SASKATCHEWAN RESEARCH COUNCIL

Evaluation of SHEC Energy's Solar Thermal Technology

Prepared for:

SHEC Energy Corporation

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By Sheldon Hill, P.Eng.

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EXECUTIVE SUMMARY

SHEC Energy's objective is to dramatically reduce the cost of solar collection for a solar power plant. They have developed several technologies and associated intellectual property for doing this. The key enabling technology appears to be the light-weight reflectors which show the potential for weight and cost reductions compared to current practices and technologies for creating Concentrating Solar Power (CSP) plants. SHEC Energy refers to this as their Ultra Lite Technology. This technology combined with other intellectual property developed by SHEC Energy has created a compelling technical case for moving forward with development and commercialization.

SRC has conducted a technology assessment of SHEC Energy's solar based technologies. The overall intent of the assessment is to provide perspective on the status of the technology in terms of the level of innovation, the development phase of the technology, the associated intellectual property, and recommendations for moving forward.

The technology reviewed includes the solar reflector system, the receiver, the heat transfer system, and the thermal storage system as they relate to providing a continuous high-temperature heat source for driving a power conversion cycle such as the well proven steam based Rankine cycle to produce base-load renewable power that is available 24 hours a day.

The author estimates that the novel light-weight reflector system has the potential for reducing system weight by 50 to 70% which should also translate into cost reductions. The author recommends that further development, testing, and demonstration be done to verify performance and to better substantiate the potential for cost reductions over conventional technology.

INTRODUCTION

This report represents a technology assessment of SHEC Energy's solar based technologies by Sheldon Hill, Manager of the Alternative Energy business unit at the Saskatchewan Research Council. This high-level assessment provides third-party review of the status of the technology along with recommendations for moving forward. The assessment does not include performance verification or test results. The opinions in this report are simply those of the author, who has 25 years of experience in product development in the alternative energy area.

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TECHNOLOGY REVIEW

Previous Technology

The Company had a 5 foot by 5 foot solar concentrator of its original design made of 25 individual mirror segments, each measuring 1 square foot. Each mirror segment was made of curved glass that the Company formed in an oven by drooping the glass over a mold. The glass was 1/8th of an inch thick. The glass was rear coated with a silver reflective layer and a protective paint layer covered the silver layer.

The super structure that held the 25 mirrors in a parabolic shape was a matrix of stainless steel connecting members. This is typical of how solar concentrators are built. On a larger scale, the mirrors can become quite heavy requiring a strong and correspondingly heavy super structure to support them.

