Photovoltaic systems: Developments and issues in view of the IEA PV roadmap

or: from kW to kWh

Stefan Nowak, Chairman IEA PVPS

PVPS

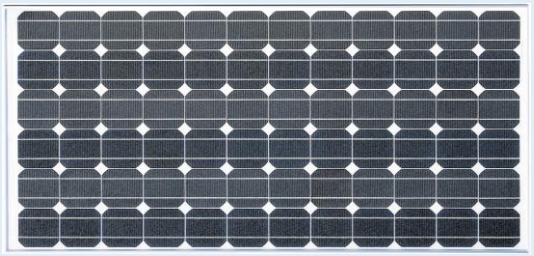
Outline

- Observations and experiences from the past
- Trends
- Issues
- Contribution to a future vision

Historic data: generally up to 2012

PV systems – the components

- Solar Module



BOS

- Mounting system

- Cables and plugs

- Inverters, chargers, batteries, etc.

PVPS

Remark: BOS more regional markets, not global commodity

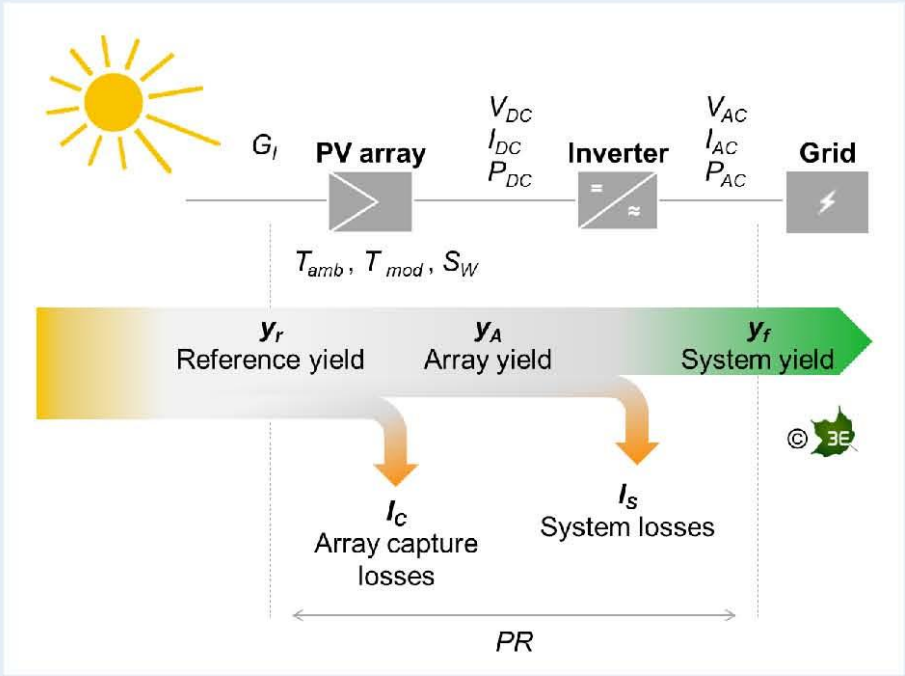
Definitions: Yields & Losses

Yields

Reference yield Y_r = in-plane irradiation / 1 kW/m^2

Array yield Y_A = DC energy / PV peak power

Final yield Y_f = AC energy / PV peak power



Losses

Capture losses $L_C = Y_r - Y_A$

System losses $L_S = Y_A - Y_f$

Performance Ratio PR

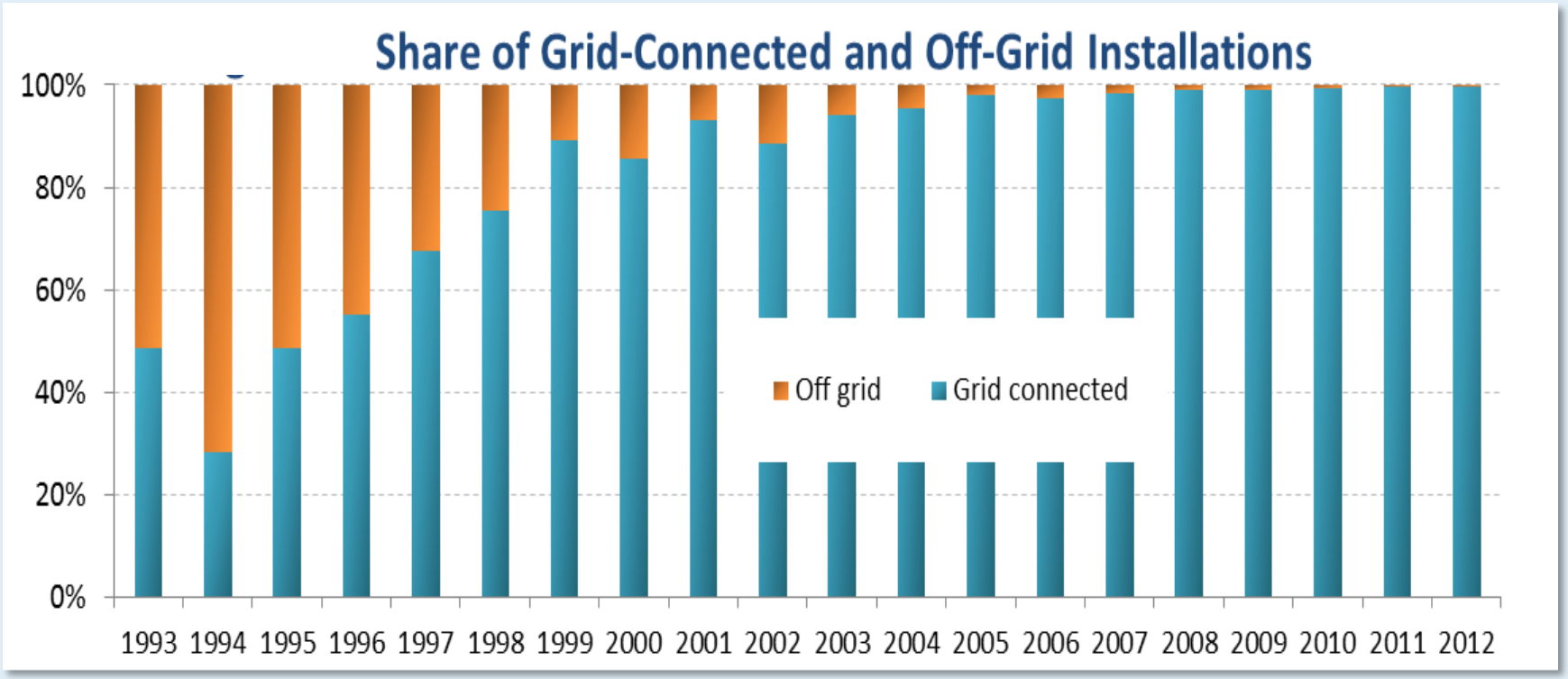
$PR_A = Y_A / Y_r$

$PR = Y_f / Y_r$

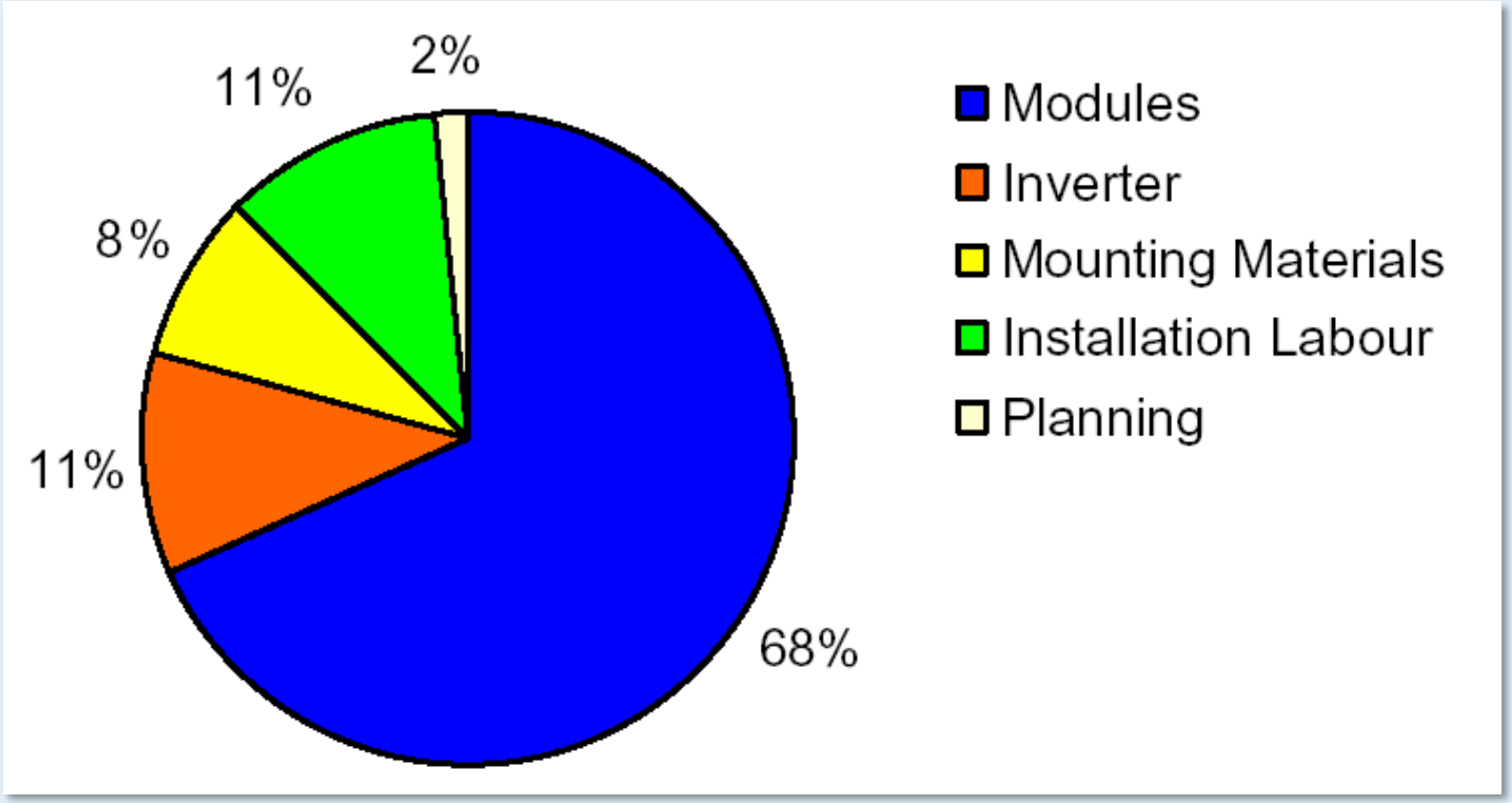
Capitals: energy [h]; small letters: power [p.u.]

