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Collaborative Prototype Development & Test Project for a Novel Hybrid Solar Concentrating Cogeneration System

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Abstract

"SuperSurya" is a novel, patented hybrid solar concentrating cogeneration system intended to synergistically and cost-effectively harvest both (a) electricity and (b) usable heat for hot water heating and supplementary building heat & optionally swimming pool heating. The electric power is harvested with a low-concentration CPV (concentrated photovoltaic) subsystem using a linear receiver and framed inflatable concentrating mirrors, building upon earlier demonstration of inflatable heliostat technology by RIC Enterprises with some Department Of Energy support. In the SuperSurya configuration, two-axis heliostatic tracking is used to optimize solar energy harvest, and a liquid cooling system uses a heat transfer fluid to convert waste heat from the CPV cooling system into value-added usable heat. Where conventional solar panels only convert around 15 - 20% of incident sunlight into beneficial use for electricity and waste the remaining 80 - 85%; with this cogeneration invention SuperSurya will be targeted to potentially convert 60% of incident sunlight into beneficial use (15 - 20% for electricity, 40 - 45% for usable heat). RIC Enterprises, a Washington State nonprofit corporation, and West Sound Technical Skills Center, a distinctive Washington State technical education institution, are working together collaboratively to design, build and test a full-scale prototype of SuperSurya, the first of its kind in the world. Future offshore versions can efficiently harvest electricity with combined CPV and solar thermal subsystems & synergistically perform low-temperature desalination.

Keywords: *solar, hybrid, concentrating, cogeneration, heating, CPV, heliostatic, tracking, electricity, heat, offshore, efficiently, solar thermal, synergistically, desalination*

1. Introduction

Current photovoltaic solar modules harvest 15- 20% of incoming solar energy, using solar cells such as high-efficiency monocrystalline silicon solar cells. The balance 80 - 85% of incoming solar energy is wasted as waste heat dumped into the environment. Despite this poor harvest efficiency, current solar modules are reasonably cost-effective and have continuing widespread and growing deployment. The solar energy industry could grow even more rapidly if means were available to double or triple solar energy harvest as a percentage of incoming solar energy. This paper presents an introduction to an innovative new technology that leverages a hybrid solar concentrating cogeneration system to harvest both electricity using a low-concentration photovoltaic subsystem, and usable heat using a heat-transfer fluid that captures heat from the concentrating photovoltaic (CPV) subsystem and provides that heat at a useful temperature of 65 - 75 degrees C to a solar hot water heater, as well as for supplementary home or building heating and optionally for swimming pool heating as well.

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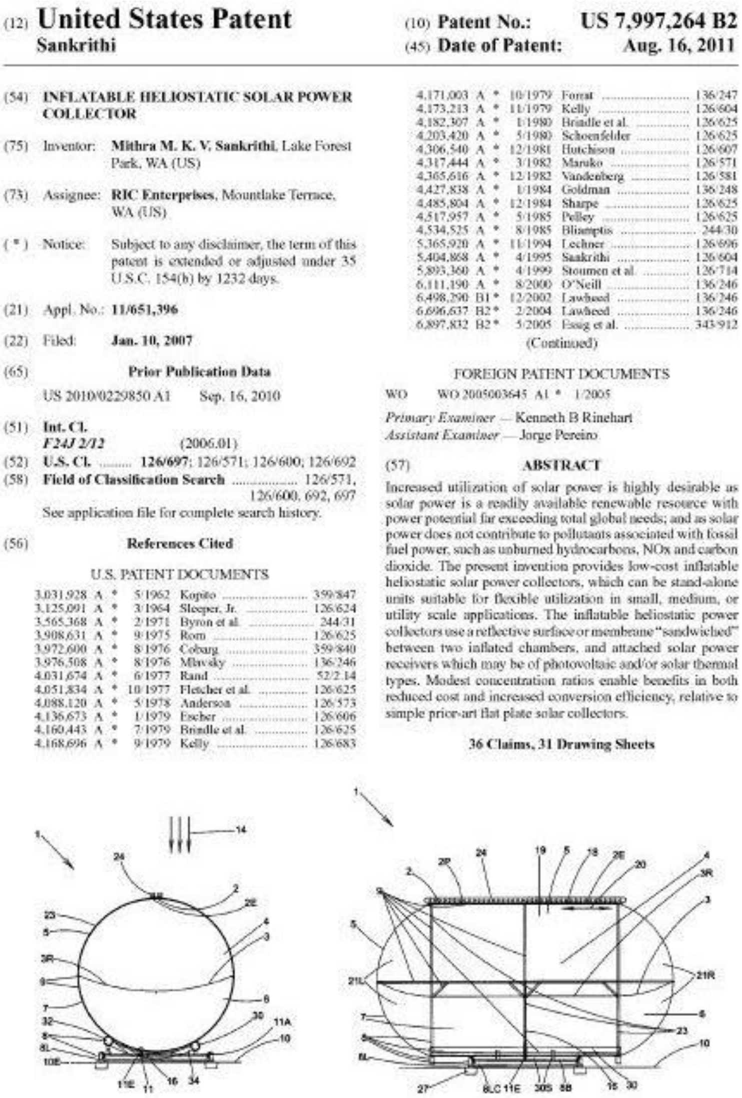
2. Technology Definition Background

