

# Perspectives for solar energy applications in Nicaragua

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# Overview

**1. Irradiance in Nicaragua**

**2. Solarthermal Systems**

**3. PV Systems:**

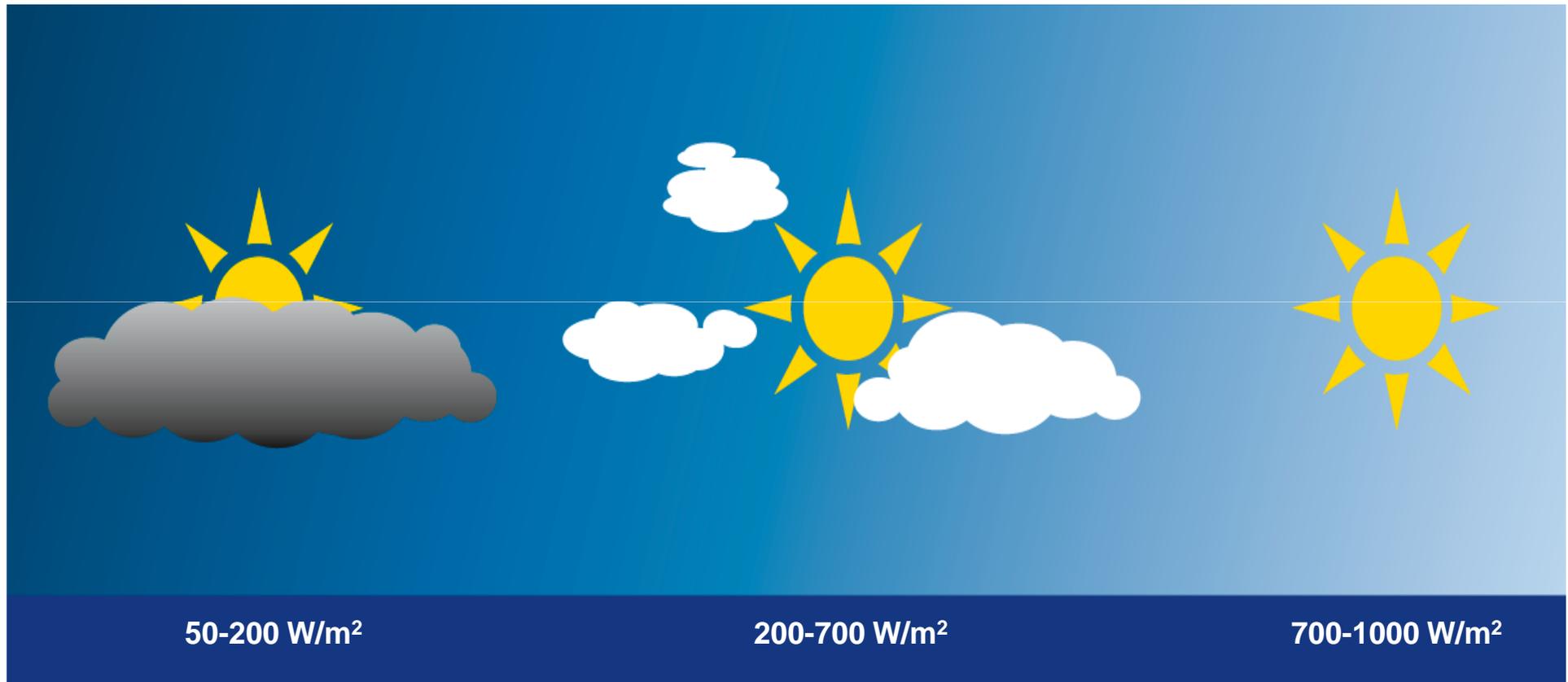
**3.1. Off-grid PV-grid systems**

**3.2. Grid-connected PV-Systems**

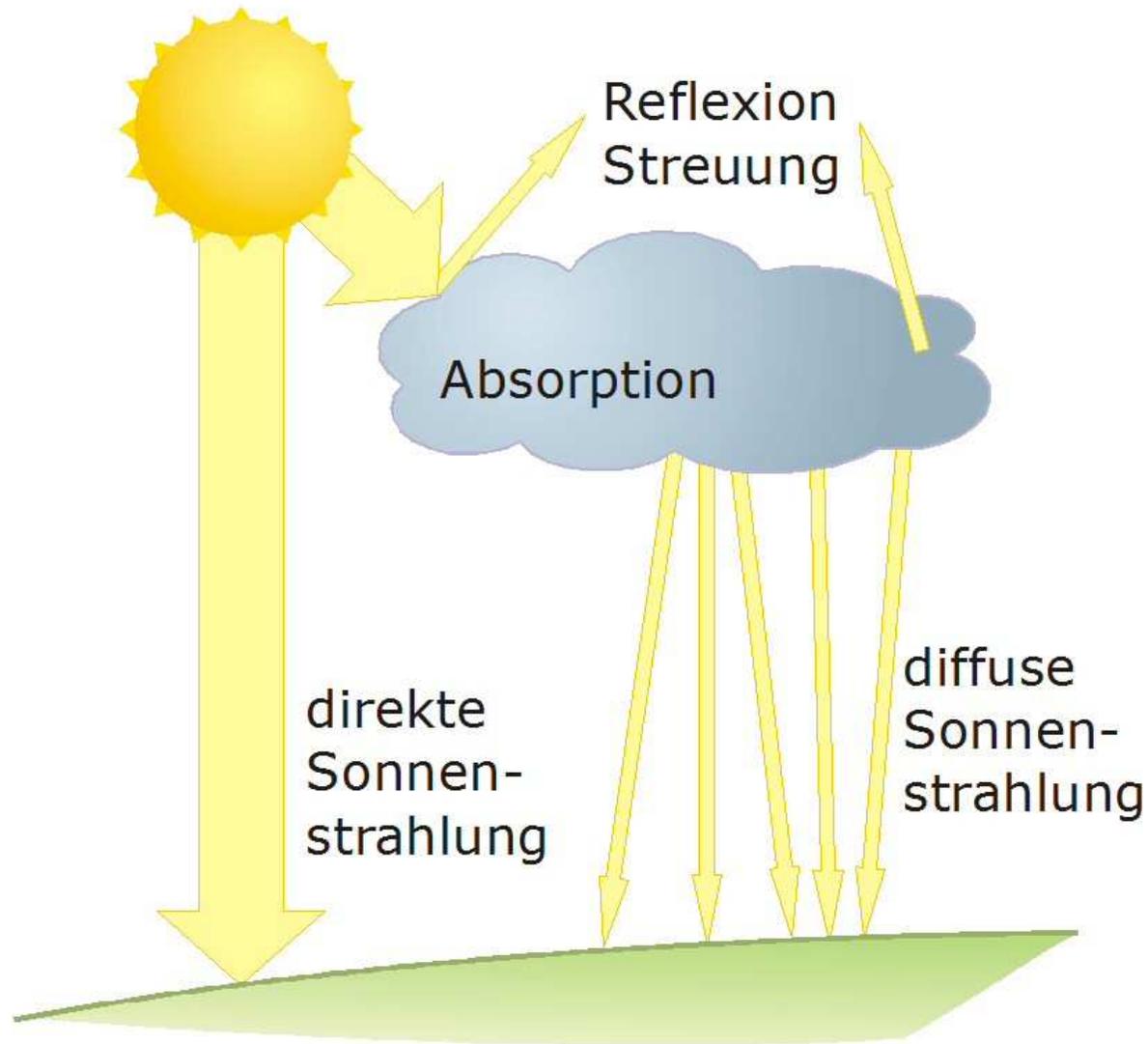
**Large & small**

**3.3. DC-Microgrids**

# Quick Estimation for the Irradiance level



# Direct vs. Diffuse Irradiance



## Measurement device to measure direct and diffuse irradiance

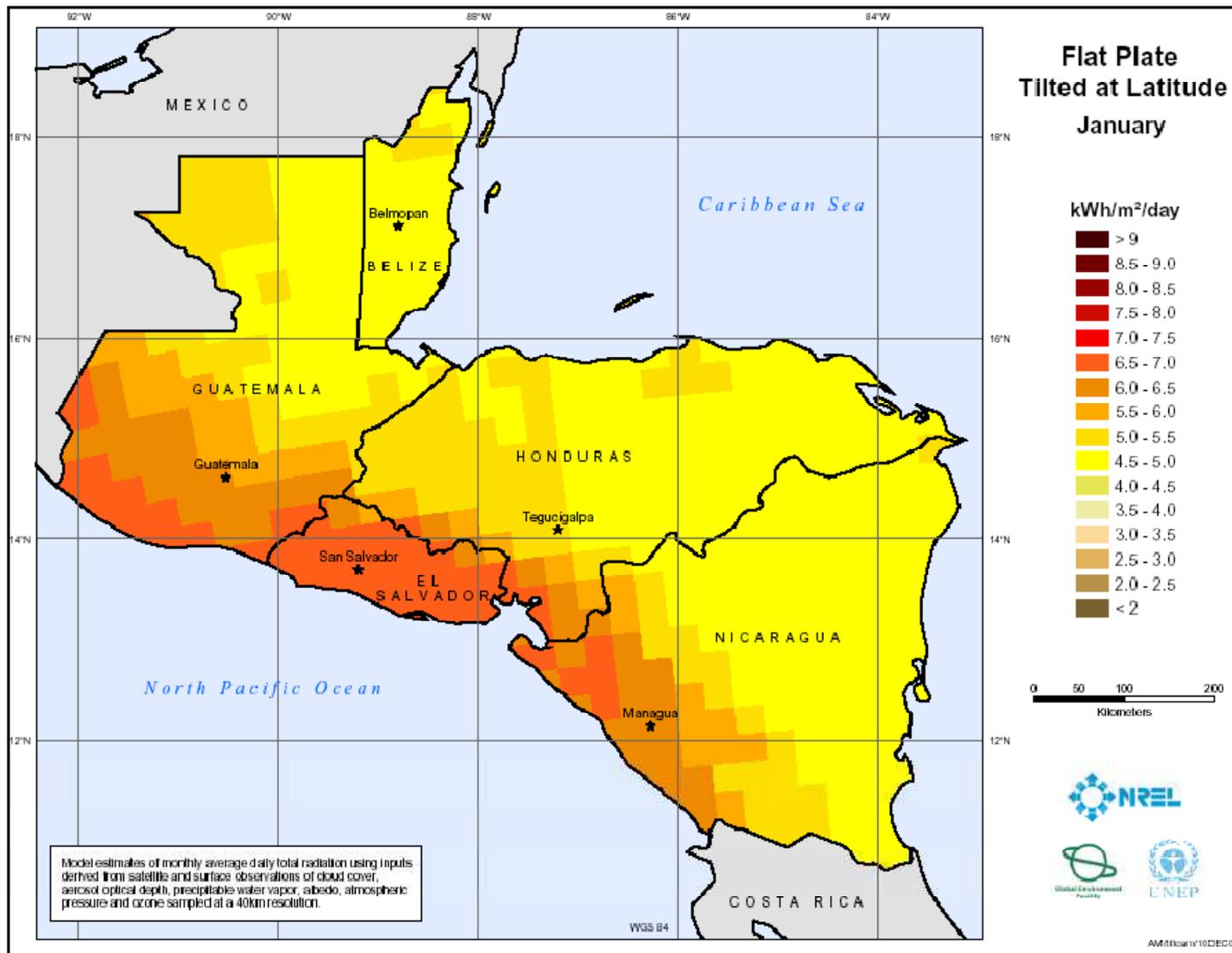


**Left: Shadow ball to measure diffuse irradiance only**

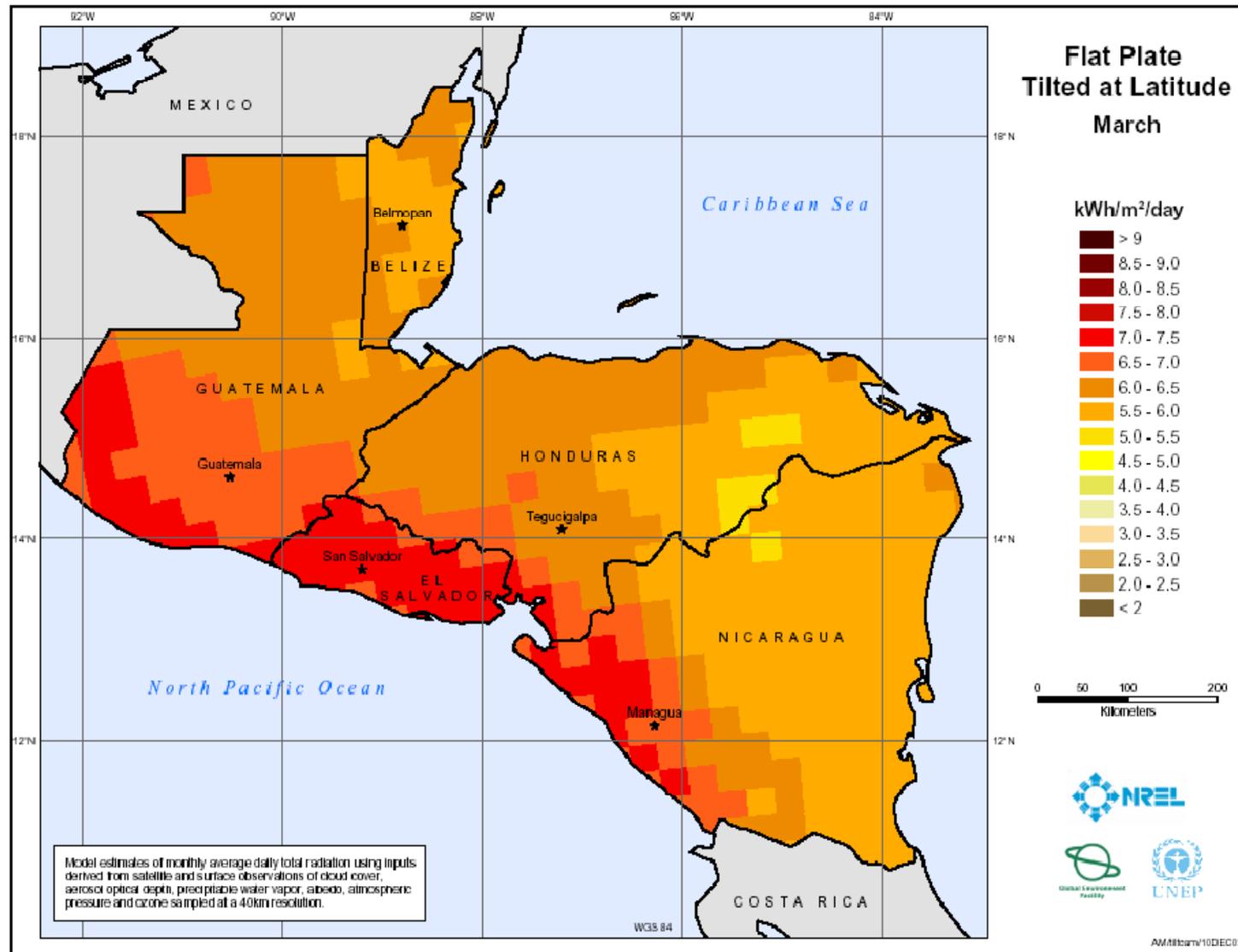
**Right: Tube sensor to measure direct irradiance only**



