco-system" units might normally have meant units which develop an ecosysytem around semiconductor fabrication, such as units for gases, chemicals, etc; in this case it is to be interpreted, as per the Guidelines issued by DIT, as a unit other than a semiconductor (chip) fabrication unit. Thus photovoltaics, displays, ATMP, etc would all be classified as ecosystem units. This is summarized in the Table given below.

Type of Unit	Threshold NPV of Investments	Incentive in SEZ	Incentive in Non-SEZ
Fab Unit	Rs. 2500 crore	20 %	25 % + exemption from CVD
Eco-System Unit	Rs. 1000 crore	20 %	25 % + exemption from CVD

Some of the other points to be noted about the Semiconductor Notification are:

- The Special Incentive Package is available only upto 31.03.2010.
- The cost of land more than 2 % will not be considered for the capital expenditure
- The incentive will be released at the end of the financial year during which the NPV exceeds the threshold value.
- Instead of subsidy on capital expenditure, a unit may claim the incentive in the form of equity participation.
- There is a ceiling on the number of units to be supported under the scheme: 2-3 Fab Units and 10 Ecosystem Units.

2.2 Response to the Scheme

In response to the Scheme, 17 proposals had been received upto December 2008, amounting to a total investment of Rs. 1,57,000 crores (about US $ 30 B). Of these 17 proposals, only 1 is for semiconductor chip manufacturing, and the remaining 16 are for other ecosystem areas. These 16 are split up into 1 for TFT-LCD Panels and 15 in the area of Solar Cells / Photovoltaics (PV) / Polysilicon. Appendix 2 gives the details of the proposals received. Thus, of the 17 proposals received, only 1 is for a "Fab Unit", and 16 are for "Ecosystem Units".

Though the number of proposals received is encouraging, it is interesting to note that there is only one in the area of chip manufacturing, and none in the area of ATMP (assembly / test / mark / package). On the other hand there is a huge interest in setting up PV related units.

2.3 Analysis of the Response

It is worthwhile to analyze the response to the SIPS in terms of the types of proposals received.

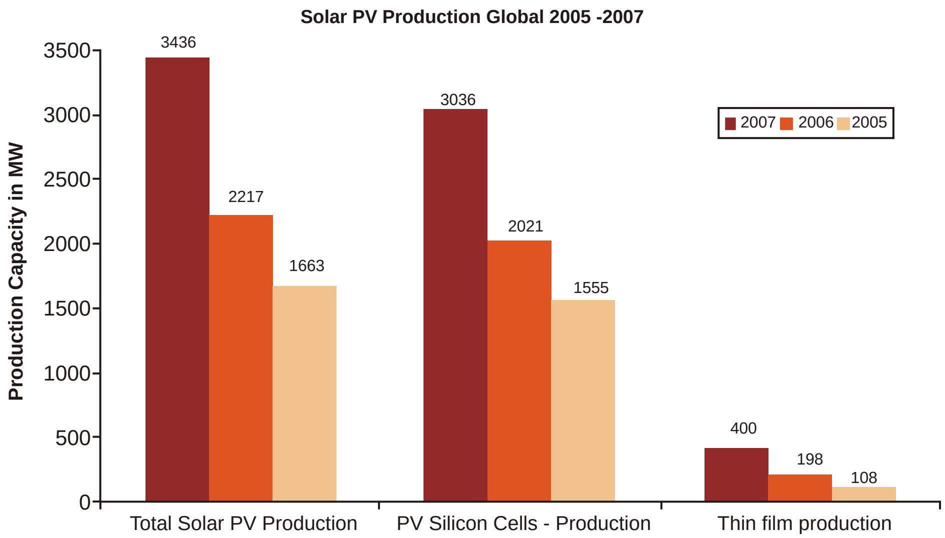
The Policy was announced after discussion between government and industry during the years 2005-2007. This was the time that many investors had expressed interest in setting up semiconductor fabs in India, and some of them had received significant media publicity. These included SemIndia, which had signed an agreement with AMD, Nanotech Silicon India Pvt. Ltd., which had a Korean promoter, and Hindustan Semiconductor Manufacturing Company, which had a technical tie-up with Infineon. These years were high-growth years for the semiconductor industry globally, emerging as it was from the 2000-2001 technology slowdown. Further, the Andhra Pradesh government had identified about 1200 acres of land near Hyderabad to be called Fab City, and several investors (including 2 of the above) had expressed interest in and actually taken possession of plots in Fab City. The India Semiconductor Association (ISA), an industry body originally set up to represent the VLSI companies present in India, also played an active role in encouraging the semiconductor manufacturing industry via policy discussion.