The foundational technology for the hybrid solar concentrating cogeneration system is contained in United States patent US 7,997,264 and United States patent-pending US 2011/0277815, that together disclose the key enabling features and technologies for a hybrid solar concentrating cogeneration system. These key enabling features and technologies include the use of heliostatic tracking; use of framed upwardly concave reflective membranes with an inflation-supported transparent upper surface to keep the reflector surfaces clean and uncontaminated; use of a low-concentration high-efficiency CPV receiver that can use monocrystalline silicon or other solar cells; and use of a CPV cooling system wherein the cooling fluid that keeps the solar cells from overheating also serves as the heat-transfer fluid providing beneficial heat to downstream subsystems such as a solar water heater, supplemental building heat, optional swimming pool heating and an optional added solar thermal electric power generation subsystem. Figures 1 and 2 below provide introductory cover-sheet information on this cited intellectual property.



(12) **United States Patent**
Sankrithi

(10) **Patent No.:** **US 7,997,264 B2**
(45) **Date of Patent:** **Aug. 16, 2011**

(54) **INFLATABLE HELIOSTATIC SOLAR POWER COLLECTOR**

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(73) Assignee: **RIC Enterprises**, Mountlake Terrace, WA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1232 days.

(21) Appl. No.: **11/651,396**

(22) Filed: **Jan. 10, 2007**

(65) **Prior Publication Data**

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F24J 2/12 (2006.01)

(52) **U.S. Cl.** **126/697**; 126/571; 126/600; 126/692

(58) **Field of Classification Search** 126/571, 126/600, 692, 697
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,031,928	A	*	5/1962	Kopito	359/847
3,125,091	A	*	3/1964	Sleeper, Jr.	126/624
3,565,368	A	*	2/1971	Byron et al.	244/31
3,908,631	A	*	9/1975	Rom	126/625
3,972,600	A	*	8/1976	Coburg	359/840
3,976,508	A	*	8/1976	Mlavsky	136/246
4,031,674	A	*	6/1977	Rand	52/2.14
4,051,834	A	*	10/1977	Fletcher et al.	126/625
4,088,120	A	*	5/1978	Anderson	126/573
4,136,673	A	*	1/1979	Escher	126/606
4,160,443	A	*	7/1979	Brindle et al.	126/625
4,168,696	A	*	9/1979	Kelly	126/683
4,171,003	A	*	10/1979	Forrat	136/247
4,173,213	A	*	11/1979	Kelly	126/604
4,182,307	A	*	1/1980	Brindle et al.	126/625
4,203,420	A	*	5/1980	Schoenfelder	126/625
4,306,540	A	*	12/1981	Hutchison	126/607
4,317,444	A	*	3/1982	Maruko	126/571
4,365,616	A	*	12/1982	Vandenberg	126/581
4,427,838	A	*	1/1984	Goldman	136/248
4,485,804	A	*	12/1984	Sharpe	126/625
4,517,957	A	*	5/1985	Pelley	126/625
4,534,525	A	*	8/1985	Bliamptis	244/30
5,365,920	A	*	11/1994	Lechner	126/696
5,404,868	A	*	4/1995	Sankrithi	126/604
5,893,360	A	*	4/1999	Stoumen et al.	126/714
6,111,190	A	*	8/2000	O'Neill	136/246
6,498,290	B1	*	12/2002	Lawheed	136/246
6,696,637	B2	*	2/2004	Lawheed	136/246
6,897,832	B2	*	5/2005	Essig et al.	343/912