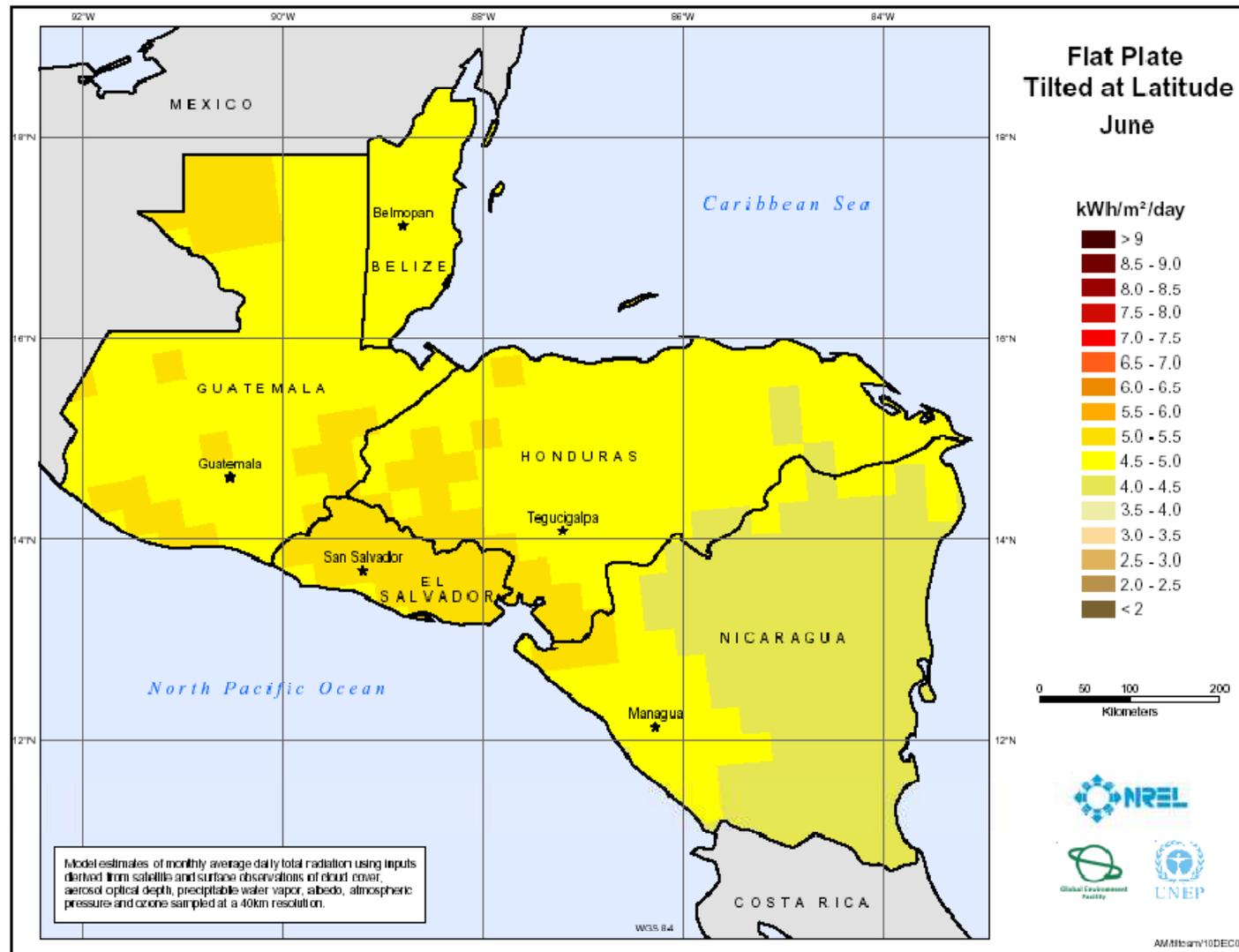
# Irradiance Central America



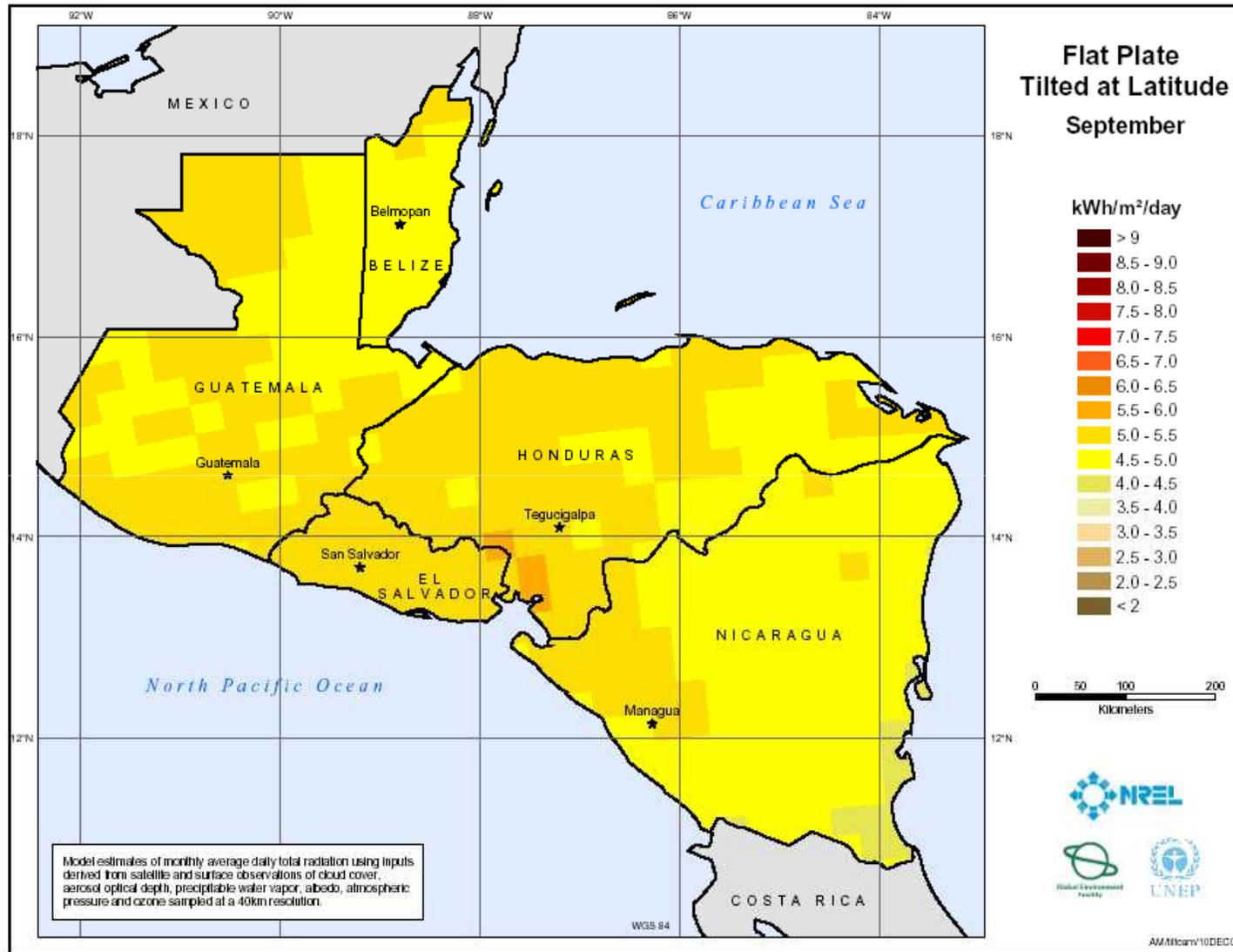
# Irradiance Central America



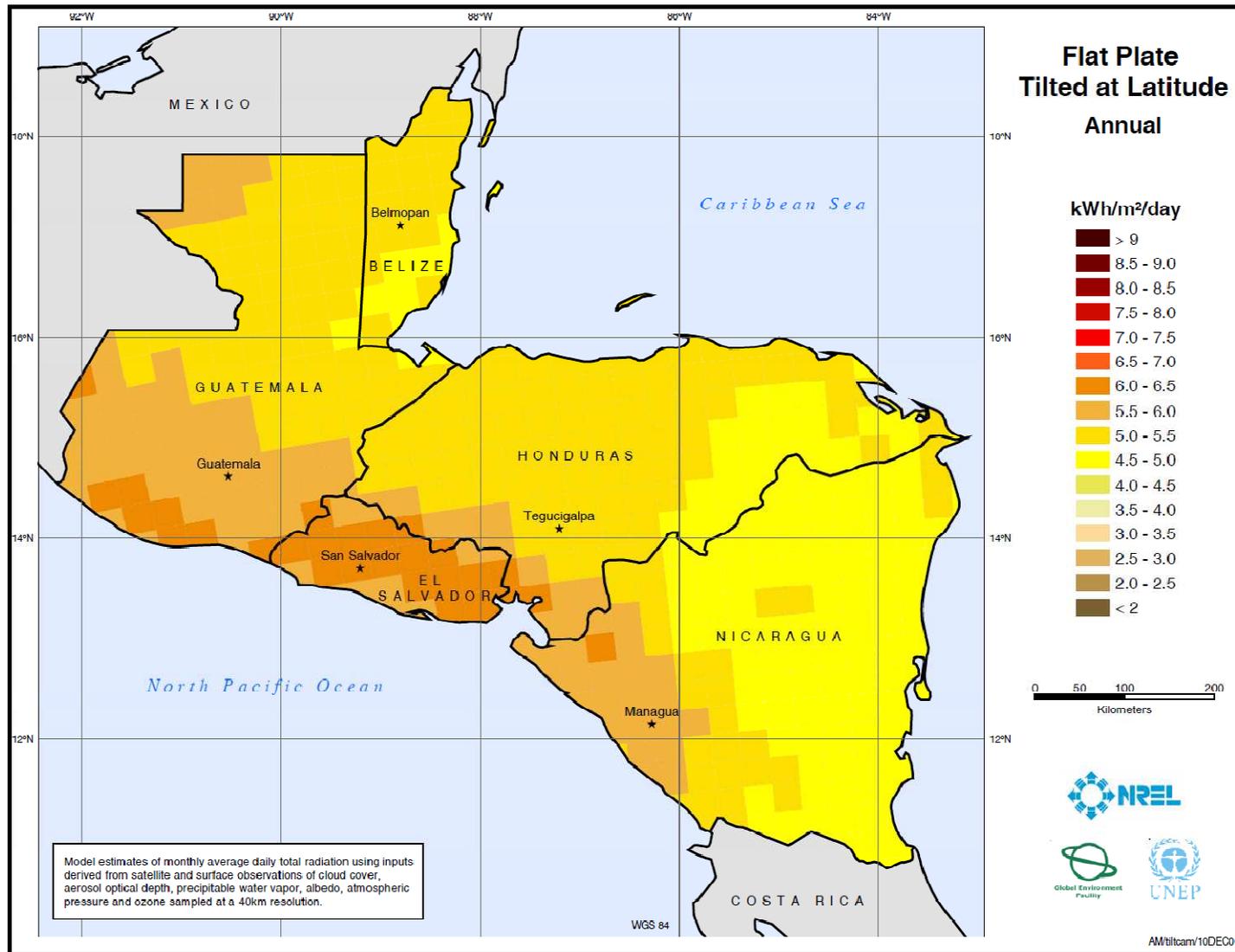
# Irradiance Central America



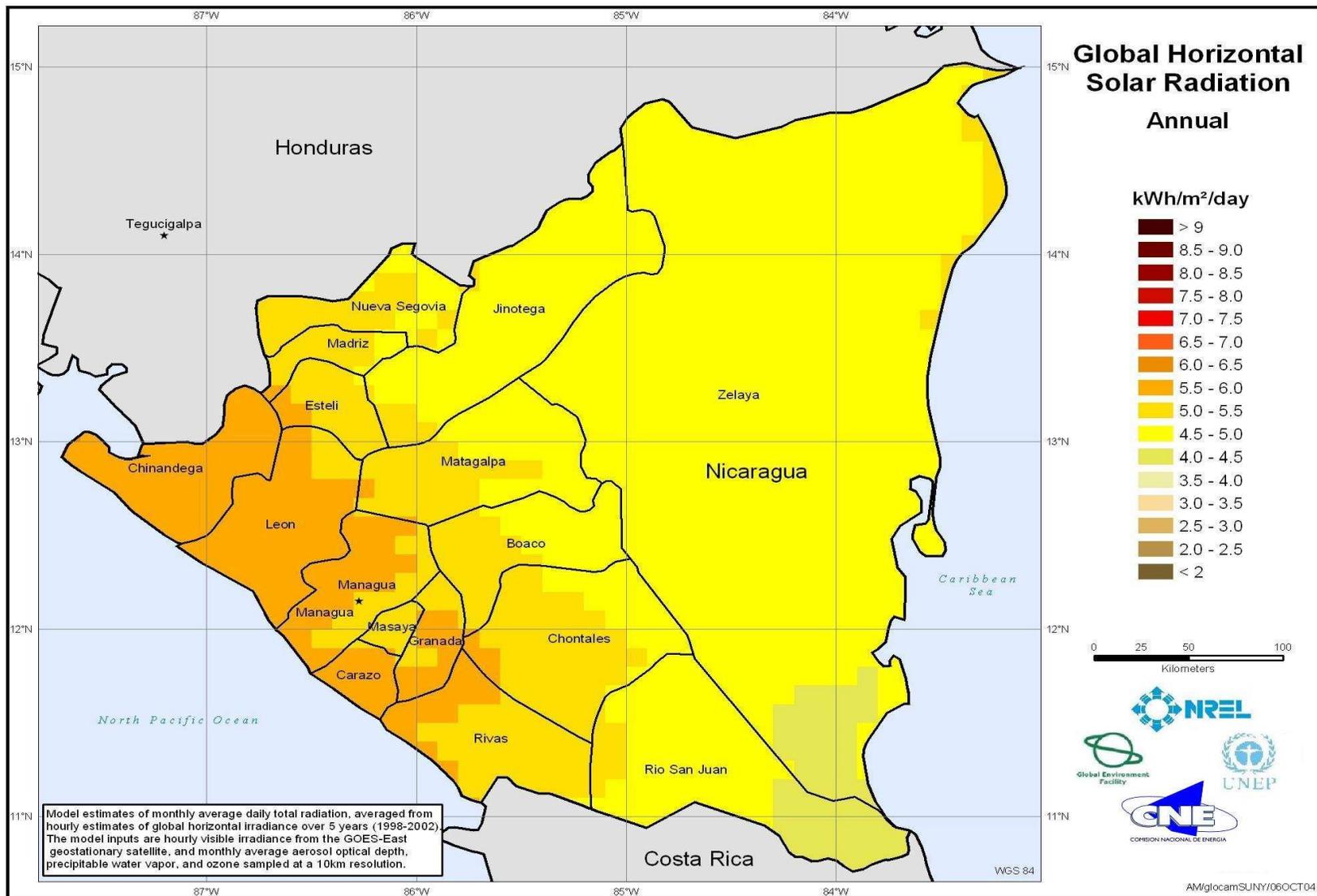
# Irradiance Central America



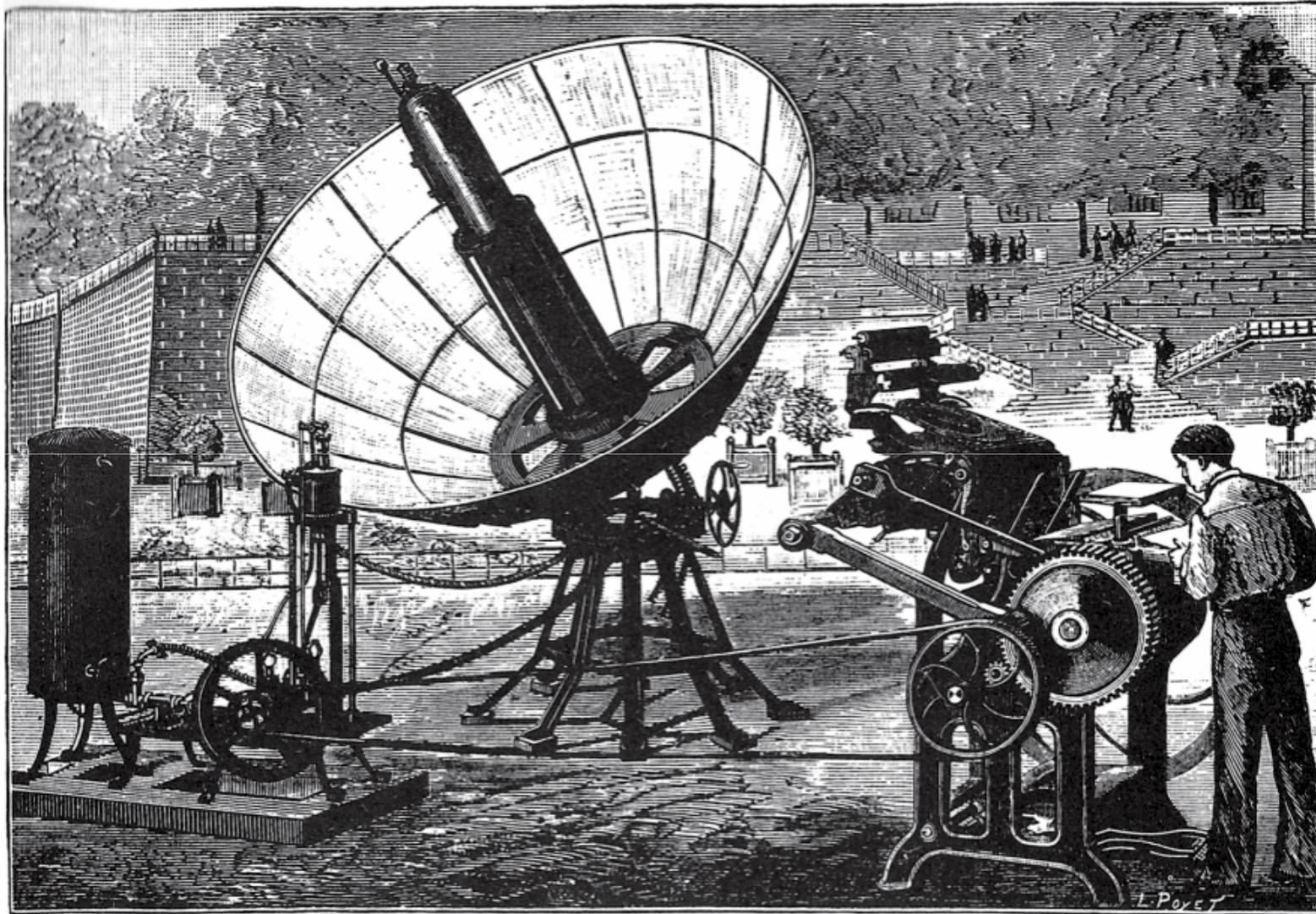
# Irradiance Central America



# Solar Irradiance in Nicaragua: 2000 kWh/(m<sup>2</sup>a)



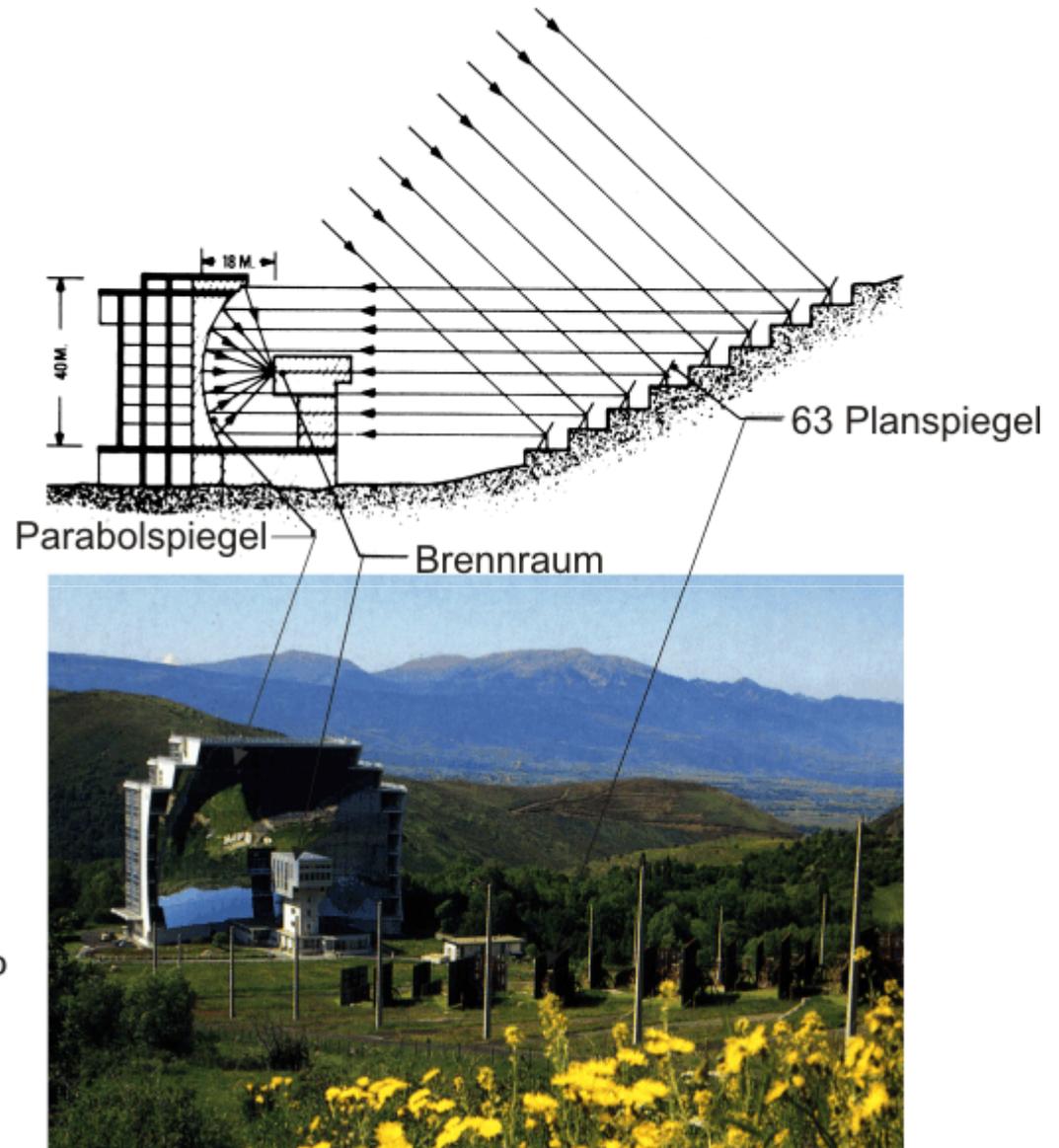
