

Concentration Photovoltaic / Thermal (CPV/T): Next Stop for Solar Power Generations

Dr. Wei ZHOU (周偉)

Mar 22, 2013



ASTRI - Early Guiding Forces



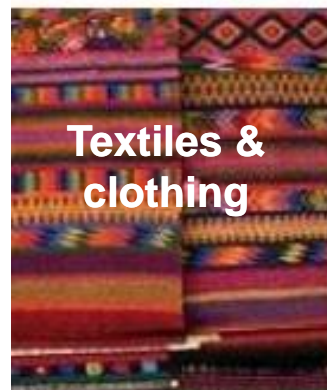
**The late Prof. Chang-Lin Tien
Chancellor of U.C. Berkeley**

**Prof. Charles Kao
2009 Nobel Laureate in Physics
Vice Chancellor of Chinese U. of HK**



5 Research & Development Centres in 2006

**ICT Center is
under ASTRI**



Research Focus

ASTRI's R&D efforts traverse six main technological areas:

- ❑ Communications Technologies (CT)
- ❑ Enterprise & Consumer Electronics (ECE)
- ❑ Integrated Circuit Design (ICD)
- ❑ **Material & Packaging Technologies (MPT)**
- ❑ Bio-Medical Electronics (BME)
- ❑ Exploratory Research Laboratory (ERL, New Initiative)

ASTRI at a Glance

- **Staff:** **586 (R&D - 501, Admin. - 85)**
(Of R&D Staff, 54% are Master holders & 25% are PhD holders)
- 2) **ITF Funding:** **HK\$267 million (FY2011-12)**
- 3) **Patent Granted:** **Over 400 since inception**
- 4) **Technology Transfer:** **Over to 400 since established**
- 5) **Spin-off:** **4 completed and several underway**

ASTRI Science & Technology Research (Shenzhen) Co. Ltd

- Established in 2008
- ASTRI's wholly-owned subsidiary

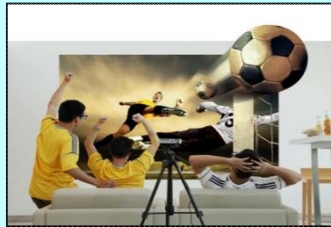
ASTRI's Locations in HK Science Park

ASTRI is located in Hong Kong Science Park
(total 6 floors in 3 buildings)



Material & Packaging Technologies

Packaging & Sensing



Intelligent Projectors

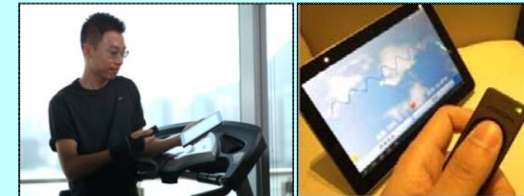


Intelligent Digital Signage



3D IC, Power Packaging, SiP for IoT

- 120** R&D staff
- 180** contracts with **110** companies, **1** spin-off (2010)
- 400** patents filed, **200** granted
- 25** technology awards



Healthcare Electronics



Compact Camera Modules

Green Technology



LED Packaging, Lighting & Control

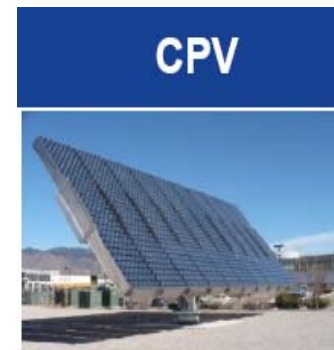
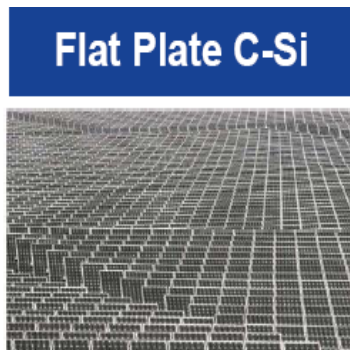
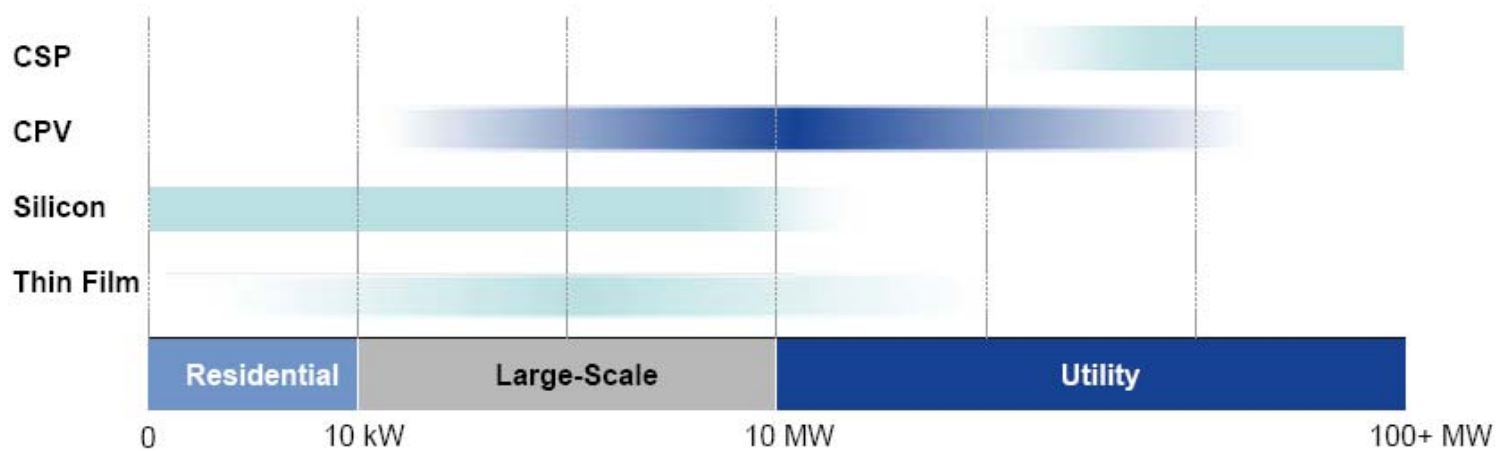


