Grid-feeding Photovoltaic

Installation and optimisation

Agenda

- Grid-feeding systems vs. Off-grid systems
- Components
  - Modules (wafertechnology vs. thin-film technology)
  - Inverters
- Optimising the generator field
  - Module orientation
  - Temperture influence
  - Shading issues
  - Further aspects

Solar Power Systems

- Off-grid PV Systems
- Grid-feeding PV Systems
- Solar Thermal Power Plants

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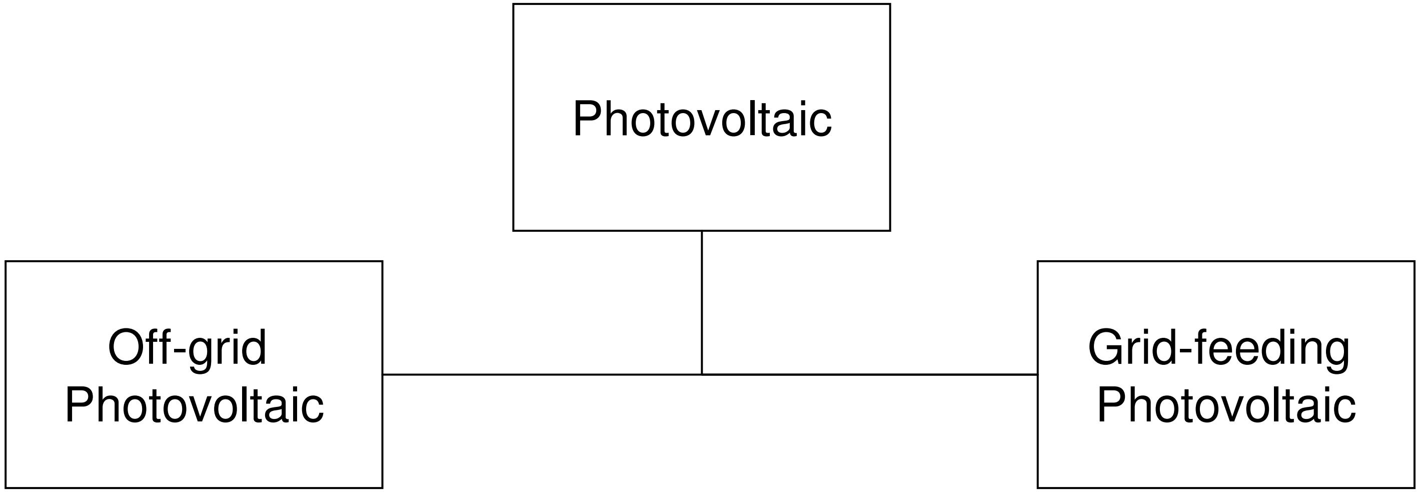
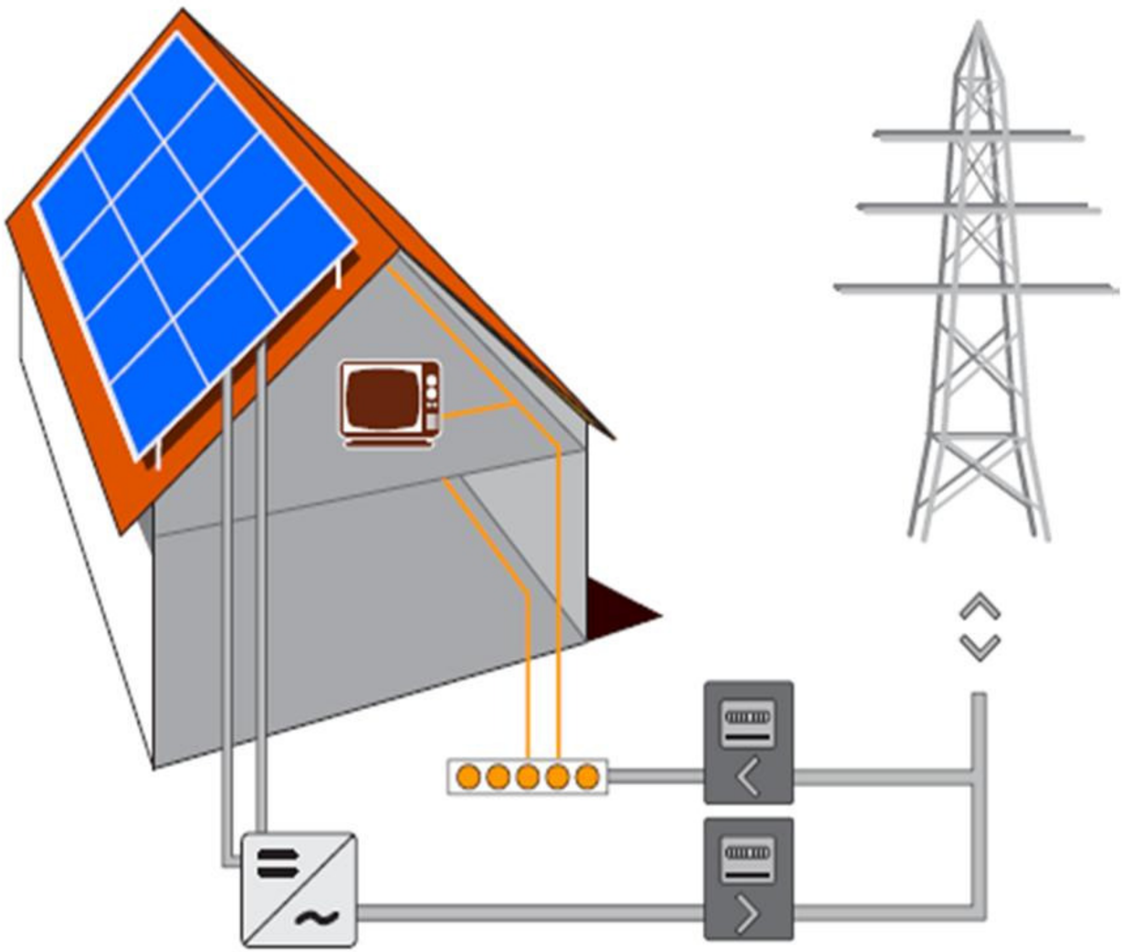


- Campervan
- calculater battery
- Parking Ticket machines
- Satelites
- Homes far away from the grid

Photovotaic produced energy gets fed into the grid at once. The generators are 1 kWp to 20 000 kWp big PV arrays

Photovoltaic feed in system



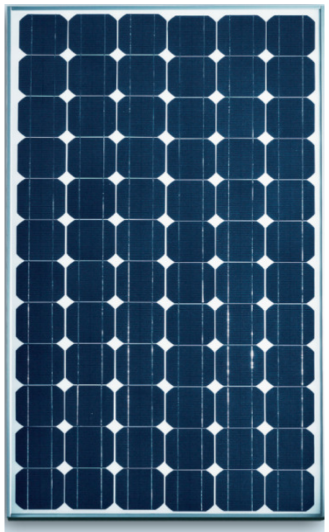
PV Feed in Systems

Necessary parts are:

- Modules
- Inverter
- Mounting Structure
- DC disconnect
- Electricity meter
- Cables

Modules

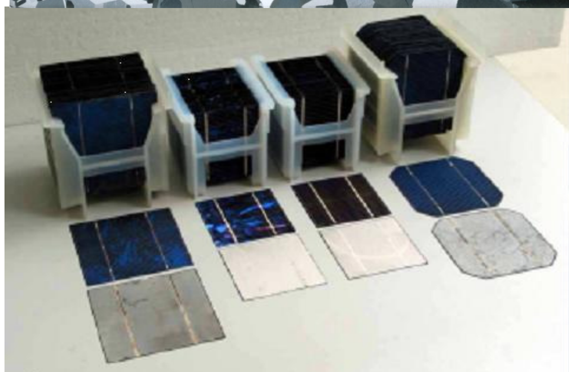
- Modules
  - Wafer technology 90 % market share
    - Monochristalline Efficiency = 16%
    - Polychristalline Efficiency = 14%
  - Thin-Film technology 10 % market share
    - A-SI:H Efficiency = 6 - 9%
    - Christalline Efficiency = 8%
    - CDTe Efficiency = 8 %
    - CIS Efficiency = 7 - 12%
  - Other technologies