# Solar power conversion in 1900



# „Four Solaire“ en Odeillo al Sur de Francia

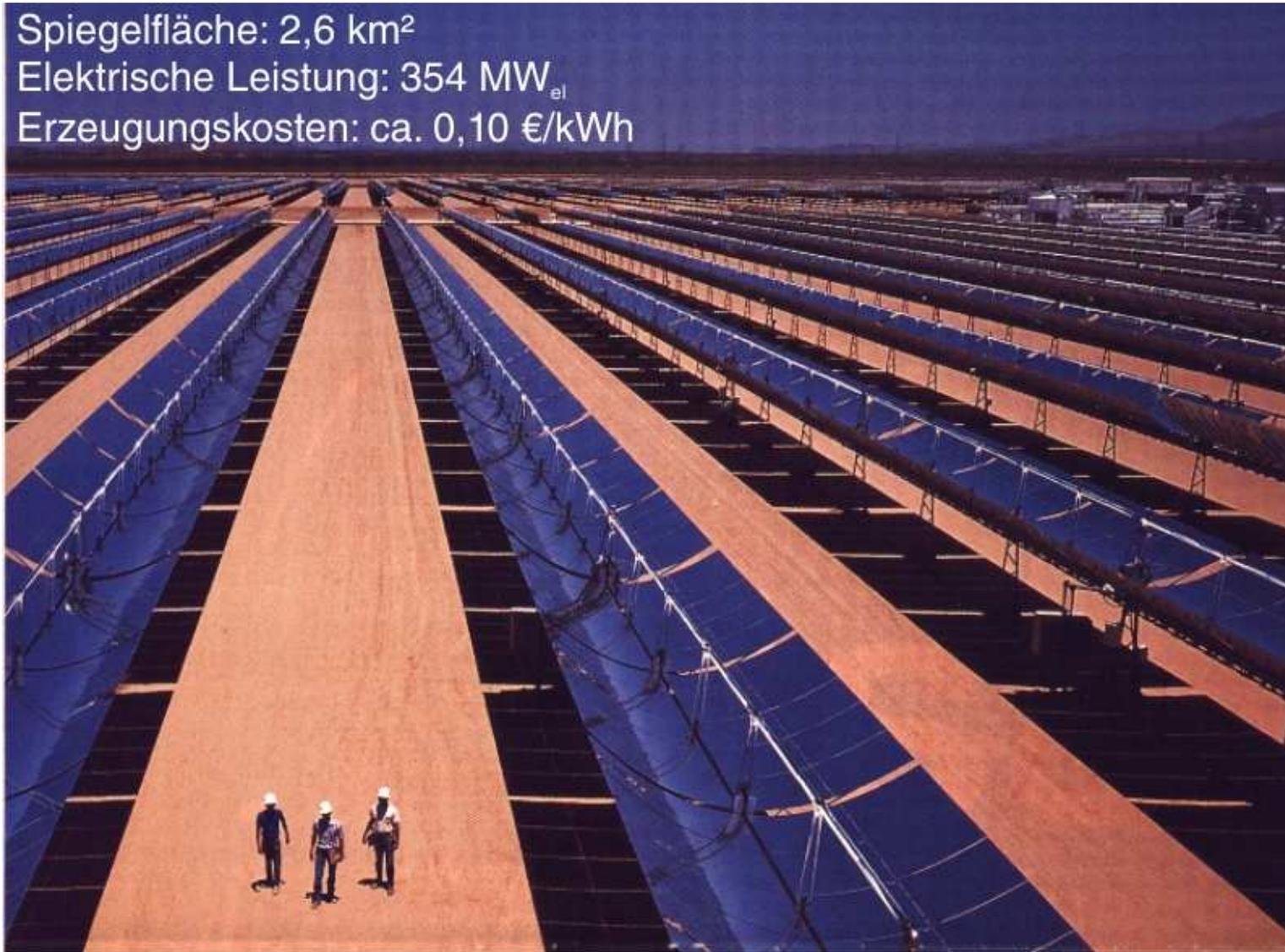
16 MW solarthermisches Kraftwerk nach dem Prinzip der „doppelten Reflexion“

Konzentration im Brennpunkt:  
16 000 entspr.  $1,6 \text{ kW/cm}^2$ ,  
maximale Temperatur:  $3\,000^\circ\text{C}$   
Einstrahlungswirkungsgrad: 60 %

