Introduction, Overview of PV Market and Technology

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Short Introduction. Our Services.

Testing

Inspecting

TÜVRheinland®
CERTIFIED

Certifying

Qualifying

Consulting

Products | Systems | Processes | People

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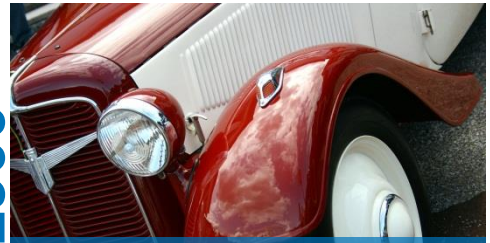
TÜV Rheinland – History.

1872

Founded to ensure the safety of manufacturing plants

1900



First Vehicle Inspection

1960

First Product Certification

1970

First Foreign Subsidiary

1997

Merger with TÜV Berlin-Brandenburg

2012

High Tech PV Labs Worldwide

!

Our goal is to be the world's best independent provider of technical services for testing, inspection, certification, consultation and training.

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Business Streams

Industry

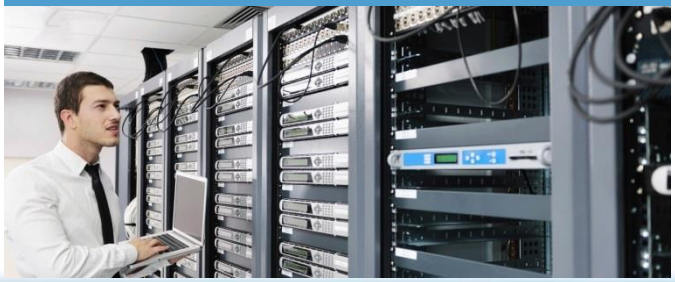
Systems

Products

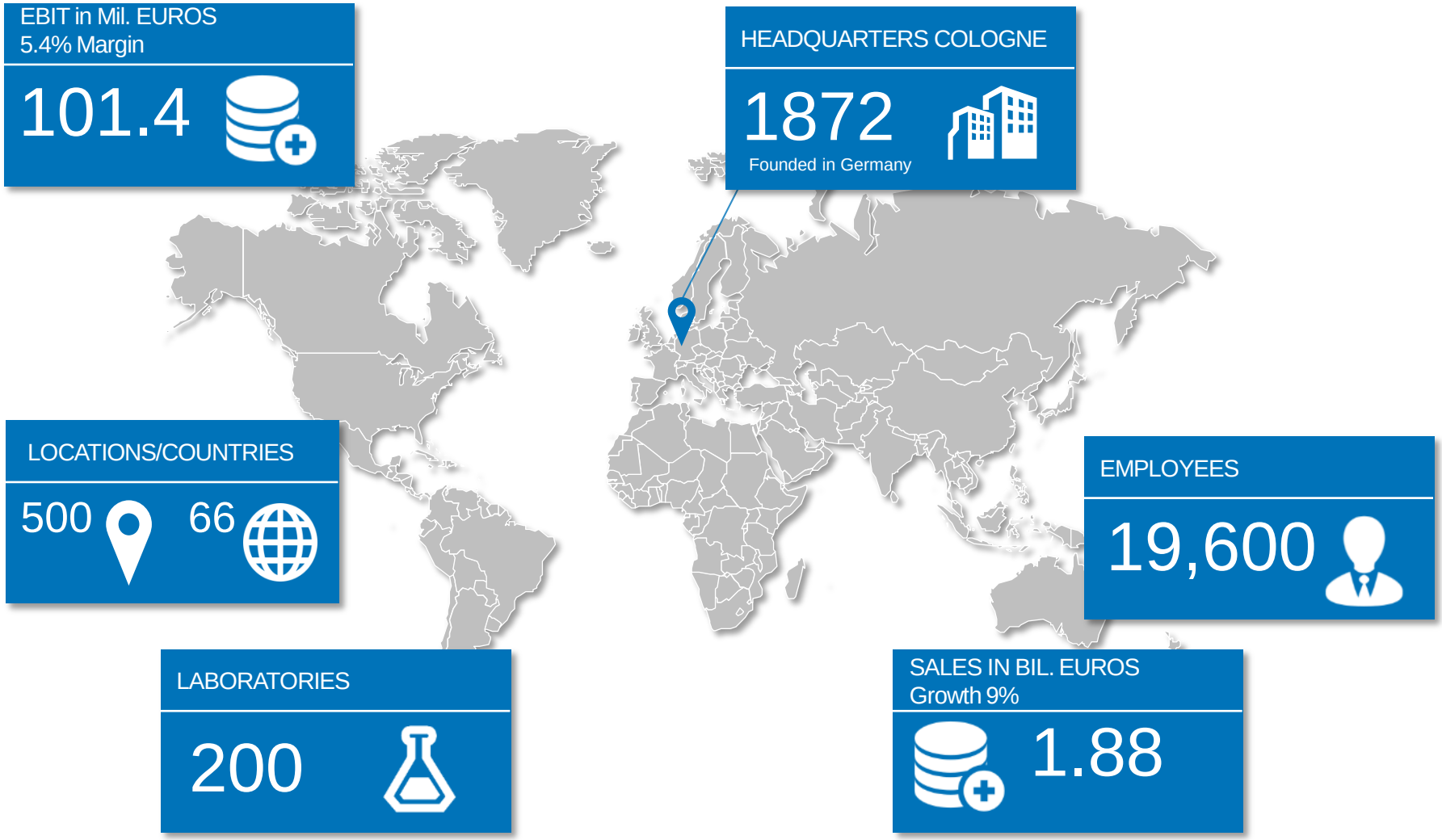
Academy & Life Care

Mobility

ICT & Business Solutions



TÜV Rheinland 2015 – Facts & Figures.



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Solar Technology

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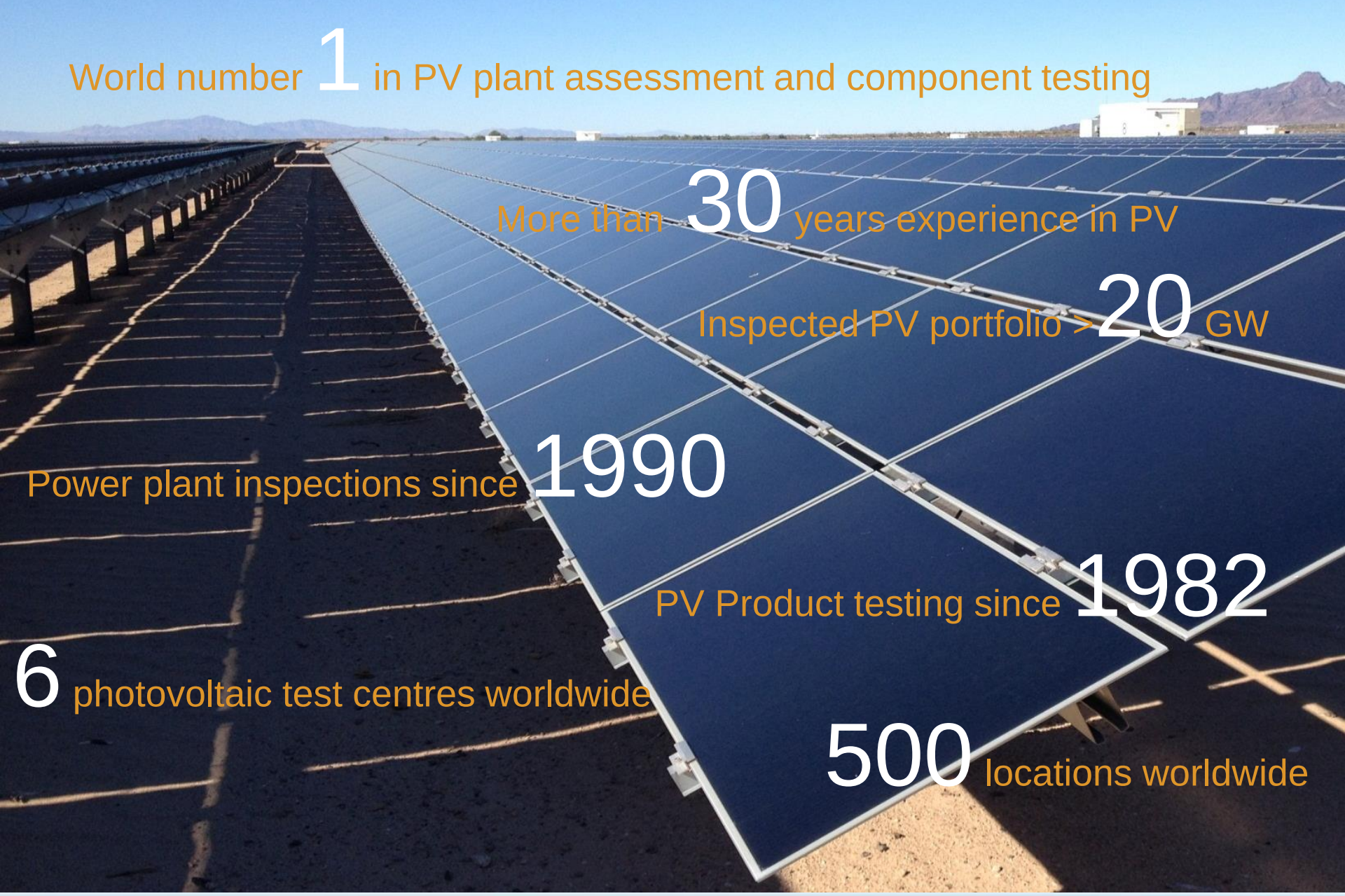

