bsqsolar
beyond the limits

High Concentrating Photovoltaics
The new frontier in solar electricity

Harvesting every last photon

By using tiny multi-junction solar cells that already double the efficiency of conventional solar cells, High Concentration PV provides a sustainable industrial path towards cheap solar electricity based on high conversion efficiencies.

In the last decade, the efficiency of multi-junction solar cells has improved, now much faster than any other PV device at a rate of 1% per year.
Cell efficiencies over 40% are already available.

Source: SolarJunction

The solution for Solar Rich Regions

HCPV is rapidly gaining traction as solar markets shift to high-irradiation areas of the world

Why HCPV? The HCPV value proposition

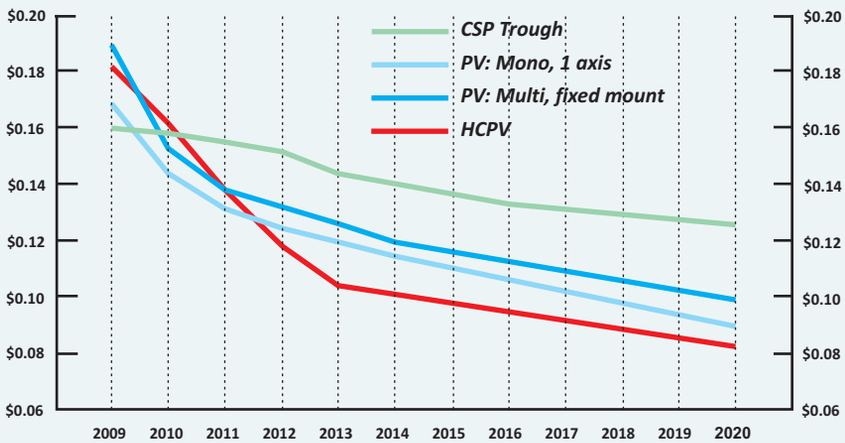
Highest energy yield among PV technologies

- ❍ Highest efficiency in solar technologies...and headroom
- ❍ Power output increases maintaining the same footprint
- ❍ Dual axis tracking providing match to peak demand timeframes
- ❍ Best-in-class temperature loss coefficients

Highest cost reduction rate with economies of scale

- ❍ Fastest learning curve in solar technologies
- ❍ Very low CapEx investment for manufacturing expansion
- ❍ Scalable manufacturing
- ❍ Lowest cost of sourcing from local industries

Least Cost of Energy (LCOE) forecast by solar technologies (DNI: 7 kWhm^2/day)
Source: GTM Research



Flexible deployment

- ❍ Fast intallations, like wind turbines, decreasing installation costs
- ❍ No grading or special site preparation is necessary
- ❍ Distributed generation near to use points
- ❍ Ability to scale-up plant size as demand increase

Superior advantages for local manufacturing and job creation

- ❍ More than 80% in-country manufacturing and project costs
- ❍ Manufacturing is optimal when done locally
- ❍ Installation with local workforce

Best cradle-to-cradle environmental footprint

- ❍ Least equipment required per MWh
- ❍ Short energy payback time
- ❍ Least CO_2 emissions and high recyclability
- ❍ No permanent shadowing enables dual land usage
- ❍ No water usage for the operation or the cooling

820 times closer to the Sun

With more than a decade of intensive field testing and thorough development in the lab, the BSQ HCPV system combines high efficiency and high concentration non-imaging optics with a simple and rugged module design. Modules are optimally complemented by a highly accurate and robust sun tracker.

Everything is optimized to provide the most cost effective path for the industrialization of competitive PV electricity generation systems.