PVPS

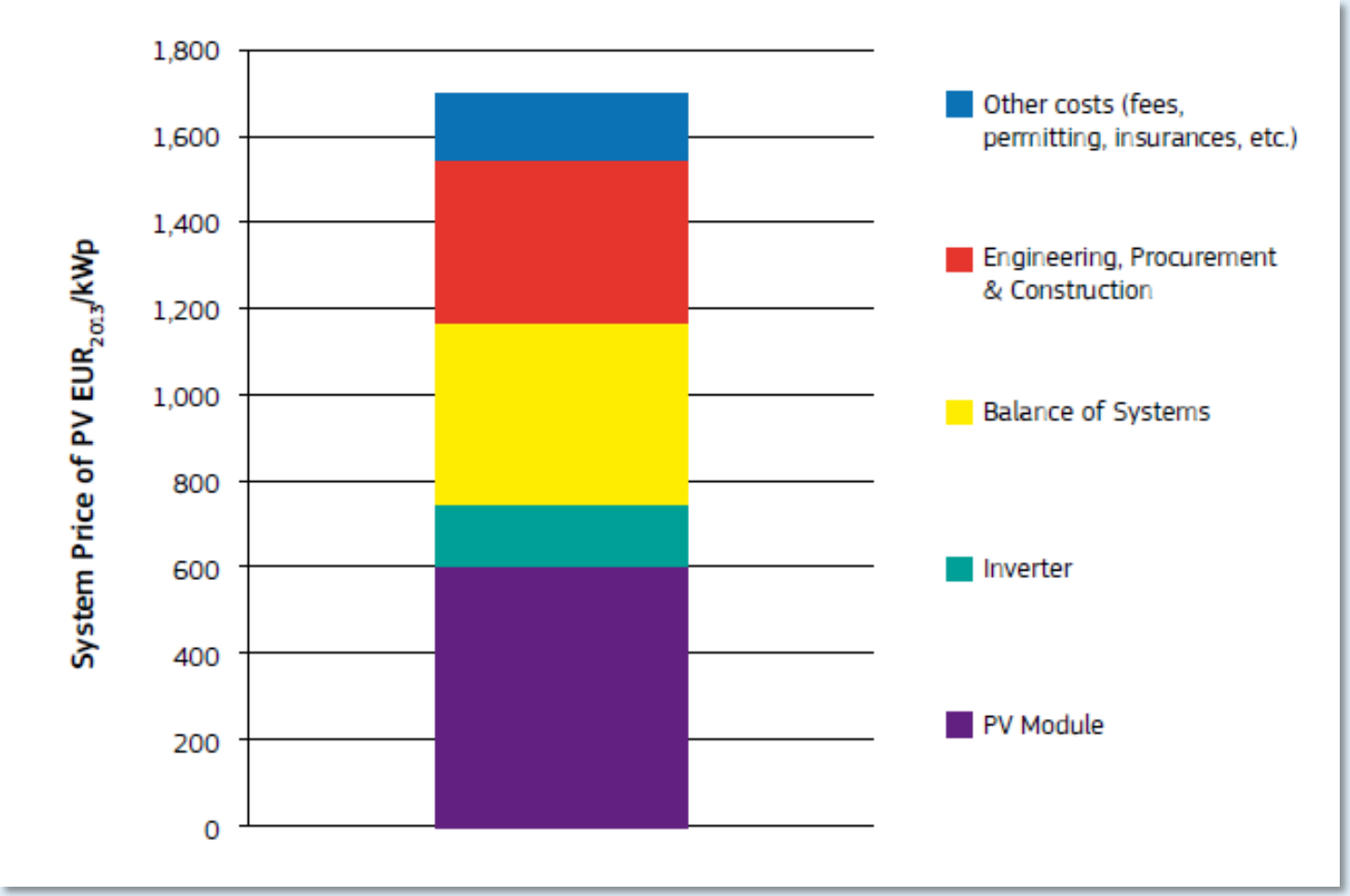
Share of grid connected systems



Price breakdown – the past

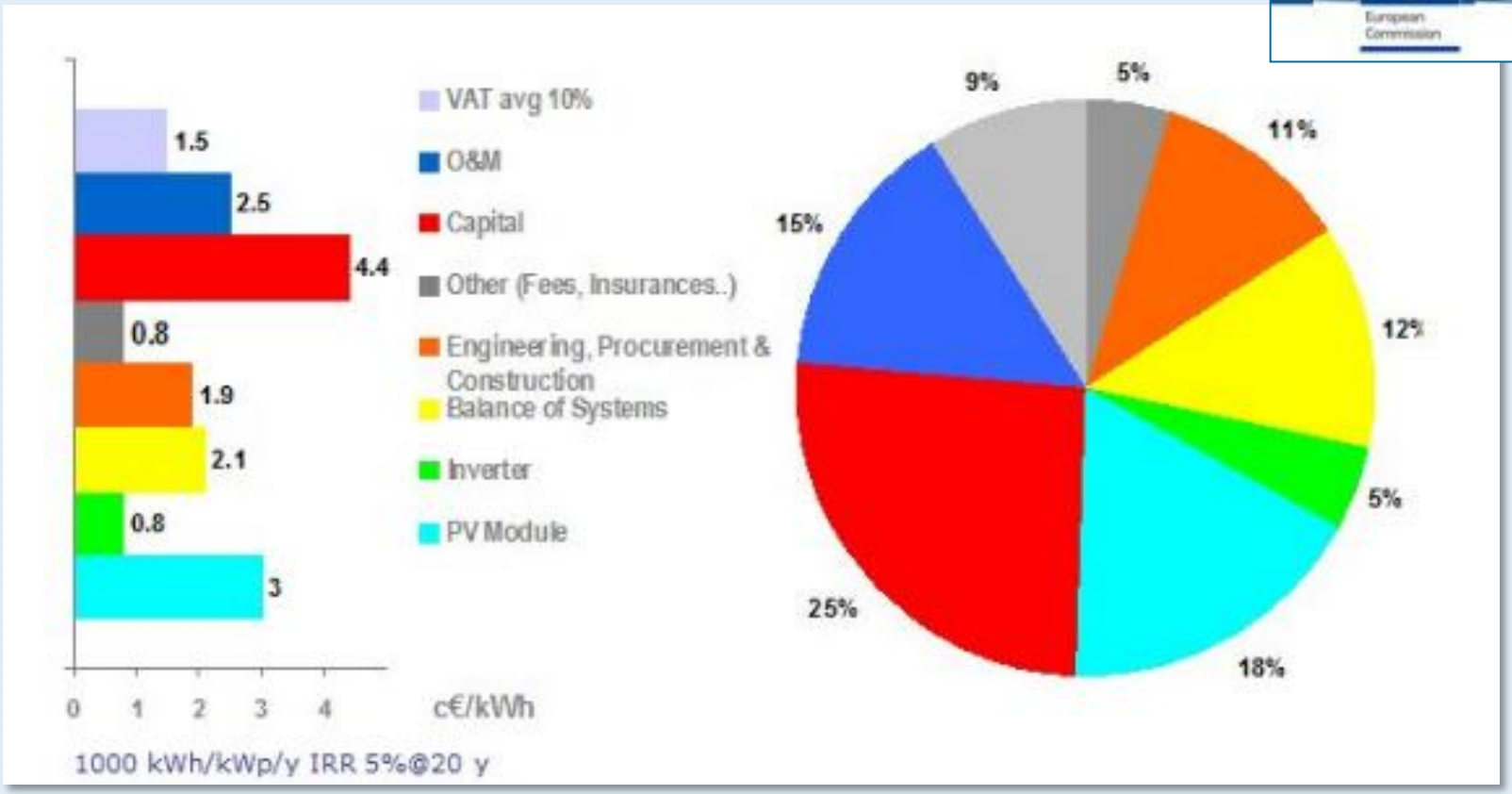


Price breakdown – the present



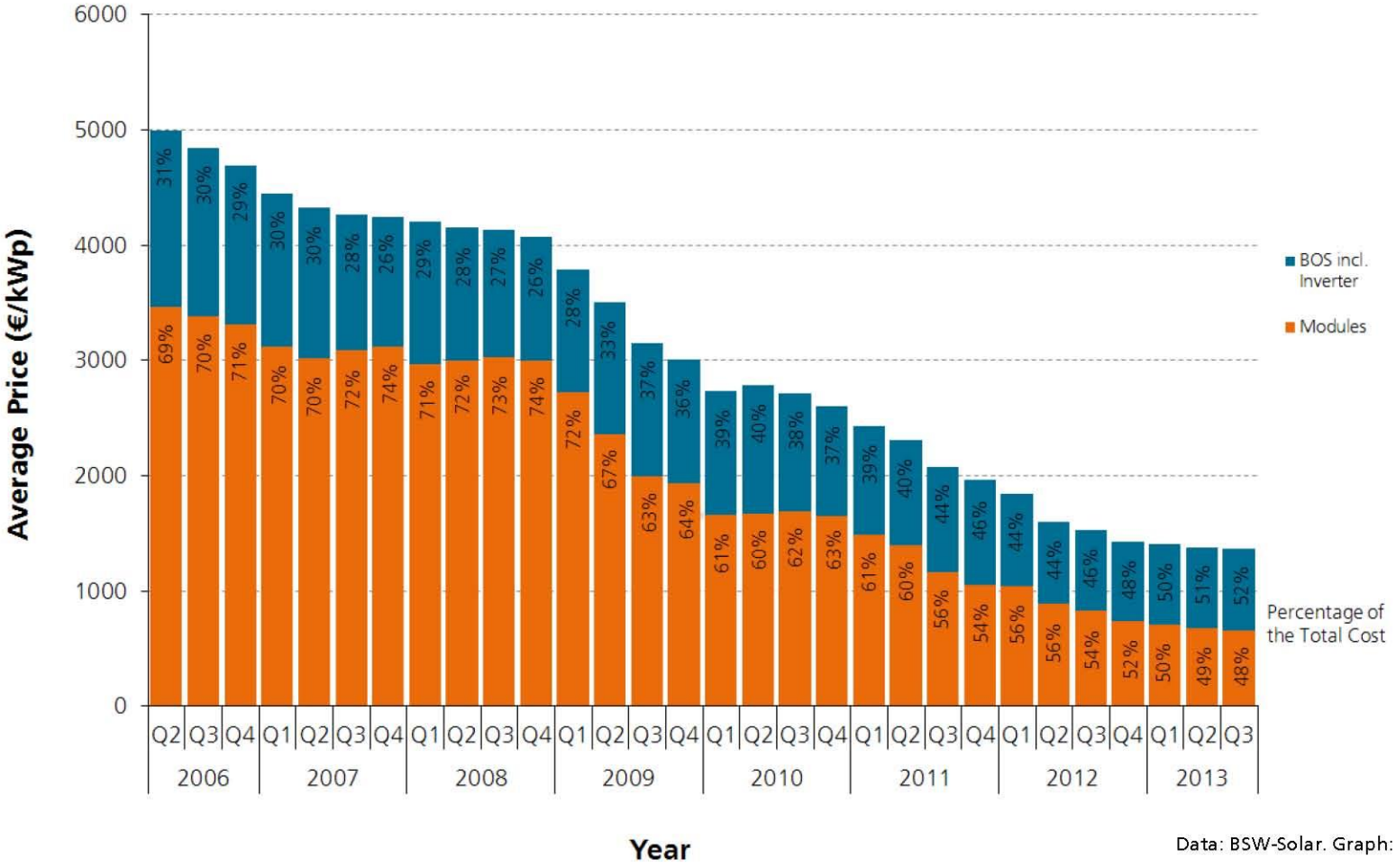
Source: Arnulf Jaeger-Waldau, JRC, EC, 2013

LCOE breakdown – the present



Source: Arnulf Jaeger-Waldau, JRC, EC, 2013

Average Price for PV Rooftop Systems in Germany (10kWp - 100kWp)