(Continued)

FOREIGN PATENT DOCUMENTS

WO WO 2005003645 A1 * 1/2005

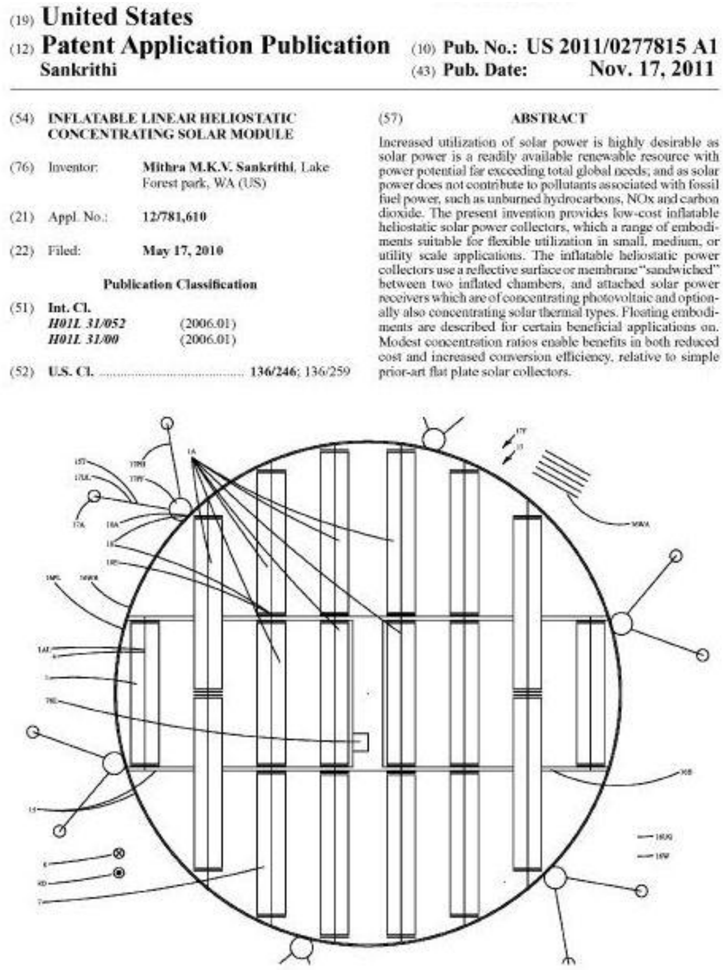
Primary Examiner — Kenneth B Rinehart
Assistant Examiner — Jorge Pereiro

(57) **ABSTRACT**

Increased utilization of solar power is highly desirable as solar power is a readily available renewable resource with power potential far exceeding total global needs; and as solar power does not contribute to pollutants associated with fossil fuel power, such as unburned hydrocarbons, NOx and carbon dioxide. The present invention provides low-cost inflatable heliostatic solar power collectors, which can be stand-alone units suitable for flexible utilization in small, medium, or utility scale applications. The inflatable heliostatic power collectors use a reflective surface or membrane "sandwiched" between two inflated chambers, and attached solar power receivers which may be of photovoltaic and/or solar thermal types. Modest concentration ratios enable benefits in both reduced cost and increased conversion efficiency, relative to simple prior-art flat plate solar collectors.