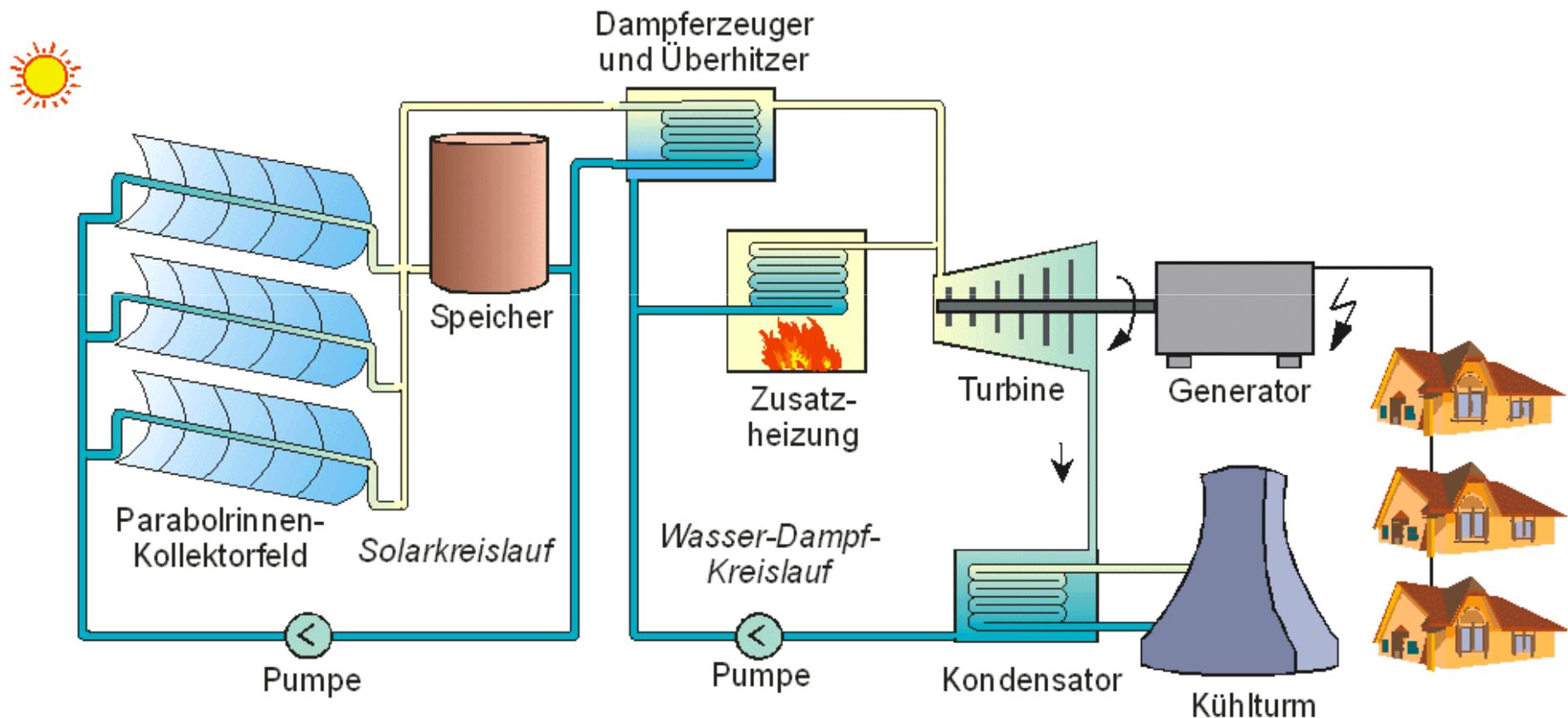


# Planta Solartérmica en el desierto de Mojave en Arizona EE UU

Spiegelfläche: 2,6 km<sup>2</sup>  
Elektrische Leistung: 354 MW<sub>el</sub>  
Erzeugungskosten: ca. 0,10 €/kWh



# Esquema de Planta de círculos Parabólicos (por ejemplo de SEGS)



Quelle: Volker Quaschnig - Regenerative Energiesysteme



Stefan  
Krauter

Typisches solarthermisches Thermosyphon-System

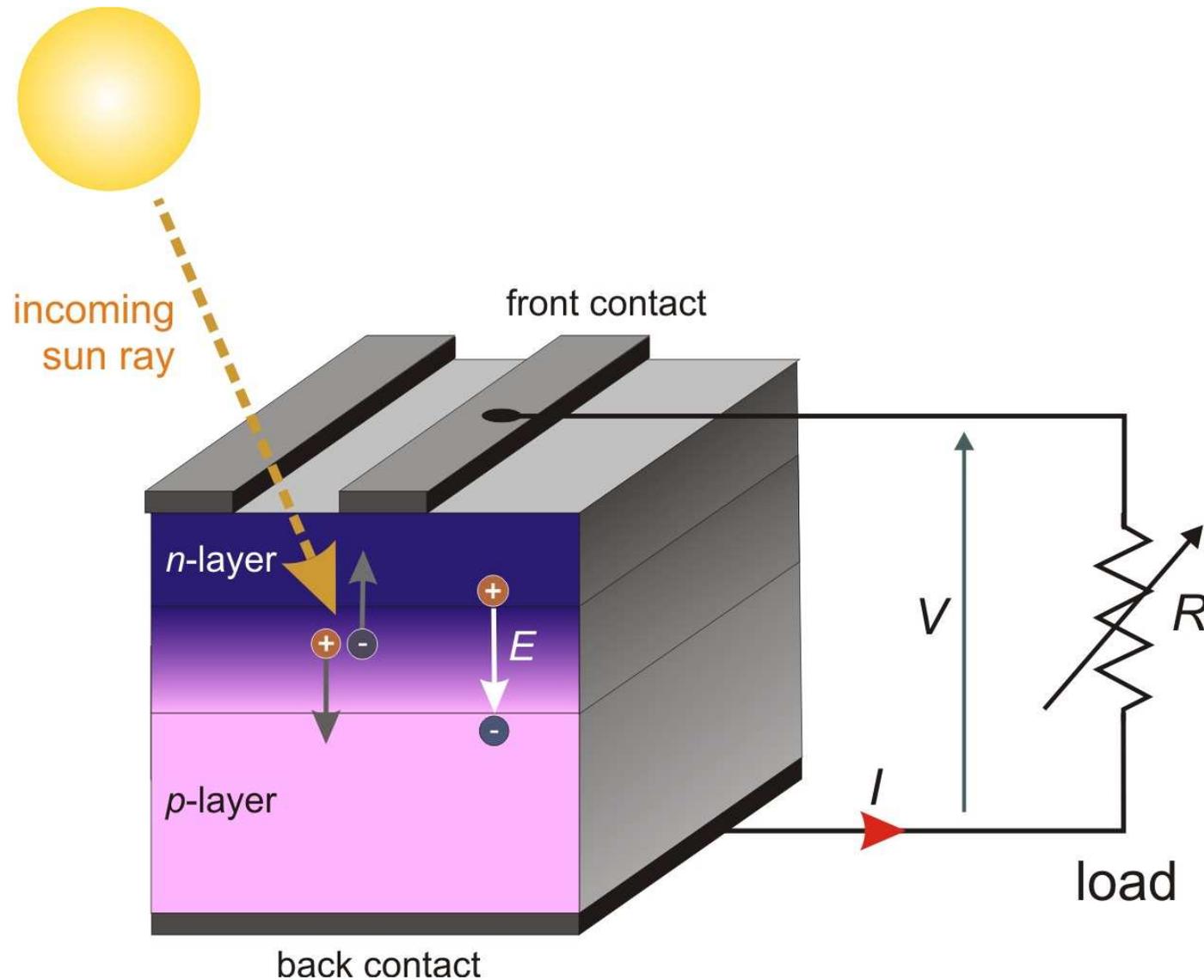
WCRE  
UECE

# Solar cooker saving firewood

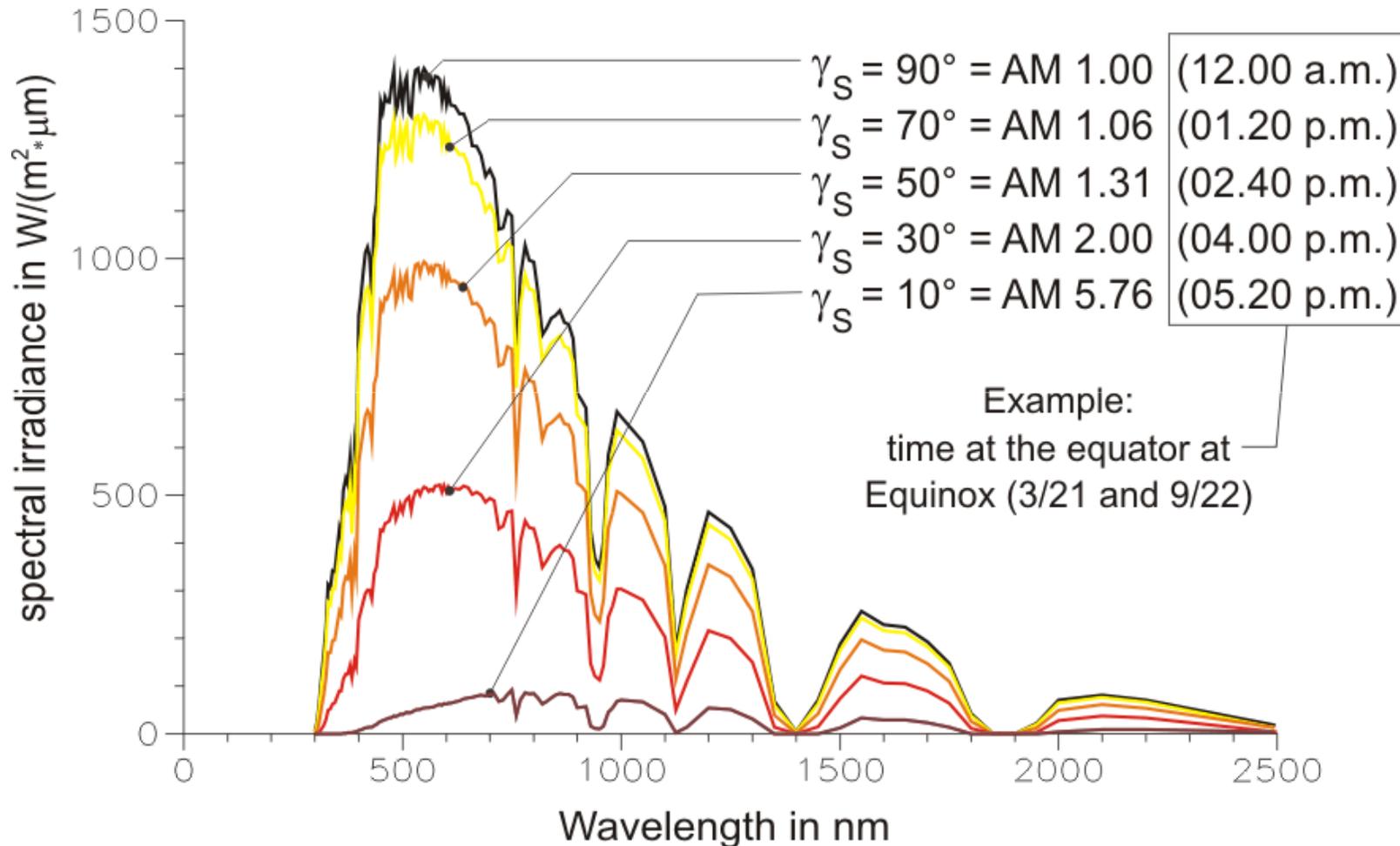




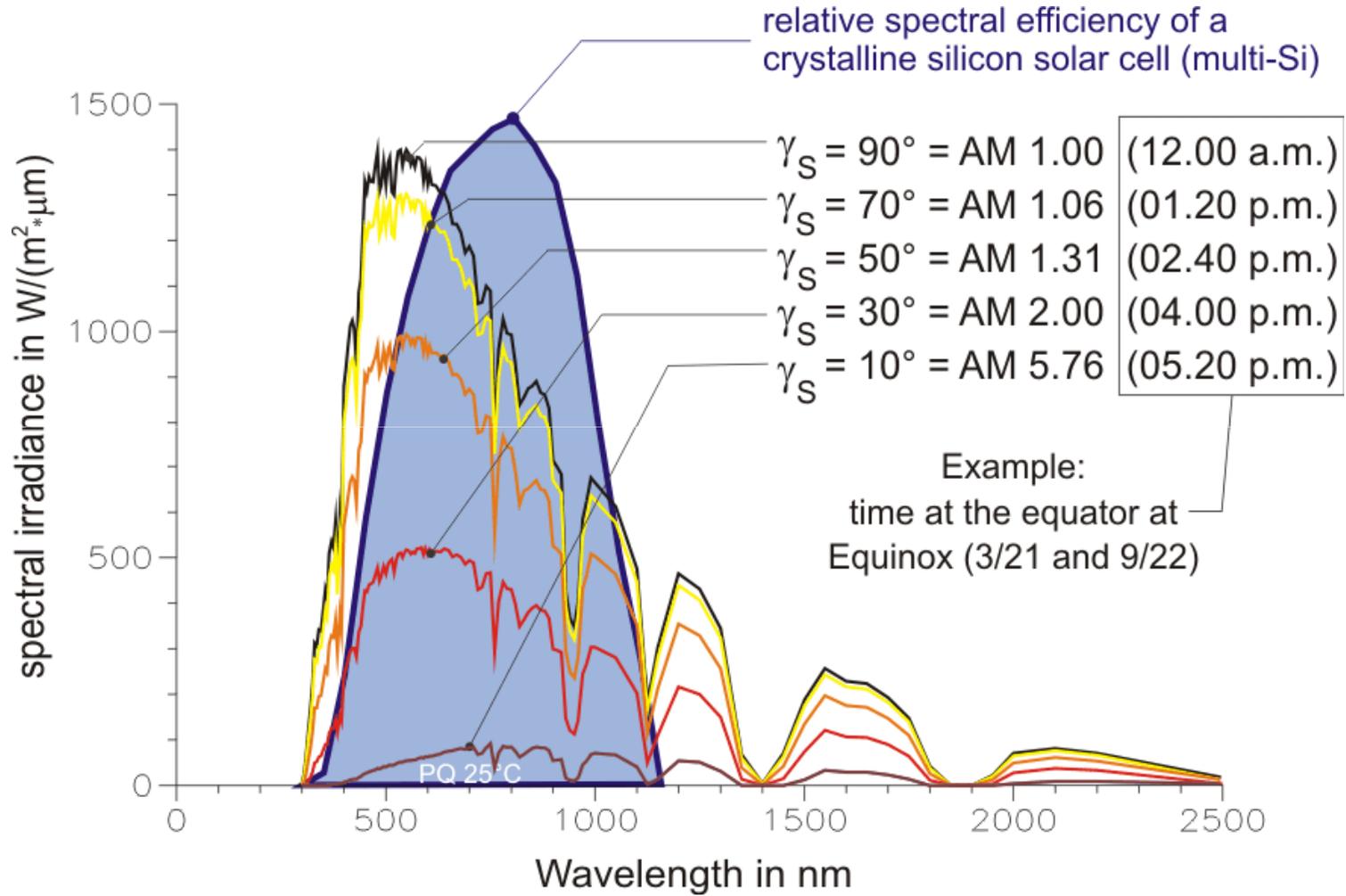
# Scheme of photovoltaic solar energy conversion



