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THE FICHTNER GROUP

Engineering & Consulting – worldwide

Technical and Commercial Aspects Related to the Implementation of Solar Power Plants – Part 1

Felix Gudat

Ukraine, March 2012

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Content

The Fichtner Group

- Established in 1922 and family owned ever since
- Germany's biggest independent engineering and consultancy enterprise
- More than 1,800 employees worldwide – 450 in our Home Office
- Project experience in 160 countries and represented in more than 50 countries (30 subsidiaries, 70 branch and project offices)
- Total turnover of €201 million in 2010
- Capital investment volume now under planning in the home office: €87 billion – of which some €21 billion is in renewable energies

Fichtner's Areas of Activity

Energy

Energy economics • power plants • renewables • district heating • energy transmission and distribution • I&C and power system technology • oil & gas • energy management • electric mobility • energy-purchasing portfolio management

Environment

Environmental management • environmental technology • environmental information systems • waste management • soil and water protection • air pollution control • sustainable development • emissions trading

Water & Infrastructure

Total water management • drinking water supply and sanitation • surface and engineering structures • traffic, transportation and civil engineering • mining and mineral economics • integrated infrastructure concepts

Consulting & IT

Studies • organization and strategy consultancy • privatizations • project management • financial modeling • infrastructure management • IT consultancy and services • geo-solutions

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Range of Engineering and Consulting Services

Analysis and Conceptual Design

Feasibility studies • environmental impact and siting studies • economic and technical analyses • masterplans • integrated infrastructure concepts • plant concepts • preliminary planning and conceptual engineering • operation management concepts • IT concepts

Engineering and Contract Award

General planning • basic engineering • permit engineering • detail engineering • plant and functional specifications • tendering • bid evaluation • contract award recommendation • contractual negotiations • contract formulation

Implementation

Check of drawings • shop acceptances • specialist site management and supervision • coordination of commissioning • final acceptance • documentation • trial operation and warranty support • interface coordination • project steering • general project supervision • health and safety coordination • staff training

Operation

Process optimization • environmental, risk and quality management • maintenance scheduling • optimization of deployment • operation, management and environmental information systems

Business Consultancy

Market analyses • tariff studies • project development • strategy and organization • financial modeling • project financing • project management • lender's engineering • due diligence • mergers & acquisitions • IT consultancy • sectorial IT solutions • energy-purchasing portfolio management

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Introduction

PV Markets and Outlooks

Overview of PV Technologies

Yield prediction

Quality and Defects

EPC and O&M

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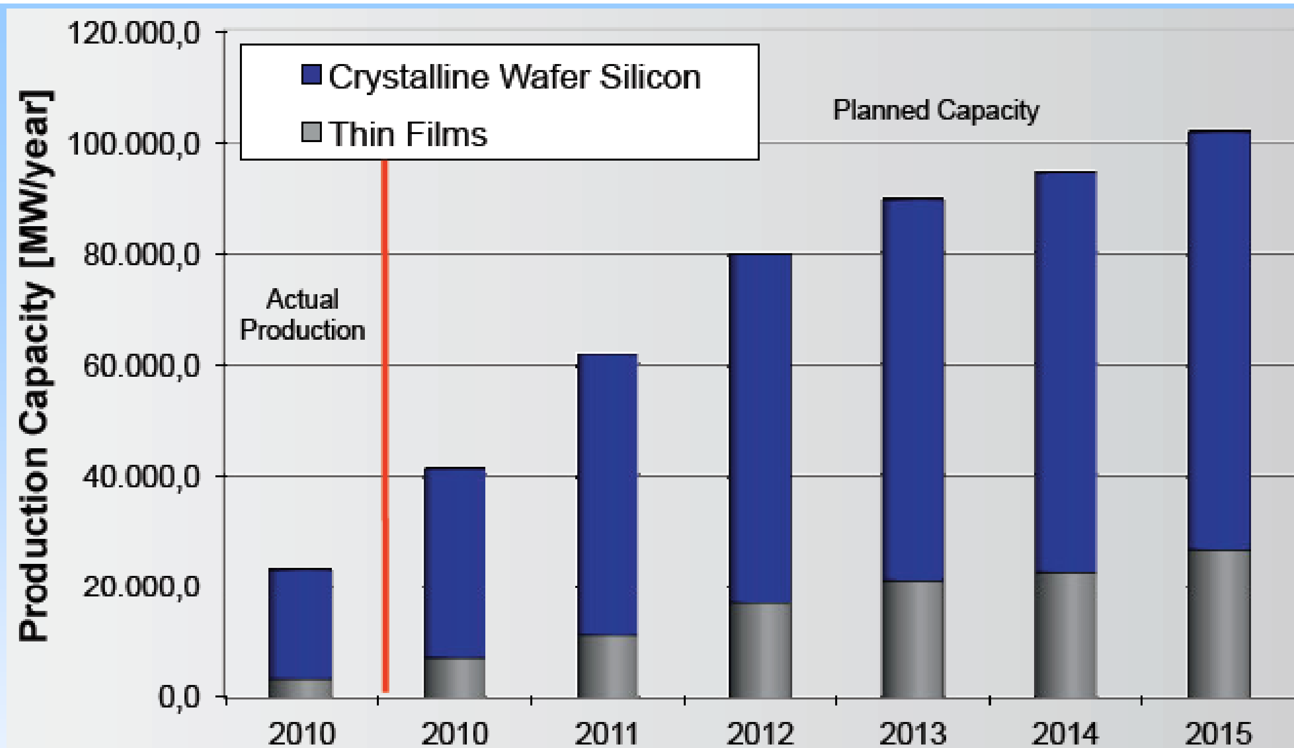
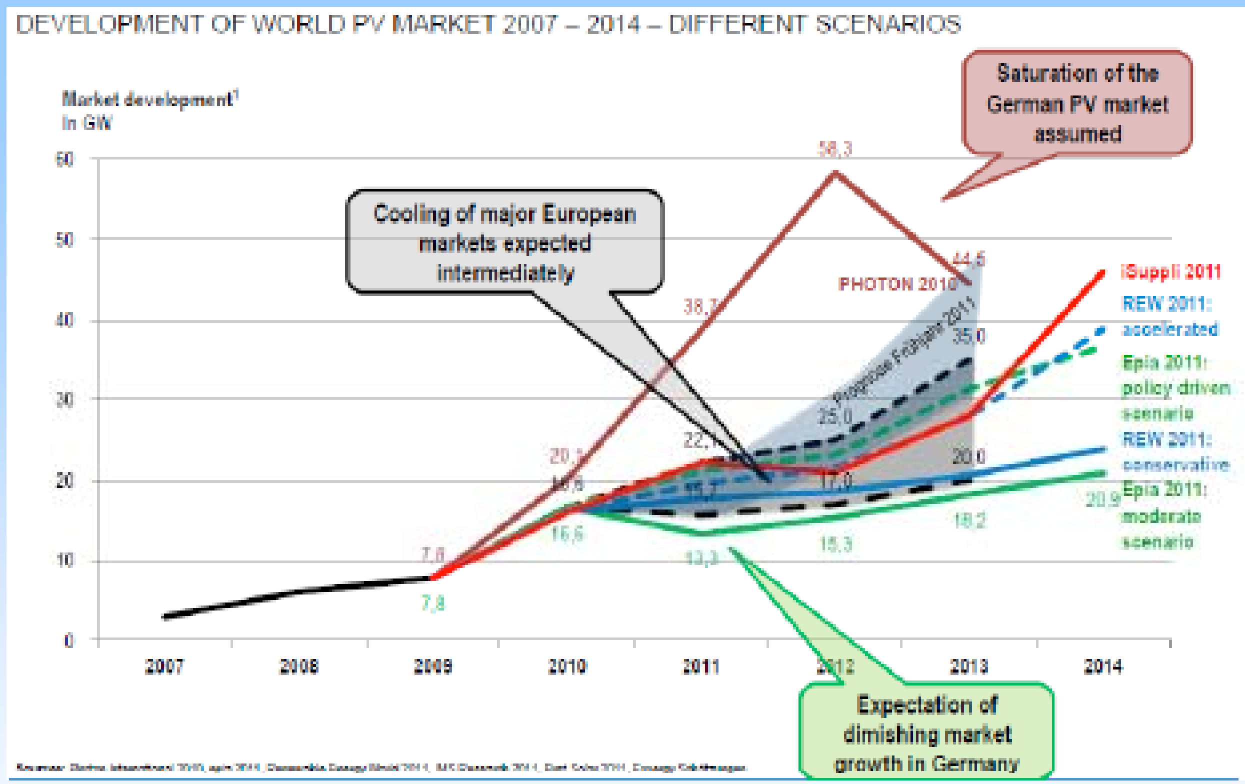
Photovoltaic – Market Growth



Source: JRC „PV Status Report 2011“

- Wafer-based c-Si solar cells is and will remain the main technology.
- If all expansion plans will be realized in time, thin-film production capacity share will be 26% of a total of 102 GW in 2015.
- Only one third of the over 120 thin-film companies, with announced production plans, have produced thin-film modules of 10 MW or more in 2010.

Development of the worldwide PV market



Source: 21 PVSEC, Fukuoka, Japan, „The Worldwide PV Market Review, Current Status, and Challenges Ahead "Thomas C. Sauer et. al.

- Predictions of market development have always been controversial.

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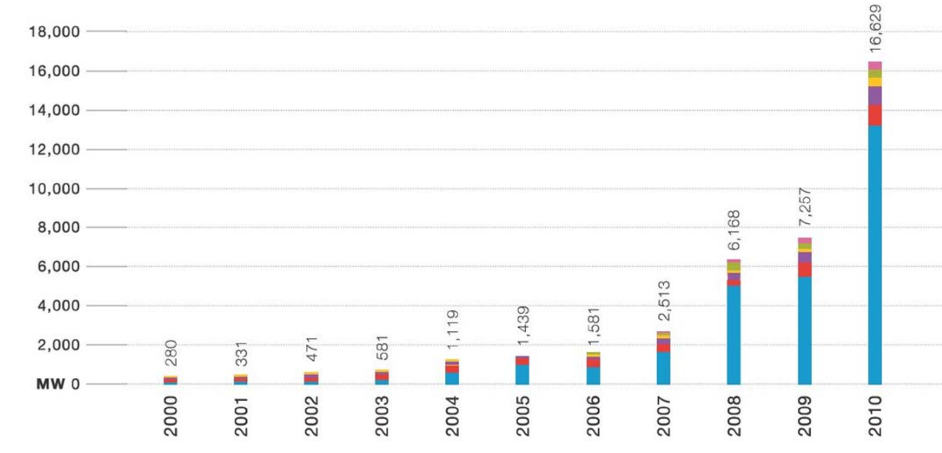
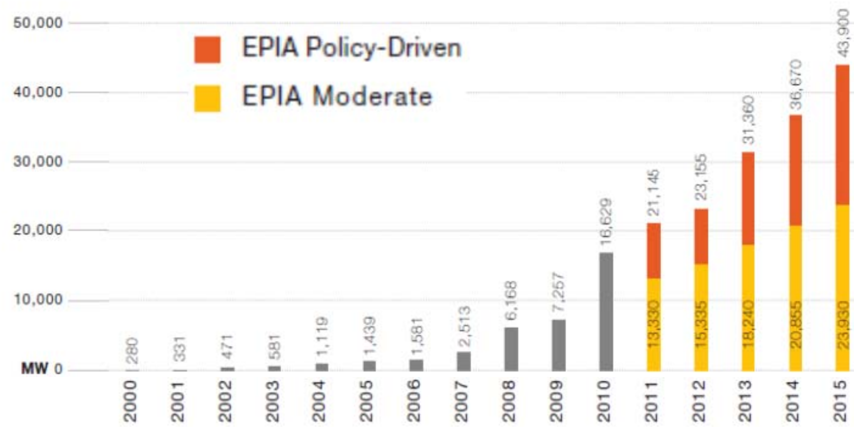
Development of new installations



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China	0	11	15	10	9	4	12	20	45	228	520
APEC	5	5	7	8	10	13	33	59	300	258	473
Rest of the world	88	56	80	77	29	10	118	63	115	130	417
North America	23	31	46	65	92	117	149	212	349	539	983
Japan	112	135	185	223	272	290	287	210	230	483	990
EU	52	94	139	199	707	1,005	983	1,950	5,130	5,619	13,246
Total	**280**	**331**	**471**	**581**	**1,119**	**1,439**	**1,581**	**2,513**	**6,168**	**7,257**	**16,629**



Quelle: EPIA

- Producers of PV Modules suffer from strong competition and small margins. At the same time, PV systems installations show enormous growth rates.
- Approximately 17 GW were installed in 2010, thereof:
  - 13 GW in the EU
    - Germany (7.4 GW)
    - Italy (2.3 GW)
    - Czech Republic (1.5 GW)
  - App. 4 GW in the rest of the world

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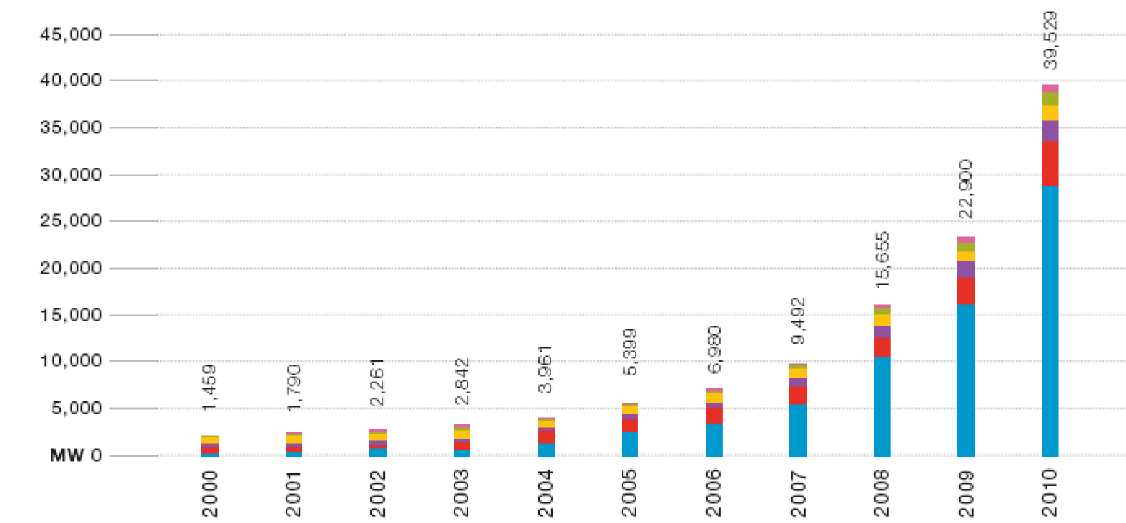
Development of the installed capacity

- Worldwide approximately 40 GW PV DC capacity is installed, thereof:
  - EU 30 GW
  - Japan 3,6 GW
  - USA 2,5 GW
  - China 1 GW (expected for 2011), growing
- This corresponds top 50 TWh electrical energy
- The new installations correspond in 2010 to almost 90% of the total installed capacity in 2009.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
China	19	30	45	55	64	68	80	100	145	373	893
APEC	38	43	49	57	66	80	112	170	466	718	1,191
Rest of the world	758	814	894	971	1,000	1,010	1,128	1,190	1,303	1,427	1,844
North America	146	177	222	287	379	496	645	856	1,205	1,744	2,727
Japan	318	452	637	860	1,132	1,422	1,708	1,919	2,149	2,632	3,622
EU	181	275	414	613	1,319	2,324	3,307	5,257	10,387	16,006	29,252
Total	**1,459**	**1,790**	**2,261**	**2,842**	**3,961**	**5,399**	**6,980**	**9,492**	**15,655**	**22,900**	**39,529**

Quelle: EPIA

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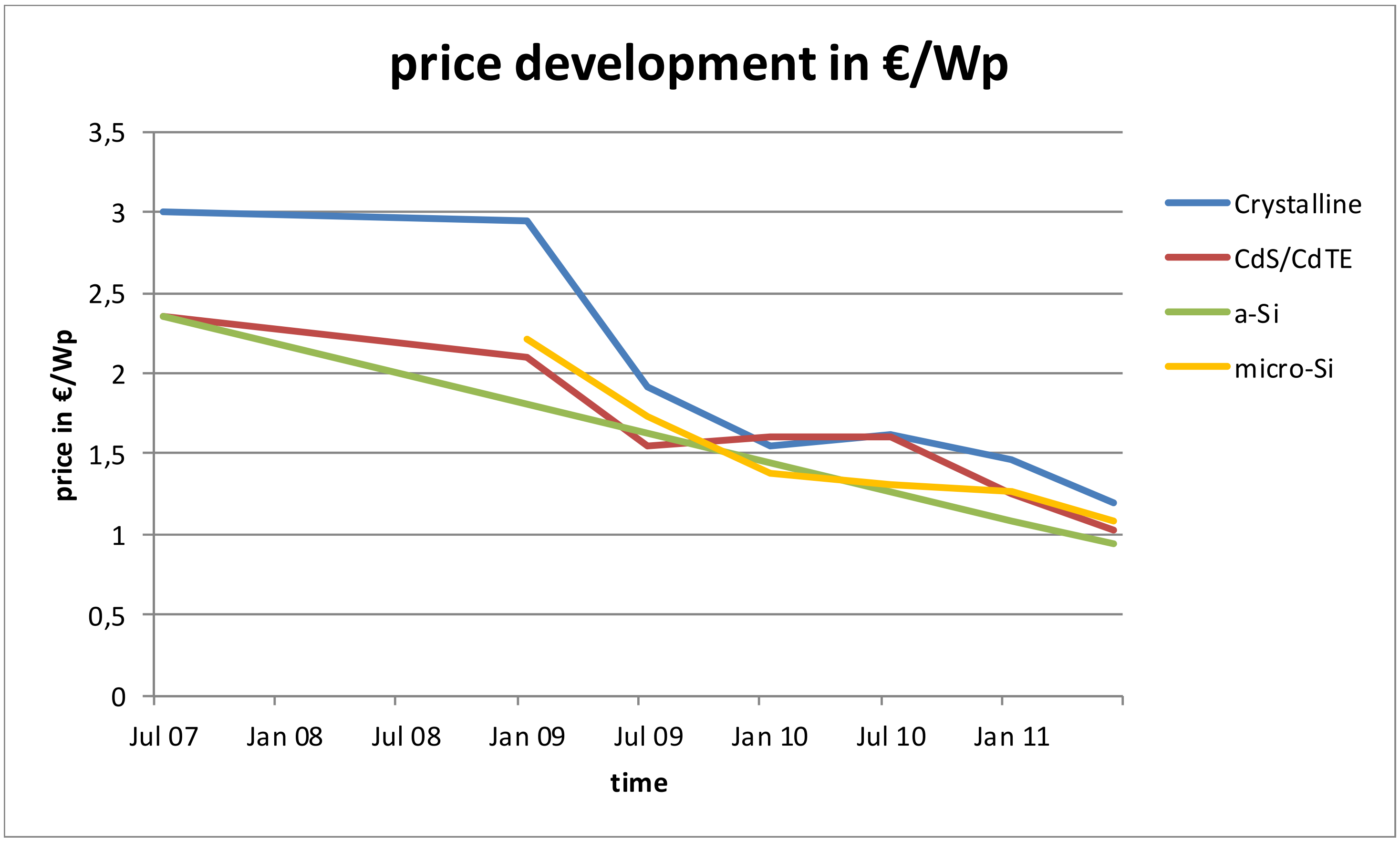
Main market driver: Cost reduction

