
Alexandre Edmond Becquerel
1821-1891

Becquerel Prize 2009,

Hamburg, 24th European PVSEC

# Thanks!





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# Thanks!

1997

2009





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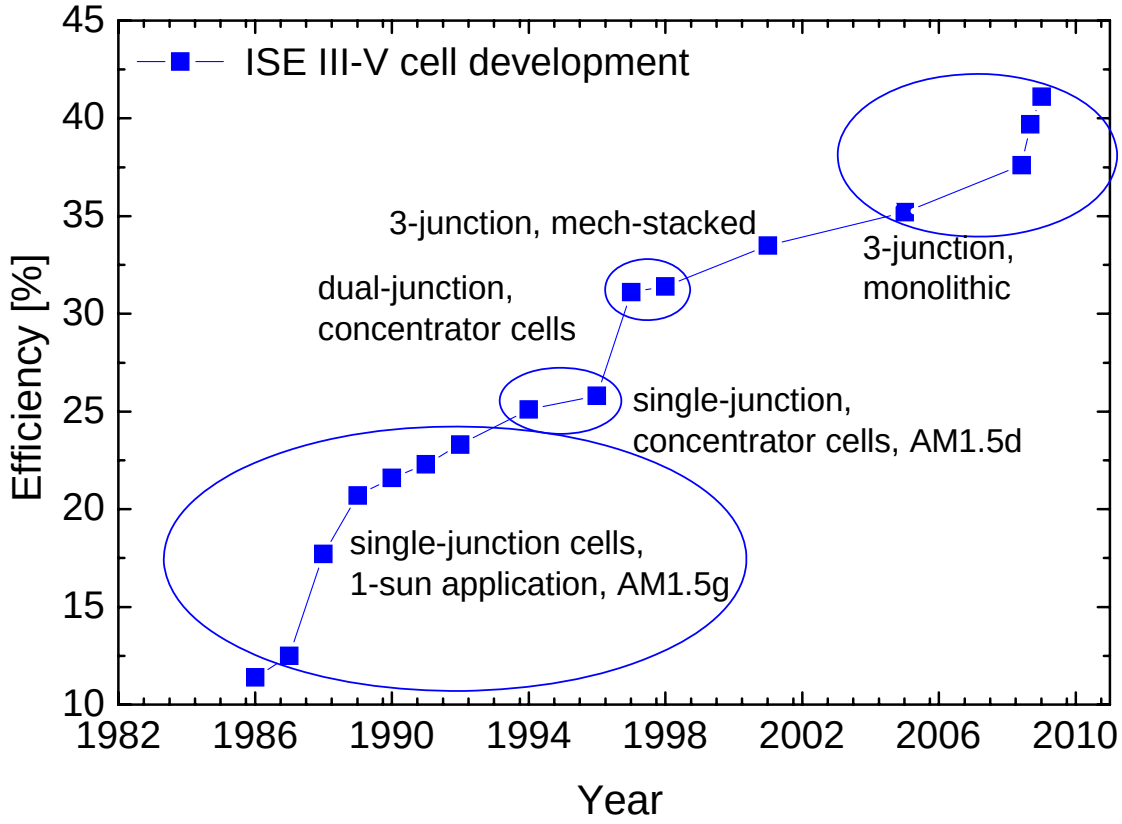
# Thanks!

# PV-Efficiency Revolution by Evolution

Successful research needs an excellent and stable environment:

- continuous financial support
- a good infra structure
- an excellent team
- **fun at work!!**





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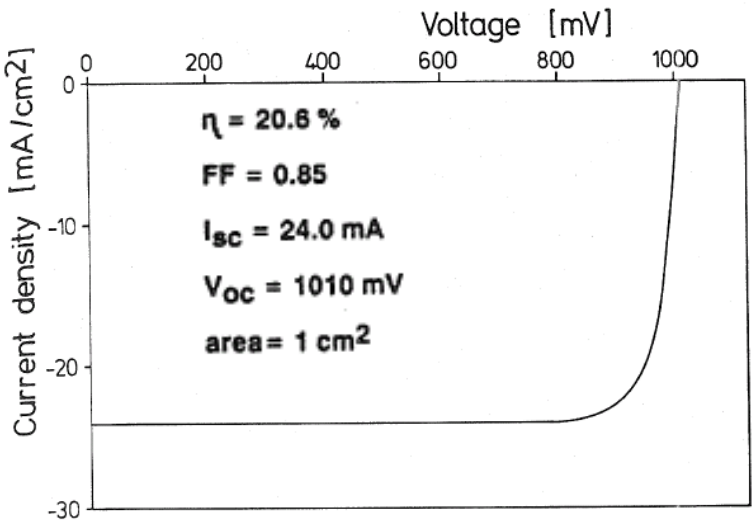
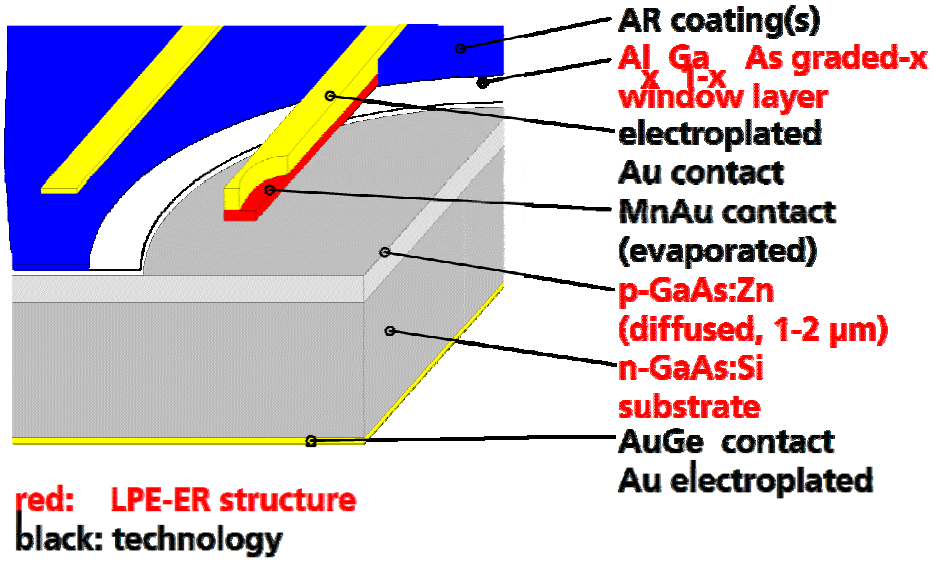
# 1989: The first Cell above 20 %!

HIGH EFFICIENCY ISOTHERMAL LPE GROWN GaAs SOLAR CELLS

WITH HIGH FILL FACTOR

A.Bett, F.Lutz, T.Nguyen, W.Wettling
Fraunhofer-Institut für Solare Energiesysteme,
Oltmannsstr.22, D-7800 Freiburg, FRG



