158

NATIONAL SILICON FACILITY

DEPARTMENT OF ELECTRONICS

HUNDRED AND FIFTY-EIGHTH REPORT

LOK SABHA SECRETARIAT
NEW DELHI

HUNDRED AND FIFTY-EIGHTH REPORT

PUBLIC ACCOUNTS COMMITTEE (1988-89)

(EIGHTH LOK SABHA)

NATIONAL SILICON FACILITY

DEPARTMENT OF ELECTRONICS

Presented in Lok Sabha on 28 April, 1989

Laid in Rajya Sabha on 28 April, 1989

LOK SABHA SECRETARIAT
NEW DELHI

April, 1989/Vaisakha, 1911 (Saka)

P.A.C. No. 1255

Price : Rs. 10.00

Published under Rule 382 of the Rules of Procedure and Conduct of Business in Lok Sabha (Sixth Edition) and printed by the Manager, Govt. of India Press, Faridabad-121001.

CORRIGENDA TO THE 158TH REPORT (8TH LOK SABHA) OF PUBLIC ACCOUNTS COMMITTEE

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7-3-1989(AN)
15-3-1989(AN) and
26-4-1989(AN)

*Not printed. One Cyclostyled copy laid on the Table of the House and 5 copies placed in Parliament Library.

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INTRODUCTION

I, the Chairman of the Public Accounts Committee, as authorised by the Committee do present on their behalf this Hundred and Fifty-Eighth Report on paragraph 5 of the Report of the Comptroller and Auditor General of India for the year ended 31 March 1987 (No. 7 of 1988) Union Government (Scientific Departments) on National Silicon Facility.

2. The Report of the Comptroller and Auditor General of India was laid on the Table of the House on 25 April, 1988.

3. In this Report the Committee have brought out many disquieting aspects of the proposed National Silicon Facility deal at the cost of Rs. 88.75 crores with Hemlock Collaboration. The Task Force set up by the Department of Electronics (DOE) with wide terms of reference to examine all relevant issues and facilities setting up of National Silicon Facility was made defunct after presenting Part-I of its report on some of the issues, apparently because the fact that some of its members had not been toeing the official line. There had been serious differences in the approach of its members and serious doubts about certain conclusions reached by the Task Force with regard to potentialities of indigenous efforts. Instead a Negotiating Committee was constituted to deliberate on all the remaining terms of reference of the Task Force. The Committee have deprecated the manner in which the Task Force was made defunct before it could carry out the functions allotted to it and its functions transferred to another body.

4. Though the demand for silicon was predominantly of terrestrial solar cells of photovoltaic (PV) quality required by the DNES. The Committee have felt that DNES would have been the right choice for nodal-department for this project.

5. The Task Force had assessed the national demand for silicon at 100 TPA in 1990 which was raised by Negotiating Committee at 2.30 TPA. Against these estimates, the actual demand today works out in the region of 57 MT. In spite of the strong reservations of the DNES, the DOE concluded that the projected demand would materialise and entered into collaboration with Hemlock to put up the project of National Silicon Facility at the cost of Rs. 88.75 crores. All the objections raised were simply overlooked to the determent of national interest. The Committee have deplored the lacadaisical way in which entire issue was handled after ignoring valid objections and timely advise of the DNES. The Committee are strongly of the view that by wrong choices of both the product as well as nodal department the solar energy programme has suffered a setback of perhaps a decade which an energy deficient country like ours can ill afford.

6. The indigenous technology developed by Mettur Chemical would produce 25 TPA silicon of good quality and capable of meeting national demand quality-wise also. The demand which could not be met by using Metkkam technology was stated to be insignificant and could be met from imports and Metkkam was stated to be capable of meeting this demand also through technology development in relatively short time. The DOE

was told well before confirmation of the agreement with Hemlock that indigenous production was economical and capable of being increased although modular approach in a comparatively short period. The Committee are surprised to note how such vital points and valid reasoning against Hemlock deal were altogether side tracked.

The Committee have concluded that the DOE was not responsive and was dead set to go ahead with Hemlock deal. All this shows lack of perception of emerging scenario in photovoltaic (PV) cell technology and inept handling on the part of DOE. The Committee have been distressed to note that DOE transgressed into the domain of another department resulting in sad consequences.

7. The Public Accounts Committee examined the Audit Paragraph at their sitting held on 7 and 15 March 1989.

8. The Committee considered and finalised this Report at their sitting held on 26 April, 1989. The Minutes of the sittings form Part II of the Report.

9. For reference, facility and convenience, the observations and recommendations of the Committee have been printed in thick type in the body of the Report and have been reproduced in a consolidated form in Appendix VI to the Report.

10. The Committee express their thanks to the officers of the Department of Electronics and Non-Conventional Energy Sources for the cooperation extending in giving information and tendering evidence before the Committee.

11. The Committee also place on record their appreciation of the assistance rendered to them in the matter by the Office of the Comptroller and Auditor General of India.

NEW DELHI;
April 27, 1989
Vaisakha 7, 1911 (*Saka*)

AMAL DATTA,
Chairman,
Public Accounts Committee.

REPORT

1. INTRODUCTORY

[*This Report is based on Paragraph* No. 5 of the Report of the Comptroller and Auditor General of India for the year ended 31st March* 1987 (*No. 7 of* 1988) *Union Government (Scientific Department)*].

1.1 Silicon is the fundamental raw material for the electronics industry. It is said: "Silicon is to electronics what steel is to a modern industrial economy". This is because a whole range of key devices from microchips to space quality solar cells, to infra-red sensors for surveillance, general purpose semiconductors of myriad types and terrestrial solar cells for remote area and energy to rural areas, would not be possible without silicon. High purity silicon is used in Solar Photovoltaics (SPV) and Semiconductor devices applications. Silicon for SPV application, compared to silicon for semiconductor devices, can tolerate certain impurities in higher concentration without deteriorating the performance of solar photovoltaics cells and therefore, Off spec Polysilicon can be used for SPV, while Prime Polysilicon is used for semiconductor devices.

1.2 The silicon of the required purity, when manufactured, is in the polycrystalline form. This is converted into single crystal rods. The single crystal rods with their both ends (conical shapes) cut are called in gots. They are then cut into wafers (as cut) and these wafers are processed further as per the requirement. But wafers are used for SPV applications, while processed wafers are used for semiconductor application and semiconductor wafers.

2. SETTING UP OF NATIONAL SILICON FACILITY

2.1 In view of the growing importance of silicon, the Department of Electronics (DOE) proposed in October 1981 the setting up of a National Silicon Facility (NSF) to undertake stockpiling, production, research and development of silicon so that the country could become self sufficient in this critical material.

A Task Force (TF) comprising of 8 specialists** was constituted in January 1982 to "configure" the NSF for investment proposals. According to the Secretary, DOE, the Task Force had wide terms of reference which included, *inter alia* :

(i) to review the world trends in silicon

(ii) to assess the long term and short term requirements

(iii) to assess the status of domestically available technology and expertise for various elements of silicon

(iv) to determine whether foreign technology may have to be purchased

*Appendix I

**List given in Appendix II

(v) to identify proper foreign sources

(vi) to obtain at least preliminary offers for technology transfer;

(vii) to define technological strategy for national silicon facility and based on demand profile and strategy;

(viii) to plan production and infrastructure etc.

(ix) to work out capital investment cost and investment profile;

(x) to recommend organisational management structure;

(xi) to work out the shortest possible time in which the facility could be set up;

(xii) to recommend immediate strategy to stockpile some or all elements of silicon;

(xiii) to review present R&D efforts for various elements both in the country and abroad, keeping in view the long-term requirements of the country to develop etc.

2.2 The Task Force submitted Part-I of its report in August 1982 wherein it assessed that the national demand for silicon would be as under :

(in tonnes)

Description	1983	1985	1990
Conventional semiconductor devices (Pure class)	3·90	6·57	12·25
Space qualified solar cells (Pure class)	0·33	0·33	0·33
Terrestrial solar cells (SPV Class)	8·81	42·59	88·12
Total	13·04	49·49	100·70
Say	13·0	50·0	100·0

2.3 To meet the above needs, the Task Force proposed the setting up of a production capacity of 50 MT a year of polysilicon in the first phase and to increase this capacity to 100 MT a year as the demand builds up/ warrants. The Task Force also observed that it had come to the conclusion that indigenous R&D efforts undertaken over the last several years had not established a technology which would be suitable for setting up a commercial plant to produce polysilicon of acceptable quality on the scale indicated by the Task Force on a time bound basis. Consequently the Task Force came to the conclusions that there would be a need to import a comprehensive technology package appropriate to the national needs.

2.4 On the selection of foreign collaborator the Task Force is stated to have addressed communication to "almost all ultrapure silicon producing

companies in the world", in order to ascertain their willingness to the transfer of relevant technology to the Indian producer. As a result of this, 14 organisations responded favourably and a few submitted preliminary brief proposals. The Task Force felt that collection of further information on both technical and financial matters could be done most effectively and speedily by discussions and visits to the production plants. A team constituted for the purpose visited Japan, USA, West Germany and Italy between May 22 and June 19, 1982 and held discussions. To arrive at the final recommendation on the transfer of technology, a format was evolved and handed over to the various interested parties. The parties were initially given time upto July 20, 1982 to submit the data and were later given extension of time upto September 15, 1982. The Task Force stated that evaluation of the detailed proposals and choice of collaborator would be discussed in Part-II of the Report. In the meantime it submitted Part-I of the Report in August, 1982. The Task Force did not submit Part-II of the Report at all nor did it meet later.

After receipt of Part-I of the Report, Government constituted a Negotiating* Committee (NC) in December 1982. According to minutes of first meeting of the N.C. held on 16 December, 1982 it was set up to evaluate the technology transfer proposals to hold technical, commercial and contractual negotiations etc. with the foreign companies and on that basis to recommend the most appropriate foreign licensor to Government. Thus in effect, the functions which were intended to be performed by the Task Force and were to be reported in Part-II of its report were transferred to the NC, though formally the Task Force was not disbanded by the Government.

2.6 Asked to indicate whether the Task Force submitted further report, the Department of Electronic stated that no further report, other than the report described at Part-I was submitted by the Task Force to DOE. It further stated :

> "The report of the Negotiating Committee covered the remaining issues of the terms of reference given to the Task Force. By the time this report was received (report of the Negotiating Committee) by DOE, the terms of the Task Force had also expired. The Chairman, TF in his comunication to DOE dated 2nd April, 1984 indicated that further more, since the terms of NSF task Force has expired, it also stands dissolved and will not be operational unless specifically called upon by the DOE."

2.7 The Secretary, DOE further clarified in evidence :

> "They gave a report on major part of it. The Chairman of the TF in the letter forwarding report (Part I), suggested that the activities of the Task Force are shifting from planning and that there will be a report dealing with detailed terms and conditions for technical collaboration and site selection. This was later handled by the Committee set up by the Department."

2.8 The Negotiating Committee held a series of meetings to consider the collaboration proposals. It also reassessed and placed the demand for polysilicon in its meeting held on November 19, 1983 at 190 M.T. in 1988-89 and the annual demand in 1990 at about 230 MT., the major portion of which would be used in solar PV industry.

*Composition of N.C. in Appendix-III.

2.9 The Committee asked about the basis on which the Negotiating Committee scaled up the demand to 190/230 TPA as against the assessment of the Task Force for 100 TPA by 1990. In reply the DOE have stated that during the intervening period of about 18 months between the submission of its report by the Task Force and preparation of its report by the Negotiating Committee, some major developments had taken place. These were mainly as under :

(i) expanded Solar Photovoltaic-Programme of both the Public Sector Undertakings, namely Central Electronics Ltd. (CEL) and Bharat Heavy Electricals Ltd. (BHEL).

(ii) Government approval for setting-up of a major production facility of large scale integrated circuits (LSI) and very large scale integrated circuit (VLSI) devices by the Public Sector Undertaking namely SCL, Chandigarh; and

(iii) the enhanced demand for small scale integrated and Medium Scale Integrated (MSI) devices and semi-conductor devices for ITI's Production Programme for Electronics Switching System.

2.10 These necessitated updating of the demand estimates and the result of the detailed exercise to up-date the national silicon demand profile by the Negotiating Committee indicated that the demand of silicon would be built up to about 230 MT per annum in the year 1990.

2.11 The DOE also stated that the sub-group on the 7th Plan Programme in the area of solar photovoltaics, set-up by the Department of Non-Conventional Energy Sources in the Ministry of Energy, assessed in March 1984 that the demand of solar photovoltaic modules would be 10 MW p.a. by 1990. This meant that by 1990 the demand of polysilicon for Solar Photovoltaic Programme, alone would be about 218 tonnes per annum in addition to 12—15 tonnes for electronic applications.

2.12 The Negotiating Committee (NC) after evaluating the collaboration efforts recommended acceptance of the offer of M/s Hemlock Semi-Conductor Corporation (USA). Based on the recommendations of the Negotiating Committee, Government decided to enter into a collaboration agreement with M/s. Hemlock for setting up a 100 tonnes silicon plant with infrastructural facilities for 200 tonnes plant at a project cost of Rs. 88.75 crores, including Foreign Exchange component of Rs. 23 crores. The proposal was approved by the competent authority on 29th March 1984, the agreement was signed by Hemlock on 16 April, 1984 and was confirmed by DOE on 19 February 1985 after Hemlock obtained necessary export permit from the US Government in January 1985. Later on grounds of indigenous capability for producing silicon having come of age, collaboration agreement was terminated in June 1987 by which time Rs. 7.92 crores had been paid to the Collaborator. One of the other considerations for termination of agreement was that the demand for silicon was not expected to reach anywhere near the projected demand of 200 MT by 1990.

2.13 The Audit para states that incorrect assessment of demand, partial analysis of potentialities in PV field, non-recognition of indigenous capability, exercise of wrong option etc. led to conclusion and subsequent termination of a contract with a foreign firm resulting in unfruitful expenditure of Rs. 7.92 crores.

3. SHORT CLOSING OF OPERATIONS OF TASK FORCE

31. As already observed, the Task Force submitted Part-I of its report in August 1982 and had mentioned that Part-II would deal with evaluation of international collaboration offers which were expected to be received by September 1982. However, the contents of the Part-I of the Report were contested by one of the members (Prof. A.R. Vasudevamurthy of the Indian Institute of Science) who was closely associated with development of indigenous technology by Mettur Chemicals (METKEM). In his letter dated 4th November*, 1982 addressed to the Chairman of the Task Force had also disputed certain conclusions of the Task Force and was given to understand that his view point would be reflected in the report. However, as it was not done, he preferred to disassociate with certain conclusions of the report.

3.2 After submission of Part-I of the Report in August 1982 the Task Force did not meet at all and in December 1982 the Negotiating Commtitee was appointed with seven members, out of which 4 were common with Task Force. 3 Members of T.F. including Prof. A.R. Vasudevamurthy were not included in the Negotiating Committee Later Shri Vasudevamurthy spoke to the Secretary, DOE personally and through his letters dated 31 Jan., 1 February, and 14 February, 1984 requested the Chairman, Task Force to initiate action for preparation and discussion of Part II of the report. He also pointed out that "his signature on the report of TF had been taken on wrong premise."

3.3 Prof. Vasudevamurthy had *inter-alia* pointed out that comments on the polysilicon by the silicon tetrachloride route made in the report that "the quality of their (Metkem's) products is reportedly poor is not true." In fact, he observed that the boron content of the polysilicon prepared by Silicon Tetrachloride (STC) route is observed to be less than the Trichlor Silicon (TCS) route. Prof. Vasudevamurthy also disputed the observations contained at page 61 in Part I report of the Task Force about industrial infrastructure at Mettur Chemicals and the process route of STC adopted by it in production of polysilicon is not suitable one. He had also pointed out in his letter that TF did not have the opportunity to review the progress made during the previous 18 months in the process and production of polysilicon. Prof. Vasudevamurthy had also drawn attention of the Chairman Task Force towards the unfinished task of the Task Force in the context of its terms of reference and requested for holding of its sittings to discuss these matters. However, no deliberations on these aspects took place, no further report was prepared and presented and in fact Negotiating Committee dealt with all these matters.

3.4 In this context, the Committee pointed out that when Task Force was still alive and was not disbanded, how far it was fair on the part of DOE to take away left over job of Task Force and assign the same to the Negotiating Committee and asked whether it was not an irregular procedure. The Committee also wanted to know if it was not done with a view to easing out Prof. Vasudevamurthy who had been opposing the views of the other members. The Secretary, DOE stated in evidence :

> "When the Chairman gave the report he talked about it. Thereafter. they constituted a Committee to work out the planning."

*Appendix IV

4. NODAL AGENCY

4.1 All over the world demand for polysilicon is for electronics grade. Unlike the world trend, in India a large part of projected demand for silicon is on account of terrestrial solar cells required for solar energy programme. According to the Secretary, DOE global solar photovoltaic use is not as much as it could be in our case. The Task Force and Negotiating Committee which also went into the issue, came to the conclusion that out of the total demand projection of 230 MT of silicon in 1990 electronics grade requirement was around 12-20 MT only. In view of this fact, the Committee enquired why NSF project was not handled by the Deptt. of Non-Conventional Energy sources as the project was mainly to be used by that Department. In reply, the Secretary DNES stated in evidence :

> "I may not be going into why the differences were there, but I want to submit that silicon of a higher grade is required in the semi-conductor materials, integrated circuits and so on. Most of the facilities which are set up, they manufacture this. Silicon of lower specification is used for terrestrial application. In terms of volume it may look not much because today I think it is about 20 tonnes for semiconductor material and around 40-50 tonnes for terrestrial. For terrestrial it is bound to go up because high volume are required in that, whereas in the semi-conductor grade silicon, smaller quantity is required. Functional efficiency of silicon conductors is very very important. Standards are also more rigorous. So, taking that into account, it is necessary to have facility which really produces top grade silicon of various varieties. In any case, when this Task Force was set up, there was anxiety about this semi-conductor grade material also at that time. I think the demand even for semi-conductor material is going to grow because the base is growing. It is used in several components and products, some of which are imported now. If we have these facilities, we can hopefully see that this itself results in use of more and more of home-made integrated circuits and so on."