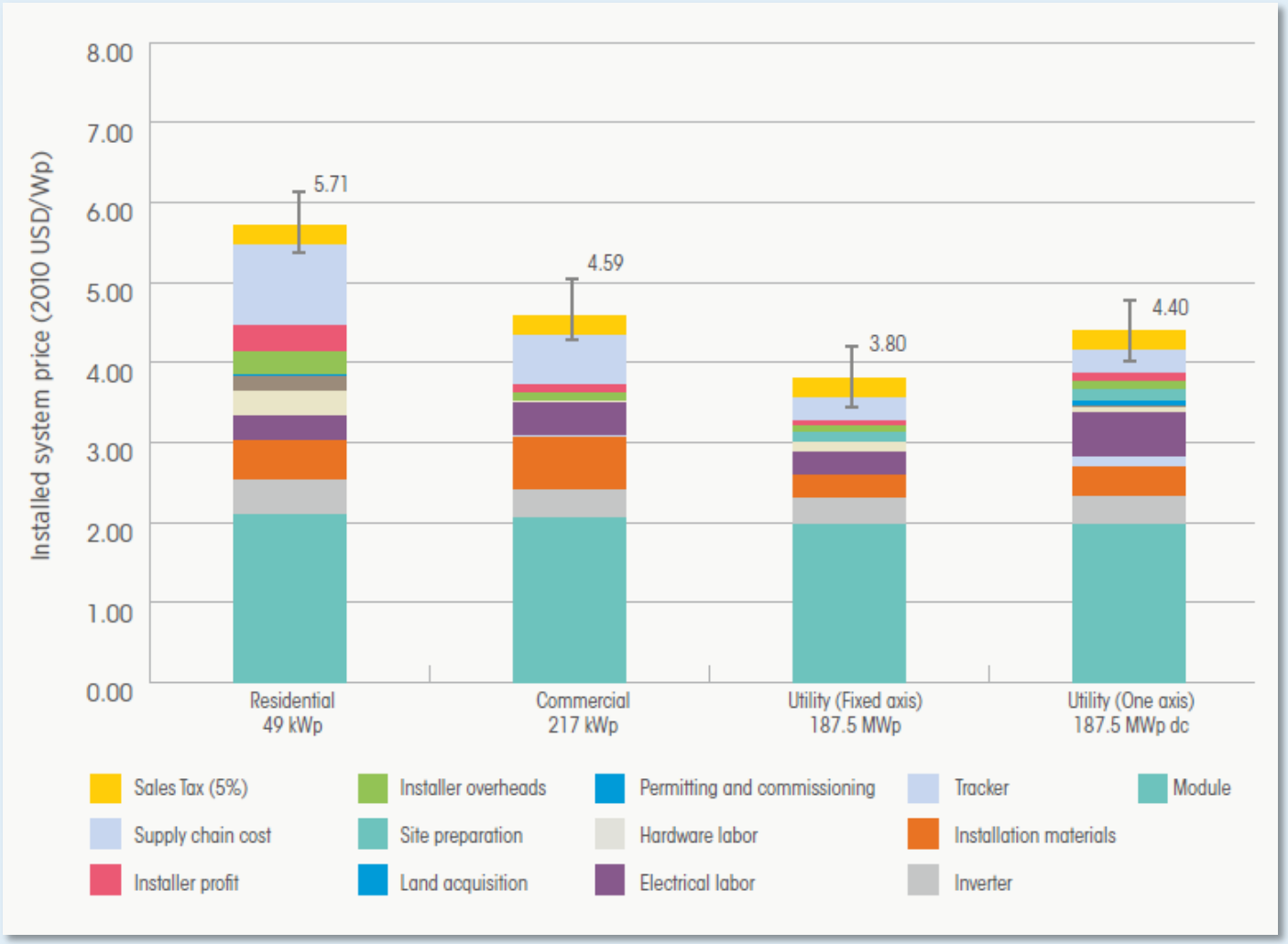
Data: BSW-Solar. Graph: PSE AG 2013

Fraunhofer ISE

Market segments (grid connected)

- Residential
- Commercial
- Utility scale

More on cost structure

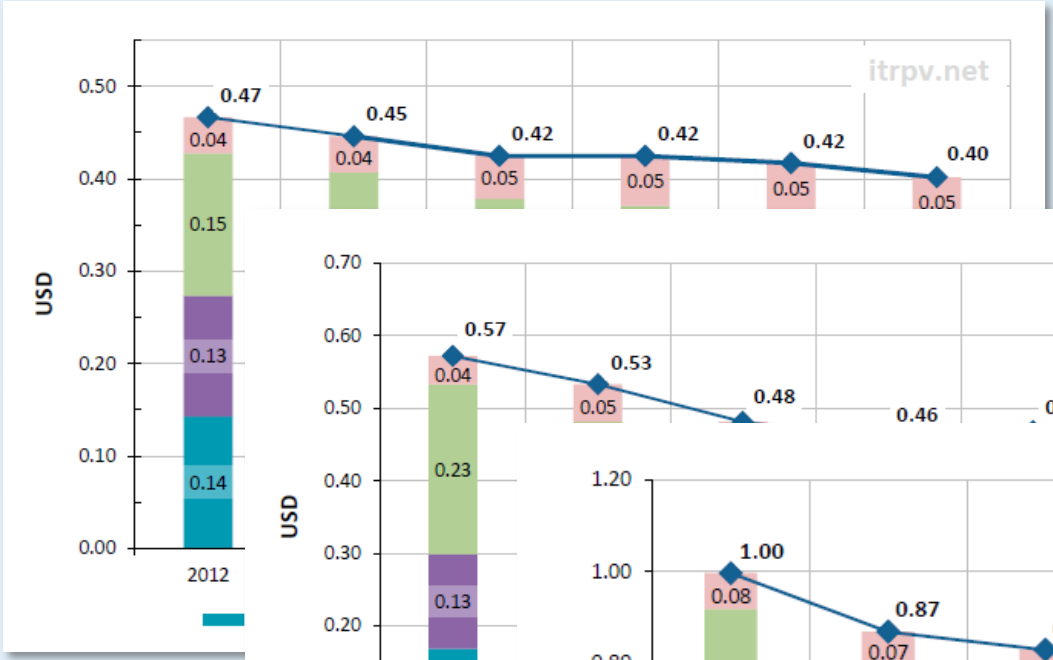


Source: IRENA, 2013 / Goodrich, 2012; US Data for 2010

PVPS

BOS cost reductions (> 100 kW)