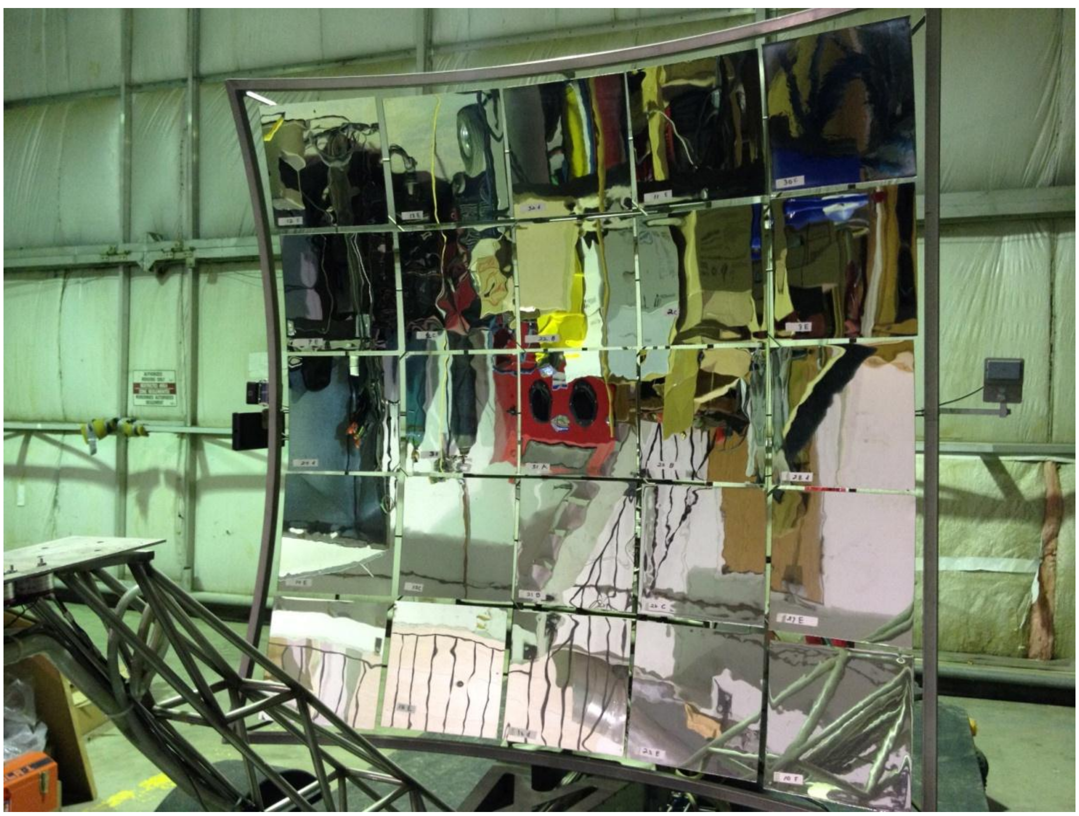

Figure 1: SHEC's Prior Technology - Glass Parabolic Mirror

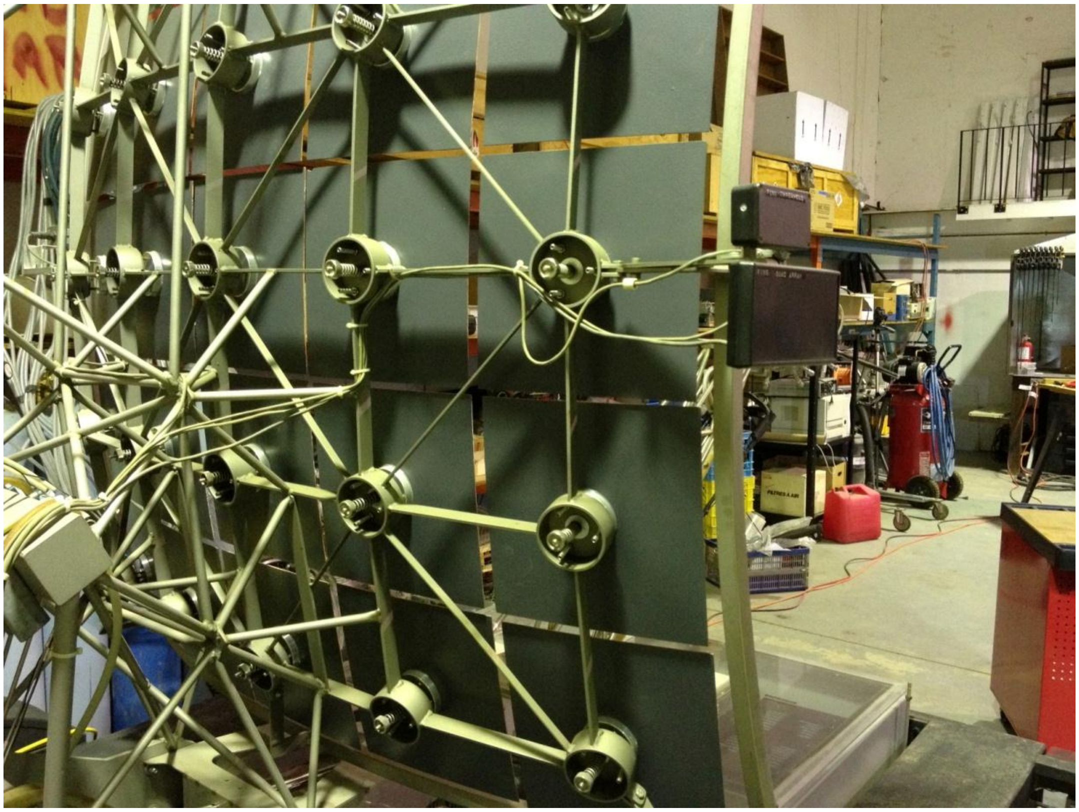

Figure 2: Backside of Prior Technology Showing Supporting Framework of Reflector

The following section presents the Ultra Lite Technology that was reviewed by SRC.

