Concentrating PV: Status and Perspectives

Andreas W. Bett

M. Wiesenfarth, S. P. Philipps

Fraunhofer Institute for Solar Energy Systems ISE

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AGENDA

- Introduction
- Market of CPV
- Technology status of CPV

The development of the photovoltaic technologies

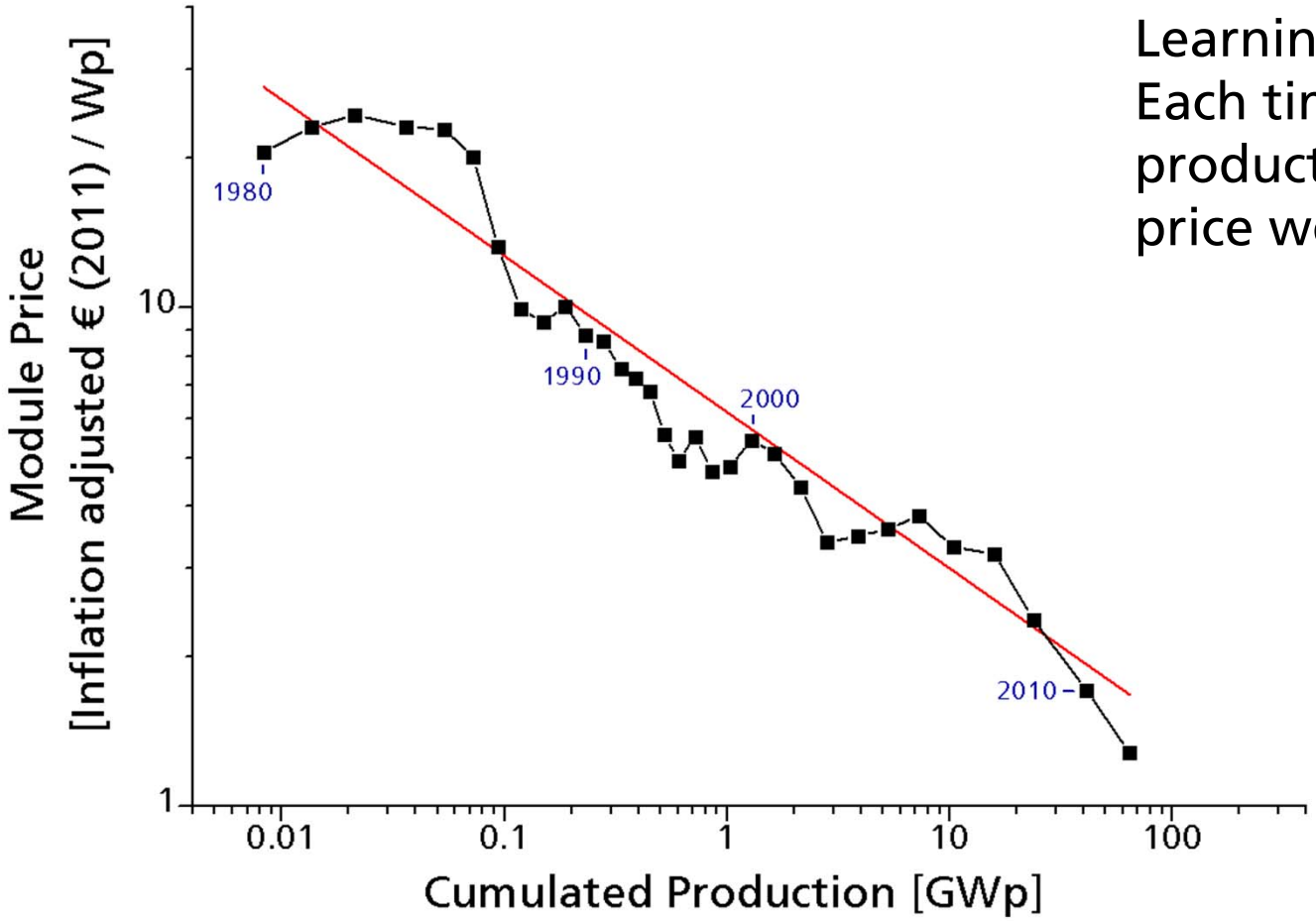
- flat plate and concentrating PV -

has been a success story

during the recent years!

Why is PV a Success Story?

The Price-Experience Curve for Flat Plate PV Modules



Learning Rate:
Each time the cumulative production doubled, the price went down by 19.5 %

Data: Navigant Consulting; EUPD module price (since 2006) Graph: PSE AG 2012

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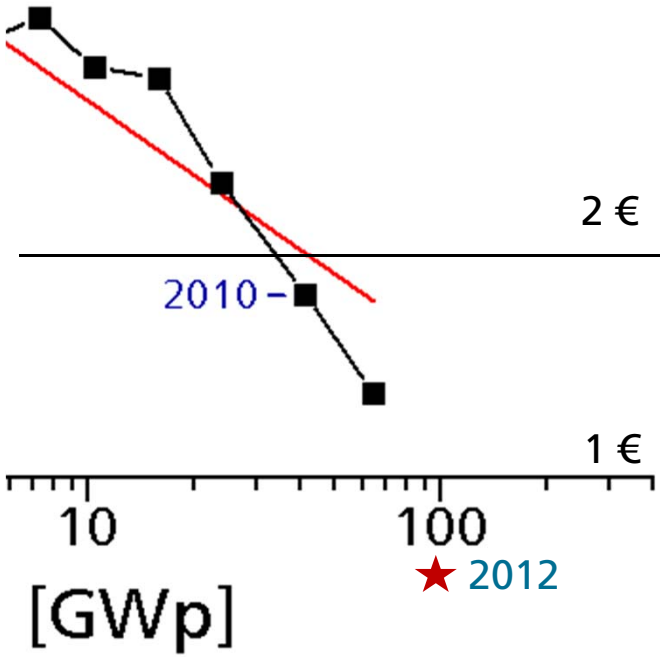
The Balance of the PV Market
The Actual Situation

Down side for the industry:

No profit

→ insolvencies



Up side for the customer:

Low prices

→ *13 €cent/kWh* electricity generation cost in Germany, fully financed!

→ The PV market will grow further!

A swing back to the price experience curve will be observed

Typical Photovoltaic Installations
Roof-Top and On-Ground

5 KW PV on a residential building

Photo: A.W. Bett, private

53 MW PV power plant at Spree-Neiße

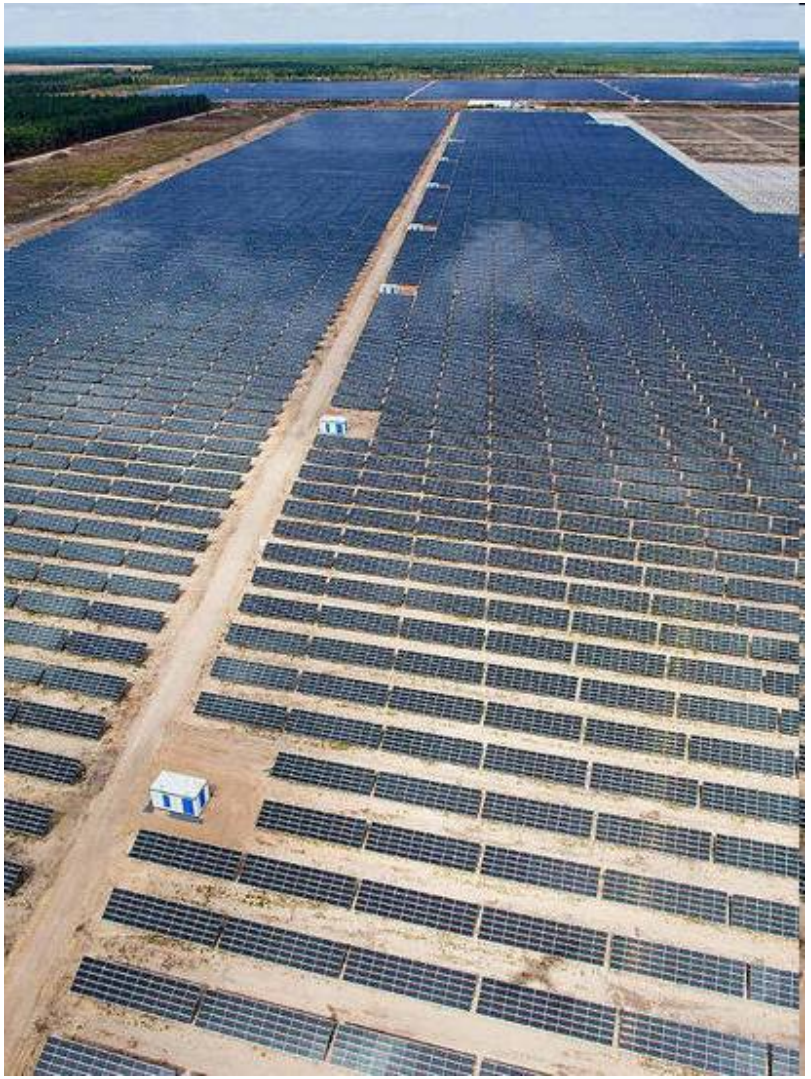


Photo: DPA

60 MWp Olmedilla Photovoltaic Park, La Mancha, Spain

Photo: knowledge.allianz.com

Photovoltaics

Standard PV and Concentrating PV

Light collection and conversion is one unit

Light collection
collection area

separated from

Light conversion
cell area

Concentration Factor = collection / cell area

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The Main Idea of Concentrating Photovoltaic Systems