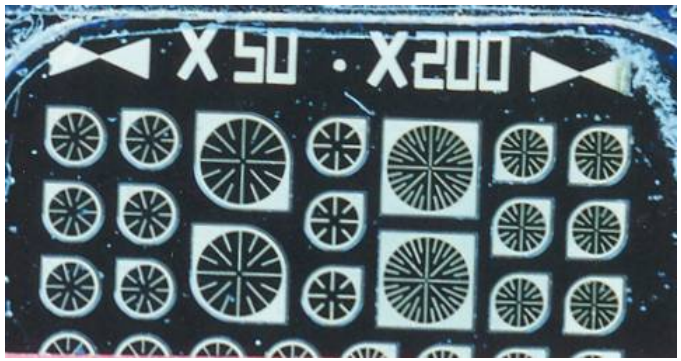



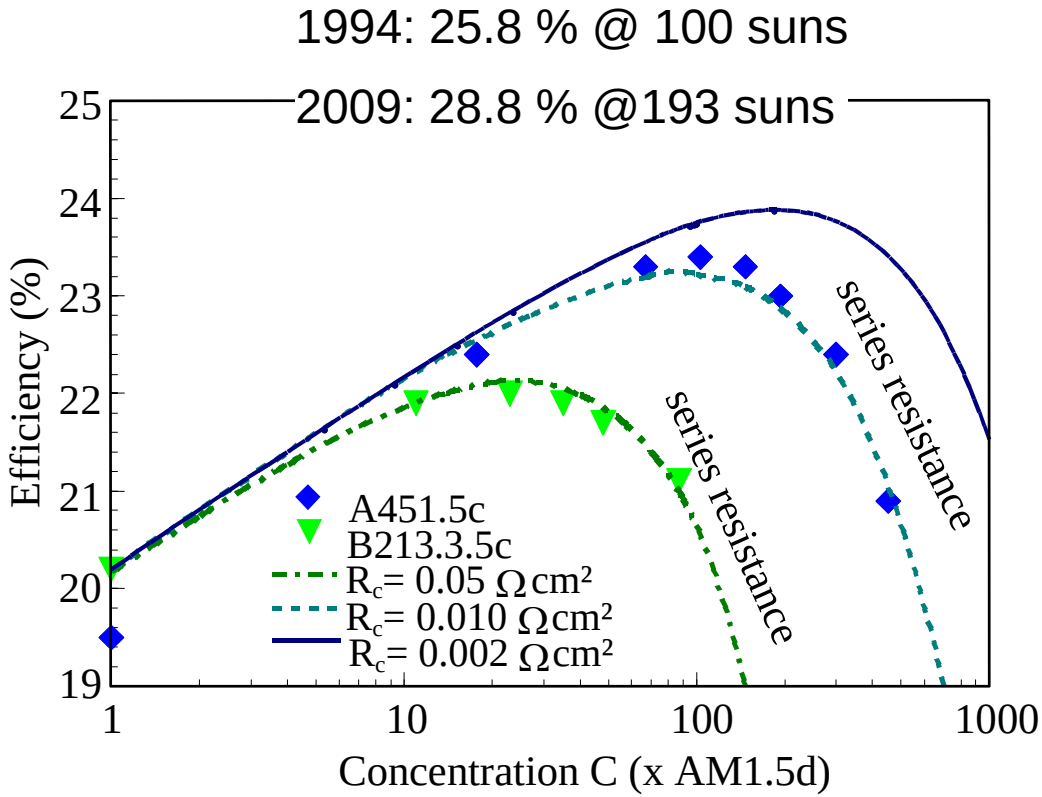

Bett, Lutz, Nugyen, Wettling, 9th European PVSEC; Freiburg 1989, p.510

# Starting in 1992: Concentrator Cell Development

Topics of interest:

- grid layout
- low ohmic contacts
- characterization of cells




Blieske, Bett, Duong, Schetter, Sulima, 12th Eurppean PVSEC, Amsterdam, 1994, 1409

Bett, Dimroth, Stollwerck, Sulima, Appl. Phys. A 69, 119-129 (1999)





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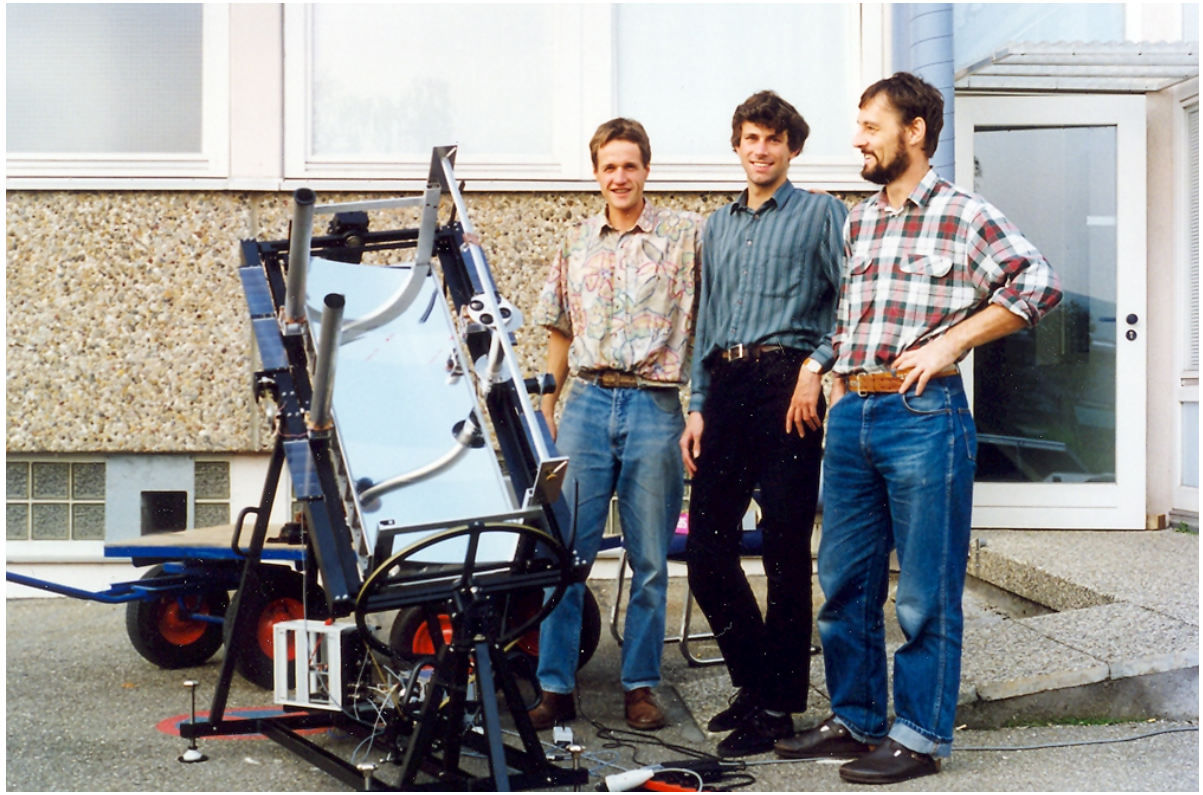
# In 1994: First Concentrator Modules, Trackers…

Topics of interest:

- module testing
- tracker
- concentrator optics

U. Blieske
A. Wegner
A. Bett



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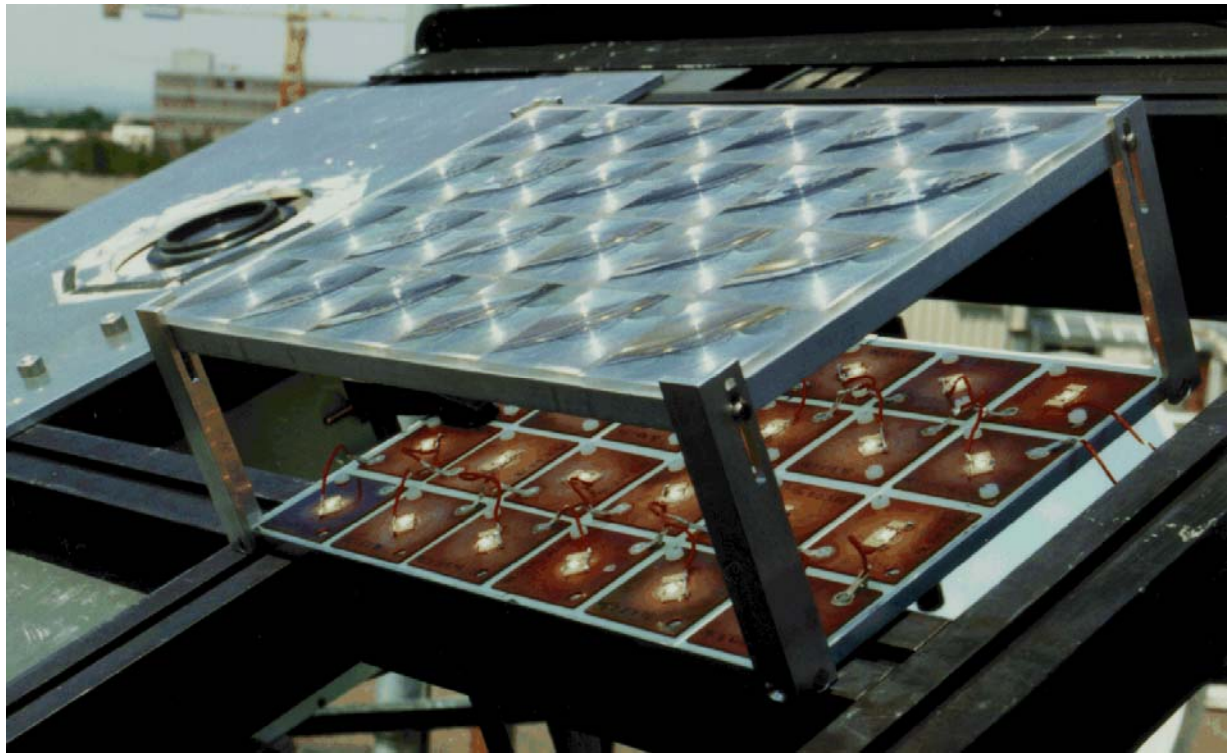
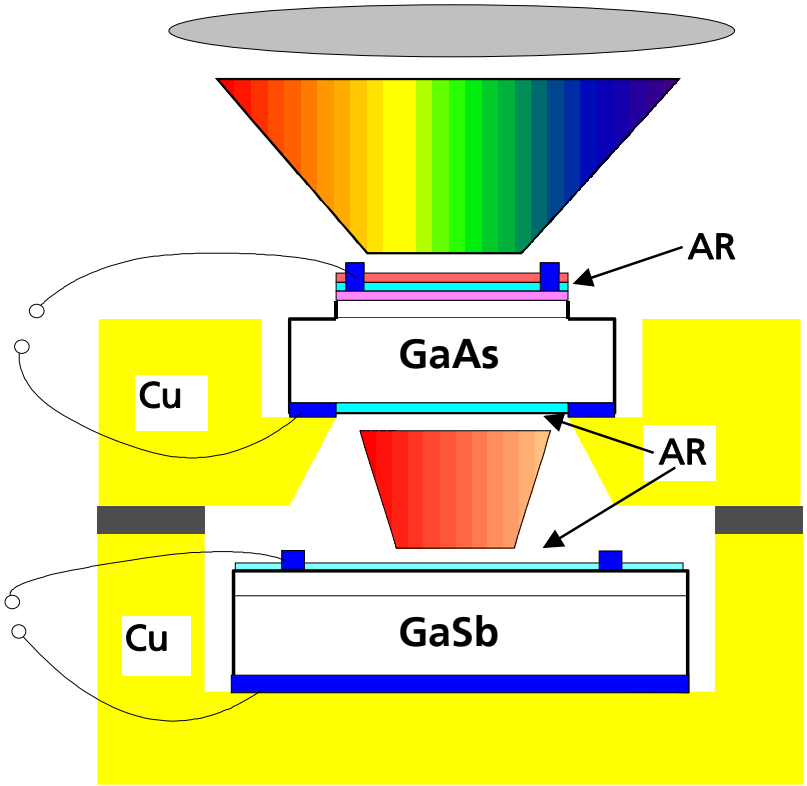