- More than 50% price decrease since 2009 for crystalline modules
- General price decrease between 10% and 20% dependent on manufacturer country and type of module per year
- Highest price drop for Chinese manufacturers



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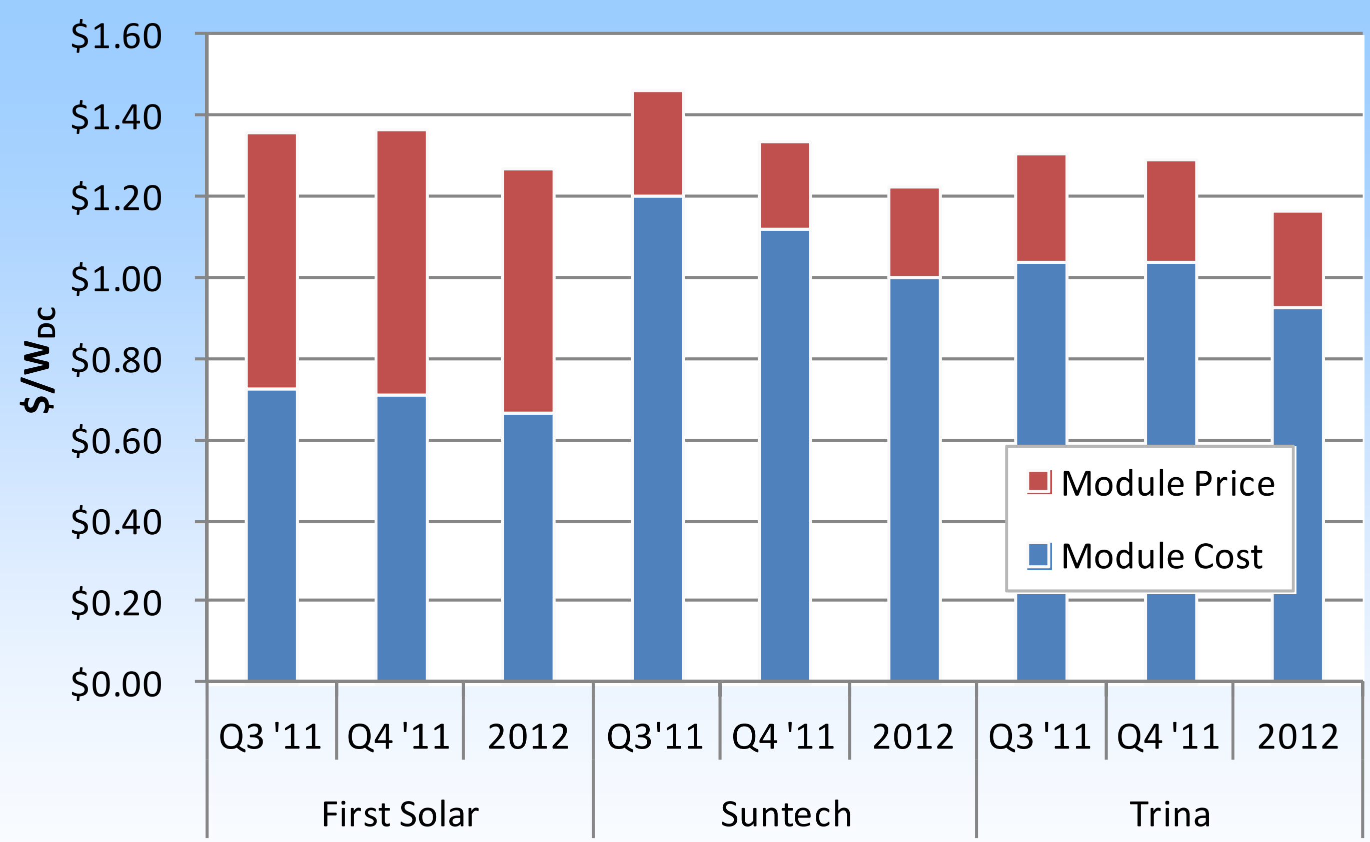
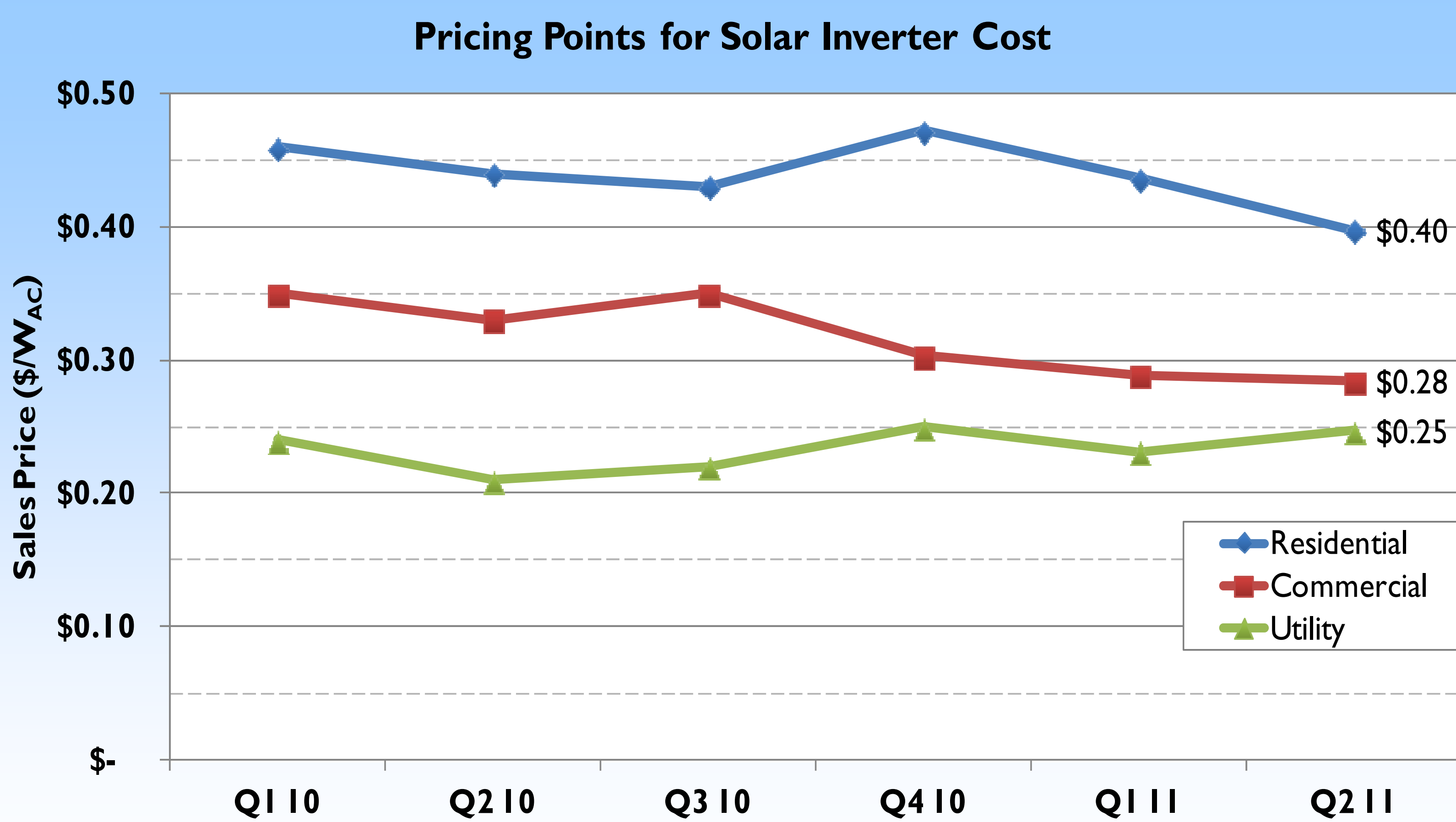
PV market – Estimated future module ASP & cost



- Analysts expect ASP reduction to continue.
- Expectations for pricing have been lowered between 2 % and 15 %.

Source: SunShot, Cowen (5/5/11, 8/10/11, 8/19/11, 8/23/11), Goldman Sachs (1/31/11, 7/7/11), Piper Jaffray (5/9/11, 9/12/11), Stifel Nicolaus (5/4/11, 5/26/11, 8/5/11, 8/18/11, 8/23/11)

PV market – Estimated inverter pricing



Source: SunShot, Photon International: (Jun/11, July 11), Energy Trend, http://pv.energytrend.com/, GTM/SEIA Q1 '11 Report, Stifel Nicolaus (8/10/11), PowerOne SEC filing.

- Inverter pricing is far more stable than the PV module market

PV market – Top ten module suppliers

Top 15 PV module suppliers 2011	Capacity (MW)	Country
LDK Solar	3,000	China
Suntech	2,400	China
First Solar	2,300	US
Canadian Solar	2,000	China
Trina	1,900	China
Yingli	1,700	China
Gintech	1,500	Taiwan
Hanwha SolarOne	1,500	China
SolarWorld	1,400	Germany
Neo Solar Power	1,300	Taiwan
JinkoSolar	1,200	China
Sunpower	1,000	US
Sharp (c-Si / a-Si)	930 / 270	Japan
Kyocera	920	Japan
JA Solar	800	China

Source: Companies presentations & financial reports.

PV Module Supplier Rankings

2010 Annual MW Shipments (excluding OEM)

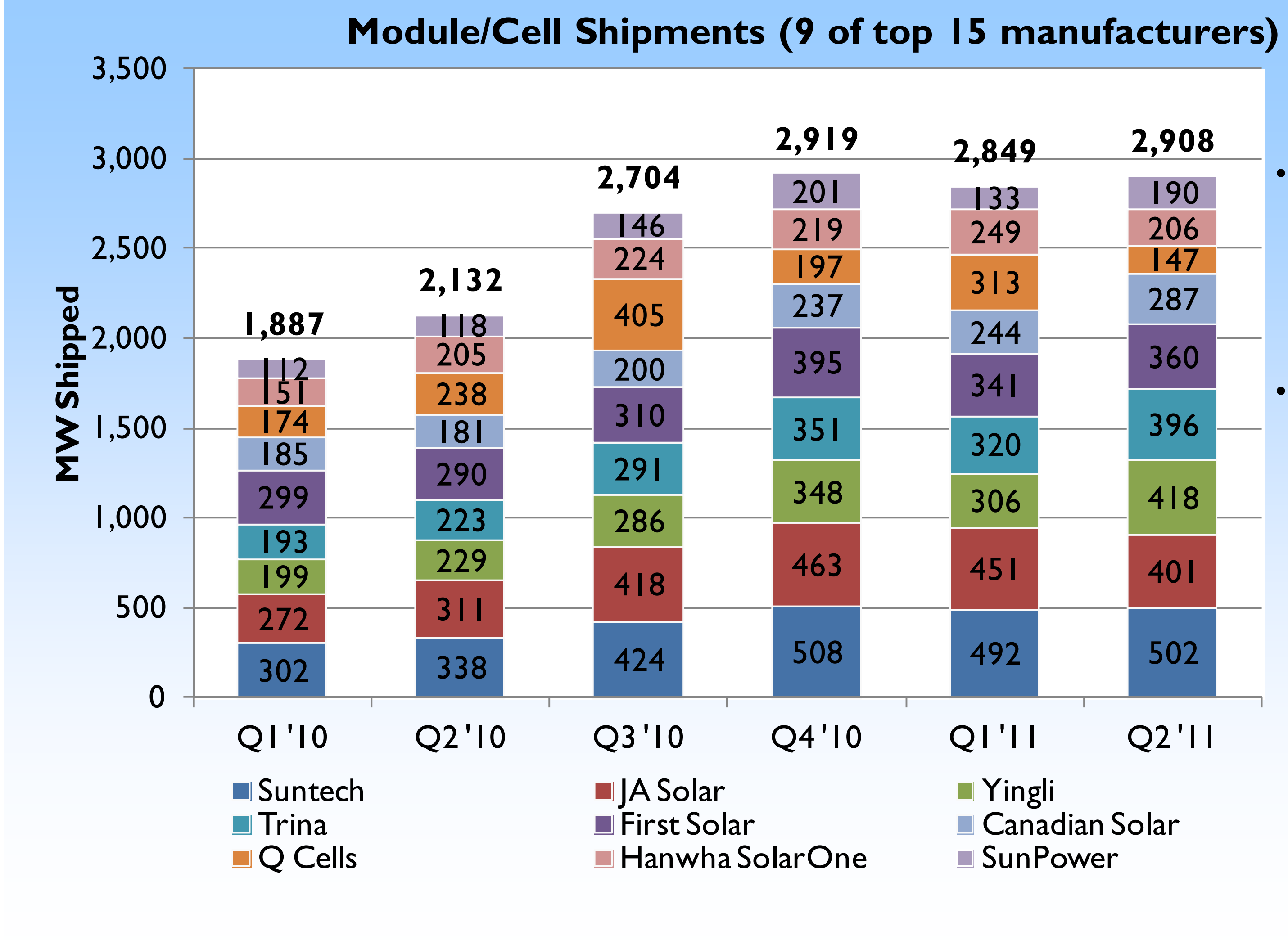
	Company Name	09-10 Change
1	Suntech	+1
2	First Solar	-1
3	Sharp	-
4	Yingli	-
5	Trina Solar	-
6	Canadian Solar	+2
7	Kyocera	-
8	Sunpower	-2
9	Hanwha SolarOne	+2
10	Solarworld	-

www.PVMarketResearch.com

Source: IMS Research **Apr-11**

- Most out of the top 15 module manufacturers are Chinese companies.

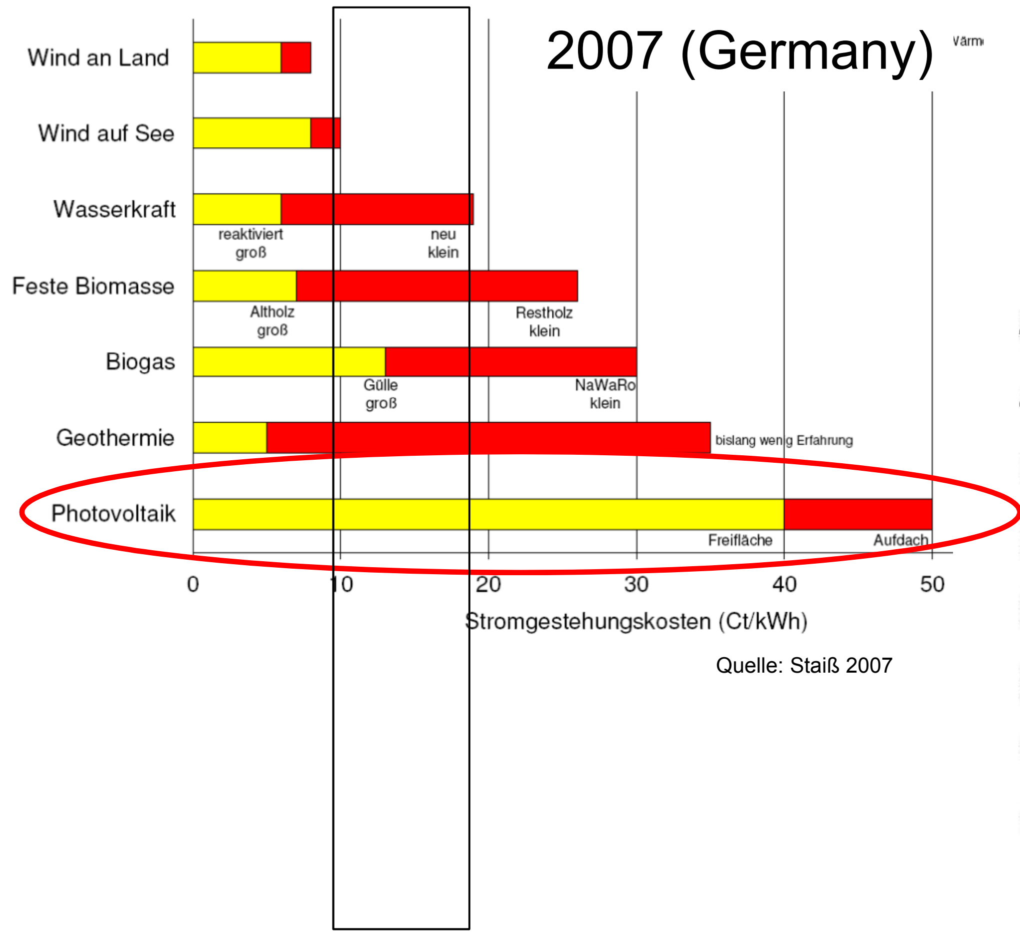
PV Market – Shipments 9 of Top 15 manufacturers

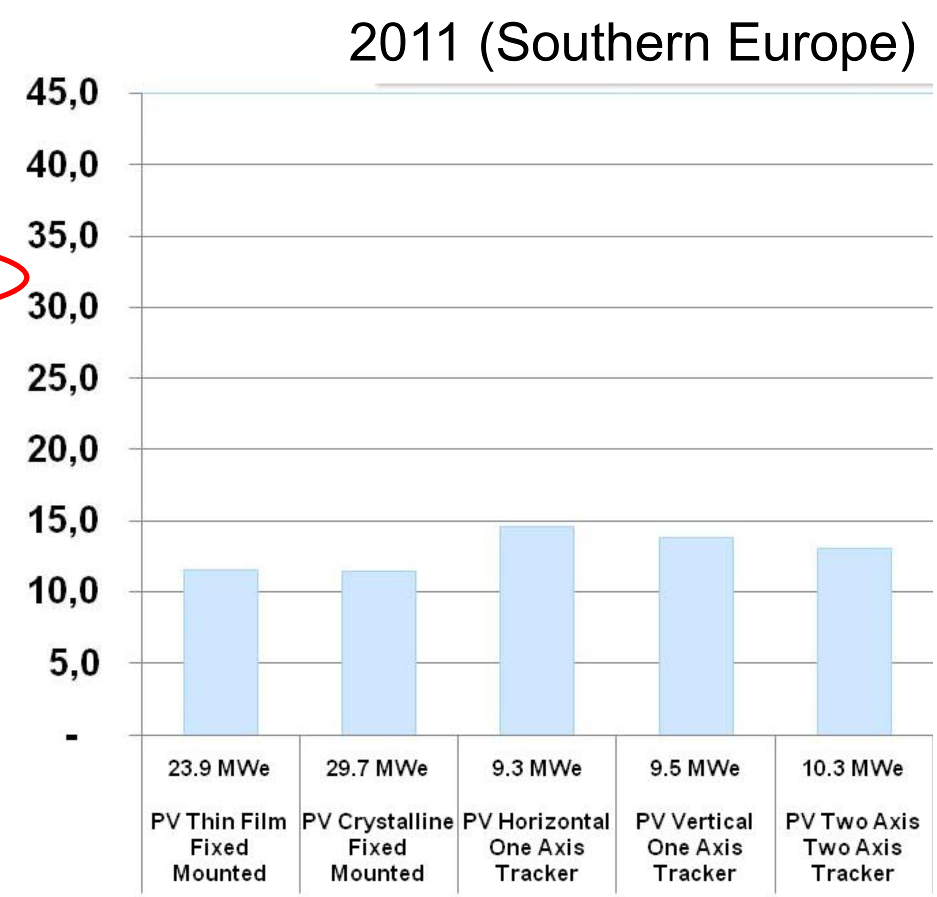


- Shipments of modules are stagnant since Q4 2010.
- Chinese companies increase shipments, while First Solar, Q-Cells drops further.