However, by 2007-2008, several changes had taken place. The chip manufacturing industry had enhanced capacity in other parts of the world, and the cost of setting up new fab units had increased. Secondly, with very steep increases in oil costs during 2007-2008, as well as wider public acceptance of climate change issues, there was a major world-wide interest in renewable energy sources, particularly semiconductor-based solar cells or photovoltaic (PV) devices. Finally, due to the economic downturn of 2008-2009, it became more difficult to obtain financing for large projects such as semiconductor chip fab units, whose cost is typically US $ 3-4 B (and will continue to increase with every technology node). The financial crisis is also likely to result in the consolidation of manufacturing fabs and foundries resulting in fewer manufacturing plants.

This explains why most of the proposals received in response to the Policy focused on PV. The next section examines the PV issues in more detail.

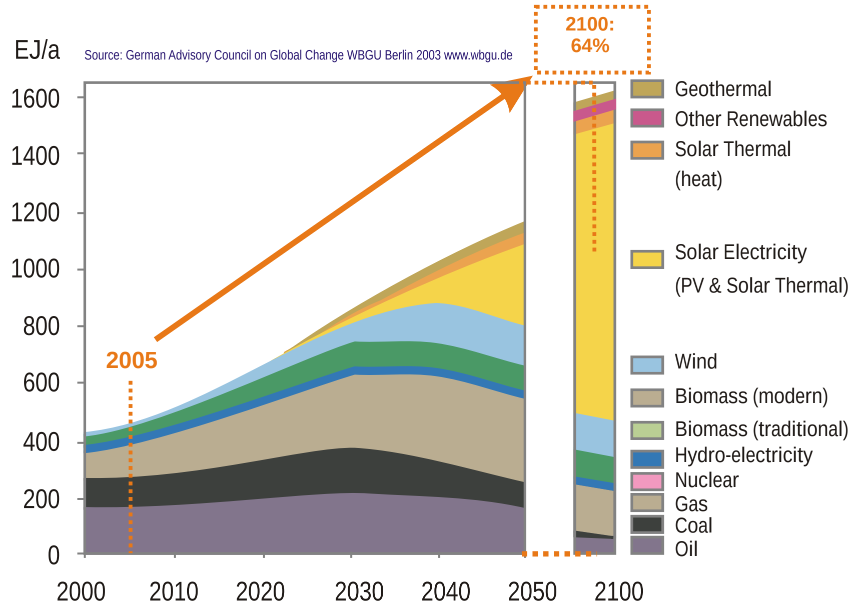
2.4. Semiconductor Photovoltaic Cell Manufacturing

The global PV production has been increasing at a rapid rate as shown below. During the year 2008, the production capacity was at about 6 GW, a huge increase over the 3.4 GW value in 2007. The PV industry revenue in 2008 was US $ 13.85 billion, a 70 % increase over the previous year. Even with the economic slowdown, PV production is projected to grow at a healthy 17 % CAGR during the period 2009-2013.



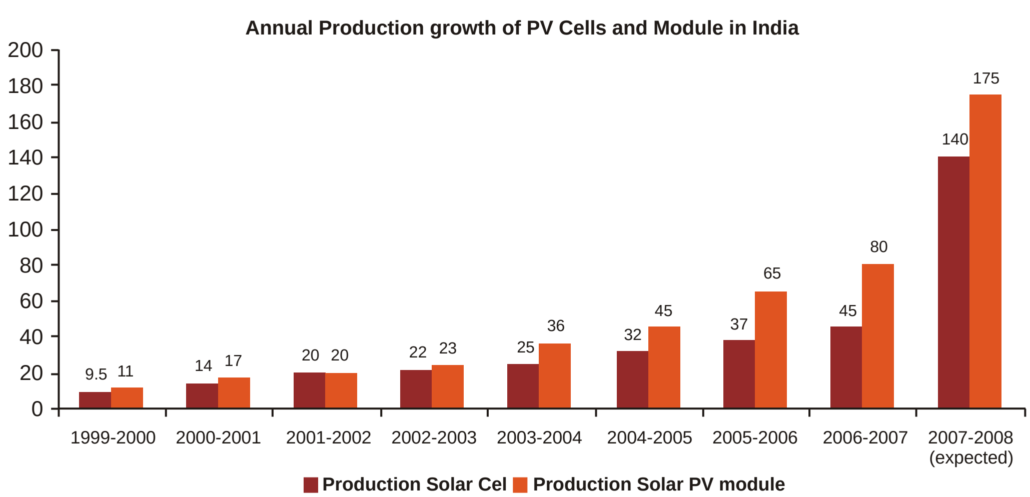
Source - PV Report 2007 and REC Annual Report 2006/2007

The expected growth of the solar contribution to the energy pool, for this century, is given overleaf.