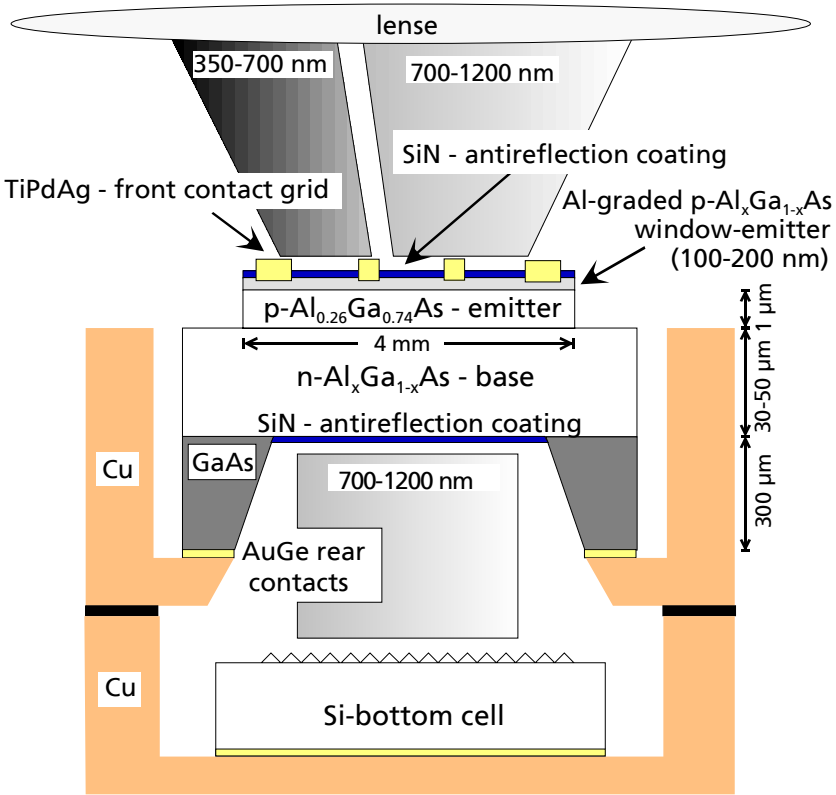
Testmodule with GaAs single-junction cells and Fresnel lenses: 19 % efficiency

Blieske, Bett, Duong, Schetter, Sulima, 12th Eurppean PVSEC, Amsterdam, 1994, 1409