Li-ion Battery Anode



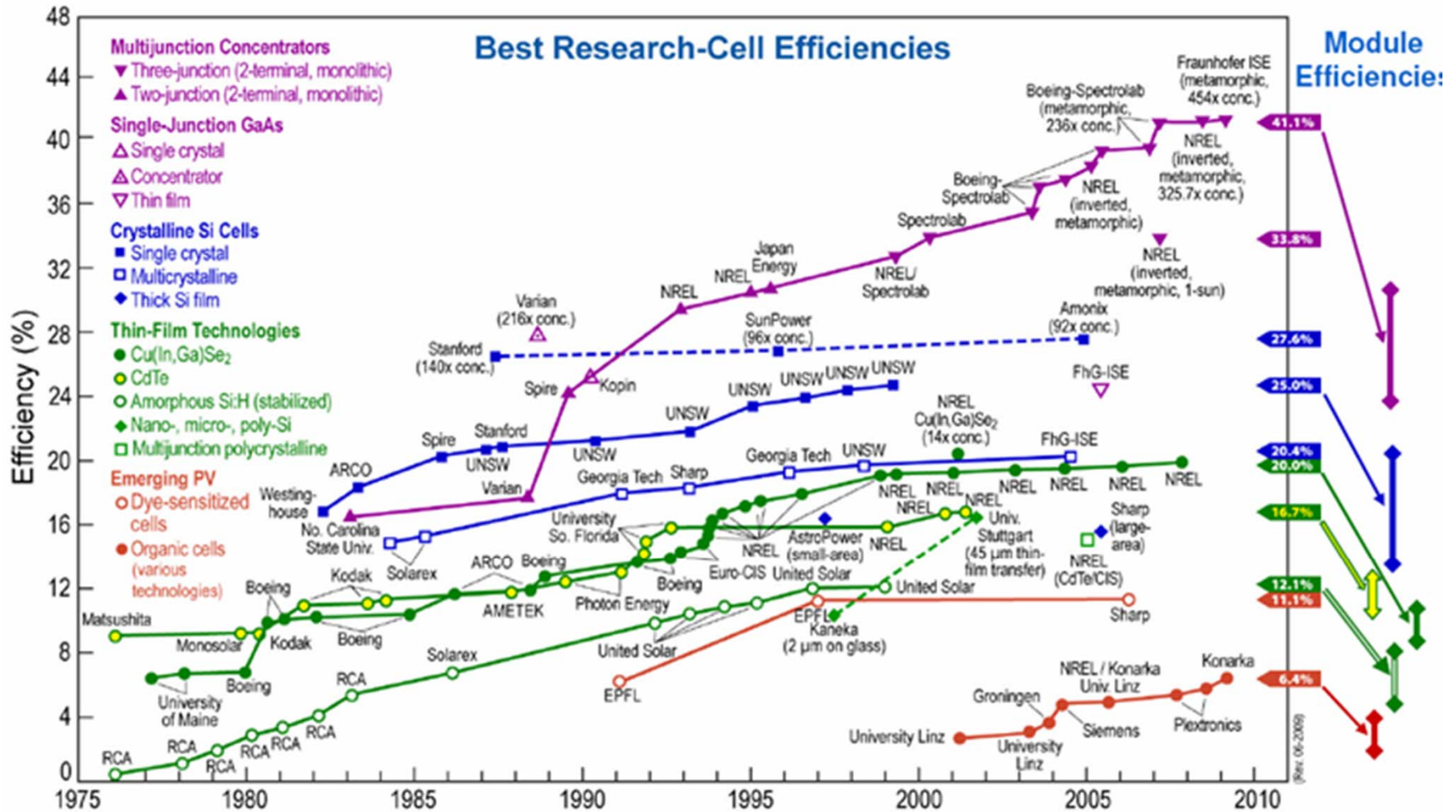
CPV/T

Different Photovoltaic System



- **CPV is the least well known of the solar technologies**
- **Each technology has strengths and weaknesses and has a place in the market**

Improvements in Solar Cell Efficiencies

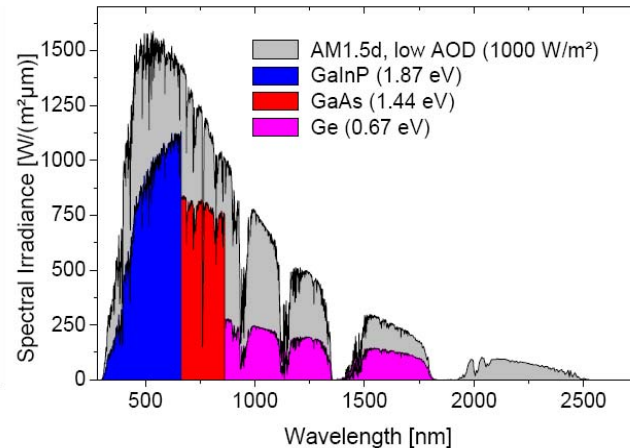
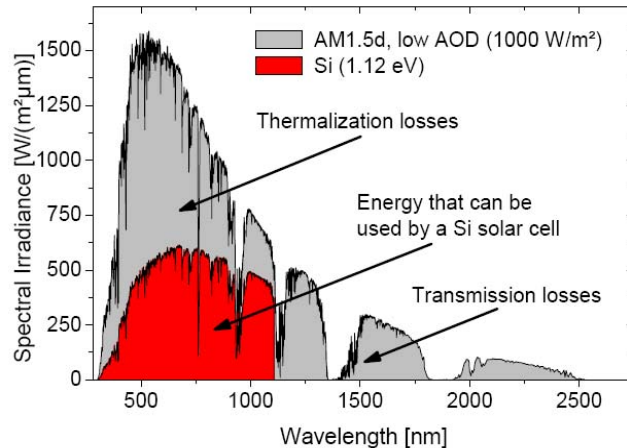
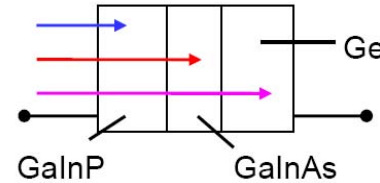
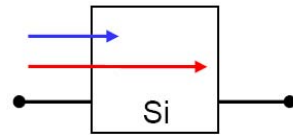


Silicon Cells vs. III-V Multi-junction Cells

Multi Junction Solar Cells Operate at Higher Efficiency:

Employs Three Compound Semiconductor Solar Cells in Series. Each cell is tuned to absorb a different color of light.

Use high-efficient Cells: III-V Multi-junction Cells!