36 Claims, 31 Drawing Sheets

Fig. 1: Technology Definition for an Inflatable Heliostatic Solar Power Collector



(19) United States
(12) Patent Application Publication
Sankrithi

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(54) INFLATABLE LINEAR HELIOSTATIC CONCENTRATING SOLAR MODULE

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Publication Classification

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H01L 31/00 (2006.01)

(52) U.S. Cl. 136/246; 136/259

(57) ABSTRACT

Increased utilization of solar power is highly desirable as solar power is a readily available renewable resource with power potential far exceeding total global needs; and as solar power does not contribute to pollutants associated with fossil fuel power, such as unburned hydrocarbons, NOx and carbon dioxide. The present invention provides low-cost inflatable heliostatic solar power collectors, which a range of embodiments suitable for flexible utilization in small, medium, or utility scale applications. The inflatable heliostatic power collectors use a reflective surface or membrane "sandwiched" between two inflated chambers, and attached solar power receivers which are of concentrating photovoltaic and optionally also concentrating solar thermal types. Floating embodiments are described for certain beneficial applications on. Modest concentration ratios enable benefits in both reduced cost and increased conversion efficiency, relative to simple prior-art flat plate solar collectors.

Fig. 2: Technology Definition for a Solar Concentrating Cogeneration System Including a Solar Thermal Subsystem and a Floating Offshore Embodiment

3. Completed Prototype Subsystem Testing

Subsystem technologies for the proposed hybrid solar concentrating cogeneration system have already been prototyped and tested to demonstrate proof-of-concept. As shown in Fig. 3 below, the subsystems that have been tested include:

- Use of a reflective concentrating framed membrane reflector
- Use of a low-cost inflatable structure with a transparent protective weather cover
- Use of an Ethylene Tetrafluoroethylene (ETFE) transparent weather cover that self-cleans in rain
- Use of one and two-axis heliostatic tracking subsystems
- Use of a CPV cooling system using forced air over heat sink extrusions
- Demonstration of an inverted-stow protection concept for storm and hail conditions