1970 to 2000	2000 to 2020	2020 to 2040	2040 to beyond	
Niche market	Rapid growth	Displacement	PV dominance	(Modified from Bradford, 2006)
$10.00	$2.50	$1.60	$1.00	Installed cost
0.3GW	60GW	500GW	>>500GW	Annual PV market
$5bn	$233bn	$1300bn	>>$1300bn	Global Revenue
<0.1%	1.8%	35%	>50%	% Total world electricity
high-subsidy grid, high value off-grid	high-sunlight, expensive grid electricity	medium-sunlight, medium cost grid developing world	worldwide	Key geographic markets

This global trend is matched in India as well, as shown in the data below.



Source - MNRE

Recognizing the need for solar PV, the Working Group for the National Facility for Manufacture of Solar Grade Polysilicon has recommended to the government in August 2008 that a national facility be set up to manufacture 2500 tons / year of solar grade polysilicon. As and when this polysilicon facility comes on line, it will be able to provide indigenously the raw material required for the PV cells.

Future growth in solar PV also seems to be assured, by virtue of two other major government initiatives:

- The National Action Plan on Climate Change (NAPCC), which incorporates the National Solar Mission, which envisages significant PV production in India.

- Incentives for grid-connected solar power generation announced by MNRE in 2008, which provides for a feed-in tariff of Rs. 15 per kWh.

Today, most PV cells use either mono- or multi-crystalline silicon wafers, or poly- or amorphous silicon thin films deposited on various substrates like glass. Although intensive research and development is being carried out in competing technologies, such as thin film CdTe technology for example, which at present offers the lowest production cost per watt, the fabrication of PV cells is likely to be based on silicon technology for the near future.

Many of the processes and materials used in the fabrication of PV cells are similar to those used for silicon chip manufacturing. One major difference is that the complexity of the cells is not very high, the cleanliness conditions required are not very stringent, and the lithography dimensions necessary are much laxer. The cost of setting up a PV fab line can therefore be much less than for a chip fab line, which is an important consideration for new initiatives in a financially constrained environment. Since the infrastructure requirements of the two are similar, the PV manufacturing ecosystem will be a stepping stone towards semiconductor chip manufacturing.

It is instructive to look at the aggressive projections under the National Solar Mission. In the near term, the projected installed solar power generation capacity is to reach 20GW by 2020, from the current capacity of about 120MW. This should be contrasted with the projected installed capacity in USA of about 16GW by 2020, from the current 900MW capacity (DOE data). Thus, for India to become global leader in solar energy, we require more than 50% CAGR through 2020. This ambitious goal can only be reached through a coordinated effort by all the stake holders such as MNRE, DIT, DST, MHRD, in conjunction with an attractive SIPS policy through these years.
The initial draft version of the National Solar Mission (NSM) Document projects for solar manufacturing in India: “One of the Mission objective is to take global leadership role in Solar Manufacturing (across the value-chain) of leading edge solar technologies and target a 4-5 GW of installed capacity by 2017, including setting up of

dedicated manufacturing capacities for poly silicon material to annually make about 2 GW capacity of solar cells."

If the 15 PV-related proposals received under the SIPS policy of DIT go ahead with their projected plan, and Government subsidy is accorded with due approvals, then the cumulative targeted installed capacity (of these 15 units alone) will be of the order of 2.3 GW by 2012 and 3.2 GW by 2013. Out of the 15, a few are involved in the manufacture of solar cells starting from polysilicon. As the units above are not involved directly in generation of solar power, it is expected that the cells and modules manufactured by these units would be exported also. Thus, only a part of the installed capacity is envisaged to be available for domestic solar electricity production.