# 1994 – 1999: Mechanical Stacked Cells: GaAs-GaSb; AlGaAs-Si




Efficiencies up to 31.4 % @ 100suns

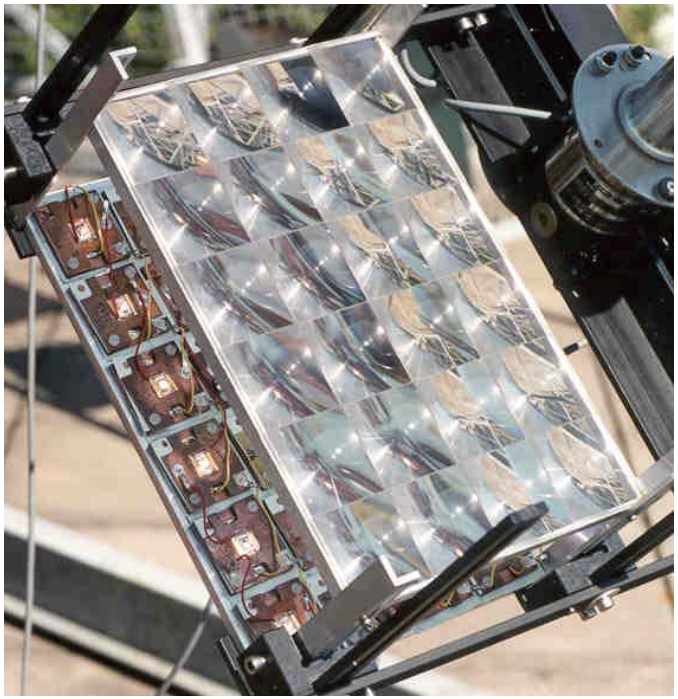


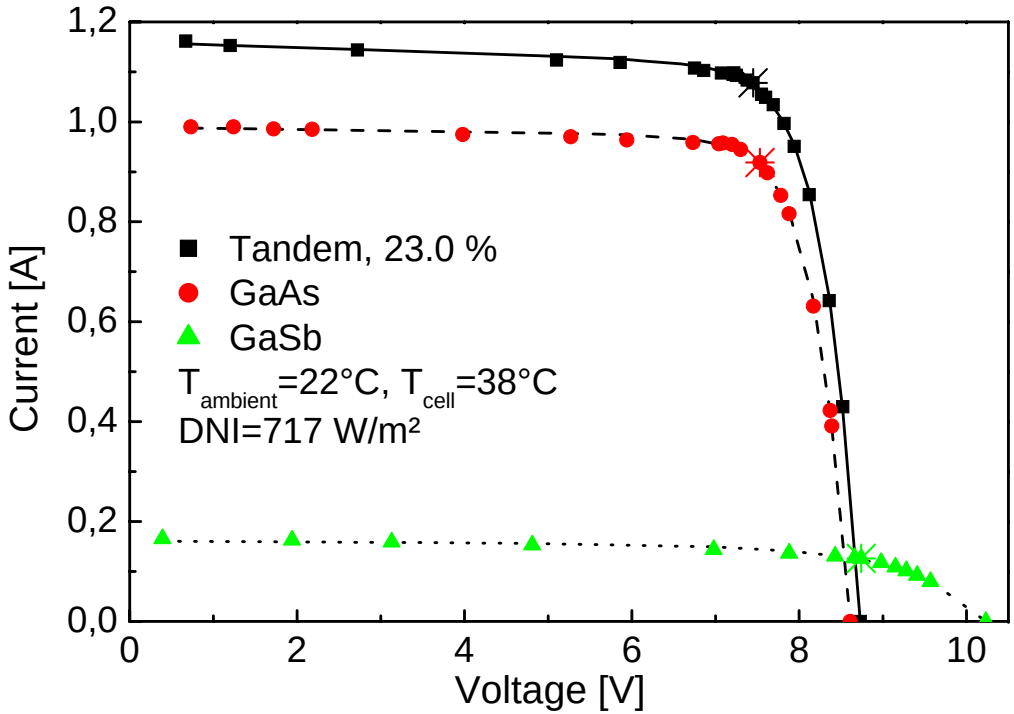

Efficiencies up to 26% @ 20suns

Bett, Keser, Stollwerck, Sulima, Wettling, 26th IEEE PVSC, Anaheim, 1997, 931

Dimroth, Bett, 14th European PVSC; Barcelona, 1997, 1759

# 1997: Module with Operating Efficiency of 23 %






Bett, Keser, Stollwerck, Sulima, Wettling, 26th IEEE PVSC, Anaheim, 1997, 931





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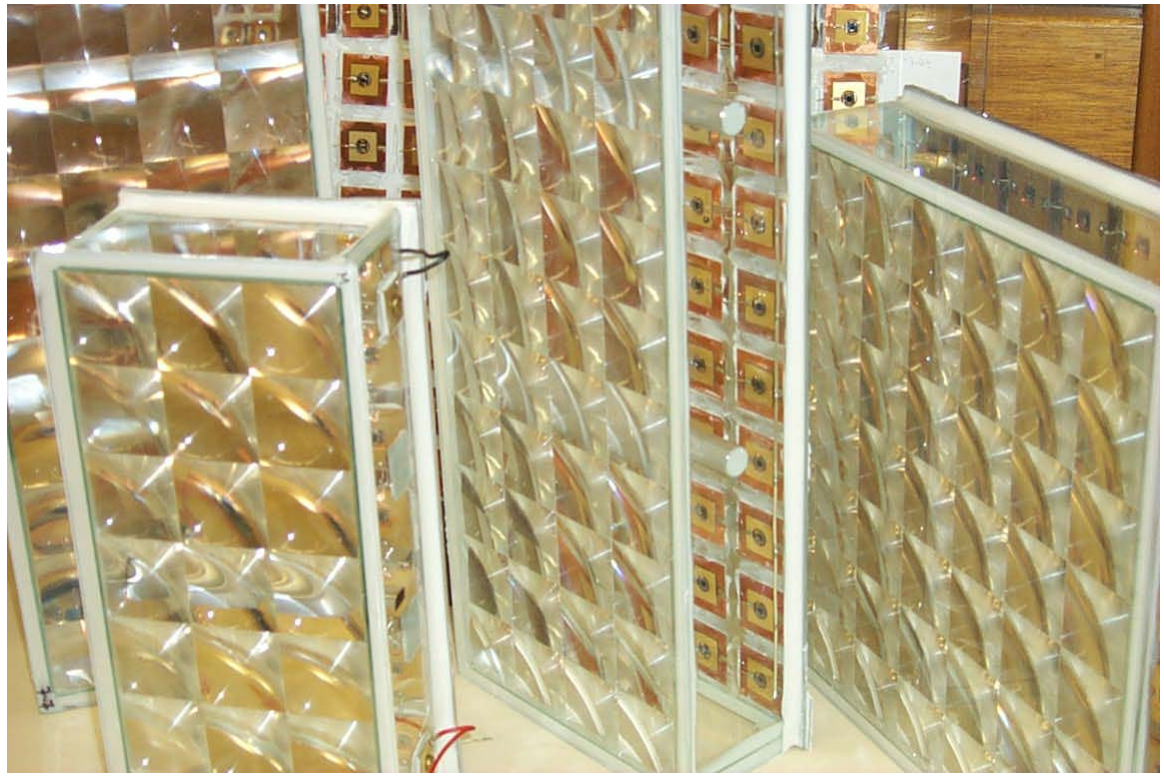
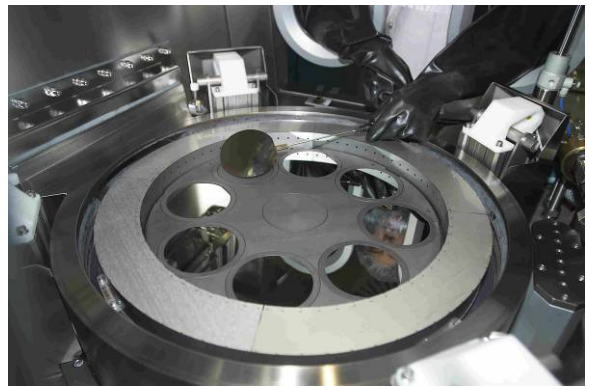
# 1998: First FLATCON-type Modules with Operating Efficiency of 17-19 %

## Developed in co-operation with IOFFE, Prof. Rumyantsev, Prof. Andreev



Rumyantsev, Andreev, Bett, Dimroth, Hein, Lange, Shvarts, Sulima, 28th IEEE PVSC; Alaska, 2000, 1169

# 1998: Industrial Feasible MOVPE Equipment







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# since 1999: The Development of Monolithic Tandem Cells

standard

$Ga_{0.51}In_{0.49}P$ top cell

GaAs middle cell

GaAs (or Ge bottom cell)

GaInP, GaAs
and
substrate lattice matched
$300 < \lambda < 900$

ISE concept

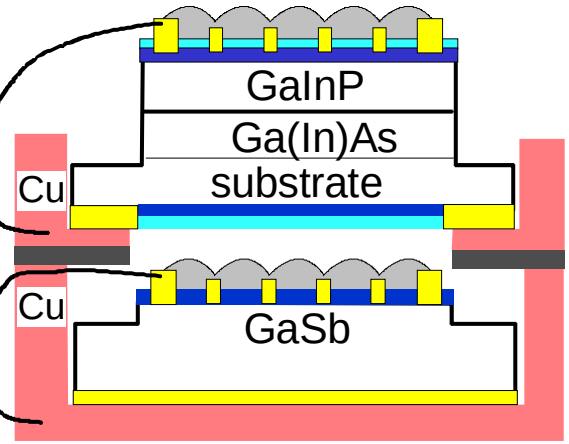
$Ga_{0.35}In_{0.65}P$ top cell

$Ga_{0.83}In_{0.17}As$ middle cell

$Ga_{1-x}In_xAs$ buffer

GaAs (or Ge bottom cell)

GaInP and GaInAs
lattice matched,
substrate mismatched
$300 < \lambda < 1050$ nm
higher efficiency potential




2001: **33.5 % (C = 308)**





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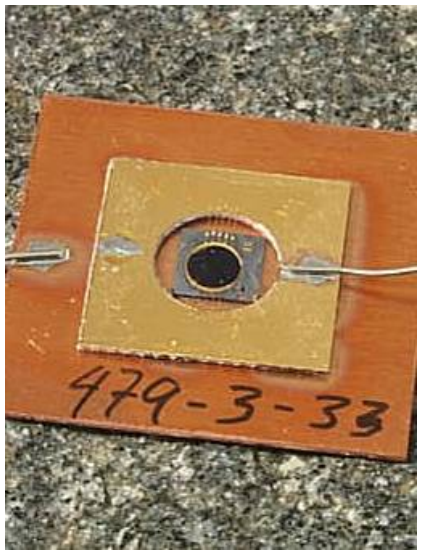
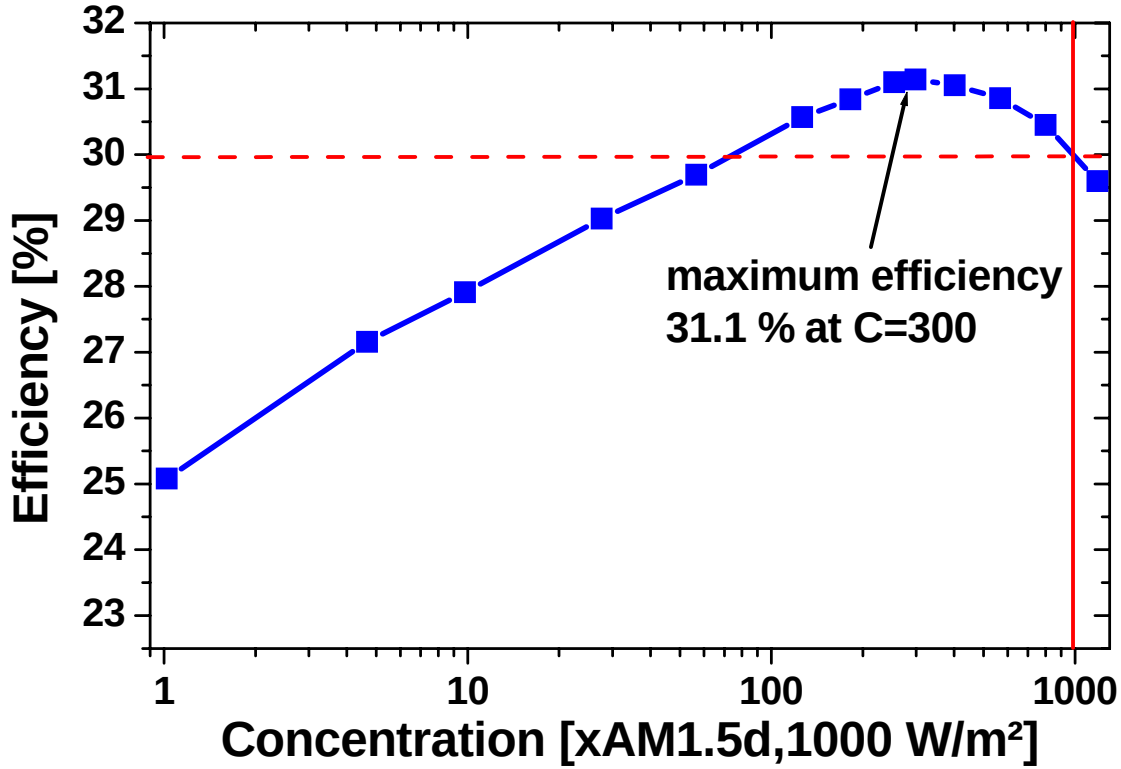
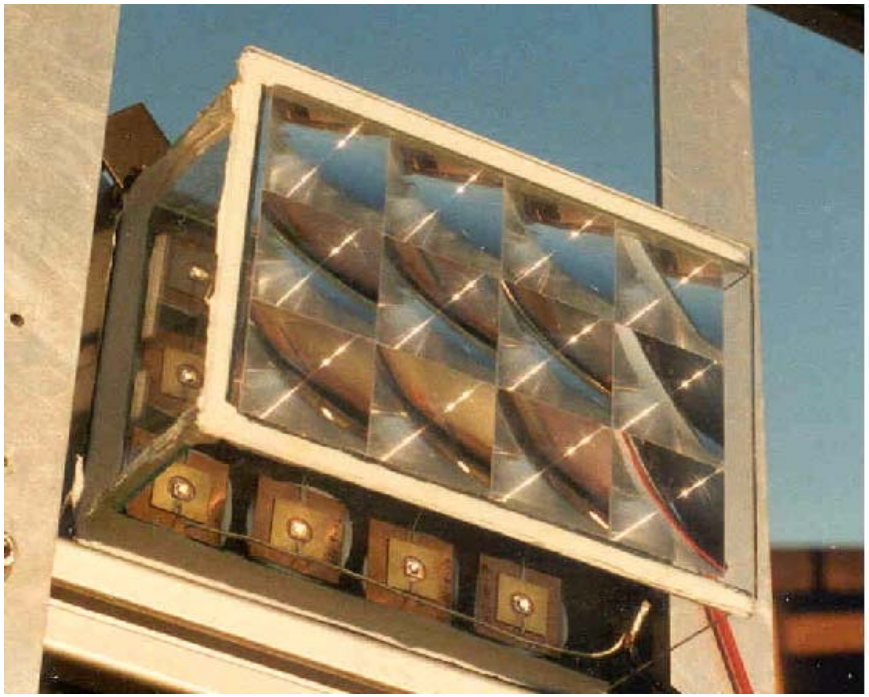
# 2000: Exceeding 30 % Efficiency with Dual-junction Cell of $Ga_{0.35}In_{0.65}P$/ $Ga_{0.83}In_{0.17}As$!