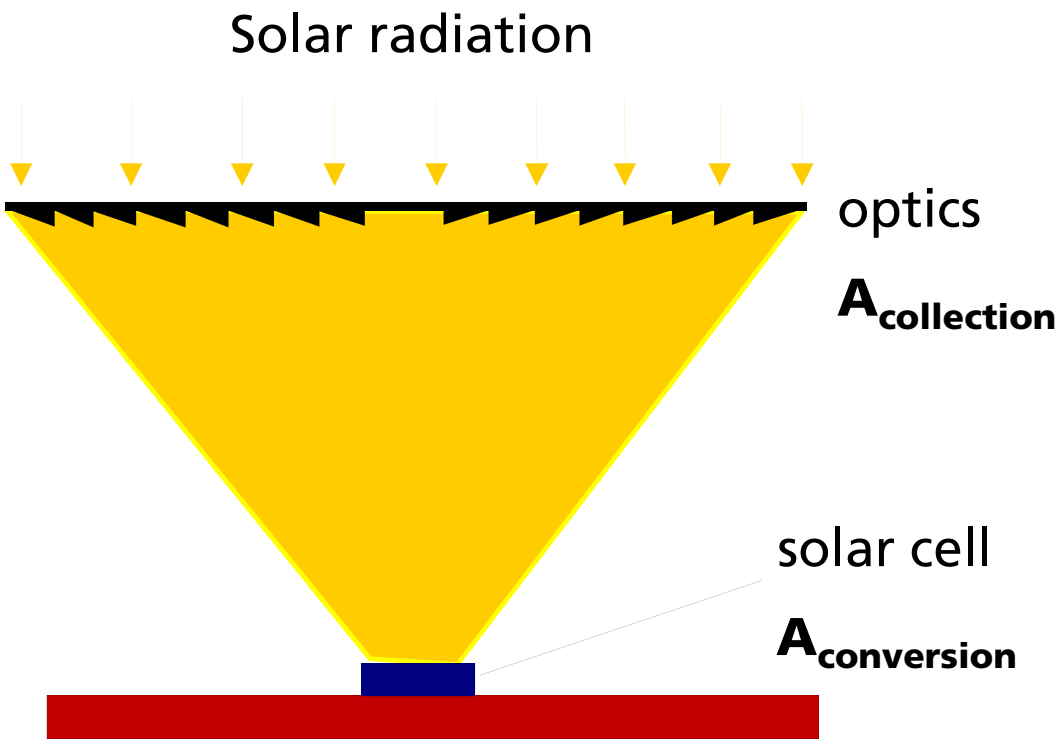
Functional decoupling of

- sunlight collection and
- location of conversion into electricity

$$C_{geo} = \frac{A_{collection}}{A_{conversion}}$$

→ Semiconductor (conversion area) is **expensive**

→ Option for **low cost** on €/kWh-level



Concentrator Photovoltaic (CPV) – the 70ies

The Idea is Old

Sandia National Laboratory:
1 kW CPV system, 1976

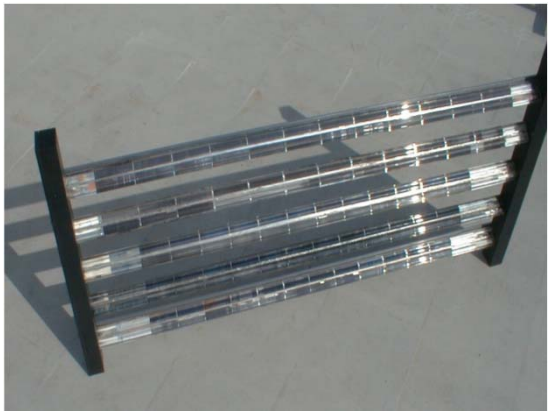
Concentrator Photovoltaic (CPV) – 2005

The Time of Prototypes

low: 2-3

Si-cells,

static



Courtesy: UPM, Madrid

medium: 30-100

modified Si-cells,

one-axis

Euclides, Tenerife

high: 300-1000

III-V-cells,

two-axis

Concentrix Solar, Freiburg

Concentrator Photovoltaic (CPV) – Today

Commercial Installations > 80 MWp

Low Concentration (LCPV)		High Concentration (HCPV)
2 – 30x		>300x