Source: SunShot, US Department of Energy Individual corporate financial statements, SunPower 2010 figures from UBS (8/10/11, 8/11/10)

Renewable Energies: Costs 2007 and 2011

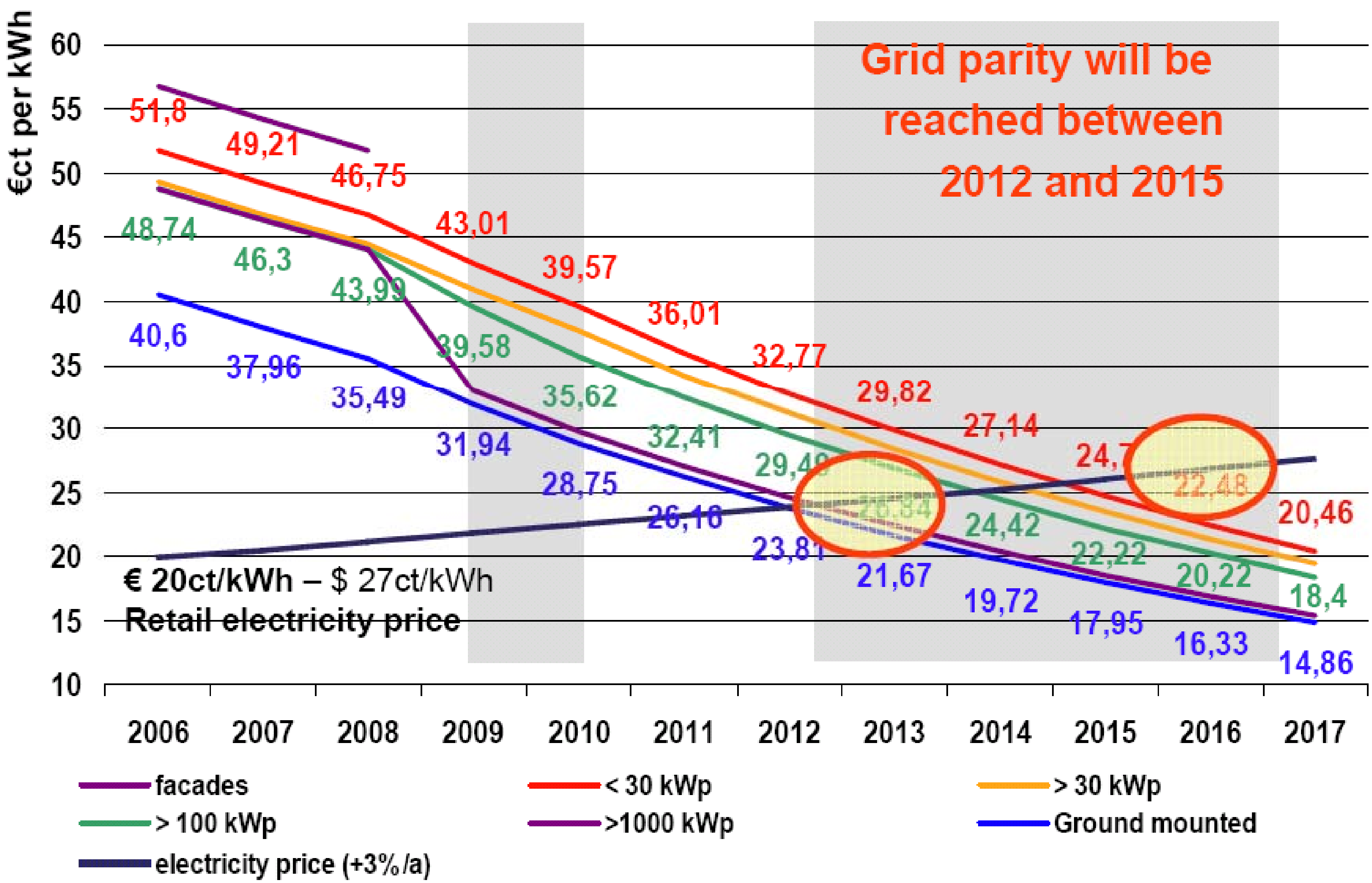




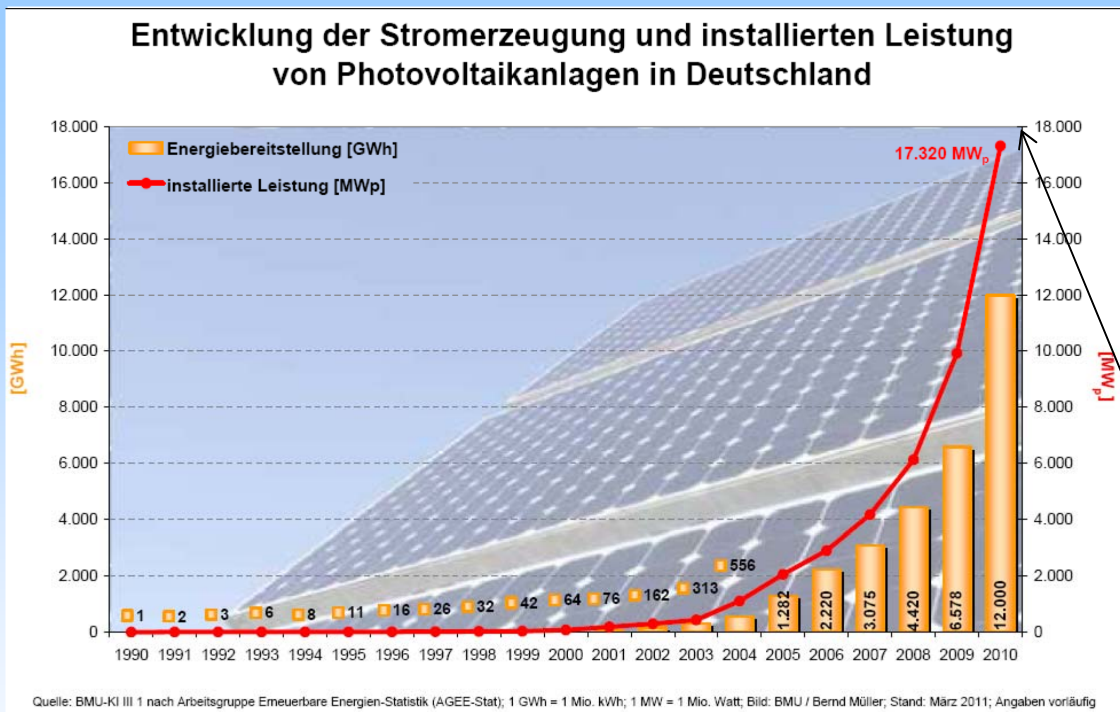
Quelle: Staiß 2007

Grid Parity Discussion

Based on degression rates decided on June 6th, 2008



Development of PV Electricity Generation in Germany



Solarpark Lieberrose (Brandenburg)
Installed capacity: 53 MWpeak

Expectation for 2015:
- **35.000 MW**
- **11 Mrd. €/a EEG-Vergütung (Stand 15.11.10)**

While in the early 1990ies predominantly small PV installations on residential roofs were built, recently very large scale plants were constructed; three digit MW plants are under development.

Quelle: www.solarserver.de / Fichtner

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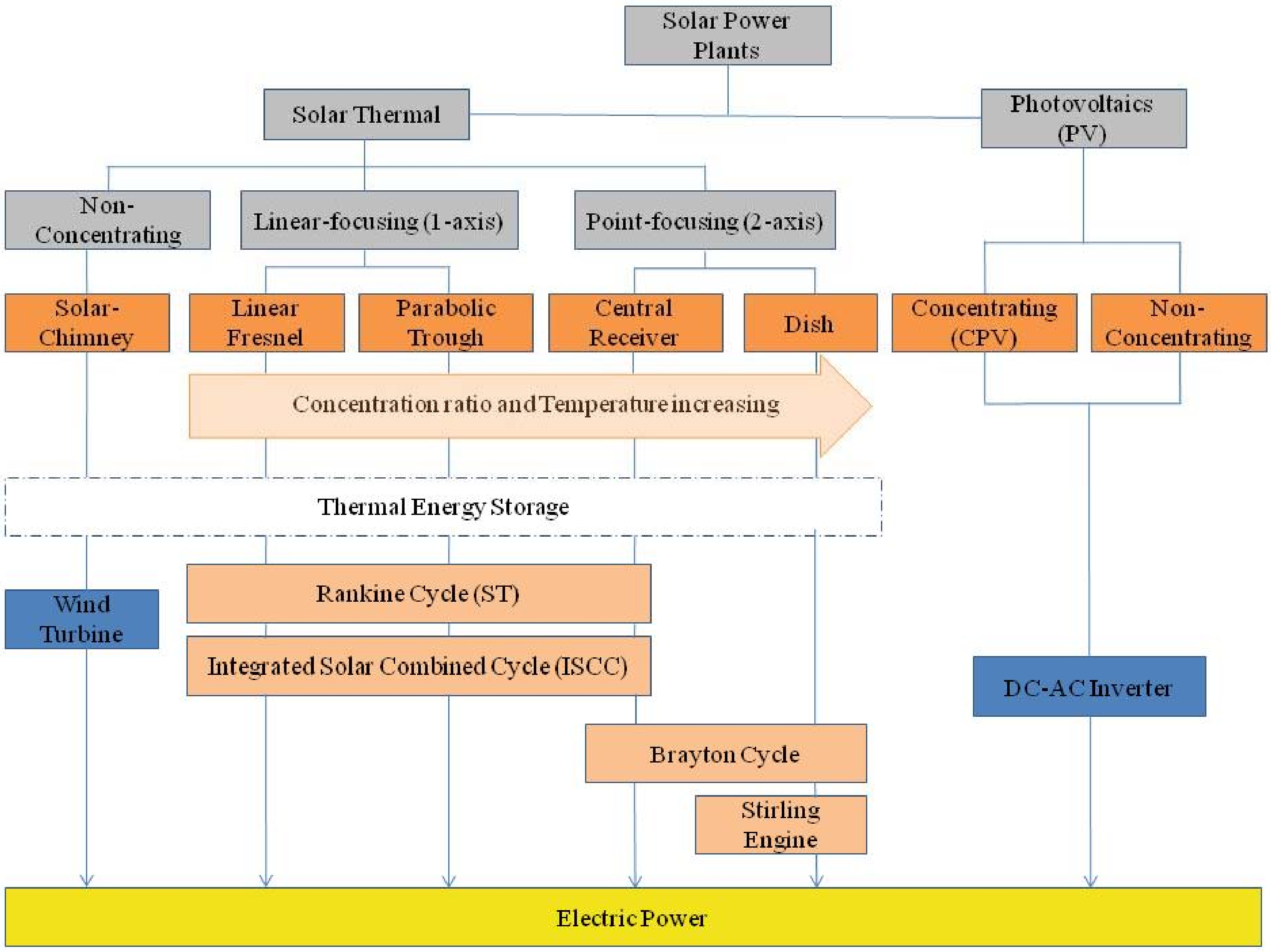
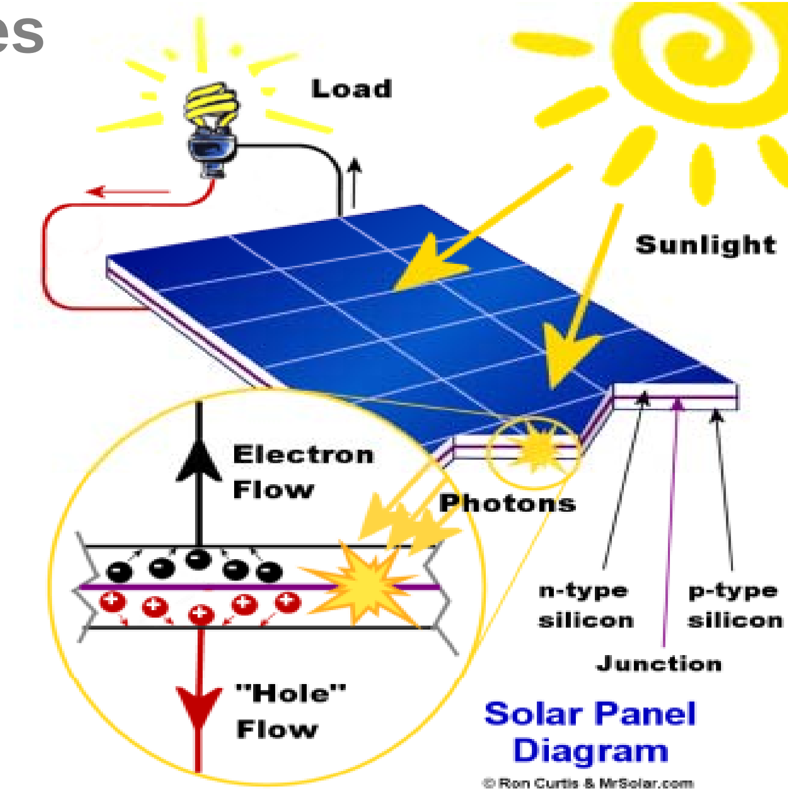
Solar Technologies



Overview Photovoltaic Technologies



Principle / Characteristics

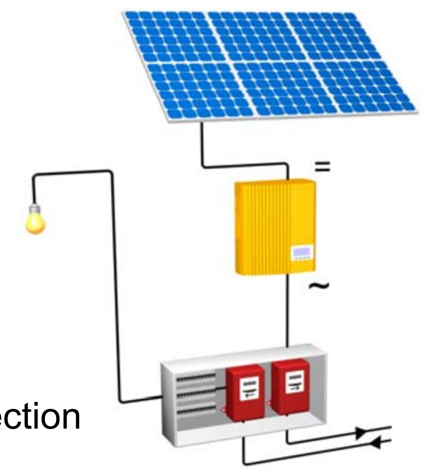
- Field of solar cells is used for collection of sunlight
- Direct transformation of sunlight into electricity by the photovoltaic effect
- Different kinds of Photovoltaic Technologies
- Different Mounting System Technologies for Photovoltaic Plants

Basic Principle of Photovoltaic Plants

Photovoltaic Modules

Inverter (DC/AC)

Electric Meter / Grid Connection

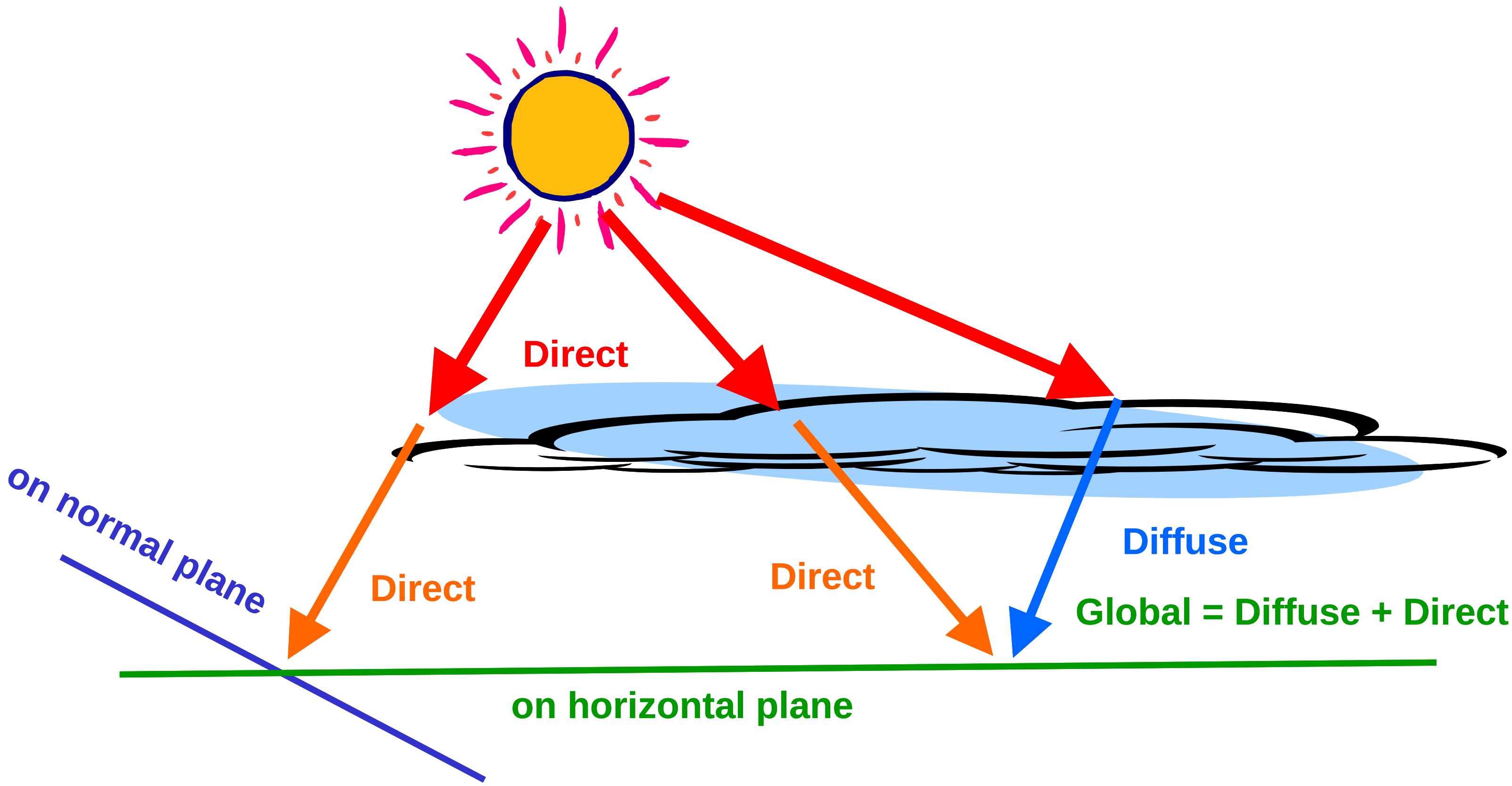


Status

All concepts are proven in numerous plants and successfully in operation

Mayor cost reduction due to mass production, economy of scale and further technological advancements

Solar irradiation



Different technologies use different type of irradiation.