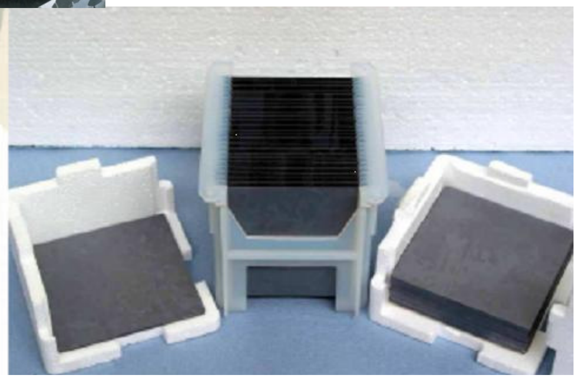


Wafer Technologiy – first generation solar cells

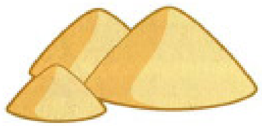
Christalline silicon as a semiconductor

- Indirecter semiconductor
- ΔE at 300K=1,17 eV
- Normally used in form of wafers (200 µm thick discs)
- Si is the second most numerous element on the earth crust

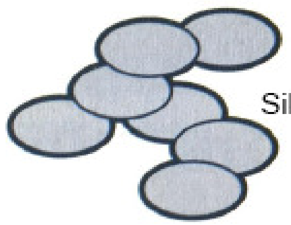




Fabrication of a wafer



Silizium-Einkristall

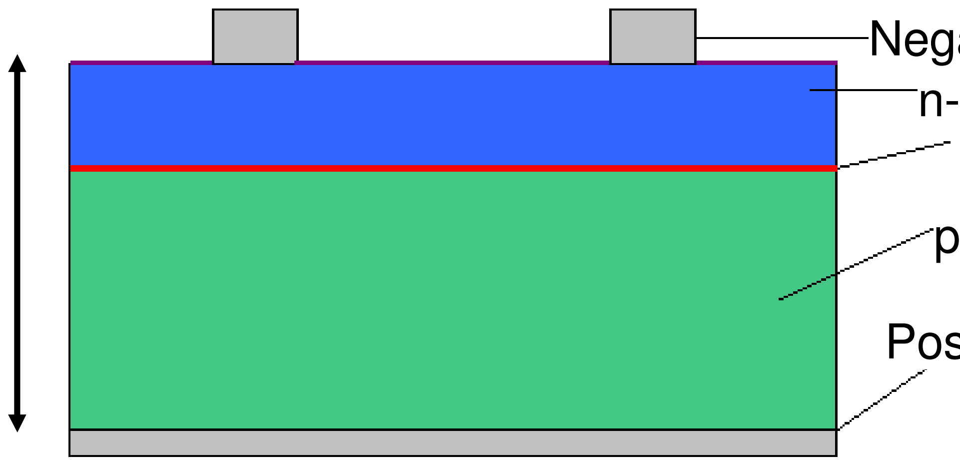


Silizium-Wafer

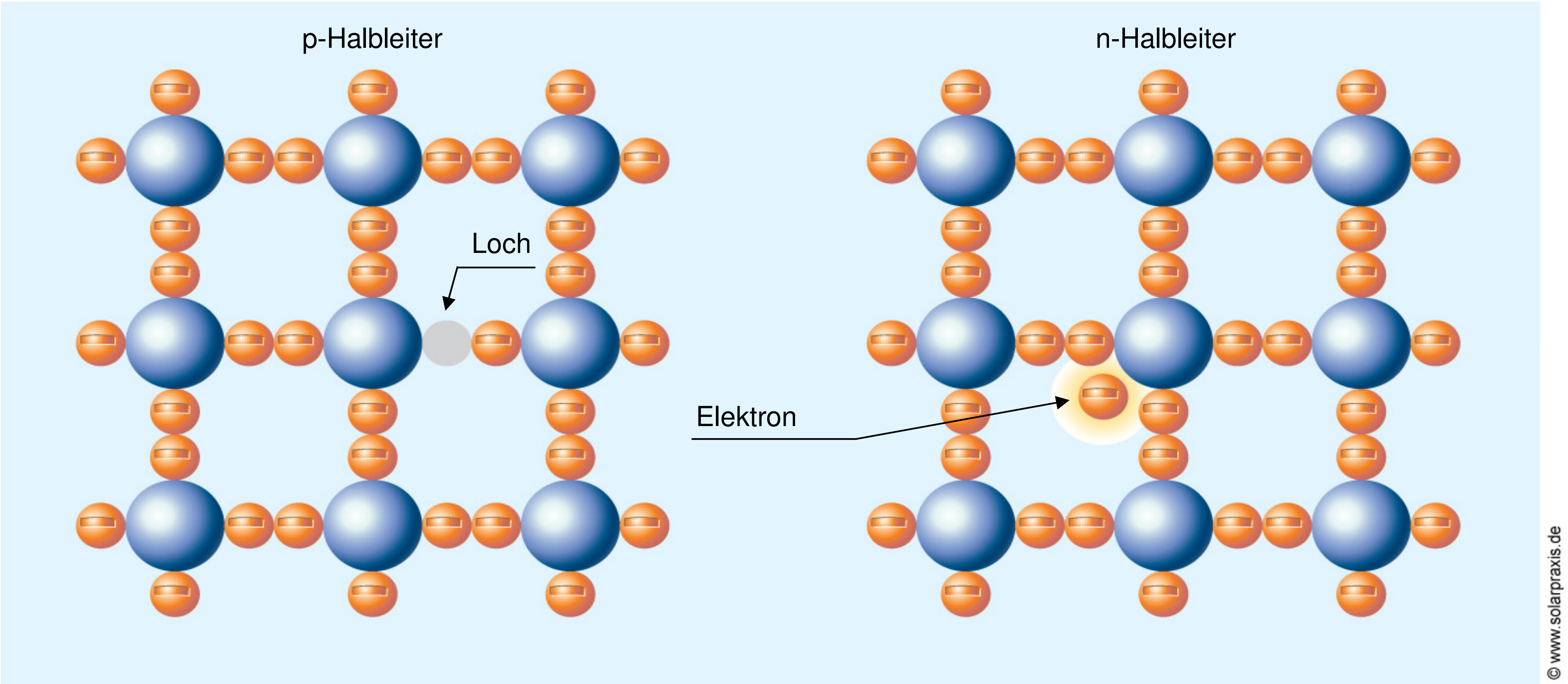
- Raw silicon is made out of sand
- Raw silicon becomes to solar grade (SG) silicon; very energy intense process
- SG silicon ingots are sawn into approximately 200 µm thick discs
- Cleaning with acid