History of TÜV Rheinlands Business Field **Solar Energy**

1979
Joint project between the Indonesian and German government to build and test different solar systems

1985
Development of the solar laboratory in Cologne

1991
Partner in the 1000 PV-roofs program

1994
First start-up of the new solar simulator in Cologne

1996
First type-approval certification of a crystalline PV module

2004
First PV conference in Cologne

2007
Opening of the PV laboratory in China

2007
Grand opening of the PV laboratory in Japan

2009
Opening of the PV laboratory in Taiwan

2008
Joint venture between Arizona State University and TÜV Rheinland

2009
First start-up of the worlds most modern solar simulator

2010
Opening of the sixth PV laboratory in India

2014
200 PV experts worldwide, 60 in Cologne

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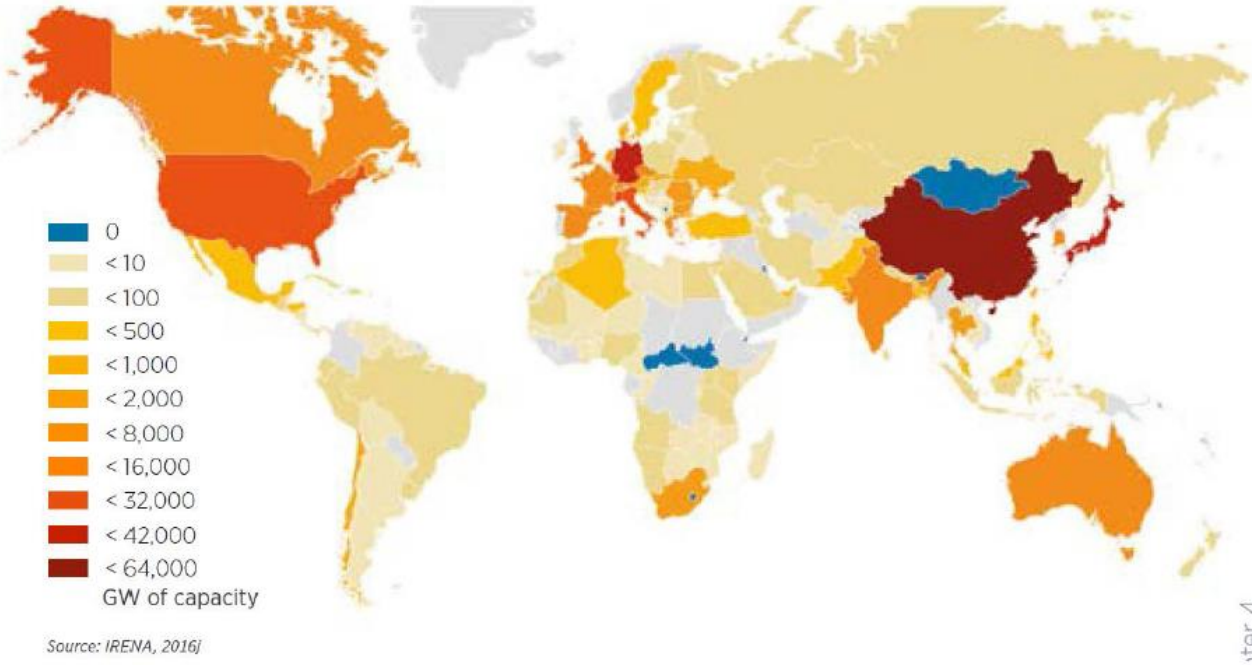
The current state of PV expansion

Global cumulative installed solar PV capacity by country, 2015

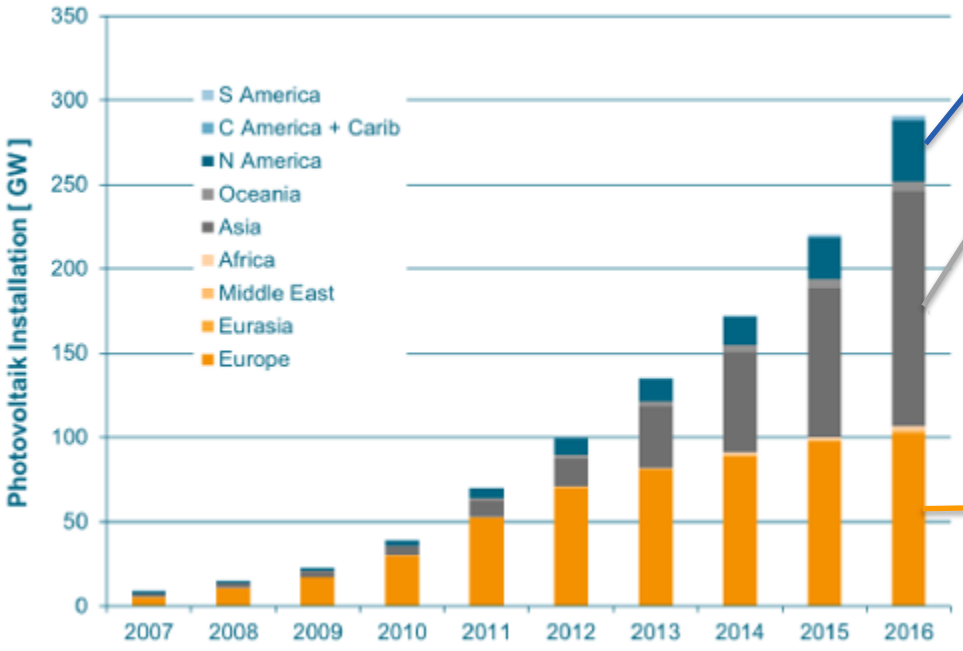


The End of 2016:

China	77 GW
Japan	41 GW
Germany	41 GW
USA	32 GW
Italy	19 GW
UK	11 GW
India	10 GW
France	7 GW
Australia	7 GW
Korea	5 GW
Spain	5 GW
Belgium	3 GW

Source: VDMA

Where is the photovoltaic market growth ?

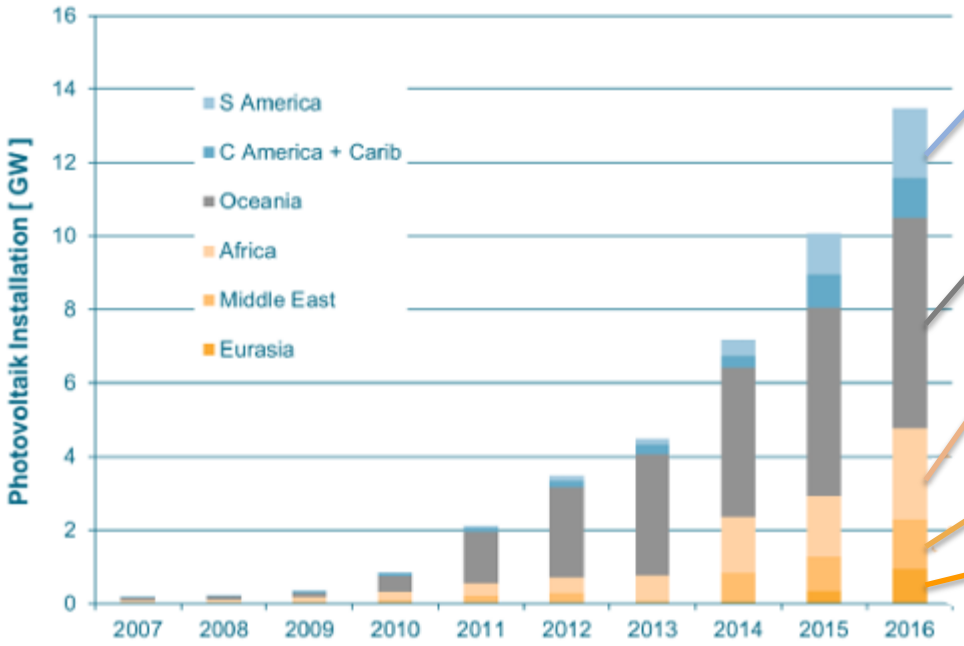


Growth 2015 > 2016

N America:	
USA	11,3 GW
Asia:	
China	34,2 GW
Japan	8,3 GW
India	4,4 GW
Korea	1,4 GW
Thailand	0,7 GW
Philippinen	0,6 GW
Europe:	
UK	2,1 GW
Germany	1,2 GW
Netherland	0,4 GW
Italy	0,4 GW

Source: VDMA

In which emerging countries is the solar PV market growing?