4.2 Clarifying the position of his Department on this subject, the Secretary, DNES stated :

> "Sir, our feeling was that since the majority requirement for high purity silicon is for photovoltaic and since we are the Department dealing with photovoltaic it would be more logical for our department to deal with all matters relating to silicon production for photovoltaic as then we will be able to make comprehensive approach to the question of solar photovoltaic to which we want to give a big thrust. So that was the view I had expressed at that time."

4.3 The Committee find that in view of the crucial importance of silicon in the growing electronic industry Government decided to set up National Silicon Facility at a cost of Rs. 88.75 crores including foreign exchange component of Rs. 23 crores with technical collaboration of Hemlock Corporation of the U.S.A. The Audit paragraph and the facts gathered by the Committee (including those narrated in sub-sequent paras of this report) amply bring out the fact that there were many disquieting aspects in the whole deal from the very start.

4.4 The Task Force set up by the Department of Electronics with wide terms of reference to examine all the relevant issues and facilitiate setting up to National Silicon Facility was made defunct after presenting Part-I of its report on some of the issues apparently because of the fact that some of its members had not been toeing the official line. There had been serious differences in the approach of its members; particularly Prof. A. R. Vasudevamurthy of the Indian Institute of Science, Bangalore who had raised serious doubts about certain conclusions reached by the Task Force with regard to potentialities of indigenous efforts. In fact he disassociated himself from the conclusions of the Task Force. However, the points raised by him remained unanswered and obviously in order to by pass him no further meeting of Task Force was held. Instead a Negotiating Committee was constituted to deliberate on all the remaining terms of reference of the Task Force. The Committee are convinced that this grossly improper and wrong procedure was resorted to just to ease out the inconvenient members of the Task Force who did not toe a particular line of action and had been critical of certain conclusions of the Task Force which later proved to be wrong. The Committee deprecate the manner in which the Task Force was made defunct before it could carry out the functions allotted to it and its balance functions transferred to another body constituted without the inconvenient members.

4.5 Of the total demand assessment of polysilicon of 13 tonnes, 50 tonnes and 100 tonnes in 1983, 1985 and 1990 respectively made by the Task Force, 8.81 tonnes, 42.59 tonnes and 88.12 tonnes i.e. about 70 to 80 per cent of the total assessed demand was for terrestrial solar cells. Similarly, the Negotiating committee while assessing the polysilicon demand at 230 tonnes in 1990, took the demand for terrestrial solar cells of photovoltaic (PV) quality at 218 tonnes. On the other hand, growth in demand for semiconductor grade silicon was admittedly much slower and was expected to remain at a low level in the foreseeable future. In view of 70–80 per cent of requirements for high purity silicon being for photovoltaic, the Department of Non-Conventional Energy sources logically felt that they should deal with all matters relating to silicon production for photovoltaic which would enable them to make a comprehensive approach to the production of solar photovoltaic cells to which they wanted to give a big thrust. On the other hand, Department of Electronics required silicon of higher grade for semiconductor materials and integrated circuits etc. in a very limited quantity i.e. not more than ten percent of the projected demand. Still for reasons, not clear to the Committee, the DOE dealt with the subject and obtained approval of the Government so set up the National Silicon Facility of 200 TPA capacity for manufacture of semi-conductor grade silicon at he cost of Rs. 88.75 crores. The committee feel that the DNES would have been and would still be the right choice for the nodal department for the project for production of Silicon of the grade required for SPV uses. The Committee are distressed that the Government by entrusting the project to the DOE who were mainly interested in purer and costlier electronic grade silicon closed the option for a less purer and less costly grade which would have been more suitable for making SPV cells at reasonable cost and thus in boosting the solar energy programme. The Committee are strongly of the view that by the wrong choices of both the product as well as nodal department the solar energy programme has suffered a setback of perhaps a decade which an energy deficient country like ours can ill afford.

5. DEMAND PROJECTIONS FOR SILICON

5.1 At the instance of the Committee the DOE furnished a copy of letter No. D.O.S.-45/DNES/84 dated 15 February 1984 from Shri B. N. Swarup, Secretary, Department of Non-Conventional Energy Sources (DNES) to Dr. P. P. Gupta Secretary, Department of Electronics (Appendix V). The Secretary DNES enclosed with the letter a copy of the note prepared by Shri S. R. Faruqui, Joint Secretary in that Department who was incharge of Decentralised Energy Programme and also of the Policy Planning and Evaluation Division on assessment of the solar photovaltaic demand.

5.2 The note pointed out : "photovoltaic market is highly price sensitive. Although the technology in regard to single crystal and polycrystalline silicon is proven, the production price is very high and efforts are going on to reduce price drastically during the next few years." It also brought out the fact that with the cost of production at Rs. 960/- per kg. of silicon the setting up of 200 tonnes National Silicon Facility and postulation that 150 tonnes of the production would be used for SPV were not realistic. The average annual requirement of SPV over the Seventh Plan period assessed in this paper was 1 MW against the 2.2 MW estimated by DOE. Thus it was emphatically made clear that assessment made by DOE was on a very high side.

5.3 Asked to state whether the assessment of demand of 200 tonnes of silicon was not based on DNES's requirement of 10 MW solar photovoltaic generation capacity, the Secretary, Department of Non-Conventional Energy Sources (DNES) stated in evidence :—

> "That is true. However the 10 MW per year figure was only given as a possibility in case module prices dropped from the then existing price. Further, our view had been that 10 MW of photovoltaic demand does not necessarily mean 200 tonnes of polysilicon because by the time 10 MW of solar photovoltaics demand is reached it could be supplied from different type of silicon and the demand for this type of silicon may not be quite that large. So, we had strong reservations about putting the demand as 200 tonnes of polysilicon straightaway. In any case, we had felt that photovoltaics would be the largest single consumer for high purity silicon in the near future."

5.4 Clarifying the position further, the DNES in a note have stated as under :

> "The Department of Non-conventional Energy Sources (DNES) has all along expressed the view that in the Indian context in the near future, silicon demand for photovoltaic constitutes the largest part—about 90 per cent of the total demand for all uses of high purity silicon. DNES has also repeatedly emphasised the dependence of demand for photovaltaics on its price which might be reduced through newer developments or improvements in technology and scale of production.

When the so called 'demand' for silicon was estimated for establishing the National Silicon Facility proposed by Department of Electronics, Photovoltaics was still in the technology development and demonstration stage and there was hardly anything like a firm figure of demand existing or projected—in the sence of market demand. The demand figure that surfaced at the time was more in the nature of a scenario based on certain assumptions regarding price of photovoltaics and technological developments that were expected to be achieved by 1990. A project proposal prepared in June, 1983 by Central Electronics Ltd., for the establishment of 5 MW Photovoltaic production had given an estimate of Photovoltaics demand reaching 10 MW by 1990 *if* the price of photovoltaic module drops to Rs. 60/- per watt peak as *against the then prevailing price of Rs. 100/- peak watt.* The then prevailing price was based on silicon price at about Rs. 650/- per kg. Obviously if the price of silicon was to *go up* to more than Rs. 1100/- per kg. (actual price without special concessions was estimated at more than Rs. 2000/- per kg.) as envisaged in the Hemlock Project, the end price of photovoltaic modules would not come *down* to Rs. 60/- per watt, and it was pointed out by DNES that it will not be possible to use 200 tonnes of silicon per year at that price. It had further been pointed out by DNES that even if a level of demand of 10 MW for *end* applications of photovoltaics materialised, it was not going to be necessarily based on a crystalline silicon technology, but could involve a mix of technologies including thin film technologies that do not require poly-silicon. This would further restrict the demand for polysilicon.

DNES had also pointed out that whatever demand existed was essentially dependent on the price at which photovoltaic systems can be produced as well as being budget-driven; this situation continues, by and large, even today. Given the outlook on these matters DNES had expressed the view that it would be prudent to build up capacity gradually rather than to commit on a single large capacity of 200 tonnes based on old technology.

It may be recalled that in the EFC meeting held in the Department of Science & Technology on 20-2-84 for consideration of CEL's proposal for the 5 MW plant, DNES had pointed out that the demand might just grow to about 3 MW by 1990. This was based on silicon price of about Rs. 650/- per kg. Even at this level, only about 60—70 tonnes of silicon would have been required, even if it was assumed that it will be based entirely on crystalline silicon. It is, therefore, clear that DNES had indeed expressed doubts about the demand for bulk silicon reaching that high a level of 200 tonnes by 1990.

When the proposed Hemlock deal was brought to DNES attention it was pointed out that the price at which silicon would be produced fro mthe Hemlock project would be so high that the demand could not build up at all."

5.5 The Committee pointed out that the demand projected by the DNES earlier was very high. In reply, the Secretary DNES stated in evidence :—

> "Apart from the price, we had also pointed out that there was the question of how we evolved up to a certain demand. There is possibility of what we mentioned in our letter also of modular approach to this whole question. The plant which we had designed at Mettur was one which was of 25 tonnes capacity per year, and it could be stepped up even to 200 tonnes per year if required. That was capable of upscaling depending on the demand. We had also pointed out that the demand would be a lot budget-driven. Today what is happening is that for photovoltaic uses the total production figures are budget-driven. So, our overall Budget that is available for supporting it is able to sustain the projection of the order of a little over 1 MW per year. And if that MW is entirely to be supplied from Polysilicon then it will require something of the order of 20 to 25 tonnes per year. In fact, we are ourselves going in for a plant to produce amorphous silicon based on our technology at our solar Energy Centre. We are going to build a pilot plant. In many Indian laboratories, they have made good progress in amorphous silicon. We have now an All India project on development of amorphous silicon which is now in existence for the last few years and it has made a very good progress. Many of our laboratories have done very good work and we are upscaling it to the scale of pilot plant which should be ready next year."

5.6 As the major requirement of polysilicon in the country was for solar PV needs, the Committee enquired why collaboration with Hemlock was signed for high grade silicon for electronic application. The DOE stated in reply that there were no plants in the world which produced silicon of photovoltaic grade alone and hence, the Task Force did not consider such a possibility and, therefore, the collaboration agreement was signed for the manufacture of high grade silicon for electronics application for which also there is requirement in the country. The DOE also stated that the process and the plant could be operated to produce polysilicon for SPV needs alone as and when required. The collaborator had indicated that in such case the throughput from the plant would be higher.

5.7 The present total demand of silicon (equivalent polysilicon) in the country is stated to be of the order of 40 MT. The demand for equivalent polysilicon for electronic industry is estimated to be around 7 MT which is met mostly through import in the form of wafers and diffused chips. Since the capacity for conversion of polysilicon to wafers is limited at about 5 lakh wafers about 8 MT of polysilicon are being consumed to produce 5 lakh wafers. Rest of the requirement of solar grade silicon wafers, totally about 15-17 lakh wafers is being met through import.

5.8 The Committee asked if the demand also depends upon the facilities for conversion of silicon into PV Cells and if so, what are the conversions facilities and on that basis what is the present demand for silicon. In reply DOE have stated that the present installed capacity for conversion of silicon into photovoltaic cells is of the order of 2.25 MW which would consume polysilicon of the order of approximately 50 MT. Taking demand for

other applications into account, the total demand for silicon in the country would work out to approx. 57 MT.

5.9 The present actual demand is however, nowhere near the projections made earlier by the TF and NC and it is apparent that exaggerated demand projections were made earlier even though the cost of production and investment cost per tonne were taken at values which turned out to be much higher than those actually obtained subsequently. The views of the eminent national scientists and views of the members of TF and NC have also been divergent. In view of this, the Committee enquired if these bodies were competent to assess the national demand for silicon. The DOE replied that they had technically competent experts from research/industry/users for silicon in the country and they were technically competent to assess the national demand for silicon.

5.10 The Negotiating Committee's assessment of national demand for silicon was at 230 tonnes per annum in 1990 i.e. much higher than the estimate of 100 tonnes assessed by the TF only 18 months earlier. Against these estimates, the actual demand today works out in the region of 57 MT. Thus the present demand is nowhere near the projections made by the Task Force and Negotiating Committee. The inflated demand assessment of NC was based on expanded solar photovoltaic programme, decision to set up a major production facility of Large Scale Integrated Circuit (LSI) Very Large Scale Integrated Circuit (VLSI) . devices and also enhanced demand for Small Scale Integrated (SSI)/Medium Scale Integrated (MSI) devices and semiconductor devices for Electronics switching system. However, the basic fact remains that the demand of 10 MW p.a. was projected as a possibility in case module prices dropped from the then existing prices. The Department of Non-Conventional Energy Sources had also made it clear at that time that 10 MW of photovoltaic demand did not necessarily mean 200 tonnes of polysilicon because by the time this demand was to be reached, it could be supplied from different types of silicon and demand for this type of silicon might not be quite that large. It is evident that the estimate of photovoltaic demand reaching 10 MW by 1990 was given on the basis of assumption that the price of photovoltaic module drops to Rs. 60 per peak watt as against the then prevailing price of Rs. 100 per peak watt. The DNES had also pointed out at that time that if price of silicon was to go up to more than Rs. 100 per kg. then end price of photovoltaic modules would not come down to Rs. 60 and it would not be possible to use projected quantity of more than 200 tonnes of silicon per year at that price. The actual price of output of National Silicon Facility was however, estimated at more than Rs. 2000/- per kg. without special concessions as envisaged in agreement with Hemlock. Thus, the Committee find that in spite of the strong reservations of the DNES, the DOE concluded that projected demand would materialise and entered into an agreement with Hemlock Corporation to put up a project for National Silicon Facility at the cost of Rs. 88.75 crores. All the objections raised appear to have been simply overlooked to the deteriment of national interest. Inflated demand was projected on unrealistic assumptions and that too, in spite of strong reservations by the department which was expected to be the consumer for 90% of the production and same advice that the capacity be built gradually. The decision of the DOE to ignore the reservations of the DNES and obtain Government approval for setting up of the facility on the basis of inflated demand projections remains totally unjustified.

5.11 The Committee find that the DNES had prudently advised the DOE to build up the National Silicon Facility gradually through modular approach and cost effective manner as the demand for photovoltaic was budget constrained and price sensitive and efforts were going on to reduce the price drastically during the next few years. Even today, annual budget of DNES can sustain the demand of about one MW per year and if that is to be supplied entirely from polysilicon, it would require 20 to 25 tonnes per year. The DNES also disputed the estimated annual requirement of 2.2 MW per year of SPV assessed by DOE over the Seventh Plan period and emphatically made clear that it would be one MW per year. The DNES also intended to partly meet this demand through development of amorphous silicon technology which was considered to be the most modern, highly efficient and economical. They also claimed to have perfected this technology in their laboratories successfully. However, the Committee are distressed to note that these views were not examined in right perspective and were ignored. In the circumstances the Committee feel that the Department took the erroneous position that the technology being imported from Hemlock was largely in use and that it would take at least five years for new and better technology to emerge on commercial scale. Both these points were refuted by the DNES and some of the eminent scientists have held that Hemlock technology was getting obsolete and new technology was fast coming up. The Committee deplore the lacadaisical way in which entire issue was handled after ignoring valid objections and timely advice of the DNES.

5.12 The present total demand of polysilicon for PV is 40 MT. Another 7 MT of higher grade is required for semiconductor devices etc. by electronic industry which is met through imports in the form of wafers and diffused chips. It is perturbing to note that existing conversion capacity from polysilicon to wafers is only to the extent of about 8 MT (5 lakh wafers). For want of conversion capacity, indigenous manufacturers are not able to utilise adequately the available capacity of 25 MT fully. The Committee expect the DOE to act promptly in the matter and build adequate wafer production facilities expeditiously enabling indigenous industry to maximise the capacity utilisation for production of polysilicon.

6. EXTENT OF AVAILABILITY OF INDIGENOUS TECHNOLOGY

6.1 The Task Force had concluded in August 1982 that the Silicon Tetrachloride (STC) feedstock was not suitable since the quality of silicon produced therefrom by Mettur Chemicals and Industrial Corporation Ltd. (METKEM) an indigenous producer was poor and instead had recommended Trichloro Silane (TCS) as feedstock. This indigenous producer had been issued a licence in March 1982 for production of electronic grade silicon and silicon wafers. The TCS route was the technology of Hemlock which was recommended for collaboration. The TF had rejected STC feedstock also on the ground that the samples of Metkem Silicon had not been fully characterised and therefore, the product remained to be proved. These conclusions were drawn on the basis of the samples taken from the pilot plant of Metkem. Subsequently, Metkem installed the plant for production of silicon having 25 tonnes capacity and just before the confirmation of the agreement with Hemlock in February 1985 an Expert Committee appointed by DNES in January 1985 to evaluate indigenous production had concluded in February 1985 that purity of Metkem Silicon as measured in samples supplied was good for Photovoltaic (PV) application as well as for many

electronic uses also, as it had come close to the specifications given by DOW Corning and SMIEL (two internationally known producers in USA). The Evaluation Group had also opined that Metkem technology was likely to make further improvements and was expected to reach the highest international standards and the material could be used for practically all electronic purposes. All this was conveyed to DOE by the DNES. Metkem had also sent their silicon for test report to Siltech, California and their report had commended quality of the material as "equal of any made by the large poly suppliers". Thus the quality of silicon produced by indigenous producer had been established before the agreement with Hemlock was confirmed by Government of India in February, 1985.