New Ultra Lite Technology (Concentrating Solar Mirror System)

Observations:

SRC observed the ability of a bench-scale, trough-style concentrator to reflect and focus light. Laser beams and a mist vaporizer were used to demonstrate the prototype showing the reflection of the lasers through a focal region. The curved surface of the reflector is not parabolic, so SHEC Energy plans to use a Fresnel lens to correct the focus. Based on this demonstration, the author was satisfied that the prototype demonstrated proof-of-concept with merit and potential as a light weight, low-cost means of concentrating solar energy.

In addition, SHEC Energy is developing a metal vapour deposition film coating system for applying reflective coatings on plastic film. The prototype unit was under construction so there has been no working experience with the system. If the system is successful, it could significantly lower the cost of producing mirrors, not only due to the reduction in material, but also due to the fact that the process should be much faster. SHEC Energy is estimating that the process will be approximately 100 times faster than their previous process.

Innovation:

The approach taken by SHEC is innovative and the resulting weight and cost reduction potential is considered an enabling development that is expected to result in significant advantage over competing technologies.

The light-weight reflectors not only reduce the weight of the mirrors themselves, but they also reduce the loads on the structure allowing for a lighter weight super structure, and smaller tracking actuators, guides, and mechanisms.

The concentrator systems may have commercial value as a stand-alone system used in a variety of solar heating applications, or it may be an enabling technology within a larger Concentrating Solar Power system.

SHEC Energy is claiming a 73% reduction in costs over its prior solar collection technology in a brochure published in the PRESS section of their web site (www.shecenergy.com/press) titled "Low Cost Solar". Although no analysis has been done, the author estimates that the weight reduction of the mirror and associated super structure could result in a weight reduction in the range of 50 to 70% for the Ultra Lite Technology. In addition, SHEC Energy is targeting larger reductions in the super structure through the use of pressurized hollow structures to provide light-weight support columns with reduced susceptibility to buckling. This may create the potential for further weight reductions but this has yet to be proven as a cost effective means of reducing weight.

Stage of Development:

This technology is at a relatively early stage of development. A bench-scale, trough-style reflector has been assembled by SHEC Energy as an early-stage proof-of-concept for demonstrating the basic functionality. Other embodiments have not been prototyped, nor has a corrective lens been demonstrated with the trough-style reflector. It should be noted that the bench-scale reflector that has been assembled is not compatible with the SHEC's solar receiver, but solar receivers are available from other companies.

Review of Intellectual Property:

SRC has also confirmed that SHEC Energy is protecting their intellectual property related to the solar concentrating technology, and has filed a patent application with the Canadian Intellectual Property Office and has plans to use the Patent Treaty Cooperation method for moving the application to additional countries.

Recommendations:

The development of bench-scale trough style reflector was a good first step and SHEC Energy has plans to develop their dish shaped parabolic reflectors using pre-formed film. This system will be compatible with SHEC Energy's solar receiver and will eliminate the need for the use of a corrective lens that is planned for the trough style concentrator.

SHEC Energy has indicated that the other option is to move forward with the trough style reflector and to integrate commercially available receiver tubes from companies such as Siemens.

Regardless of which style of reflector is developed, it will be important to design, test, and demonstrate the system in order to validate both the performance characteristics, and the potential for weight and cost reduction.

Solar Receiver

Observations:

SRC also reviewed SHEC's solar receiver technology although testing and measurement was not done. SHEC Energy did review the key innovative aspects of the technology with SRC and based on the observations, the technology does appear to be well designed for the application required.

Innovation:

The solar receiver technology appears to be highly innovative and SHEC Energy is pursuing the protection of the associated intellectual property. Innovative aspects include the shutter design for variable aperture, an isothermal heat transfer system using a heat pipe, along with material selection, surface finish, and emissivity selection of internal surfaces.