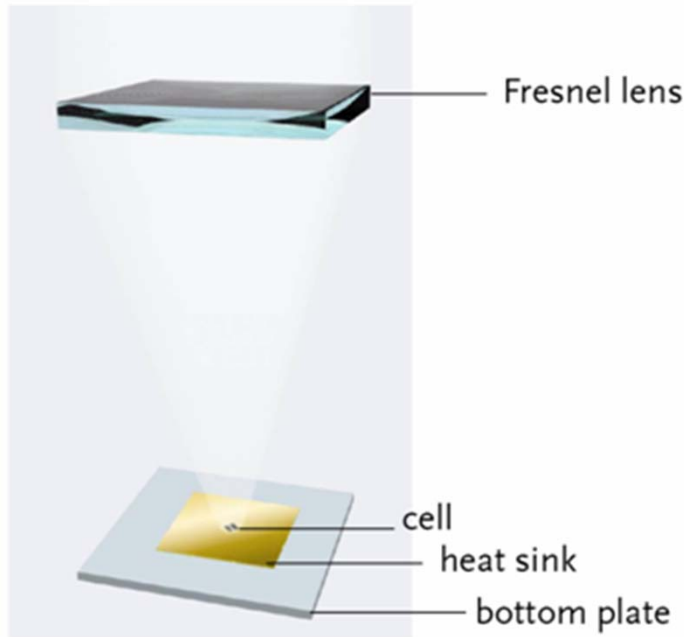


Efficiency Mainly Boosted by:

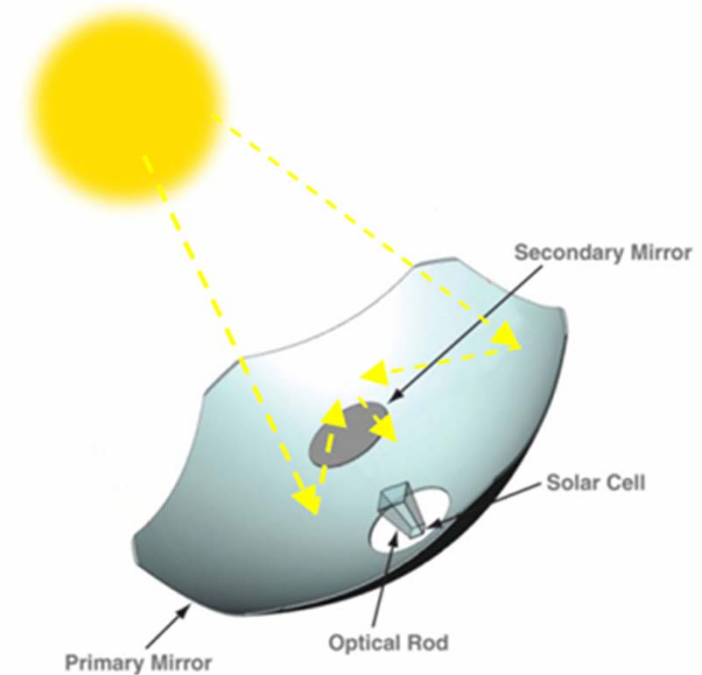
Number of junctions + Spectral matching + Concentrated light

What is CPV ?

Saving cost by focusing the sunlight onto solar cells through an optical device that is less costly than the solar cells.



Typical refractive optical device



Reflective optical device

Why CPV: High Efficiency

Conversion efficiency improves under concentrated illumination

Classification		Material	Lab		Mass Production	
			Cell Eff.	Module Eff.	Cell Eff.	Module Eff.
Silicon	Crystalline	Mono-Si	25.0	21.4	17-19	11-14
		Multi-Si	20.4	18.2	13-15	10-12
	Amorphous	a-Si	19.6		<10	
Multi-junction (3J)			43.5		37-40	21~26

High Efficiency

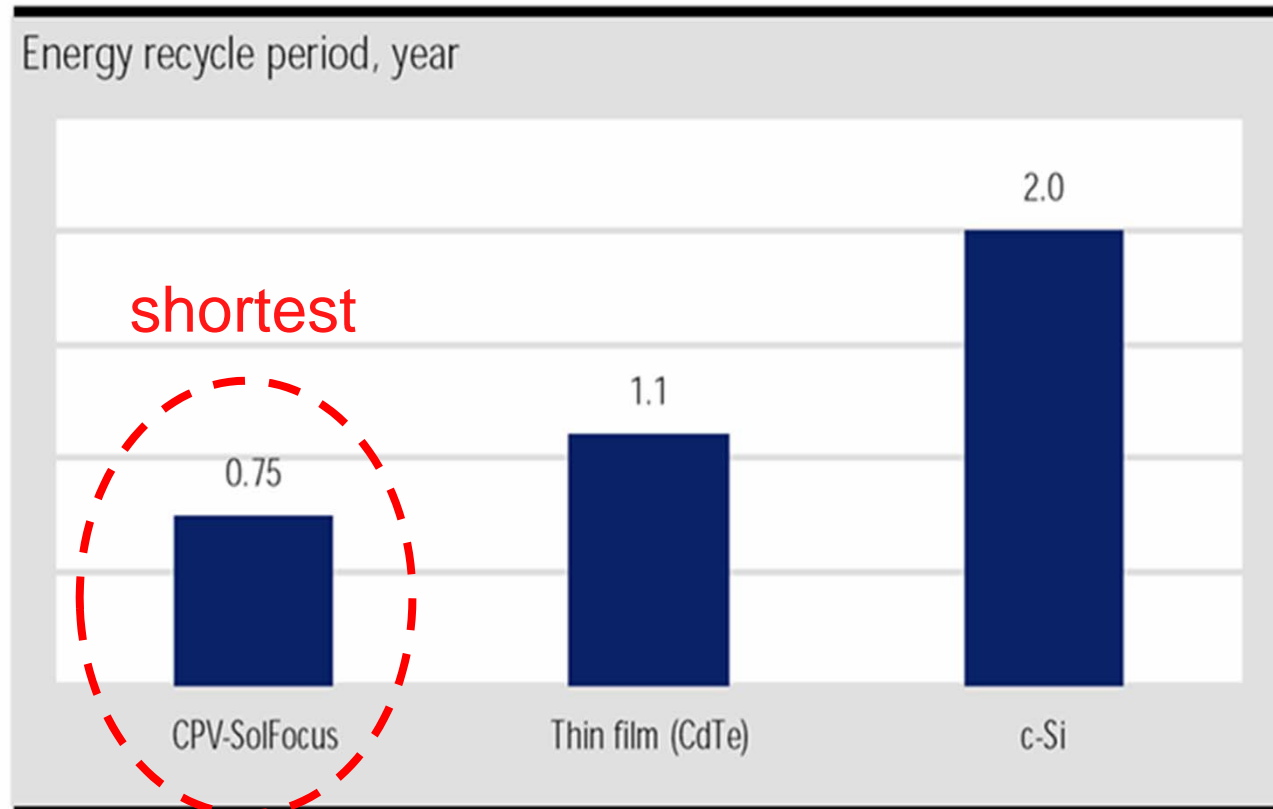
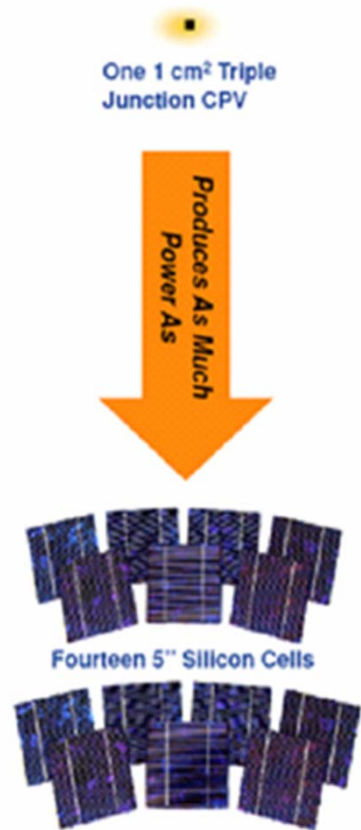


