

sunrgiTM

solar energy systems



XCPVTM

xtreme concentrated photovoltaicsTM

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Executive Summary
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The Bottom Line

Using SUNRGI's proprietary technology
it is possible to produce large amounts
of electricity from solar radiation
at a wholesale price of US **5**¢ kWh

SUNRGI's Business:

SUNRGI is in the business of designing and developing solar energy systems. It was formed by five, experienced, entrepreneurial, inventive individuals with the goal of creating a renewable energy source that would be available at fossil fuel prices. Its work has led to the development of an entirely new solar energy category -

Xtreme Concentrated Photovoltaics™ or XCPV™

SUNRGI's **XCPV™** concentrates the energy from the equivalent of more than 1,500 suns onto highly-efficient, triple-junction solar cells that are mounted to a SUNRGI proprietary cooling system. The result:

It is possible to produce large amounts of electricity from solar radiation at a wholesale price of 5 cents/kWh (U.S.)

Defining Attributes:

There are 3 key attributes that define and differentiate SUNRGI's solar energy system:

- **Xtreme Concentrated Photovoltaics™**
- **Proprietary Cooling Technology & Methodology**
- **Low-Cost:**
 - Mass Production Manufacturing**
 - Field Assembly & Installation**
 - Operation & Maintenance**

Work To Date:

SUNRGI has been conducting in-house research and development in selected technical areas that are strategic to its core intellectual property development. This has encompassed system design and engineering, component design, material science, materials engineering, materials/component manufacturing and optical design and engineering. This R & D effort has resulted in the achievement of a number of significant milestones, namely:

- An initial thermodynamic analysis was calculated to determine initial design parameters and an approach to a cooling solution for a 1-cm² solar cell subjected to high-concentration solar energy.
- An experimental system concept-solution for cooling a **1,089X** Suns concentration on a 1-cm², triple-junction solar-cell was theorized, designed, developed, constructed, calibrated and tested;
- This triple-junction solar cell is a 35% efficient, terrestrial version of the PV cells used in space-based applications;
- SUNRGI's experimental testing included supplier pre-mounted solar-cells on ceramic substrate and a bare-cell. Proprietary techniques were used to directly mount the solar chip on to SUNRGI's cooling technology;
- SUNRGI's solar cell cooling technique was successful and resulted in a cooling improvement of approximately **300%** in comparison to supplier's own testing data-sheets (around 36°C compared to supplier's 105°C).

With 1,089 Suns concentration and SUNRGI's proprietary cooling technology, 28 watts of electricity was generated from the 1 cm² solar cell. By maintaining a relatively cool solar cell operating temperature, SUNRGI ensured that the cell maintained a high level of operating efficiency. Concentrating sunlight on a PV cell greatly increases its output. However, cells become less efficient as cell temperatures increase. PV performance falls by about 4% for every 10° C rise in cell temperature. Accordingly, at high concentrations, effective cooling becomes absolutely critical.

Generating 28 watts of electricity at a 1,089 Suns concentration represented a significant breakthrough in concentrated photovoltaics (CPV). The combination of concentrated sunlight with SUNRGI's proprietary cooling methodology and the efficiency of the triple-junction PV cells meant that solar energy could now be generated at a price competitive with energy generated by fossil fuels.

After several months of additional research and development activities, SUNRGI was able to achieve additional, significant milestones, namely:

- A system solution was developed for cooling a **1688X** Suns concentration (optical area ratio concentration) irradiated solar cell;
- Experimental testing (at **1688X** Suns concentration) on a single, 1-cm² solar-cell generated **37 watts** of electrical power while attaining a surface temperature of only **60°C** after continuous exposure to the concentrated solar energy. This test was conducted with a supplier's ceramic pre-mounted cell. SUNRGI's direct mount will produce even greater cooling and thus greater cell operating efficiency;

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- Theoretical, one-dimensional, steady-state heat transfer calculations were made for 1,000X Suns, and they were within 3% of the measured surface temperature, which confirmed the experimental results;
- Additional theoretical calculations were made at 1,500X Suns and 2,000X Suns with ceramic substrate-pre-mounted and with bare solar-cells using both passive and liquid cooling techniques;
- By way of comparison, calculations of the solar cell's equilibrium surface temperature, without SUNRGI's proprietary cooling technology, would be **1,861°C** or **3,382°F** (i.e. greater than the melting point of chrome-steel);

These milestone achievements confirmed, unequivocally, SUNRGI's ability to generate **XCPV™ - Xtreme Concentrated Photovoltaics™**.