6.2 About grading of silicon material Secretary, DNES stated in evidence that if the material produced is of a good quality, it can be used for photovoltaic (PV) purposes and can also be used for a number of electronic functions. For many of the electrical grade devices, the purity requirements are not that high. A large part of the electronic requirements can also be met.

6.3 Continuing, he further stated :

> "It had been our feeling that all this can be met from indigenous development and the other timings which could not be met are in insignificant quantity. These could also be met from our technology development in a relatively short period. And all this was made clear."

6.4 On the status of indigenous production at the relevant time, DNES has clarified the position as under :—

> "DNES also felt that indigenous technology had developed and could produce silicon at a lower price than the Hemlock plant, even at a lower production capacity of 25 tonnes/year. Further this was modular, and could be built up if demand increased and in accordance with actual increase. Thus, even if the demand were to go up to 200 tons/year, DNES had pointed out that it could be met more economically by our own technology and our own plant. Thus the demand question was not material insofar as the Hemlock project was concerned. The initial investment proposed for the Hemlock project appeared excessive and the cost of the silicon product would be too high and we could get stuck with a large capacity plant which may soon become obsolete. When we had cheaper indigenous technologies, there seemed no need to import technology. All this was mentioned by DNES."

6.5 The Secretary, DNES vide his letters dated 11 Dec. 1984 and 2 February 1985 (Annexure VI) had brought all these facts to the notice of the Secretary DOE, Cabinet Secretary and also Chairman, Electronics Commission with the plea that substantial quantities of silicon could be produced with a total capital investment of Rs. 100 per Kg. i.e. a plant of 200 tonnes capacity would cost only Rs. 20 crores. He also emphasised the fact that rapid advances were being made in amorphous silicon technology and other silicon technologies. The Secretary, DNES, apprehended that a big plant on prevailing technology as the proposed NSF, would be out of date soon after its commissioning within

4 years or so. He emphasised that it would be much better not to persist with the NSF but to have a smaller scale plant which could go on stream quickly to meet the immediate requirements and to add production capacity based on developments of newer technologies thereafter.

6.6 Since the Government of USA had delayed clearance of NSF proposal and not granted export licence to Hemlock by that time (it was actually done in January 1985), the Secretary, DNES also suggested that the DOE could get out of the proposed deal at that time.

6.7 In a subsequent note furnished to the Committee the DNES have stated :

> "As had been foreseen, Amorphous silicon solar cell technology is emerging as a low cost PV option and this would have an impact on polysilicon demand for photovoltaics. World-wide shipment of amorphous silicon modules have increased from a level of 6.95 MW in 1984. to 13.9 MW in 1988 and presently constitutes nearly 40% of the total shipment of PV modules including those for outdoor applications, as against 28% in 1984. DNES had also embarked on a major project for the development and commercialisation of this technology. Under an All-India project of DNES, research is being carried out at seven institutions in the country. Specific research tasks have been assigned and good progress has been made on the technology front. A pilot plant for making high purity silane and a pilot plant for producing amorphous silicon modules (the end product) are under construction."

6.8 Earlier in January 1985 an Expert Committee appointed at the instance of the Ministry of Science & Technology had commended in Feb. 1985 the work done by Metkem Silicon in successfully setting up pilot production. The Committee had anticipated stabilised industrial production of 25 TPA to take place by the end of 1986 or early 1987 which came true.

6.9 In the 69th meeting of the Electronics Commission held on 23 January 1984 (Appendix VII) the Director-General CSIR had also stated that CSIR would guarantee the development and commissioning in four years of a plant up to 200 TPA capacity to make poly-silicon both for PV application and other applications. The various points discussed in the meeting, which indicated that there was need for review of the proposed arrangement for import of technology were also mentioned in the minutes of the meeting.

6.10 The Task Force in August 1982 had recommended Hemlock technology based on Trichloro Silane (TCS) as feedstock as it considered the quality of silicon produced by Mettur Chemicals and Industrial Corporation (MCIC) in their pilot plant based on Silicon Tetrachloride (STC) as feedstock poor. It also rejected STC feedstock route of silicon on the ground that samples of Mettur Chemicals Silicon had not been fully characterised and therefore, the product remained to be proved, Subsequently, when the MCIC had installed the plant of 25 TPA capacity through its subsidiary Metkem just before the confirmation of the agreement with Hemlock in February 1985, an Evaluation Groups of the DNES opined in February

1985 itself, before conclusion of the agreement that purity of Metkem Silicon was good for photovoltaic as well as for many electronic uses also as it had come close to the specifications given by DOW Corning and SMIEL, the two internationally known producers of silicon. The Evaluation group also held that Metkem technology was likely to make further improvements and expected to reach the hightst international standards and the material could be used for practically all electronic purposes. Quality of silicon produced by MCIC's subsidiary company Metkem was also commended by M/s. Siltec California as "equal to any made by the large poly suppliers." Similar views were expressed by an Expert Committee of the Ministry of Science and Technology. The 69th meeting of the Electronic Commission also, similar views were expressed by some members and the Director-General, CSIR had stated CSIR would guarantee development and commissioning in four years of a 200 TPA capacity plant. The arguments put forward by Negotiating Committee in favour of Hemlock deal were also refuted in this meeting. The Committee are constrained to observe that all these latest developments in improvement of indigenous technology 30 months thence were knowingly ignored to the deteriment of national interest. The DOE preferred to confirm the agreement on the premise of their earlier findings which in course of time had proved to be wrong. In Committee's views, these acts of negligence on the part of the DOE to say the least are inexplicable.

6.11 According to the DNES, the indigenous technology developed at Mettur Chemical (Metkem) could produce 25 TPA silicon of good quality and was capable of meeting the national demand at that time qualitywise also as the material produced could be used alternatively for photovoltaic (PV) purposes and also for a number of electronic applications. The demand which could not be met by using Metkem technology was stated to be insignificant and could be met from imports and it was also claimed that Metkem technology would be capable of meeting this demand also in a relatively short period through further technology upgradation. When Hemlock deal was brought to the notice of the DNES it had pointed out that the demand would not grow upto the level assumed in the arrangement for collaboration on the basis of the cost at which silicon would be produced. It was also brought to the notice of the DOE that indigenous production, besides being economical was capable of being increased through modular approach in a comparatively short period. It had also been pointed out that initial investment in the proposed Hemlock project was excessive; cost of silicon product would be too high and the country would be stuck with a large capacity plant which would soon become obsolete. On the other hand indigenous technology was much cheaper. Some of the eminent scientists of the country on this subject had also opposed this deal. It is surprising to note how such vital points and valid reasoning against Hemlock deal were altogether side tracked. Evidently the DOE was not responsive to these reasonings at all and was dead set to go ahead with the Hemlock deal. The Committee are gravely concerned and take a serious note of it.

6.12 All this show inept handling and lack of perception of emerging scenario in photovoltaic (PV) cell technology and its economics on the part of the DOE. The Committee are distressed to note that DOE's transgression into the domain of another department resulted in sad consequences for the country. The Committee would like to be apprised of the grounds on which

valid points raised by the DNES and other eminent scientists/organisations working in this sphere were set aside.

6.13 The Committee are happy to note that the DNFS continued its valiant fight against this deal and brought the relevant facts to the notice of the Prime Minister and consequently Government decided to give up the deal. The Committee commend the efforts of the DNES in saving the country from the loss which would have been suffered by setting up the Rs. 90 crores project which was not required at all and would have because obsolete soon after commissioning.

7. APPROVAL OF COLLABORATION

7.1 Notwithstanding the opinions expressed by the DNES and CSIR, Scientists and others, the Secretaries' Committee which met on 16 February, 1985 held that Hemlock technology could be imported since it was largely in use and it could take upto 5 years for a new and better technology, to be established on commercial scale.

7.2 Justifying the decision for import of technology, the Department of Electronic, however, contended that the Committee of Secretaries, at their meeting held in February 1985, considered various alternatives available to the country. The DOE have further stated that during the course of the meeting, they were also given a brief summary of the present status, prospects and a comparative evaluation of the indigenous technology including the then capacity/likely capacity to be installed. The views of the Department of Non-conventional Energy Sources were that around 90% of the domestic requirement was for photovoltaic silicon and could be met from domestic technology and for the rest of the requirement, which would be of high purity for special application, the same could be met by import. According to the DOE, the various factors taken into account, *inter alia*, by the Committee of Secretaries included, the following :

(a) The time limit for conclusion of the agreement with Hemlock Corporation had already expired and the President of the Company had indicated that the extension of time could be granted upto one month failing which the experts would be re-deployed elsewhere and the agreement would have to be re-negotiated later.

(b) The current status and prospects of indigenous technology/ capacity.

(c) Alternative technology from GDR.

(d) While the maximum capacity of the indigenous project *viz.* Metkem would be 25 TPA, the overall demand in the country would be of the order of 200 TPA in the very near future.

(e) As the requirement for the electronic industry (though not of a large order) would be critical depending on high purity poly-silicon, it would be desirable to have a reliable and readily available technology for producing these requirements within the country.

(f) Some difficulties in procuring imported poly-silicon had been experienced.

7.3 In the circumstances, the DOE stated that the Committee of Secretaries came to the conclusion that there was need for a parallel facility for large scale production using current technology and capable of yielding high purity silicon and therefore, import of technology was considered necessary by them.

7.4 The Secretaries' Committee had held that alternative technology, say Amorphous Silicon, may take five years to strike commercial routes whereas Audit have pointed out that this was not correct as the shipment of Amorphous silicon was on the increase. In reply to these Audit observations, the DOE have stated : "No authentic figures relating to 'shipment' *i.e.* production level of photovoltaic modules based on amorphous silicon technology are available. However, there was some increase in the production in developed countries of photovoltaic modules using amorphous silicon technology". These observations are, however, in-contradiction from the data given by DNES which stated that world-wide shipment of amorphous silicon stood at 6.95 MW in 1984.

7.5 The Audit, however, pointed out to the DOE that its analysis about indigenous technology was not adequate as borne out by the findings of Expert Committee, Evaluation Group and from views of eminent scientist. In reply, the DOE have stated that various views/opinions expressed by different scientists/organisations were taken into account both by Electronics Commission and the Department of Electronics before coming to conclusion regarding the need for setting up the plant. It also stated that the National Silicon Facility was to be set up as an additional facility for large scale production of silicon. The DOE have further stated that financial help was provided to Indian scientists/organisations to develop indigenous technology and that the level of improvement was still not adequate to meet the country's requirement of silicon specially electronic grade.

7.6 The Committee asked for the minutes of the meeting of the Secretaries Committee to form an idea about the points discussed for and against Hemlock technology collaboration and how the opinion of eminent scientists against it was over-ruled. But the same were not made available to the Committee.

7.7 The Audit had pointed out during vetting of advance information furnished to the Committee that apart from the proposals received from National Chemical Laboratory, National Physical Laboratory and Indian Institute of Science which have been supported by DOE, several eminent scientists and professors had written to DOE about the need to abandon the Hemlock agreement and supported indigenous production and enquired why this was not heeded. In reply the DOE have stated that apart from various letters referred to in the minutes of the Electronics Commission meeting (dated 16-2-1985), the Department have been able to locate only two letters : one from Indian Institute of Science, Bangalore and the other from Mettur Chemicals. The DOE stated that no specific disposal of these letters was available on the file, though the following were identifiable with the DOE :

"(a) Regarding the views of Prof. C. N. R. Rao of Indian Institute of Science—a letter from Prof. Vasudev Murthy, IISc Bangalore addressed to Dr. P. P. Gupta, Secretary, DOE was considered at the meeting of the Electronics Commission held on March

13, 1984. It may, therefore, be said that the views of the Indian Institute of Science, Bangalore were taken into account by the Electronics Commission while coming to a conclusion.

(b) Points raised by Mettur Chemicals appear to have been discussed in a wider forum on 16/2/85 when experts were present".

7.8 Strangely, the Committee of Secretaries also cleared the project of Hemlock technology in its meeting held on 16 February 1985, notwithstanding the opinion expressed against it by the DNES, CSIR, renowned scientists and others. According to the DOE, the Committee considered various alternatives and were also apprised of the present status, prospects and evaluation of indigenous technology. The views of the DNES were also placed before it. The Committee are shocked to note that Secretaries' Committee appears to have been overwhelmed by the fact that time limit for conclusion of the agreement with Hemlock Corporation had already expired and the President of the Company had indicated that if agreement was not approved within a month, it would have to be renegotiated later and the experts would be redeployed elsewhere. It also appeared to have been misled by the exaggerated demand projected by the DOE and it failed to appreciate the latest developments in the indigenous technology as well as emerging amorphous technology.

7.9 The Committee consider it highly unfortunate that no specific disposal of the objections raised by Indian Institute of Science, Bangalore and Mettur Chemicals and several eminent scientists in their letters addressed to the DOE have been made. The Committee would like to know the reasons as to why specific notice of these eminent organisations and persons was not taken.

8. TECHNOLOGY AGREEMENT

8.1 As already stated, the Department of Electronics obtained approval of the Government in March 1984 for a 200 tonnes plant at a cost of Rs. 88.75 crores with foreign exchange components of Rs. 23 crores in technical collaboration with Hemlock Corporation. The 200 tonnes plant was recommended by DOE since the incremental capital cost for higher capacity plant was marginal and a larger plant would reap economics of scale. The Negotiating Committee considered the technology transfer offers of 3 foreign companies without any global tenders being floated and recommended in December 1983 conclusion of technical collaboration agreement (TCA) with Hemlock Semi-conductor Corporation (USA) for setting up a 100 t.p.a. silicon plant with infrastructure facilities for a 200 t.p.a plant. The Committee asked why global tenders were not invited, the DOE stated that the Task Force had addressed a communication to all the known silicon manufacturers in the world. The DOE added that since all the manufacturers had been contacted and their proposals/ responses obtained, adequate competition was available and even if global tenders were floated, the offers would not have been more competitive.

8.2 The Committee enquired if issue of floating global tenders was considered at all, the Secretary, DOE replied "I do not find anything on record".

8.3 The Secretary, DOE subsequently stated in evidence that initial enquiries were addressed to 46 companies though only 16 companies were actually manufacturing poly-silicon. Out of these, 14 responded and the 3 furnished full data.

8.4 Out of these 3 shortlisted firms, one had a different process and the final decision was made out of the two quotations of Hemlock and Siemens.

8.5 As per the agreement a lumpsum fee of US $ 6.70 million was payable for process knowhow, basic engineering documentation etc. Production was to commence 42 months after the signing of agreement in April, 1984. The financial analysis of the 3 shortlisted offers as done by DOE was as under :

Comparison of Technology Transfer offers made by Potential Collaborators

The offers made by HEMLOCK, SIEMENS and KOMATSU for a 100 TPA plant are given below :

Elements of Payments	HEMLOCK	SIEMENS	KOMATSU
		(Rs. in crores)	
Process knowhow, Basic Engineering, Licensor's expert's services, training of Licencee's personnel abroad, and Indian taxes.	9·5 (7·7)*	4·6 (3·6)	12·4 (9·7)
Royalty payable to Licensor for 5 years after Acceptance of Plant, including Indian taxes.	1·6 (1·1)	3·2 (12·3)	5·2 (3·7)
FOB cost of proprietory equipment to be supplied by Licensor	3·3 (3·3)	28·8 (28·8)	74·3 (74·3)
Total	14·4 (12·1)	36·6 (34·7)	91·9 (87·7)

*Figures in brackets indicate the FE component.

Capital Cost Estimates based on the Offers made by Potential Collaborators

The capital cost estimates based on the offers made by HEMLOCK, SIEMENS and KOMATSU for a 100 TPA plant located in a green-field site are given below :

	HEMLOCK	SIEMENS	KOMATSU
Capital Cost (Rs. crores)	64	73	154
FE Component (Rs. crores) *	16	40	101
Cost of Production (Rs./Kg.) including Royalty	1400	1570	2660

*This includes a few direct import items other than the proprietory equipment indicated in section 11.1 and the FE expenditure on ocean freight.

Because the capital cost of HEMLOCK's offer was the lowest and the technical collaboration offer was the best, detailed financial analysis were undertaken to work out the capital cost and cost of production of a

"200/150 plant" and a "200/200 plant" in a 'green field' site based on the HEMLOCK offer. The results are :

	"100/190 Plant"	"200/150 Plant"	"200/200 Plant"
Capital Cost (Rs. crores)	64	91	95
FE component (Rs. —crores)	16	21	21
Cost of production (Rs./kg) including royalty	1400	1290	1140

8.6 It would be seen that in the offers of Hemlock Corporation, Siemens and Komatsu for technology transfer, there were wide variations. The offers were for Rs. 14.4 crores, Rs. 36.6 crores and Rs. 91.9 crores respectively. In this context, the Committee enquired if any techno-economic analysis of the three offers was done, the Secretary DOE stated in evidence :

> "Techno-economic analysis of the type you are asking might not be there to work out informal rate of return etc., but technical analysis was done. The relevant comparison and financial analysis was done".

8.7 The Committee are surprised to note that no global tenders were floated for technology transfer although the project was not considered as urgent at any stage. There is nothing on the records of the DOE to suggest that issue of global tenders was considered at all. The Task Force had addressed a communication making preliminary enquiries from 46 companies in the field the world over though only 16 of them were manufacturing silicon. Out of them, 14 responded and only three furnished full data. Out of the three short listed companies one namely Komatsu of Japan had a different process and the final decision was made of the two quotations of Hemlock and Siemens. This cannot be termed as broad-base for award of a contact of Rs. 90 crores. It was highly improper not to have invited global tenders. A communication seeking certain information can in no case be equated with the formal invitation to tender. Since, the global tenders were not floated it is hypo-critical to assume that even if global tenders had been floated, the offers would not have been more competitive.