Types of Solar Cells

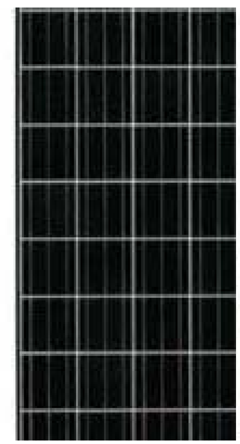
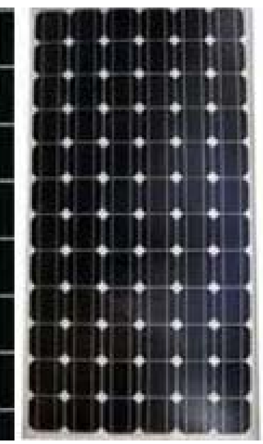
- There are basically two different technologies to manufacture PV solar cells:

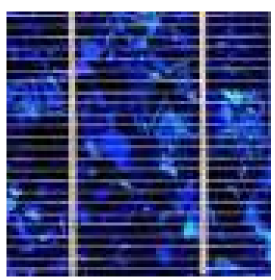
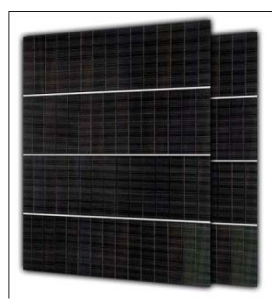
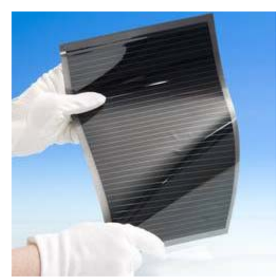
- **Wafer based crystalline silicon solar cells**
  Represent the bulk of the market

a) Mono-crystalline cells
b) Poly-crystalline cells

- **Thin-film technology**

c) Different materials and deposition processes


Types of Solar Cells

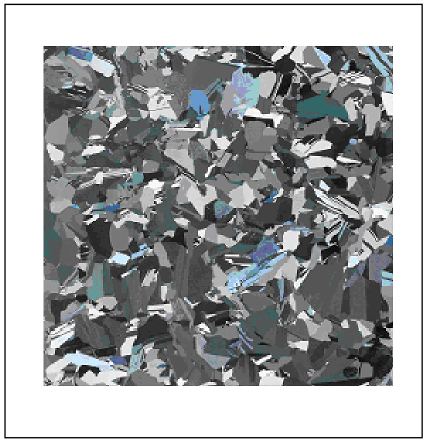
A) Mono-crystalline cells Mono-Si

- The silicon block consists of one crystal only
- Manufacturing is complex and energy intensive
- The atoms have a completely homogeneous structure
- Mono-crystalline silicon as raw material for solar cells is relatively expensive
- Most efficient technology (efficiencies of around 15% (commercial) to 25% (research)

Types of Solar Cells

B) Poly-crystalline cells

- Silicon solidifies and forms blue gleaming structures.
- Material of the cell is heterogeneous.
- Light refraction at the solidified edges decreases the efficiency.
- Cheaper than mono-crystalline silicon but also less efficient
- Research cells approach 20% efficiency, and commercial modules approach around 14% efficiency

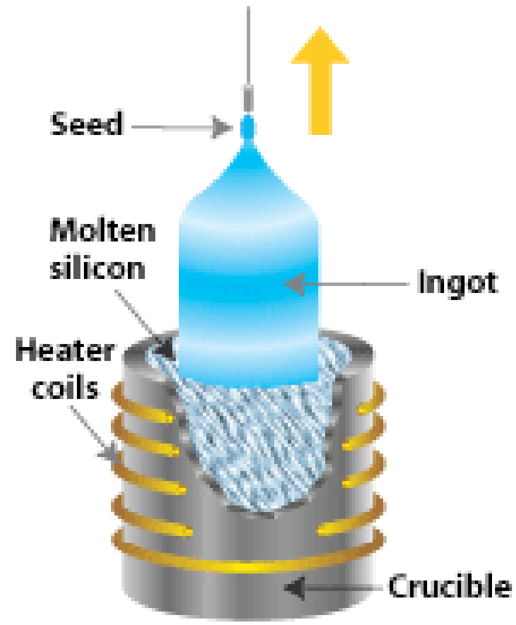


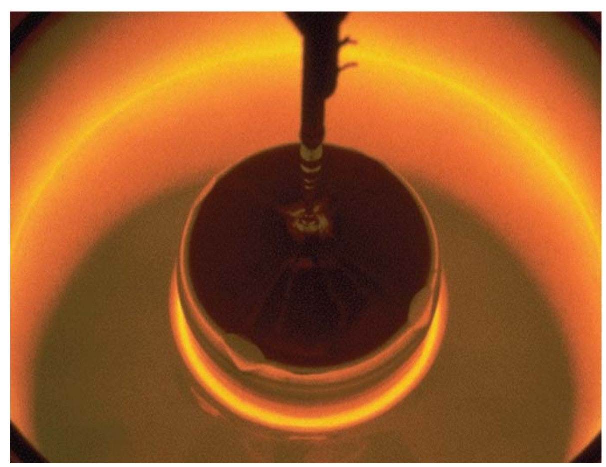
Manufacturing Process of Wafer Based Solar Cells

- Use of polycrystalline fragments as feedstock
- The solar grade silicon with a purity of 99.999% is produced by a chemical vapour deposition process

Manufacturing Process of Wafer Based Solar Cells

- Single crystalline ingots are mostly produced by the so called Czochralski process
- Polycrystalline fragments of highly purified silicon are molten in a graphite crucible
- A single crystalline seed crystal is immersed in the liquid compound and withdrawn under rotation



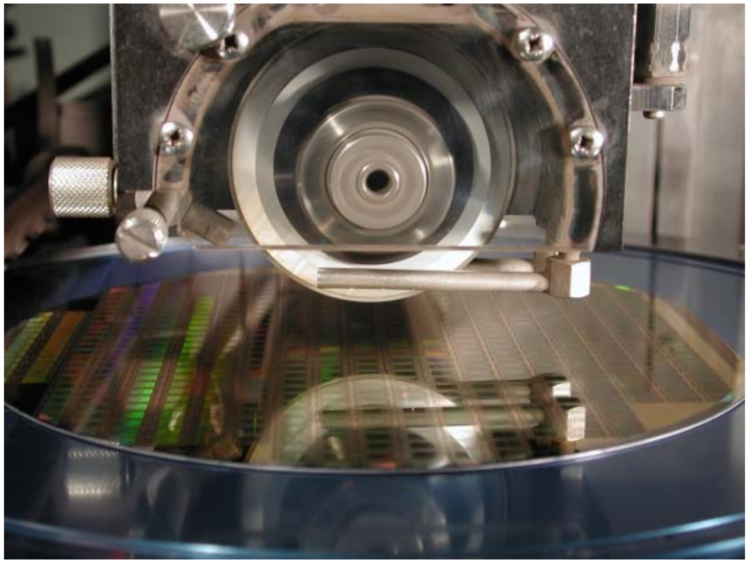


Manufacturing Process of Wafer Based Solar Cells

- Poly crystalline ingots are produced mostly by an ingot casting process
- Silicon is melted and poured into a square, graphite crucible
- Controlled cooling produces a polycrystalline silicon block

Manufacturing Process – Wafer Cutting

- Ingot is cut into wafers of 200 µm to 500 µm thickness
- Sawing losses can amount to 50% of the source material



Manufacturing Process – Chemical Surface Treatment

- Etching process on the wafer's surface
- Fulfills three functions
  - Removes a thin layer of the wafer's surface, which was damaged by the sawing process
  - Textures the surface, which is necessary reduce reflection of the solar cell
  - Cleans the surface from impurities

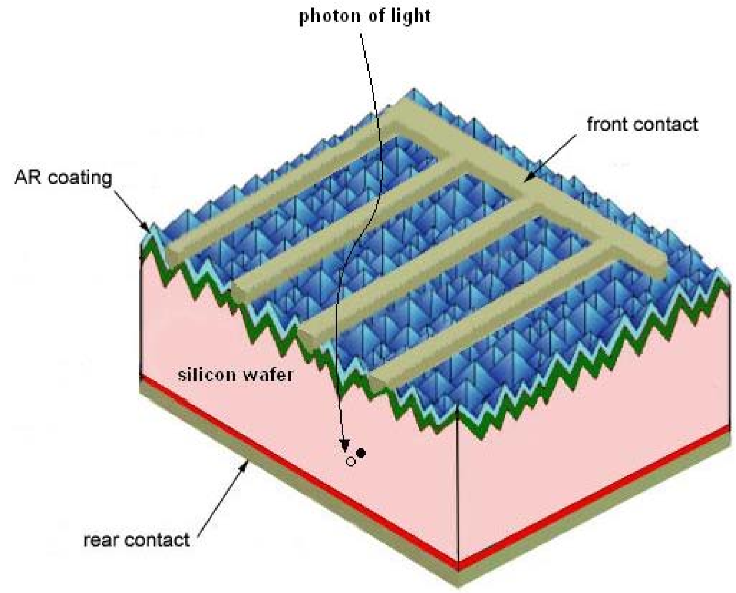
Manufacturing Process – P N Junction

- P-doping was already conducted when the silicon ingot was grown so only the n-layer has to be created
- Diffusion process where phosphorous atoms are built into the crystal lattice

→ A thin n-doped layer is created in the otherwise p-doped crystal

Manufacturing process – Creation of front and back contacts

- Contacts are applied:
    - The front, the sun side
    - Back, the shadow side
- Metallic paste is screen-printed onto the wafer
- Wafer is sintered
- Heat adhesion → the metallic paste converts to metallic contacts



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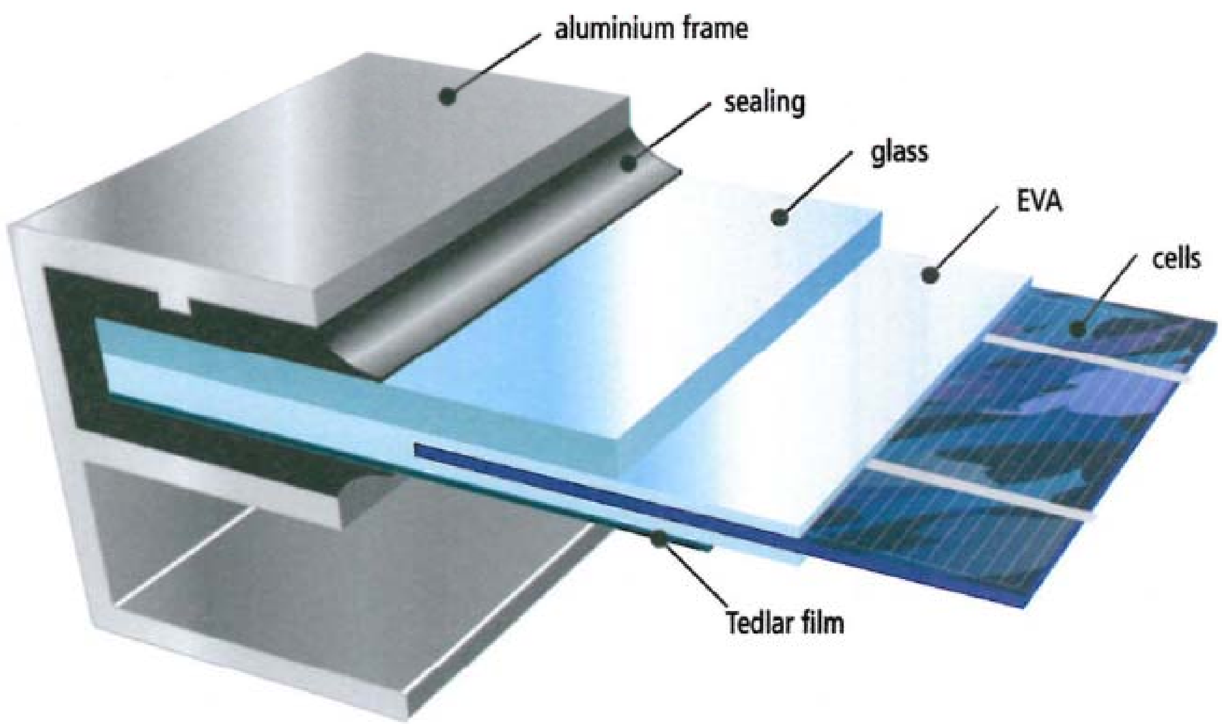
Manufacturing process – Cross section of the module

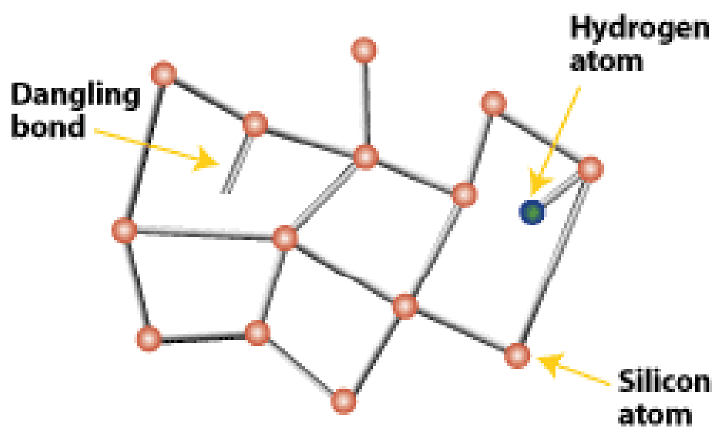
- Typical cross section of a poly-crystalline modules comprising standard components:



Types of Solar Cells

C) Amorphous silicon cells / thin-film cells

- Thin, non-crystalline (amorphous) silicon film, e.g. by vapor deposition.
- Cheaper than crystalline silicon but less efficient
- Advantages during fewer light, diffused light and during high operating temperature
- No fixed carrier structures necessary
- E.g. on calculators and watches



Types of Solar Cells

C) Amorphous silicon cells / thin-film cells

- Various materials:
  - Amorphous silicon, efficiencies of around 6% (commercial) to 9.5% (research)
  - CdTe, efficiencies of around 12% (commercial) to 16% (research)
  - CIS, efficiencies of around 12% (commercial) to 19% (research)

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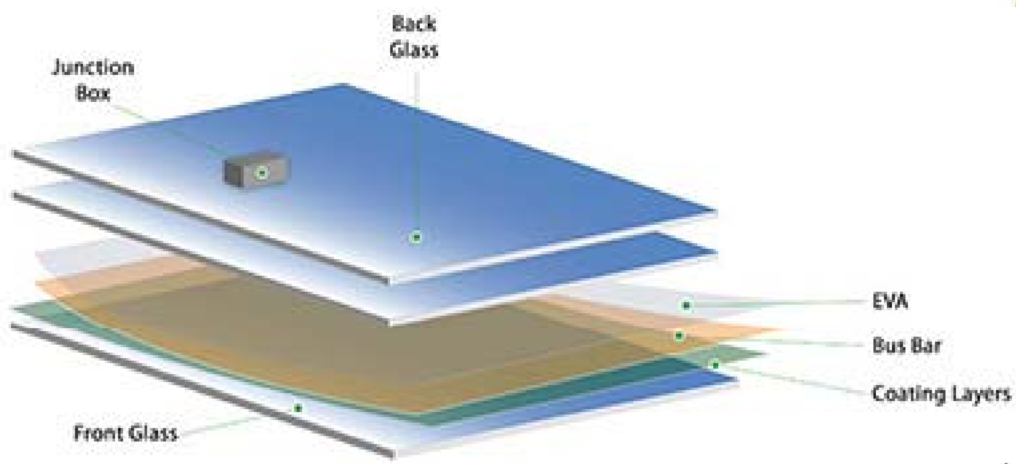
Types of Solar Cells

D) Micro-crystalline cells

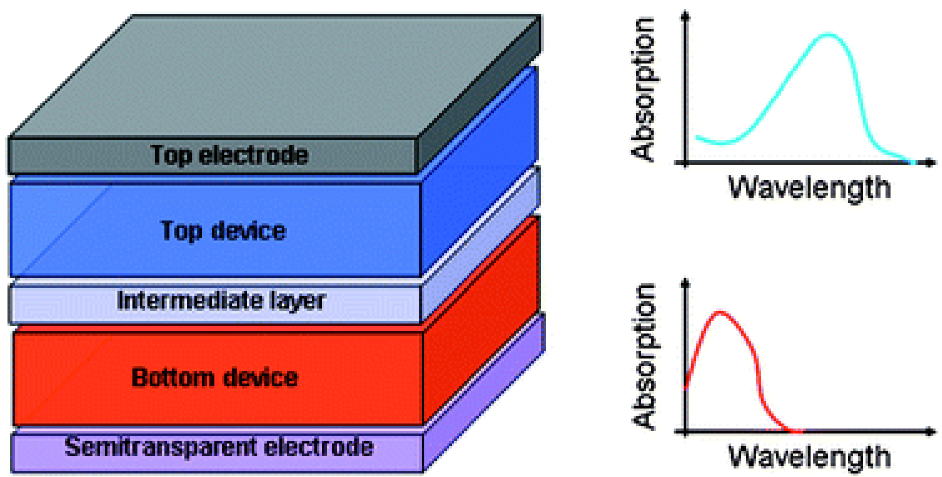
- Thin-film cells with micro-crystalline structure
- Higher efficiency than amorphous silicon cells and not as thick like the usual poly-crystalline cells
- Not yet widespread