Europe



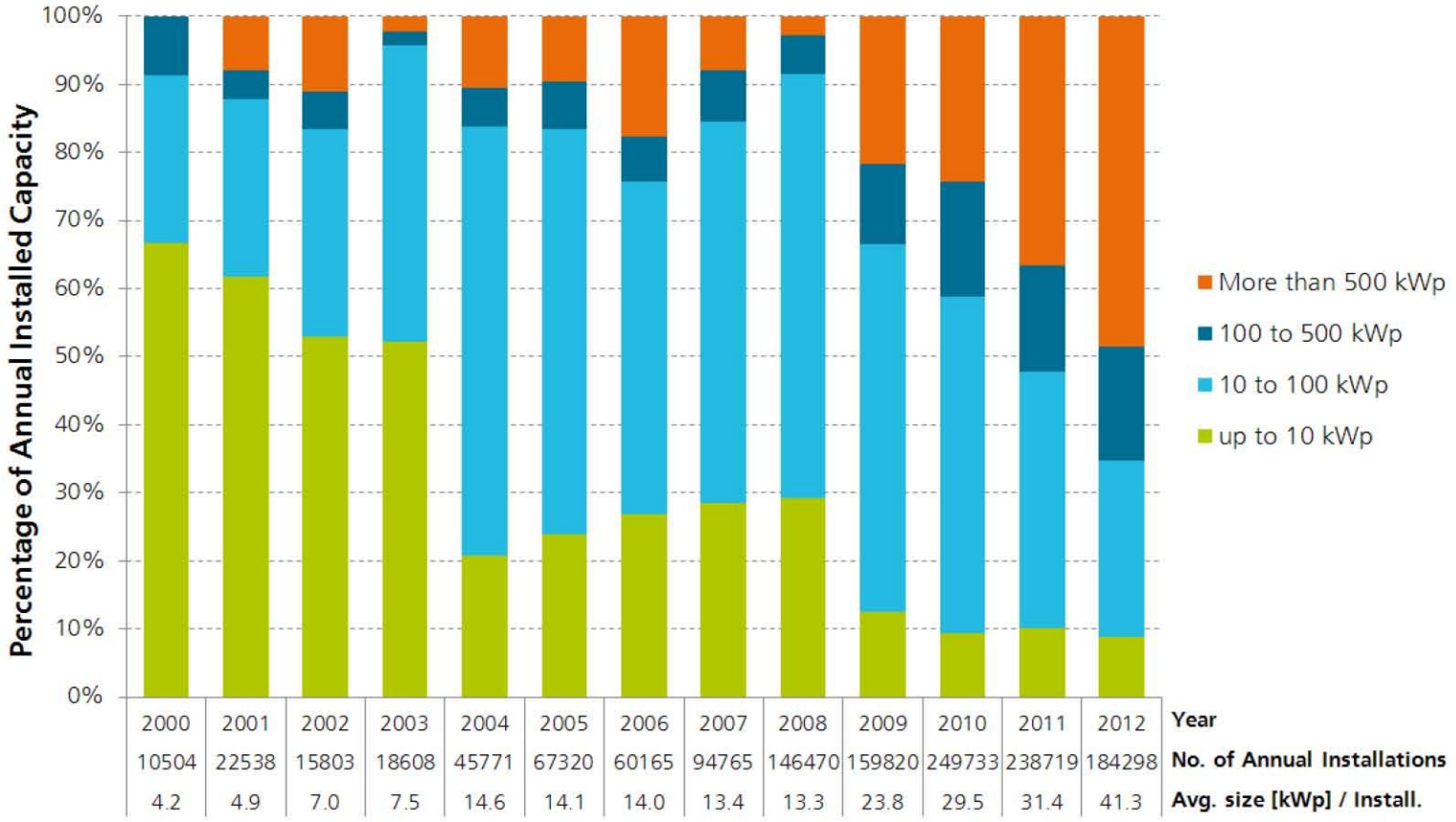
Asia

US

ITRPV, 2013
SEMI / PV-Group

PVPS

PV Systems Yearly Installed in Germany
Shares by System Size

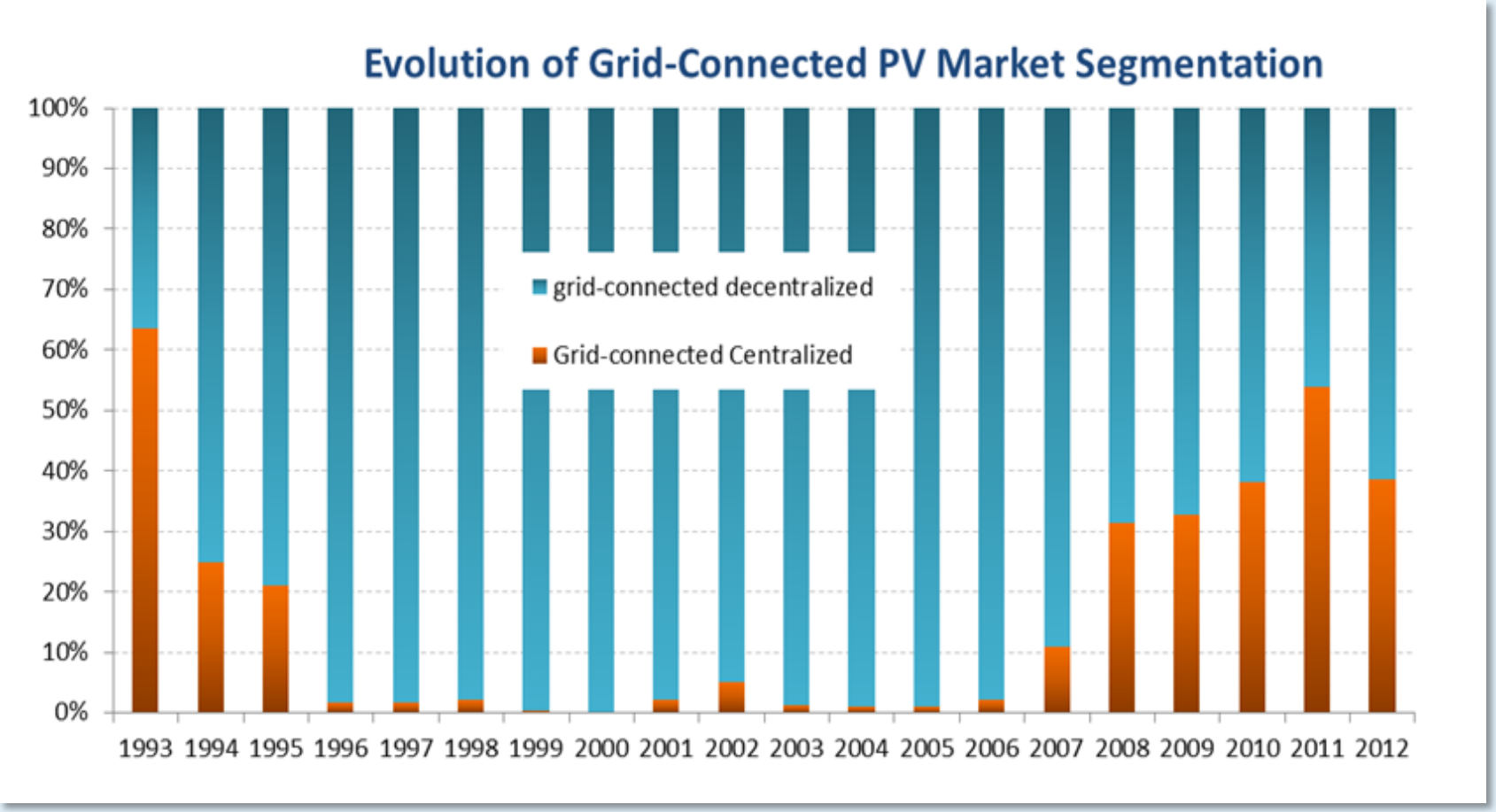


	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Year													
No. of Annual Installations	10504	22538	15803	18608	45771	67320	60165	94765	146470	159820	249733	238719	184298
Avg. size [kWp] / Install.	4.2	4.9	7.0	7.5	14.6	14.1	14.0	13.4	13.3	23.8	29.5	31.4	41.3