The draft NSM document further states: "The National solar mission proposes to collect and disburse funds to various projects through a non-lapsable Solar Fund in order to insulate the program from budget related variability. Initially, Rs. 5,000 crores is proposed to be sought from the Central Government during the 11th plan period as budgetary support. The strategy should be to tax fossil fuels and fossil fuel based power generation to mobilize additional resources"

It can be seen that the SIPS policy and the National Solar Mission have much in common, and each will bring considerable synergy to the other.

3. Status of Semiconductor Education, Research and Human Resources in India

3.1 Semiconductor and VLSI Education

India has had a long tradition of education in semiconductors, dating back to the 1950's and 60's at places like University of Calcutta and Indian Institute of Science. With the setting up of the IITs in the same period, semiconductor education flourished there as well. The early semiconductor education was rooted in Physics Departments, and later migrated to Departments of Electronics, Electrical Engineering and Materials Science. Though teaching in semiconductors continues at many places, the number of graduates being produced is not enough to man a sizeable semiconductor industry in India.

With a booming IT sector in India, many students are attracted away from traditional science and engineering. This is one reason that education in the semiconductor area, which has in the past not provided many job opportunities, has remained limited in size. As a consequence, many of the semiconductor manufacturing industries setting up new plants face a dire shortage of appropriately trained manpower.

It is instructive to look at the area of VLSI training in India. The spread of VLSI design and VLSI education in the country is a success story. Though semiconductors and VLSI are related, there are some important differences. The former mainly deals with the physics and technology, whereas the latter deals with design, simulation and software. Nevertheless, it may be possible to emulate the VLSI success in semiconductors.

A strong thrust was given to Microelectronics, including VLSI, by MHRD in the early and mid 1980's. This led to some highly trained graduates in this area in the job market. It is likely that this attracted the first design companies to India in the mid- and late-1980's. This led to a further interest and increase in VLSI courses in the country, and a virtuous cycle ensued. A notable role was played by the Department of Information Technology, which launched 2 phases of the “Special Manpower Development Programme” (SMDP) in 1998 and 2004. This resulted in about 3000-4000 trained personnel with hands-on experience in VLSI being created every year at 7 resource centres (IITs, IISc, CEERI) and 25 other participating institutions. Besides these, many other colleges started a VLSI design programme because of its popularity. A similar focused thrust in semiconductor physics and technology can be made.

3.2 Courses in Semiconductors

Many Institutes today offer programmes in Microelectronics / Nanoelectronics which have courses on semiconductor physics, materials, devices and technology. In addition, many Institutions offer programmes in Energy or Energy Conversion, which have some courses on photovoltaics. Some of the existing courses include:

Semiconductor Materials and Devices
Semiconductor Technology
Semiconductor Growth ,Fabrication Processes and Characterisation
Special Semiconductor Devices
Solar Cells : Devices and Materials Technology
Semiconductor LEDs and Lasers
Semiconductor Laboratory Practice
Nanoelectronics Device Fabrication and Characterization
Electronics Systems Packaging
Microsensor Technologies
Micromachining for MEMS Technology
Advanced CMOS and Beyond CMOS
VLSI Device and Process Simulation
Submicron Device Modeling and Simulation
Introduction to MEMS
Plasma Processes
High Vacuum Technology and Applications
Microelectronics Devices and Applications
Thin Film Deposition and Characterization
Thin Film Devices and Applications
Microsystems Materials, Processes and Devices
Concepts in Material Science Electronics Properties
Characterization Techniques in Materials Science
Crystal Growth: Thin Films and Nanostructures
Thin Film Materials and Devices: Science and Engineering
Condensed Matter Physics
Semiconductor Physics and Technology
Physics at the Nanoscale

3.3 Networking of Institutions

A major obstacle in quickly ramping up output of trained manpower in any high-technology area is the unavailability of a sufficient number of teachers. Fortunately, the proposed installation of high-speed 1-10 GB dedicated networks between educational institutes via the initiatives of the National Knowledge Network (NKN), and MHRD's National Education Mission through ICT, will allow institutions to be connected together and share resources. It will be possible to plan live lectures being broadcast to different locations. Equally important, since an area like semiconductors is highly experimental, it will allow for remote laboratory demonstrations and remote experimentation. If these new technologies are appropriately exploited, it is possible to produce a significant number of trained graduates quite efficiently.

3.4 Semiconductor Research

For a knowledge-intensive area like semiconductor technology to grow, and for industries in this area to remain competitive, continuous R&D is essential. Again, India has a good tradition of research in these areas, starting with places like the Institute of Radio Physics, University of Calcutta, TIFR, CEERI, SPL, IISc, and later the IITs. The main problem has been the rather small research community, probably limited by the small industrial base in the country.