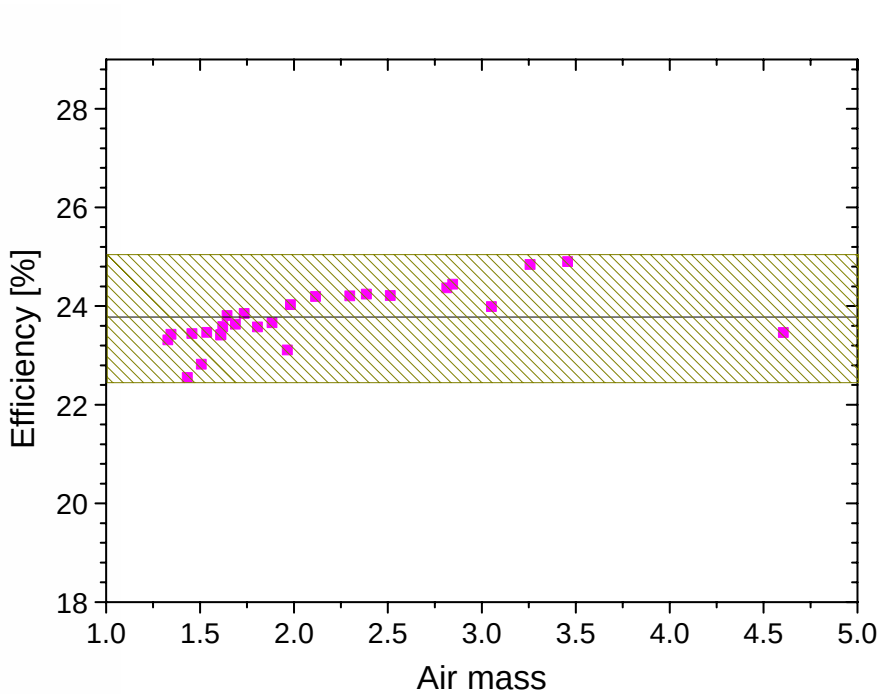



Bett, Dimroth, Lange, Meusel, Beckert, Hein, van Riesen, Schubert, ,28th IEEE PVSC, Anchorage, 2000, 961

# 2001: Concentrator Module with monolithic Tandem Cells exceeds 25 %






Hein, Meusel, Baur, Dimroth, Lange, Siefer, Tibbits, Bett, Andreev, Rumyantsev, 17th European PVSEC, Munich, 2001, 496





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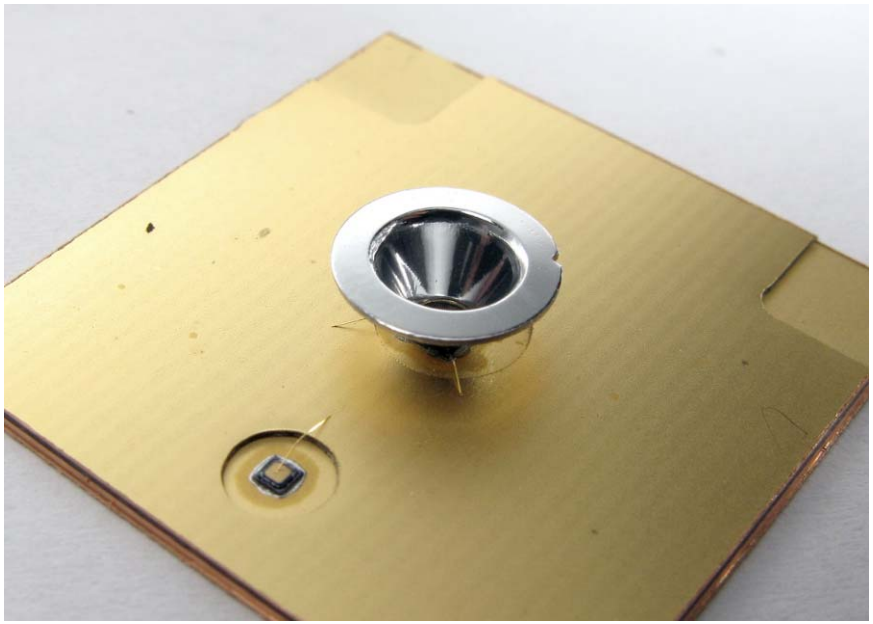
# 2005: Foundation of Concentrix Solar

FLATCON-modules, 22-26 %,first 1 kW grid-connected demonstration in Freiburg

Bett, Burger, Dimroth, Siefer, Lerchenmueller, 4th WCPEC, Hawaii, 2006, 615

# 2008: Next Generation of FLATCON Modules

FLATCON-modules with secondary optics and triple-junction cells,
> 28 % under outdoor operation



Jaus, Nitz, Peharz, Siefer, Schult, Wolf, Passig, Gandy, Bett, 33rd IEEE PVSC, San Diego, 2008, 391





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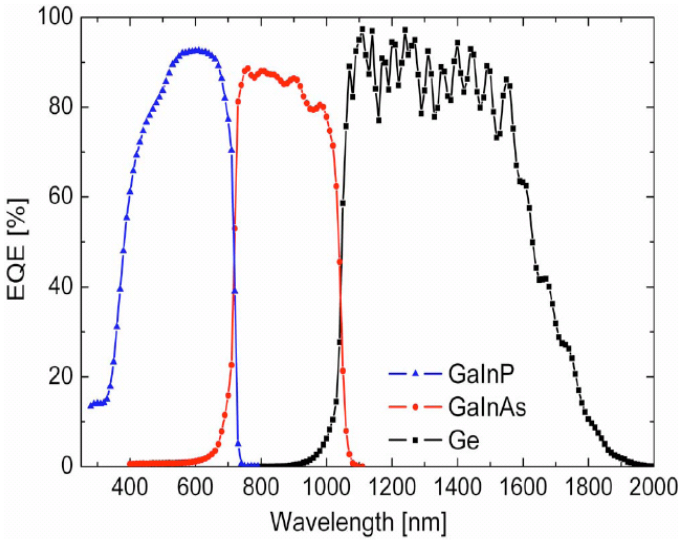
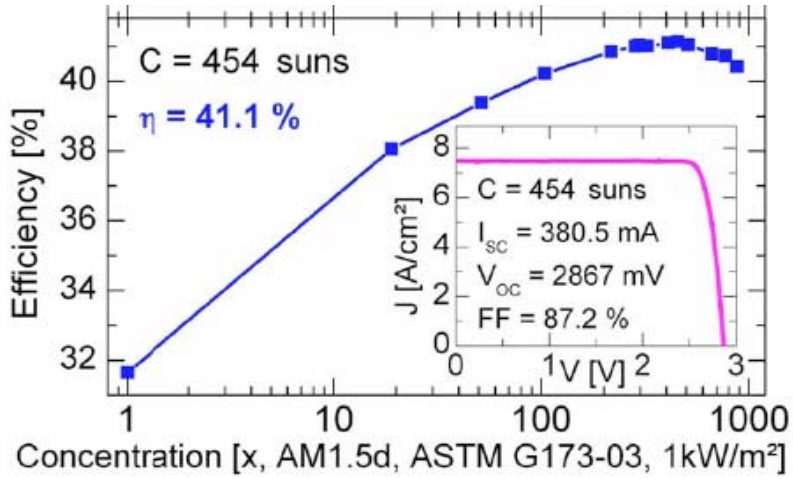
# 2009: 41.1 % for the Metamorphic Triple Solar Cell