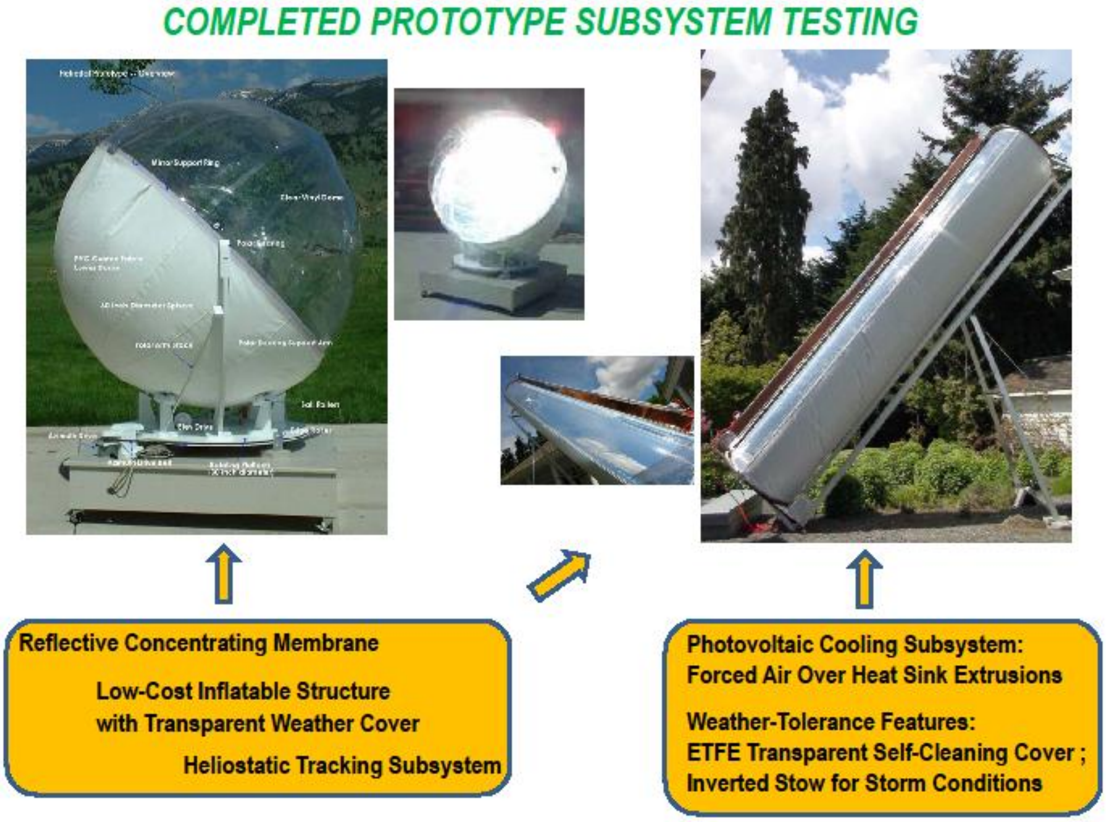

Fig. 3: Completed Proof-of-Concept Prototype Subsystem Testing

4. Baseline Design, Test & Development Plan

The baseline design for a hybrid solar concentrating cogeneration module, designed "SuperSurya," has been completed and is shown in Fig. 4 below. SuperSurya is designed to harvest 1.5 kilowatts of electric power (1.5 kWe) and 4.5 kilowatts of usable thermal power (4.5 kWt) that leverages a working heat transfer fluid at 65 - 75 degrees C to provide high-value usable heat for a solar hot water heater as well as remaining usable heat for supplementary home or building heating. SuperSurya modules can be mounted on the roofs of homes with flat or sloping roofs, and can also be mounted on roofs of commercial or industrial buildings and public service buildings such as schools, libraries & community centers. Ground mounting is also possible.

Two-axis heliostatic tracking is provided using a Sun-sensor and azimuth and elevation control systems. The 7-sun concentration system uses 10 square meters of framed shaped reflective membranes, and inflation-supported Ethylene Tetrafluoroethylene (ETFE) transparent weather covers are provided that self-clean in rain. Inverted stow is provided so that the ETFE membranes are not damaged in the event of very severe weather conditions such as hail, severe snow, or gale force winds. The SuperSurya design has been optimized to be robust, simple, reliable, easy to maintain and cost-effective. Fig.4 below summarizes the baseline SuperSurya design.