Types of Solar Cells

E) Tandem solar cells

- Layered cells, mostly a combination of poly-crystalline and amorphous cells.
- Single layers consist of different material and are tuned for different wavelengths of the light
- Take advantage of the wide range of the light spectrum which leads to a higher efficiency than for common solar cells



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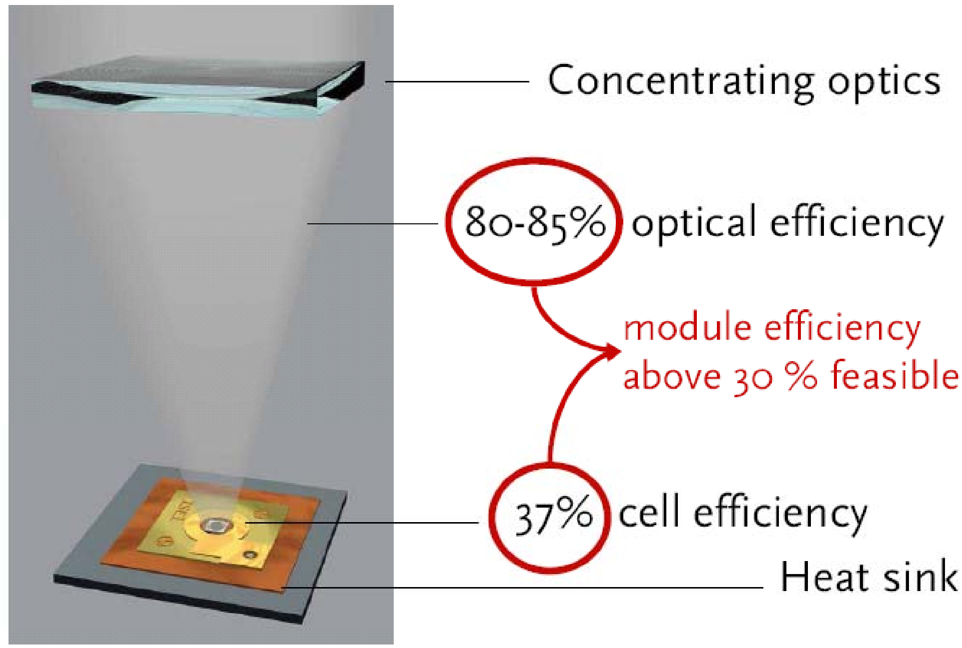
The Technology of Concentrating Photovoltaics (CPV)

F) Concentrated solar cells

- CPV systems use optical lenses to focus direct sunlight onto small and high-efficiency multijunction solar cells
- Designed for areas with high Direct Normal Irradiation (DNI)
- Require two-axis suntracking systems
- CPV aims to lower costs by using less expensive semiconductor material and cheap optical systems



The III-V Multijunction Solar Cell

- High efficiency by using three stacked subcells that convert a specific spectral region of the incident radiation
- GaInP top subcell lattice-matched to a Ga(In)As middle subcell
- Ge substrate bottom cell
- Produce a higher voltage and a lower current than single-junction silicon cell
- Top and bottom subcells limit the overall current (more than 1/3 of available photons reach
- the bottom cell

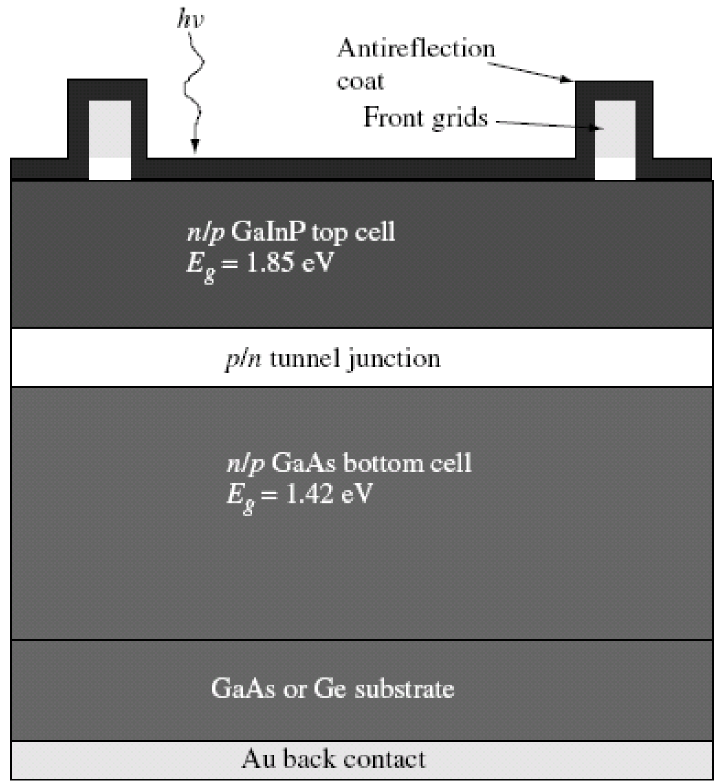
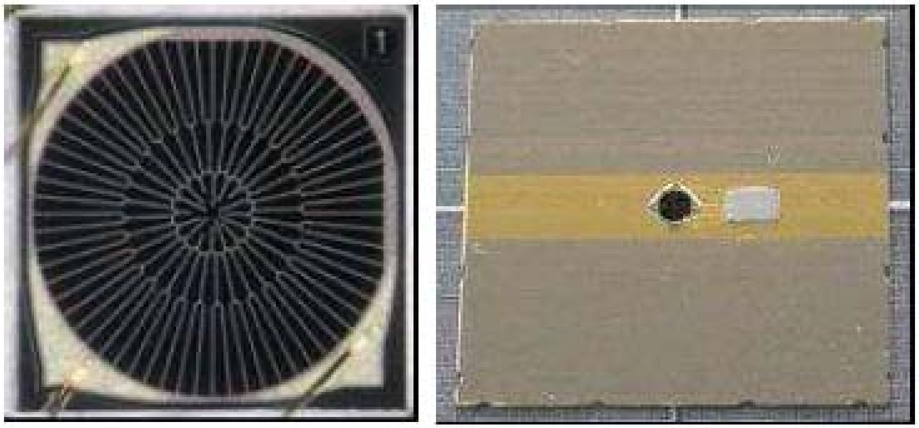
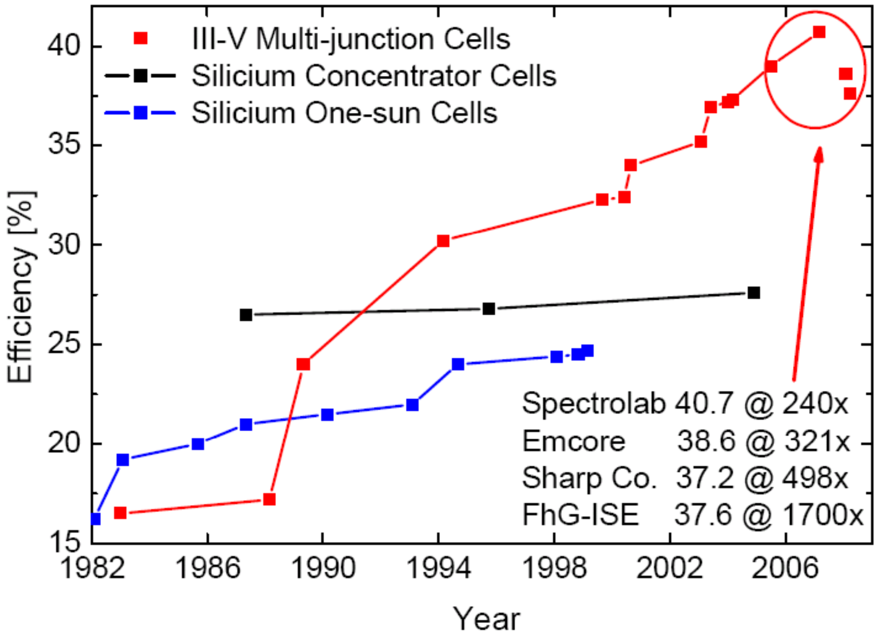


Figure 9.1 Schematic of GaInP/GaAs multijunction solar cell. When grown on a Ge substrate, there is an option for introducing a third junction in the Ge substrate, thus boosting the voltage and efficiency of the overall device. Dimensions are not to scale

The III-V Multijunction Solar Cell





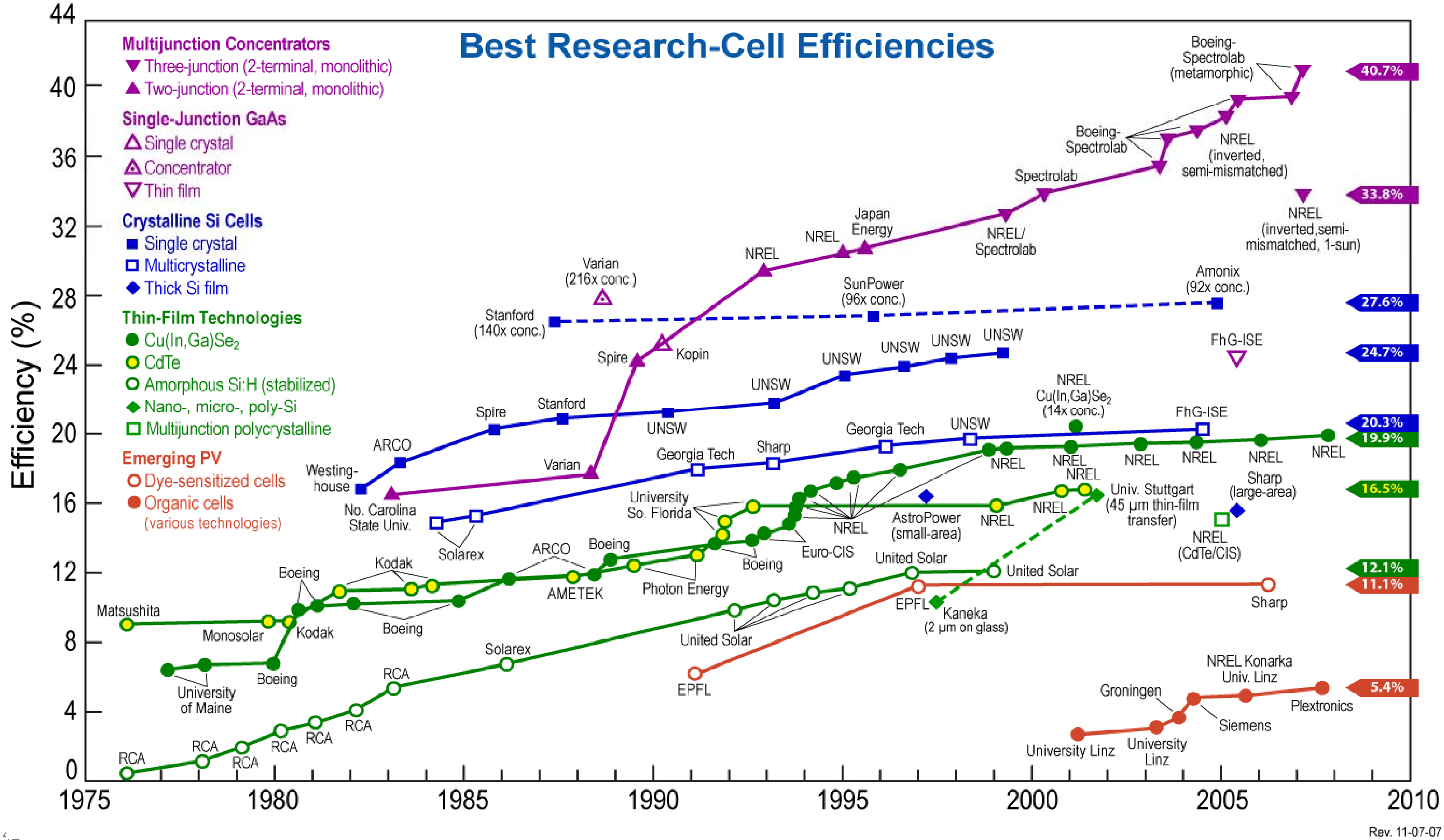
- 3-mm diameter triple junction solar cell and passing cooling with copper
- III-V multijuction cells have achieved efficiencies over 40 %, however, module efficiency ranges between 25-30%

Types of Solar Cells II

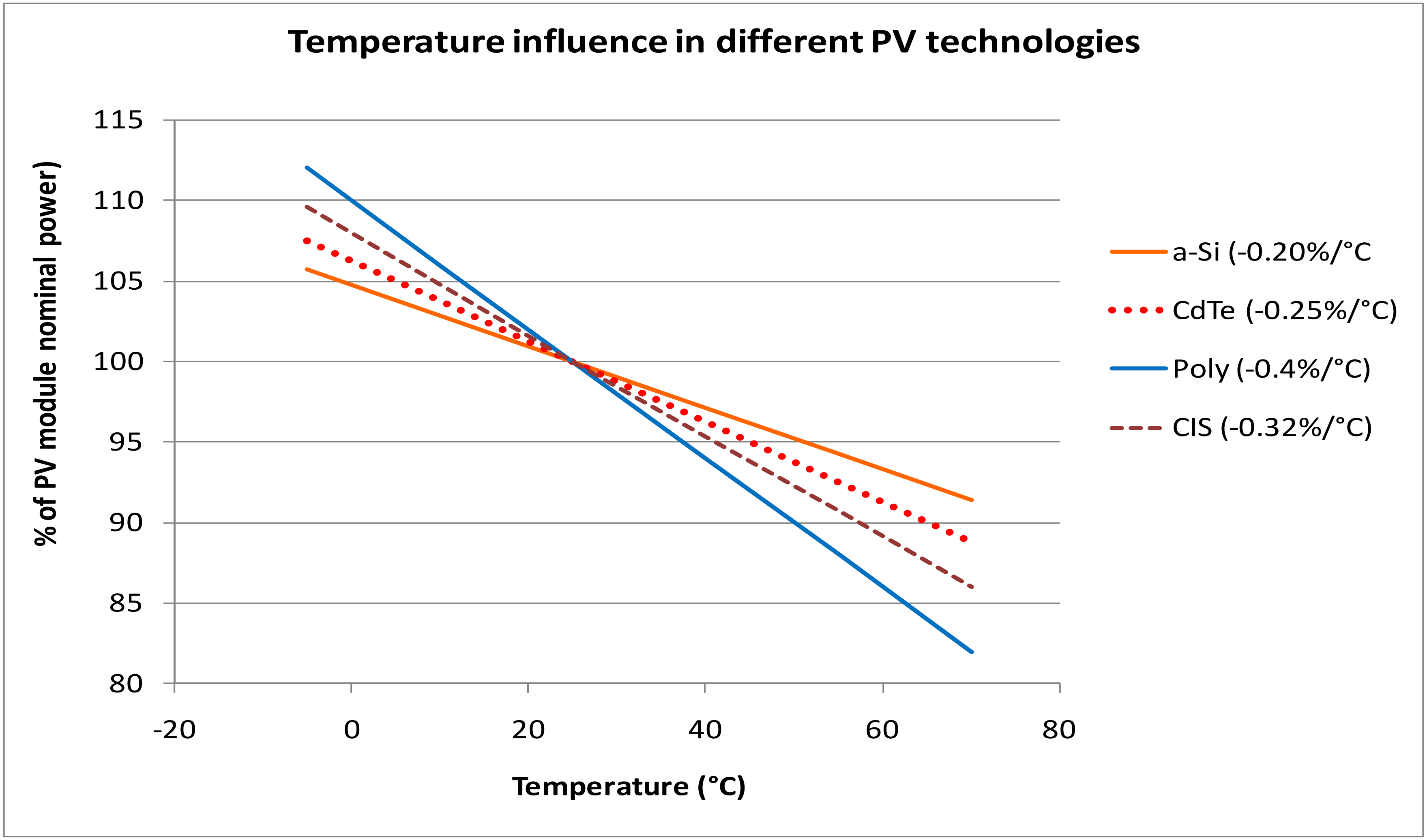
Type of solar cell	Material properties	Efficiency		Stage of development
++++++++++++++++++++++	++++++++++++++++++++++++	laboratory scale*	module	++++++++++++++++++
Monocrystalline silicon sc-Si	uniform crystalline structure	25 %	14 – 21 %	industrial production
Polycrystalline silicon mc-Si	multi-crystalline structure, monocrystals visible	20.4 %	12 – 17.5 %	industrial production
Hybride HIT cell	combination of crystalline and amorphous	22.8 %	15 – 17.5 %	industrial production
Amorphous silicon	atoms irregularly arranged, thin-film technology	10 - 13 %**	5 – 8 %**	industrial production
Micromorph silicon	atoms irregularly arranged, thin-film technology	12.5 %**	7.5 – 10 %**	industrial production
Gallium-Arsenid (GaAs)	multi junction, crystalline	42 %	25 %	first production lines
Copper-Indium-di-Selenide/Sulphide (CIGS, CIS)	thin-film, polycrystalline	20.3 %	8 – 15.7 %	industrial production
Cadmium-Telluride (CdTe)	thin-film, polycrystalline	17.3 %	9 – 13.4 %	industrial production
Organic cells	thin-film, crystalline	5.4 %	2%	research and development stage, not commercially available
Dye sensitised	thin-film, nanocrystalline	10.4 %	8.4 %	research and development stage, not commercially available

*cell efficiency is based on laboratory samples and is always higher than the module efficiency ** stabilized

Types of Solar Cells VI – PV Cell Efficiencies



Types of Solar Cells VII – Temperature Influence



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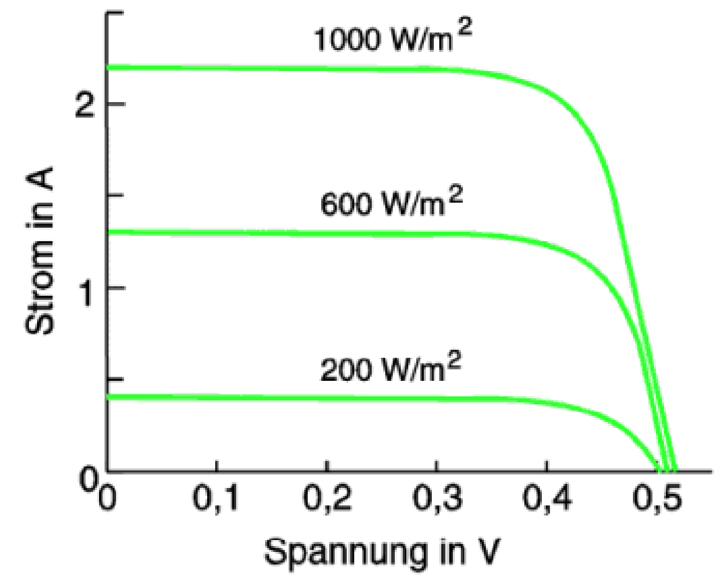
Types of Solar Cells VIII - Degradation

- PV solar modules experience a performance degradation process during their lifetime
- On average, degradation of crystalline PV modules is considered as 0.5% per year
- Thin film modules tend to have an increased degradation and are more sensitive to ambient conditions (annealing effect)

Characteristics of Solar Electricity Generation

- DC electricity generation depends on solar level of irradiation
- Voltage and current depend on electrical resistance
- P = U x I
-
- Inverters track for maximum power production.