APPLIED PHYSICS LETTERS 94, 223504 (2009)

## Current-matched triple-junction solar cell reaching 41.1% conversion efficiency under concentrated sunlight

Wolfgang Guter,[a] Jan Schöne, Simon P. Philipps, Marc Steiner, Gerald Siefer, Alexander Wekkeli, Elke Welser, Eduard Oliva, Andreas W. Bett, and Frank Dimroth
*Fraunhofer Institute for Solar Energy Systems, Heidenhofstr. 2, 79110 Freiburg, Germany*





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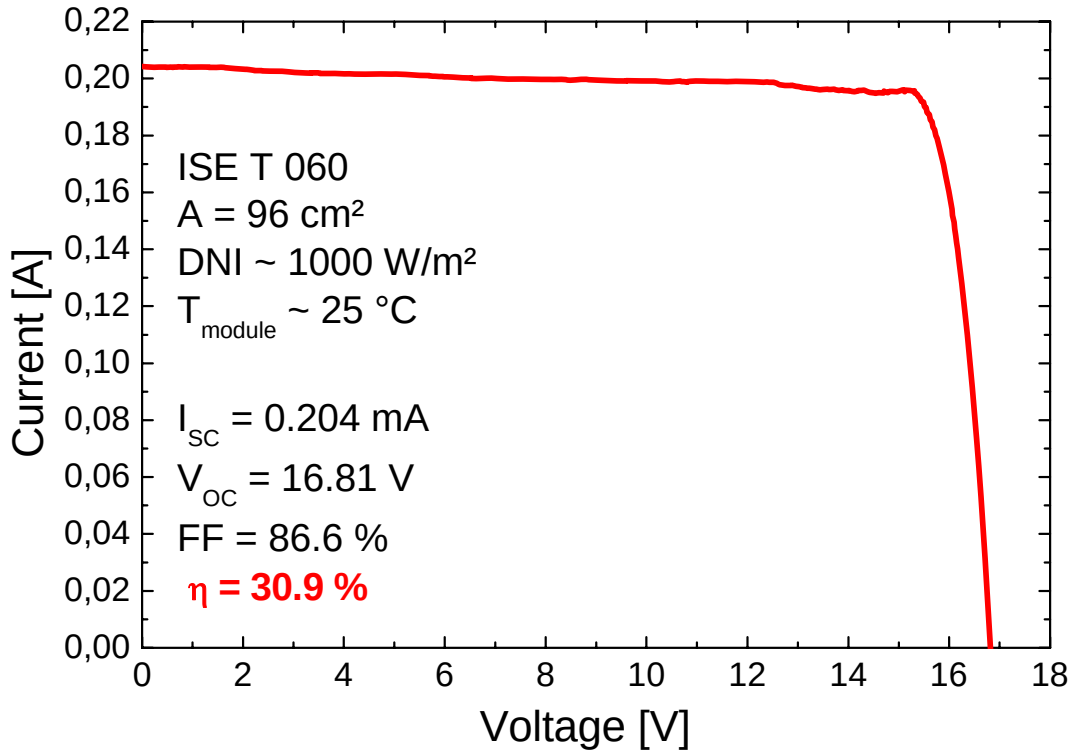
# 2009: Test-Module with Metamorphic Triple-Junction Solar Cells

Measured under indoor simulator, not calibrated!





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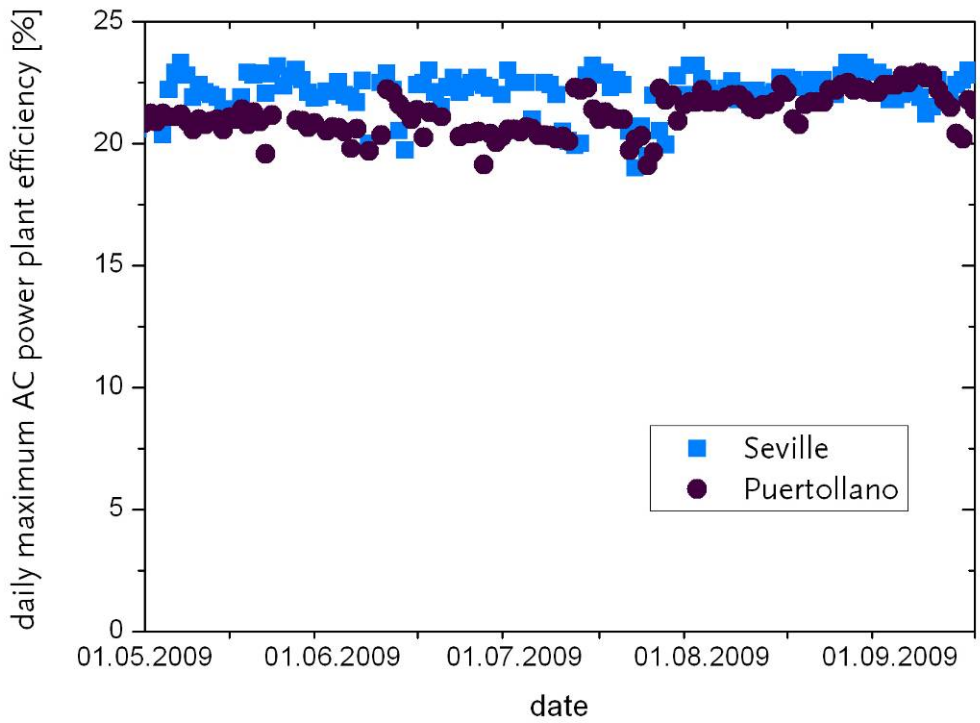
# CPV-Technology is going to the Market