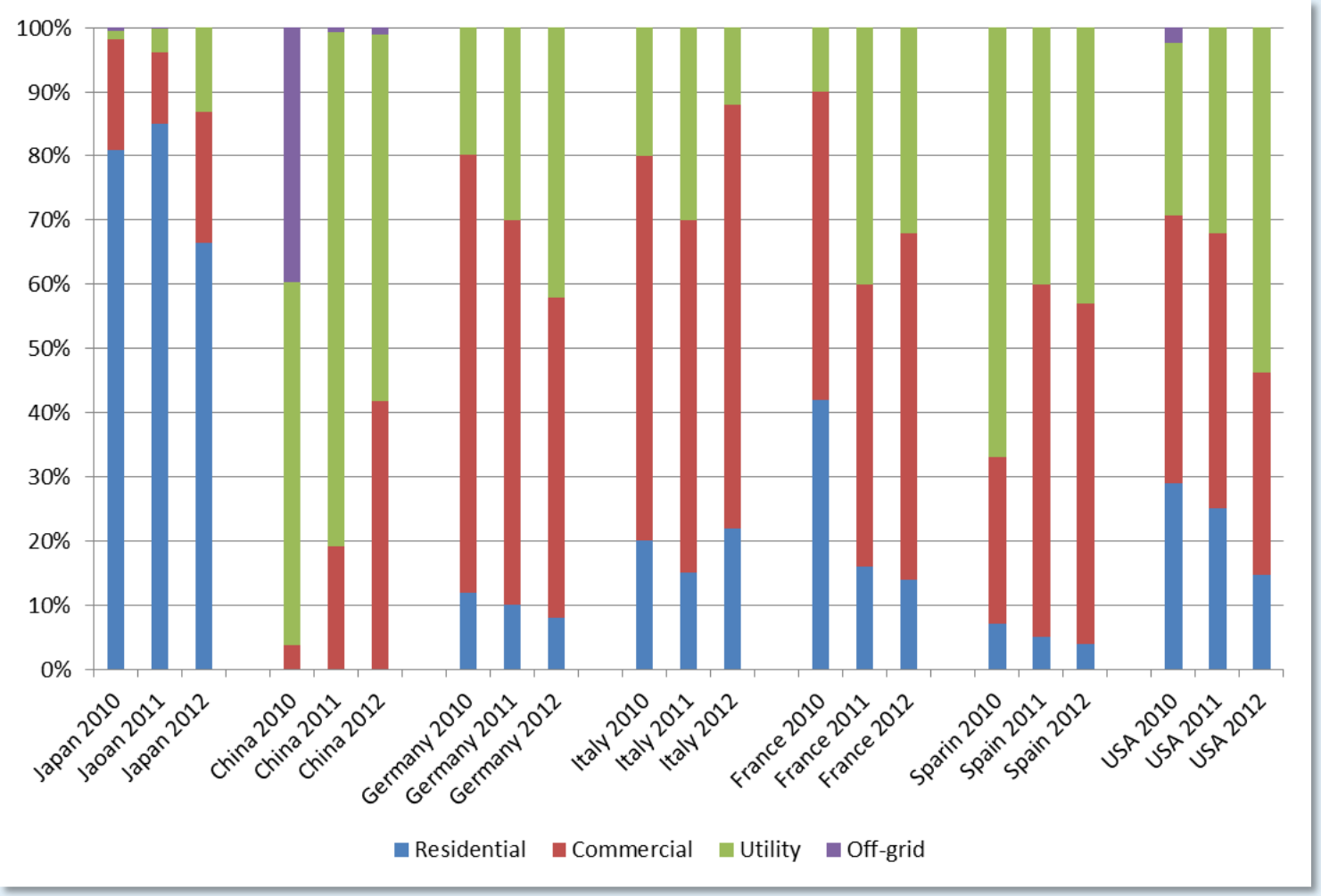
Data: up to 2008: extrapolation from utilities data; since 2009: Bundesnetzagentur. Graph: PSE AG 2013

Fraunhofer ISE

Grid connected market segments



Market segments



Source: I. Kaizuka, RTS

System diversification

- PV-T hybrid systems, (H)CPV

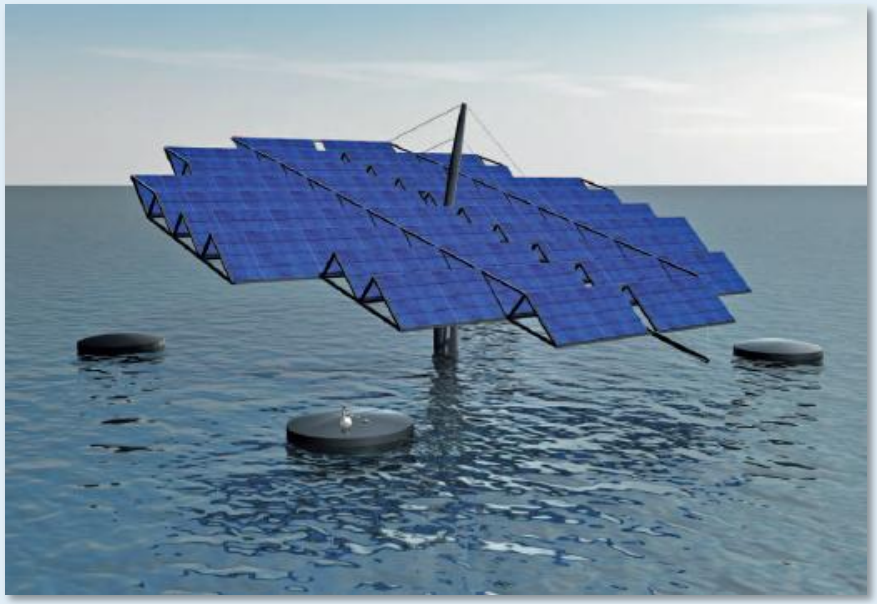
Source: Meyer Burger

Source: Fraunhofer ISE

System diversification

- Carports, sound barriers, facades, etc.
- „Exotic“ PV systems, examples:

Source: F. Baumgartner, ZHAW

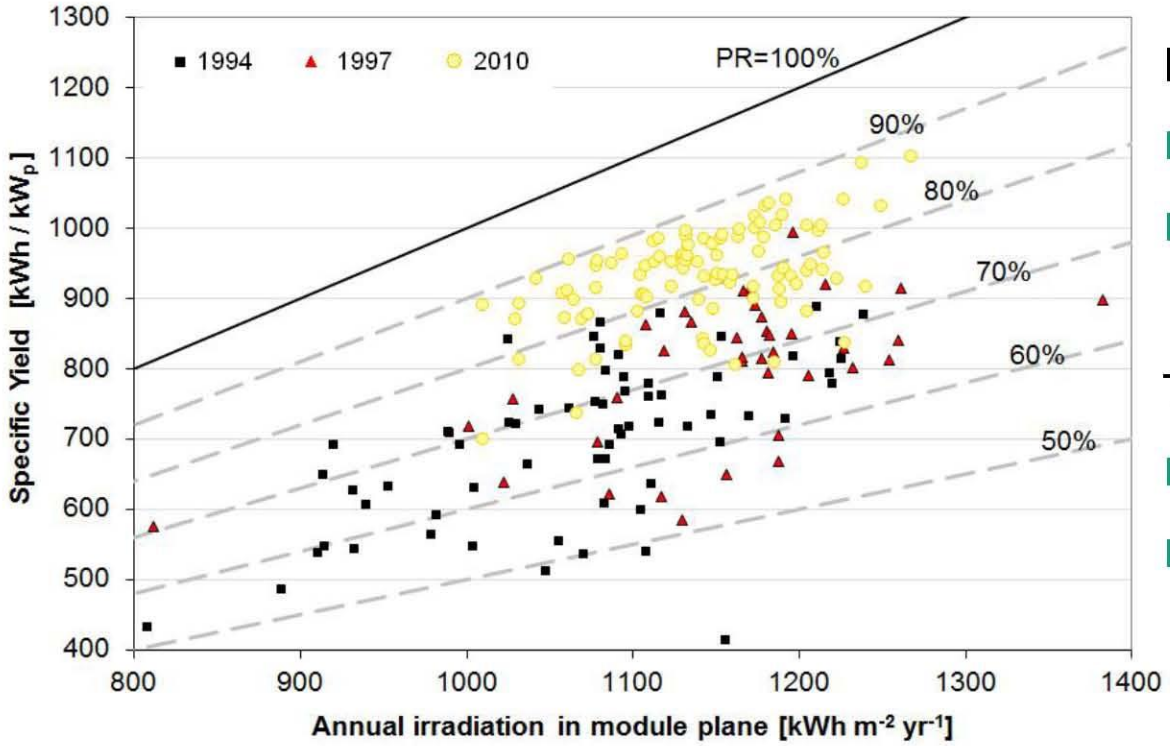


Source: HYDROSUN (Concept)

