

Market Progress Evaluation Report Executive Summary
Silicon Crystal Growing Facilities, No. 1

prepared by

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Executive Summary

This is a market evaluation and progress assessment report for the Siemens Silicon Crystal Growing Facilities Project. In April 1998, Siemens Solar Industries and the Northwest Energy Efficiency Alliance entered into an agreement under which Siemens is redesigning and testing hot zone components for crystal growers. The goals of the redesign are to improve the energy efficiency of the growers, reduce the cycle time required to grow silicon ingot, improve the quality of the ingot that is produced and reduce the consumption of other materials, mainly argon. An additional goal is to transfer the innovations resulting from the project to the semiconductor silicon crystal growing market. The Siemens project is an applied research and development project with a marketing component.

The purpose of this assessment is to evaluate the potential for the Siemens innovations to penetrate the semiconductor silicon crystal grower market and to provide feedback on the progress of the project. The data for this report come mainly from project documentation and from interviews and / or information obtained from 26 individuals, representing 16 different companies or institutions.

Siemens has achieved or nearly achieved several of its goals:

- Power consumption has been reduced by 51 percent (measured in kWh/kg) when the rate of growth of the crystal is taken into account.
- Cycle times have been reduced by 20 to 40 percent as measured in mm/day.
- Argon flows have been reduced by as much as 85 percent cf/kg.
- Crystal growth yields have been increased by four percent.
- The amount of pot scrap at the end of the run has been reduced from about 4 kg to 1 kg.
- Preliminary findings suggest an average increase of .2 amps per wafer or about a four to six percent improvement in output from wafers produced using the redesigned process when compared to wafers produced using a standard process.
- Siemens has continued to refine a recharge system design and has eliminated many of the problems it experienced early in the development process. At this time there are still issues to be resolved.

Siemens has now committed to implementing these changes in its 40 plus growers in the Vancouver facility.

In terms of improving the energy efficiency of the Siemens facility, this project is a major success story.

In assessing the potential for the innovations in the broader market, we find that:

- Many of the grower modification concepts are not new and some companies have previously implemented them in some form. It is not clear whether these early implementations may be as effective as those being done by Siemens.
- In their specifics, the innovations are not necessarily applicable to other models of growers. However, the concepts are transferable.
- Companies are likely to implement the Siemens innovations (concepts) selectively based on their needs and whether they perceive the innovations will lead to improvements in their processes. Wacker has already expressed interest in the innovations with respect to insulation and is seeking to become involved in the recharge system effort.
- If the recharge system proves successful, it is likely to be widely adopted.
- A key barrier to the adoption of the Siemens innovations is whether the innovations will result in silicon of a quality that is acceptable to the semiconductor industry. Data about the quality of the crystal produced in the redesigned system is needed.
- The business-to-business approach that Siemens is taking to market the innovations is an effective way to communicate about complex technical issues such as these. Both Siemens and the vendors who manufacture components for Siemens communicate the results to other companies. The marketing strategy is appropriate to the size of the market and quite likely to be effective in terms of reaching the target audience with appropriate information.
- Those who have been briefed on the results of the project have been impressed with the reductions in energy use, the increase in pull rate, and the general quality of the work.
- The innovations might be more widely considered if Siemens publishes the results of the project as benchmarks for the industry. This would allow other manufacturers to compare their operations and to perhaps publish responses that would show additional improvements.

Based on the preceding, the following are recommended:

- The effort to design the recharge system should continue.
- Siemens and the Alliance should complete an informal technical review of the project focusing on what has been accomplished, what remains to be accomplished, what can be technically possible that is not currently within the boundaries of the project

with particular emphasis on the recharge system and outstanding technical issues. Such a review will allow Siemens and the Alliance to make decisions about continuing commitments to the technical and marketing aspects of the project.

- We strongly encourage that tests for evaluating the purity of the silicon crystal being produced be conducted as soon as possible so that the results can be made available.
- If possible, we recommend that staff of semiconductor crystal growing firms be invited to participate in defining and completing the testing.
- We commend Siemens for its initial efforts to involve semiconductor firms in the project and we encourage Siemens and the Alliance to look for additional opportunities to do this.
- We recommend that consideration be given to mounting a demonstration project aimed at transferring the Siemens results to a manufacturer of semiconductor grade silicon crystal. Such a project will aid in understanding what results are transferable to the semiconductor industry and, if successful, will aid in transferring the results to the semiconductor market.
- Once Siemens has assured itself that it has protected its intellectual property rights, we suggest that contacts be initiated with the Super Silicon Crystal Research Institute.
- It would be valuable for the results of this project to be presented in a variety of formats:
 - One format aimed at technical and engineering staff is to present the results as a set of technical benchmarks with appropriate detail describing how the benchmarks were determined.
 - A second format is to present the results from a performance improvement perspective and target this piece to upper level managerial audiences in the semiconductor industries.
 - A third perspective is to produce a case study focusing on an overall approach to industrial process improvement, highlighting the broad array of benefits being derived from the project and the direct and indirect connections of those benefits to energy efficiency. The audience for this piece would be industrial managers outside silicon manufacturing industries who might benefit from the description of a more holistic approach that utilizes modeling. This piece might emphasize how the current project has bypassed cultural barriers to technological change.