Stage of Development:

This technology is one of the more mature technologies that SHEC Energy has developed. The system has been successfully demonstrated in a similar form, both in the lab and in Arizona.

Review of Intellectual Property:

The design including material selection, geometry, surface finish, and other aspects represent intellectual property in the form of trade secrets and proprietary information owned by SHEC Energy. In addition, SHEC Energy has patents protecting aspects of this technology.

Recommendations:

This appears to be a valuable piece of SHEC Energy's technology that would integrate with the parabolic dish based system.

<u>Heat Transfer System</u>

Observations:

The heat transfer system uses liquid metal and high-temperature materials for transferring heat from the solar receiver to the heat storage medium.

Innovation:

The key enabling technology is the specialized pump design that has been developed by SHEC Energy that will eliminate cavitation when pumping high temperature liquid metals.

Stage of Development:

This technology is at a fairly early stage of development, but prototype systems have been developed and tested by SHEC Energy.

Review of Intellectual Property:

SHEC Energy indicates that it has filed patent applications related to the heat transfer system with the Canadian Intellectual Patent Office.

Recommendations:

The specialized liquid metal pump is expected to require further refinement and development from a mechanical engineering perspective.

Energy Storage Technology

Observations:

SHEC Energy uses a solid phase material as its storage medium. Current technology for thermal energy storage is primarily based on molten salt. In a molten salt storage system, there is typically both a hot tank and a cool tank. The hot tank can be heated up to 560°C. The molten salt flows from the hot tank through a heat exchanger to generate steam for a turbine. As heat is given up to generate steam, the molten salt temperature drops to the range of 280°C and flows into the cool tank. It is necessary to keep the molten salt above its freezing point which may be in the range of 250°C.

With SHEC Energy's technology, the storage medium is in a solid phase and cannot flow like a liquid. In keeping with the Company's objective of low cost and producing power and base-load power at grid parity, the Company devised a thermal energy storage system that uses earth based storage media. This may be any earth based material that can withstand the maximum temperature. Sand is a primary material that could be used. Sand is primarily silicon dioxide which has a melting point of about 1,600°C, well above the operating temperature of molten salt. Sand is abundantly available and is free in many parts of the world.

A series of pipes placed in the earth-based storage carries a heat transfer fluid to carry heat into and out of storage. The earth-based storage media is in an insulated tank. This tank can be placed in the ground. It is very economical in the sense that a hole can be excavated and the tank placed in the ground and back filled with the earth. The surrounding earth outside the tank provides structure support to hold the earth within the tank. The tank can be thin walled resulting in lower costs. The tank provides a moisture barrier to the surrounding earth. An insulation layer in the tank retains heat in the earth storage media.

Innovation:

Two primary challenges exist with transferring heat out of a solid heat storage medium. The first is that the heat transfer process is lower as conduction through the medium and through the heat exchanger walls is less effective than convective heat transfer from a fluid. This is relatively simple to address as more pipe, or heat exchanger area can be created.

A second challenge is that liquid thermal storage systems can maintain a high working temperature for steam production, whereas, typical solid thermal storage systems have degrading working temperatures as heat energy is drawn off of the system. Similarly, the recharge rate for producing high working temperatures is faster with liquid based systems as small amounts of mass can be heated as it is transferred from the cold tank to the hot tank. For solid thermal storage systems, the recharge rate can be low in terms of reaching ideal working temperatures because the entire mass must be heated at once. SHEC energy has developed a practical solution to this by compartmentalizing the storage such that a smaller mass can be reheated thereby creating the ideal working temperature more rapidly.

SHEC Energy's approach to thermal storage seems like a pragmatic approach resulting in low cost energy storage with the primary benefit of achieving higher storage temperatures.

Stage of Development:

The concept has been developed and supporting testing has been done to address some of the key assumptions. Specifically, the sand thermal storage media has been tested through dozens of thermal cycles from room temperature to 900C with no discernible degradation in granularity. Only a color change was noted as the sandy color took on a reddish tinge. The full system has not been fully developed or tested, but it appears that there will be minimal technical risk as engineering can move this from concept to design.