Puertollano

Seville




Excellent plant performance:
up to 23 % AC efficiency





Concentrix solar

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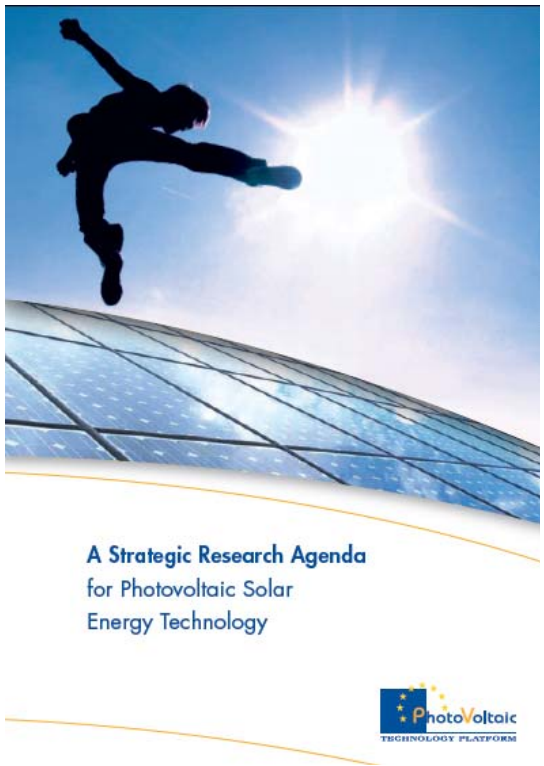
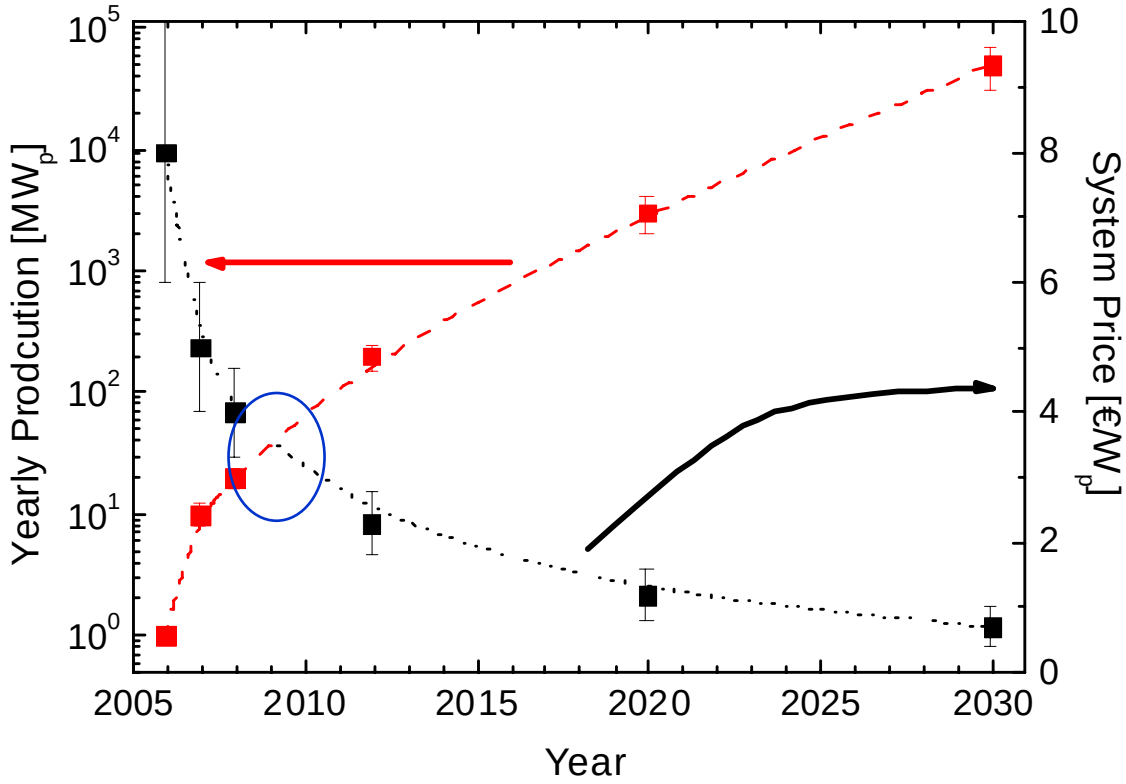
# The Future of CPV and other PV-Technologies





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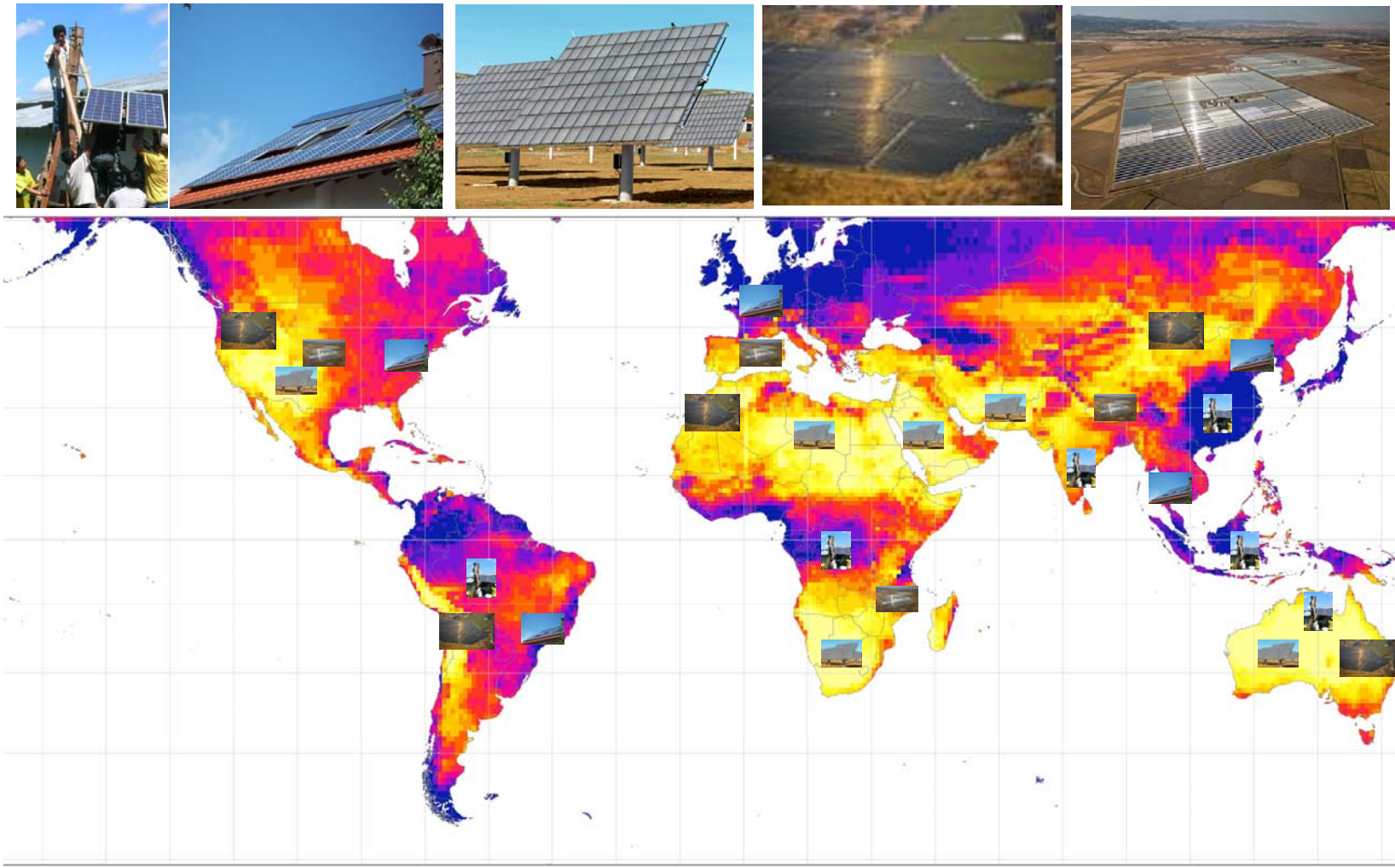
# The Vision: Worldwide Energy Supply by Solar







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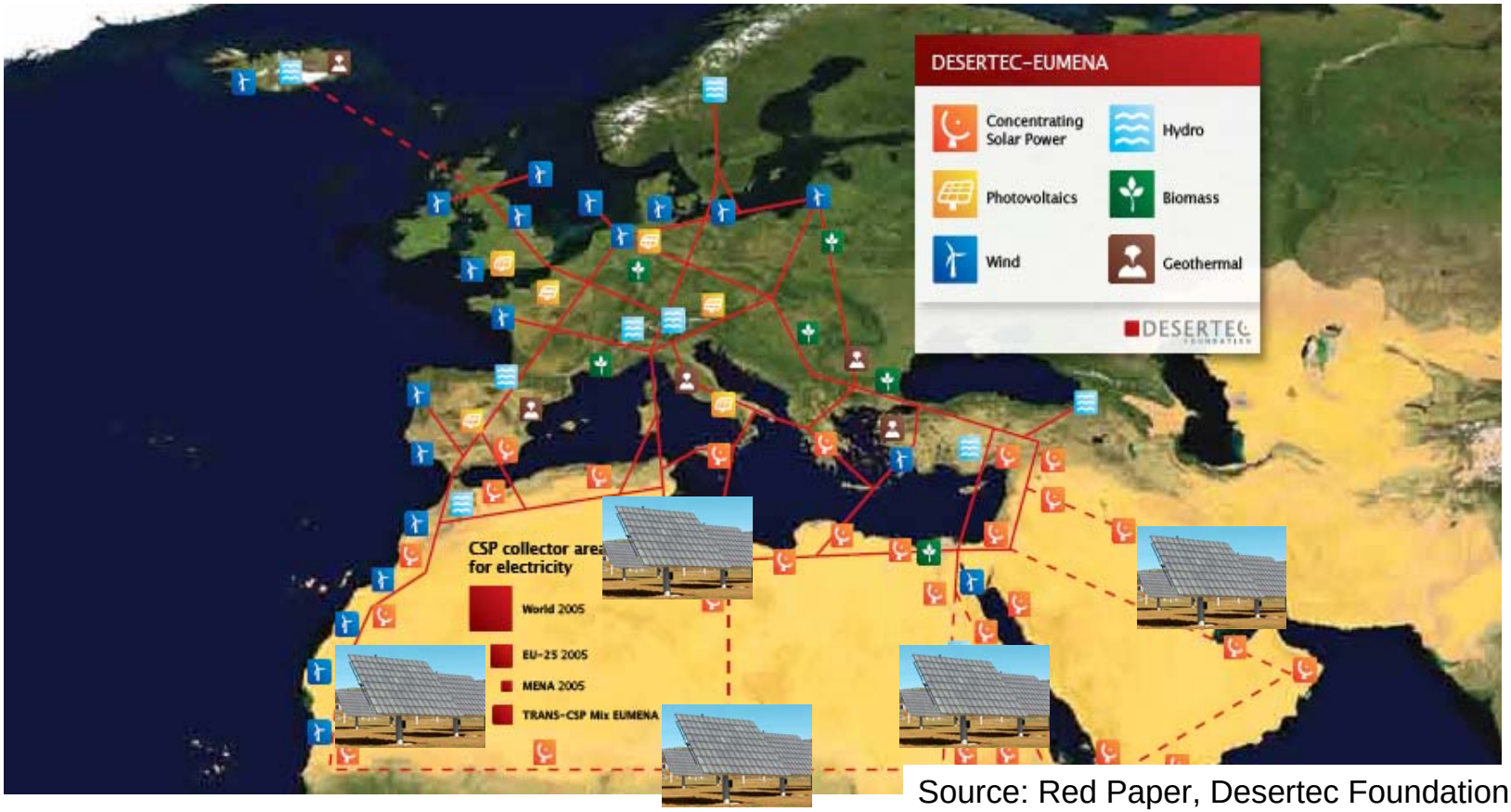
# DESERTEC - Renewable Electricity for Europe