Resource: Solar Cell Efficiency Tables (Version 39)



Why CPV: Low Energy Payback Time

- Lens concentrates solar flux from 500 to 1,200 times

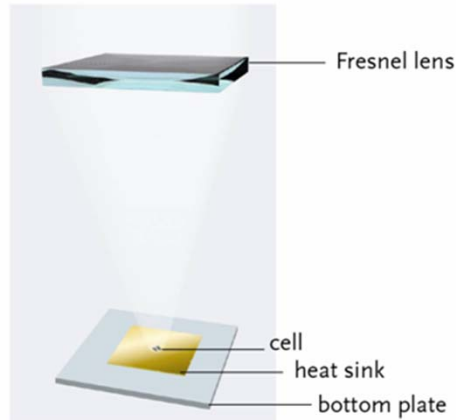


Source: KGI Asia Limited

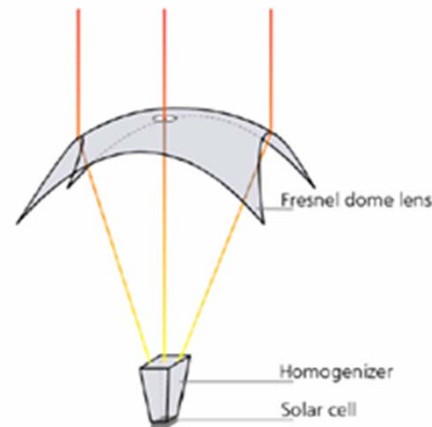
For a CPV module with 1000 sun and 25% eff., producing 1W energy, requires more than 1500 times less cell surface than by Si module without concentration.