Structure of a wafer cell

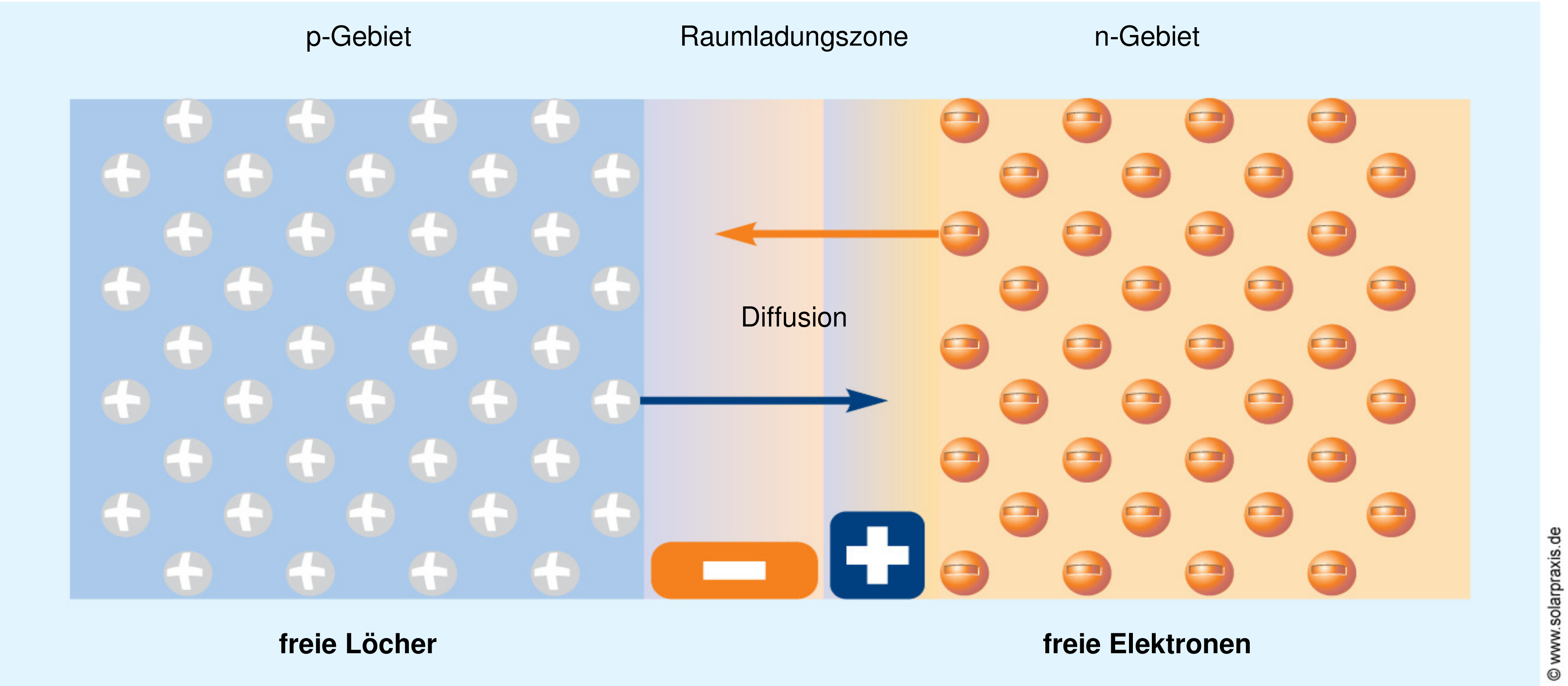
200 µm
SG silicon



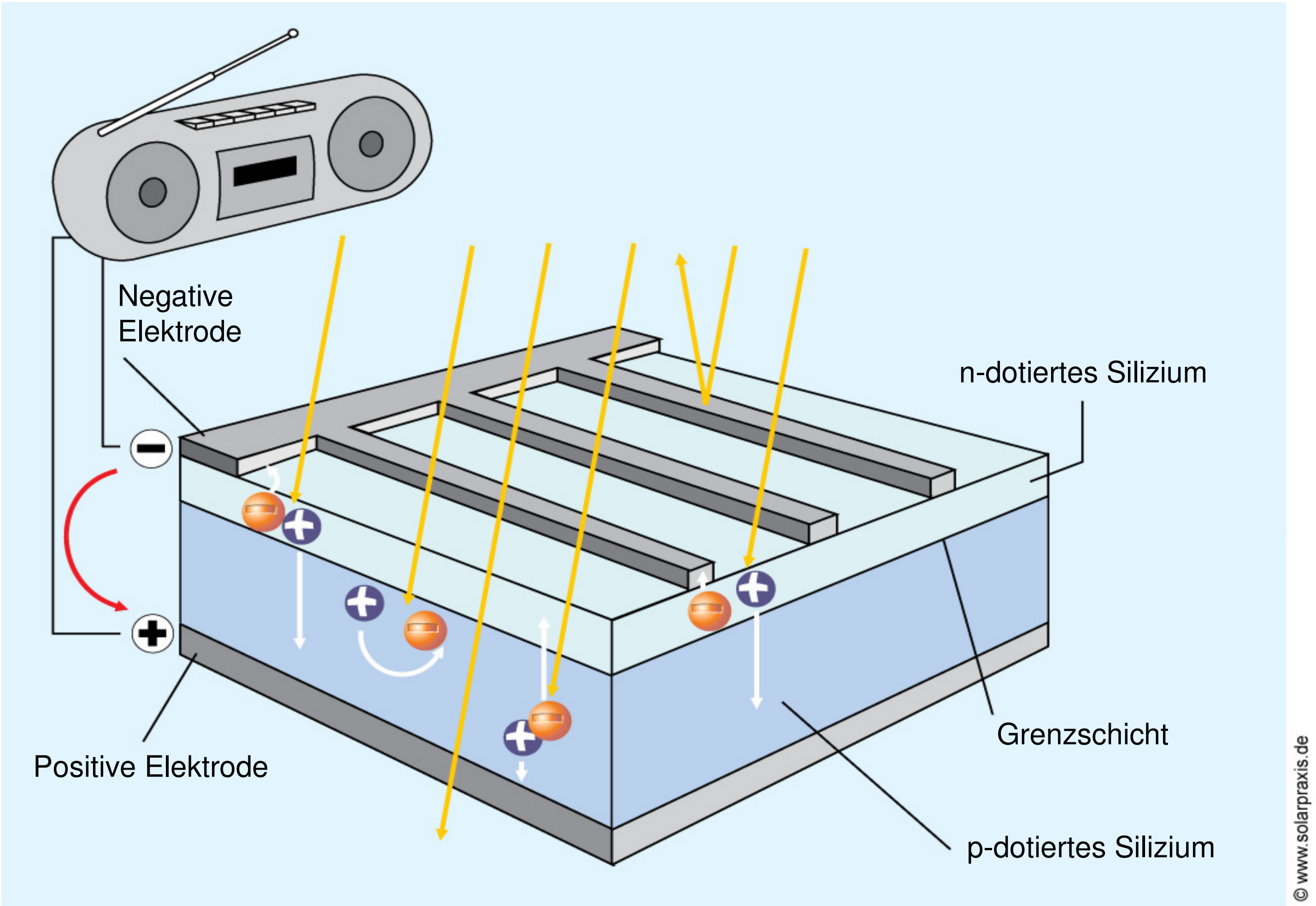
n and p doped silicon



Electric field due to p-n junction



How a christalline silicon cell works



Properties of wafer cells

- Relatively high efficiency (up to 19% in mass fabrication)
- Silicon is harmless (but harmful doping gases)
- There are no silicon supply problems

- High solar grade silicon demand
- High energy demand at the fabrication
- High energy pay back time
- Established technology; no huge improvements are expected