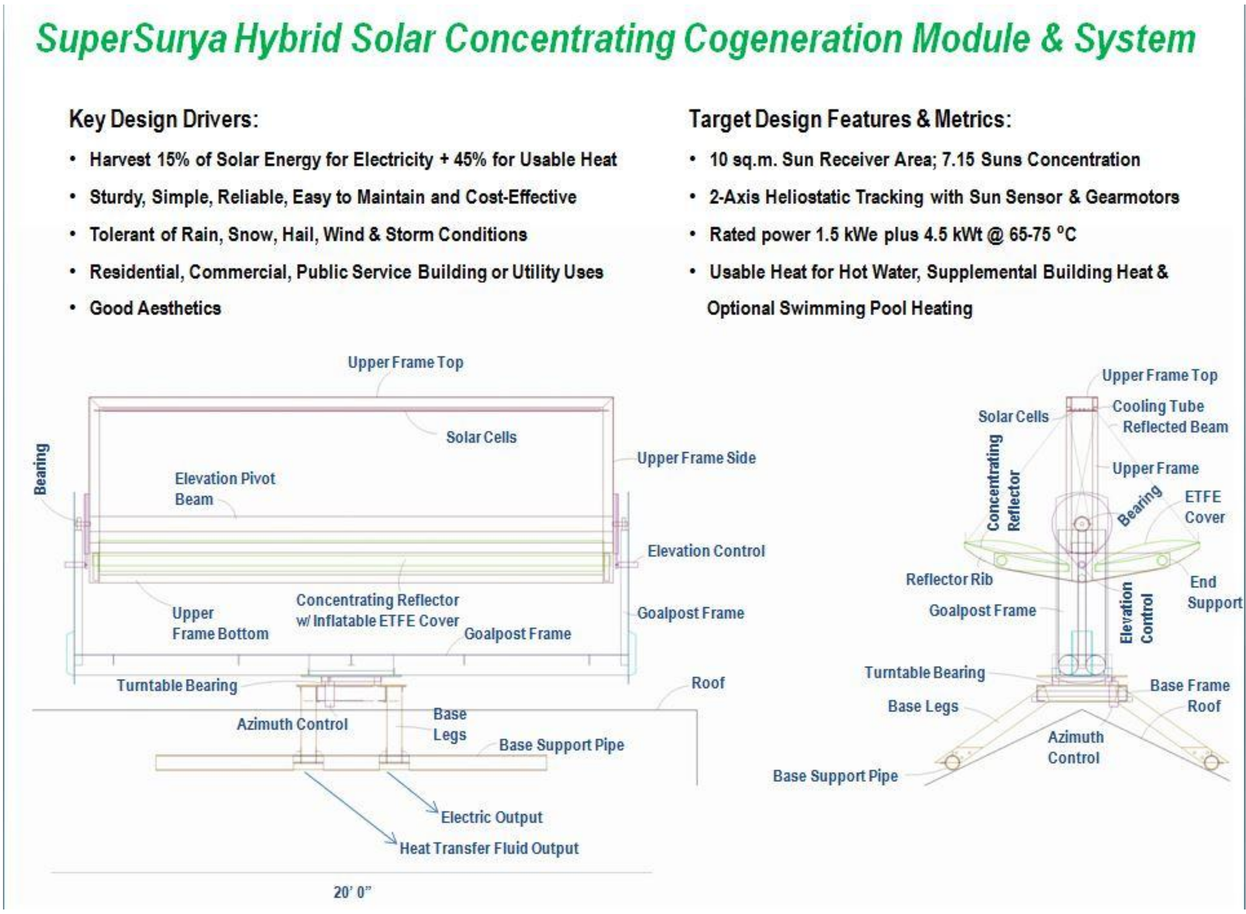

Fig. 4: Baseline SuperSurya Module Design

Following some subsystem testing of the liquid cooling and heat-transfer subsystem, West Sound Tech will build a full-scale fully functional prototype of SuperSurya, and conduct comprehensive testing in collaboration with RIC Enterprises. Contingent on funding and collaboration constraints, the plan is to harvest learnings from the prototype testing to refine the design and proceed to hand-built pre-production units of SuperSurya for sale and monitored in-service testing, and thence on to certification and eventual commercial production. With future collaboration and funding, prototype development and testing is also planned for an Offshore Concentrating Solar (OCS) System that uses a floating offshore assemblage of SuperSurya modules, to harvest electricity with even greater efficiency by adding a solar thermal power subsystem in addition to the CPV subsystem. The OCS System will also be tested with an optional low-temperature desalination system that operates with heat at the 50-60 degrees C range. Fig. 5 below summarizes the project plan and preliminary development plan.