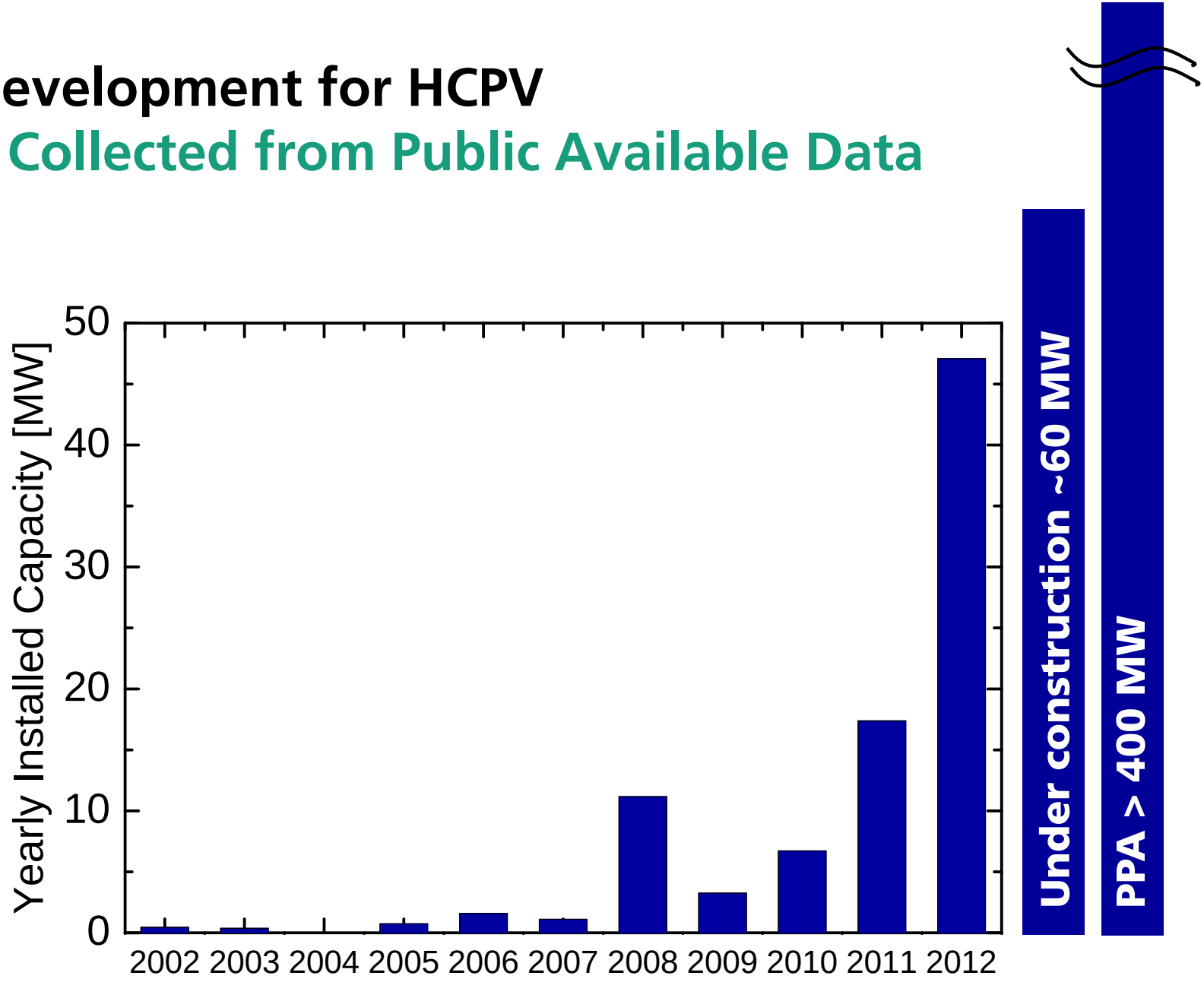
Solaria / Convert Italia, 2 MW in Italy

Amonix, 30 MW in USA

30 MW	**Production capacity**	200 – 500 MW

Market Development for HCPV

Numbers Collected from Public Available Data



Adapted from Wiesenfarth et al., EU-PVSEC, 2012

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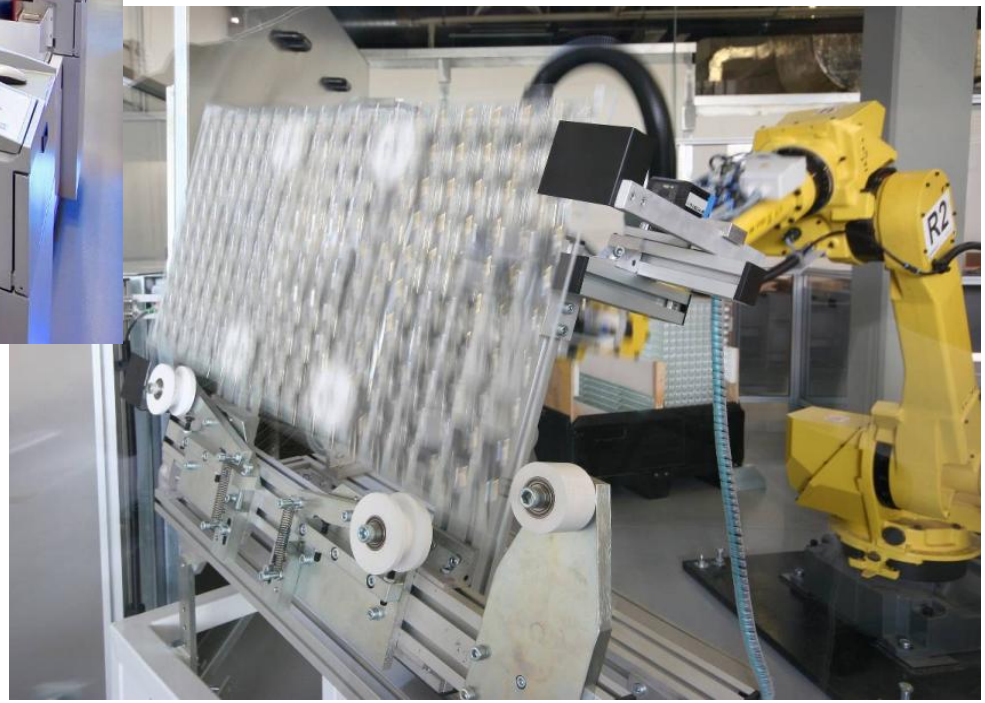
Concentrator Photovoltaic (CPV) – Today

Industrial Manufacturing is a Key for Quality and Low Costs



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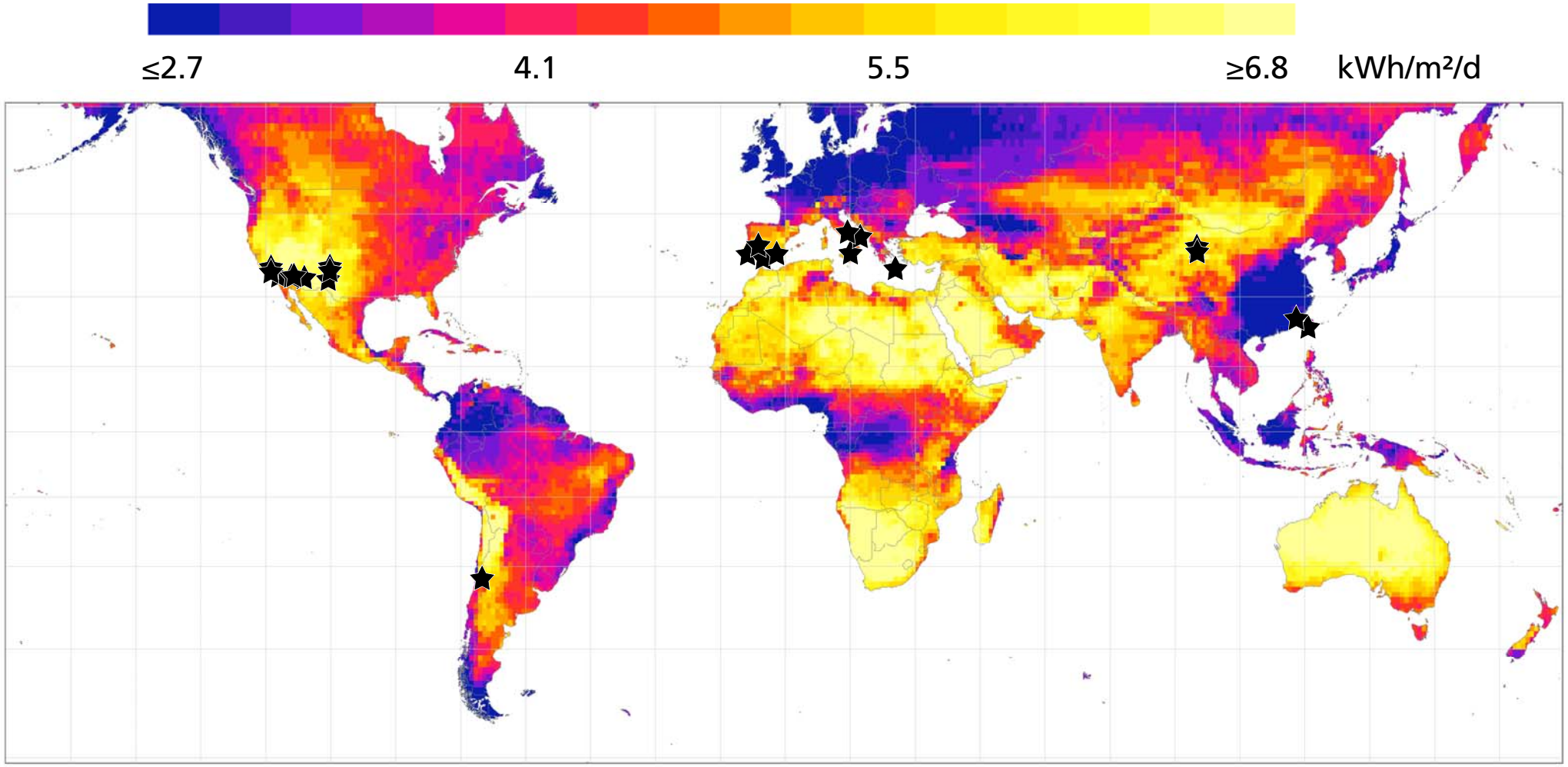
Concentrator Photovoltaic (CPV) – Market

HCPV-Installations of 1 MWp and more



Source of DNI map: Soitec Solar

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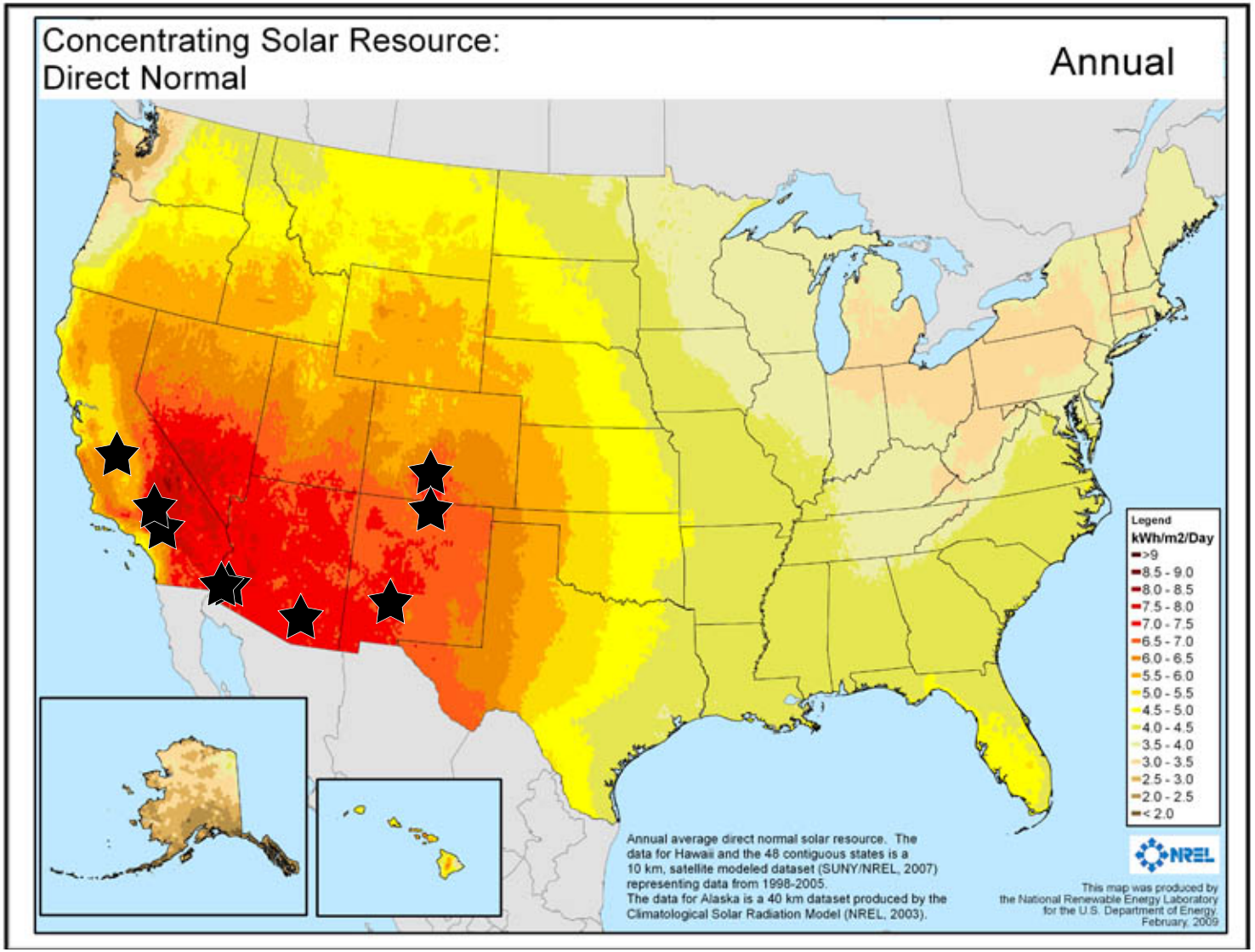
Concentrator Photovoltaic (CPV) – Market in USA