Different Optical Designs

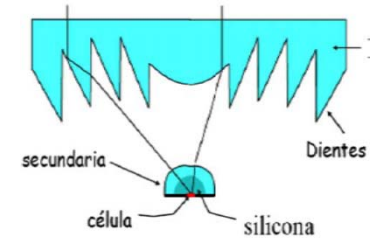
Flat Fresnel lens



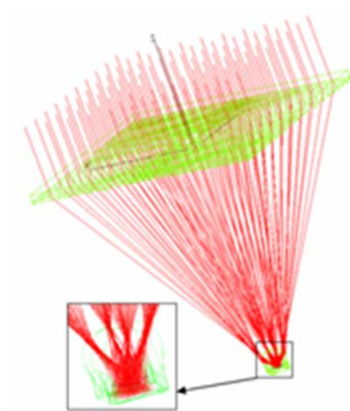
Fresnel Dome lens



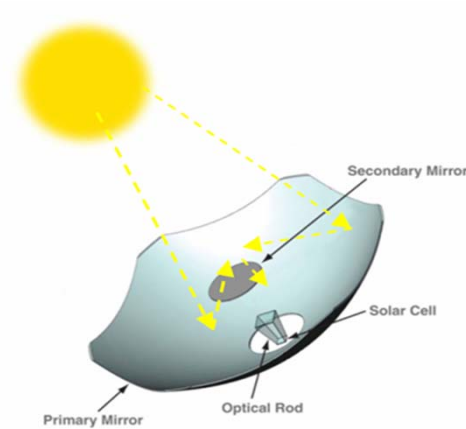
TIR Fresnel lens



Free-form SOE

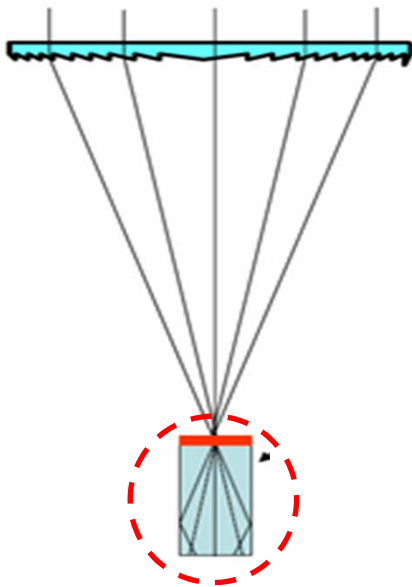


Cassegrian two-mirrors

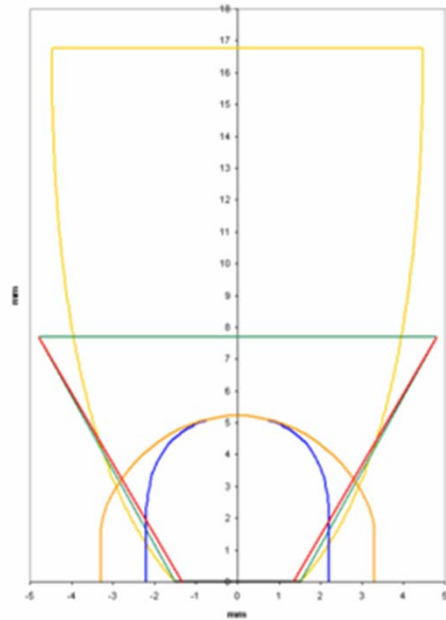


Secondary Optical Elements

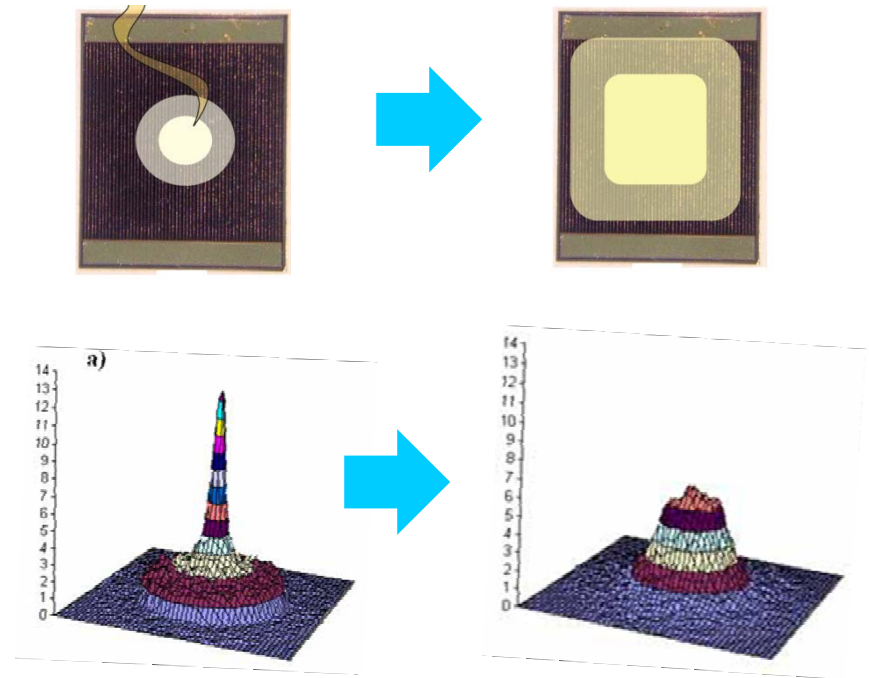
In CPV module, **Secondary Optical Element (SOE)** was used to increase optical angle tolerance and improve irradiance uniformity on the solar cells surface.



Classic non-imaging secondary optical elements (SOE)



Cone (green) and pyramid (red), parabolic (yellow), dome A (blue), dome B (orange).



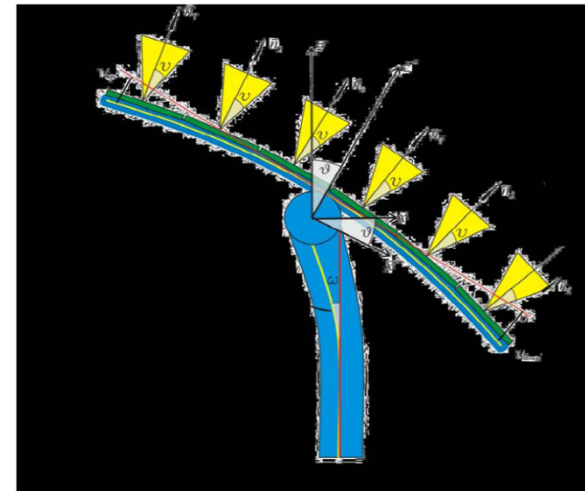
Irradiance Uniformity was improved

Aims of solar tracking

- **CPV use only DNI because the limited acceptance angle**
They must follow the sun position in sky;
Static concentrators, with $G < 5X$ can avoid tracking;
Using two axis tracking with flat panel allows 40% production increase.
- **For Flat module applications**
Errors of several degrees do not cause problem;
Designing aim: Survival to wind.
- **For CPV arrays**
Even one degree error can reduce drastically the power output;

Not only the pointing to sun is important, but all receiving components are aligned to receive the same irradiance.

Designing aim: stiffness.
More stiffness uses currently ask more steel.



CPV Applications



Roof Type CPV

CPV Solar Farm



Implementation of 30kW CPV Power Plant



Foundation



Module assembly



Carry-in



Installation



Frame Assembly



Module fastening



Panel installation



Cable connection

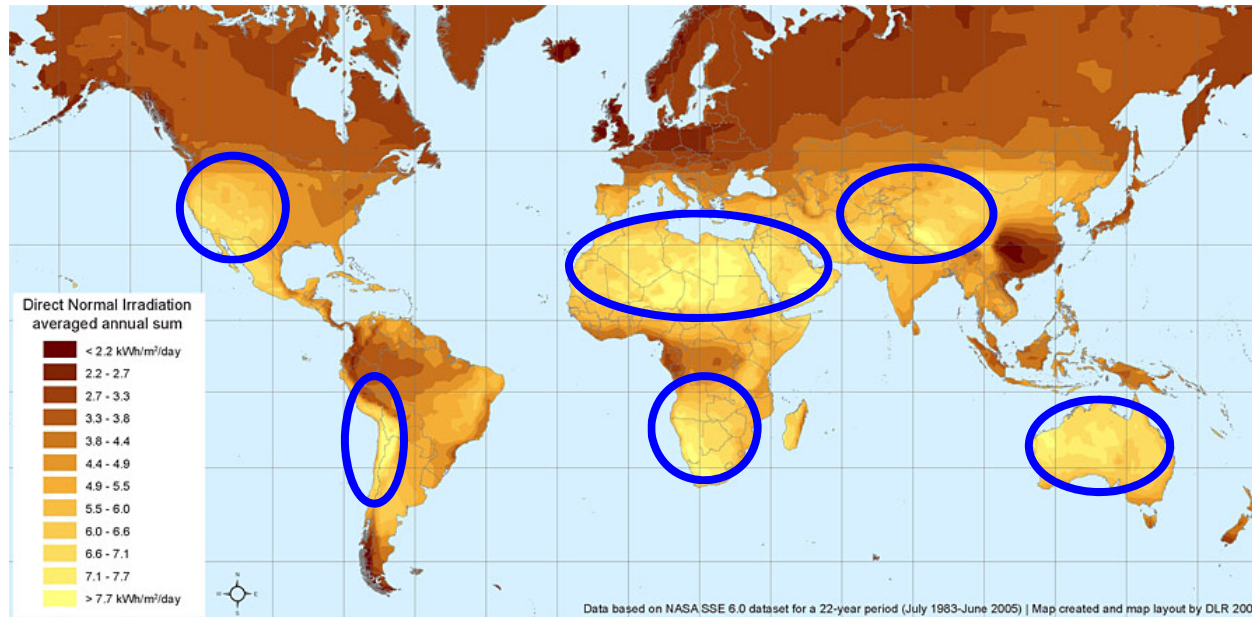


Completed



Operation

Suitable Regions for CPV Plants



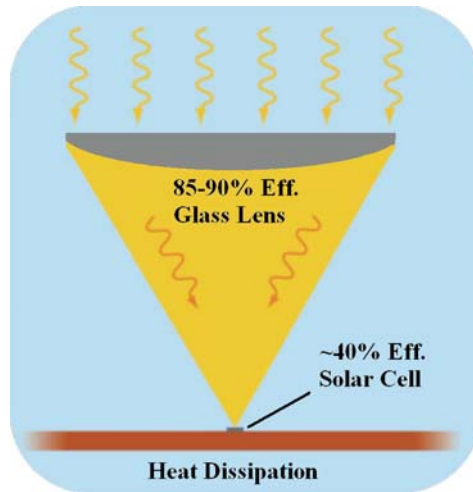
CPV technology is ideally suited for **high solar resource regions** around the globe.