SUNRGI's most-recent research and development efforts have indicated that additional cooling of the measured surface temperature of the solar cell looks promising. Additional cooling would in turn enhance the solar cell's operational efficiency, extend its life span and increase electrical output. Generating additional electrical output with essentially similar system costs would further increase the cost-efficiency of SUNRGI's system.

Advantages of Xtreme Concentrated Photovoltaics™:

Resource availability – solar energy is widespread and unlimited;

A high-performance capability; and

A pathway for continuous, technological improvement;

Conventional photovoltaic (PV) products do not use concentrated sunlight. They are "1-Sun" systems that require large PV cell panels, which are costly. Concentrated PV is quickly developing into the most cost-effective renewable energy generation source. In the past 2 years there has been a surge of interest in this technology.

Concentrator System Design Activities:

In developing its system design, SUNRGI investigated a number of high-solar-concentrator system designs. They were analyzed using to-scale, ray-trace geometry and focal-length versus optical image size calculations in order to determine the optimal configuration. Also, solar collector device-to-device placement effects have been calculated in order to understand the effects of seasonality and daily shadowing on performance. Shadowing factors have been included in all of SUNRGI's power output-per-land-area performance estimates.

SUNRGI has also conducted extensive optical performance comparisons of both tracking and non-tracking solar energy systems. These comparisons have been conducted using rigorous mathematical analysis, to-scale ray-tracing, concentration ratios, image size and focal-length calculations with system manufacturing tolerance and error analysis being factored-in.

Comparisons been made between the following:

- Very-large, high-performance, multi-acre, flat, ground-based, lenticulated/linear flat-reflector/compound concentrator systems. These are ideal for solar thermal steam-turbine electricity generation.
- Large-scale, linear troughs (concentration < 200 Suns);
- Reduced-scale, compound troughs (concentration <200 Suns);
- Non-imaging optics (good only for secondary concentration);
- Holographic optics (low concentration only);
- Quantum-dot optics (low concentration only);
- Various parabolic reflector combinations (concentration > 1,000 Suns), which combinations were both selected and concept-designed specifically for SUNRGI;
- Various Fresnel lenses, including refractive, reflective, square, linear and circular;

These comparisons and investigations have been used to optimize the system's design. In addition, a considerable effort has been put forth to determine what would and would not work by evaluating compatible computer hardware and modules of equation based upon simulation software. This software has been used in SUNRGI's thermal, fluid, electrical and mechanical modeling and in the simulation of SUNRGI's proposed solar energy concentrator system;

SUNRGI's investigative efforts have lead to rejection of the following:

- All non-tracking and single-tracking technologies. These were determined not to be feasible for solar concentrations above 200X Suns as they are incapable of accurate focusing at high-concentrations;
- All large-scale and large-size concentrator systems. They were found to be economically uncompetitive because of high in-field manufacturing costs;

Cost estimates for materials and manufacturing have been made for various prototypes, large-product design approaches at a variety of solar concentrations. These estimates have indicated that, at concentrations of greater than 1,000 Suns, the cost of the solar cells is no longer a major contributor to overall system costs.

With all of the above investigation and analysis, a best-to-date manufacturability, small-scale modular design has been envisioned and calculated. Concept drawings have

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been completed and have been submitted to SUNRGI's patent attorney for the preparation of patent applications.