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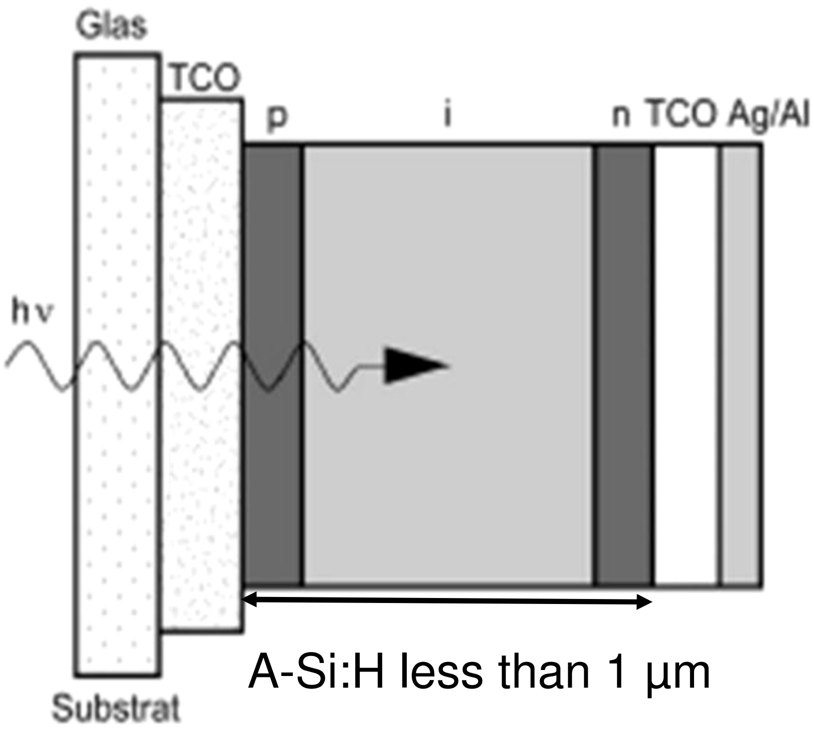
Thin-Film Technology – second generation solar cell

Kriterium	c-Si (Dünn-schicht)	µc-Si/ micro-morph	a-Si; a-Si/Ge	CdTe	CIS		CIGS/ CIGSSe
					$CuInSe_2$	$CuInS_2$	$CuInGaSe_2$/ $CuInGaS_2Se_2$
Produktions-technik	- ind. Massenprod. i. Aufb.	- industrielle Massenprod., - Komplettlösungen am Markt		- ind. Massenprod - sehr schnell herstellbar	- ind. Massenprod. im Aufbau - versch. HL-Verbindungen lassen gr. Variabilität der Eigenschaften zu		
η_{Modul} 2005	7,5%	6 - 9%	5 - 7%	7 - 9%	**9 – 12%**	7,6%	10 – 12%
η_{Modul} 2010	9,5%	10%		12%	14%		15%
erford. Fläche je kWp	14m²	14,3m²		11,1m²	8,3m²		
Flächenverhältnis	1,4	1,5		1,2	1		
Energierücklfzt		2-3 a		1a	1-2a		
Modul-Füllfaktor	0,6 ... 0,7	0,56...0,64		0,47...0,55	0,64...0,7	0,67	
Kapazität Ende 2005		115 MWp		50 MWp	8,2 MWp		
Kapazität Ende 2006		225 MWp		75 MWp	44 MWp		
Umweltaspekte	keine Bedenken			- Cd (100g/kWp) im Modul als stabile Verbindung eingebunden (s. hohe Bindungsenergie v. 5,8eV), nur bei T>1000°C gespalten, - vollst. Recycling - Te-Verfügbarkeit begrenzt	- vollst. recyclebar - Indium- Verfügbarkeit begrenzt		
Temperatur-abhängigkeit (P)	-0,5%/K	- 0,23%/K	**-0,1...-0,3 %/K**	-0,18...-0,36 %/K	-0,25...-0,6 %/K	-0,35 %/K	
Schwachlichtverhalten $50W/m^2$ $100W/m^2$ $200W/m^2$			Vgl. zu c-Si: U_L +45% U_L +33% U_L +4%	Vgl .zu c-Si: η: +22% η: +15% (sogar +2% im Vgl zu sich selbst bei 1000W/m²)	η: -5...-8% U_L: -11% (i.V.zu sich bei 1000W/m²)		
Degradation (im 1. Jahr/ 1000h)	-0,4%	-0,5...-24%	-20...-40%	- 3%	- 3...-5%	-6...-9%	
Degradation (gesamt)	0	0	- 0,74%	- 0,5%	- 0,6%	0	
Kostenprognose 100MW-Prod. €/Wp			1,40	0,95	1,0		

Energielücke		1,1-1,3		1,45 eV	1,04 eV	1,5 eV	2,7 eV
Hersteller am Markt (Kapazität in MWp/a) bis Ende 2006	- CSG Solar (25 i.Bau)	- Kaneka (3) - Sharp - Mitsubishi - Unaxis	- Mitsubishi (10) - Kaneka (25) - RWE Schott (3) - Sanyo (7) - Sharp (15) - Unisolar (25) - ErSol (40 i.Bau) - CSG (20 i.Bau)	- Antec- Solar (10) - First Solar (75)	- Shell Solar (3) - Würth-Solar (1,3) - Honda (27,5 i.Bau)	- SulfurCell (0,5)	- Global Solar (<0,4) - Aleo Solar
max. Systemspg.	1000V	530...930 V	600...1000 V	1000 V	600...1000 V	1000V	
Marktanteil (2004)		79,6%		15,4%	5%		
Standardgröße	1,1 x 1,25	1,1 x 1,4 m	1,1 x 1,2 m	0,6 x 1,2 m	0,6 x 1,2 m	0,65x1,25 m	
Technologie		Superstrate (Beginn m. Frontglas, darauf TCO etc.), bes. anfällig für TCO-Korr.		Superstrate	Substrate (Beginn m. Rückseite, darauf SZ...Glas)		
Zellfarbe	rotbraun	rotbraun	rotbraun	dunkelgrün-sw	dunkelbl-sw	sw	sw
Leistungsgarantie	25a (80%)	25a (80%)	20 (80%)	25a (80%)	10a (90%)	20a (80%)	

Structure of a Thin-Film solar cell (here a-Si:H)



A-Si:H less than 1 µm

- The semiconductor is evaporated onto a substrate (for example glass or plastic) in a high vacuum.

  The front contact is often realized with a TCO layer (*transparent conductive oxide*).

  The back contact has also got the function of a photon reflector.

Properties

- Smaller fabrication costs per kW_p
- Smaller silicon demand
- Smaller energy demand
- Shorter energy pay back times (1 to 2 years)
- Flexible sizes of the solar cells and the modules possible
- Less temperature sensitive
- Better performance with smaller radiation
- Bigger potential for major impovements
- Different substrates are useable (for example plastic)

- Smaller efficiency
- More area is needed
- More installation work
- Degradation with a:si-H as the semiconductor