Some major recent initiatives have sought to overcome these limitations. The Government of India, recognizing the need to capitalize on the emergence of new disruptive technologies, set up two Centres of Excellence in Nanoelectronics at IISc and IIT Bombay. These have been functioning for the last 1-2 years, and besides conducting research, have been producing many graduates well versed in modern semiconductor and related technologies. In addition, the Department of Information Technology has recently initiated the Indian Nanoelectronics Users Programme (INUP) to encourage and allow researchers from all over the country to utilize the facilities created at IISc and IIT Bombay. As this programme spreads, it is likely that a wide base of semiconductor researchers will be available in the country.

In addition to research in academic institutions, there is significant goal-oriented research in national laboratories such as CEERI, SPL, BARC and ISRO in areas related to semiconductors.

4. Recommendations and Way Forward

4.1 General Comments

The Committee noted that due to the points discussed in Section 2.3, there has been a sea change in the environment over the last few years. Today, there is significant interest expressed by industry in photovoltaics. On the other hand, interest in setting up a chip fab unit appears to have declined. The former phenomenon is likely to be a permanent development whereas the latter is inevitable in a notoriously cyclical industry like chip manufacture, and will probably reverse in a couple of years.

The Committee further noted that in today's context, photovoltaic applications of semiconductors constitute an extremely important segment. This has been growing rapidly (better than 30% CAGR) over the last few years, and is expected to grow rapidly for the next 5 years and more. This application meshes in well with the National Mission on Solar Energy under the NAPCC, the initiatives taken by the MNRE, and the proposal to set up a national facility to manufacture solar grade polysilicon. Further, it will be in consonance with green growth projected the world over. It is an area the youth of India will be interested in. The investment required in photovoltaics is much less than for a chip fab unit, and hence is a more viable option for entrepreneurs. Nonetheless, it does use semiconductor fabrication processes similar to those used in chip fab, and the creation of a healthy PV semiconductor sector can be a stepping stone to creating more complex semiconductor manufacturing units.

It is a well known fact that for any semiconductor fab to succeed in a new environment, it must tie up with a local and / or international industry which has a saleable "product", whether computers, telecom or entertainment. For India today the product can be PV panels, with the semiconductor input being the PV cell, as well as full systems / utilities (including storage, conversion, appliances, etc) as complete products.

The Committee, therefore, recommends that the Government strongly support semiconductor PV manufacturing, thereby leveraging the interest shown by industry and synergizing with other national initiatives like the National Solar Mission. This will set the stage for an entry into semiconductor manufacturing which will later develop into strengths in other semiconductor and nanomanufacturing areas.

4.2 Committee's Recommendations on Semiconductor Industry

Some specific recommendations of the Committee to make SIPS and the semiconductor industry in India more successful are given below.

4.2.1 Extend the deadline for SIPS from 31.3.2010 to 31.3.2015. This is important in view of the current global financial position.

4.2.2 Government should appoint a technical review committee for the proposals, which will help in the evaluation of the proposals.

4.2.3 The time line for response to the proposals should be clearly identified.

4.2.4 The threshold value for investment in Ecosystem Units should be reduced. The reason is that many units such as ATMP and initial phases of PV may not need very heavy funding, but will create a viable ecosystem. One possible approach is to have different subsidy levels of say 10%, 15% and 20% on threshold values of Rs. 300, 600 and 1000 crore, with a full 20% entitlement after the maximal threshold is reached.

4.2.5 “Early bird” promoters may be given extra incentive.

4.2.6 Government should issue a letter of intent to promoters whose projects are cleared, so as to enable them to reach financial closure more easily.

4.2.7 Government should set up an industry-academia-government consortium based research entity for pre-competitive research. This will help track the R&D in various universities and industries, and also help collaborative programs within India and abroad.

4.2.8 Banks and lending institutions which do not understand semiconductors find it difficult to evaluate and fund such projects. It is recommended that some specified banks be targeted and their personnel be trained in these new areas. Companies seeking funding may approach these banks for faster processing.

4.2.9 Lending to the semiconductor PV sector may be deemed to be priority lending due the announcement of the National Solar Mission.