8.8 The Committee find that there were wide variations in the cost of technology transfer offers made by the three potential collabora-tors. It varied from Rs. 14.4 crores for Hemlock, Rs. 36.6 crores for Siemens and Rs. 91.9 crores for Komatsu. The capital cost and cost of production of silicon per kg. also varied widely. Strangely, no efforts were made to find out the reasons for such wide variations. Nor any effort was made to work out the rate of return on capital employed. Had it been done, the Committee feel, Government would not have perhaps allowed the DOE to venture in this project. Still, on the basis of analysis done it was clear that cost per kg. of output was out of proportion and exorbitantly higher than the prevailing world price. In spite of this, the DOE decided to set up the project rather than explore the other cheaper alternatives that were available including indigenous development of technology.

9. COST OF IMPORTED TECHNOLOGY

9.1 According to the DOE, the cost of production of silicon with imported technology in green field conditions worked out at approximately Rs. 1,130 per kg. based on the Hemlock offer with a complete plant of 200 tonne capacity whereas the cost of production with indigenous technology at METKEM was only Rs. 850 per kg. Audit has pointed out that the cost of production with imported technology would be more if return on investment and non-subsidised electricity cost are taken into account and that even otherwise the cost of production is more than the landed cost of the material and more than the cost of production with indigenous technology.

9.2 Though, the Electronics Commission in January, 1984 had also observed that on the basis of commercial norms, the cost of production of polysilicon at NSF at 75 percent installed capacity would be in the neighbourhood of. Rs. 2600 per kg. or more as against it the international price ranged between Rs. 500-600 per kg. Notwithstanding, the Electronics Commission also supported the import of technology.

9.3 The high price of production with imported technology was also pointed out by the Secretary, DNES in November 1984 itself and subsequently at various points of time. He supported this argument in his communication dated 2 February, 1985 on the basis of the opinions expressed by eminent scientists. The Secretary, DNES had also pointed out in that letter of 2 February, 1985 that these scientists had given solid reasons why Government should not proceed to import a 200 tonnes polysilicon plant at a pay high cost and knowhow from the Hemlock Corporation, USA.

9.4 Shri Virendra Mohan who was chairman of the Task Force and the Negotiating Committee had himself mentioned that if METKEM could demonstrate even a few grams of satisfactory material, he would himself propose jettisoning the proposed collaboration deal with Hemlock. In this connection it may be mentioned that the high quality of material was amply demonstrated by METKEM subsequently by January 1985 as per report of Expert Committee of February 1985 and this was testified by various technical Committees appointed for this purpose.

9.5 The Secretary, DNES also observed during evidence as under :

> "I had written letters at that time and I think one of those letters which is quoted in the Audit Report is on the file. It has clearly expressed the view and the reason why we felt that it was too high. We had got estimates from approved sources, tactical sources and that is what we had quoted there. We have also got figures for investment in our own plant at Mettur which we had worked out on the basis of some reasonable scaling. This seems to match with the figures which we have got from international data. On that basis we felt that the projected cost of the Plant using imported Hemlock technology was excessively high. This was the word which I had used at that time in my letter. We had mentioned that price of the product would therefore, be high and that in turn will affect the demand because of the price is going to be Rs. 2000/- odd per kg. then that demand will not be able to sustain".

9.6 Apart from DNES, an Evaluation Committee had also commended in June 1986, Metkem Silicon's capabilities in having installed, commissioned and operated a plant for high purity silicon in such a short time of less than a year. The Evaluation Committee had also observed that for upscaling of the present Metkem technology, to a capacity of 200 TPA the investment is not likely to exceed to Rs. 20 crores if such a plant is situated under similar circumstances prevailing at Metkem.

9.7 The DOE have stated that "It would not be correct to attempt a direct comparison of costs or the time frame for the proposed National Silicon Facility vis-a-vis Metkem for the following reasons :

(a) Metkem was an existing project. As such, in their case, it would be an upscaling of the technology/equipments etc. In the case of National Silicon Facility, it would be setting up a completely new plant etc.

(b) Metkem draws some of the raw material (crude silicon, tetrachloride, hydrogen etc.) required for the silicon manufacture from Mettur Chemical and Industrial Corporation, a sister concern.

(c) The technologies proposed to be followed by the two plants and as such the scope of the plant as well as the quality of products contemplated were different.

(d) The cost of production for the Hemlock process envisaged by the Negotiating Committee included all relevant elements of cost. No governmental concessions/subsidies appear to have been taken into account while arriving at these costs.

9.8 The Committee find that cost of production of silicon with imported technology from Hemlock was calculated at Rs. 1130 per kg. by the Negotiating Committee excluding return on investment and subsidies on power etc. and at full capacity utilisation of plant. The Electronics Commission on the basis of commercial norms and at 75 per cent capacity utilisation observed in January 1984 that the cost would be in the region of Rs. 2600 per kg. or more. The cost of production with indigenous technology at 'Metkem' was indicated at Rs. 850 per kg. and the international price ranged between Rs. 500-600 per kg. On account of the high cost of production with imported technology, it was opposed by the DNES at various points of time and some eminent scientists working in this field and all the drawbacks were brought to the notice of the DOE.

9.9 The Evaluation Committee had also observed that for upgrading the production level to 200 tonnes plant based on Metkem technology additional investment would not exceed Rs. 20 crores. In spite of these facts, the DOE have defended Hemlock technology project on ground of lower power consumption per kg. of polysilicon; wider production range and opposed Metkem on various irrelevant grounds. The Committee do not consider these reasons convincing at all. They are of the firm opinion that decision to import technology and set up Rs. 88 crores project was not justified at all in the context of several objections raised to the proposal. The Committee not only deplore the decision which led to avoidable expenditure in terms of foreign exchange but also the arbitrary and capricious method of taking the decision in total disregard of all relevant facts, data and other information furnished by various bodies and persons having expertise in the field.

The Committee desire that suitable methodology should be evolved by the Government to ensure that relevant and authentic data and information are not ignored in taking investment decisions particularly those involving huge sums like the NSF.

10. TERMINATION OF AGREEMENT AND PAYMENTS TO HEMLOCK

10.1 According to the Audit paragraph, on the ground that the indigenous capacity for producing silicon had, in the meantime, come of age, Government ordered its evaluation and directed in October 1986 that future developments on silicon front should be based on indigenous technology and that the agreement with Hemlock should be terminated in the best possible manner. The agreement was accordingly terminated in June 1987 by which time Rs. 7.92 crores were paid to Hemlock, including a sum of Rs. 2.15 crores which fell due for payment in April 1987 under the contract.

10.2 The Committee enquired about the reasons for delay of more than six months in termination of the agreement after the decision was taken. The Secretary, DOE replied :

> "There had to be consultations from legal angle and so on. It had to be done slightly at a higher level."

10.3 According to Audit, as per agreement maximum payment of 60 per cent of lumpsum fee for know-how technology was only payable had the agreement been terminated due to default of Licensee (DOT). The DOE had however paid US $ 8,70,000 (Rs. 1.12 crores) in excess of 60 per cent lumpsum fee separately paid.

10.4 The Committee enquired if the technology can be put to use. In reply, the Secretary, DOE stated in evidence:

> "We are exploring the ways to use it."

10.5 The Committee take a serious note of the fact that the DOE took unusually long time to terminate the Collaboration agreement with the Hemlock Corporation. The Government had decided in October 1986 to give up the agreement but the DOE finally carried out the decision in June 1987 i.e. after a period of 8 months. As a result of this delay a further instalment of Rs. 2.15 crores became due in April, 1987. The delay has been ascribed to legal consultations at a higher level. The Committee are not at all convinced by this excuse. They feel that the DOE failed to expedite the matter as the delay has cost a sum of Rs. 1.12 crores in excess of the 60% restriction intended for termination of the contract.

10.6 The Committee fail to find any substance in the claim made by the DOE that technology received at the cost of Rs. 7.92 crores could be put into effect with indigenously designed and manufactured equipment and that the DOE are exploring the ways of using it. As the cost of production with indigenous technology is much cheaper as compared to the cost of production with the imported technology and so far Government have not succeeded in putting the know-how received to any use, the Committee are convinced that the expenditure of Rs. 7.92 crores in foreign exchange was totally infructuous. The Committee deplore strongly the avoidable expenditure and recommend that action be taken against those responsible.

11. OTHER ISSUES

11.1 After termination of the collaboration agreement, a CBI enquiry was conducted against some officers of the DOE and to establish their culpability in this deal. The Committee asked about the nature of CBI enquiry, the officers involved and the extent of their culpability established in the case and also the action taken on the CBI report. The DOE in reply stated that "it would not be in public interest to furnish copies of the Report of the CBI of the enquiry conducted by them in this case." However, it has been stated : "an enquiry was ordered by Government into the entire matter. This enquiry included investigation by CBI. Based on the results of the enquiry, Government came to the conclusion that certain officials had failed to adequately assess indigenous technological developments in the field of polysilicon". It was further stated that "appropriate action against the concerned officials has been taken."

11.2 Besides the CBI Enquiry Report and minutes of the sitting of the Committee of Secretaries as discussed earlier, the Committee also asked for CCPA papers on the basis of which approval was granted for Hemlock agreement and subsequent directive for cancellation of these arrangements. These were also not made available to the Committee on the ground of "public interest".

11.3 The Committee are unable to appreciate denial of copies of CBI enquiry report, CCPA papers and also minutes of the meeting of the Secretariat Committee on grounds of "public interest". As a close scrutiny by the Committee of CBI enquiry report would have highlighted the extent and nature of culpability of erring officials, the Committee feel public interest would have been served better by furnishing these documents.

11.4 The Committee find that on the basis of CBI enquiry government have concluded that certain official have failed to adequately assess indigenous technological developments in the field of polysilicon and appropriate action against them has been taken. However surprisingly, in replies to Committee's questions both in writing and in oral evidence the DOE have taken altogether a different position which is in conflict with the position now explained. In view of it, production of these documents to the Committee and their close scrutiny becomes all the more important and the refusal to produce the documents called for by the Committee totally inexplicable. Since the refusal to furnish the documents stated to have been taken at Ministrial level has been referred by the Committee to the Hon'ble Speaker and his decision is awaited the Committee is unable to make a final report and is constrained to make this report an interim report.

NEW DELHI;
April 27, 1989
Vaisakha 7, 1911 (*Saka*)

AMAL DATTA,
Chairman,
Public Accounts Committee

APPENDIX I

Paragraph 5 of the Report of the C & AG of India for the Year Ended 31 March, 1987 (No. 7 of 1988), Union Govt. (Scientific Departments) on National Silicon Facility—Unfruitful Expenditure in Import of Documents for a Technology not in use relating to Department of Electronics

5.1 In view of the growing importance of silicon, which is a crucial raw material in the electronic industries, the Department of Electronics (DOE) proposed in October 1981 the setting of a National Silicon Facility (NSF) to undertake stock-piling, production, research and development so that the country could become self-sufficient in this critical material. This was approved in November 1981 and a Task Force (TF) of specialists was constituted in January 1982 to configure the NSF for investment proposals.

The TF submitted Part I of its report in August 1982, suggesting the production process to be adopted and setting up a Negotiating Committee (NC) to finalise the collaboration proposals. The TF also assessed that the national demand for silicon would be 100 tonnes *per annum* (TPA) by 1990. No further part of the report was submitted by the TF.

The NC appointed in January 1983 considered the technology transfer offers of three foreign companies, without any global tenders being floated and recommended in December 1983 conclusion of technical collaboration agreement with Hemlock Semi-Conductor Corporation (U.S.A.) for setting up a 100 tonnes silicon plant with infrastructural facilities for a 200 tonnes plant at a project cost of Rs. 65.75 crores. According to the NC, the estimated demand for silicon could be 190 tonnes in 1988-89 and 230 TPA from 1990-91.

After Electronic Commission (EC) had recommended the NC proposals in February 1984, the DOE put up a proposal to Government in March 1984 for a 200 tonnes plant at a cost of Rs. 90.75 crores with foreign exchange component of Rs. 23 crores with technical collaboration from Hemlock. The DOE had recommended 200 tonnes plant since the incremental capital cost for higher capacity plant was marginal and a larger plant would reap economies of scale. The proposal was approved on 29th March 1984.

The agreement with Hemlock was signed on 16th April 1984. As per the agreement, a lumpsum fee of US $ 6.70 million was payable for process know-how, basic engineering documentation, etc. and US $ 7.65 million for proprietory equipments. In all, US $ 14.35 million (approximately Rs. 18 crores) was payable in instalments.

In addition, Rs. 70 crores was to be spent towards indigenous equipments, buildings, land, etc. for setting up the NSF. The production was to commence after 42 months.

Hemlock obtained the necessary export licence from the US Government in January 1985 and thereafter the agreement was confirmed by the

DOE on 18th February 1985. Until June 1987, the first two instalments of Rs. 2.93 crores had been paid to Hemlock. In addition, Rs. 1.56 Crores were paid as Income Tax on behalf of Hemlock and Rs. 15.84 lakhs were paid to Engineers India Limited as consultancy charges for NSF configuration.

Since the indigenous capability for producing silicon had, in the meantime, come of age, Government ordered its evaluation and in October 1986, directed that future developments on silicon front should be based only on indigenous technology and the agreement with Hemlock should be terminated in the best possible manner. The agreement was accordingly terminated after further negotiations. In all, Rs. 7.92 crores had been paid and no technology benefit has accrued to the country or the industry. The details are discussed in the following paragraphs.

5.2 *Technology Arrangement*

The TF had concluded in August 1982 that the Silicon Tetrachloride (STC) feedstock was not suitable since the qualtiy of silicon produced therefrom was poor and instead recommended Trichloro Silane (TCS) as feedstock. The STC feedstock was the one adopted by M/s Metkem Silicon, an indigenous producer, who had been issued in March 1982, with the industrial licence for production of electronic grade silicon and silicon wafers. The TCS route was the technology of Hemlock which was recommended for collaboration/import.

The TF had also rejected STC feedstock on the ground that the samples of Metkem silicon had not been fully characterised and therefore the product remained to be proved. However, just before the agreement with Hemlock was confirmed in February 1985, an Evaluation Group appointed by the Department of Non-Conventional Energy Sources (DNES) had concluded that the purity of Metkem silicon as measured in the sample supplied was good for Photo Voltaic (PV) application and for some electronic devices as it had come close to the specification given by DOW Corning and SMIEL (the two internationally known producers). The Evaluation Group had further opined that Metkem technology was likely to make further improvements and was expected to reach the highest international standards.

M/s Metkem Silicon had also earlier sent their silicon for test report to M/s Silitech, California and their report of January 1985 stated that "we have measured the poly crystalline silicon from India, using the equipment we keep at MIDAC and we were impressed with its purity. The material we have seen is fully the equal of any made by the large poly suppliers". Thus, the quality of silicon produced by the indigenous producer had been established before the agreement with Hemlock was confirmed in February 1985.

Earlier an Experts Committee appointed at the instance of the Ministry of Science and Technology had commended the work done by M/s Metkem Silicon in successfully setting up pilot production. The Committee anticipated stabilised industrial production of 25 TPA to take place by end of 1986 or early 1987, which came true. Also in the 69th Meeting of the EC held in January 1984, the Director General, CSIR had stated that CSIR would guarantee the development and commissioning in four

years of a plant upto 200 TPA capacity to make poly silicon both for PV application and other applications.

Yet, the Secretaries Committee which met on 16th February 1985 held that Hemlock technology could be imported since it was largely in use and it could take upto 5 years for a new and better technology to be established on commercial scale. The Government of India confirmed the agreement with Hemlock on 18th February 1985.

5.3 *Over estimation of demand*

Another reason that weighed with the Secretaries Committee to clear the NSF project was the limited capacity available (25 TPA) with the indigenous producer when the country's demand was estimated to be 200 TPA. The estimation proved incorrect. But at that point of time demand projection of 200 TPA precluded adoption of indigenous technology and led to import of technology.

However, the Evaluation Committee appointed by the DOE had observed (July 1986) that the earlier estimates of demand for silicon needed downward revision in the light of the developments in the field of thin film solar cell technology. The Committee had also recommended adoption of indigenous technology since M/s Metkem Silicon was able to produce 25 TPA and the capacity could be easily expanded. Thus, the conclusion of the Evaluation Committee was totally different from that of the Secretaries Committee. Since the Secretaries Committee was aware that silicon scenaio was fast changing it could have recommended payment of US $ 2,00,000 to keep the options open for future decision as was offered by Hemlock. Instead, the Secretaries Committee recommended confirmation of the contract and ultimately when the contract was terminated after negotiations, US $ 2,00,000 was additionally paid to Hemlock. In other words, the payment was ultimately made without the benefit of future option.

Even with incorrect assessment of demand, it was possible to adopt indigenous technology because the NE had indicated earlier that the production of poly silicon was highly modular and scaling up was dependent upon addition of new reactors. In February 1985, before the agreement with Hemlock was confired, the DNES had indicated the possibility of adopting indigenous technology without difficulty. This was considered but not accepted and import of technology was resorted to.

5.4 *Cost of imported technology*

The EC, in January 1984, had observed that on the basis of commercial norms, the cost of production of poly silicon at NSF at 75 *per cent* installed capacity would be in the neighbourhood of Rs. 2,600 per kg or more. As against this, the Metkem cost of production was Rs. 850 per kg. without the economies of scale, subsidised financing and subsidised electrical power. The international price ranged between Rs. 500 and Rs. 600 per kg. Thus, the EC had noted the high price at which NSF was being established but supported it.