Growth 2015 > 2016

S America:

Chile	755 MW

Oceania:

Australia	595 MW

Africa:

S Africa	505 MW
Algeria	171 MW
Morocco	162 MW

Middle East:

Jordan	262 MW

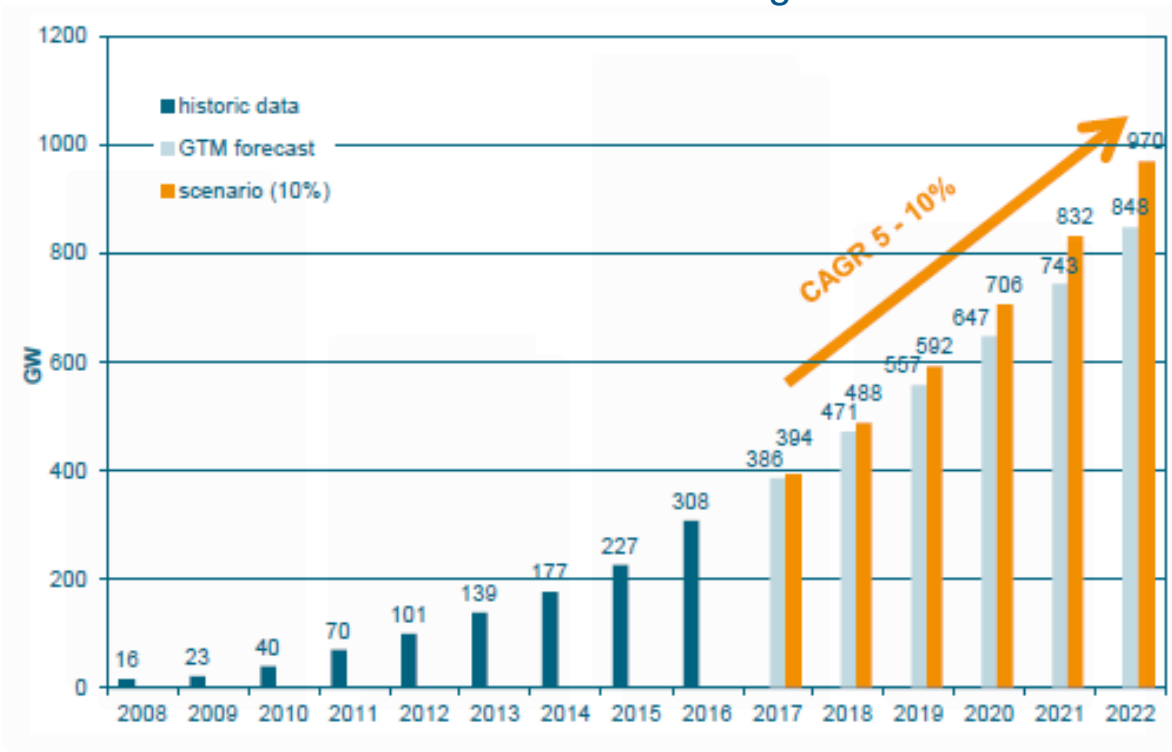
Eurasia:

Turkey	577 MW

Source: VDMA

The key to success: highly efficient Wafer-, cell- and module technology

End-Market installed PV Basis global



78 GW

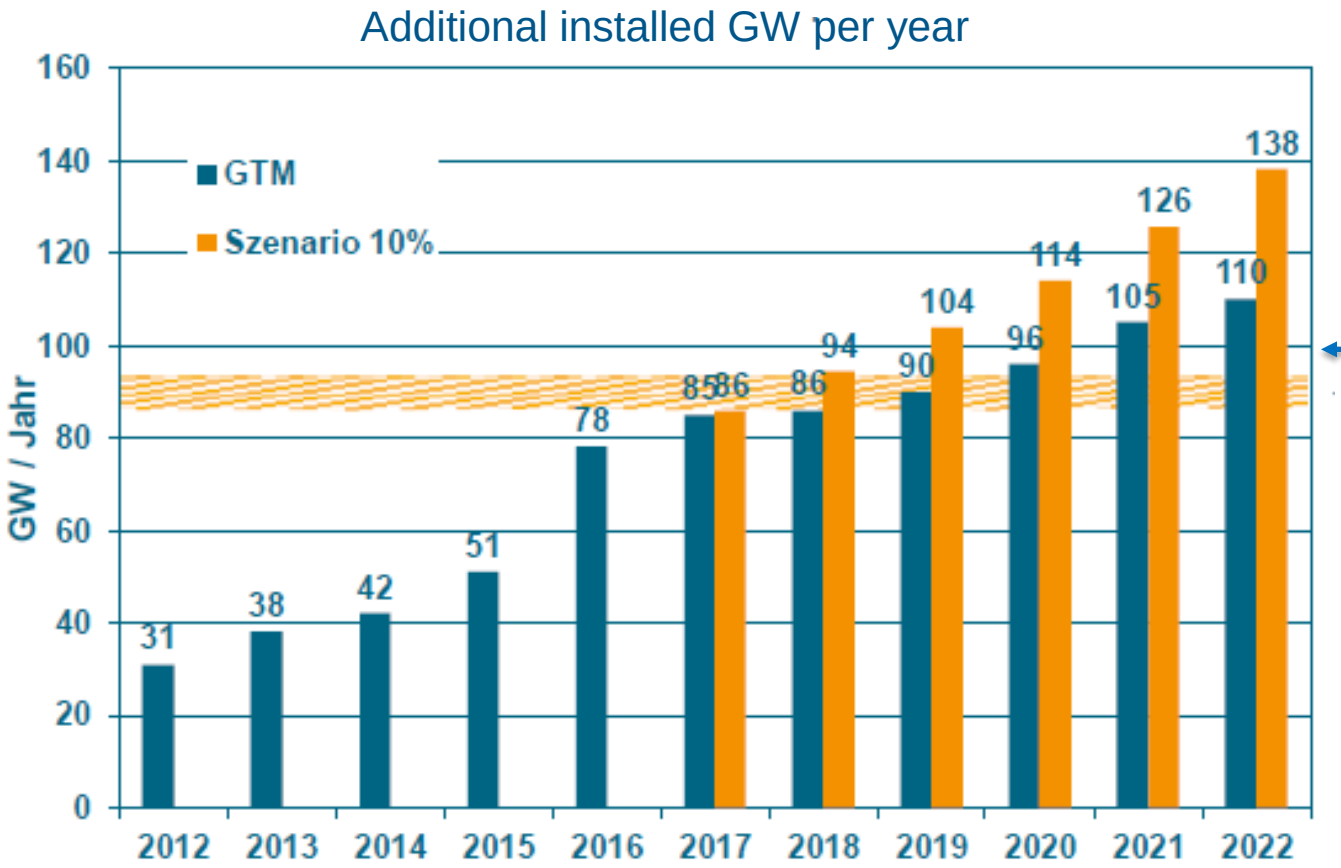
New installed PV-Base in 2016

The total installed PV capacities with 308 GW in 2016

- Until 2022 the estimated installe PV-basis will increase to aroun 800 –1000 GW

Source: VDMA

The annual growth of the PV market



The current production capacity

About 90 GW end of 2016

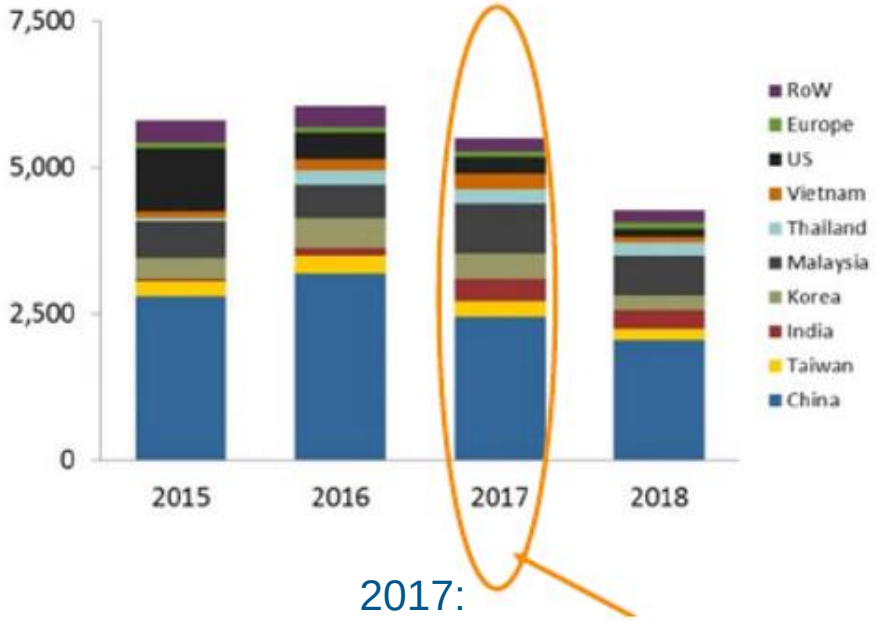
Untill 2022 necessary production extension

5 – 15 GW per year

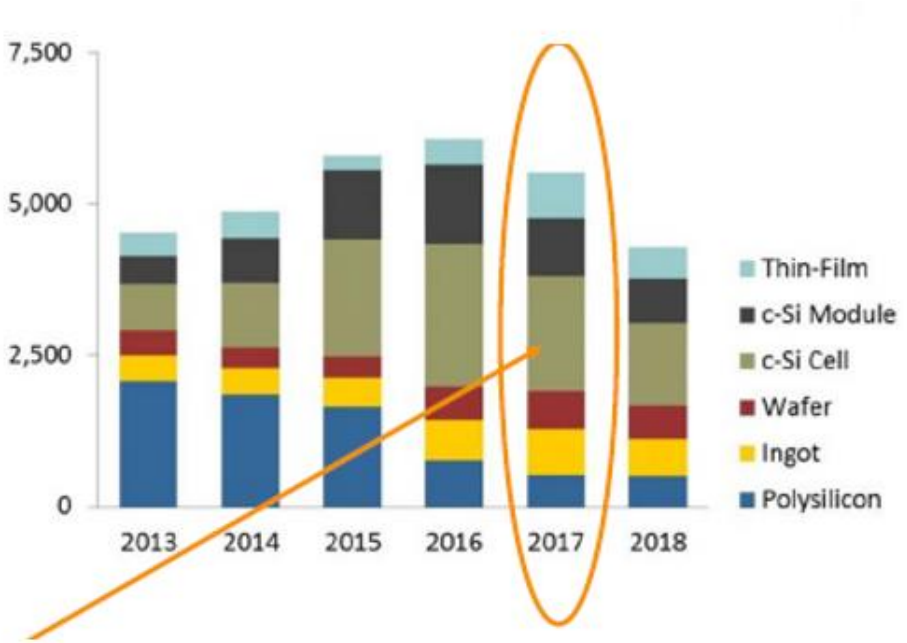
Source: VDMA

What are the planned investments for PV manufacturing and in which part of the value chain?

Total PV Capex by Spending Location (USD$M)



Total PV Capex by Value-Chain Segment (USD$M)

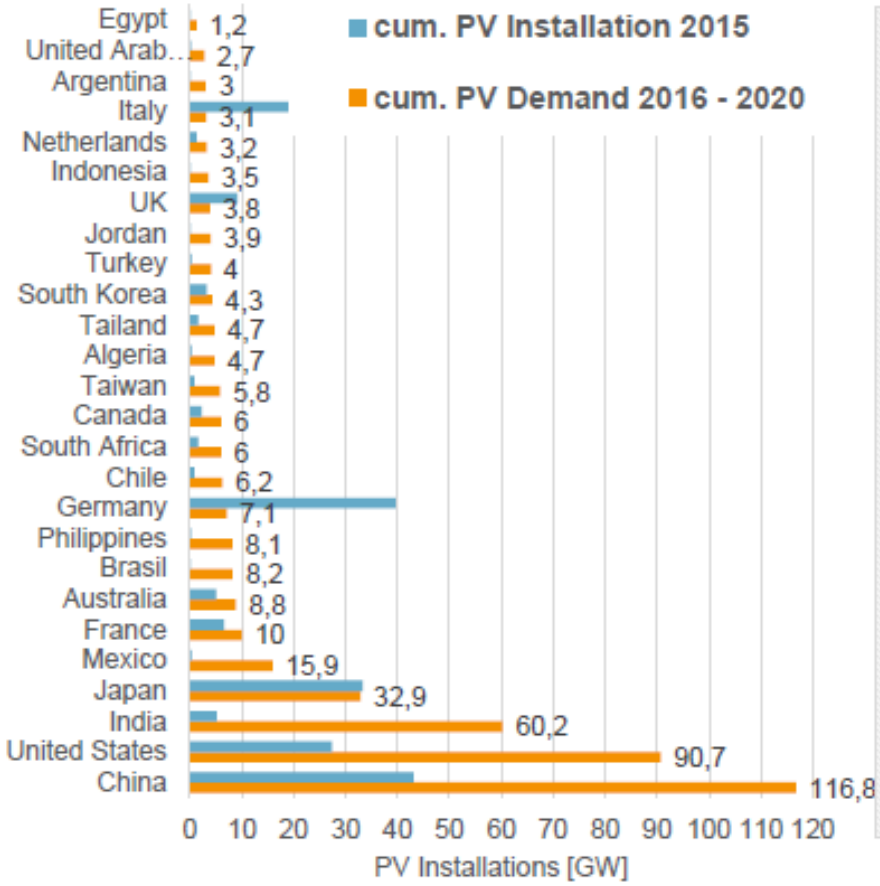


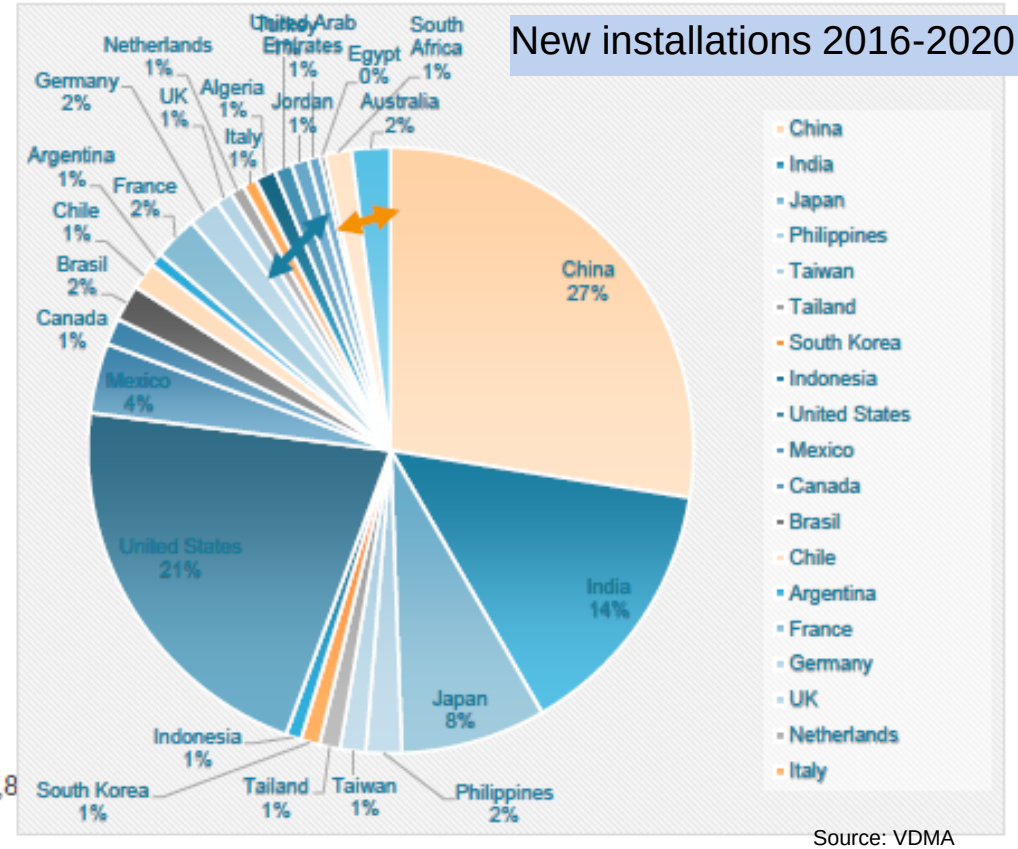
2017:
Planned installations in: China, Malaysia, Korea, India,…
Biggest percentage in Cell