4.2.10 The customs duty / excise structure should be rationalized to ensure that local manufacture of semiconductors is not penalized compared to import. This will help grow the domestic market, which is critical for the growth of local industries. At present, all raw materials including capital goods required for manufacture of semiconductor devices is at zero duty. To protect the interest of the local manufacturer, CVD (countervailing duty) equal to the excise duty is applied on certain imports.

4.2.11 Investors should be encouraged for indigenous production of raw materials, including chemicals, gases, laminates, etc. which will generate an appropriate ecosystem.

4.2.12 Active steps should be taken to sponsor and subsidize local consumption of PV modules, so that the industry is not overly dependent on export.

4.2.13 Development of semiconductor manufacturing equipment is an important part of the semiconductor ecosystem. India has the mechanical expertise to design and fabricate such equipment at a fraction of the international cost. Thus, the development of capital equipment for semiconductor industry could be taken in the next phase once the semiconductor industry itself stabilizes and caters to export as well as internal demands.

4.2.14 Government may co-ordinate the efforts of DIT, MNRE, DST and MHRD in this initiative, and create a high-powered "Oversight" committee to follow up the recommendations (if accepted) over a five year time frame. A suitable Ministry or Department with appropriate technical expertise should be made in charge.

4.2.15 For overall success of the National Solar Mission to meet the proposed goals of the mission, it may be advisable to bring all the solar applications received under SIPS under the ambit of the National Solar Mission. This would not only take care of the fund required for subsidy but also act as single window clearance for speedier approval of the individual proposals. Further, this could also relax the limit restrictions on SPV (eco-system) units posed by the SIPS notification.

4.2.16 It is also important to identify an agency which can be a "standards body" for qualifying the quality and reliability of PV products for the local market.

4.3 Committee's Recommendation on Semiconductor Education & Research

The Committee noted that much-expanded education and research in the area of semiconductors is critical if the industry is to come up and flourish in India. The Committee feels that there is an enormous requirement of manpower at all levels and this should be developed with focussed programs in the country.

For example, if we consider the PV modules alone (cell and module manufacturing), the manpower requirement, to meet the demand through the local manufacturing, is summarized in the table below:

Year	Installed PV Capacity	Technicians Diploma/ITI	B.Tech.	M.Tech.	Ph.D.
2015	3 GW	5,250	2,700	900	300
2020	20 GW	35,000	18,000	6,000	2,000
2030	100 GW	1,75,000	90,000	30,000	10,000
2050	200 GW	3,50,000	1,80,000	60,000	20,000

Similarly, manpower would be required at different stages like poly-silicon production, systems and utilities and products manufacturing, solar power plant installation and maintenance, etc. In addition, the PV manufacturing will also eventually lead to other semiconductor manufacturing sectors, such as chip manufacturing, which will require significant additional manpower. Hence it is important that various training and educational programs be defined and set up towards developing the suitable number of trained human resources.

Some specific recommendations towards reaching these numbers are given below.

4.3.1 The SMDP model of DIT has been a successful model for targeted manpower development in a niche area. This model should be replicated, with inputs/co-ordination with MHRD. This may be called SMDP-S (S standing for semiconductors).

4.3.2 To overcome the paucity of teachers in these high-tech areas, use the distance education mode aggressively, leveraging the potential of the NKN and the National Mission on Education via ICT, as well as courseware produced through the national programme NPTEL.

4.3.3 Use the NKN network also to transmit interactive laboratory demonstrations, and formulate "virtual" laboratory experiments. This can be complemented by Technology CAD tool generated process flow running in the background to render the graphics.

4.3.4 Since photovoltaics is likely to be an important part of semiconductor teaching for many years to come, include elements of photovoltaics in appropriate UG courses, and also offer electives at this level.

4.3.5 A possible basket of courses for post-graduate courses available to many colleges via NPTEL and / or NKN are the following:

Semiconductor Materials and Process Technology
Semiconductor Device Physics and Technology
Semiconductor Materials and Device Characterization Techniques
Semiconductor Equipment Technology
Silicon Photovoltaics : Process and Device Technology
Compound Sem. Photovoltaics: Process and Device Technology
Alternate and Renewable Energy Sources
Phtovoltaics Modules and Systems Technology
Solar Thermal Energy
Grid Power Distribution Pricniples with Mutiple Energy Sources
Energy Storage : Fuel Cells and Batteries
Energy conservation and efficient utilization
LEDs: Process and Device Technology
Nanotechnology enabled photovoltaics and LEDs

Organic Photovoltaics : Process and Device Technology
Semiconductor Nanotechnology for Information storage
Semiconductor Nanotechnology for Information Processing
Semiconductor Technology for Sensors and Actuators

4.3.6 Since semiconductor education has a desirable laboratory component, establish a Rs. 50 lakh "kit" which can be replicated at the SMDP-S participating institutions, and nurture small industries which could fabricate the kits. Also explore models where theory courses can be done in an SMDP-like manner, and hands-on fabrication be offered at national laboratories and facilities.