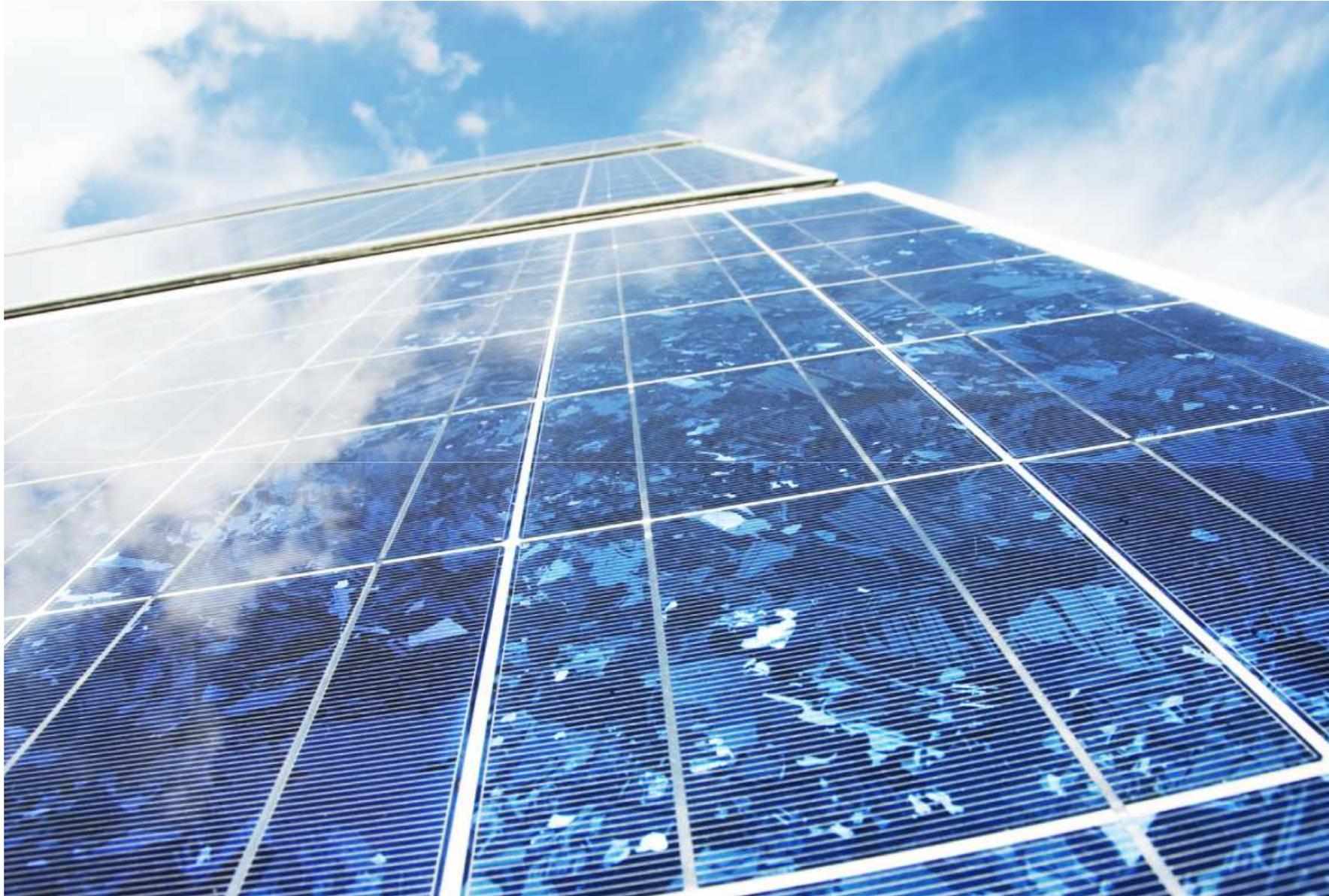
# Sun's spectra for different times of a day