Source: PVTech
https://www.pv-tech.org/editors-blog/global-solar-pv-manufacturing-capacity-expansion-plans-rebound-in-q1
http://www.pv-tech.org/editors-blog/capital-expenditure-in-the-pv-industry-for-2017-and-2018,PVManufacturing& TechnologyQuarterlyreport.Jan 2017

Cumulative PV installations 2015 vs. Demand 2016-2020

Shift also to the new market





Source: VDMA

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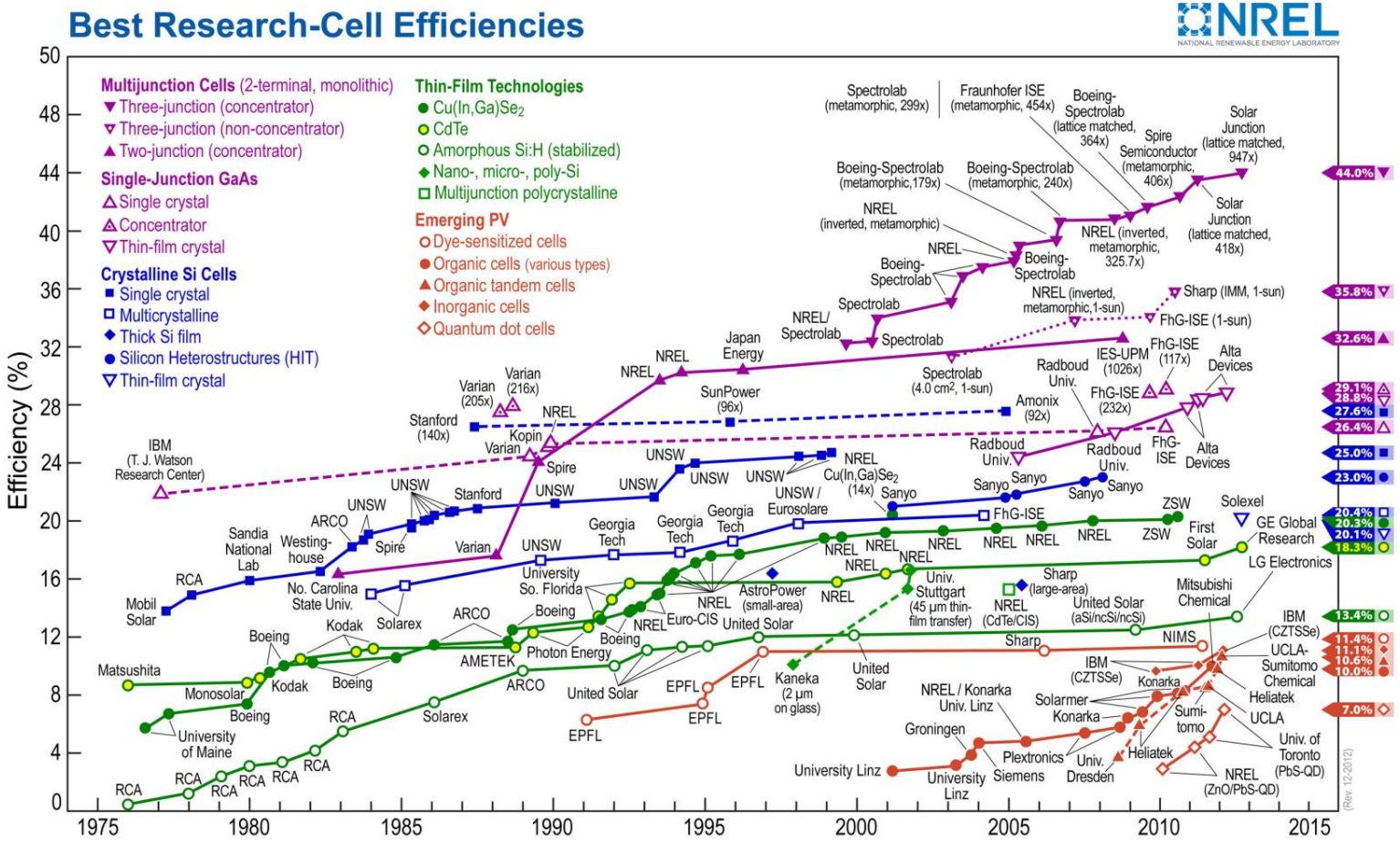
PV Module
Technologies, Efficiencies

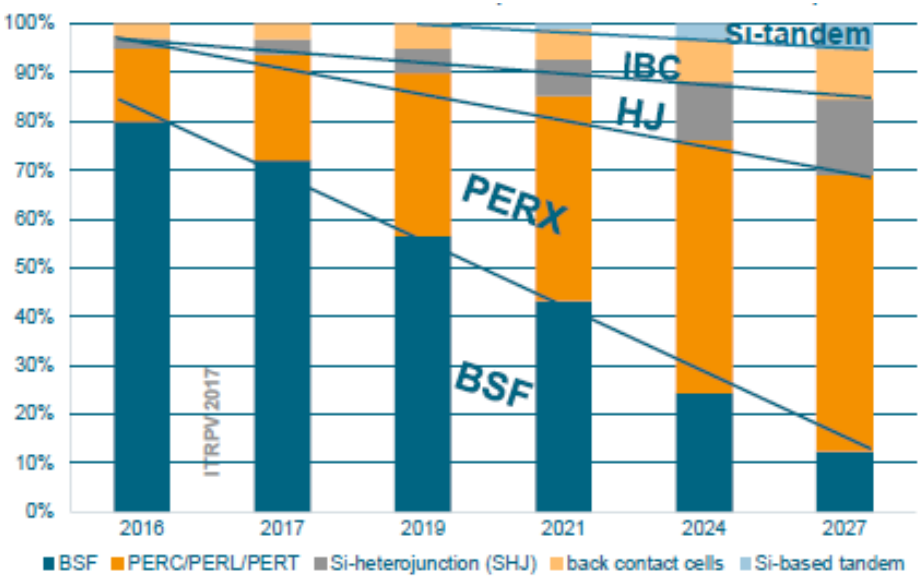
- Cell efficiency records / thin-film efficiency records (laboratory results) [1]



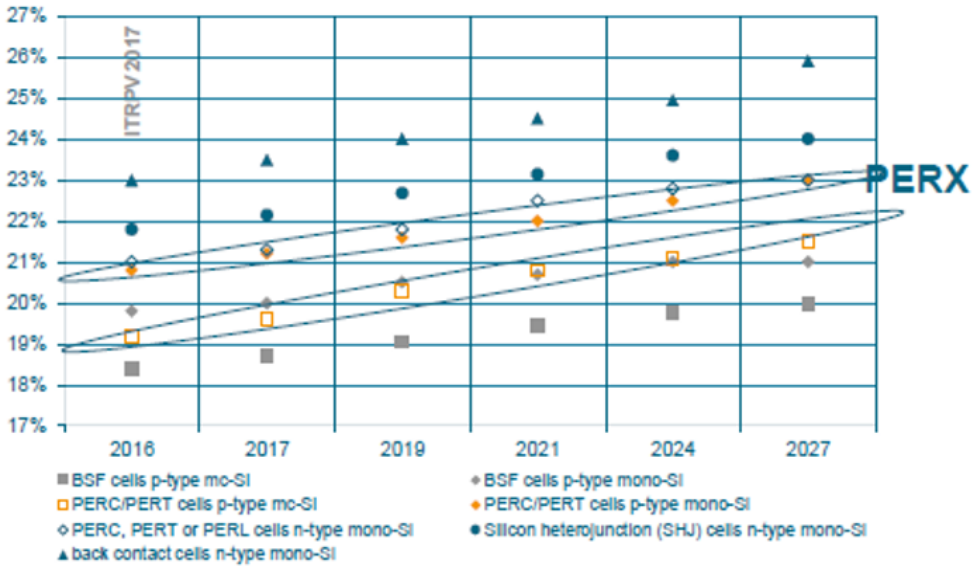
References: [1]: NREL

Cell Production: technologies / efficiency trends

Trend: market share of cell concepts 2016:
PERX ≈15% (in line w/ IHS Markit)