Operational CPV Power Plants with 1 MW or more

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Largest CPV Power Plant with 30 MW in Colorado

Several CPV Power Plants with ≥ 1 MWp
In the Southwest of the USA

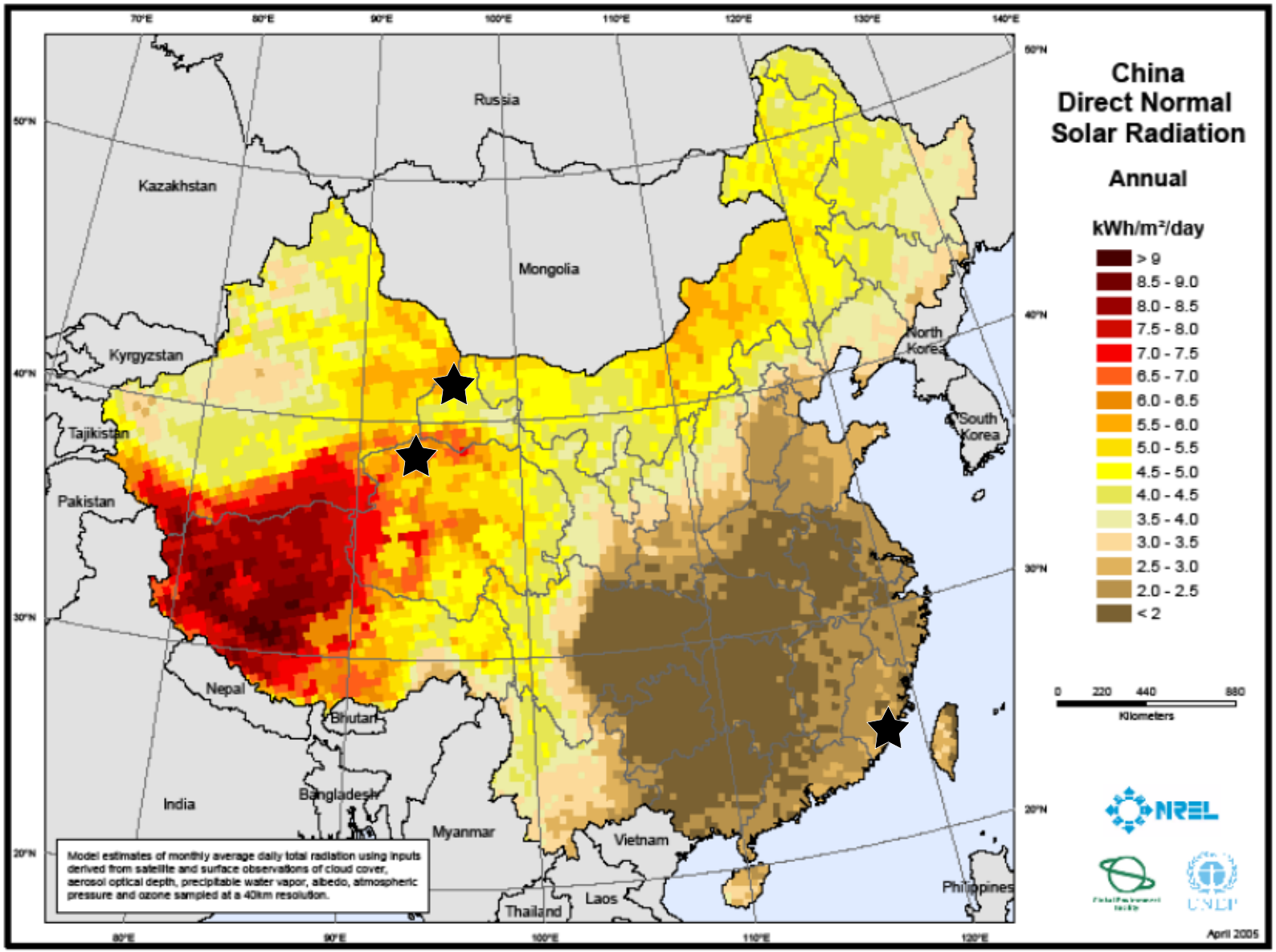
Soitec

173 trackers

SolFocus

122 trackers

Concentrator Photovoltaic (CPV) – Market in China



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Project Location: Golmud, Qinghai Province

5 MWp in operation / 50 MWp under construction

- altitude 2800 m, average annual solar radiation: 2676 hours/year
- annual average temperature: 5.3 ° C (high 18 ° C, low -9 ° C)

Isofoton

100 kWp in operation

BEGI (Beijing General Industries)

1 MWp in operation

Project Location: Golmud, Qinghai Province

5 MWp in operation / 50 MWp under construction

- Suntrix

  700 kWp in operation

- Suncore

  3 MWp in operation,

  50 MWp under construction

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Project Location: Hami, Xinjiang
460 MWp planned

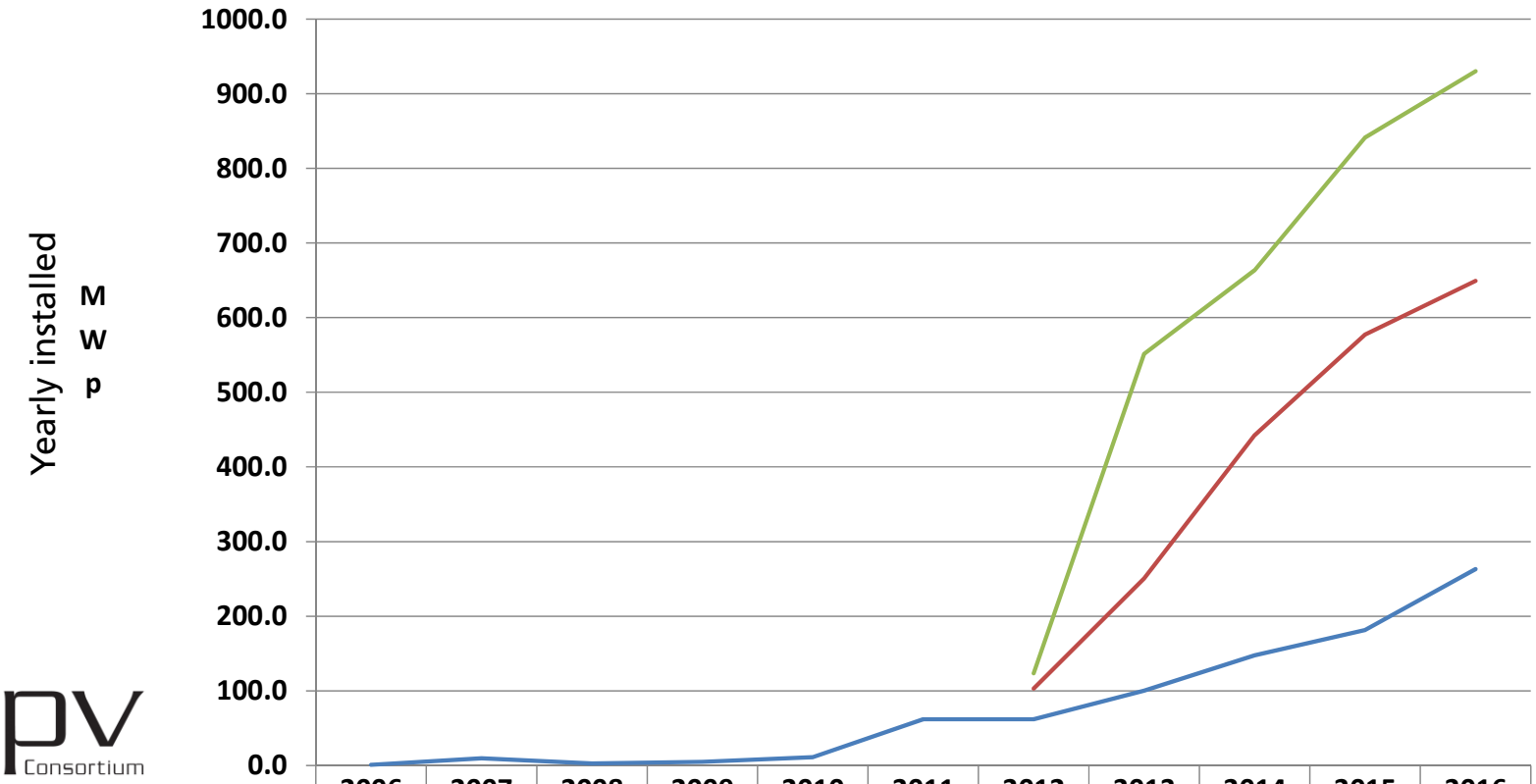
- altitude 1300 m, DNI 2335 kWh/m²/a
- extreme temperature differences (high 34 °C, low -16 °C)

Planned Hami PV/CPV Park (460 MWp)

Focusic: 3 MW of Concentrix™ technology under construction
17 MW in planning

Concentrator Photovoltaic (CPV) – Future Market

The View of Analysts: Navigant, Paula Mints



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
HCPV History & Low Forecast	0.7	9.5	2.8	5.0	11.2	62.0	61.8	100.3	147.5	181.5	263.3
HCPV Conservative Forecast							103.0	250.8	442.5	577.5	649.4
HCPV Accelerated Forecast							123.6	551.7	663.8	841.5	930.2