# Matching of spectral efficiency with sun's spectra

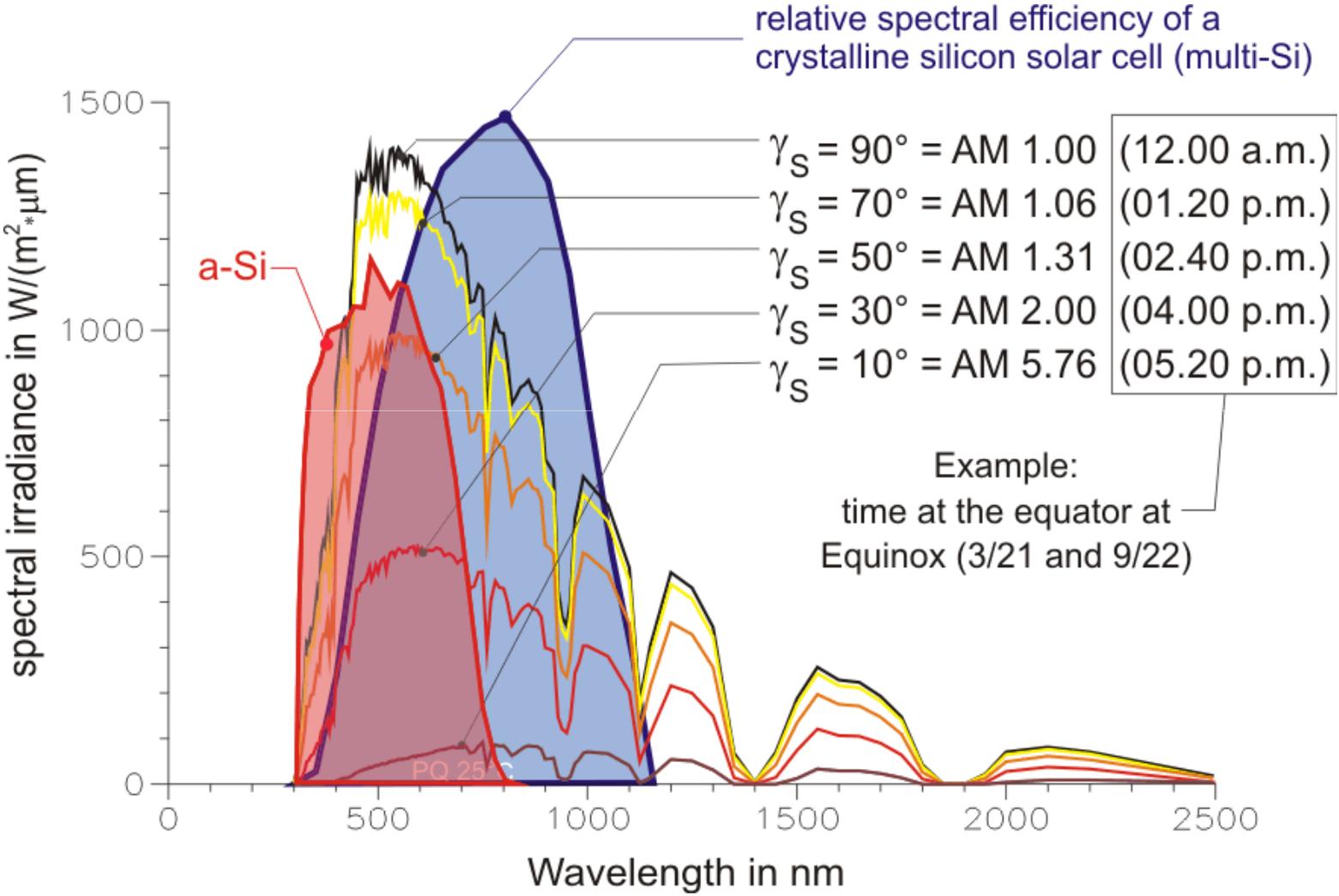


# Multi-crystalline PV modules (mc-Si)



© www.solarpraxis.de / Tom Pischell

# Matching of spectral efficiency with sun's spectra

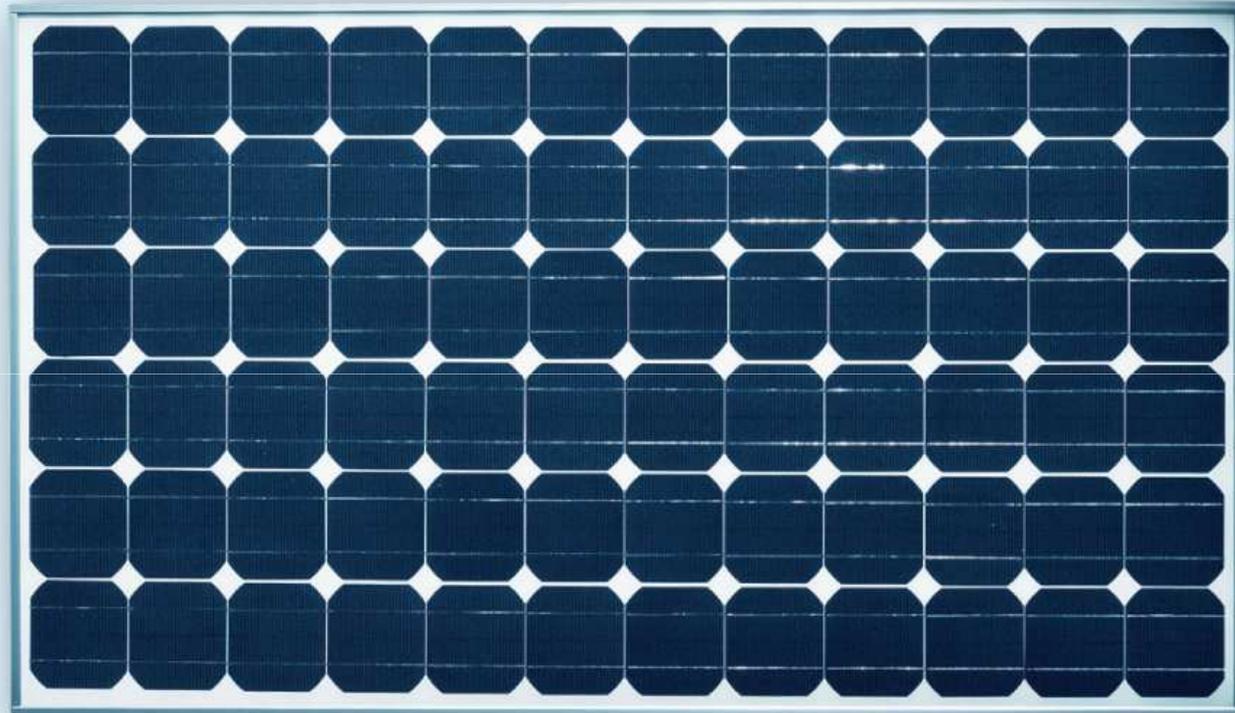


# Flexible multi-junction thin film module



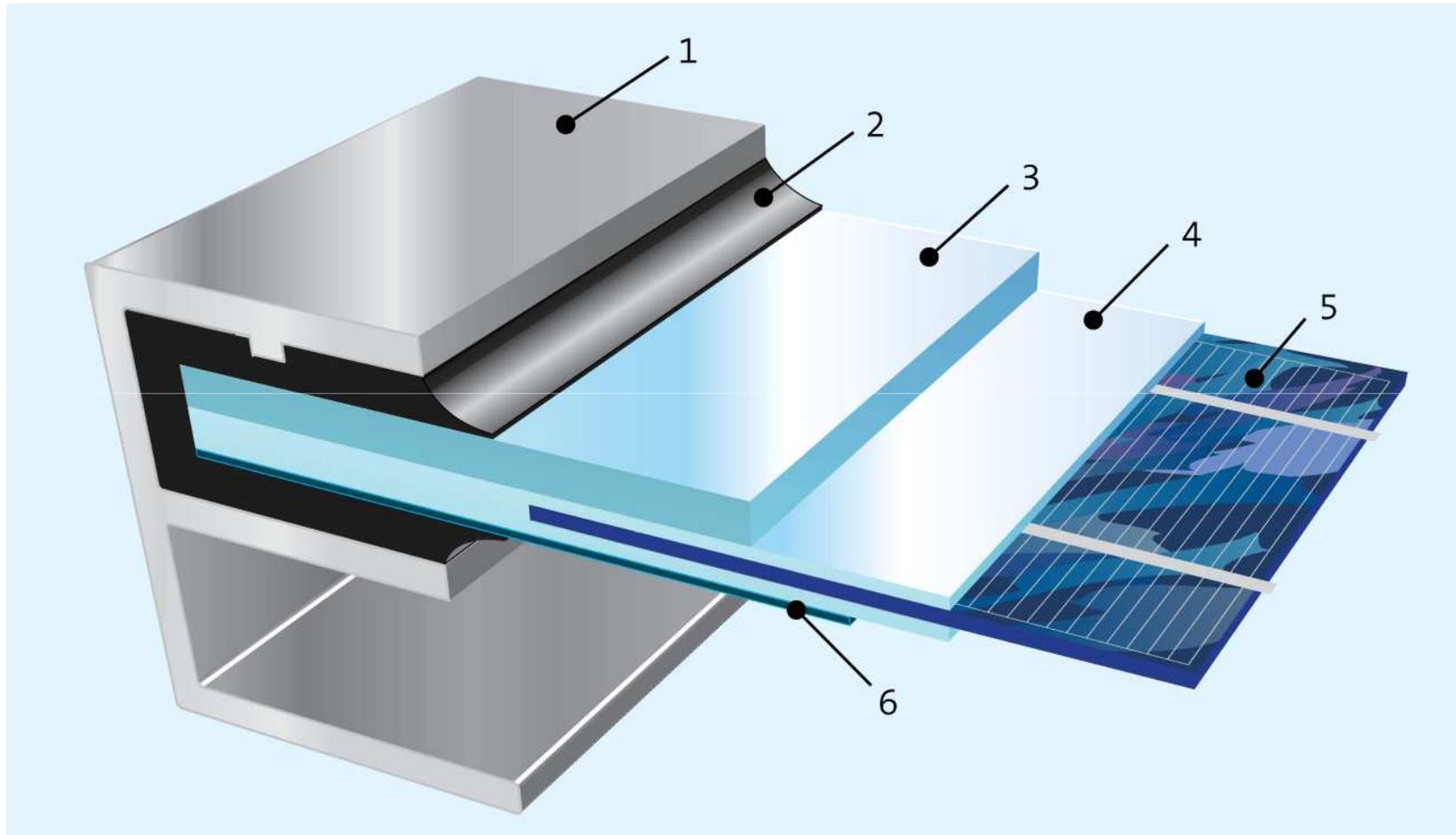
© United Solar Ovonix

# Single crystalline PV module (sc-Si)



© Vaillant

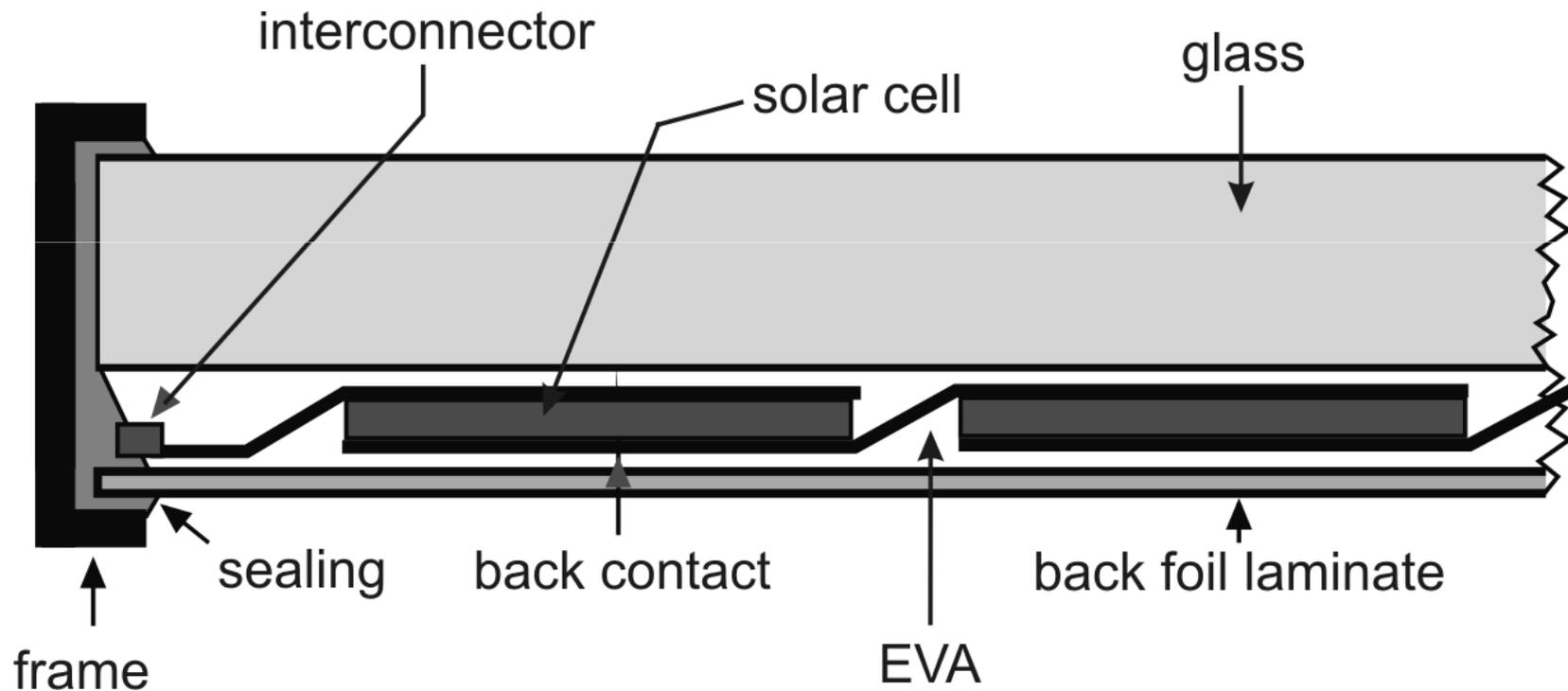
# Laminated PV Module for crystalline solar cells with frame



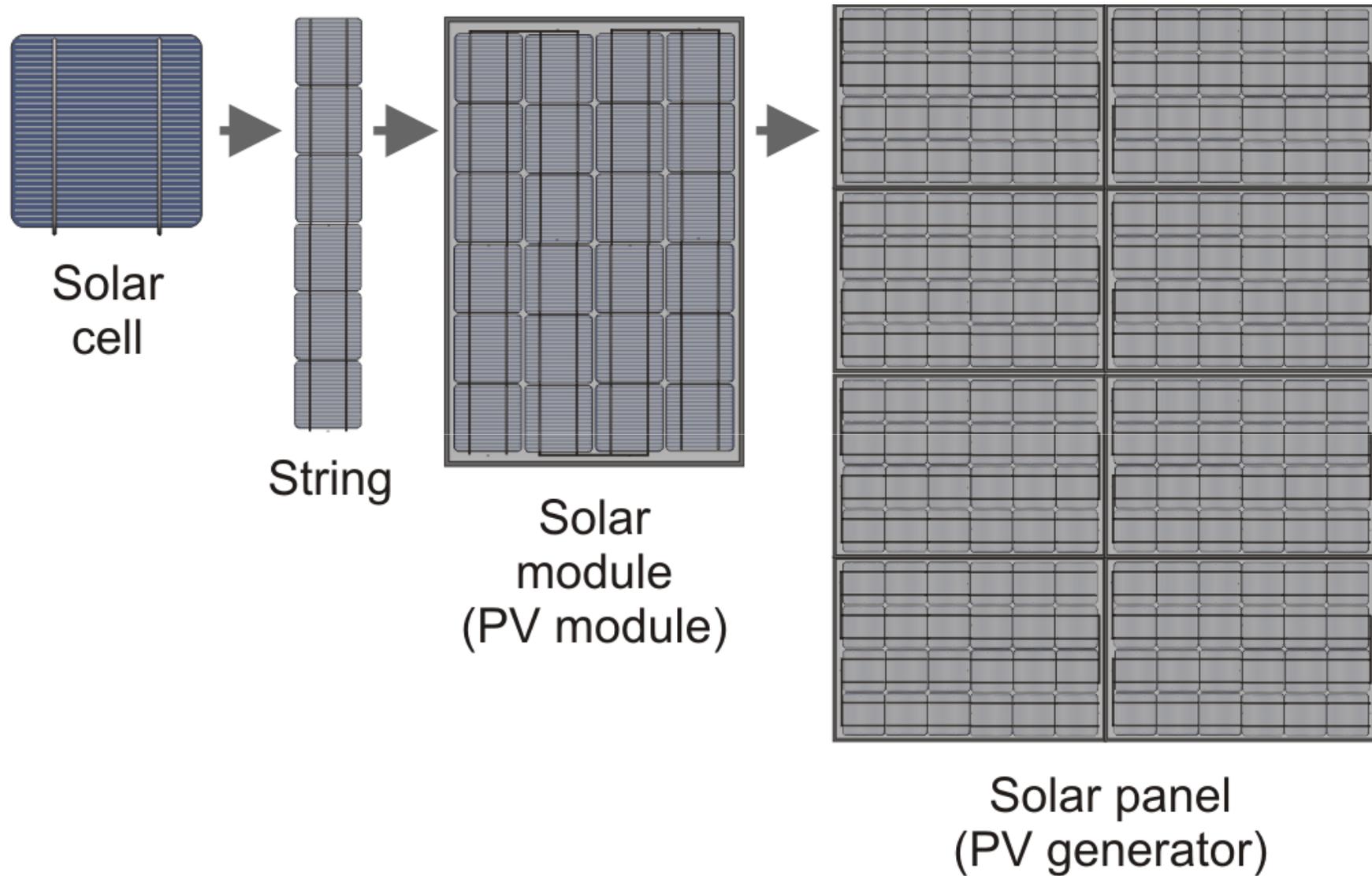
© www.solarpraxis.de

1 Aluminum frame, 2 seal, gasket, 3 Glass, 4 EVA embedding, 5 crystalline solar cell, 6 Tedlar-Polyester-Foil

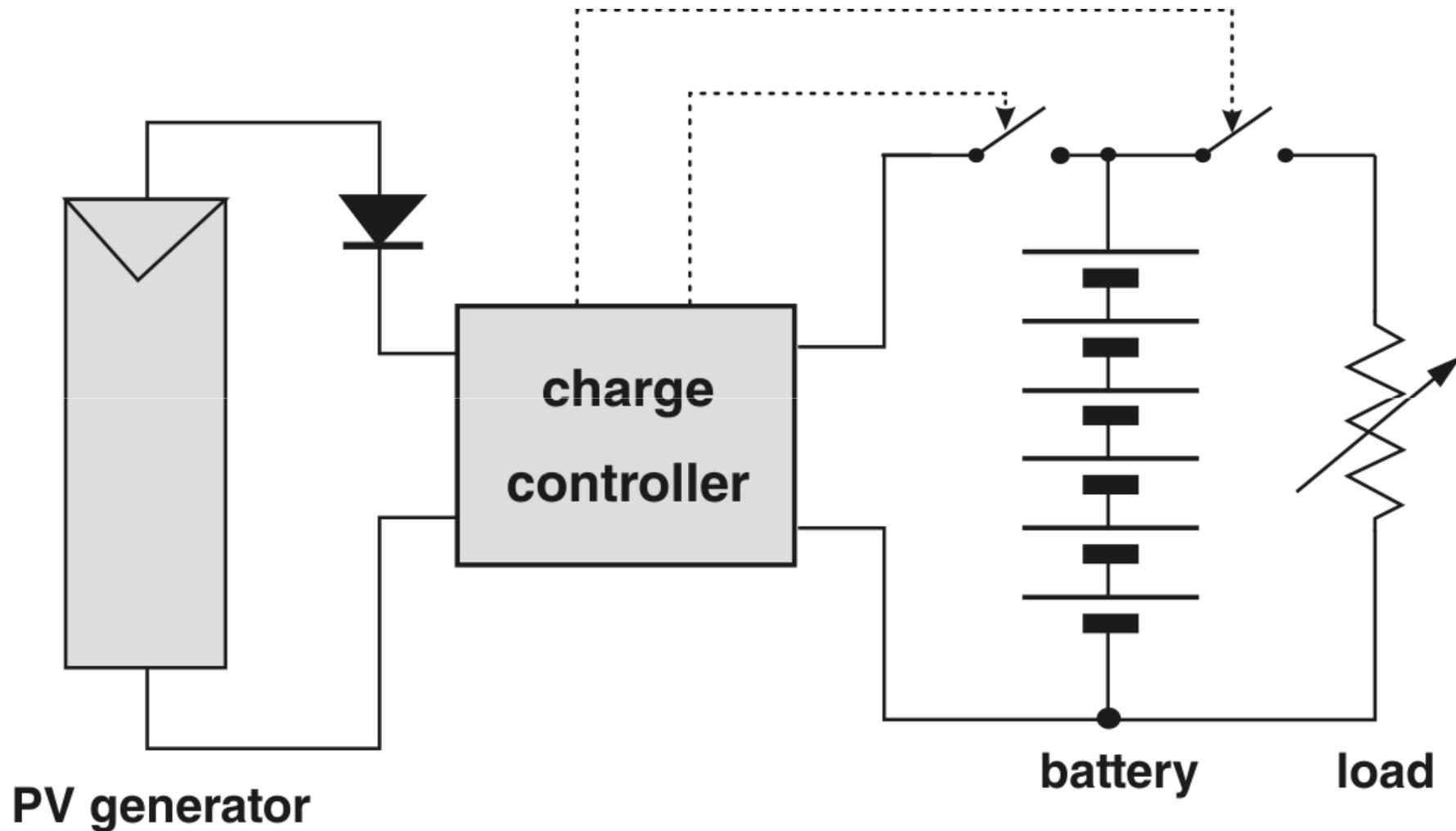
## Cross section of a laminated PV module based on crystalline Silicon cells