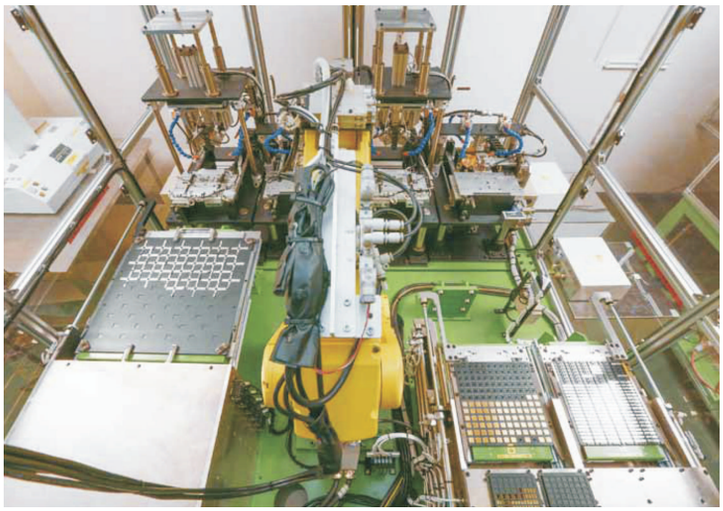
The HCPV Module

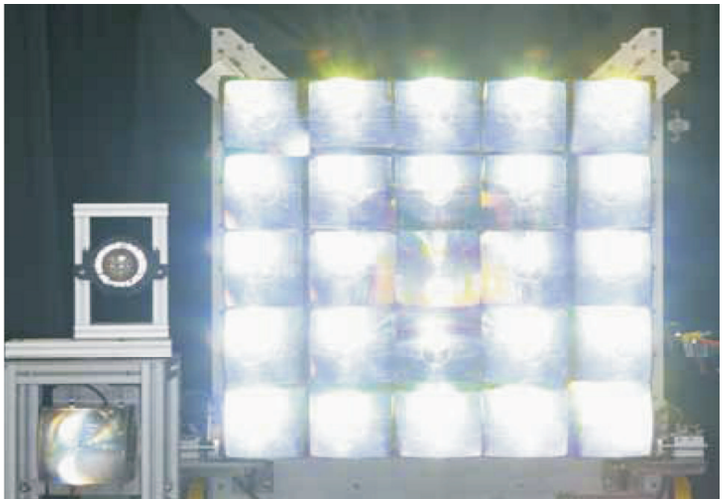
- ❍ Very high concentration ratio of 820X
- ❍ Unique dome-shaped concentrating Fresnel lens maximizes acceptance angle pointing tolerance up to 1°
- ❍ Secondary optical stage based in kaleidoscopic optics, that through total internal reflection, creates uniform light flux over the cell, preventing conversion losses due to chromatic aberration or inhomogeneous intensity distribution
- ❍ Integration of high efficiency triple junction cells from first tier manufacturers
- ❍ Kaleidoscopic homogenizer and 3J cell, both packaged in fail-proof receiver block with encapsulation polymers with well over 30 years lifetimes, when subject to accelerated aging under most critical conditions: concentrated UV radiation in damp heat environment
- ❍ Only passive cooling required, with cell directly laminated in receiver block onto aluminum substrate, with no need for fin heat

The HCPV Sun Tracker

- ❍ Two axis pedestal tracker designed for optical quality stiffness: maximum 0.3° flexure under maximum service conditions
- ❍ Numerically optimized aperture surface for least structural weight and cost
- ❍ Auto-calibrated open loop tracking controller achieves 0.1° minimum tracking accuracy