SUNRGI's Energy System's Advantages:

The SUNRGI **XCPV™** solar energy system that has been developed as a result of the research, design and development activities described above, offers the following advantages:

- **Designed for low-cost mass production;**
- **Xtreme concentration;**
- **Fail-safe design;**
- **2D, ganged tracking;**
- **Low-cost / high-volume manufacturability -**
 - Pick-and-place surface mount manufacture compatibility.
 - Automated assembly and test.
- **Low-cost field installation, operation & maintenance -**
 - Low-cost field assembly and testing.
 - Low-cost remote Internet maintenance and monitoring.
 - Small, low-profile array.
 - High-Watt output.
 - Longer life.
- **On and Off-Grid Distribution** – Other solar technologies, solar thermal in particular, need to be implemented as part of large power stations. SUNRGI's system however, can be deployed in small configurations allowing lower and more variable entry points into the solar market. SUNRGI can provide discreet, off-grid “power plants” that can be sited in any sun-suitable location.
 - **Modularity** – SUNRGI's modular design modular enables a power station to be distributed over a number of sites. A large power station can be divided into a number of sub-stations which makes for easier access to suitable land.
 - **Upgradeability** – Unlike traditional PV technology, SUNRGI's design is upgradeable, allowing it to take advantage of future advances in PV technology.
 - **Concentrated Energy** – Since the sunlight is concentrated, fewer PV cells are needed thereby reducing the cost-per-watt of generated electricity. Also, it is more efficient format from which to extract heat.

- **Longevity** – With SUNRGI’s proprietary heat removal technology the PV cells have a longer useful life.
- **Economy** – SUNRGI’s system costs significantly less per installed Watt than traditional PV technology. Expected advances in technology, maturity and volume production will further increase this cost advantage.

SUNRGI makes solar energy cost-efficient for ubiquitous deployment.

	SUNRGI: HCPV	SOLAR THERMAL	WIND	HYDRO	NUCLEAR	OIL, GAS, COAL-FIRED
PROVEN TECHNOLOGY	X	X	X	X	X	X
RENEWABLE “NO WASTE” DERIVATIVE	X	X	X	X		
SOCIALLY POPULAR	X	X	X	X		
OFF-GRID CAPABILITY	X		X			
SUPPLY CHAIN EFFICIENCY	X			X		
CAPITAL COSTS ASSOCIATED WITH INFRASTRUCTURE AND / OR LAND MASS		X	X	X	X	X

Intellectual Property:

As indicated above, SUNRGI has been taking appropriate steps in to protect its intellectual property. Provisional patents have been filed with the United States Patent and Trademark Office. Activities relating to additional patent filings are on-going.

Due to the sensitive nature of the technology referenced in these patent filings, they will be reviewed only with qualified investors’ as part of due diligence being conducted pursuant to executed non-disclosure agreements.

Next Steps – System Simulations:

Over the near term SUNRGI plans to continue its research and development activities. In particular, the company is creating a demonstrable performance simulation of its concentrated solar energy system that can be showcased to prospective customers.

It will also be used to fine-tune the system's design attributes and parameters. Module design concepts will be simulated at Sun concentrations of **1,000, 1,500 and more.**

These concept design simulations will allow for the credible presentation and verification of SUNRGI's:

- Thermal concept designs;
- Mechanical packaging structure, including the effects of variability in manufacturing tolerances on system performance;
- Modular, solar cell-to-cell array connectivity. SUNRGI will be able to determine the effects of various configurations of conductive material laminates to line loss and to other thermal and environmental effects; and
- System simulation of multiple module arrays within a low-profile, horizontal, two-axis frame structure. This will allow for the determination of optimum module placement, including minimizing shadowing and seasonality effects.

The company's simulation plan will model its original, simple experimental set-up. This will allow for comparison of the earlier actual experimental data to confirm the validity of the software simulation.

The end result of these simulation efforts will be to arrive at an optimal prototype design that will lead, first to a final demonstration simulation, then to the manufacture and assembly of prototype units, and finally, to the building of pre-production systems.

In addition, a 40% efficient PV cell is expected to be released soon. Once it becomes available, SUNRGI will be conducting extensive solar concentration and cooling tests using this cell. As well, additional cells from multiple supply sources are under investigation.

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