# From the solar cell to the PV generator



## Scheme of PV off-grid system



# Inverter for off-grid systems and charge controller

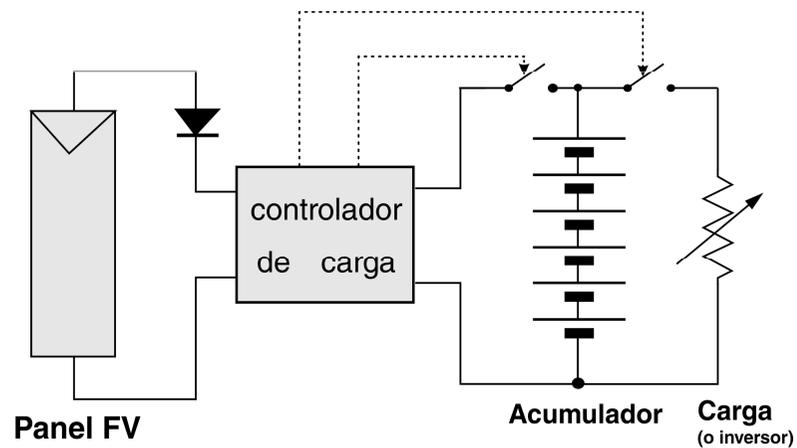


© SMA

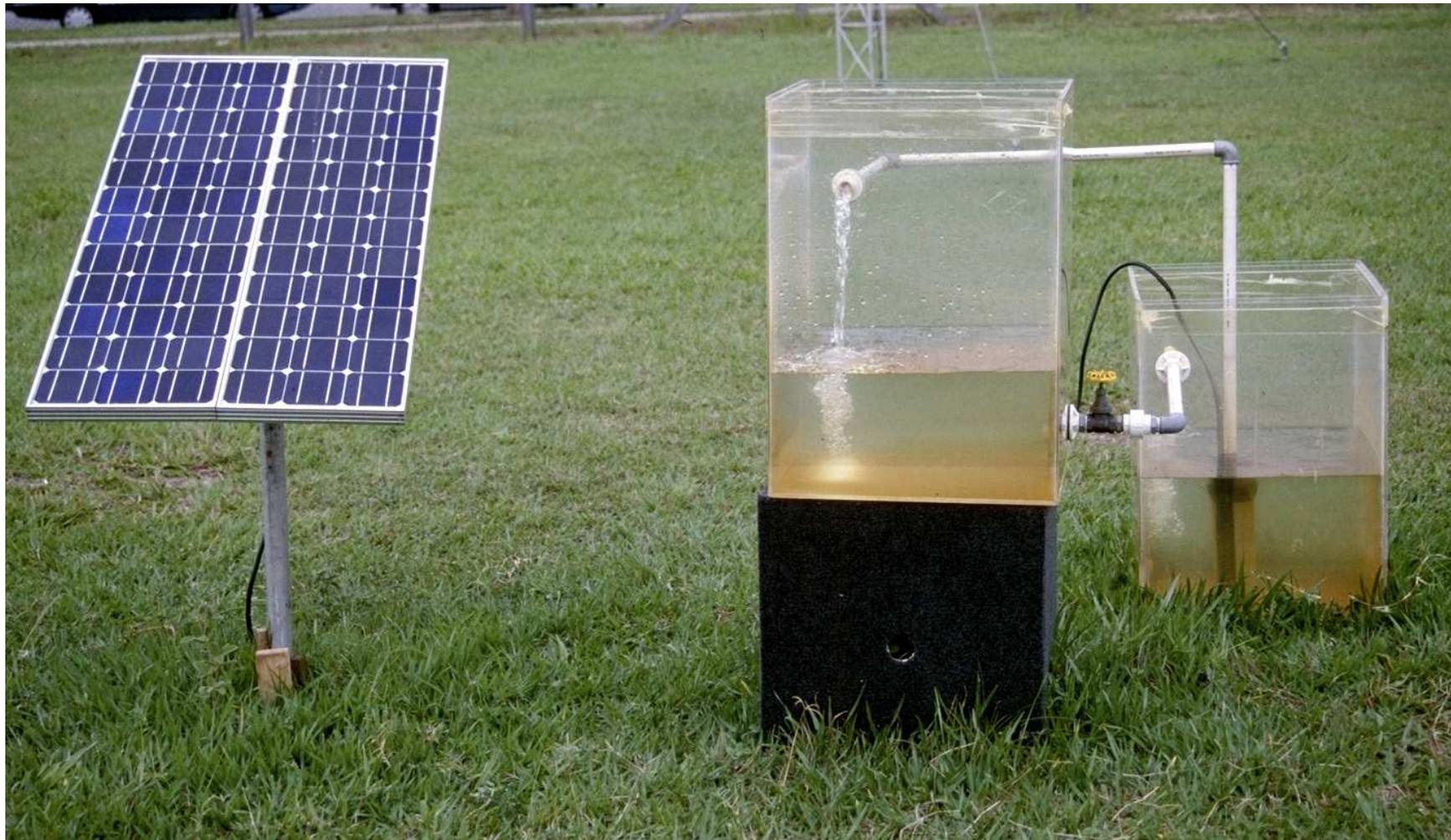


© Steca

# Micro-Kit para instalación fotovoltaica



# Sistema fotovoltaico para bombeamiento de agua



# Sistema fotovoltaico de 300 W<sub>p</sub> para uma escola indígena



## Off-grid middle class 400 W<sub>p</sub> PV-system in Brazil





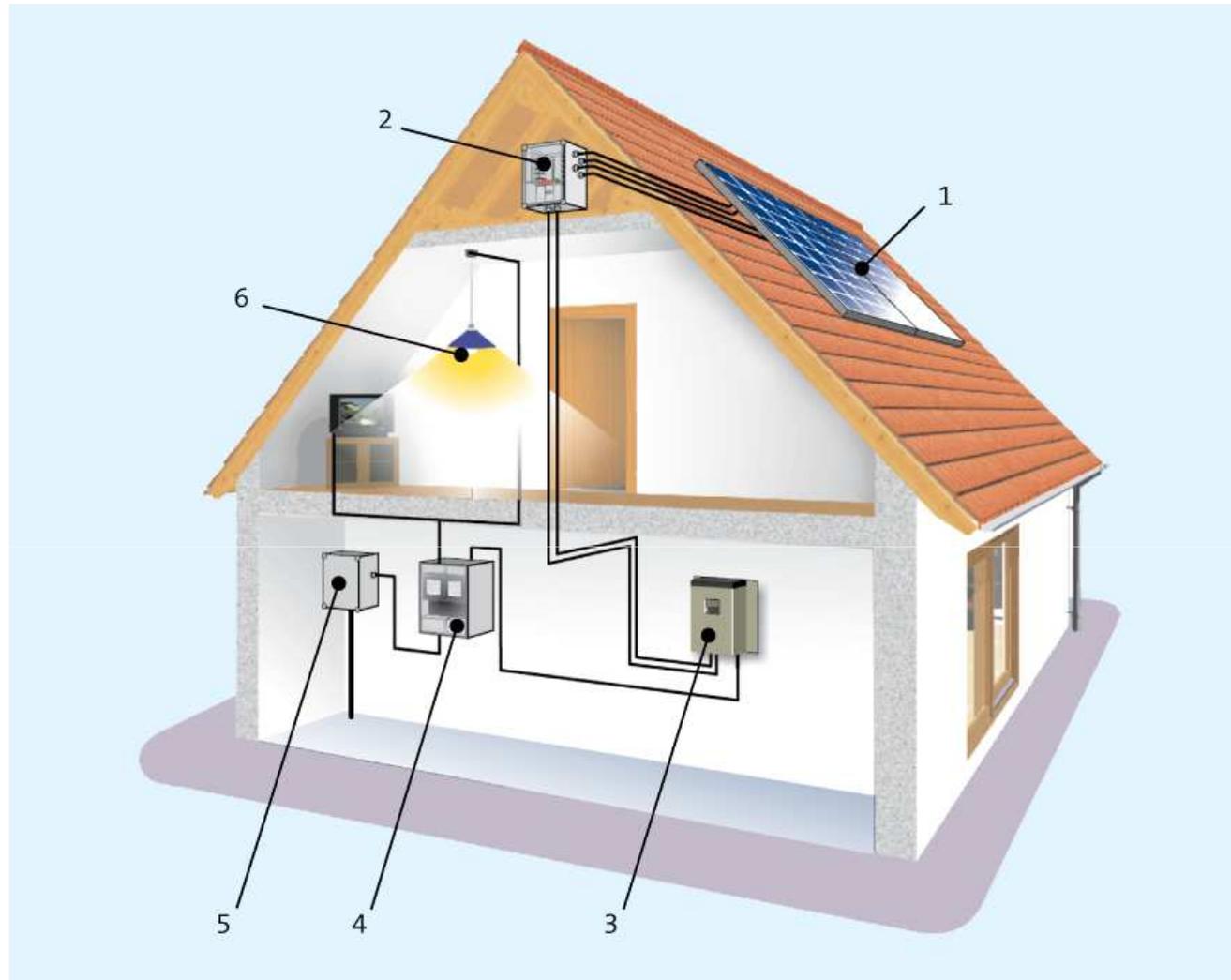
2 x 2,5 kW.FV, Baleia, Ceará

Stefan  
Krauter

Sistema fotovoltaico autônomo para uma fábrica de gelo

WCRE  
UECE

# Grid-connected PV system („PV grid injection“)



1 PV generator, 2 junction box, 3 Inverter, 4 kWh counter for electricity consumption and PV injection, 5 grid connection, 6 loads

© www.solarpraxis.de

# PV Roof in Freiburg, Germany



## 2 MW<sub>p</sub> PV generator integrated in the airport of Munich 2000



# 11 MW PV power plant in Sherpa, Portugal



# Cost of a PV power plant in Nicaragua

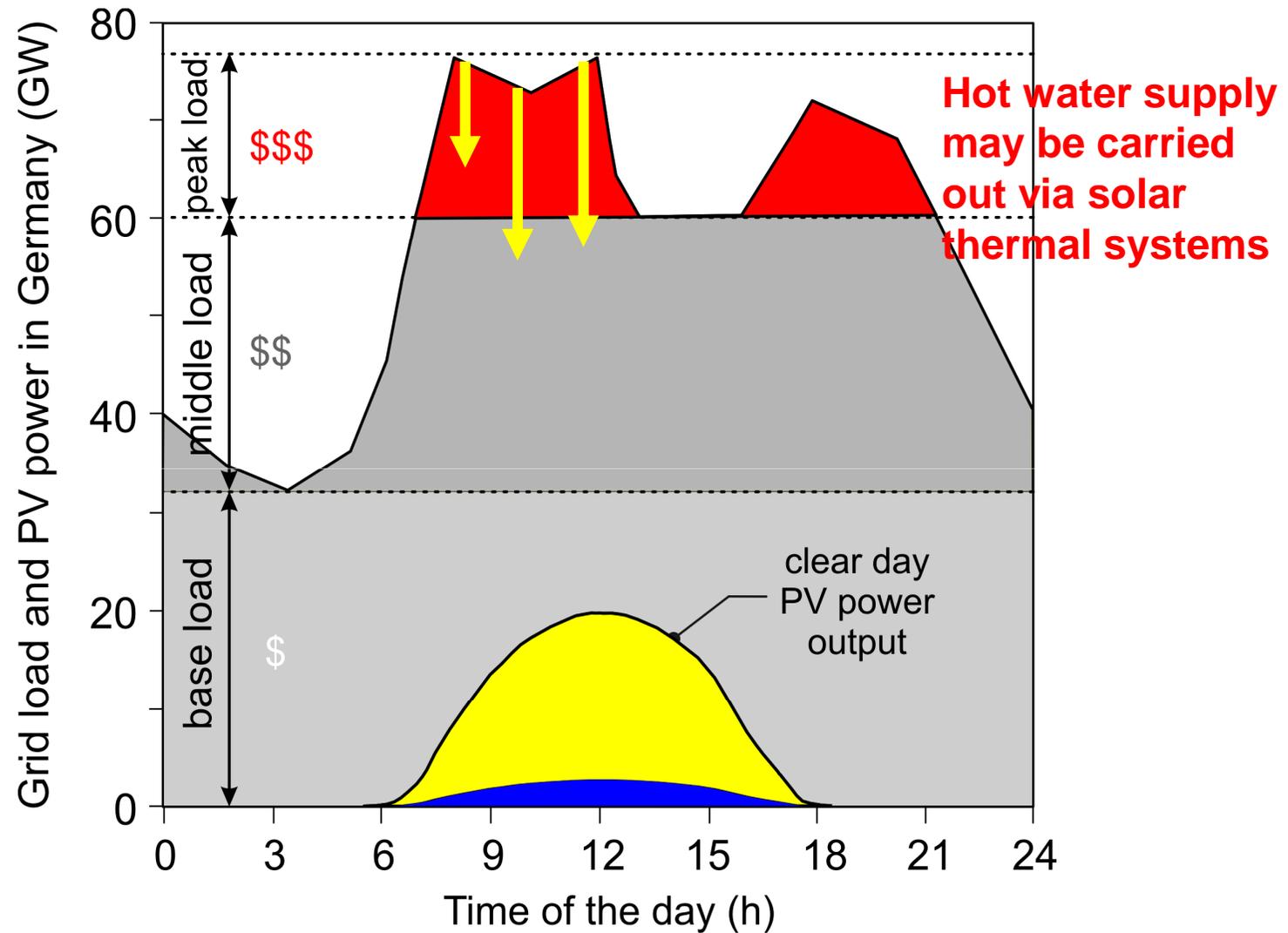
## Base costs from factory of a 10 MW PV power plant:

• PV modules	0.82 €/W <sub>p</sub>
• Inverters & power electronics:	0.22 €/W <sub>p</sub>
• Mounting structure	0.22 €/W <sub>p</sub>
• Cables & distribution	0.15 €/W <sub>p</sub>
• <b>Hardware costs:</b>	<b>13.1 mio €</b>
• Planning, set-up, product testing & selection	1.15 mio €
• Transport & Import	0.85 mio €
• Land preparation, foundations	1.10 mio €
• Installation	1.15 mio €
• Grid connection	0.15 mio €
• Maintenance	0.25 mio €
• <b>System costs</b>	<b>17.75 mio €</b>

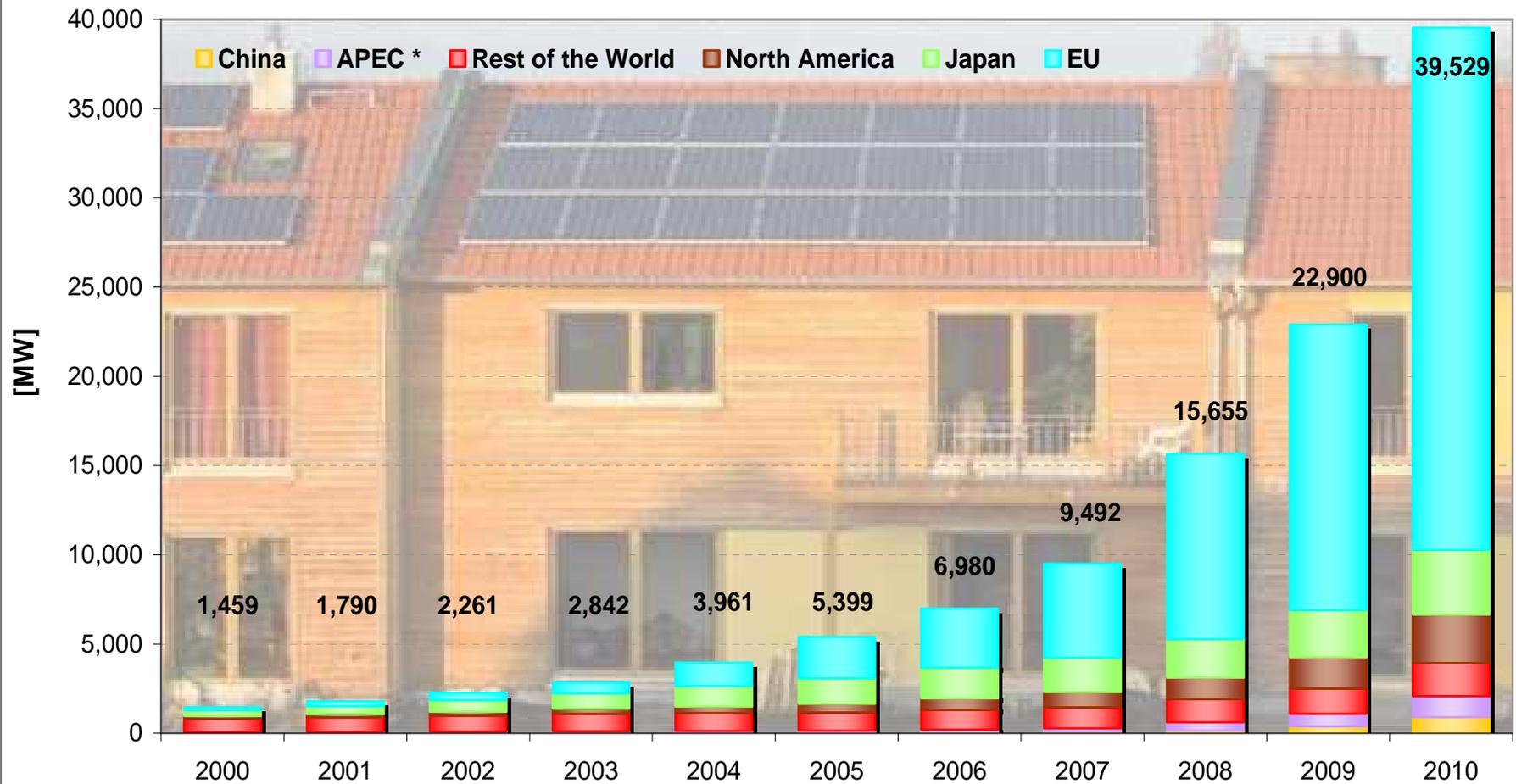
# Cost of PV electricity in Nicaragua

- Yield:
- Performance-Ratio von 0.77, module efficiency 10%, irradiance 2000 kWh/m<sup>2</sup>a, energy generation: 154 kWh/m<sup>2</sup>a, for a 10 MW System: 15.4 GWh/a. For 20 years of lifetime and power degradation of 10% (after 10 years) **total electricity yield: 292.6 GWh.**
- **PV electricity generation costs:**
- **0.061 €/kWh = 0.079 US\$/kWh = 1.78 Cordobas / kWh** (at 0% interest rate, zero land costs). Land area: 0.3 km<sup>2</sup>.