On the new frontier of solar electricity





Installs fast and green

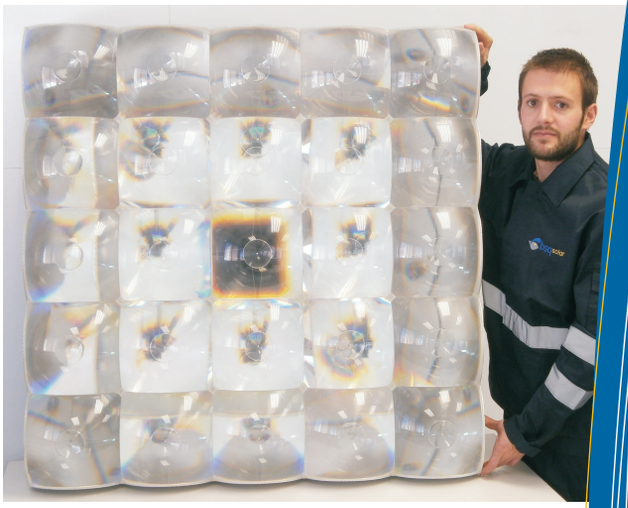
- Modules are pre-assembled and pre-leveled in factory and shipped as packs of “Super Modules” ready for quick installation in the field
- Super Module packs are specially designed to be carried in standard truck trailers and maritime containers and to be handled by regular cranes
- Sun tracker accuracy calibration is automatically carried out during installation and will then operate on an open-loop basis with no dependence on faulty or maintenance prone tracking sensors
- Pedestal trackers with single point foundations allow for less land preparation and installation in undulating terrain
- Surface environmental impact is reduced. No permanent shadowing allows dual-use of land

Local value

- Replicable and proven manufacturing models requiring low CapEx
- Superior advantages for local manufacturing and job creation regarding tracker manufacturing, module assembly, and plant construction, operation, and maintenance
- Indirect jobs through sourcing from local industry suppliers
- Installation with local workforce and only a few specialists

Specifications

HCPV Module



Design & Mechanical Features

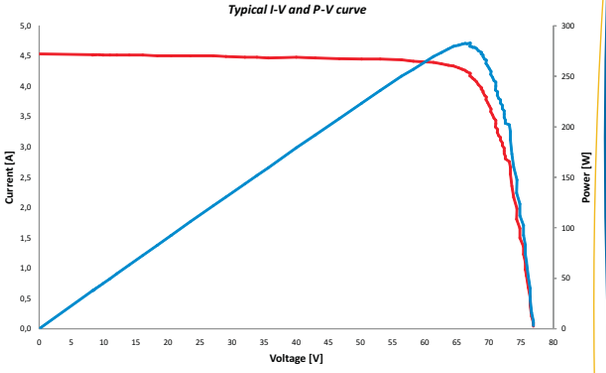
Dimensions (mm)	1005x1005x238
Solar aperture (m^2)	1.01
Weight (kg)	23.6
Maximum static load (Pa)	2400 (backpanel) 5400 (else)
Distance of gravity center to backpanel (mm)	70
Cells per module	25
Lens Material	PMMA
Enclosure Material	Aluminum Alloy
Cell Material	InGaAs/GaAs/Ge
Geometric Concentration	820X
Acceptance Angle (90% output)(deg.)	±0.92

Electric Features

Cell efficiency @ STC(%)	38.5
Module Efficiency @ STC (%)	28
V_{OC} @ STC (V)	78
I_{SC} @ STC (A)	4.3
V_{mpp} @ STC (V)	70
I_{moo} @ STC (A)	4.0
Power @ STC (W)	280
Max. System Voltage (V)	900
Temperature Coefficient (%/K)	-0.21
Connector model	Amphenol-Helios4
Pigtail length (m)	0.25

STC: DNI1000W/m^2, 25C cell temperature

Typical I-V and P-V curve



HCPV System

Sun Tracker - Mechanical & Structural Features

Aperture - Height (m)	6.13
Aperture - Width (m)	8.77
Aperture - Area (m^2)	53.76
Coverage radius (m)	5.34
Maximum height (m)	6.79
Unloaded weight (kg)	2465
Weight with modules (kg)	3598
Max. service wind speed (m/s)	10
Max. flexure @ max. service loads (deg)	0.3
Lowest resonance frequency (Hz)	3