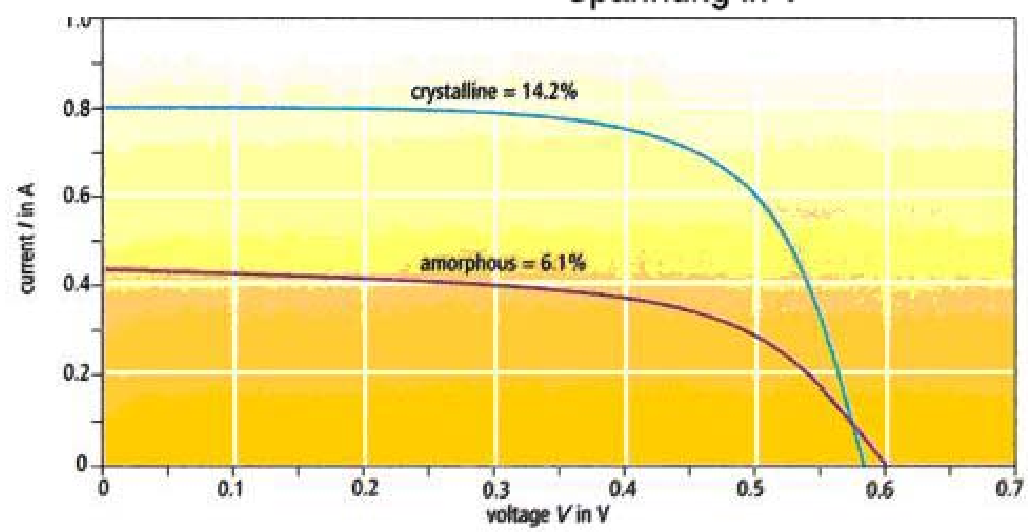
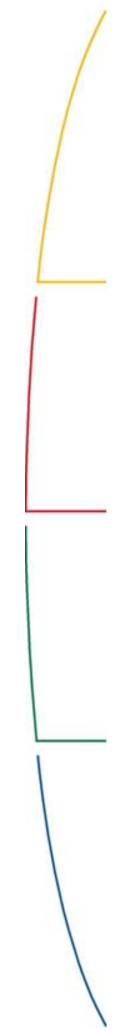


Figure 1.126
Comparison of current/voltage characteristic curves (I–V curves) of crystalline and amorphous silicon solar cells with an irradiance of 1000W/m² on 5cm × 5cm cell surface area and a temperature of 28°C
Source: R. Haselhuhn



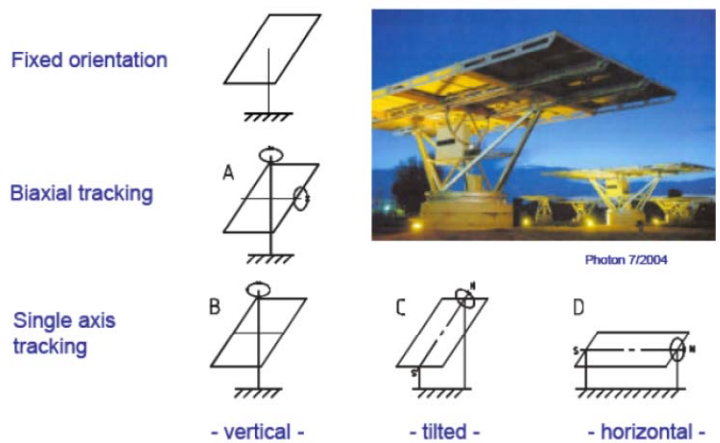
Inverter Concepts

- Central Inverters
  - Large, utility scale (1MW+)
  - Increased efficiency and lower inverter costs

- String Inverters
  - Applied in lower to mid power range
  - 15 kW up to 1 MW
  - Higher modularity, system outage less probable

- Commercial inverters of present generations provide monitoring and protection functions

Installation – Fix Installation vs. Tracking



	Mean annual radiation gain in Central Europe	Mean annual radiation gain in Southern Europe
Fix, optimum tilt angle	0%	0%
Horizontal N-S axis	11.5%	17.4%
30° tilt axis	22.9%	29.8%
Vertical axis, module tilt 50°	23.1%	29.6%
Biaxial tracking	27.2%	34%

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Installation – Building Integrated (BIPV)

- Consists of integrated PV modules into the building envelope
- Simultaneously serving as building envelope material and power generator
- Connection possibilities
  - Interfaced with the available utility grid
  - Designed as stand-alone, off-grid systems

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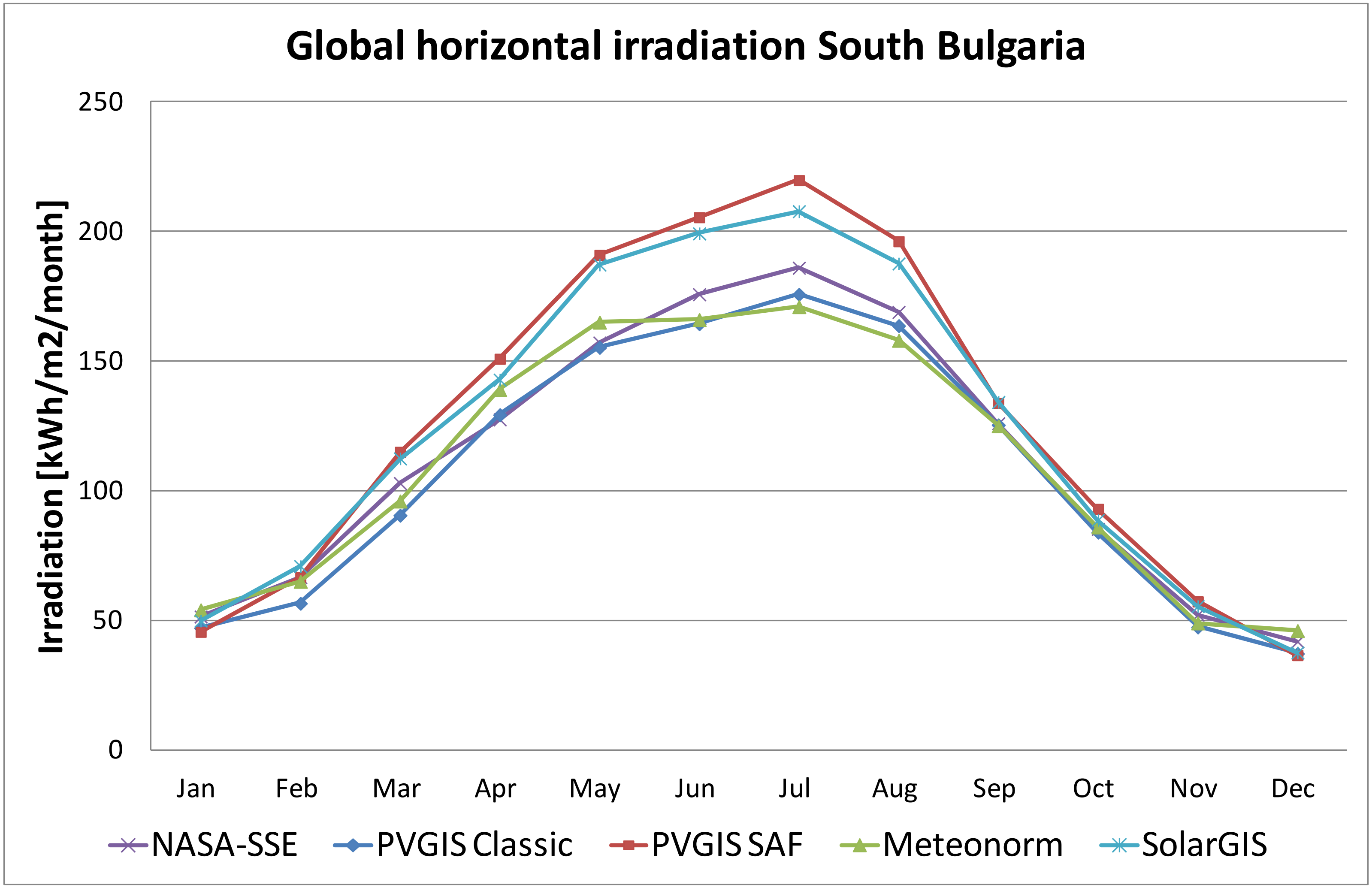
Content

Yield projections – Irradiation overview

- Assessment of available data sources
- Ground measurements / satellite data
- Accuracy
- Period and time series

Data Source	**Time Period**	**G_h [kWh/m²]**
NASA-SSE	1983 – 2005	1,342
PVGIS Classic	1981 – 1990	1,277
PVGIS SAF	1998 – 2010	1,511
Meteonorm 6.0	1981 – 2000	1,320
SolarGIS	**1994 – 2010**	**1,474**

Irradiation distribution for south Bulgaria



Total GHI: 1277 - 1511 kWh/m²yr

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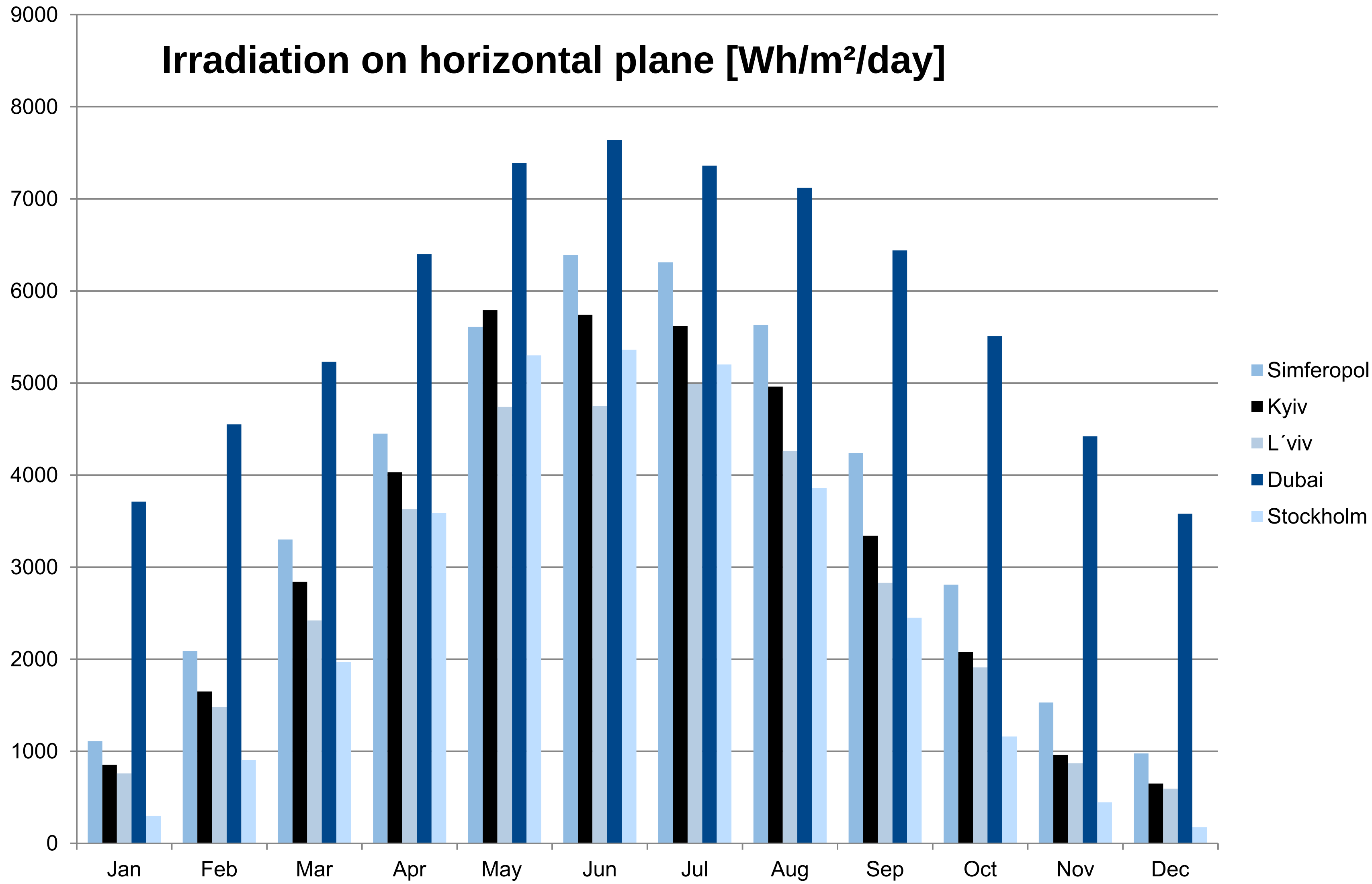
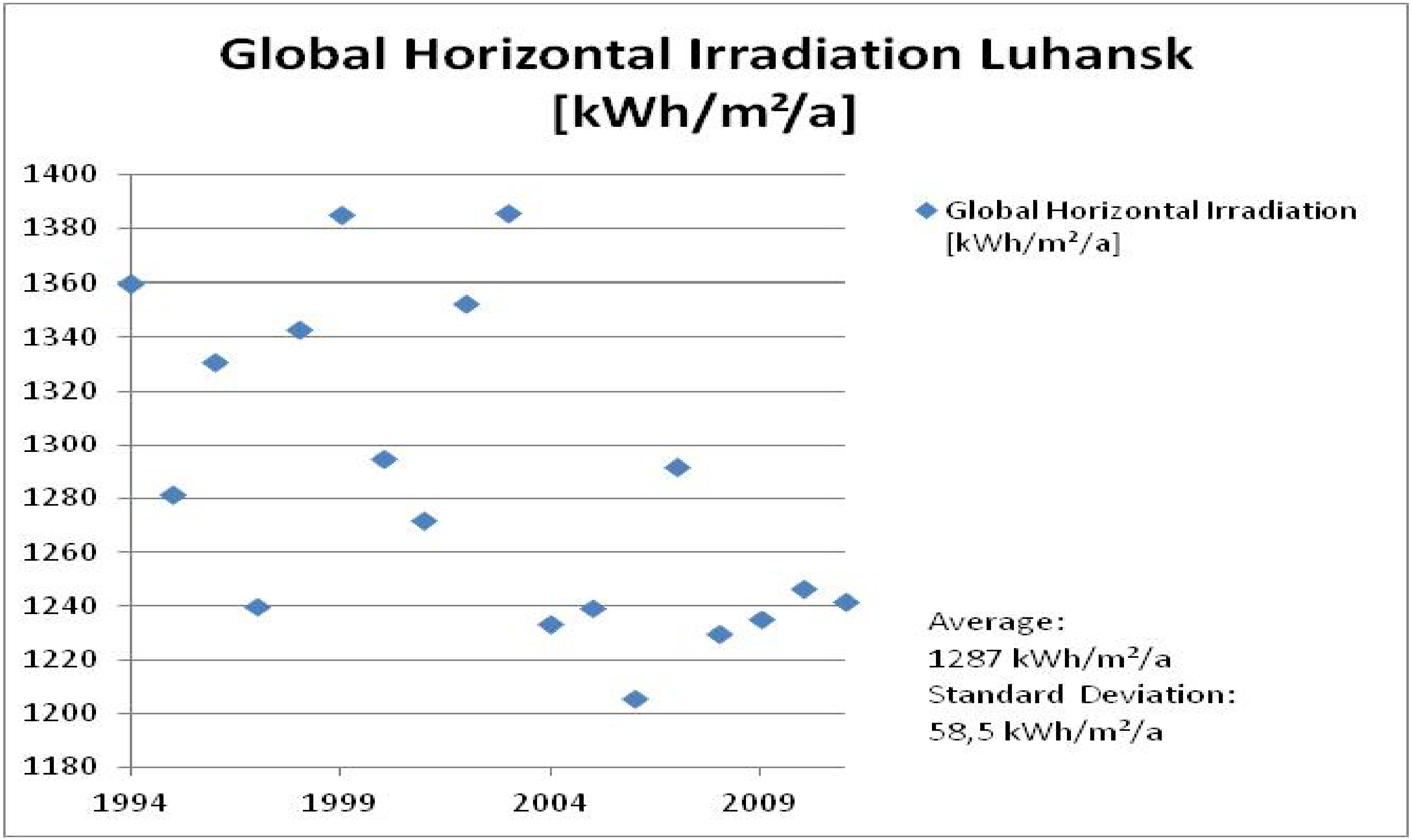
Irradiation in Ukraine