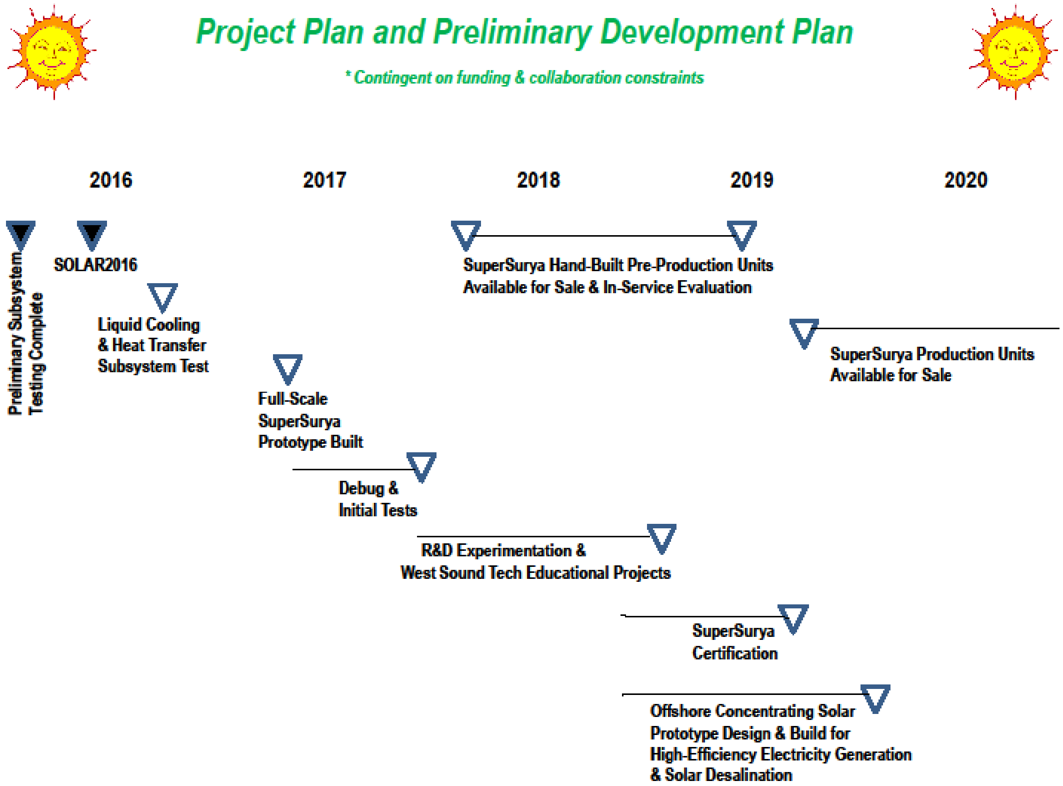

Fig. 5: Baseline Project Plan and Preliminary Development Plan

In the long-term, the dramatic improvement of solar energy harvest increasing from 15-20% of incoming solar energy to around 60% of incoming solar energy, should enable practical, cost-effective and low-risk achievement of a Vision in which these hybrid solar concentrating cogeneration technologies find wide application for residential customers, public sector customers such as schools, libraries and community centers, and commercial and industrial customers as well. The Concentrating Offshore Solar (COS) Systems can find farm/ranch-scale and utility-scale applications for extremely efficient electric power generation with essentially zero land use. Finally, future developments of COS Systems can also cost-effectively provide solar-powered desalination systems to provide clean potable water for coastal communities in arid areas of the World.

Fig. 6 below summarizes this Vision of potential wide-ranging applications. RIC Enterprises (ricenterprisesinvent@gmail.com) welcomes discussion with colleagues and collaborators on potential additional Research, Development and Demonstration (RD&D) activities that can accelerate development and deployment of this promising new approach for the benefit of humankind and our global environment.

Fig. 6: Long-Term Vision for Hybrid Solar Concentrating Cogeneration System Applications

5. Conclusions

Work is progressing satisfactorily on the design and development of a novel, patented hybrid solar concentrating cogeneration system. A full-scale system being prototyped is designed to harvest 1.5 kilowatts of electric power (1.5 kWe) and 4.5 kilowatts of usable thermal power (4.5 kWt), capturing approximately 60% of incoming solar energy, and leveraging a liquid-cooled CPV subsystem that employs a working heat transfer fluid at 65 - 75 degrees C to provide high-value usable heat for a solar hot water heater as well as remaining usable heat for supplementary home or building heating and optionally swimming pool heating. The target 60% energy harvest is approximately triple the level obtainable from conventional solar panels with high-efficiency monocrystalline silicon solar cells. A roadmap for development includes already completed subsystem tests and upcoming full-scale prototype tests, leading to pre-production units for in-service evaluation. Future developments are also targeted to include a floating embodiment for offshore use, that can very efficiently harvest solar energy with no land use, and cost-effectively yield beneficial combinations of electricity, usable heat, and optionally also desalinated water through use of a low-temperature solar desalination subsystem.

6. References

Sankrithi, M, Sankrithi, U, 2010. Prototype Development and Testing of Inflatable Concentrating Solar Power Systems. SOLAR2010, Paper 0251.

Sankrithi, M, Sankrithi, U, 2012. Beneficial Applications of Inflatable Heliostatic Mirrors. World Renewable Energy Forum, Paper 0273.