The high price for the imported technology was also pointed out by the Secretary, DNES in November 1984 itself. He had indicated that NSF with 200 TPA capacity could be established within Rs. 21 to 25 crores.

Yet, establishing NSF with Hemlock technology, at a total cost of Rs. 92 crores was decided upon.

The Evaluation Committee also stated (June 1986) that "Metkem Silicon had done a very commendable job in having installed commissioned and operated a plant for high purity silicon in such a short time of less than a year. They have adequate capabilities in the area of process technology, engineering and characterisation. In the context of the proposed National Silicon Facility, involving a production capacity of 200 TPA, the Committee observed that for upscaling of the present Metkem technology, the investment is not likely to exceed Rs. 20 crores if such a plant, if at all required, is situated under similar circumstances prevailing at Metkem".

This was a total reversal of the earlier assumptions of other Committees and the DOE. It is also noteworthy that apart from the cost of imported technology, the indigenous technology had come of age within one year, whereas Hemlock wanted 4 years to establish the 200 TPA Plant.

5.5 *Payments to Hemlock*

In October 1986, Government ordered that the future development of production facility in the country for poly silicon should be based on indigenous technology and agreement with Hemlock should be given up in the best possible manner. Till then, the DOE had paid Rs. 2.93 crores towards two instalments for the know-how and process package.

By April 1987, when the DOE submitted a further note, another instalment of Rs. 2.15 crores for basic design engineering documentation had become due but remained to be paid.

As per Clause 13.2.2 of the agreement, termination of the agreement would have meant a minimum payment of 60 *per cent* of lumpsum fee for know-how technology if the training of licensee's personnel had not been completed by the licensor. According to Clause 10.1.1(a), the lumpsum fee was US $ 6,70,000 net of Indian taxes. Thus, at the time of terrmination of the agreement, 25 *per cent* had become due since 35 *per cent* of the lumpsum fee had already been paid. Instead of paying the balance 25 *per cent* amounting to US $ 16.75 lakhs (Rs. 2.15 crores), the department negotiated and paid (June 1987) Rs. 2.15 crores plus US $ 8,70,000 (Rs. 1.12 crores). This latter amount represented the instalment towards standard operating procedures (US $ 6,70,000) which was supplied after the Government ordered the annulment of the agreement and US $ 2,00,000 for agreeing to terminate the agreement. This was not within the confines of the agreement and was, therefor, irregular.

The department stated (October 1987) that the technology agreement was entered into as an insurance for meeting the demands of strategic silicon. This is not tenable since the demand for strategic silicon was miniscule whereas the amount paid to Hemlock was for 200 TPA plant which was essentially to be used for solar cells application.

Thus, incorrect assessment of demand, partial analysis of potentialities in PV field, non-cognizance of indigenous capability, exercise of wrong option etc. led to conclusion and subsequent termination of a contract with a foreign firm resulting in unfruitful expenditure of Rs. 7.92 crores.

APPENDIX II

Composition of Task Force set up to prepare Techno-Economic Feasibility Report for investment approval by Government in National Silicon Facility.

1. Shri Virendra Mohan, Chairman & Managing Director, Semiconductor Complex Ltd.	*Chairman*
2. Dr. A. P. Kulshreshtha, Electronics Group, Indian Satellite Centre. ISRO.	
3. Dr. T. K. Bhattacharya Project Manager, National Solar Photo Voltaic Demonstration Programme, Central Electronics Ltd.	*User*
4. Dr. N. S. K. Prasad, Chemical Engineering Division, BARC.	*Scientist*
5. Professor A. R. Vasudevamurthy, Department of Chemistry, Indian Institute of Science.	*Scientist*
6. Dr. S. Sivaram, R & D Centre, Indian Petrochemical Complex Ltd.	*User*
7. Shri E. S. Ramamurthy, Senior Manager, Bharat Heavy Electricals Ltd.	*User*
8. Dr. S. G. Patil, Principal Scientific Officer, IPAG, Electronics Commission.	*Member-Secretary*

APPENDIX III

Composition of the Negotiating Committee

1. Shri Virendra Mohan, Chairman NSF Task Force & Chairman & Managing Director, Semiconductor Complex Ltd.	*Chairman*
2. Shri V. K. Beri. Chairman & Managing Director, Engineers India Ltd.	*Member*
3. Dr. T. K. Bhattacharya, Member NSF Task Force & Project Manager, NASPED, Central Electronics Ltd.	*Member*
4. Dr. N. S. K. Prasad. Member NSF Task Force & Head, Silicon & Silicon Products Section, Bhabha Atomic Research Centre.	*Member*
5. Shri S. B. Seth, Project Manager for NSF. Engineers India Ltd.	*Member*
6. I.F.A., Department of Electronics.	
7. Dr. S. G. Patil, Member Secretary, NSF Task Force, Department of Electronics.	*Member-Secretary*

APPENDIX IV

Prof. A. R. VASUDEVAMURTHY

No. LPC/105/90-A/NSP/6952 The 4th November 1982

Dr. Virendra Mohan,
Chairman and Managing Director,
Semi-Computer Complex Ltd.,
Phase-VIII, S.A.S. Nagar-160051,
Punjab.

Dear Dr. Virendra Mohan,

I am in receipt of the Report of the Task Force on National Silicon Facility, Part I.

I invite your kind attention to some of the points that were raised by me during the discussion at the meeting on 27-8-1982. You were good enough to indicate that these points will be incorporated in the Report. Moreover, I find that those observations are not reflected in the Report. It will not be possible for me to agree to the following points.

I. Page 15, Lines 3 and 4. While commenting on the POLYSILICON by the silicon tetrachloride route, it is mentioned that "The quantity of their products is reportedly poor".

This is not true. In fact, the boron content of the polysilicon prepared by STC route is observed to be less than the TCS route. I give the following reference in support of this observation.

TOPSIL/Denmark produces polysilicon from $SICI_4$ and is able to achieve boron levels of 7 to $9 \times 10^{11}/cm^3$. Reduction by a factor of 10 is believed possible through redesign of the reactor. An advantage of working with $SICL_4$ rather than $SIHCI_3$ is the greater separation of boiling temperatures of the boron containing compounds which makes the purification process more efficient".

This is quoted from "The Preparation and Characterisation of silicon for Infra red Detectors". Report of the Committee on the preparation of ultra high purity, low-boron silicon—by National Material Advisory Board—Commission on Sociotechnical Systems, National Research Council. Publication NMAB-382, National Academy Press, Washington D.C., 1981, Page 49.

Similarly, it is known that poly silicon prepared from silicon tetrachloride is reported to contain less carbon impurities than the one produced from trichlorosilane feed stock as it is difficult to remove traces of carbon analogues which are likely to be associated with it.

II. Page 61, "Although industrial infrastructure at Mettur Chemicals is generally adequate to set up a large scale plant, it is to be noted that 90—95 percent of world production of poly silicon is based on the TCS process as against the STC process being put forward at Mettur Chemicals in collaboration with Indian Institute of Science. Whereas the problems

associated with the purification of STC are similar to these as in the case of TCS, the STC process requires, higher temperatures and consequently high power. Additionally, polysilicon deposition rates are slower in the case of STC. The process adopted at Indian Institute of Science/Mettur Chemicals is, therefore, not suitable one especially with our higher cost of electrical power. The use of graphite rods for deposition of silicon is likely to result in higher carbon contamination which is undesirable. Further, while the resistivity values for N-type poly sicilon obtained are reported to be about 10 chm-cm. The samples have not been fully characterised and therefore, the quantity of the product remains to be proved. The low resistivity values of the samples reported indicate that the materials being produced at present may not be suitable for semiconductor devices including PV Solar Cells."

This paragraph needs to be deleted in the light of the following points :

(a) It is true that trichlorosilane is extensively used in the Western countries for the manufacture of poly silicon. Trichlorosilane is available in large quantities from silicon industry. Even if trichlorosilane is manufactured by the reaction of hydrogen chloride and metallurgical grade silicon about 20% of the silicon comes out as silicon tetrachloride which has to be separated and a gainful use to be found for it.

(b) The boiling point of trichlorosilane (31.8°C) is considerably lower than silicon tetrachloride (57.3°C) and consequently the vapour pressure of $SiCl_4$ will be very much higher than $SiCl_4$ as is given below :

Temperature	Vapour pressure of $SiCl_4$ in mm of Mg	Vapour pressure of $SiCl_4$ in mm of Mg.
30°C	502	195
30°C	700	300
31°C	760	—
40°C	1000	400

In India, the embient temperatures are of the order of 30°—40°C. In addition, the heat of evaporation and specific heat of trichlorosilane are higher than silicon tetrachloride. As such, considerably amount of extra energy is required including for refrigeration while purifying and recovering trichlorosilane from the reactor affluents. The flash point of trichlorosilane is considerably low (—25°) and it is inflammable. As such, more safety measures are called for whereas no such hazard is associated with silicon tetrachloride as it is not flammable. The product from the reactor contains a substantial fraction of silicon tetrachloride (upto 40—50°C) even when pure trichlorosilane is used as a feed stock. The silicon tetrachloride produced in the reaction chamber will have to find a gainful use. It is invariably in practice to use a mixture of trichlorosilane and silicon tetrachloride as a feed stock instead of any one chlorosilane alone. The use of trichlorosilane alone is not all that advantageous although its decomposition temperature is little lower. Also with modern sultired deposition chambers of 6 to 12 rods, rediation losses from the hot filament is severely

curtailed and thereby leading considerable saving of electrical energy. The production of poly silicon is only an intermediate step in the manufacture of semiconductor silicon and consumes about 60% of the total elctrical energy and the remaining 40% is used auxiliaries for further processing of the poly silicon, whatever may be the route to manufacture the same.

It will, therefore, not be correct to say the STC process is not a suitable one without proper assessment. This statement needs correction.

(c) I did point out that for obtaining experimental parameters in growing large size poly rods (110 mm long and 70—80 mm dig.) graphite rods have been employed as substrates. However, for actual production of poly rods, tungsten/Tantalum rods have been successfully employed in the earlier medium scale experiments. The purity of poly silicon thus obtained would be quite adequate for most of the semiconductor devices. It would be traventy of facts to state that such poly silicon is not suitable even for P. V. solar cells. I also mentioned that most of the companies in U.S.A. use tungsten rods for the deposition of poly silicon except for PZ material for which silicon substrates are employed.

In the light of these observations. it becomes imperative to delete these erroneous points and modify the paragraph.

I request you to take steps to introduce these modifications to the Report.

Thanking you,

With kind regards.

Yours sincerely,
Sd.
A. R. VASUDEVAMURTHY

P.S. : I shall deeply appreciate if you can kindly send the proposals sent by the few foreign companies on Silicon Technology for a detailed study.

Thanks.

Sd.
A. R. VASUDEVAMURTHY

Copy to :
Dr. S. G. Patil,
Principal Scientific Officer,
Electronics Commission (IPAG).
B-Wing, Pushpa Bhawan,
Madangir Road,
New Delhi-110 062.

APPENDIX V

SECRET
Telegram : RENEWABLE
Telephone : 694481
D.O. No. S-45/SNES/84

GOVERNMENT OF INDIA
DEPTT. OF NON-CONVENTIONAL ENERGY SOURCES
MINISTRY OF ENERGY
BLOCK NO. 14, C.G.O. COMPLEX, LODI ROAD,
NEW DELHI-110 003

Dated 15th February 1984

B. N. SWARUP
SECRETARY

My dear Dr. Gupta,

The question of assessing the likely demand of Solar Photovoltaic devices in the country has been engaging the attention of the Department of Non-conventional Energy Sources. After the last meeting of the Electronics Commission, Dr. J. Gururaja, Director in this Department had consulted Shri Ashok Parthasarthy, Secretary of the Electronics Commission to seek clarification in regard to the basis on which the solar photovoltaic demand had been assessed in the Department of Electronics. Shri Ashok Parthasarthy had also seen me recently. Shri S. R. Faruqi, Joint Secretary in this Department who is incharge of Decentralised Energy Programme and also of the Policy Planning and Evaluation Division had also undertaken an assessment of the solar photovoltaic demand after consulting some of the likely user Departments. I enclose a copy of a Secret Note recorded by Shri Frauqi on the subject for your information.

With kind regards,

Yours sincerely,
Sd/-
(B. N. SWARUP)

Dr. P. P. Gupta,
Secretary,
Department of Electronics,
Lok Nayak Bhavan,
Khan Market,
New Delhi.

Encls :
As above

Copy to Shri Ashok Parthasarthy, Secretary, Electronics Commission Lok Nayak Bhavan, New Delhi.

Sd/-
(B. N. SWARUP)
Secretary

SECRET

A NOTE ON THE POSSIBLE DEMAND FOR SPV FROM 1985

This note has been prepared with the following assumptions :—

(1) The term "demand" has been taken to mean "absorption capacity" and includes the different components of such capacity;

(2) Subsidies, if any, will be payable by the purchasing departments.

2. The photovoltaic market is highly price sensitive. Although the technology in regard to single crystal and polycrystalline silicon is proven, the production price is very high and efforts are going on to reduce the price drastically during the next few years. The present note has been prepared with reference to the existing technologies. It therefore does not take into account the qualitative changes that may come about on account of the amorphous technology/becoming commercially viable.

3. It may be noted that there are certain situations where SPV is almost the only answer to the energy problem. Systems based on other NPSE need greater maintenance, management, and replenishment of the raw material used to generate energy. The SPV has a fairly long life and needs almost no maintenance and no raw material once the system is installed. It is therefore clear that decentralised applications of SPV can be extremely useful for all locations, and particularly for remote locations. The SPV becomes the best choice for locations where other sources of electric power are too expensive or there are problems of logistics which are very nearly insurmountable.

4. At present, the production of SPV in this country is being carried on by the CEL, Shahibabad and the BHEL, Bangalore. Their installed capacity is 270 KW/year, going upto 1 MW by 1985 (CEL) and 100 KW/year going upto 250 KW/year by 1985 (BHEL). The actual production at CEL has been much lower than anticipated. It reached 47.5 KW in the six months from April 1983 to September 1983. The production of BHEL will be about 20 KW in this financial year. The target of production at the CEL under the NASPED was 1 MW per year at the end of October 1985. As against that the CEL has so far produced about 160 KW. A proposal from the CEL to produce 5 MW in the next Plan is at present being discussed in various quarters.

5. Enhancing the production of SPV is contingent upon the availability of silicon. The Department of Electronics has proposed the setting up of a national silicon facility with the capacity to produce 200 tonnes per annum @ Rs. 960/- per kg. It is postulated that nearly 150 tonnes of this production will be used for SPV, enabling a production of 7.5 MW SPV.

6. SPV is at present being used in small quantities in this country in the following areas :

(1) Oil Drilling and Oil gas pipelines.

(2) Telecommunications for P&T and Railways.

(3) Defence and limited consumer applications; and

(4) Rural applications like pump sets for irrigation, drinking water, lighting.

Most of the latter applications are through the DNES and are highly subsidised. In the current year, so far, the CEL has supplied 13.5 KW for irrigation, drinking water, lighting etc. under the demonstration programmes supported by DNES.

7. The reasons being offered for expected high demand for SPV during the coming years are as follows :

(1) The necessity for providing power to the rural areas, particularly remote areas for the purpose of drinking water supply, lighting and irrigation. It is argued that the cost of the SPV system in remote areas will be less than the conventional system. Also, the SPV will need little or no maintenance.

(2) Specialised agencies like the Oil Industry, the Railways, the P&T and Defence will have to make more and more use of SPV for satisfying their requirements for remote and other areas where no other viable source of power can be envisaged.

(3) The Government intends to set up a large number of low powered transmitters (LPT) for the purpose of relaying television programmes. The Government also intends to supply a large number of community television sets to the people in the rural areas. These two things will combine to generate a heavy demand for power. Much of this demand will have to be met through SPV only.

8. Working on the above assumptions, the Department of Electronics has made a projection of a demand 2.20 MW per year over the Seventh Plan from Government departments. The DOE also postulates that the current price of the SPV is Rs. 65 per peak watt and is expected to come down to Rs. 40 per peak watt by 1988.

9. So far as the current price of the CEL and BHEL is concerned, it is nearer to Rs. 120 per peak watt and is certainly not Rs. 65 per peak watt. For our purposes, we can assume a cost of Rs. 115 per peak watt. The CEL has of course claimed that if it is allowed to produce 5 MW, the cost will come down to Rs. 65 per peak watt. The DNES has nowhere claimed that the cost per peak watt will come down to Rs. 40 in 1988. This is not to deny of probability. However, the fact remains that the current Indian price per peak watt is not less than Rs. 115. The demand/adsorption capacity projections need therefore to be made at different price levels beginning from Rs. 100 + per peak watt to Rs. 30 + per peak watt.

10. So far as the demand/absorption capacity of Government departments are concerned, we do not know the exact source of the figures projected by the DOE. Apparent merits of the projections made by DOE, are discussed below :

(1) *Oil and Gas Industry* : 150 KW per annum has been projected. we have no hard information about the actual offtake of SPV by these industries so far. The projection is, however, modest and may be accepted.

(2) *Telecommunications* : A Projection of 1 MW has been made. On checking up with the P&T authorities, I was given to understand that their present assumption is that they would be able to use about 100 KW per annum over the next Plan period, and a total of half a MW would have been used by the end of that period. I would, therefore, put the projection in favour of P&T at 100 KW per annum for the time being.

(3) *Railways* : A Projection of 350 KW has been made. Here again, we do not know the planned level of consumption in that department, but the projection is modest and may be accepted.