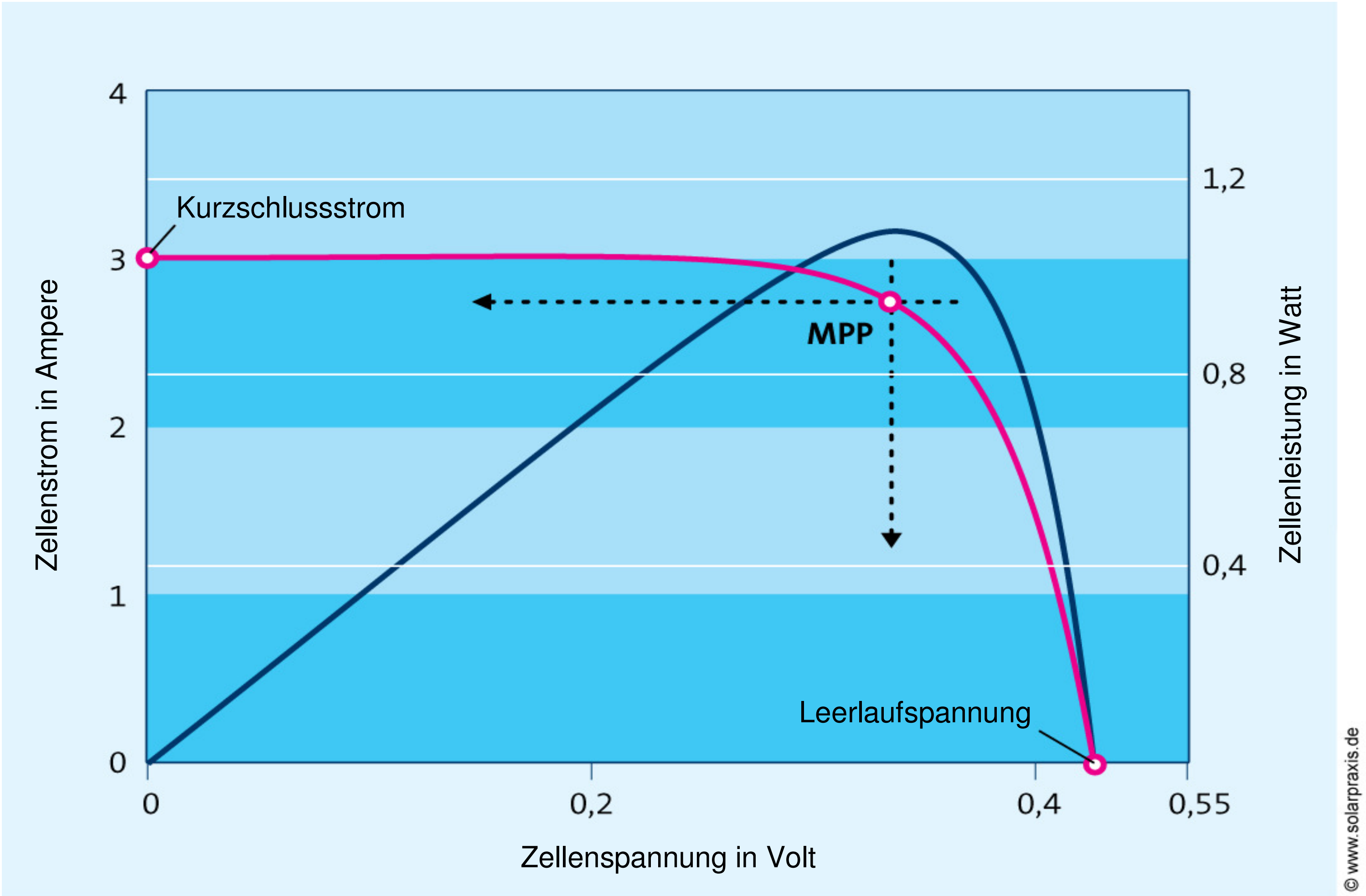
Inverters

- Inverters
  - String inverters
  - Central inverters

Single phase inverters
Up to 5 kWp

Three phase inverters
30 kWp to 280 kWp

I-V curve of a christalline silicon solar cell



Inverter dimensioning

- Optimal AC/DC ratio
- Right number of modules per string so that inverter works in its voltage area
- Sometimes better or necessary to have more than one inverter

Data sheet of a PV module

Technical data Conergy C 175M

Max. output (Pmax) as per STC*	175 W ± 5 %
MPP voltage (Vmpp)	35.4 V
MPP current (Impp)	4.95 A
No-load voltage (Voc)	44.4 V
Short-circuit current (Isc)	5.40 A
Temperature coefficient (Pmpp)	-0.5 %/°C
Temperature coefficient (Voc)	-0.144 V/°C
Temperature coefficient (Isc)	2 mA/°C
Maximum system voltage	1.000 V
Cells	72 monocrystalline

Cell dimensions	125 x 125 mm
Module dimensions (L x W x H)	1575 x 826 x 46 mm
Weight	17 kg

1 Standard Test Conditions, which are defined as follows: radiation output of 1000 W/m2 (max. insolation) at a spectral density of AM 1.5 (ASTM E892). Cell temperature of 25°C.

Your specialist supplier:

Data sheet of an inverter

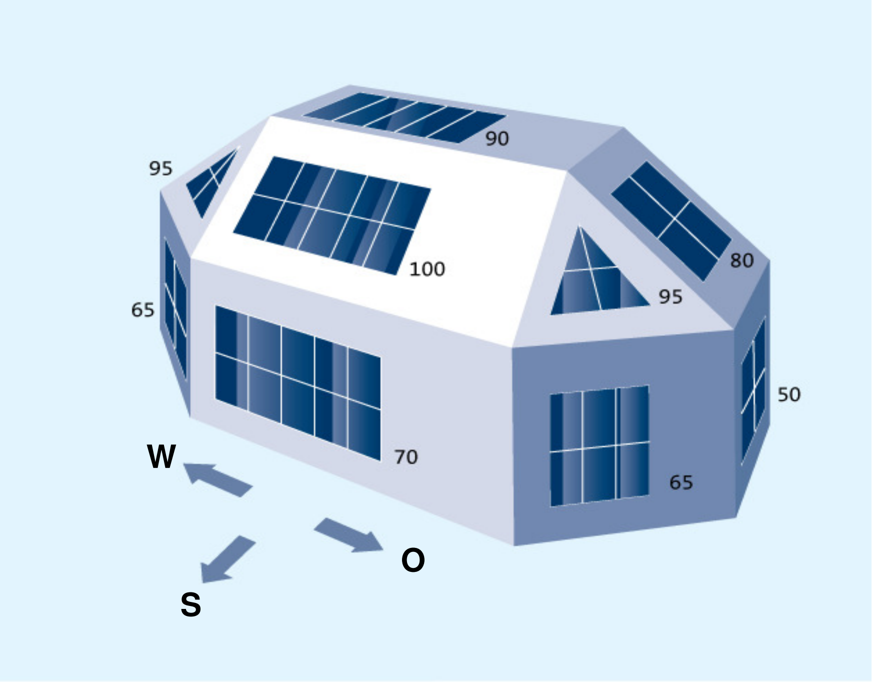
	Conergy IPG 2000	Conergy IPG 3000	Conergy IPG 4000	Conergy IPG 5000
Input data				
Received DC power(P_{DCmax})	2,000 W	3,000 W	4,000 W	5,000 W
Max. input current (I_{DCmax})	10.2 A	10.2 A	15.2 A	16.2 A
DC voltage range	200–800 V	200–800 V	220–800 V	220–800 V
Max. MPP voltage (U_{MPPmax})	700 V	700 V	700 V	700 V
Reverse polarity protection	DC-side short-circuit diodes			
DC connect	MC IV	MC IV	MC IV	MC IV
Max. number of strings	2	2	2	2
DC overload behaviour	Shifting of the working point on the solar generator characteristic curve			
Ambient temperature	–10 to +40 °C/up to +60 °C with derating			
Cooling	Convection	Convection	Convection	Convection
Output data				
Max. AC power (P_{ACmax})	2,000 W	2,800 W	3,800 W	5,000 W
Nom. AC power (P_{ACnom})	1,800 W	2,600 W	3,400 W	4,600 W
Distortion factor	< 3 %	< 3 %	< 3 %	< 3 %
Mains voltage (U_{AC})	196–253 V_{AC}	196–253 V_{AC}	196–253 V_{AC}	196–253 V_{AC}
Frequency (f_{AC})	47.5–50.2 Hz	47.5–50.2 Hz	47.5–50.2 Hz	47.5–50.2 Hz
Efficiency level				
Max. efficiency	96 %	96.1 %	96.5 %	96.7 %
European standard efficiency	93.6 %	94.5 %	95 %	96 %
Protective equipment				
Protection type	IP 65	IP 65	IP 65	IP 65
Earth fault monitoring	Yes	Yes	Yes	Yes
Casing material	Aluminium	Aluminium	Aluminium	Aluminium
DC overvoltage protection	Varistors and spark gaps			
General data				
LED display	Yes	Yes	Yes	Yes
Touch-screen display	Only with Conergy IPG vision[1]			
Communication	CAN-Bus	CAN-Bus	CAN-Bus	CAN-Bus
Noise emissions	<30 dB	<30 dB	<30 dB	<30 dB
Own power consumption	0.28 W (during overnight connection)			
Physical dimensions (W × H × D)	377 × 620 × 226 mm	377 × 620 × 226 mm	377 × 620 × 226 mm	377 × 620 × 226 mm
Weight	23 kg	24 kg	27 kg	28 kg