Performing well even in high temperatures (Lower Temperature coefficient, only **1/5** of conventional Si based PV modules).



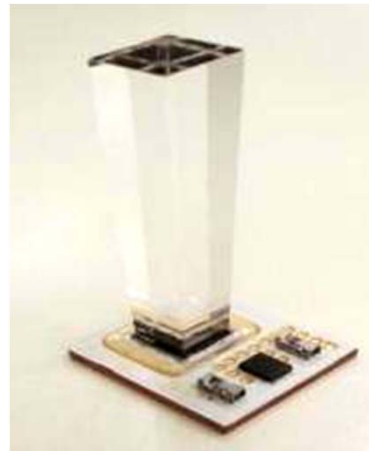
ASTRI's Way to High Eff. CPV Module

Novel Optics Design + Solar Cell Package = High Eff. CPV Module



Reflective & Wave guide

- High optical Eff.: >85%;
- High reliability: Glass;
- High concentration: 500X & 1000X;
- High angle tolerance: +/-1.2°.



Low Thermal Resistance

- Novel MCPCB packaging design;
- Void free solar cell soldering;
- Lead frame wire bonding.



Integrated CPV Module

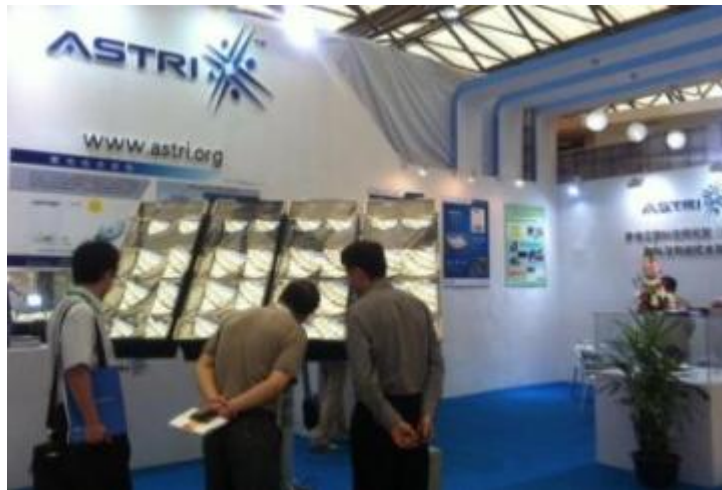
- Efficiency: >25%;
- Slim form factor (Half of Fresnel lens design).

High Eff.

Characteristics of ASTRI' CPV Module



Golden Prize on SNEC 2012



Exhibition booth on SNEC 2012

❑ High Efficiency

Module Effi.: **~25%** (Twice the Si module)

❑ High Concentration

Concentration Ratio: **500X & 1000X**

❑ High Angle Tolerance

±1.2° (Lower requirement for tracking)

❑ Slim Form Factor

Half of Fresnel lens design

❑ Long-term Stability

Glass material, green and stable

❑ **3 US & 3 CN** patents filed



Concentrating Photovoltaic (CPV) System



With Hong Kong Science Park in Phase III



With a Hong Kong Government Department



- **Key features:**

Rated power: **1kW**

~25% efficiency (**Twice** the Si approach)

500x high concentration ratio

Long term stability (All glass design)

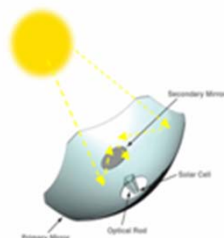
Competition Analysis - CPV

We Offer highest concentration (1000X) CPV solution

- with **largest angle tolerance** (low requirement for sun tracker);
- and **thin form factor** (40% of Fresnel lens design).

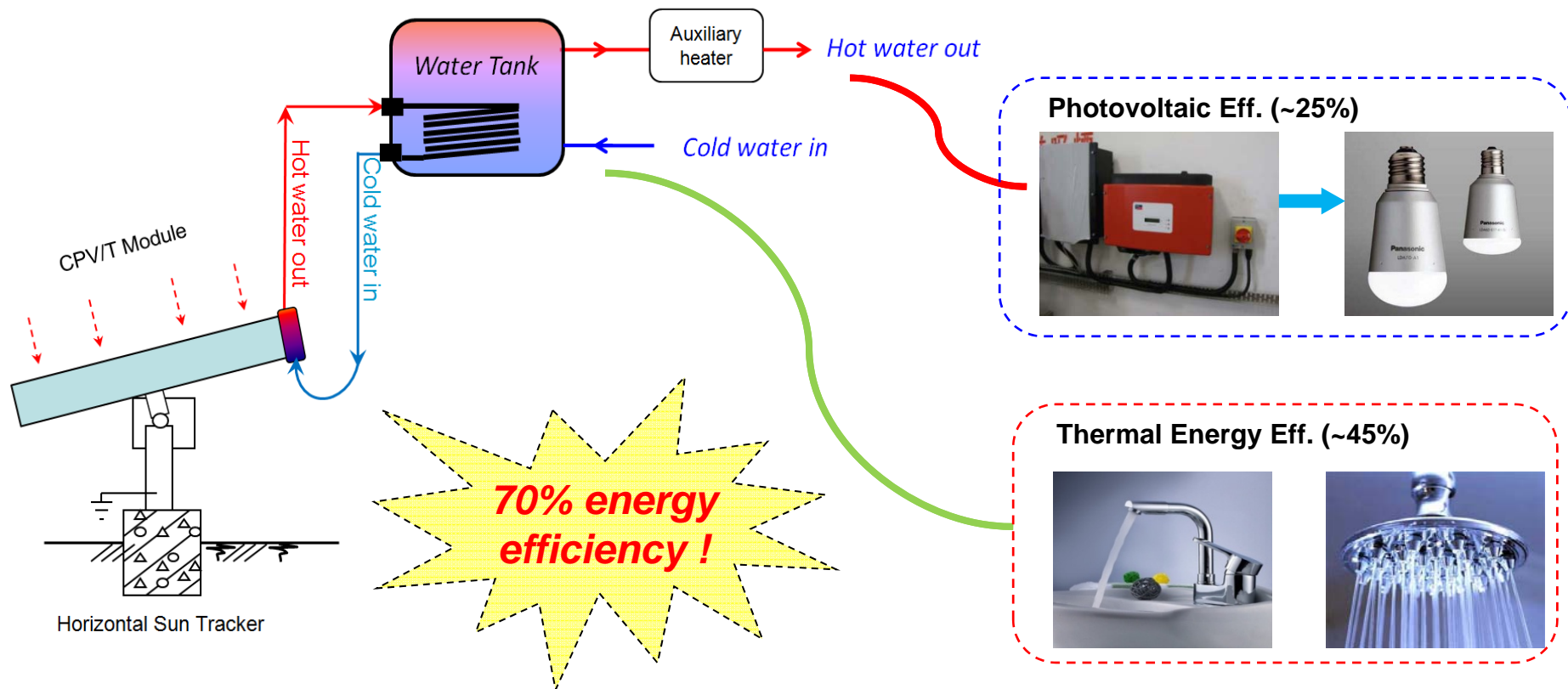
Company	Concentrix	SolFocus	Amonix	Emcore	ASTRI
Country	German	USA	USA	USA	Hong Kong
Optics	Fresnel Lens	Reflector + SOE	Fresnel Lens + SOE	Fresnel Lens + SOE	Reflector + Wave-guide
Tolerance	±0.6°	±1°	~ ±0.5°	±0.7°	±1.2°
Concentration	500 X	625 X	500 X	1000X	1000X
Solar Cell Size	Ø3mm	10*10mm	10*10mm	10*10mm	10*10mm
Thickness	102 mm	100 mm	>400mm	640 mm	250 mm