signing an MoU of an industry consortium to work together, July 13th, 2009




Source: Red Paper, Desertec Foundation





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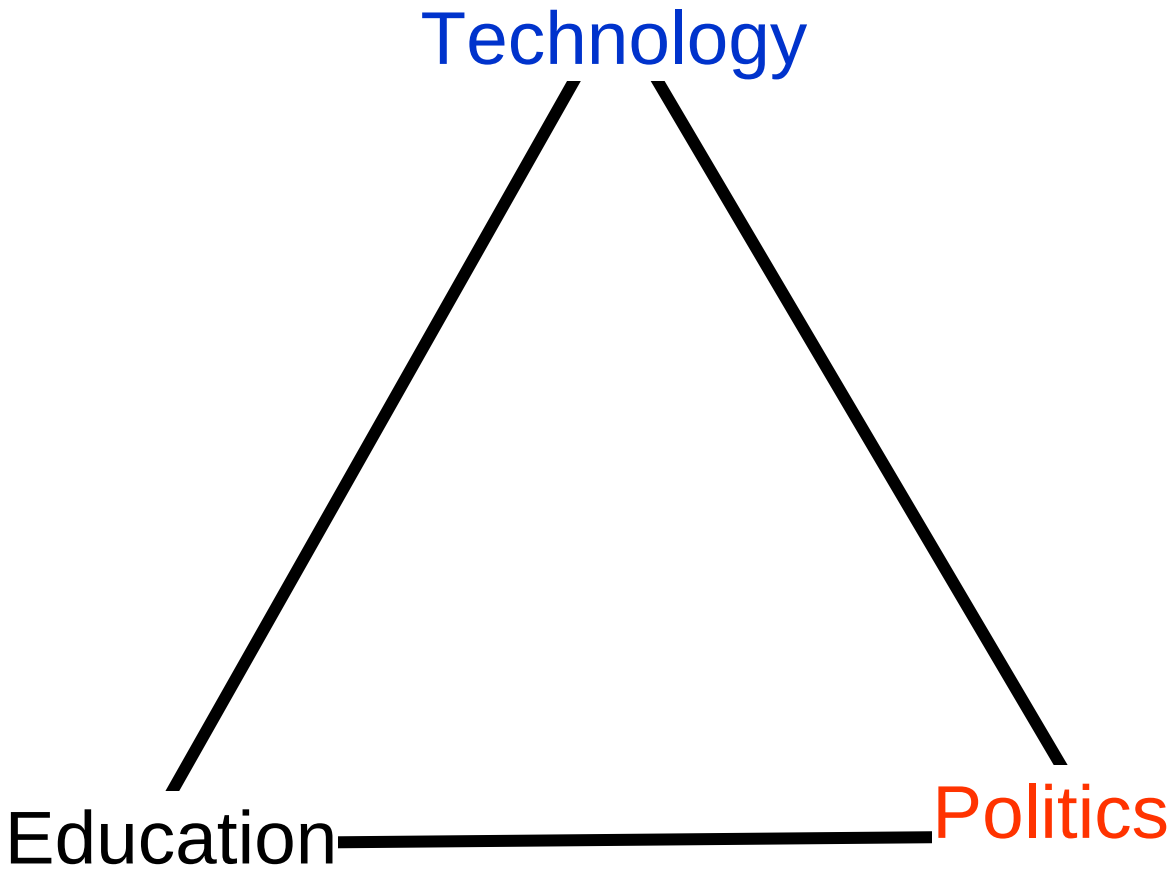
# The Magic Triangle must Work Together!



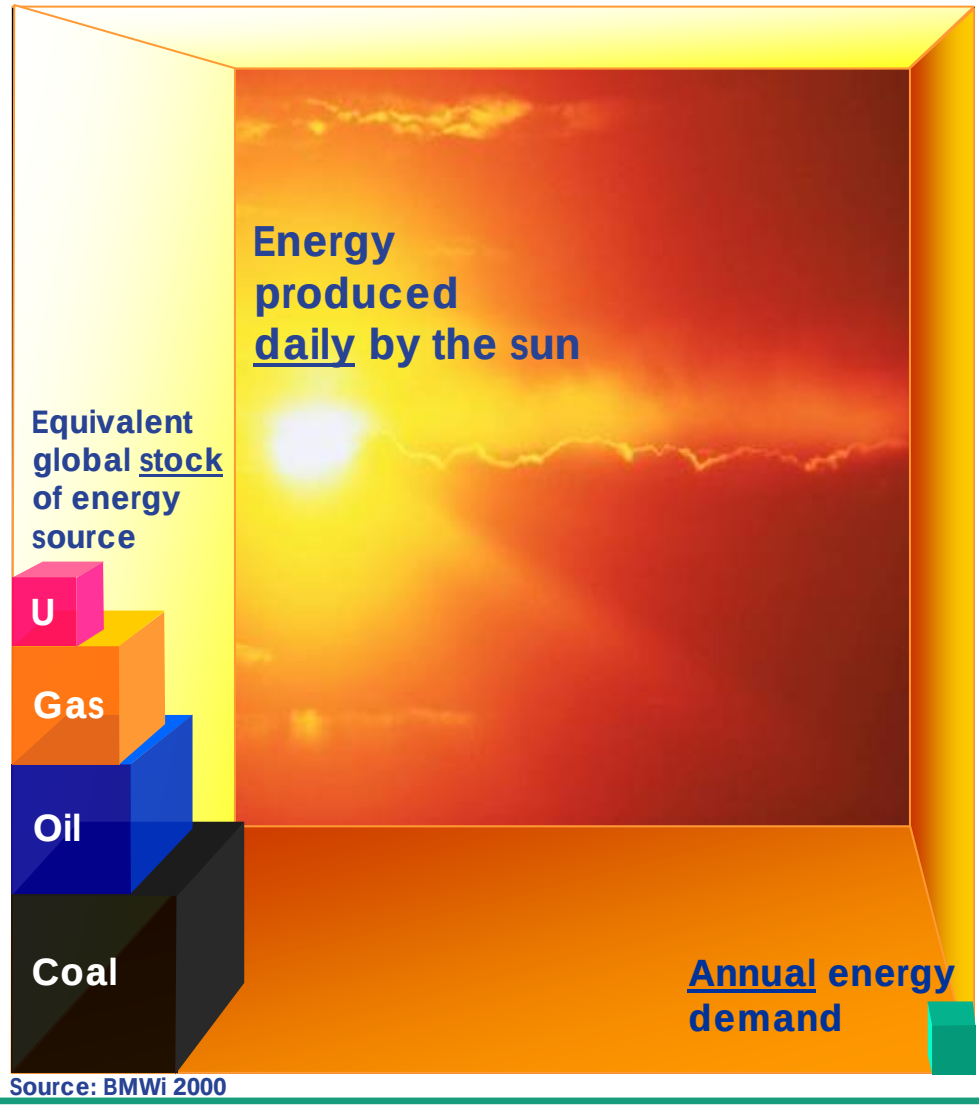
# Our Future is Solar!

**EU commitment**:
20% renewable by 2020

**If we all work together we will fulfill this commitment with**

**SOLAR POWER!**

There is no source nor technical limitation!




Source: BMWi 2000





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# Thank you for your attention!