Trend: stabilized cell efficiencies;
➔ p-type PERX outperforms



PERX is gaining market share (20% 2017)

- **Back Surface Field** share is shrinking
- Back contact + HJ: slow increase in share
- Si tandem: under development

- stabilized >21% p-type mono PERX is in production

Source: VDMA | International Technology Roadmap PV, ITRPV 2017

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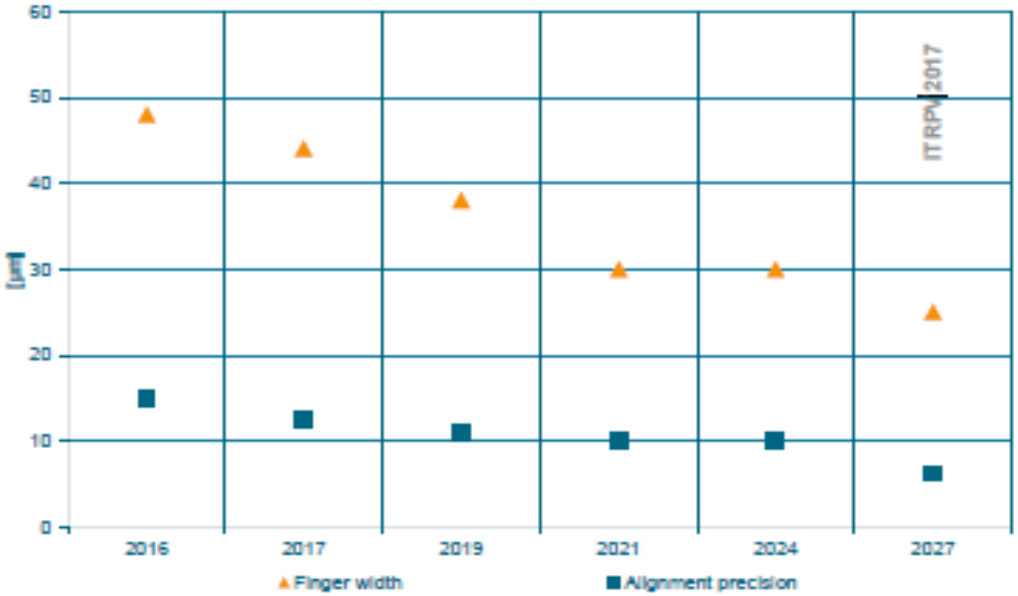
Cell processes: finger width / number of bus bars / bifacial

Trend: Finger width / alignment precision



Front side grid finger width reduction continues
→Ag reduction

→4BB are mainstream –3 BB will disappear

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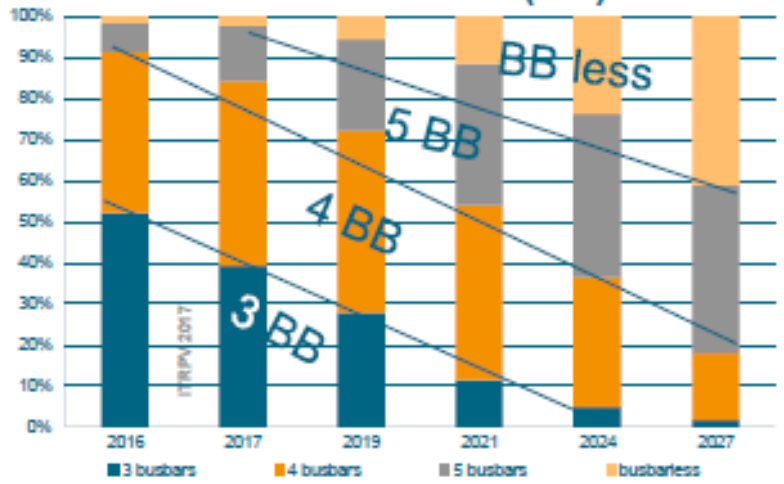
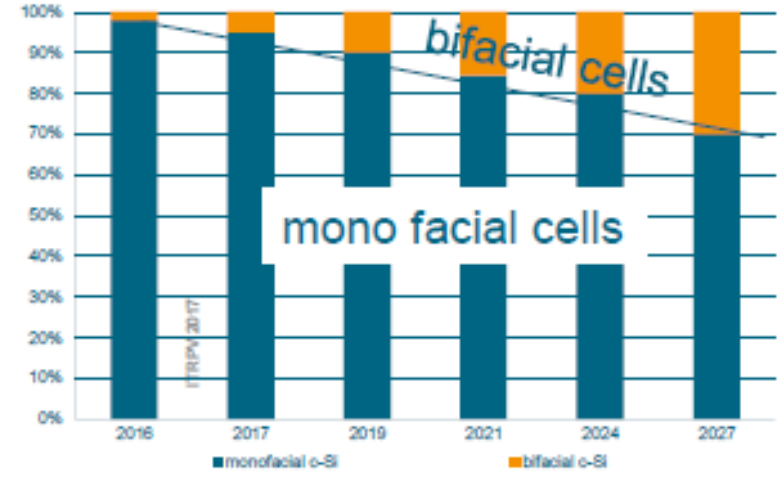
→Selective emitters + Bifacial cells require good alignment
→Bifacial cells will increase market share

Trend: number of bus bars (BB)



Trend: market share of bifacial cells



Source: VDMA | International Technology Roadmap PV, ITRPV 2017

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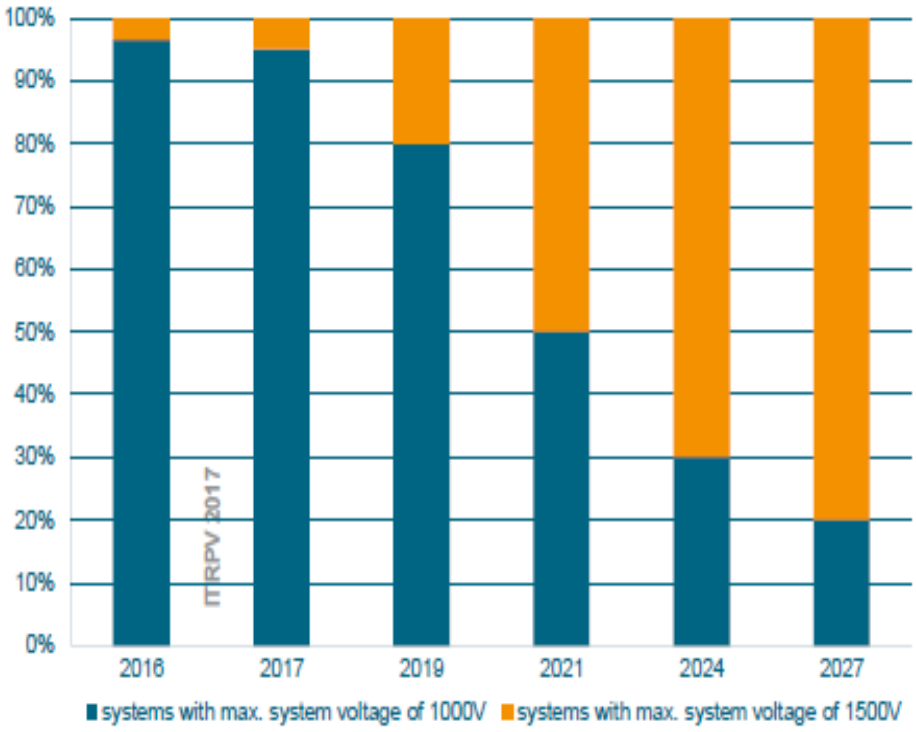
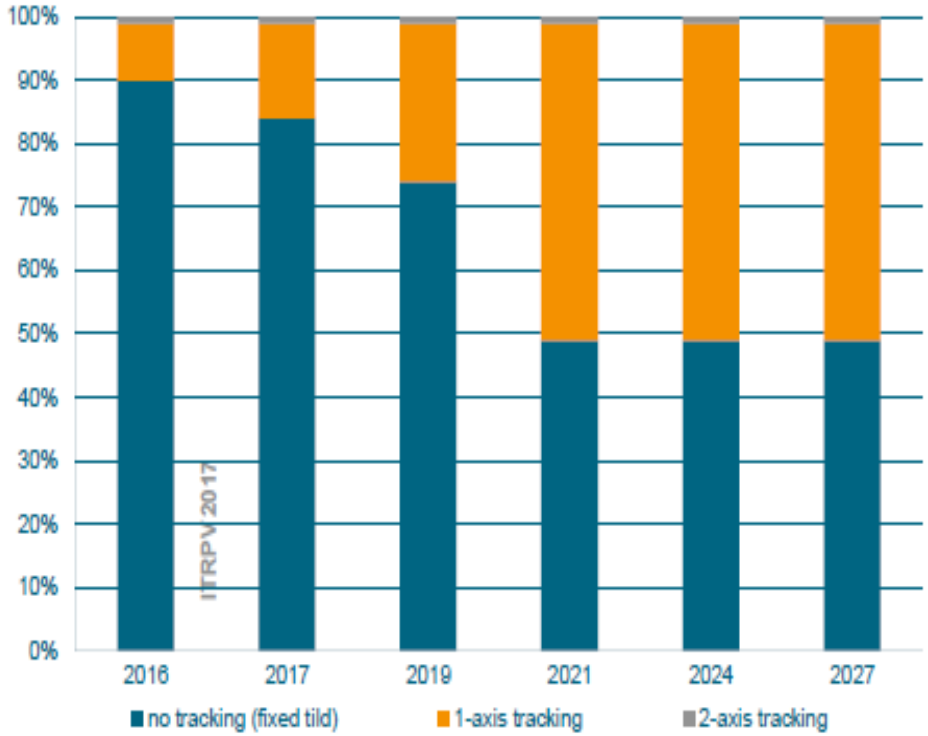
System Components: System voltage / tracking