Overall trends

- Increasing the energy production and performance while reducing costs further
- Combination with advanced building concepts
- BIPV: rather slow development
- Commercial projects in regions with high electricity tariffs and high PV yields
- More utility owned systems
- Ancillary inverter functions (e.g. reactive power, power quality, curtailment, smart home control)
- Local storage

Performance Ratio Development of PV Systems in Germany



In the 1990's

- Typical PR ~70 %
- Very wide PR-range

Today

- Typical PR ~80-90 %
- Less variance in PR as compared to 1990's

Source: Fraunhofer ISE "1000 Dächer Jahresbericht" 1994 and 1997; 2011 system evaluation

Fraunhofer ISE

System design

- Simple project concepts with high efficiency: mainly with three phase, transformerless multi string inverters
- Less material
- High voltage design
- Oversizing of the solar array DC/AC
  ... 120% (depending on location)
- Module inverter / optimizer
- Maximized use of available land or roof area
- Increased east/west orientation

Inverter/Converter Market

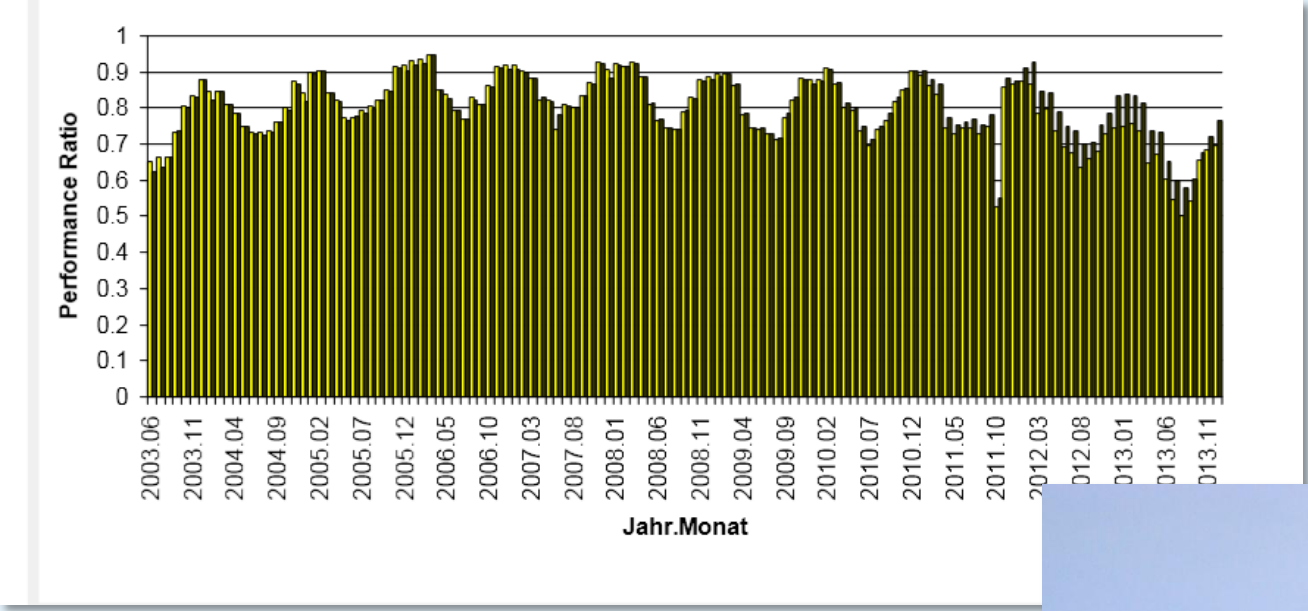
Inverter / Converter	Power	Efficiency	Market Share (Estimated)	Remarks
String Inverters	Up to 100 kWp	98%	90%	• 15-20 €-cents /Wp • Easy to replace
Central Inverters	More than 100 kWp	Up to 98.5%	9%	• 10-20 €-cents /Wp • High reliability • Often sold only together with service contract
Micro-Inverters	Module Power Range	90%-95%	<1%	• 50-80€-cents /Wp • Ease-of-replacement concerns
DC/DC Converters (Power Optimizer)	Module Power Range	Up to 98.8%	~ 0.3%	• Average 40-80 €-cents /Wp • Ease-of-replacement concerns • Today 4 producer each with about 20 MWp annual production. • Output is DC with optimized current

Data: Fraunhofer ISE 2013. Graph: PSE AG 2013

Issues

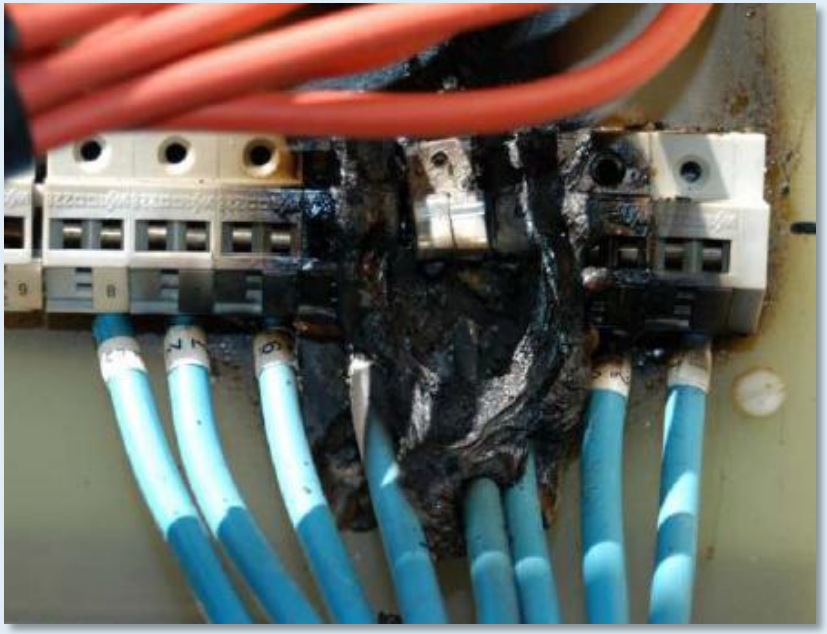
- Quality and reliability of components and systems: Crucial in the rapidly expanding PV market
- Quality of installation
- Safety: materials, electrical, fire
- Standards: behind market expansion, lacking resources, activities in various IEC TC‘s - TC 82, TC 8, TC 64