Irradiation in Luhansk



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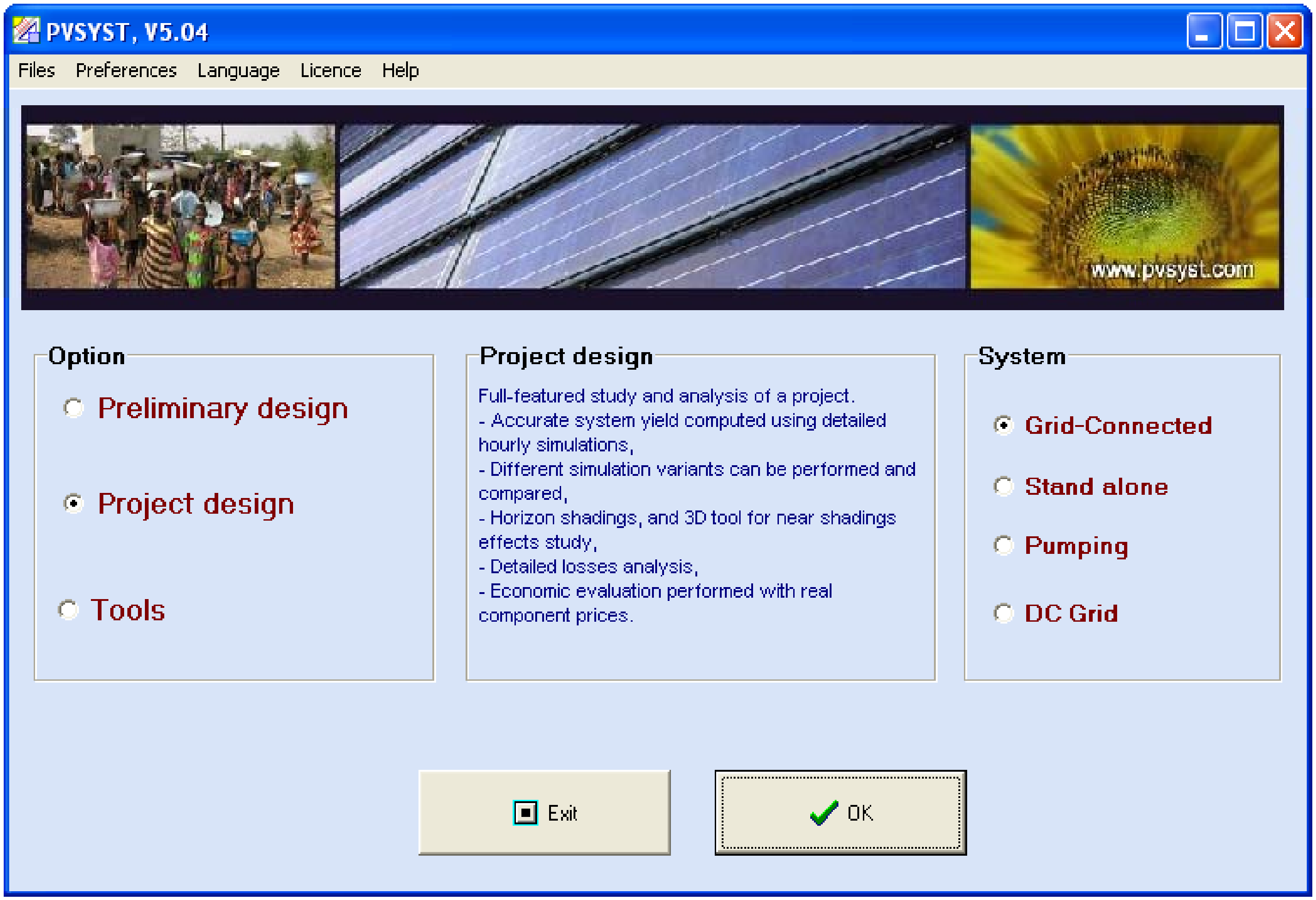
Yield projections – Plant design

- Location
- Topography
- Layout (incl. shading)
- Modules
- Inverters
- Mounting Systems
- Transformers
- Cabling
- Data sheets, single line diagrams and AutoCAD layout files are most essential information

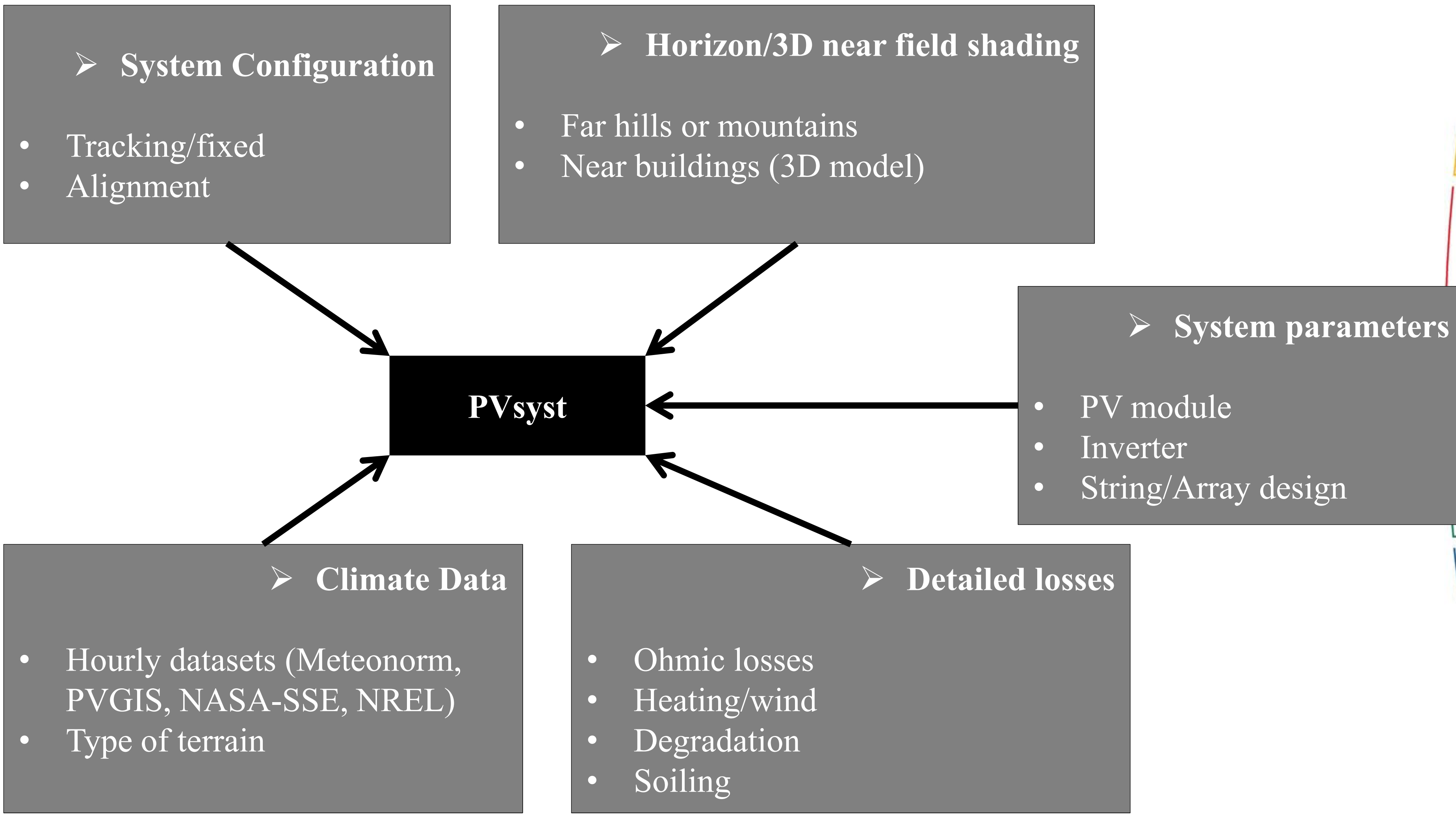
Yield projections – Simulation tool overview

- PVsyst (University Geneva)
- PV*SOL
- INSEL
- HOMER
- Sunny Design (SMA)
- Other self-computed programs

Simulation with PVsyst

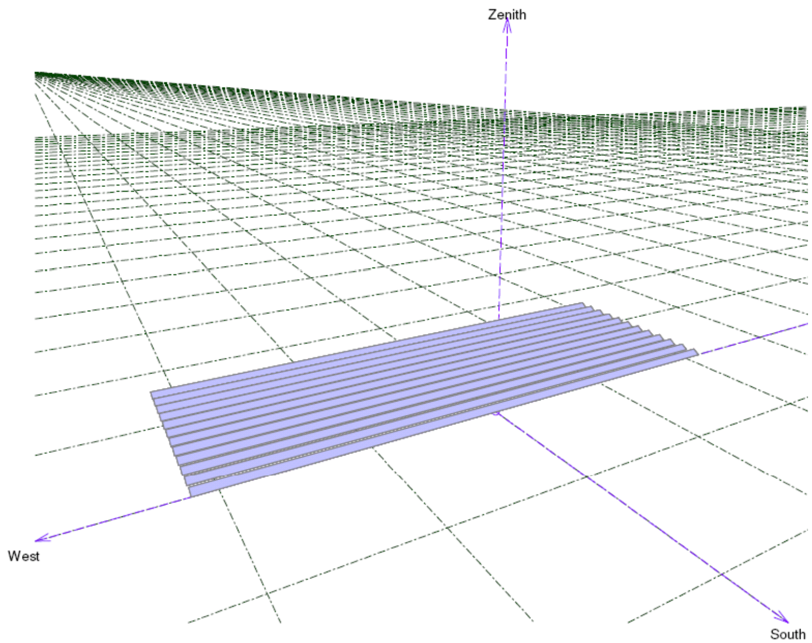


Simulation with PVsyst – Workflow and Boundary Conditions



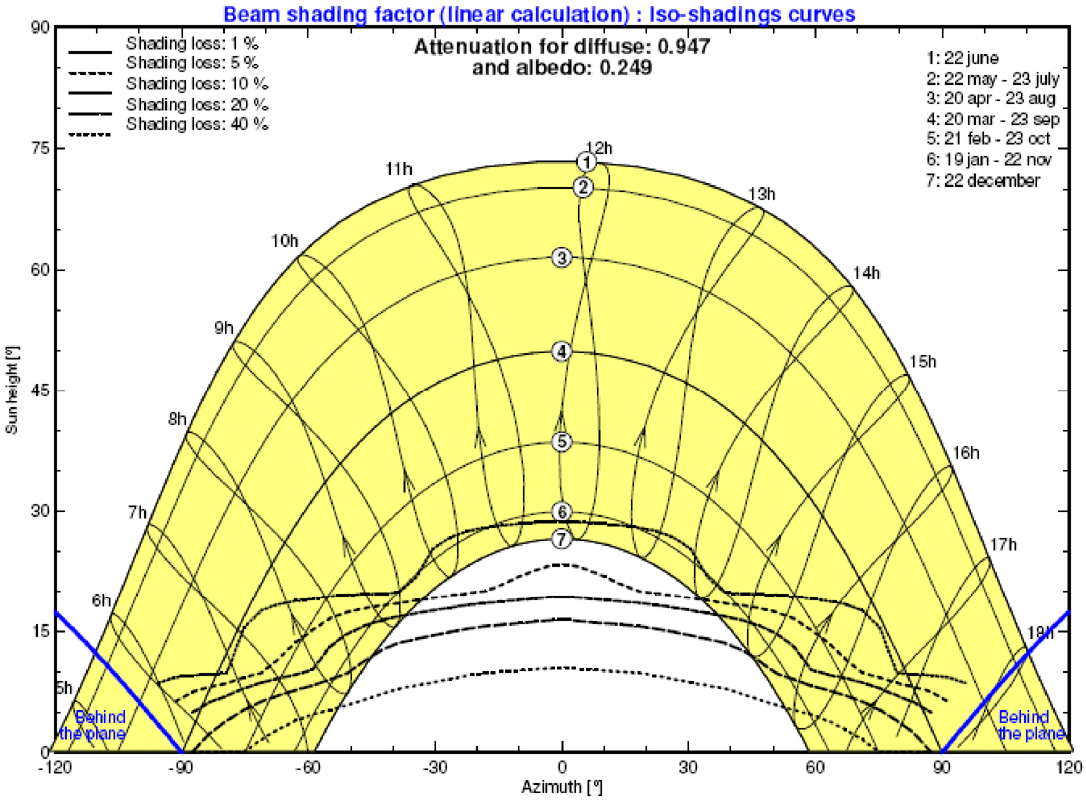
Simulation with PVsyst

Perspective of the PV-field and surrounding shading scene

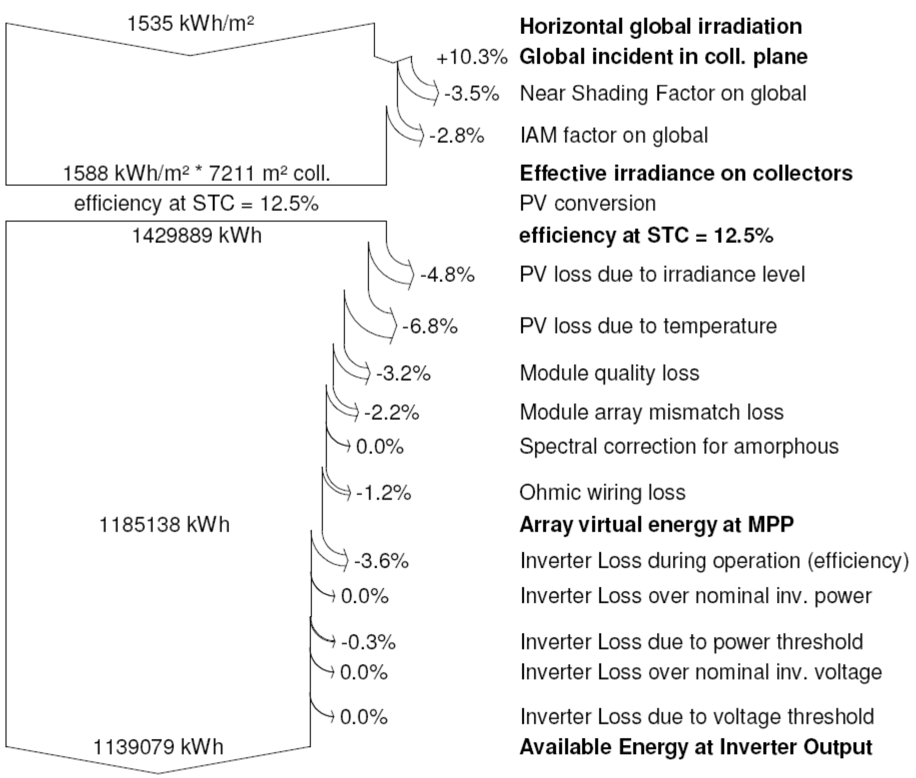


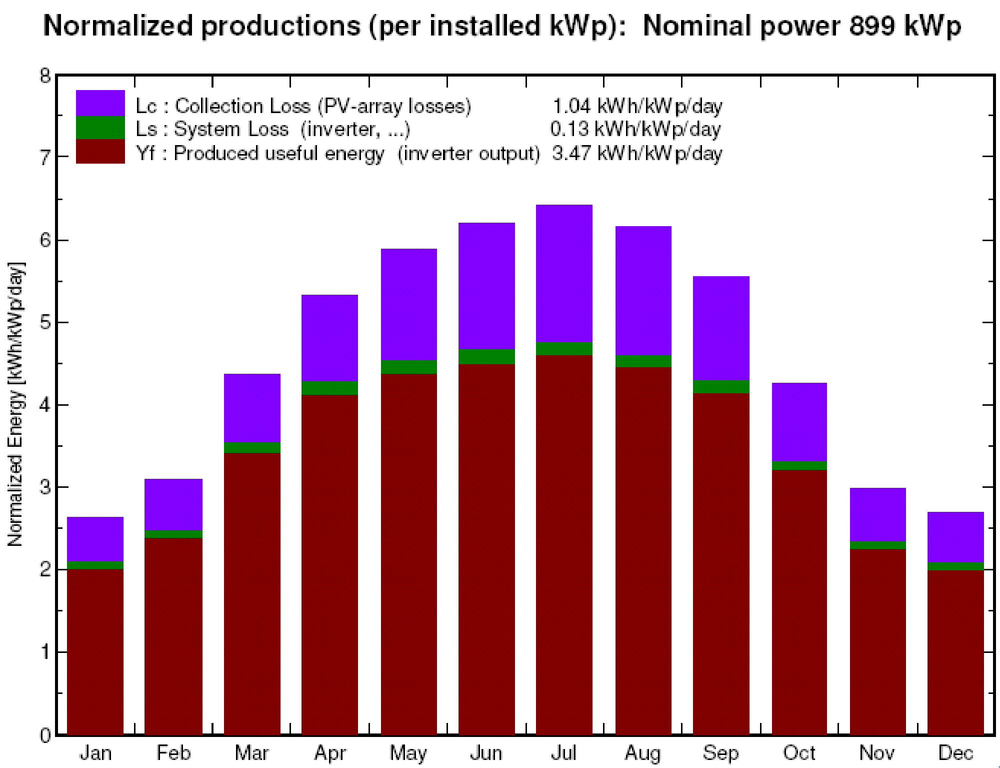
Iso-shadings diagram

PV Apulia: DIA SPC 190 D Shading



Simulation with PVsyst





Yield projections – Typical loss parameters

- PVsyst calculated loss parameters:

Item	%
Near shading factor	-3.4
IAM on Global	-2.9
Irradiance level	-4.8
Temperature losses	-4.9
Soiling losses	-1.1
Module quality	-1.1
Mismatch losses	-1.6
DC wiring losses	-0.9
AC wiring losses	-0.5
Transformer and substation losses	-1.1

Yield projections – Main simulation results

- PVsyst calculated main simulation results:

Specific Yield [kWh/kWp/a]	Performance Ratio [%]	Energy Production [MWh/a]
1,304	78.2	78,882

- Still to be accounted for:
  - Module degradation (initial and linear)
  - Plant availability
  - Grid availability

- Accordingly reduced specific yield for uncertainty evaluation (degradation normally considered separately in financial models)

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Yield projections – Uncertainty evaluation

- Simulation and data uncertainties to be considered:

Duration [years]	1	2	3	4	5	10	20
σ_{Sim}	4.00%	4.00%	4.00%	4.00%	4.00%	4.00%	4.00%
$\sigma_{Irr,acc}$	3.22%	3.22%	3.22%	3.22%	3.22%	3.22%	3.22%
$\sigma_{Irr,ltc}$	3.85%	2.72%	2.22%	1.92%	1.72%	1.22%	0.86%
σ_{Tot}	**6.42%**	**5.81%**	**5.59%**	**5.48%**	**5.41%**	**5.27%**	**5.20%**

- Probability cases for downside scenarios:

Duration [years]	1	2	3	4	5	10	20
Total uncertainty [%]	6.4%	5.8%	5.6%	5.5%	5.4%	5.3%	5.2%
P50	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
P75	95.7%	96.1%	96.2%	96.3%	96.3%	96.4%	96.5%
P90	91.8%	92.6%	92.8%	93.0%	93.1%	93.2%	93.3%
P95	89.4%	90.4%	90.8%	91.0%	91.1%	91.3%	91.4%
P99	85.1%	86.5%	87.0%	87.3%	87.4%	87.7%	87.9%
P50 [kWh/kWp]	1,291	1,291	1,291	1,291	1,291	1,291	1,291
P75 [kWh/kWp]	1,235	1,240	1,242	1,243	1,244	1,245	1,246
P90 [kWh/kWp]	1,185	1,195	1,198	1,200	1,201	1,204	1,205
P95 [kWh/kWp]	1,155	1,168	1,172	1,175	1,176	1,179	1,180
P99 [kWh/kWp]	1,098	1,117	1,123	1,126	1,129	1,133	1,135