4.3.7 Use the DIT-sponsored Indian Nanoelectronics Programme (INUP) to train researchers in hands-on semiconductor fabrication.

4.3.8 Academic institutions, in collaboration with an industry body (like SEMI or ISA), should create and run certification programmes for technicians for the semiconductor industry.

4.3.9 Create a Research Thrust Area for funding research in semiconductor Materials and Devices, for energy efficient solutions such as Solar Cells and LEDs. This could be done in a consortium mode, like the SRC or MARCO programmes in USA.

4.4 Conclusions and the Way Forward

4.4.1. India is at a threshold of making a big global impact in the area of PV manufacturing, consumption, and economy. This potential needs to be realized.

4.4.2. The momentum gained so far should not be lost. An "overseeing" committee under the PSA to be set up to ensure that the recommendations are carried through, and the objectives realized.

4.4.3. The importance of the program, and the synergy with the National Solar Mission under the NAPCC, needs to be constantly kept in mind.

4.4.4 The PV industry should be seen as a stepping stone to semiconductor manufacturing, which will mature naturally in the years to come.

Appendix 1
Semiconductor Policy Notification 2007

1.0) The semiconductor industry and other high tech industries are characterized by specific constraints that challenge their viability.

These are highly capital intensive and have to deal with constantly changing technology. It, therefore, becomes imperative on the part of the Government to create a conducive environment for manufacturing and offer a package of incentives comparable with other countries to attract global investments into the manufacturing sector as well as help bridge the viability gap due to lack of adequate infrastructure and eco-system. While this will involve an initial cost incurred by the Government to seed the manufacturing industry in the country, the return on investments by way of contribution to GDP will succinctly justify the incentives planned as a part of the Special Incentive Package for semiconductor manufacturing and other high tech industries in the country.

2.0) Special Incentive Package as indicated. The Special Incentive Package is as under:

2.1) The investment will be for the manufacture of all semiconductors and eco-system units, namely displays, including Liquid Crystal Displays (LCD), Organic Light Emitting Diodes (OLED), Plasma Display Panels (PDP), any other emerging displays; storage devices; solar cells; Photovoltaics; other advanced micro and nano technology products; assembly and test of all the above products.

2.2) The Special Incentive Package shall be for state-of-the art technology.

2.3) In the case of semiconductor manufacturing (Fab units) products, the threshold Net Present Value (NPV) of investment will be Rs. 2,500 crore or US$ 566 million and above. The threshold NPV of investment in manufacture of other eco-system products will be Rs.1,000 crore and above. This threshold value shall be taken as the Net Present Value (NPV) of investments made during the first 10 years of the project life and the discount rate will be at the rate of 9%.

3.0) The Central Government or any of its agencies shall provide incentive of 20% of the capital expenditure (as defined in sub-paragraph 3.3) during the first 10 years for the units in SEZ and 25% of the capital expenditure for non-SEZ units. Non-SEZ units shall be exempt from CVD. The incentives, if any, offered by the State Government or any of its agencies or local bodies shall be over and above this amount.

Note: The customs notification exempting CVD for non-SEZ units will be issued separately by the Ministry of Finance.

3.1) The period of 10 years shall be the first 10 years of the project life from the start of the project and not with regard to the start of any subsequent phase of the project.

3.2) The capital expenditure will be the total of capital expenditure in land, building, plant and machinery and technology including R&D. The cost of land exceeding 2% of the capital expenditure shall not be considered for calculation in this regard.

4.0) Any unit may claim incentives in the form of capital subsidy or equity participation in any combination of the following:

(i) equity in the project, not exceeding 26%.
(ii) capital subsidy in the form of investment grant and interest subsidy.

The entire equity contribution will be taken towards the value of incentive package. There shall be an exit option, to be exercised by the Government, at a suitable point of time in the future, after the project goes on stream.

5.0) Those investors who choose equity as part of their incentive package shall be given such equity after the financial closure for the project and equity shall be released on a proportionate basis as equity is brought in by the promoters.