Trend: system voltage



1500V are the future

Trend: tracker systems in power plant applications

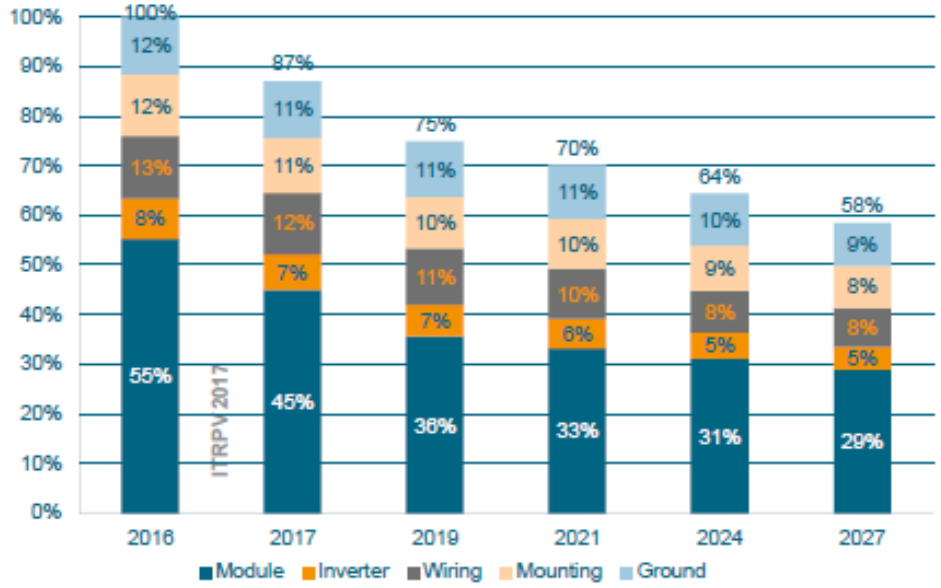


1-axis trackers will gain market share

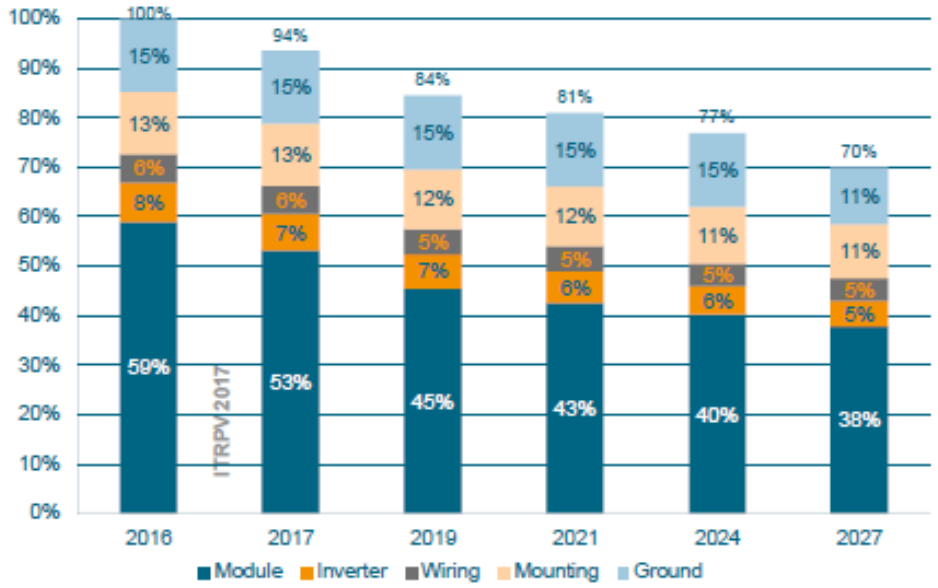
Source: VDMA | International Technology Roadmap PV, ITRPV 2017

Balance of system (BOS) for power plants

Trend: BOS in Europe and US



Trend: BOS in Asia



Significant cost reduction still foreseen

Costs in Asia are assumed to be significantly lower

Source: VDMA | International Technology Roadmap PV, ITRPV 2017

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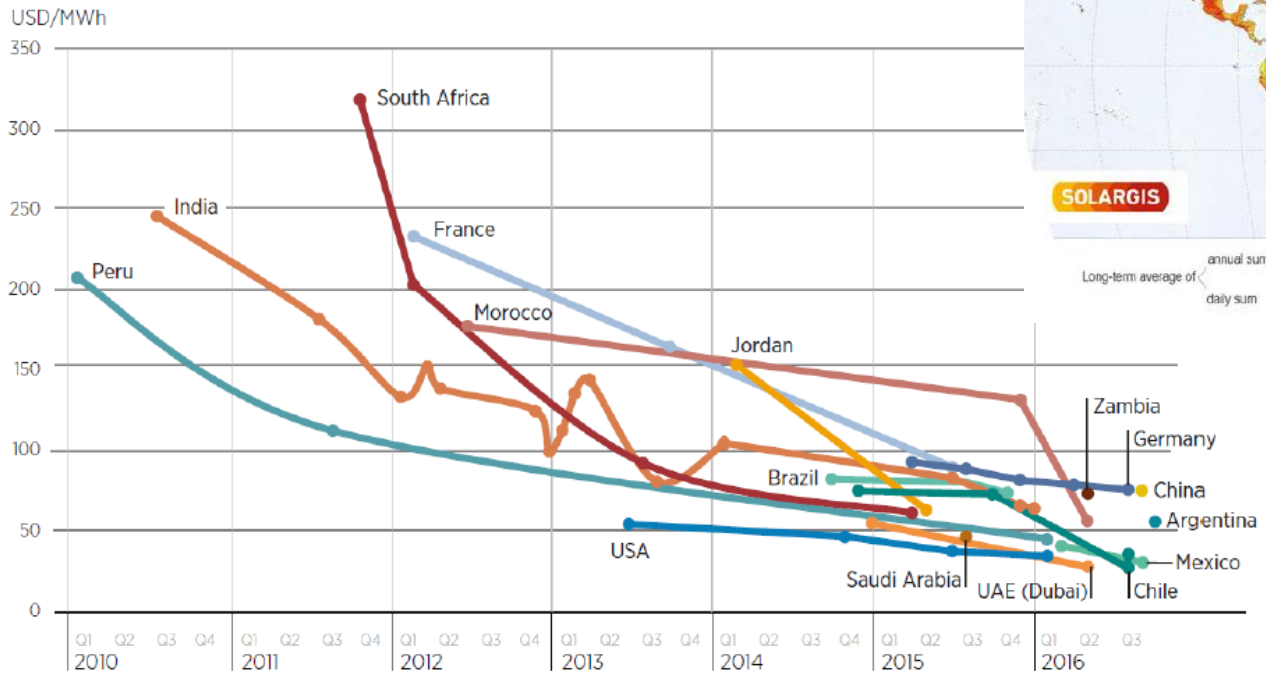
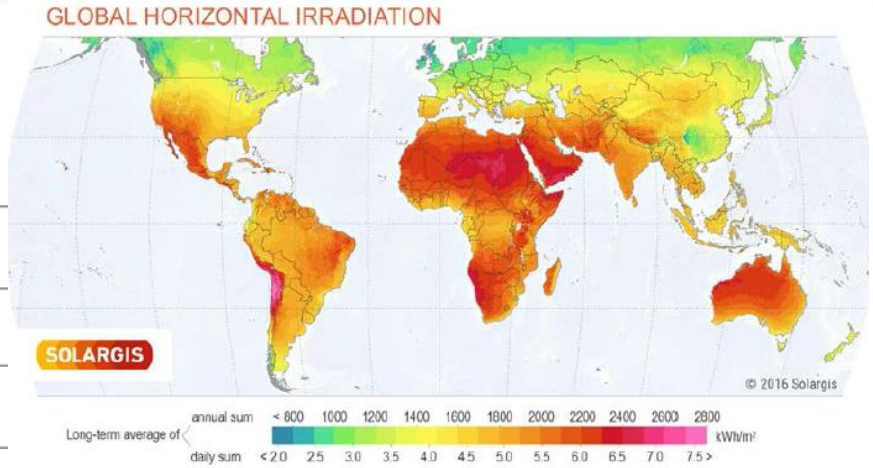
Evolution of the PV bid prices utility-scale