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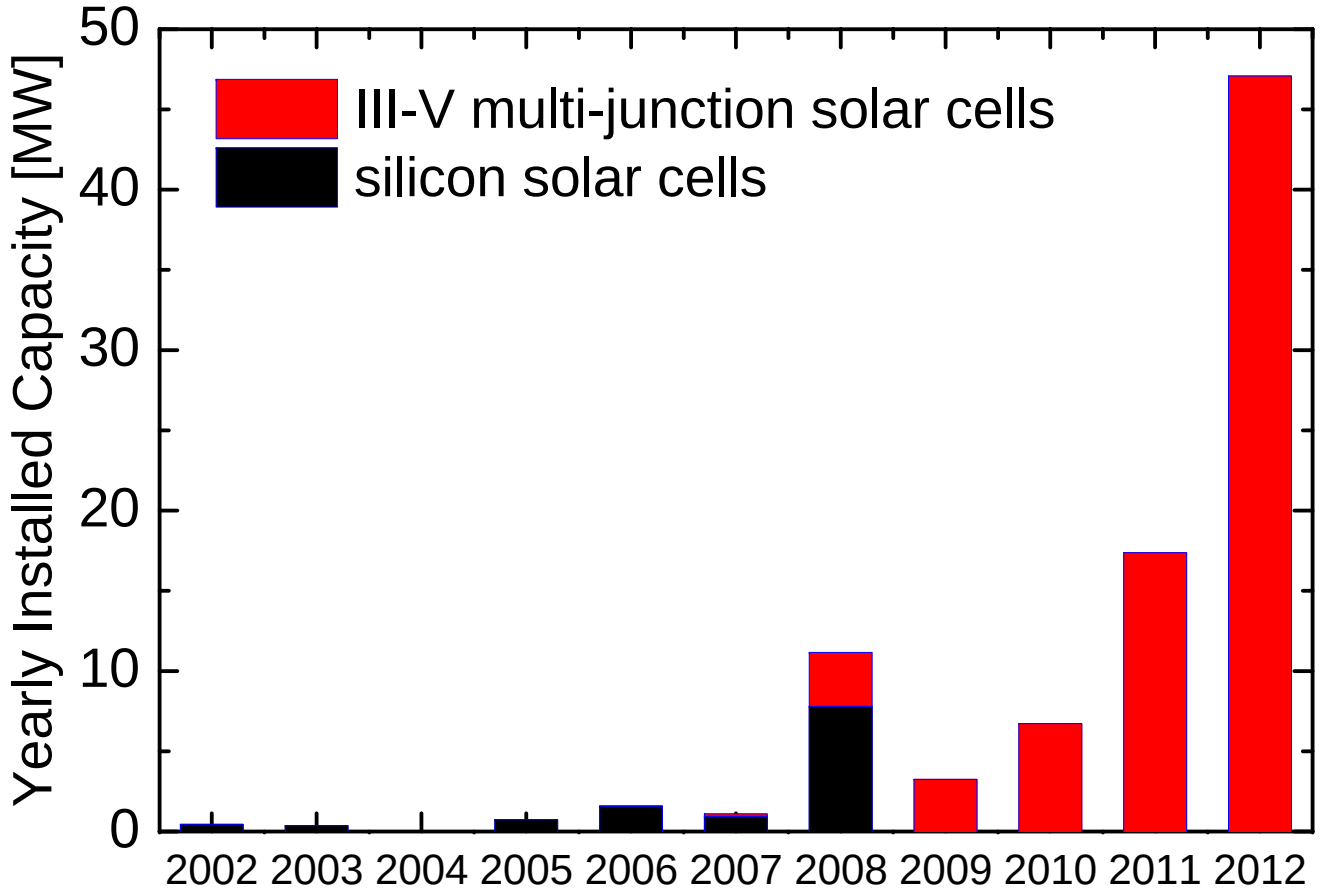
High Concentrator Photovoltaic (HCPV)

Yearly Installed Capacity

2005 introduction of III-V multi-junction solar cells



Adapted from Wiesenfarth et al., EU-PVSEC, 2012

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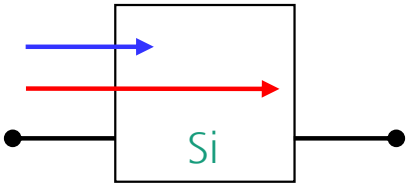
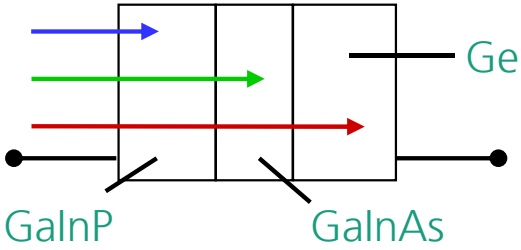
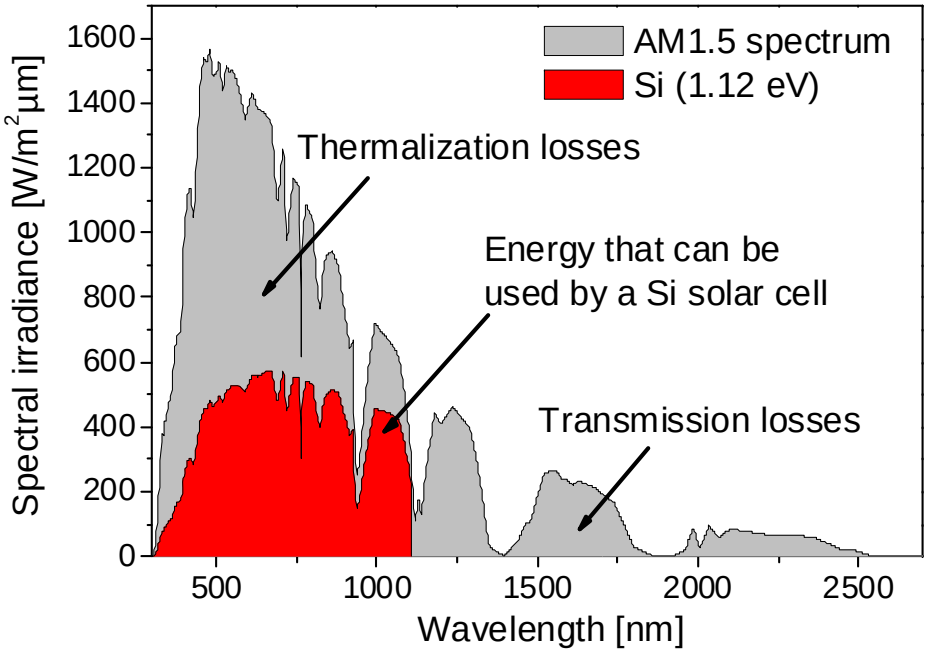
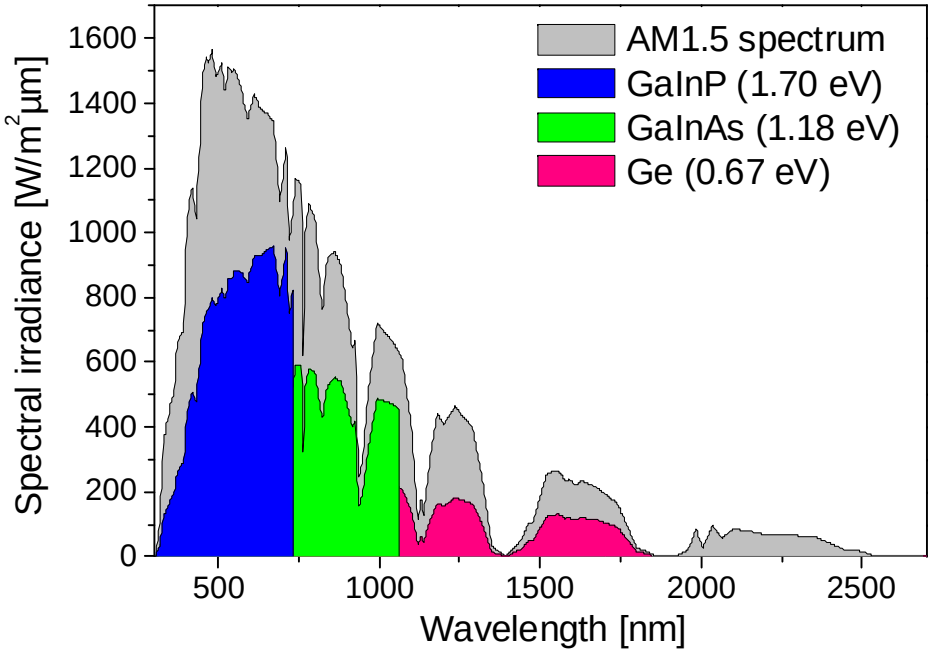
The Benefit of Multi-Junction Solar Cells

Reduction of Thermalisation and Transmission Losses!