Review of Intellectual Property:

SHEC Energy has filed a related patent application with the Canadian Intellectual Property Office.

Recommendations:

The author recommends that work proceed to design, test, and demonstrate the thermal storage technology and to compare the performance and cost effectiveness of the system to that of molten salt based thermal storage systems.

CONCLUSIONS

Sheldon Hill, Professional Engineer and Manager of the Alternative Energy Business Unit at the Saskatchewan Research Council has conducted a high-level technology review of SHEC Energy's new Ultra Lite technology. The review did not constitute performance verification, but rather a preliminary review of the status of the technology development with consideration given to general observations, level of innovation, the stage of development of the technology, the associated intellectual property, and recommendations for moving forward.

The primary system is comprised of the following sub-systems:

- concentrating mirror system,
- solar receiver,
- heat transfer system, and
- heat storage system.

SHEC Energy has developed a portfolio of technologies related to these sub-systems and several combinations of technology show promise for developing Concentrating Solar Power systems. The portfolio of intellectual property appears to be significant creating some good opportunity for the development of Concentrating Solar Power systems. The patents cover a range of embodiments to protect future opportunities. The key enabling technology appears to be the light-weight solar concentrator or Ultra Lite Technology. The intellectual property related to this provides options for three types of concentrating solar mirror systems. This includes:

- the light-weight trough style reflector,
- the light-weight parabolic dish design, and
- the heliostat system with central tower.

SHEC Energy has investigated a range of possible embodiments of their intellectual property and appears to be well positioned to move to the next stages of product development including design and testing of the necessary subsystems followed by system integration, further testing, demonstration, and commercialization.

The author is recommending that initial efforts would focus on developing and demonstrating a concentrated solar thermal system without the high-temperature storage or power conversion cycle. The Ultra Lite technology appears to be the key enabling technology and should be validated first.

The other forms of proprietary technology owned by SHEC will be a significant advantage once the core technology is validated. Future integration with power conversion cycles using steam to drive a Rankine cycle for the generation of electricity is expected to be a relatively straightforward engineering task.

The following summarizes the key observations and opinions of the author with respect to the evaluation of the technology being developed by SHEC Energy:

1. The author is satisfied with the level of disclosure made by SHEC Energy with respect to their technology for the purposes of conducting this technology evaluation.

2. The author believes that SHEC Energy has a good portfolio of innovative technology related to the Concentrating Solar Power system being developed.

3. The author believes that there is a large amount of intellectual property that has been developed and protected in the form of patents, pending patents, patent applications, and trade secrets.

4. Intellectual property relates to the light-weight reflector system, the solar receiver, the heat transfer system and pump, and the high-temperature thermal storage system.

5. The light-weight solar reflector system appears to be one of the key technologies that is expected to provide an economic advantage over competing technologies.

6. The inherent opportunity for weight and cost reduction of the solar concentrator is sufficiently high and warrants the design of a prototype system to help quantify the material reduction levels.

7. The employees of SHEC Energy appear to be knowledgeable, skilled, and experienced in the areas that they are working in.

8. The author recommends that further development and demonstration be done, along with performance verification, and cost analysis.

9. Specifically, the author recommends that SHEC Energy develop and demonstrate one embodiment of the concentrating solar thermal system. This could either include the parabolic dish style reflector system in combination with SHEC Energy's solar receiver; or the trough style reflector in combination with a solar receiver developed by a company like Siemens. The system demonstrated

should also include the heat transfer and thermal energy storage system. This demonstration would advance the product development and better quantify performance capabilities, material savings, and production cost estimates.

LIMITATIONS

This evaluation is a high-level review of the technology by a subject matter expert, and the observations and views are the sole opinion of the author based on a site visit and inspection of equipment, along with technical information provided by SHEC Energy. No performance measurements were made, and no analysis was done. In addition, no investigations were made as to the accuracy or completeness of the information provided by SHEC Energy to support this evaluation.