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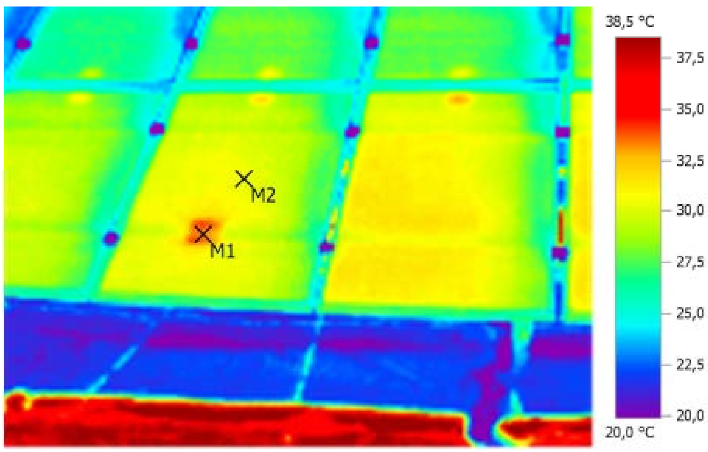
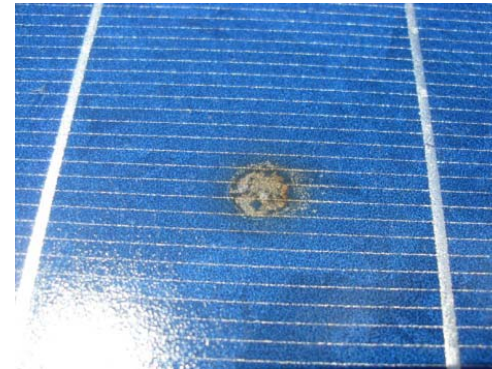
Fault Detection by IR Imaging

Device	testo 875-2	Serial No.:	2067495
Task	IR measurements at the PV-Modules		





Picture data:	**Date:**	11.05.2011	**Emissivity:**	0,85
	Measuring Time:	12:04:48	**Refl. temp. [°C]:**	-40,0
	File:	IV_00073.BMT		

Picture markings:

Measurement Objects	Temp. [°C]	Emiss.	Refl. temp. [°C]	Remarks
Measure point 1	33,2	0,85	-40,0	Cell defect, visual check shows no result
Measure point 2	30,2	0,85	-40,0	-

Remarks: Module Ser.No. 07181143504000722210

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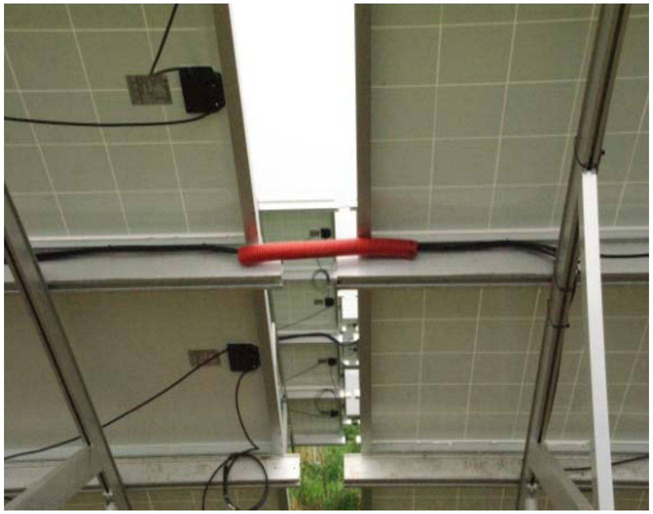
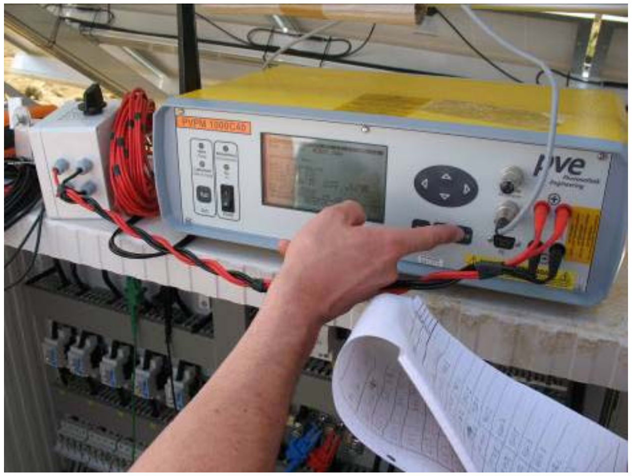
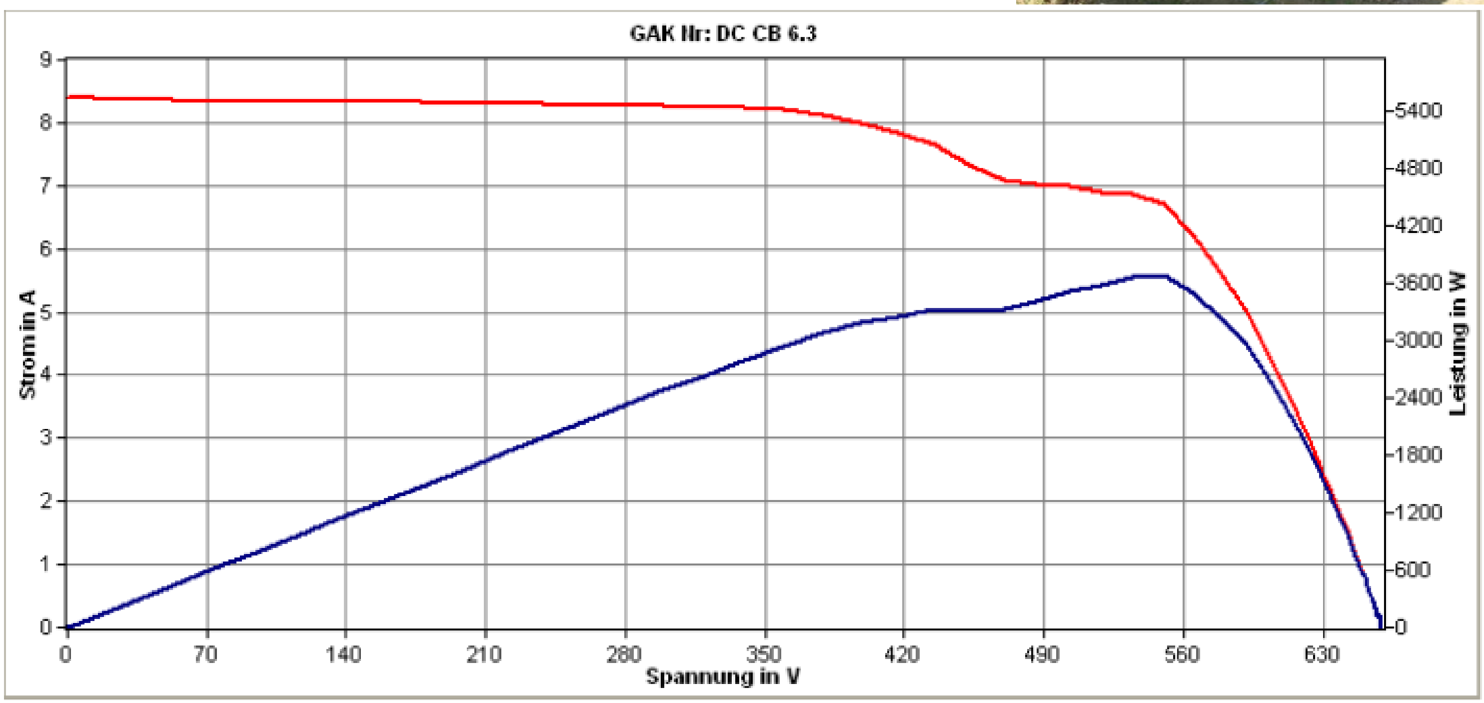
Module defects and required cable sleeves at sharp edges



Fault Detection by IV-Curve Measurement





Mounting Problems

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Damage at Mounting Structure

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Incorrect Installation of Mounting Structure

Excessive Plant Growth and Remediation

Severe weather conditions

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Inappropriate Drainage System – Erosion

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Water Infiltration to Sub-combiner Box

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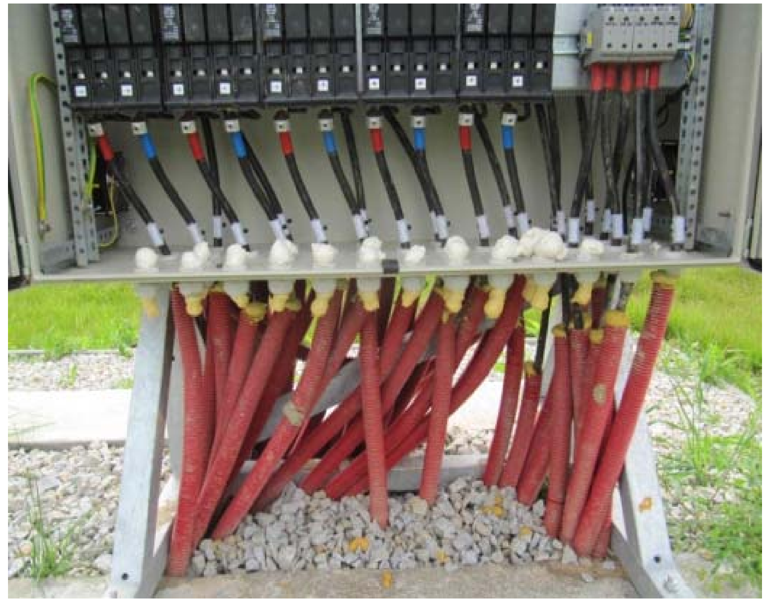
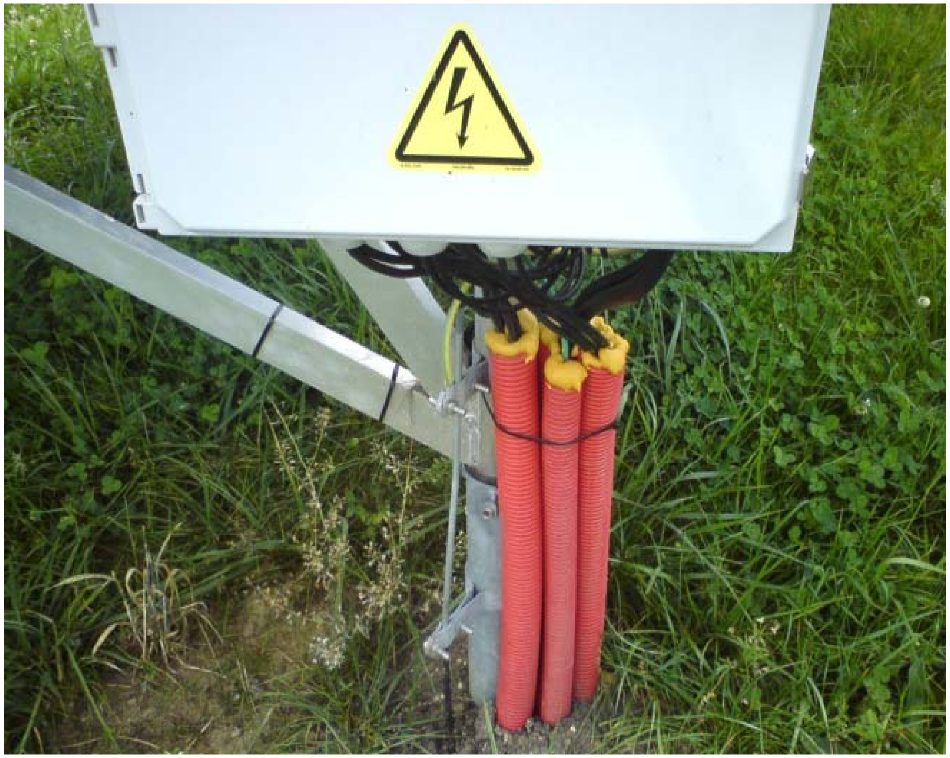
Molten Cable Connections at Sub-combiner Box

Foam Sealing of Combiner Box Cable Entries



Foam Sealing of Cable Ducts



Metal Protection for Cable Ducts at Combiner Boxes

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Wrong Pyranometer Installation

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Preventing measures

- Careful planning and Due Diligence
- Construction monitoring on regular basis
- Commissioning in accordance with international applicable and recognized norms
- Retention amount for correction of punch-list items (correction cost max 4% of EPC price)
- Appropriate preventive maintenance
- Thermograph imaging check of modules before end of warranty period
- I-V-curve measurement of strings before end of module warranty period

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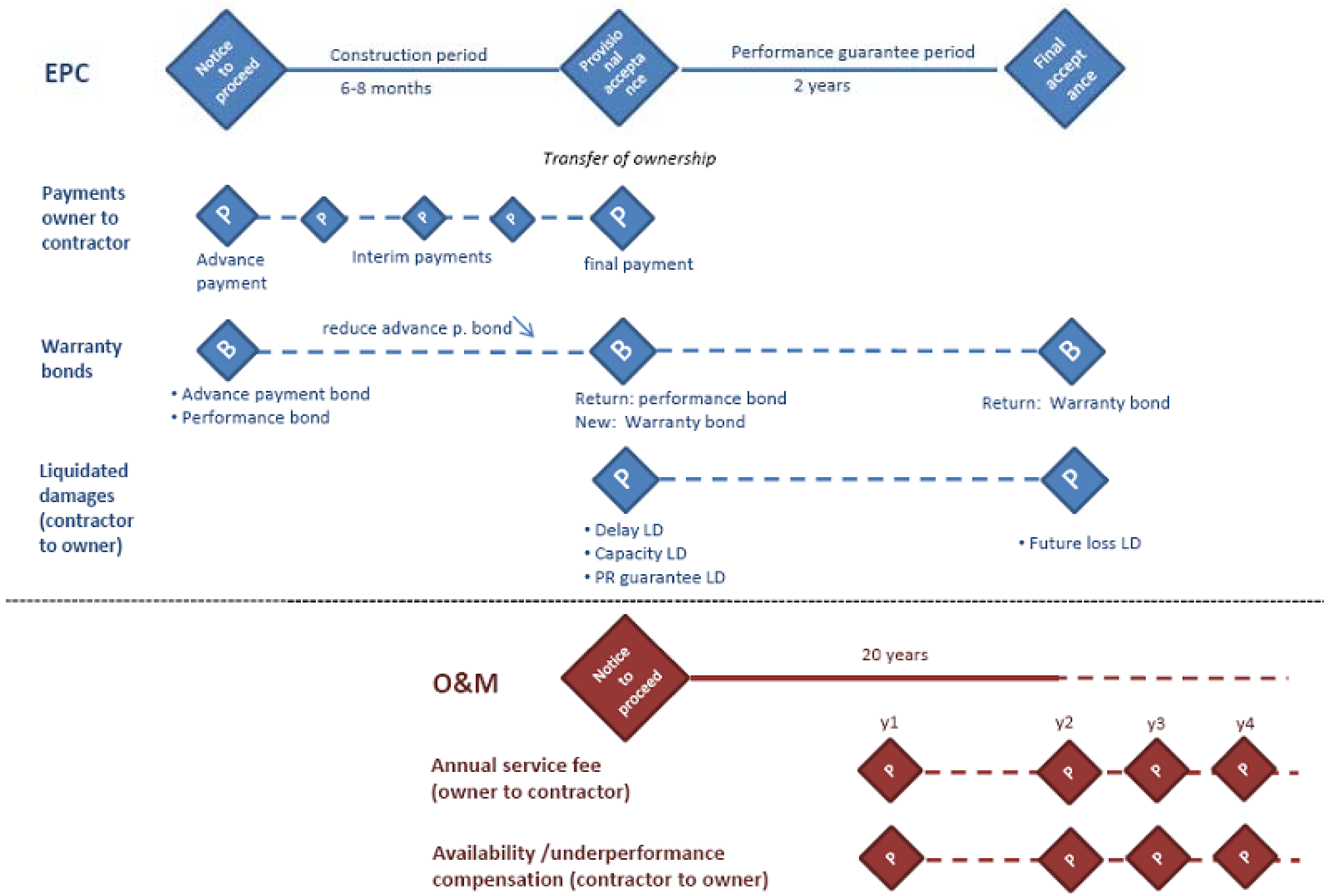
EPC and O&M Contracts



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Basic concept of EPC and O&M

Review of the EPC Contract and Project Schedule

- EPC contract structure/ general completeness
- Scope of Work
- Technical specifications / Owner's Requirements
- Milestones and Completion deadline
- Contract Price and Remuneration
- Acceptance
- Guarantees, liquidated damages (LD) and bonds
- Insurance issues

Provisional and Final Acceptance

Performance guarantee :

● Provide plant owner with security for future yield of the plant

● Setting a minimum guaranteed performance ratio (PR) to be achieved during the 24-months testing period

Contract stipulations:

● Compensation payments in case of non-achievement of guarantee values (PR or yield between 90% and 100% of guaranteed value)

● Plant rejection for severe underperformance (PR or yield lower than 90% of guaranteed value)

● Bonus payment for over-performance are not usual and can only be accepted if the guaranteed values are market standard

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Basic concept of EPC and O&M

Review of O&M contract

- O&M contract structure/ general completeness
- Preventive maintenance (regular services)
- Corrective maintenance (irregular repair services)
- Contract Price and Remuneration
- Guarantees and liquidated damages (LD)
- Spare parts
- Plant security
- Insurance issues

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Preventive Maintenance works

- General visual inspection (+ operation reports)
- Mechanical / Array preventive maintenance
  - Visually inspection of module defects
  - Check of grounding continuity
  - Check of mounting system
  - Check of weather station items
- Electrical / Array preventive maintenance
  - DC string testing (Voc and Isc)
  - Check of inverter (shut-down, connections, filter)
- Module Cleaning
- Vegetation abatement (mowing machines or sheep)
  - Avoidance of shading
  - Enabling fans to work properly
- O&M costs of around 20 € / kW / year

Maintenance costs

- O&M costs of around 20 - 25 € / kW / year
- Exchange of inverters (around year 8 – 15; MRA built up at year 10 or extended warranty)
- Exchange of modules (0.1% - 1% of total amount; 0.1% in spare stock)
- Refurbishment of spare parts stock

Challenges for PV

- Managing quality and growth in PV power plant sector
- Surviving competition in module production sector
- Grid integration / storage

- Continue to lower costs by
  - Increasing module efficiencies
  - Improving module production processes
  - Lowering balance of plant costs

- Site requirements (land demand etc.)
- Financing costs (finance sector confidence, country risks)

- Low costs of fossil fuels (or even subsidies)
- Insufficient or improper incentives

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Thank You!