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The “Standard” III-V-based Triple-junction Solar Cell

Structure

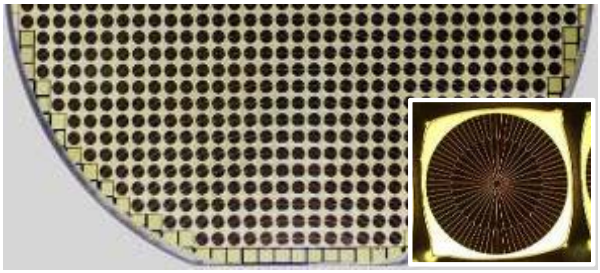
- 19 layers
- doping levels:

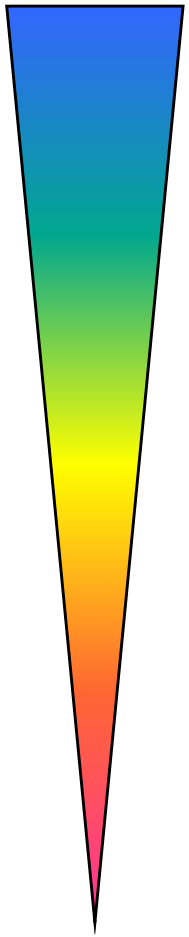
  $5*10^{16} – 2*10^{20}\ cm^{-3}$
- thicknesses:

  0.02 – 4.0 µm
- layer compositions:

  binary – quaternary

  As/P hetero-interfaces





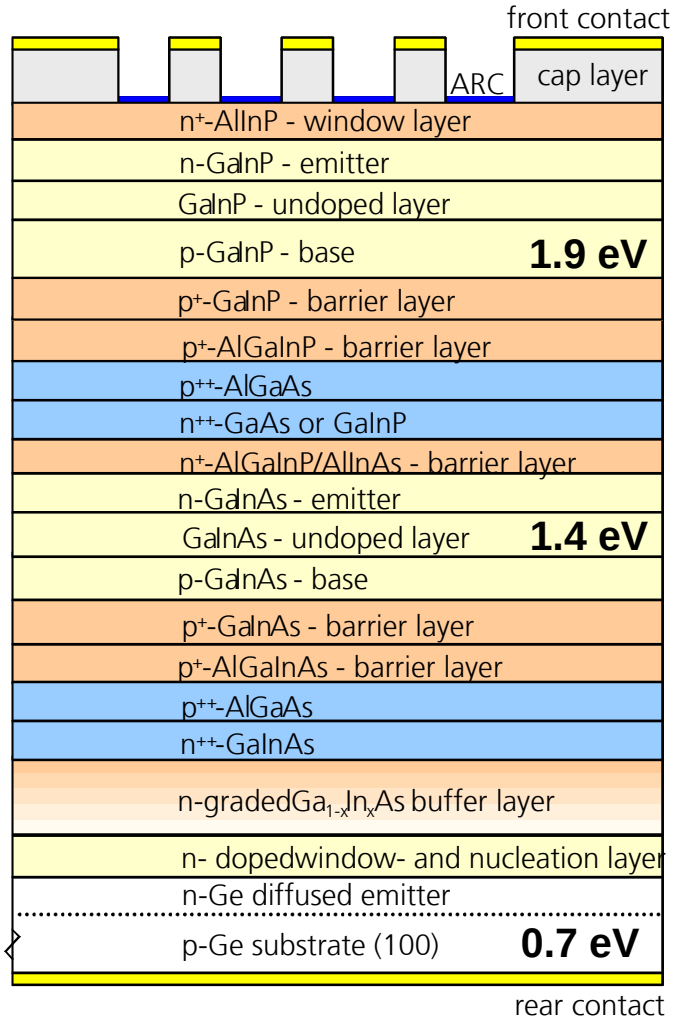
GaInP

tunnel diode

GaInAs

tunnel diode

Ge



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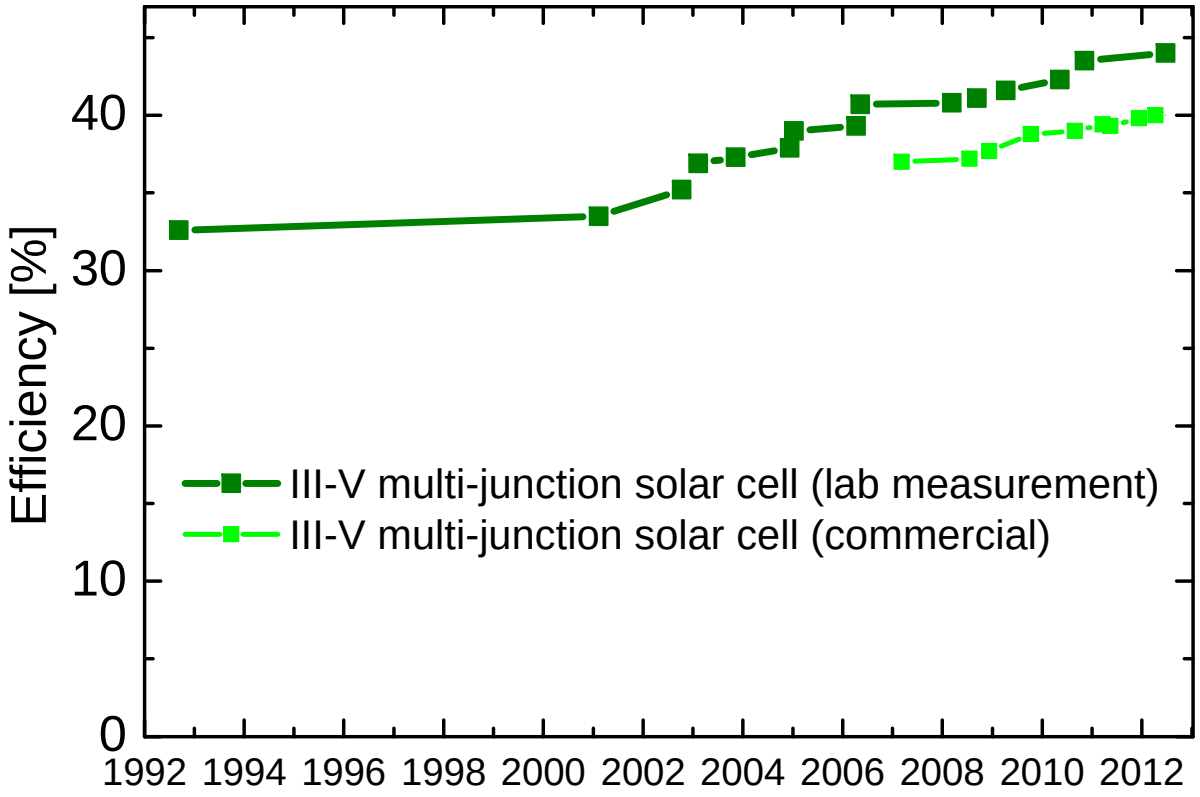
Multi-junction Solar Cells
The Key for High Efficiencies

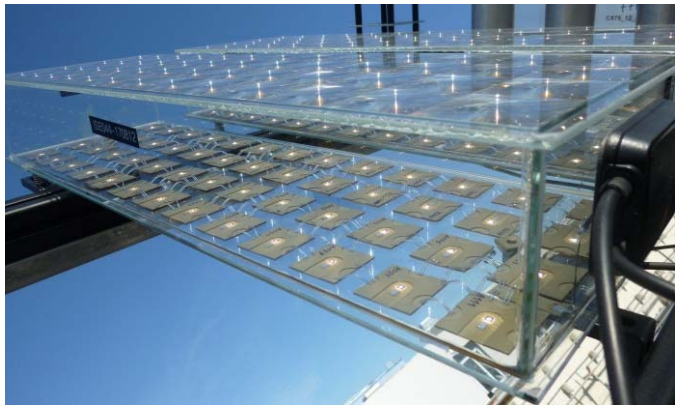
Solar Junction	44.0% @ 947x
Sharp	43.5% @ 306x
Spire	42.3% @ 406x
Spectrolab	41.6% @ 364x
AZUR Space	41.2% @ 453x
Fraunhofer ISE	41.1% @ 454x