Aging of PV systems



PVPS

Safety issues



Issues

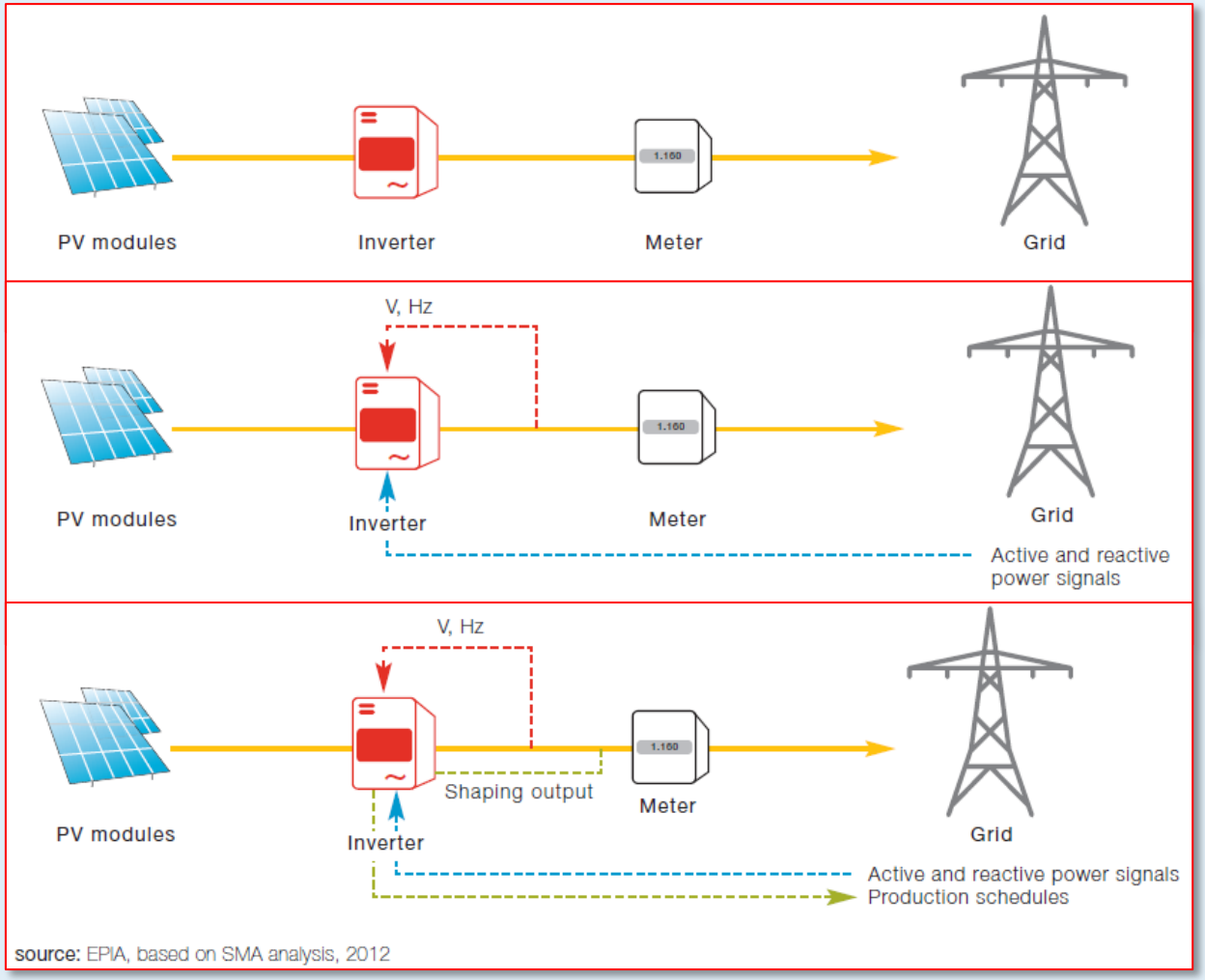
- Simplified and unified grid interconnection standards all over the globe
- Standardised administrative and safety procedures
- Many small steps in product and system improvement are required, for example the module design and the mounting system often do not fit well together

Grid integration: changing role of PV

Yesterday

Today

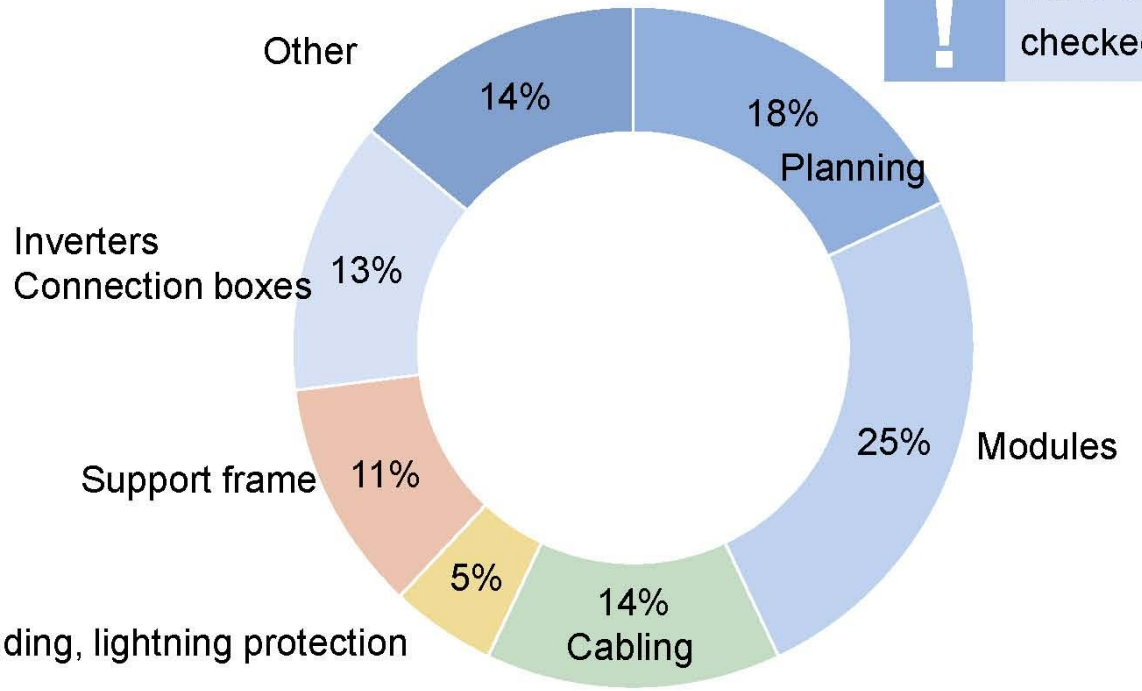
In future



Photovoltaic Systems: Fault Statistics from Acceptance

- Results from 125 large-scale systems analyzed and inspected.
- 20 % show serious defects (direct action required).
- Further 10 % demonstrate high error rate.
- Around 50 % of defects in the individual segments are installation errors.

More than 1 GWp checked to date



Quality Assurance for PV Power Plants

Project qualification

Quality assurance in PV power plants		
Module 1	Evaluation	▪ Site evaluation incl. Shading analysis ▪ Energy yield predition, glare report
Module 2	Planing	▪ Planung support and control ▪ Tender review and evaluation
Module 3	Installation	▪ Component qualification, PV module benchmark, ▪ Performance Check, construction surveillance
Module 4	Acceptance	▪ Safety inspection and acceptance check ▪ Certification and test mark ▪ Energy yield control and rating
Module 5	Operation	▪ Technical and monetary monitoring ▪ Periodic inspection / testing ▪ 3 /10 year check (end-of-warranty inspection)

Conclusions

- Rapid market expansion in all major segments, broad experience available
- Strong global diversity
- Quality and reliability vs. cost
- BOS cost reduction / increased lifetime
- Grid integration
- Safety aspects
- Standards

For the roadmap update

- Build on best practice
- Challenge of a maturing industry
- Integration in various systems
- Standardisation / quality assurance
- Statistics become relevant
- System issues crucial in market expansion – costwise, performancewise, reliabilitywise
- What counts: GWh and not „just“ GW !

Thank you for your attention !

and many thanks to

Peter Ahm, PA Energy
Izumi Kaizuka, RTS
Ulrike Jahn, TÜV Rheinland
Christian Reise, Fraunhofer ISE
Peter Toggweiler, Basler & Hofmann
Achim Woyte, 3E

http://www.iea-pvps.org

Dr. Stefan Nowak, Chairman IEA PVPS
NET Nowak Energy & Technology Ltd.
Waldweg 8, CH – 1717 St. Ursen, Switzerland

Tel. +41 26 494 00 30 / Fax +41 26 494 00 34

Email: stefan.nowak@netenergy.ch