Highest!
Highest!
60% less!



Concentrating Photovoltaic & Thermal (CPV/T)

Based on **concentration technology**, sunlight is concentrated onto high efficiency solar cell for **power generations**, the waste heat from concentrated sunlight will be collected for **hot water productions**.



Competition Analysis – CPV/T

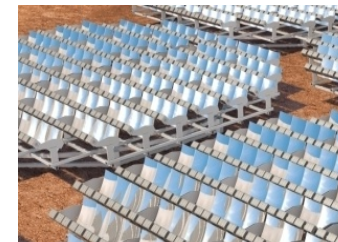
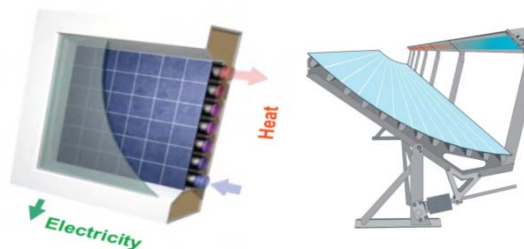
□ We offer **70% Energy Efficiency** (Half roof area):

- **25% Electricity + 45% Hot Water;**
- **Concentration optics: 1000X** for PV, **2000X** for thermal;
- **Slim Form Factor: ~1/3 less** structure materials.

	Hybrid System	Integrated PV/T	Conventional CPV/T	ASTRI's CPV/T
Solar Cell Type	Silicon based solar cell			Concentration cell (Triple-junction)
Concentration Ratio	1	1	~10	1000X for PV, 2000X for thermal
Efficiency (%)	36*	53.1	62.5	70
System cost ** (USD)	1610	1520	1481	1207
Payback Period (Year) w/o gov. subsidies	5.2	5	4.9	4.0
Roof Area Needed (m²)	11	~ 8	~ 7	4.7

Highest!
>25% less!
50% less!

* 1:1 area for PV and thermal;
 ** Same energy output. 4kWh/day energy for Photovoltaic, and 7.2kWh/day energy for solar thermal. in Hong Kong.

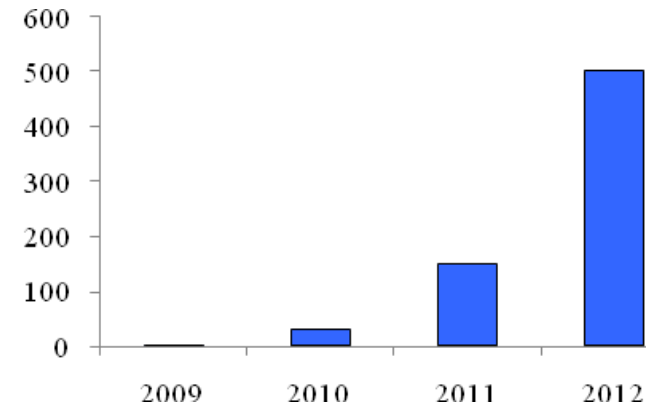


Market Size and Trend

□ Market Size

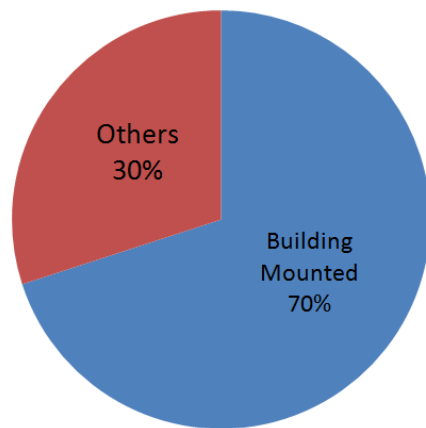
- **Solar Thermal:** China account for **47%** of worldwide 245GW (~50billion USD) market;
- **CPV:** Installed ~600MW (~1.2billion USD) CPV modules, dominated by few players: Solfocus, Emcore, Amnix, etc.

Global CPV Installations (MW)