5.1) All other incentives shall be released after the end of the financial year in which the NPV of the total investment exceeds the threshold value.

5.2) Thereafter, the incentives shall be provided on an annual basis on the value of investments made during the year and be restricted to the first 10 years of the project life.

6.0) There shall be a ceiling on number of units - 2 to 3 'fab' units and 10 eco-system units.

The Special Incentive Package shall be available only up to 31.3.2010.

Appendix 2
Proposals received in response to the Semiconductor Policy

S. No	Name of the Applicant	Investment		Items of Manufacture
		In Rs. Cr	In US$ Mns	
1	M/s Videocon Industries Ltd.	8,000	2,000	LCD Flat Panel
2	M/s PV Technologies India Ltd.	6,000	1,500	Solar PV
3	M/s Titan Energy System Ltd.	5,881	1,470	Solar PV and Polysilicon
4	M/s KSKSurya Photovoltaic Ventures Pvt. Ltd.	3,211	803	Solar PV
5	M/s Signet Solar Inc.	9,672	2,418	Solar PV
6	M/s Reliance Industries Ltd.	11,631	2,908	Solar PV and Polysilicon
7	M/s Reliance Industries Ltd.	18,521	4,630	Semiconducter Wafer Fab
8	M/s Phoenix Solar India Ltd.	1,200	300	Solar PV
9	M/s Tata BP SOLAR India Ltd.	1,693	423	Solar PV
10	M/s Solar Semiconductor Pvt. Ltd.	11,821	2,955	Solar PV
11	M/s TF SolarPower Pvt. Ltd.	2,348	587	Solar PV
12	M/s Lanco Solar Pvt. Ltd.	12,938	3,235	Solar PV and Polysilicon
13	M/s Vavasi Telegence Pvt. Ltd.	39,000	9,750	Solar PV and Polysilicon
14	M/s EPV Solar India Pvt. Ltd.	4,278	1,069	Solar PV
15	M/s EMCO Energy Ltd.	9,902	2,476	Solar PV
16	M/s OptiSolar Inc.	5,424	1,356	Solar PV
17	M/s Bhaskar Silicon Pvt. Ltd.	5,900	1,475	Solar PV and Polysilicon
TOTAL		**157,420**	**39,355**	

List of Abbreviations

AMD	Advanced Micro Devices
ATMP	Assembly Test Mark Package
BARC	Bhabha Atomic Research Centre
BEL	Bharat Electronics Ltd.
BHEL	Bharat Heavy Electricals Ltd.
CAD	Computer Aided Design
CAGR	Compound Annual Growth Rate
CdTe	Cadmium Telluride
CEERI	Central Electronics Engineering Research Institute
CMOS	Complementary Metal Oxide Semiconductor
CVD	Countervailing Duty
DIT	Department of Information Technology
DOE	Department of Energy
DST	Department of Science and Technology
GaAs	Gallium Arsenide
GAETEC	Gallium Arsenide Enabling Technology Centre
Ge	Germanium
ICT	Information and Communications Technology
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
INUP	Indian Nanoelectronics Users' Programme
ISA	India Semiconductor Association
ISRO	Indian Space Research Organization
ITI	Indian Telephone Industries
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MARCO	Microelectronics Advanced Research Corporation
MCIT	Ministry of Communications and Information Technology
MHRD	Ministry of Human Resource Development
MNRE	Ministry of New and Renewable Energy
NAPCC	National Action Plan on Climate Change

NKN	National Knowledge Network
NPTEL	National Programme on Technology Enhanced Learning
NPV	Net Present Value
NSM	National Solar Mission
OLED	Organic Light Emitting Diode
PDP	Plasma Display Panels
PSA	Principal Scientific Adviser to the Govt. of India
PV	Photovoltaic
R& D	Research and Development
RCA	Radio Corporation of America
SAC-C	Scientific Advisory Committee to the Cabinet
SCL	Semiconductor Complex Ltd
SEMI	Semiconductor Equipment and Materials International
SEZ	Special Economic Zone
Si	Silicon
SIPS	Special Incentive Package Scheme
SMDP	Special Manpower Development Programme
SMDP-S	Special Manpower Development Programme for Semiconductors
SPL	Solid-State Physics Laboratory
SRC	Semiconductor Research Corporation
TFT	Thin Film Transistor
TIFR	Tata Institute for Fundamental Research
TTL	Transistor Transistor Logic
VLSI	Very Large Scale Integration