(4) *Rural Television* : A Projection of half a MW has been made @ 5000 TV sets per annum. On consulting the I&B Ministry, I gathered that no view has so far been taken on supplying television sets to rural unelectrified areas. I would, therefore, put this projection for the present at nil.

(5) *Miscellaneous, including Defence* : 210.4 KW has been projected. This seems reasonable and may be accepted.

Thus the total notional requirement (absorption capacity) over the next Plan period per annum would seem to be 810.4 KW or say 1 MW.

11. Since the P&T and Railways are commercial departments and the Government Oil Industry also function like one, these will buy the Indian SPV at a cost not higher than the landed cost of a comparable foreign system plus 20%. This is obviously going to be higher than the cost of Indian SPV, even if we calculate the Indian cost at Rs. 115 per peak watt. So, other things being equal, we can anticipate a steady absorption of Indian SPV by these three agencies.

12. So far as rural energy applications are concerned, the SPV can be successful only if it is heavily subsidised, or if it can be shown that the cost of SPV is going to be less than the cost of a conventional energy system. The level of subsidy will, of course, depend on the cost of production. The cost of production again will depend on the firmness of the proposition that the Indian SPV is going to cost less than the conventional energy system.

13. Given the fact that the current cost of SPV in this country is Rs. 115 per peak watt and that the costs are expected to come down, the projection can be made on the basis of three models, namely :

(1) Cost at Rs. 100 + per peak watt
(2) Cost at Rs. 65 per peak watt
(3) Cost at Rs. 40 per peak watt

14. From a report of the Sub-Group of Rural Electrification for the Seventh Plan, we find that the total number of villages likely to remain unelectrified in the country by the end of the Sixth Plan period would be approximately 2.04 lakhs. Of these, 1.14 lakh villages will be the so called normal villages, leaving a little more than 90,000 villages in tribal/hilly/desert areas. It has been calculated that the average cost of electrifying a remote or tribal etc. village is Rs. 1.40 lakhs at 1982-83 prices. Cost escalation upto 20% could be expected by 1985-86. Assuming that only

3% of the 90,000 villages will be practical and cost effective from the SPV point of view for drinking water applications, there will be nearly 3,000 villages where a 500 watt SPV pump can be installed. Similarly, we can assume that there will be at least 2% of the 2.04 lakh unelectrified villages where electrification through SPV will be practical and cost effective and systems with an average capacity of 500 watt per village can be installed.

15. The economics of the above two should work out cheaper than conventional electricity (with SPV @ 100 + per peak watt. The SPV demand could be anticipated as .67 MW per year. These figures could go up to 1.8 MW per year if the prices were Rs. 65 per peak watt. This is because more villages could be added to the list of eligible ones.

16. So far as irrigation is concerned, we should not hope for absorption of SPV in this sector so long as the price does not come down to the level of Rs. 40 per peak watt. This is because it is only at that level that the proposition could be acceptable to the farmer even with the subsidy that will have to be paid.

17. To sum up, it would be perhaps realistic to assess the absorption capacity at 1.70 MW per annum and 2.80 MW per annum if the price level is taken as Rs. 100 + per peak watt and Rs. 65 per peak watt respectively.

18. Two tables are enclosed to explain the above proposition.

AVERAGE ANNUAL REQUIREMENT OF SPV OVER THE 7TH PLAN PERIOD

Sl. No.	Application Area	SVP Demand per year, over 7th Plan (DPE)	(DNES)
1.	Offshore Platforms	50 KW	50
2.	Oil Gas Pipelines	100 KW	100
3.	Telecommunication (P & T) (Rural, UHF and Narrow Band Microwave)	1000 KW	100
4.	Telecommunications (Railways)	250 KW	250
5.	Signalling & Level Crossing (Railways)	100 KW	100
6.	Rural TV @ 5000 TV sets (VHF+ DRS)/Year	500 KW	
7.	Met. DCSTS (50% of the 300 stns. over 7th Plan)	10 KW	10
8.	Flood Forecasting	0·4 KW	0·4
9.	Defence (a) Army Communications	200 KW	200
	(b) Navy		
	(c) Air Force		
10.	Consumer Electronics and other applications	To be worked out	—
	Total	2210·4 KW per year	810.4 KW per year or
	or	2·2 MW per year	1·0 MW per year

DEMAND PROJECTIONS

No. Application	Rs. 100/W		Rs. 65W		Rs. 40W	
1. Drinking Water Supply	Remarks 3% of Tribal villages with 1/2 KW pumps (in 5 years)	1351 KW (0·270MW/ year)	Remarks 2% of advanced villages and 5% of Tribal villages with 1 kw & 1/2 kw respectively (in 5 years)	4532·5 KW (0·906MW year)	Remarks 5% of advanced villages and 10% of Tribal villages with 1 kw & 1/2 respectively (in 5 years)	10255KW (2·04 bar)
2. Lighting (Street)	2% of 2·04 lakh unelectrified villages @500W/villages in 5 years)	2040 kw (year)	3% of 2·04 lakh unelectrified villages @ 750W/ vllages (in 5 years)	4590 kw (0·918 MW/ year)	5% of 2·04 lakh unelectrifed vilages @1KW/ villages (in 5 years)	
3. Irrigation	—	—	—	—	10% of 1·5 lakhs Diesel pumps in unaccessible areas to be replaced by pv 1 KW pumps (in 5 years)	15·00 (3MW)
Total Requirement	678 MW/Year		1.824 MW/Year			7·08 MW

Basis for Calculation the above Demand Projection

Drinking Water Supply : Total number of villages likely to remain unelectrified by the end of 6th Five Year Plan (31-3-85), according to a report of the sub-group on Rural Electrification for the Seventh Plan, November 1983 would be about 2.04 lakhs. Out of which 114005 are so called "Normal" villages (Advanced Areas) and 90096 are tribal/hill desert villages (backward areas).

Lighting (Street/Community): There will be 2.04 lakhs unelectrified villages including normal and tribal/hill/desert villages by the end of Sixth Five Year Plan.

Irrigation: There are about 5 million electric pumps and 3 million diesel pumps used in the country. It is assured that 5% of diesel pumps are energised in remote areas figuring to 1.5 lakhs diesel pumps.

APPENDIX VI

SECRET

Copy No. 4

6/PS/Secy 84

Dated 12-11-1984

My dear Shri Vijayakar,

A meeting of the Adhoc Expert Group which we had constituted to evaluate the high purity silicon produced by M/s. Mettur Chemicals Ltd., in cooperation with IISc, Bangalore, was held on 4-12-1984. They went over the results of the tests carried out on this material by SILTEC, USA as well as the Indian Institute of Science, Bangalore* and confirmed that, based on these results, the material looked quite satisfactory for the intended purposes. For making full checks, crystals as well as cells are to be produced from the Mettur material as fast as possible. For this purpose, *immediate arrangements* are being made in India as well as in the USA (SILTEC Corporation as well as JPL). These results should be available to us *very shortly*.

2. Dr. Gururaja of this Department had visited Mettur fairly recently and I personally visited the plant of Mettur Chemicals on December 4 and 5 and gave the production of high quality silicon in substantial quantities. It seems quite clear from these visits and examination of the equipment as well as cost data that substantial quantities could be produced with a total capital *investment* (including land, buildings, utilities etc.) of Rs. 100 per kg. of throughput (Rs. 2 crore for a 20 ton/yr plant or Rs. 20 crore for a 200 ton/yr plant)**. The quality checks mentioned in para 1 above will confirm the quality: even if there are any inadequacies, these could be overcome quickly with some effort.

3. The recently international photovoltaic conference held in Japan from 13th November to 16th November and subsequent International workshop in Thin Film Devices held in Delhi from 19th to 30th Nov., 1984 (at which also a leading Japanese photovoltaic Specialist, Prof. Hamakawa was present) confirm the rapid advances being made in amorphous silicon technology. Prof. Hamakawa met us and several Scientists specialising in photovoltaics. The reports of all this interaction indicates that by 1990, almost certainly, amorphous silicon will start becoming available for outdoor photovoltaic purposes on economic terms. Rapid developments on commercial scale are also taking place in other silicon technologies. A big plant based on present technologies such as the proposed NSF, will in any case be out of date for photovoltaics almost as soon as it is commissioned after

*Sent to you with my letter of 24th November, 1984.

**A new plant at a new site should cost at the most twice those figures.

4 years or so. This further confirms that it is much better for India not to persist with the NSF but to have a smaller scale plant, which can come on stream quickly to meet the immediate requirements (such as the Mettur plant and the GDR smaller plant proposal) and to add production capacity based on development's newer technologies thereafter. Since I understand that the USA had greatly delayed clearance of the NSF proposal and formal and final signing may not have taken place, the Government could extract itself out of the proposed deal even now.

With kind regards,

Yours sincerely,
Sd/-
(MAHESHWAR DAYAL)

Shri S. R. Vijayakar,
Secretary,
Department of Electronics,
Lok Nayak Bhavan,
New Delhi-110003.

Copy to :

1. Shri C. R. Krishnaswamy Rao Sahib, Cabinet Secretary, Cabinet Secretariat, New Delhi.

2. Shri Arvind Pande, J.S. to P.M., PM's Office, New Delhi.

This is in continuation of my note dated 19-11-1984 and letter dated 24-11-1984 to Shri S. R. Vijayakar, Secretary, Department of Electronics (copy endorsed to you).

The present demand for high purity silicon for electronic purposes is only of the order of 5 tonnes per year which may rise at the most to 20 tonnes per year by 1990. The potential demand for *photovoltaic* application on the other hand is very much higher, and is an area where new technologies have to be progressively introduced to keep reducing costs. Since this is inter-related with the growth of the photovoltaic industry, the DNES should be allowed to deal with all matters relating to *silicon production for photovaltaics* as we will then have a comprehensive and coordinated approach to the question of photovoltaic development to which we want to give a big thrust. Our recently initiated projects, including the electrification of villages through photovoltaics, have shown the high potential that exists. This can be effectively developed and applied, if we can deal with the total question in a coordinated manner including that of related silicon supply which is a basic raw material.

MAHESHWAR DAYAL

4—200 LSS/89

SEAL

महेश्वर दयाल
सचिव

MAHESHWAR DAYAL
Secretary

Telegram : RENEWABLE
Telephone : 694481

D.O. No. 6/PS/Secy/84

भारत सरकार
गैर-पारम्परिक ऊर्जा स्रोत विभाग
ऊर्जा मंत्रालय

GOVERNMENT OF INDIA
DEPTT. OF NON-CONVENTIONAL ENERGY SOURCES
MINISTRY OF SCIENCE AND TECHNOLOGY
BLOCK NO. 14, C.G.O. COMPLEX, LODI ROAD,
NEW DELHI-110003

Dated 2-2-1985

Dear

Further to our meeting on 21-1-1985, I am enclosing herewith copies of letters from Prof. C. N. R. Rao, FRS, Director, IISc, President of the INSA, Prof. V. G. Bhide, Vice-Chancellor, University of Poona, Mr. U. V. Warlu, Chairman & Managing Director, Andhra Pradesh Electronics Development Corporation, Shri Virendra Mohan, Chairman & Managing Director, Semiconductor Complex Ltd., and Shri J. C. Kapur, President, Solar Energy Society of India, in connection with the question of silicon production in the country. They have all given solid reasons why we should *not* proceed to import a 200 tonnes polysilicon plant and know-how from the Hamlock Corporation, USA in accordance with the proposed NSF project with its very high cost. Prof. Bhide mentions that 'the technology they are offering is obsolete and highly capital intensive. Investment envisaged to be made will make polysilicon available at a price which will never make solar cells made therefrom economically competitive. Further, if amorphous silicon solar cell route becomes competitive then the borrowed technology will be of no use for solar cell fabrication.' The writers all support the view that much better alternatives both from the financial and technical points of view are available and should be implemented. This is also the view of almost all people who are knowledgeable in regard to photovoltaics and silicon production.

2. In this connection, the indigenous development is particularly note worthy. We have succeeded in actually making solar cells from this material (which I showed you on 21-1-1985). (These are comparable to cells from imported polysilicon). This is final confirmation that the material is satisfactory. The Specialist Group we set up consisting of Dr. Sridhar & Dr. Borle of SSPL (Defence R&D), Dr. Anantha Prasad of BEL, Dr. Dass of NPL, Dr. A. P. B. Sinha of NCL, Mr. E. S. Ramamurthy of BHEL, after several different tests conducted at different places in the country and abroad,

has now officially confirmed the suitability of this material for photovoltaics; in fact, a very large proportion of electronic requirements could also be met from this material. This has been achieved even without process optimization, which will further improve performance. Upscaling is not going to be difficult for Indian capacity to handle, particularly since this is a modular operation, only needing the addition of a number of reactors similar to the one which is now in regular operation at the rate of about 2½ tons/year. In fact, 22 tons/year capacity can be built up within 1½ years with equipment mostly already at hand. Additional capacity can also be added as required. Shri Virendra Mohan (who was Chairman of the Task Force and the Negotiating Committee of the DEO itself) had himself mentioned that if Mettur Chemicals could demonstrate even a few grams of satisfactory material, he would himself propose jettisoning the proposed collaboration deal with Hamlock. He has also pointed out that 'regarding upscaling we have sufficient expertise and once the basic materials for the high purity plant have been identified, the production quantities could easily be increased to meet the demand. He has also mentioned the recent developments in amorphous technology as well as GDR offer for a smaller capacity plant.

3. I had shown you the cells which we had got produced from the indigenously produced polysilicon prepared from the IISc—Mettur project. You had very kindly suggested preparation of a few electronic devices also. I am having this attended to urgently and we hope to have some such devices very shortly. I will report to you in person in this regard.

With kind regards,

Yours sincerely,

Sd/-
(M. DAYAL)

Dr. M. S. Sanjeevi Rao,
Chairman,
Electronics Commission,
Lok Nayak Bhavan,
New Delhi-110 003.
Encl : As above.

No. 6/PS/Secy/84 dated New Delhi, the 5-2-1985

Copy, along with enclosures, forwarded to Shri Arvind Pande, Joint Secretary to Prime Minister, Prime Minister's Office, New Delhi.
Encls : As above.

(M. Dayal)

Encls : As above.

INDIAN INSTITUTE OF SCIENCE

BANGALORE-560012, INDIA

DIR. D. 26
9th January, 1985.

PROFESSOR C. N. R. RAO
DIRECTOR

Dear Mr. Dayal,

Sub : Silicon production in the country

I am writing this to point out the major progress made by this Institute in collaboration with Messers Mettur Chemicals & Industrial Corporation in the production of polycrystalline silicon. Polycrystalline silicon produced at Mettur is of a quality that would more than suffice for photovoltaic devices, Single crystals have been grown from this polycrystalline silicon material and they also satisfy the requirements. Mettur Chemicals can easily produce 20 tons per year of the polycrystalline silicon and this would meet our national needs at this stage. I am enclosing a detailed note on our collaboration for your perusal. In view of the progress made by this collaboration, I believe that the country should not go for the purchase of any major equipment for producing silicon. Such an investment would discourage all those who have put in so much effort in producing silicon indigenously. Furthermore, we are now at a stage where success for indigenous technology seems certain. I would therefore urge that no foreign technology be thought of for at least the next six to eight months.

I should also point out that National Chemical Laboratory, Pune is working on a fluidised bad process, which would be a major contribution to silicon technology development in the country. I hope that NCL would also get the necessary support for fostering this effort.

Yours sincerely,
(Sd/-)

Mr. Maheshwar Dayal,
Secretary,
Department of Non-conventional Energy Sources,
Block No. 14,
CGO Complex,
Lodi Road,
New Delhi-110003.
Encl : 1

Phone : 31690 (Office), 31264 (Residence)
Grams : CARE SCIENCE BANGALORE
0845-8349 IISC IN

I. STATUS OF TECHNOLOGY AND MANUFAUCTURE OF SEMICONDUCTOR GRADE SILICON—IISc.—METTUR COLLABORATION

(a) *Raw Material* : The feed stock for the process is high purity fractionally distilled optimal mixture of trichlorosilane and silicon tetrachloride. The trichlorosilance is produced in situ to avoid storage and liquifaction problems. The fractional distillation column has been erected. Silicon tetrachloride plant is fully functional with provision for quadrupling the output if necessary to 4000 ton per annum.

(b) *Hydrogen* : The ultra high purity and hydrogen compressor and purification train has been fully engineered. The hydrogen feed stock is available in plenty from the electrolytic cell.

(c) *The Reactor* : A novel high pressure reactor has been fabricated which can produce 2.5 tons per/annum of polycrystalline silicon. One such reactor is now working on a pilot basis. Arrangements are afoot to install nine more such reactors. The reactors require high current sources (4000 amperes) and controls. These have also been designed, fabricated and installed.

The reactor shell is made of stainless steel with a quartz lining. In all this, only the large size quartz bell jars are the only imported item.

Recycling : Considerable work has gone in designing a recycling system for the feed stock.

(d) *The Process* : Adopts reaction of hydrogen with silicon tetrachloride, trichlorosilane mixture with hydrogen on a hot filament which is either tungsten or silicon itself. For most normal purposes tungsten is eminently suitable.

Effluents : In any such reactor there is a certain proportion of unreacted hydrogen, trichlorosilane and silicon tetrachloride. Considerable developmental work has gone in converting this to commercial useful products like fused silicon and ethyl silicate.