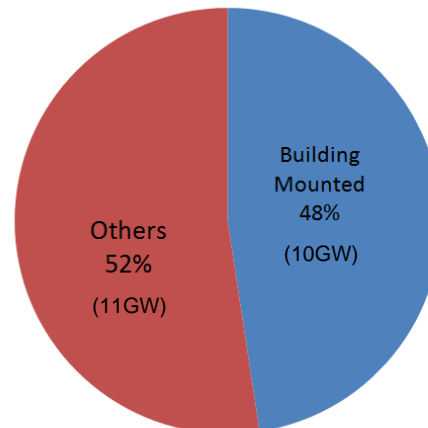


□ Market Trend

- Growth towards **self-sustained building energy solution.**



PV Installation Worldwide in 4Q 2011

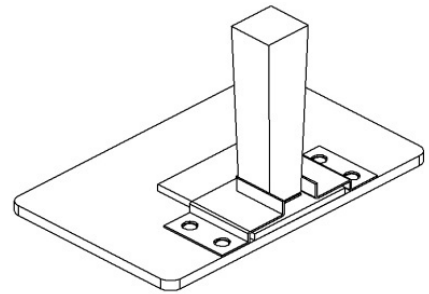
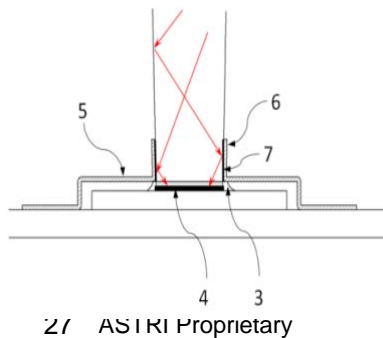
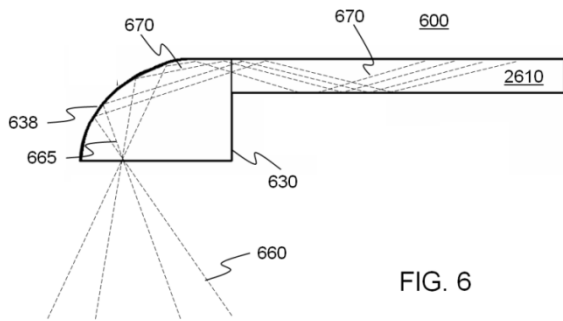
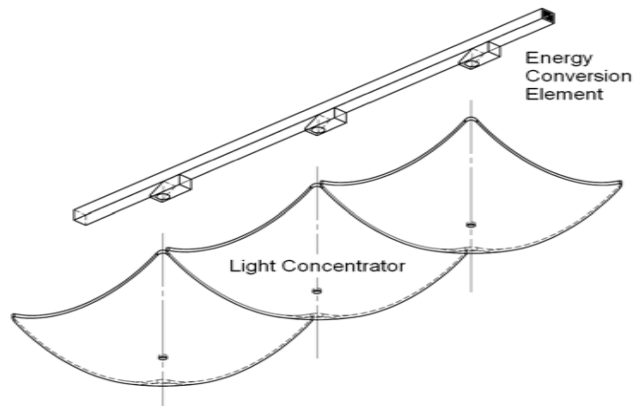


PV Installations in China During 12th Five-Year Plan

China allowed PV Grid Connections: **Encourage distributed solar photovoltaic installations.**

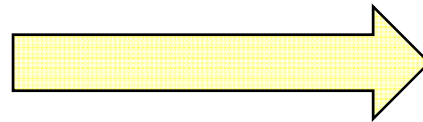


Patent Portfolio

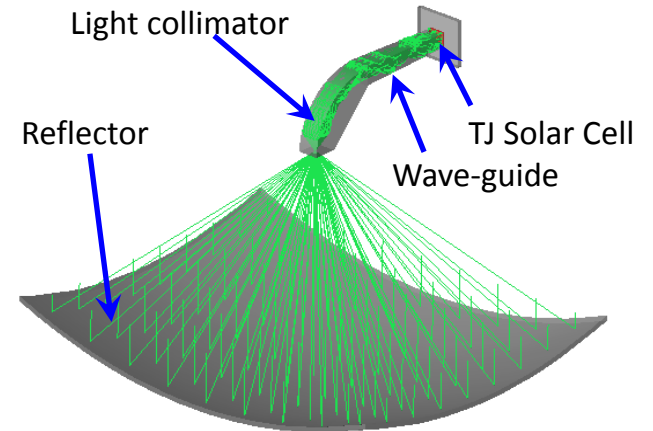


Module Performance

- ❑ High Efficiency: **~25%** (Twice the Si module);
- ❑ **500X & 1000X** Concentration;



- ❑ **±1.2°** High Angle Tolerance;
- ❑ Slim Form Factor: **Half** of Fresnel lens design;
- ❑ Long-term Stability: **All glass**



1000X CPV Module



Target Market Segments (CPV/T)

Stage I: Commercial Buildings

- Hotel (>20,000 in China), factory building;
- Release pressure of electricity quota;
- Hot water for shower, space heating.



Typical chain hotel:

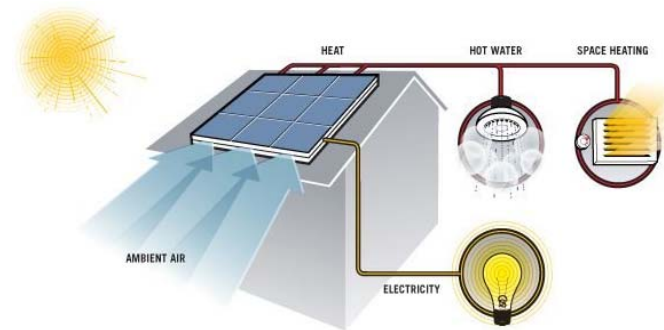
- ~100 hotel rooms;
- ~150kWh power for public lighting (LED) /day;

30kW CPV/T system generate:

- 120~210kWh power & 6~10m³ hot water (60°C) every day in China;
- Power cover all public lighting;
- Hot water satisfy showing for all rooms.

Stage II: Residential buildings

- Residential community in China;
- House.



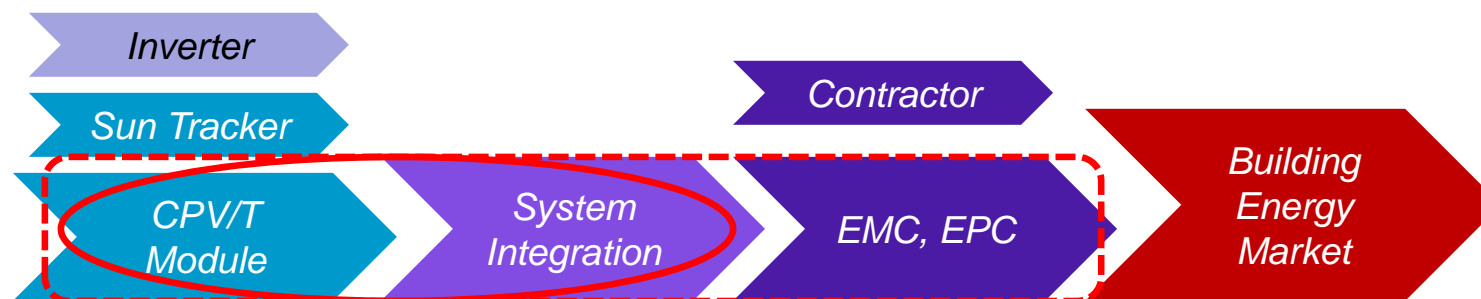
1kW CPV/T system generate:

- 4~7kWh power & 7~12kWh hot water every day in China;
- Cover all energy demand (LED lighting, TV, digital devices and showing) of the house except air conditioning.



Business Model – Spin Off Company

- Develop strategic relationships with **EMC** (Energy Management Contract) & **EPC** (Engineering, Procurement & Construction)
- Use direct technical sales force to target **self-sustained building energy solution segments** (Commercial, Factory Buildings, etc.)
- Build a comprehensive patent portfolio
- Seeking for **Government subsidies**, such as Golden Sun Project and local government support.



End of Presentation

Thank you. Questions are welcome.

Our corporate website: www.astri.org

or

Contact us:

Dr. ZHOU Wei

Tel: (+852) 3406 0329

Email: weizhou@astri.org