Dimensioning the inverter

- How many modules per inverter?
  - Minimum voltage per module = (Vmpp – φ (Tmin – 25)) * 0.95 (voltage drop) * 0.90 (safety)
  - Maximum voltage per module = (Voc - φ (Tmax – 25)) * 1.05 (safety)
  - Minimum amount of modules to reach the inverter voltage field
  - Maximum amount of modules to stay in the inverter voltage field
- What is the desired power of the PV generator ?
- Can a sensible AC DC ratio be realized be realized with this inverter theses modules? (using maybe more than one string)?
- If no satisfying solution can be found consider using different modules or a different inverter. Maybe two inverters.

Optimizing the PV array

The yield depends on tilt azimuth and declination



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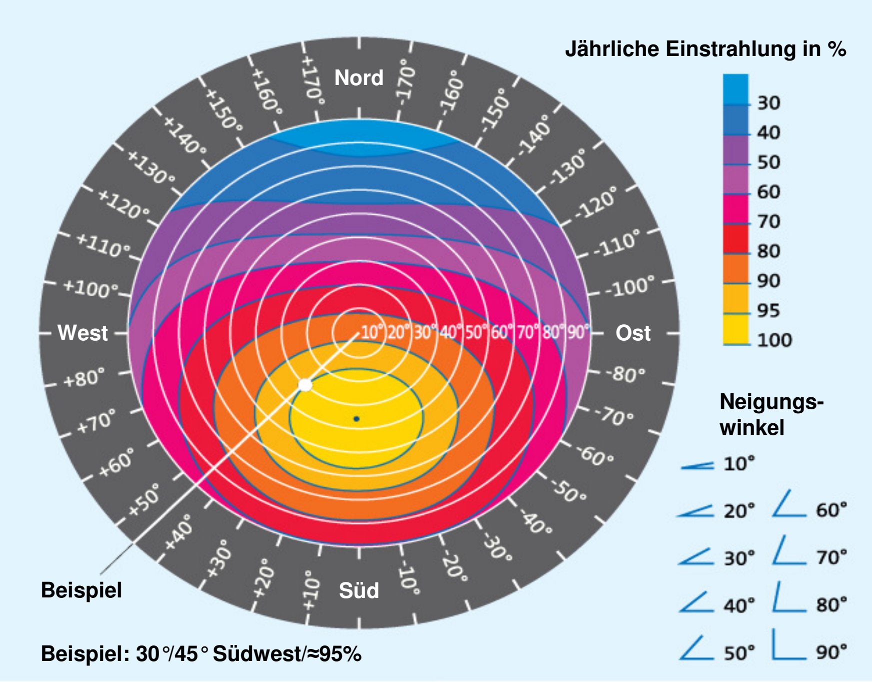

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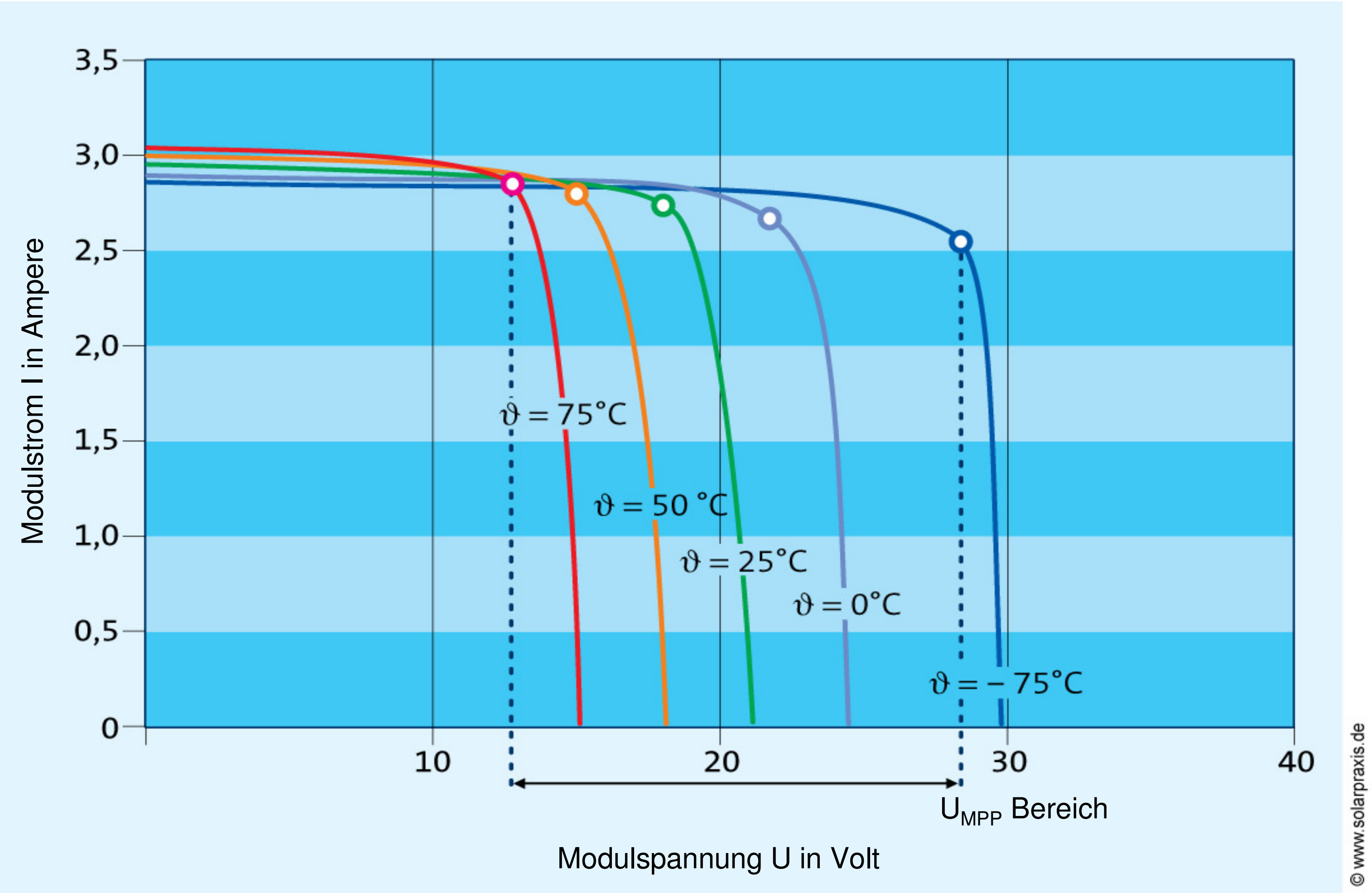
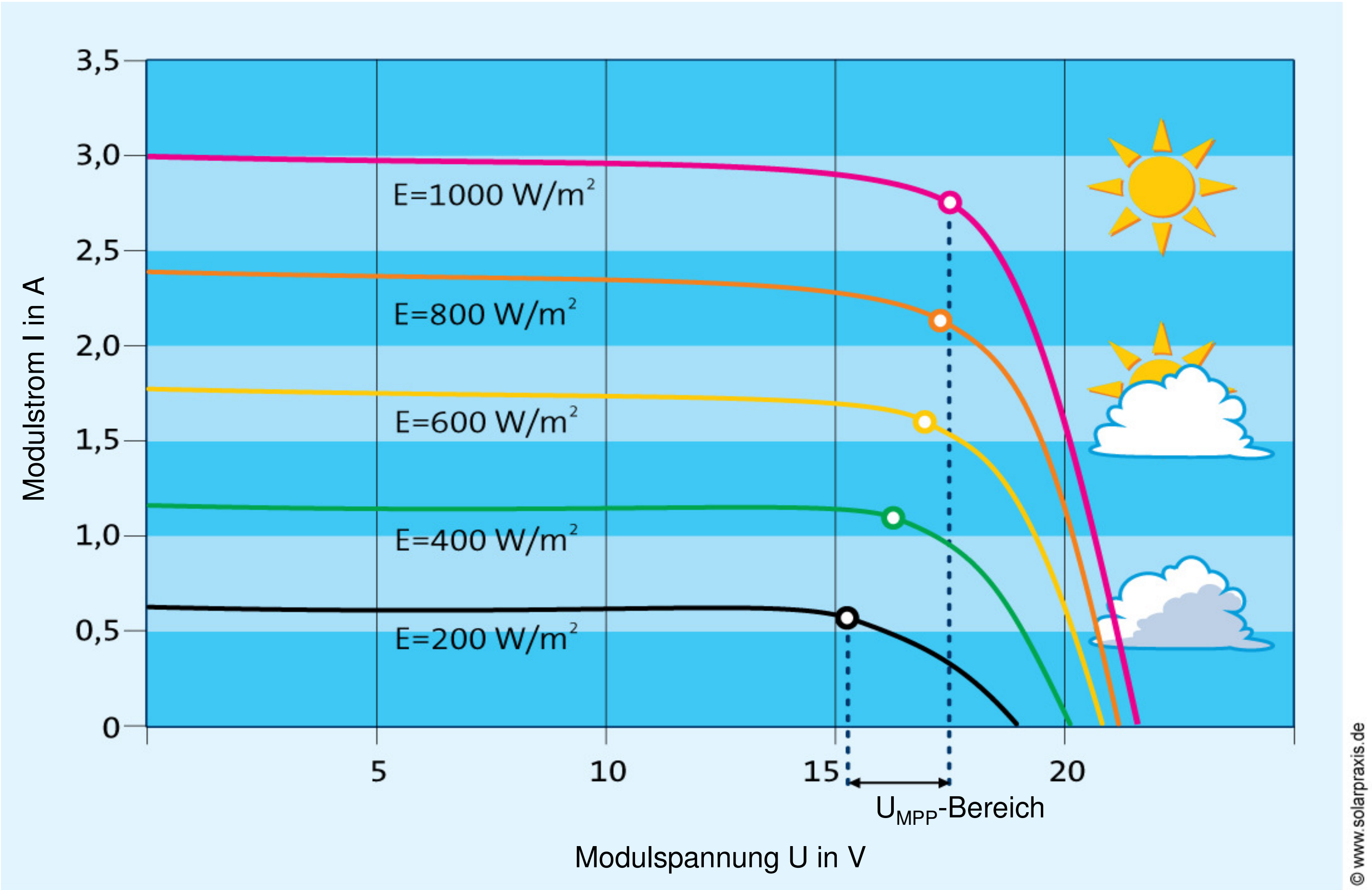
Temperature influence