(e) *Product Quality* : The product quality is found to be highly satisfactory and compares favourably with imported material. The material is in the range of 300 to 1000 ohm-cm, n-type with p-type impurities lower than equivalent to 1000 ohm-cm. Specifically the impurity contents have been brought down to the fractional ppb level. Suitable chromotographic techniques and other physico-chemical techniques have been developed for this purpose. The materia has also been evaluated abroad. Some material has already been sent for crystal growing to USA. In the meanwhile a crystal, 80mm dia) has been grown in India and it is found that the CZ crystal produced is also highly satisfactory. It is also found that the material melts without dross or scum and gives good quality single crystal.

(f) *Product Quantity* : The plant that is being erected is estimated to produce about 25 tons of material/annum should need arise, there would be no difficulty in scaling up to 200 tons or more.

(g) *Down Stream Facilities* : M/s Mettur Chemicals with whom the Institute has closely worked over a long period of time in developing and engineering this technology have also made investments to the tune of Rs. 3.5 crores which includes crystal growing, wafering, lapping and polishing etc. to international specifications. These equipment have already been procured and are in place. Technical and R&D personnel have been recruited and the new building is in the process of construction, plans which have been drawn up. The building would include modern clean room facilities and adequate ancillary facilities for high purity water, gases etc. and other essential facilities. As per present plans the full scale plant (25 tons/annum) is likely to be in operation in about 6—8 months.

SOLAR ENERGY SOCIETY OF INDIA

INDIAN SECTION OF INTERNATIONAL SOLAR ENERGY SOCIETY

President's Office :

Kapur Solar Farms, Bijwasan Najafgarh Road, P.O. Kapas Hera.
New Delhi-110037, Tel. : 391747/391936

Ref.....

Dated 8th January 1985

Mr. Maheshwar Dayal,
Secretary, DNES,
Govt. of India,
Block No. 14,
C.G.O. Complex,
Lok Udyog Bhawan,
Lodi Road, N. Delhi-3.

Dear Maheshwar

I had recently gone to Japan to give a keynote address to the first International Photovoltaic Conference at Kobe. The conference was attended by most of the leading manufacturers, technologists and research organisations connected with this field and provided an opportunity to assess the present and expected status of the emerging industry and technologies. Now that we are in the process of formulating our plans for the new sources of energy, I thought it appropriate to write to you and bring to the notice of the Government some of the significant features of development in this area.

(1) Most of the major American companies and European companies of any significance have been taken over directly or indirectly by the oil companies, who obviously have decided to pre-empt any major developments in this area. Japan is however an exception in this regard.

(2) A few years ago all the significant developments were in the area of single crystal, in which case the American companies had a dominent role. It would appear that there has been a significant shift in this with the emergence of Japan as a major contender in the areas of poly-crystalline and amorphous silicon cells. Even in the area of single crystal, a company in Northern Japan has developed a continuous casting process for wafers, which would reduce the cost of manufacturing by many orders of magnitude. They claimed that their factory will be in production in March 1985.

Therefore, a significant development is, firstly the rapid emergence of Japan and secondly, the emergence of two new technologies, *i.e.* poly-crystalline and amorphous. My assessment is that by the year 1990 amorphous silicon may constitute at least one-third of the total production, while the balance will be equally shared by single and poly-crystalline silicon.

The projected cost levels per peak watt in Dollars for various technologies during the coming five years is expected to be as under :

	1985	1988	1990
	U.S. Dollars		
Space —Single Crystal	50	25	15
Single Crystal	6	4	2—3
Poly Crystalline	4	2	1
Amorphous	1·5	1	40—80C

Leading companies in the United States and Japan—two major producers of silicon, are shifting to new processes to achieve major cost advantages. Most of the new facilities are of the order of 1000 tons per year or more, and the prices are expected to come down by 2-3 orders of magnitude. On a comparative study it would appear that the cost of production of existing Hemlock technology is one of the highest, i.e. about $ 40/- per Kg. They are themselves shifting to a new process with SIH2CL2, which is likely to reduce the price to about $ 10—12 per Kg. The new prices of Texas and Union Carbide are also expected to reach similar levels.

Another very interesting feature which emerges out of the examination is that 1982-83 investments in a plant of 1000 metric ton capacity is of the order of $ 100 per Kg. and the same $ 100 per Kg. is for a 200 metric ton plant of Union Carbide. This would therefore mean that the investment made in a 200 metric ton plant by Union Carbide or Hemlock or Wacker would be of the order of Rs. 25 crores. My own assessment is that there is a worldwide scramble to get into new silicon facilities and in the light of the present worldwide recessionary conditions, which I do not see improving significantly during the remaining part of this decade, there is a likelihood of large surpluses of silicon with most manufacturing countries and the prices will tumble from the present average range of $ 40/-.

I believe that from the threshold where India stands today, we can become a leader in the area of photovoltaics if we can somehow manage to get one of the new technologies for the low cost production of silicon and also do intensive work, either to import or to create within the country, technologies relating to poly-crystalline or amorphous. But if we do not succeed in this, or we build up a high cost raw material base, we are likely to loss a major advantage which the Indian environment today provides. In this note I am commenting only on the photovoltaic industry and my suggestions relate only to economics relating to the area.

In order to assure that we do not come under the pressure of international manufacturers or barter away our long term technological options, it would be desirable to approach this problem from the following angles :

(a) We should build up a silicon facility of a modular type with options to increase production as required or as the new and emerging technologies may dictate. Shortfalls, if any, can be made up from imports. I do not see any approaching dearth of silicon and in fact I foresee growing international competition and reduced prices.

(b) We should take active R & D and other steps in acquiring national capabilities in the two emerging technologies, that is amorphous and poly-crystalline. If the public sector does not succeed in obtaining these technologies because of reluctance on the part of the two dominent countries, that is United States and Japan, the private or joint sector may have a better chance. The significant point is that the national capability must somehow be developed as early as possible.

I am writing this note both in my capacity as the President of the Solar Energy Society of India as also, as a person who has spent over 25 years in dealing with problems relating to new sources of energy.

With kind regards,

Yours Sincerely,
J. C. KAPUR

UNIVERSITY OF POONA
Ganeshkhind, PUNE-411 007

PROF. V. G. BHIDE, M.Sc., Ph.D. (Nag. & Lond.), FNA, F.A.Sc.
Vice-Chancellor

Tel. : Office : 53868, Res. : 56765 & Telex : 145 259 RCC
VC/84

13th January, 1985

Dear Shri Dayal,

1. You might kindly recall that on several occassions I had voiced my concern regarding the indigenous production of poly-silicon at a price which would make it possible to make photovoltaic, solar cells and electricity generated using them competitive with other conventional sources of energy.

2. It is understood that the Department of Electronics has decided to set up silicon facility in Ahmedabad with borrowed knowhow. The installed capacity of this facility is said to be 200 TPA and the investment is supposed to be Rs. 90 crores. In view of the delay in setting up this facility, it is understood that the Department of Electronics may approach the Government for further cost escalation and it is feared that by the time the plant is set up, it would cost roughly Rs. 120 crores. This is a very prohibitive capital cost.

Name of the Company	Size of Plant (TPA)	Capital Investment Total (million US$)	$/Kg.
Wacher	1800	170	95
Hemlock	1000	100	100
Osaka Titanium	450	32	70
Dynamit	300	24	80
General Electric	200	20	100

Note : In no case does the average investment exceed $ 100/kg. Thus a 200 TPA plant should need a capital investment of 20 million dollers or Rs. 25 crores only.

3. It appears that the technology that is going to be borrowed is based on trichlorosilane. Even with using trichlorosilane as a base material, it was reported that no arrangements have been made to recycle the by products. It is now wellknown that the recent technology is based on dichlorosilane, and the use of fluid bed technology in the deposition unit. It may be of interest to note that Hemlock Corporation has decided to switch over from the technology offered to us to the recent dichlorosilane technology. It may also be mentioned that in the photovoltaic technology, there are two

contending candidates which are likely to give photovoltaic cells with prices matching their targets. These are :

(a) Amorphous silicon based solar cells

(b) Polycrystalline silicon solar cells

4. At the present moment, it appears that amorphous silicon solar cells have an edge and it is likely that by 1990, amorphous silicon solar cells would be competitive and may prove as viable alternatives to the conventional energy sources. Under such circumstances, it is necessary to re-examine the technology that we wish to borrow, if at all. If amorphous silicon solar cell technology succeeds, then we would need silane, rather than chlorosilane. I may point out that the demand for silicon from photovoltaic area may be an order of magnitude greater than the demand for polysilicon from other areas in electronics. It is, therefore, necessary, to seriously consider whether we should import the absolute technology or base our polycrystalline production on silane route rather than on chlorosilane route.

5. It is suggested that the silicon facility we wish to set up should have a capacity of 200 TPA. It may also be necessary to look at the choice of the capacity. If the choice is based on indigenous demand, then this capacity is rather high. If, however, the choice is based on economic viability and international competitiveness, then this appears to be severely undersized. The scale of activity of the leading manufacturers is as follows :

Wacker—2500 TPA
Hemlock—1400 TPA
Osaka Titanium—800 TPA
Dynamit Novel—800 TPA
Union Carbide (silane route)—3000 TPA

6. I may also point out that the production cost of polysilicon with this silicon facility that is sought to be established by the Department of Electronics will be exhorbitantly high. Costing on commercial norms and providing for interest on investment and depreciation, then the cost of polysilicon per kg. assuming that the plant runs at full rated capacity of 200 TPA would be Rs. 1600 per kg. This cost is roughly three times the international price and obviously we will not be able to sell any polysilicon internationally and then the demand would be restricted to indigenous market. In such a case, we will have to scale down the production from 200 TPA to say, about 50 TPA. In such an eventuality, the cost of silicon, would be about Rs. 2700 per kg. which would be more than five times to the international price. It would be most unfair to the internal market to dump raw material at 5 times the international price and expect them to obtain the products based on it at a price comparable to the obtainable in international market. It appears that the whole facility would be sick right from the start. It is reported that the Department of Electronics may ask the Government to write off the initial capital investment but this is not fair and goes contrary to our Prime Minister's view. He has clearly stated, "We must run our public sector industries like public sector industries and not like Government Departments". I may also draw your attention to the fact that for silicon solar cells, one requires roughly 20 gms of silicon per watt and the cost of silicon is Rs. 2700 per kg. then the cost of polysilicon for one watt of solar cells would be Rs. 54/-. If you add to

this material cost, the cost of converting into single crystal, cell, fabrication, panel making, encapsulation etc. how is it possible ever to reach the goal of Rs. 10 per watt.

7. It is, therefore, extremely urgent to look at the whole question of establishing the silicon facility based on imported knowhow. It may also draw your attention to the indigenous development which are quite promising.

8. M/s Mettur Chemicals & Industrial Corporation Ltd. has already set up 2 TPA Pilot plant for polysilicon. This pilot plant has started operating. The commercial production plant of 22.5 TPA would cost Rs. 1.75 crores and is in the stage of being set up. Even assuming linear extrapulation the 200 TPA plant at their site would cost Rs. 20 crores.

9. Similarly, it is understood that HICO has recently set up a plant based on dimethyl chlorosilane, a technology which is almost identical to that of trychlorosilane, based to the figures available, the cost of setting up 300 TPA trichlorosilane plant yielding 200 TPA of silicon should be round about 15 crores. Cracking units with full controls are available from USA at approximately 0.4 million $ per cracker unit, each capable of yielding 6-7 tons of polysilicon per annum. Thus, one would need 12 million dollars for 200 TPA of cracking unit. Taking all this into consideration, the investment figure is not expected to exceed Rs. 30 crores.

10. The international situation in relation to silicon technology, and the photovoltaic technology is rather fluid. Polysilicon is now increasingly being made using either trichlorosilane or silane with various improvements such as recycling of by-products, use of fluidized bed, metal belljars etc. The situation in relation to photovoltaics is still more fluid. Although the single crystal silicon solar cell technology is fairly well established, it is not expected to yield silicon solar cells which may ever compete with the conventional sources of energy. Amorphous silicon solar cell technology is being hotly pursued and is expected to meet both the cost and the energy pay back period targets.

11. Taking all these into consideration, it is necessary to look at, in depth, whether it is prudent to set up the silicon facility as envisaged by the Department of Electronics. I may suggest for your consideration the following :—

1. Ignore the Dow-Corning offer unless the suppliers are prepared to bring down the total installed capital cost to a reasonable level of Rs. 30 crores.
2. Stock pile polysilicon to meet roughly 2 years requirements for photovoltaics and 3 years requirements for semiconductor devices.
3. Give full encouragement to M/s Mettur Chemicals and M/s HICO so that they are able to instal the licenced capacity of 20 TPA of polysilicon within 1985. The polysilicon which M/s Mettur Chemicals are making available is found to be suitable for photovoltaic requirements.
4. Give full support to the R & D on new and innovative projects being attempted at NCL.
5. Continuously watch the situation in relation to both the silicon technology, as well as silicon solar cell technology and then opt for either the silane route or the trichlorosilane route.

I have written a fairly longish letter only with a view to bring home to you the urgency of taking a rational decision rather than being swayed by emotions and repenting at leisure. I do hope you will give it a due consideration and move the department of Electronics to reconsider their decision. I am marking a copy of this letter to the Secretary, Department of Electronics, Government of India.

With kind regards.

Yours sincerely,
(Sd./-)
(V. G. BHIDE)

Sh. Maheswar Dayal

Secretary, Department of Non-Conventional Energy Sources,
CYO Complex, Block No. 14, Lodi Road,
NEW DELHI-110003.

APPENDIX VII

Extracts from the minutes of the 69th meeting of the Electronics Commission held on January 23, 1984.

7. Dr. Sidhu, who was then asked by Chairman to give his views, said that he had not been given the full report of the Negotiating Committee in spite of specific requests and as such could not make any comments on it. However, the Executive Summary of the Report which had been sent to him and the presentation by Shri Mohan led him to make the following observations :—

(a) The quantity of polysilicon needed in India for strategic purposes was very little and this quantity could be met by import or laboratory/bench scale production without difficulty. Import from USSR and GDR can also be explored.

(b) While silicon may be strategic, production of polysilicon required quartz bell jars as a consumable item. These bell jars were not available indigenously and so would have to be imported. If their import was prevented due to embargoes, poly production would be extended. So he felt that we need to specify the many important things without which we cannot manufacture and produce needed for strategic purposes and define the need for silicon in an overall perspective.

(c) The Committee does not seem to have made any efforts to consider technology acquisition from the East-European countries.

(d) The 7% of world production of polysilicon based on monosilane indicated in Shri Mohan's presentation, will shortly increase to about 20% due to the 1000 TPA Union Carbide Corporation Plant now under construction in the USA. In future, more plants may be built using the silane process.

(e) Polysilicon production has been regarded as an integrated process by the NC whereas it is separable into two very distinct components : (a) manufacture of the chemical feedstock, TCS; and (b) thermal cracking of TCS to give polysilicon. It would be of interest to negotiate whether the collaborators will agree to unpackaging the total technology and sell the know how and engineering only for the thermal cracking. He was making this enquiry because a 1000 TPA plant to make methyl chlorosilanes of 99.5% purity had been erected in 1983 based on NCL know how. This plant set up on a greenfield site had cost about Rs. 7 crores.

(f) While HEMLOCK had agreed to NSF having the right to export poly to several regions of the world, it was not clear whether

any export market survey had been done. If the capacity of NSF's plant had been sized to meet only our own needs, would there be any exportable surplus ? Will it be possible to export any silicon produced at the cost indicated from NSF's plant ?

(g) If commercial norms were to be applied to NSF's plant, the indirect charges would be approx. Rs. 30 crores, on the capital investment of Rs. 92 crores. At 75% production, these charges would be Rs. 2000/kg. of polysilicon and the cost of production may therefore, be in the neighbourhood of Rs. 2600/kg. or more.

(h) JPL's analysis of the UCC Process indicated that a 200 TPA polyplant would require only Rs. 24 crores at 1984 (dollars) as capital investment, although he did not wish to comment on the costs as worked out by the NC, since a reputed organisation like EIL had worked them out.

(i) CSIR along with Indian Manufacturing and Design Engineering Companies can design, erect and commission in 3 years, a 1000 TPA plant to make TCS of specifications to be given by the NC. CSIR will guarantee the development and commissioning in 4 years, of a plant of up to 200 TPA capacity to make polysilicon of resistivity up to 100 ohm-cm, which would be adequate for PV cells. Such poly constitutes the bulk of the polysilicon proposed to be produced in NSF's plant. As regards the high purity silicon needed for VLSI, power devices etc. where the resistivity needed is around 1000 ohm-cm, CSIR undertakes to develop this within 3 years and to make the production almost co-terminus with the photovoltaic-quality silicon.

(j) CSIR had asked DOE in October 1983, for funding of Rs. 2.2 crores for pilot plant work on polysilicon at NCL. Secretary, DOE had taken a meeting and a reduced allocation was agreed to, but this has not yet been received.

(k) Mettur Chemicals also had made significant progress and has already produced about 500 kg. of poly.

9. Dr. Gupta said that in the light of the discussions it appeared that, as an alternative to setting up the poly plant, the amount of silicon required for electronic devices could be stockpiled while the capacity of the poly plant proposed by the NC was carefully looked into. He said it was his understanding that with the estimated price of polysilicon from NSF's plant worked out by the NC, the proposed 5 MW solar photovoltaic programme would have to be given an annual subsidy of Rs. 20 crores to correct for NSF's poly price being higher than the current international price. He was not convinced with the sensitivity analysis on this point presented by Shri Mohan as the picture he had from the MD of CEL was different. Dr. Gupta therefore felt it would take some time to work out these details and arrive at the optimum capacity of NSF's poly plant. Meanwhile, it would be worthwhile to request HEMLOCK for extension of the validity date of the offer.....