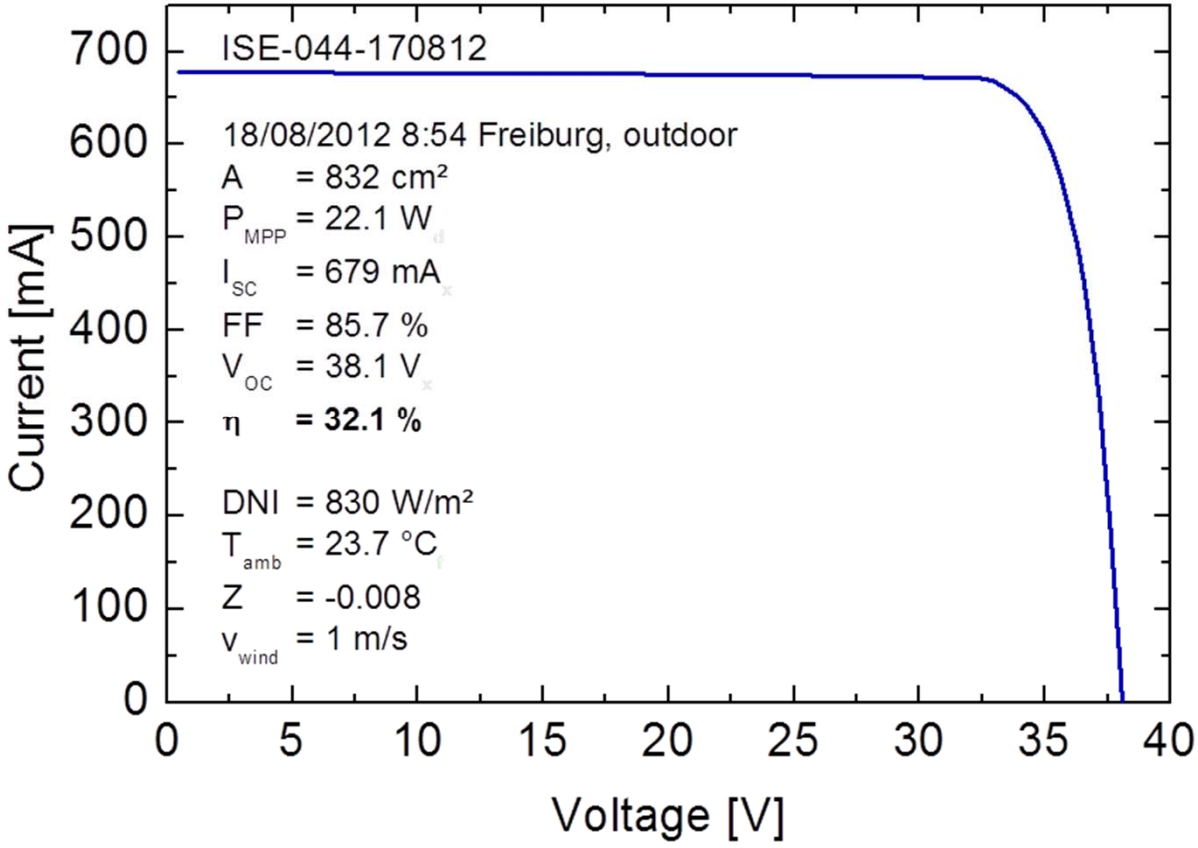


Graphic adapted from Wiesenfarth et al., EU-PVSEC, 2012
Data for solar cell efficiencies: Green et al. Progress in Photovoltaics (1993-2012)

CPV Module
Outdoor Measurement for FLATCON®-Module

- Outdoor operating DC-efficiency: 32.1 %
- 52 triple-junction solar cells from AZUR Space





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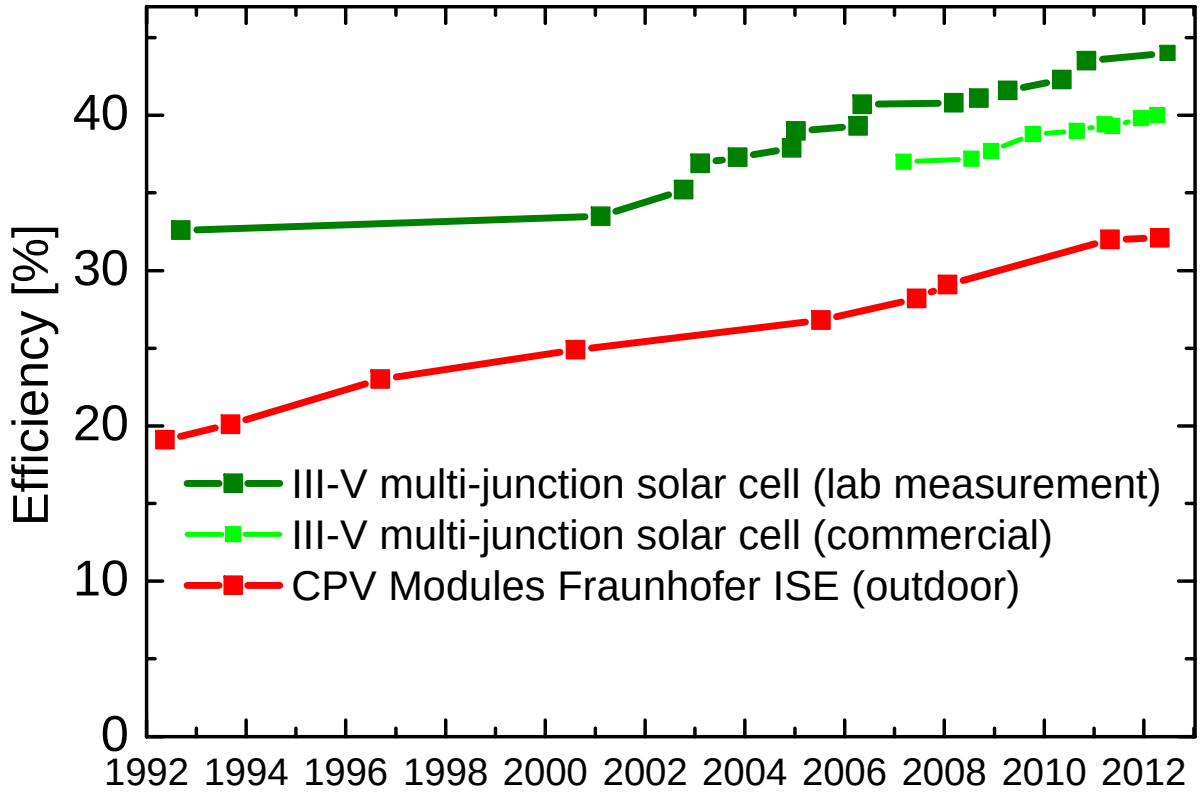
CPV Module
Using the High Efficiency

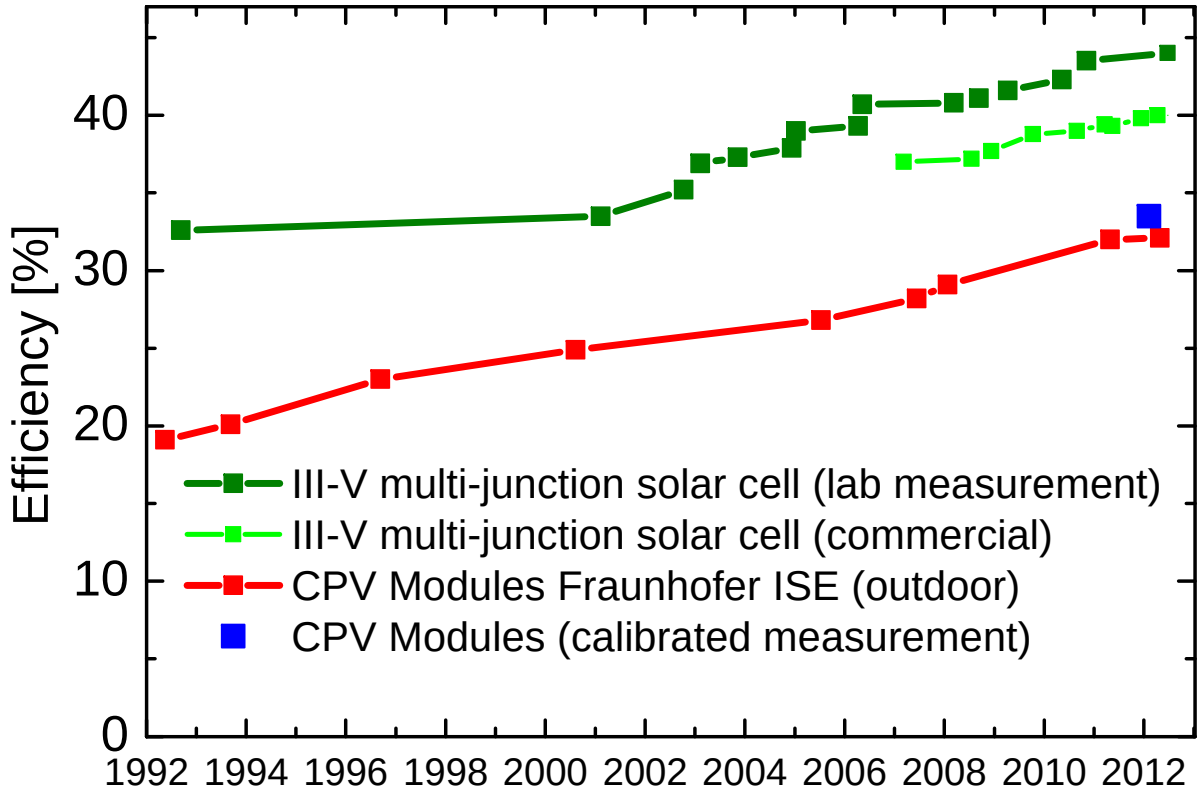


Semprius	33.9 %
Fraunhofer ISE	32.1 %

Graphic adapted from Wiesenfarth et al., EU-PVSEC, 2012
Data for solar cell efficiencies: Green et al. Progress in Photovoltaics (1993-2012)

CPV Module
Using the High Efficiency

Amonix	33.5 % (SOC)
Semprius	33.9 %
Fraunhofer ISE	32.1 %



Graphic adapted from Wiesenfarth et al., EU-PVSEC, 2012
Data for solar cell efficiencies: Green et al. Progress in Photovoltaics (1993-2012)