I V curve of a christalline silicon cell for different temperatures



I V curve depending on the intension of the radiation



Shading

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Shading movement during the day

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Shading analysis

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CONERGY

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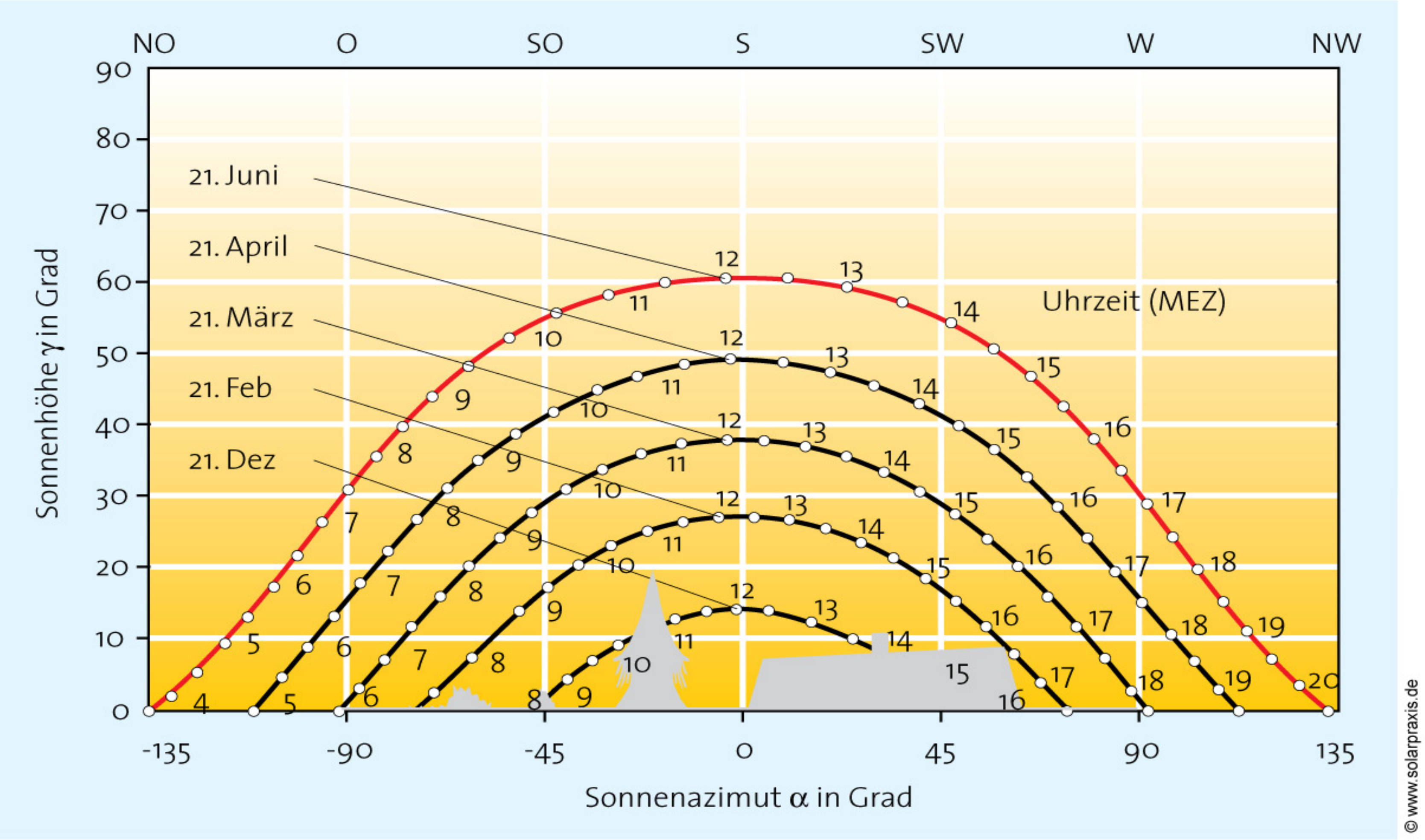
Shading analysis