APPENDIX VIII

Statement of Observations and Recommendations

Sl. No.	Para No.	Ministry/ Department concerned	Observations and Recommendations
1	2	3	4
1	4.3 & 4.4	DOE	The Committee find that in view of the crucial importance of silicon in the growing electronic industry Government decided to set up National Silicon Facility at a cost of Rs. 88.75 crores including foreign exchange component of Rs. 23 crores with technical collaboration of Hemlock Corporation of the U.S.A. The Audit paragraph and the facts gathered by the Committee (including those narrated in subsequent paras of this report) amply bring out the fact that there were disquieting aspects in the whole deal from the very start. The Task Force set up by the Department of Electronics with wide terms of reference to examine all the relevant issues and facilitate setting up of National Silicon Facility was made defunct after presenting Part-I of its report on some of the issues, apparently because of the fact that some of its members had not been toeing the official line. There had been serious differences in the approach of its members; particularly Prof. A. R. Vasudevamurthy of the Indian Institute of Science, Bangalore who had raised serious doubts about certain conclusions reached by the Task Force with regard to potentialities of indigenous efforts. In fact he disassociated himself from the conclusions of the Task Force. However, the points raised by him remained unanswered and obviously in order to by pass him no further meeting of Task Force was held. Instead a Negotiating Committee was constituted to deliberate on all the remaining terms of reference of the Task Force. The Committee are convinced that this grossly improper and wrong procedure was resorted to just to ease out the inconvenient members of the Task Force who did not toe a particular line of action and had been critical of certain conclusions of the Task Force which later proved to be wrong. The Committee deprecate the manner in which the Task Force was made defunct before it could carry out the functions allotted to it and its balance functions transferred to another body constituted without the inconvenient members.
2	4.5	—do—	Of the total demand assessment of polysilicon of 13 tonnes, 50 tonnes and 100 tonnes in 1983, 1985 and 1990 respectively made by the Task Force, 8.81 tonnes, 42.59 tonnes and 88.12 tonnes *i.e.* about 70 to 80 per cent of the total assessed demand was for terrestrial solar cells. Similarly, the Negotiating Committee while assessing the polysilicon demand at 230 tonnes in 1990, took the demand for terrestrial solar cells of photovoltaic (PV) quality at 218 tonnes. On the other hand, growth in demand for semiconductor grade silicon was admittedly much slower and was expected to remain at a low level in the foreseeable future. In view of 70—80 per cent of requirements for high purity silicon being for photovoltaic, the Department of Non-Con-

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			ventional Energy sources logically felt that they should deal with all matters relating to silicon production for photovoltaic which would enable them to make a comprehensive approach to the production of solar photovoltaic cells to which they wanted to give a big thrust. On the other hand, Department of Electronics required silicon of higher grade for semiconductor materials and integrated circuits etc. in a very limited quantity *i.e.* not more than ten percent of the projected demand. Still for reasons, not clear to the Committee, the DOE dealt with the subject and obtained approval of the Government to set up the National Silicon Facility of 200 TPA capacity for manufacture of semi-conductor grade silicon at the cost of Rs. 88.75 crores. The Committee feel that the DNES would have been and would still be the right choice for the nodal department for the project for production of Silicon of the grade required for SPV uses. The Committee are distressed that the Government by entrusting the project to the DOE who were mainly interested inpurer and costlier electronic grade silicon closed the option for a less purer and less costly grade which would have been more suitable for making SPV cells at reasonable cost and thus in boosting the solar energy programme. The Committee are strongly of the view that by the wrong choices of both the product as well as nodal department the solar energy programme has suffered a setback of perhaps a decade which an energy deficient country like ours can ill afford.
3	5.10	DOE	The Negotiating Committee's assessment of national demand for silicon was at 230 tonnes per annum in 1990 i.e. much higher than the estimate of 100 tonnes assessed by the TF only 18 months earlier. Against these estimates, the actual demand today works out in the region of 57 MT. Thus the present demand is no where near the projections made by the Task Force and Negotiating Committee. The inflated demand assessment of NC was based on expanded solar photovoltaic programme, decision to set up a major production facility of Large Scale Integrated Circuit (LSI), Very Large Scale Integrated Circuit (VLSI) devices and also enhanced demand for Small Scale Integrated (SSI)/ Medium Scale Integrated (MSI) devices and semi-conductor devices for Electronics switching system. However, the basic fact remains that the demand of 10 MW p.a. was projected as a possibility in case module prices dropped from the then existing prices. The Department of Non-Conventional Energy Sources had also made it clear at that time that 10 MW of photovoltaic demand did not necessarily mean 200 tonnes of polysilicon because by the time this demand was to be reached, it could be supplied from different types of silicon and demand for this type of silicon might not be quite that large. It is evident that the estimate of photovoltaic demand reaching 10 MW by 1990 was given on the basis of assumption that the price of photovoltaic module drops to Rs. 60 per peak watt as against the then prevailing price of Rs. 1100 per peak watt. The DNES had also pointed out at that time that if price of silicon was to go up to more than Rs. 100 per kg. then and price of photovoltaic modules would not come down to Rs. 60 and it would not be possible to use projected quantity of more than 200 tonnes of silicon per year at that price. The actual price of out put of National Silicon Facility was however, estimated at more than Rs. 2000/- per kg. without special concessions as envisaged in agreement with Hemlock. Thus, the Committee find that in spite of the strong reservations of the DNES, the DOE concluded that projected demand would materialise

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			and entered into an agreement with Hemlock Corporation to put up a project for National Silicon Facility at the cost of Rs. 88.75 crores. All the objections raised appear to have been simply overlooked to the detriment of national interest. Inflated demand was projected on unrealistic assumptions and that too, in spite of strong reservations by the department which was expected to be the consumer for 90% of the production and same advice that the capacity be built gradually. The decision of the DOE to ignore the reservations of the DNES and obtain Government approval for setting up of the facility on the basis of inflated demand projections remains totally unjustified.
4	5.11	DOE	The Committee find that the DNES had prudently advised the DOE to build up the National Silicon Facility gradually through modular approach and cost effective manner as the demand for photovoltaic was budget constrained and price sensitive and efforts were going on to reduce the price drastically during the next few years. Even today, annual budget of DNES can sustain the demand of about one MW per year and if that is to be supplied entirely from polysilicon, it would required 20 to 25 tonnes per year. The DNES also disputed the estimated annual requirement of 2.2 MW per year of SPV assessed by DOE over the Seventh Plan period and emphatically made clear that it would be one MW per year. The DNES also intended to partly meet this demand through development of amorphous silicon technology which was considered to be the most modern, highly efficient and economical. They also claimed to have perfected this technology in their laboratories successfully. However, the Committee are distressed to note that these views were not examined in right perspective and were ignored. In the circumstances the Committee feel that the Department took the erroneous position that the technology being imported from Hemlock was largely in use and that it would take at least five years for new and better technology to emerge on commercial scale. Both these points were refuted by the DNES and some of the eminent scientists have held that Hemlock technology was getting obsolete and new technology was fast coming up. The Committee deplore the lacadaisical way in which entire issue was handled after ignoring valid objections and timely advice of the DNES.
5	5.12	DOE	The present total demand of polysilicon for PV is 40 MT. Another 7 MT of higher grade is required for semiconductor devices etc. by electronic industry which is met through imports in the form of wafers and diffused chips. It is perturbing to note that existing conversion capacity from polysilicon to wafers is only to the extent of about 8 MT (5 lakh wafers). For want of conversion capacity, indigenous manufacturers are not able to utilise adequately the available capacity of 25 MT fully. The Committee expect the DOE to act promptly in the matter and build adequate wafer production facilities expeditiously enabling indigenous industry to maximise the capacity utilisation for production of polysilicon.
6	6.10	DOE	The Task Force in August 1982 had recommended Hemlock technology based on Trichloro Silane (TCS) as feedstock as it considered the quality of silicon produced by Mettur Chemicals and Industrial Corporation (MCIC) in their pilot plant based on Silicon Tetrachloride (STC) as feedstock poor. It also rejected STC feedstock route of silicon on the ground that samples of Mettur Chemicals Silicon had not been fully characterised and therefore, the

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			product remained to be proved. Subsequently, when the MCIC had installed the plant of 25 TPA capacity through its subsidiary Metkem just before the confirmation of the agreement with Hemlock in February 1985, an Evaluation Group of the DNES opined in February 1985 itself, before conclusion of the agreement that purity of Metkem Silicon was good for photovoltaic as well as for many electronic uses also as it had come close to the specifications given by DOW Corning and SMIEL, the two internationally known producers of silicon. The Evaluation Group also held that Metkem technology was likely to make further improvements and expected to reach the highest international standards and the material could be used for practically all electronic purposes. Quality of silicon produced by MCIC's subsidiary company Metkem was also commended by M/s Siltec California as "equal to any made by the large poly suppliers". Similar views were expressed by an Expert Committee of the Ministry of Science and Technology. In the 69th meeting of the Electronic Commission also, similar views were expressed by some members and the Director General, CSIR had stated that CSIR would guarantee development and commissioning in four years of a 200 TPA capacity plant. The arguments put forward by Negotiating Committee in favour of Hemlock deal were also refuted in this meeting. The Committee are constrained to observe that all these latest developments in improvement of indigenous technology 30 months thence were knowingly ignored to the detriment of national interest. The DOE preferred to confirm the agreement on the premise of their earlier findings which in course of time had proved to be wrong. In Committee's views, these acts of negligence on the part of the DOE to say the least are inexplicable.
7	6.11	DOE	According to the DNES, the indigenous technology developed at Mettur Chemical (Metkem) could produce 25 TPA silicon of good quality and was capable of meeting the national demand at that time qualitywise also as the material produced could be used alternatively for photovoltaic (PV) purposes and also for a number of electronic applications. The demand which could not be met by using Metkem technology was stated to be insignificant and could be met from imports and it was also claimed that Metkem technology would be capable of meeting this demand also in a relatively short period through further technology upgradation. When Hemlock deals was brought to the notice of the DNES it had pointed out that the demand would not grow upto the level assumed in the arrangement for collaboration on the basis of the cost at which silicon would be produced. It was also brought to the notice of the DOE that indigenous production, besides being economical was capable of being increased through modular approach in a comparatively short period. It had also been pointed out that initial investment in the proposed Hemlock project was excessive: cost of silicon product would be too high and the country would be struck with a large capacity plant which would soon become absolete. On the other hand indigenous technology was much cheaper. Some of the eminent scientists of the country on this subject had also opposed this deal. It is surprising to note how such vital points and valid reasoning against Hemlock deal were altogether side tracked. Evidently, the DOE was not responsive to these reasonings at all and was dead set to go ahead with the Hemlock deal. The Committee are gravely concerned and take a serious note of it.

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8	6.12	DOE	All this show inept handling and lack of perception of emerging scenario in photovoltaic (PV) cell technology and its economics on the part of the DOE. The Committee are distressed to note that DOE's transgression into the domain of another department resulted in sad consequences for the country. The Committee would like to be apprised of the grounds on which valid points raised by the DNES and other eminent scientists/organisations working in this sphere were set aside.
9	6.13	-do	The Committee are happy to note that the DNES continued its valiant fight against this deal and brought the relevant facts to the notice of the Prime Minister and consequently Government decided to give up the deal. The Committee commend the efforts of the DNES in saving the country from the loss which would have been suffered by setting up the Rs. 90 crores project which was not required at all and would have become obsolete soon after commissioning.
10	7.8	-do-	Strangely, the Committee of Secretaries also cleared the project for import of Hemlock technology in its meeting held on 16 February 1985, notwithstanding the opinion expressed against it by the DNES, CSIR, renowned scientists and others. According to the DOE, the Committee considered various alternatives and were also apprised of the present status, prospects and evaluation of indigenous technology. The views of the DNES were also placed before it. The Committee are shocked to note that Secretaries' Committee appears to have been overwhelmed by the fact that time limit for conclusion of the agreement with Hemlock Corporation had already expired and the President of the Company had indicated that if agreement was not approved within a month, it would have to be renegotiated later and the experts would be redeployed elsewhere. It also appeared to have been misled by the exaggerated demand projected by the DOE and it failed to appreciate the latest developments in the indigenous technology as well as emerging amorphous technology.
11	7.9	-do-	The Committee consider it highly unfortunate that no specific disposal of the objections raised by Indian Institute of Science Bangalore and Mettur Chemicals and several eminent scientists in their letters addressed to the DOE have been made. The Committee would like to know the reasons as to why specific notice of these eminent organisations and persons was not taken.
12	8.7	-do-	The Committeee are surprised to note that no global tenders were floated for technology transfer although the project was not considered as urgent at any stage. There is nothing on the records of the DOE to suggest that issue of global tenders was considered at all. The Task Force had addressed a communication making preliminary enquiries from 46 companies in the field the world over though only 16 of them were manufacturing silicon. Out of them, 14 responded and only three furnished full data. Out of the three short listed companies one namely Komatsu of Japan had a different process and the final decision was made of the two quotations of Hemlock and Siemens. This cannot be termed as broad-base for award of a contact of Rs. 90 crores. It was highly improper not to have invited global tenders. A communication seeking certain information can in no case be equated with the formal invitation to tender. Since, the global tenders

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			were not floated it is hypocritical to assume that even if global tenders had been floated, the offers would not have been more competitive.
13	8.8	DOE	The Committee find that there were wide variations in the cost of technology transfer offers made by the three potential collaborators. It varied from Rs. 14.4 crores for Hemlock, Rs. 36.6 crores for Siemens and Rs. 91.9 crores for Komatsu. The capital cost and cost of production of silicon per kg. also varied widely. Strangely, no efforts were made to find out the reasons for such wide variations. Nor any effort was made to work out the rate of return on capital employed. Had it been done, the Committee feel, Government would not have perhaps allowed the DOE to venture in this project. Still, on the basis of analysis done it was clear that cost per kg. of output was out of proportion and exorbitantly higher than the prevailing world price. In spite of this, the DOE decided to set up the project rather than explore the other cheaper alternatives that were available including indigenous development of technology.
14	2.8	-do-	The Committee find that cost of production of silicon with imported technology from Hemlock was calculated at Rs. 1130 per kg. by the Negotiating Committee excluding return on investment and subsidies on power etc. and at full capacity utilisation of plant. The Electronics Commission on the basis of commercial norms and at 75 per cent capacity utilisation observed in January, 1984 that the cost would be in the region of Rs. 2600 per kg. or more. The cost of production with indigenous technology at 'Metkem' was indicated at Rs. 850 per kg. and the international price ranged between Rs. 500-600 per kg. On account of the high cost of production with imported technology, it was opposed by the DNES at various points of time and some eminent scientists working in this field and all the draw backs were brought to the notice of the DOE.
15	9.9	-do-	The Evaluation Committee had also observed that for upgrading the production level to 200 tonnes plant based on Metkem technology additional investment would not exceed Rs. 20 crores. In spite of these facts, the DOE have defended Hemlock technology project on ground of lower power consumption per kg. of polysilicon; wider production range and opposed Metkem on various irrelevant grounds. The Committee do not consider these reasons convincing at all. They are of the firm opinion that decision to import technology and set up Rs. 88 crores project was not justified at all in the context of several objections raised to the proposal. The Committee not only deplore the decision which led to avoidable expenditure in terms of foreign exchange but also the arbitrary and capricious method of taking the decision in total disregard of all relevant facts, data and other information furnished by various bodies and persons having expertise in the field. The Committee desire that suitable methodology should be evolved by the Government to ensure that relevant and authentic data and information are not ignored in taking investment decisions particularly those involving huge sums like the NSF.
16	10.5	-do-	The Committee take a serious note of the fact that the DOE took unusually long time to terminate the Collaboration agreement with the Hemlock Corporation. The Govern-

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			ment had decided in October 1986 to give up the agreement but the DOE finally carried out the decision in June 1987 i.e. after a period of 8 months. As a result of this delay a further instalment of Rs. 2.15 crores became due in April, 1987. The delay has been ascribed to legal consultations at a higher level. The Committee are not at all convinced by this excuse. They feel that the DOE failed to expedite the matter as the delay has cost a sum of Rs. 1.12 crores in excess of the 60% restriction intended for termination of the contract.
17	10.6	DOE	The Committee fail to find any substance in the claim made by the DOE that technology received at the cost of Rs. 7.92 crores could be put into effect with indigenously designed and manufactured equipment and that the DOE are exploring the ways of using it. As the cost of production with indigenous technology is much cheaper as compared to the cost of production with the imported technology and so far Government have not succeded in putting the know-how received to any use, the Committee are convinced that the expenditure of Rs. 7.92 crores in foreign exchange was totally infrustuous. The Committee deplore strongly the avoidable expenditure and recommend that action be taken against those responsible.
18	11.3	-do-	The Committee are unable to appreciate denial of copies of CBI enquiry report, CCPA papers and also minutes of the meeting of the Secretariat Committee on grounds of "public interest". As a close scrutiny by the Committee of CBI enquiry report would have highlighted the extent and nature of culpability of erring officials, the Committee feel public interest would have been served better by furnishing these documents.
19	11.4	-do-	The Committee find that on the basis of CBI enquiry government have concluded that certain official have failed to adequately assess indigenous technological developments in the field of polysilicon and appropriate action against them has been taken. However surprisingly, in replies to Committee's questions both in writing and in oral evidence the DOE have taken altogether a different position which is in conflict with the position now explained. In view of it, production of these documents to the Committee and their close scrunity becomes all the more important and the refusal to produce the documents called for by the Committee totally inexplicable. Since the refusal to furnish the documents stated to have been taken at Ministerial level has been referred by the Committee to the Hon'ble Speaker and his decision is awaited the Committee is unable to make a final report and is constrained to make this report an interim report.

MGIF—200 LSS/89—8-8-89—1050