Sun Tracker - Drive Specifications

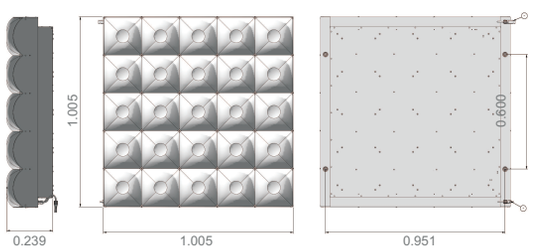
Tracking geometry	Az.-El
Azimuth range (deg)	±160
Elevation range (deg)	0 to 90
Azimuth gearing	Worm gear
Elevation gearing	Screw jack
Tracking mode max. speed (°/min)	15
Manual mode speed (°/min)	18
Max. azimuth power consumption (W)	136
Max. elevation power consumption (W)	130
Power consumption in idle mode (W)	47
Max daily energy consumption (Wh)	1250
Max. time to stowage (min)	8
Axes turning angle measurement	Optical encoder
Limit switches	Soft and hard

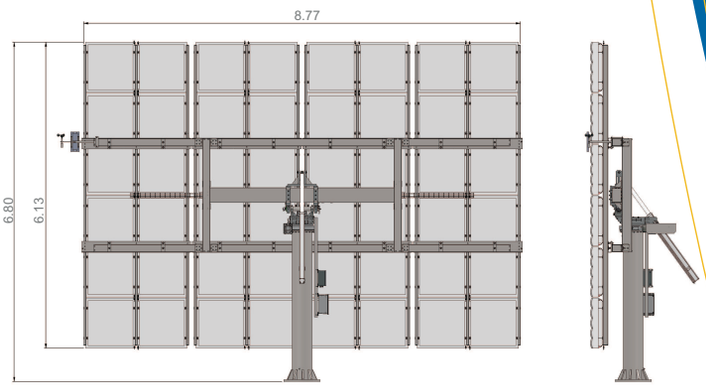
Sun tracker - Controller Specifications

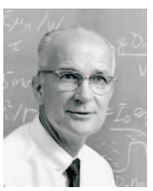
Min. pointing accuracy (Average) (deg)	0.1
Min pointing accuracy (Std. Dev.) (deg)	0.04
Min. positioning resolution (deg)	0.05
Position resolution (deg)	0.018
Sun Ephemeris Mean Accuracy (deg)	0.01 with built-in GPS
Wind Stow Condition (m/s)	12
Basic connectivity	RS232-485, Modbus
Tightness condition	IP65
Temperature range (C)	-10 to 60

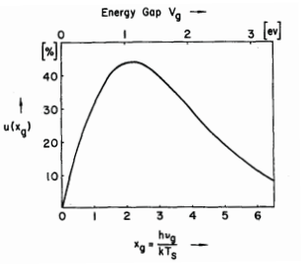
Array Configuration

No. modules per tracker	48 (13.44kW @ STC)
No. modules per string	6
No. strings	8









In 1961 Nobel laureate William Shockley and co-worker Hans Queisser (SQ) published a cutting-edge paper establishing the efficiency limit of an ideal solar cell at 32%. They considered the solar cell as a system of two levels, the valence band and the conduction band. They stated that only photons with energy above the bandgap can pump one electron from the valence band to the conduction band. Photons with higher energy than the bandgap lose this excess as heat.

While most of today´s photovoltaic industry, still relies on silicon single bandgap solar cells, with their ultimate efficiency bounded by the SQ limit, other semiconductor materials and designs are possible that can circumvent this efficiency barrier. Among these, multijunction solar cells are already available, having demonstrated efficiencies over 40%. Also other possible designs are now being cooked in research labs worldwide, bearing exotic names such as, intermediate band cells, hot carrier cells, or multi exciton cells. Limiting efficiencies for this new generation of cells, under SQ assumptions, are over 85% when operating under highly concentrated sunlight.

This new generation of high efficiency photovoltaic cells, integrated in high concentration systems of as much as 1000 suns, has the true potential to mass produce cheap solar electricity in the highly insolated regions of the world.

BSQ stands for Beyond Shockley-Queisser and there´s where we want to go.

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