Module positioning due to shading

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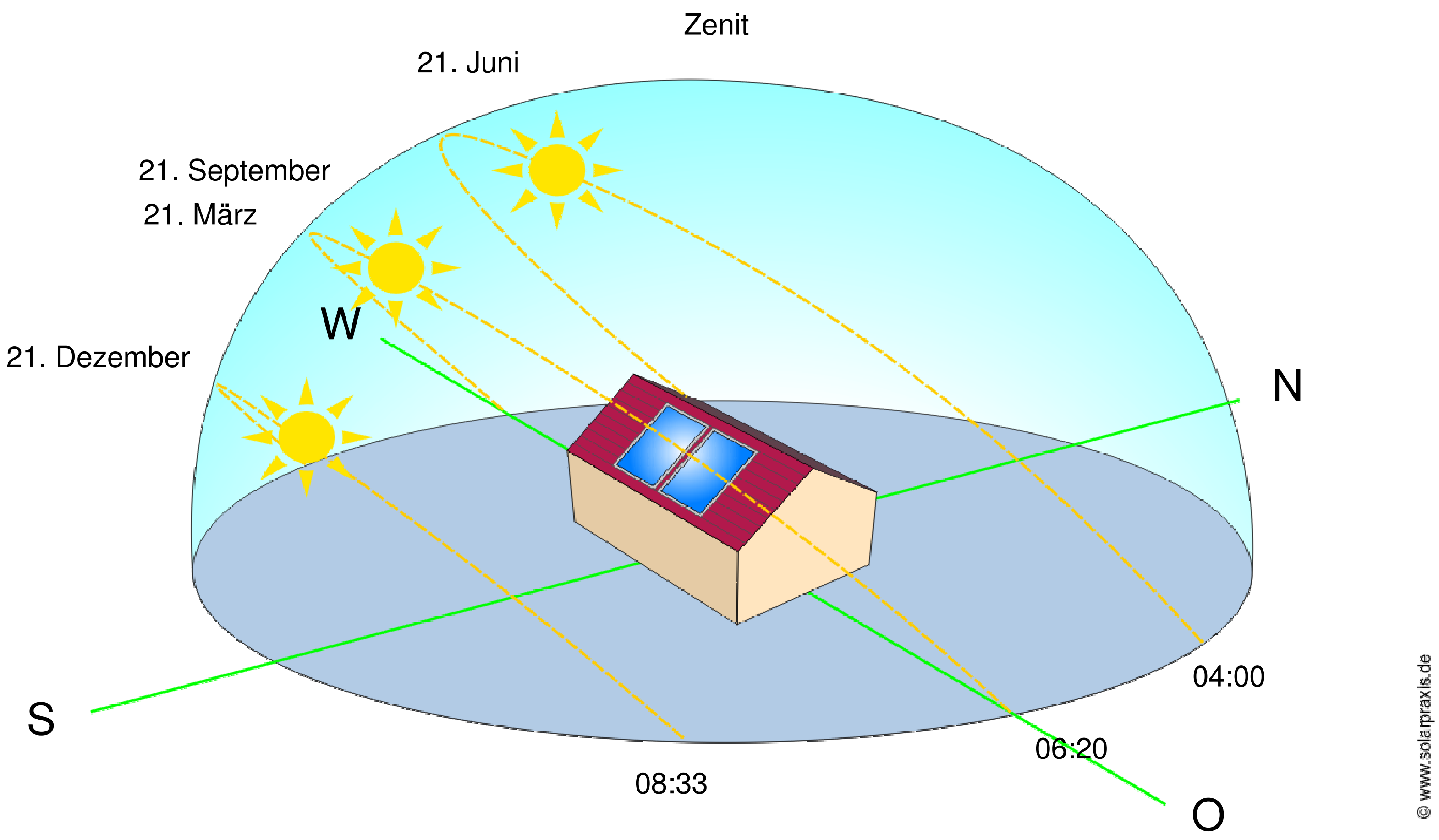
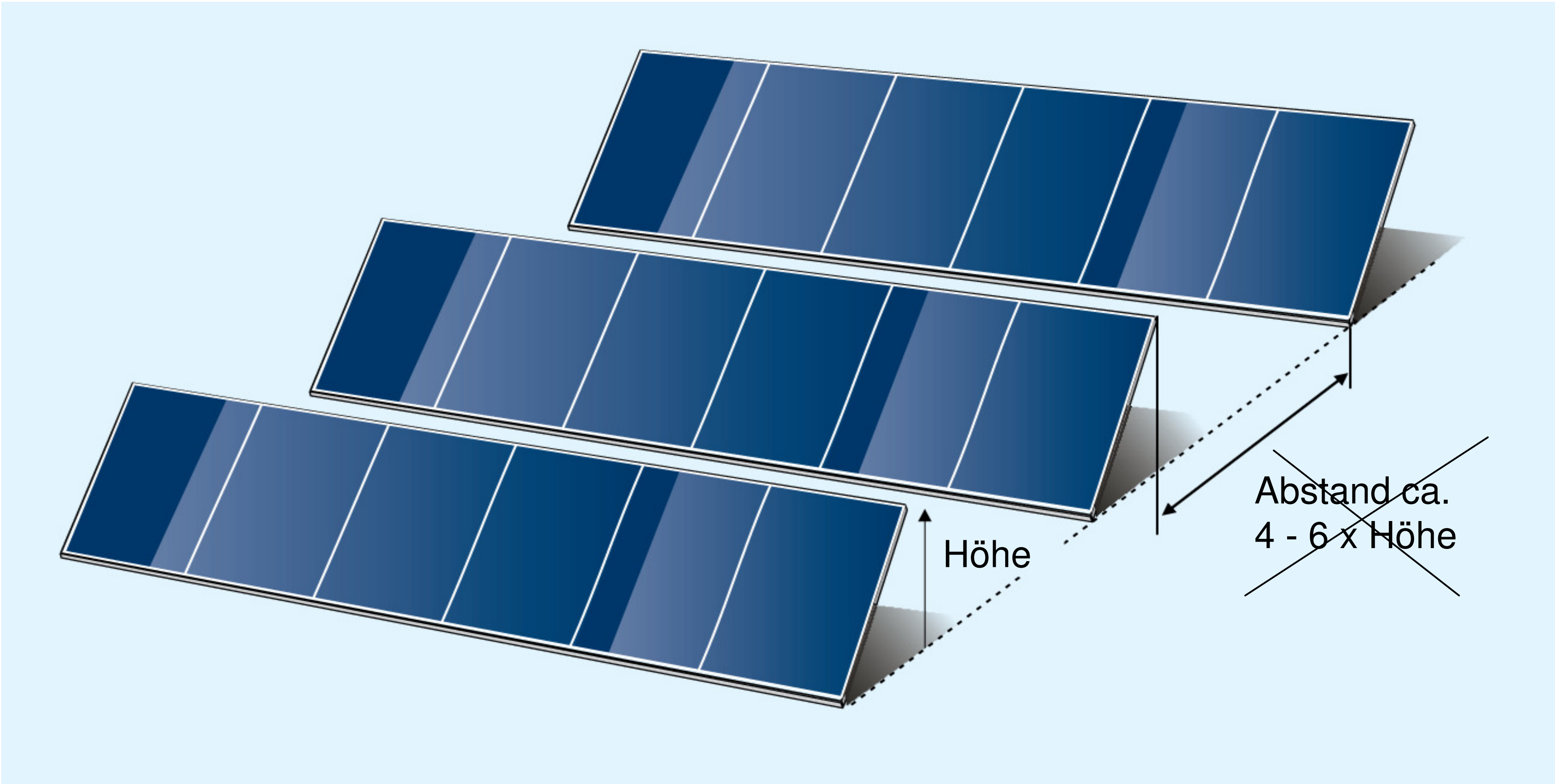
Sun movement on different days of the year (northern hemisphere)



Self shading of tilted modules (on flat roofs) must be avoided



Other optimisation

- Right sized cables to the inverter and to the meter
- Short distances to the inverter and to the meter (distance inverter to the meter is about two times more critical)
- Always same modules on one sting
- Never different tilted modules on one string

Thank you for your attention!