CPV Systems
Basis for High Energy Yield of the System

Reported values:
25 – 27 %

Abengoa

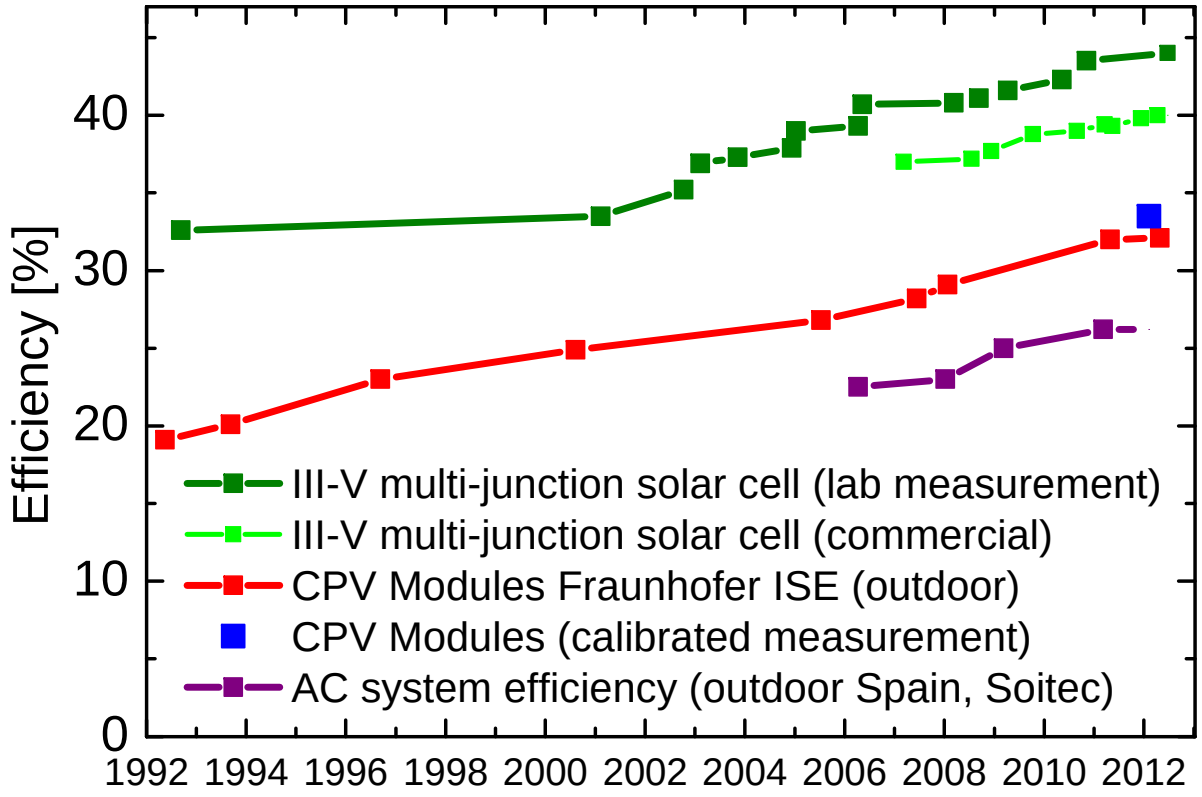
Amonix

Emcore

Soitec

SolFocus

Suntrix



Graphic adapted from Wiesenfarth et al., EU-PVSEC, 2012
Data for solar cell efficiencies: Green et al. Progress in Photovoltaics (1993-2012)

Advantages of HCPV

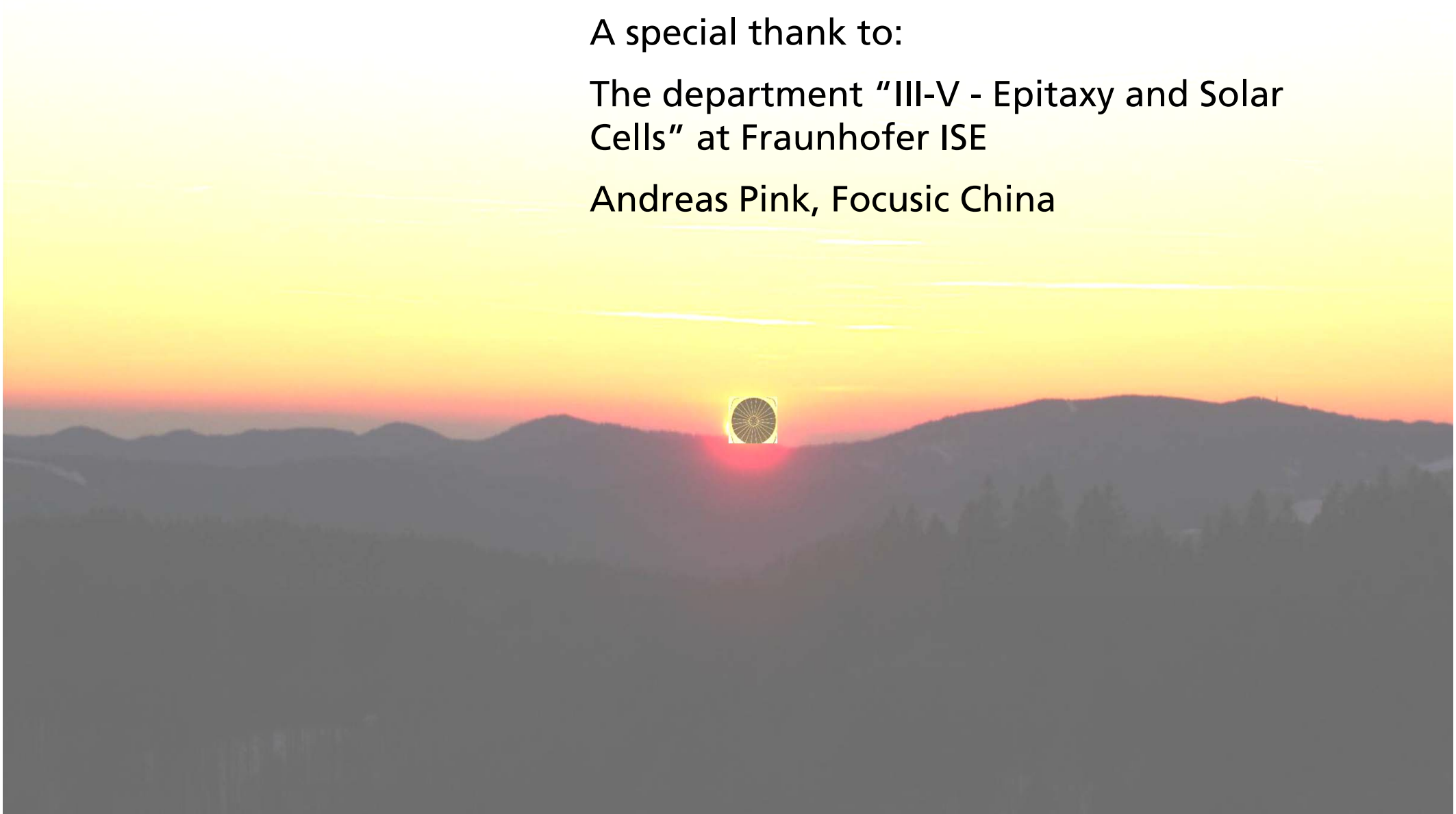
- High system efficiencies between 25 and 27 %
- Dual use of land possible
- No water needed during operation – only small amounts for cleaning
- Low energy payback time (6 – 8 months)
- Electricity costs of less than 10 €cent/kWh

Acknowledgements

A special thank to:

The department “III-V - Epitaxy and Solar Cells” at Fraunhofer ISE

Andreas Pink, Focusic China



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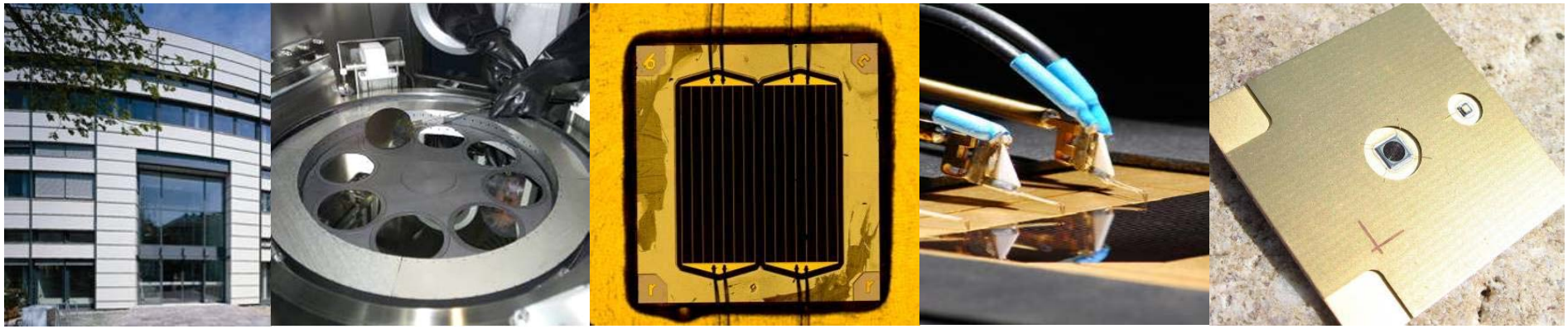

Fraunhofer Institute for Solar Energy Systems ISE

Dr. Andreas W. Bett

www.ise.fraunhofer.de

andreas.bett@ise.fraunhofer.de