# Electric Grid load and Solar PV Power output during a day



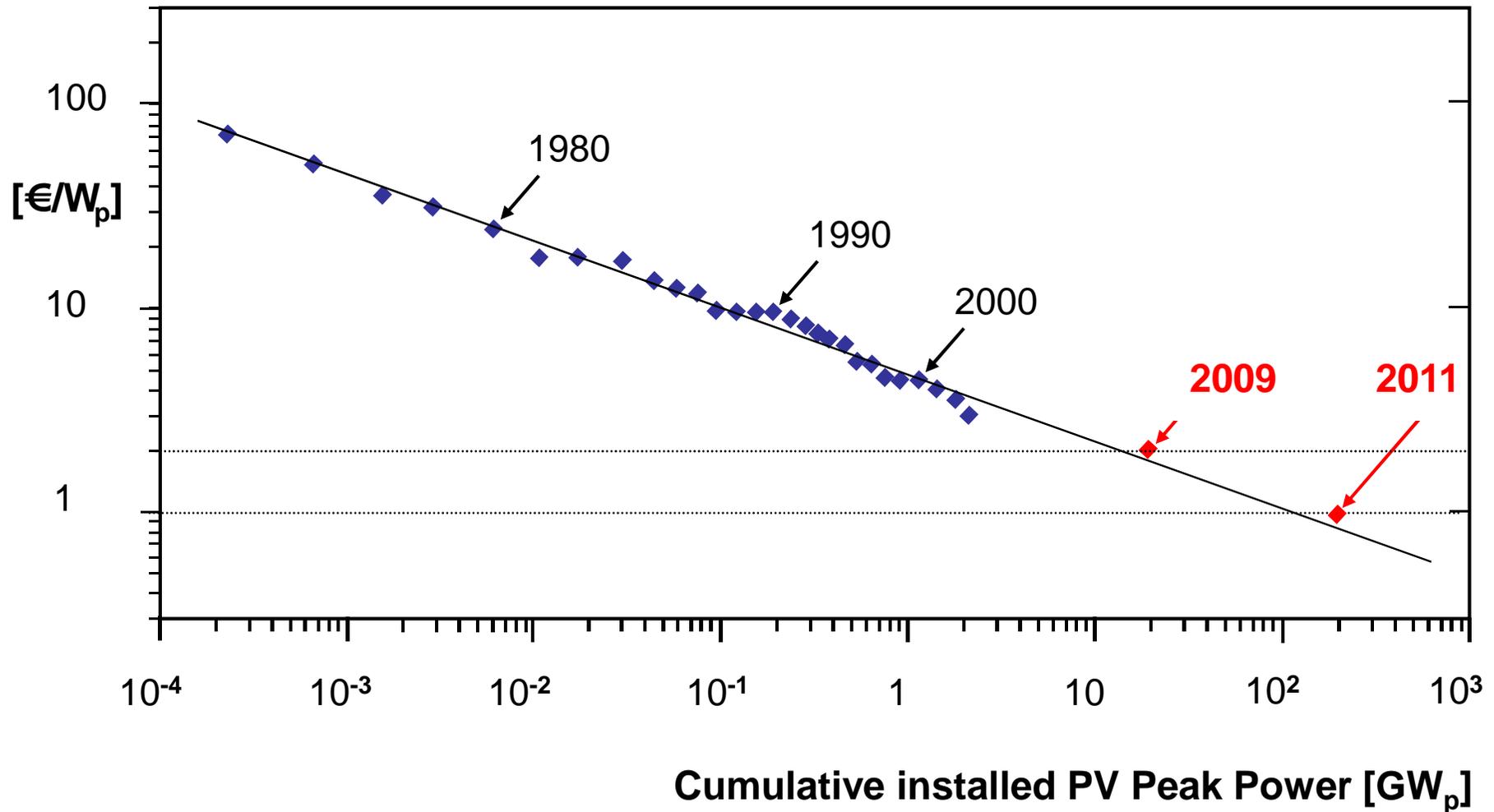
# Worldmarket photovoltaics 2000 - 2010 cumulated installed capacity



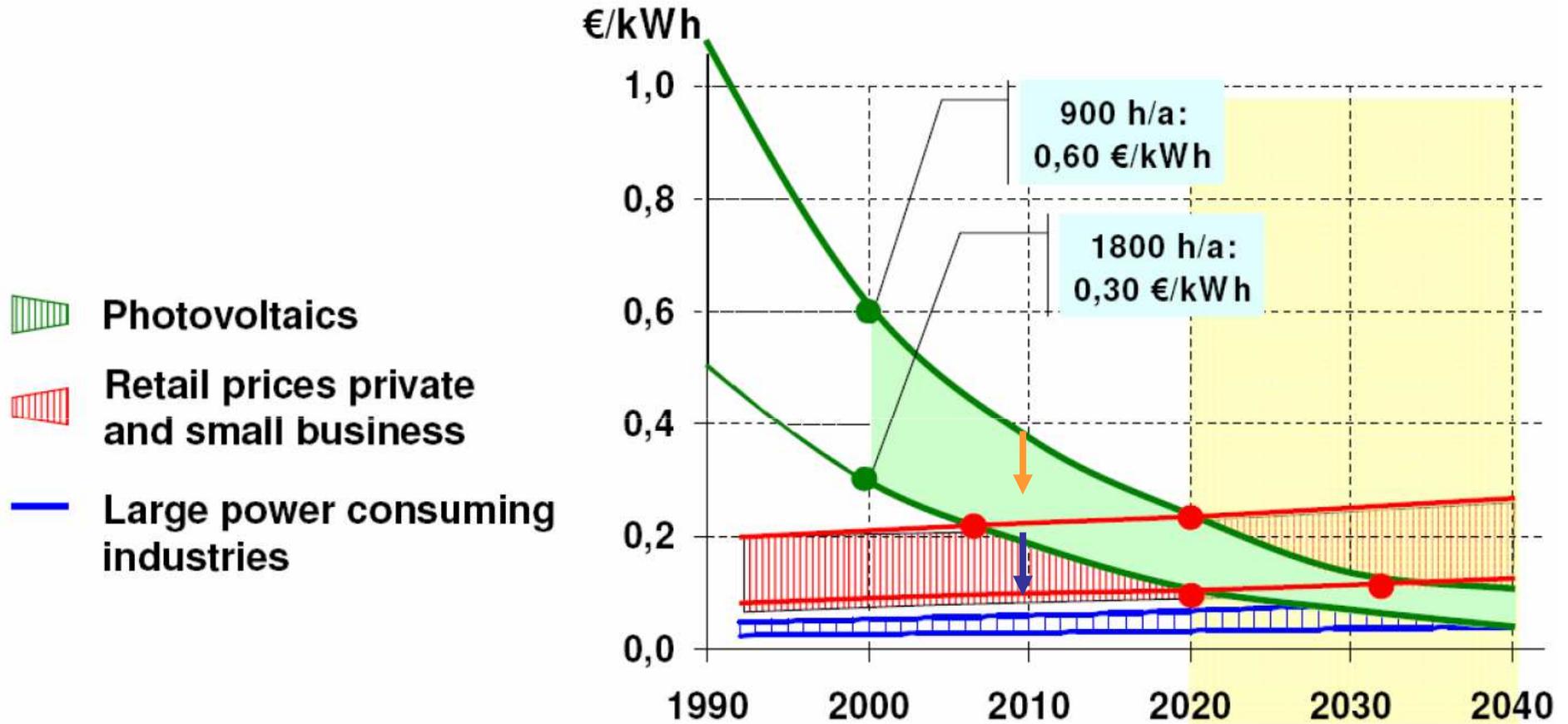
Members of Asia-Pacific Economic Cooperation (APEC) are: Australia, Brunei, Canada, Indonesia, South Korea, Malaysia, New Zealand, The Philippines, Singapore, Thailand, USA, Panama, Taiwan, Hongkong, Mexico, Papua New Guinea, Chile, Peru, Russia, Vietnam plus China and Japan, visualised separately.

Source: European Photovoltaik Industry Association (EPIA): "Global Market Outlook for Photovoltaics until 2015"; Image: BMU / Brigitte Hiss; as at: May 2011; all figures provisional

# „Learning curve“ of PV (for crystalline Si-wafer based PV)



# Roadmap to „grid parity“ of PV



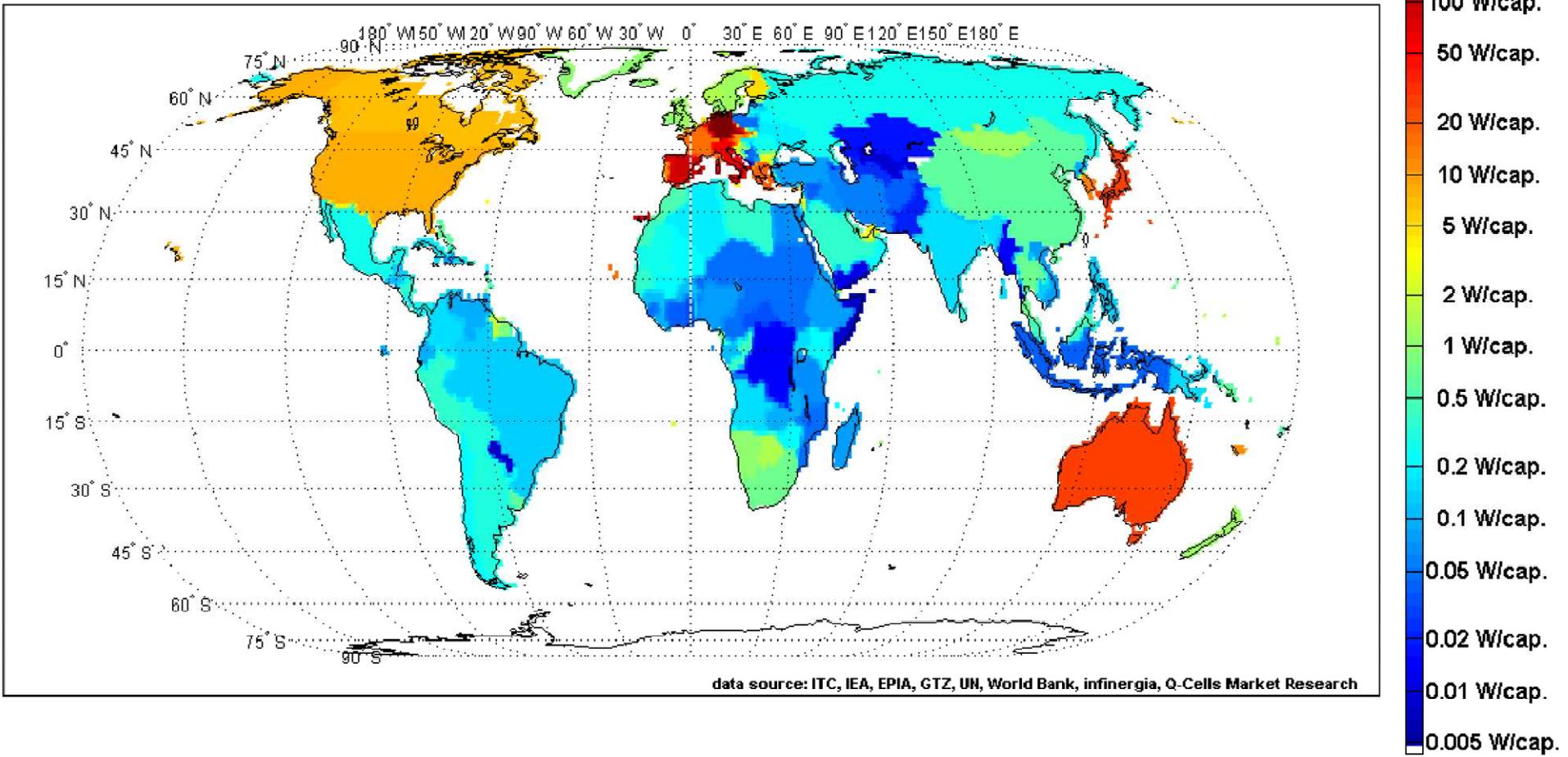
market support programs necessary:



Ref: W. Hoffmann, personal estimates, 1999

# Installed PV per capita worldwide

Global installed PV capacity per capita end of 2010



# Increase of PV installations



# Let's improve conditions for solar investments here !

**Higher volumes, lower prices, cheaper & faster importation, Qualified personnel, Public interest**

**Local production: e.g., solar thermal systems, mounting stands, inverters, batteries, charge controllers**

## Thank you !