Bid pricing: 2,49 $cent/kWh (UEA) - 6,9 €cent/kWh (DE)

Factor 2,5 in solar radiation

Source: VDMA

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More for less money: The renewable energy in 2016 was cheaper than ever before

UN-Environment, Bloomberg New Energy Finance and the Frankfurt School-UNEP Collaborating Centre :

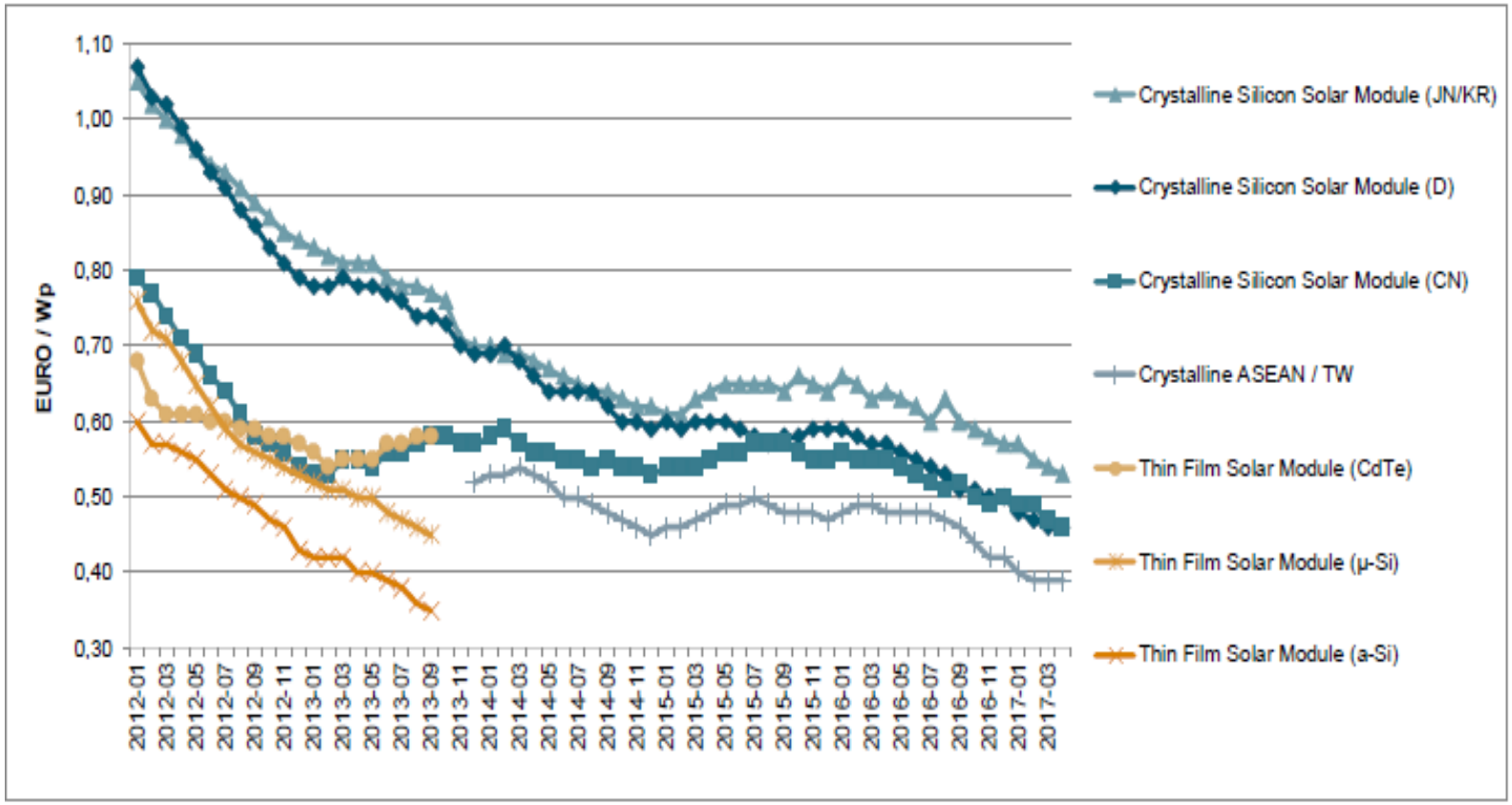
Investment 34% lower (Comparison of 2015 and 2016)

But the capacity has increased by 50 % (50GW > 75GW)

The new investment in solar totaled $113.7 billion, is enough for adding new 75 GW capacities.

Source: VDMA

PV Cell Weekly Spot Price
Crystalline-Si–Thin Film Modules



Module price:

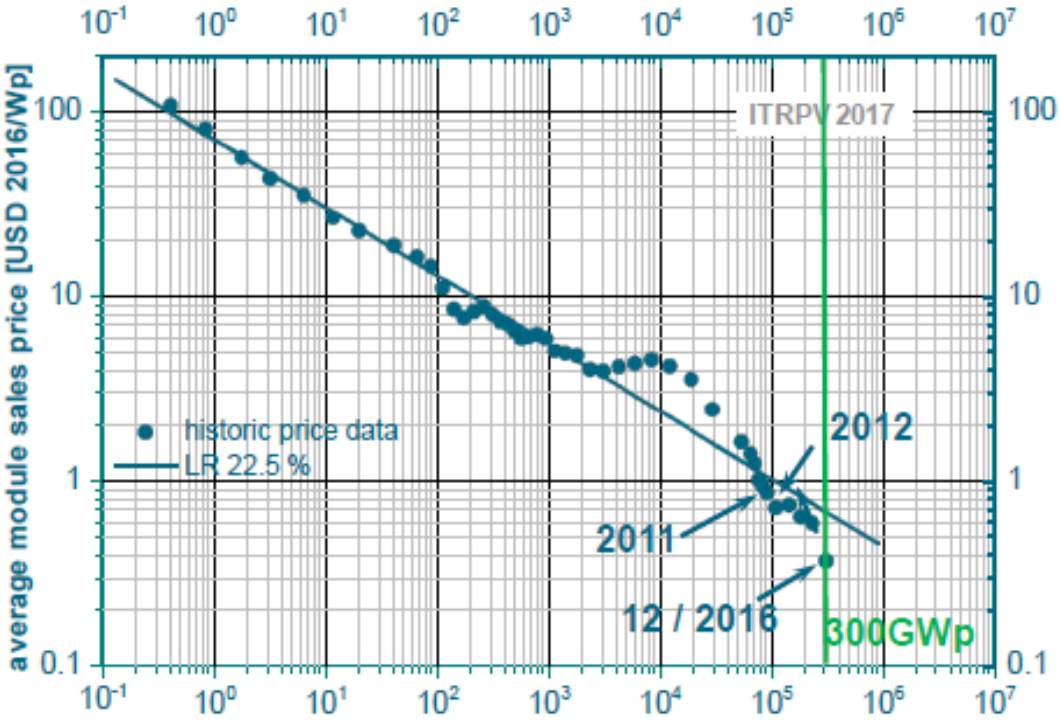
JP / KR the highest

D / CN same price

Asean / TW the cheapest

Source: pvinsights

PV learning Curve



Shipments / avg. price at years end:

2016: 75 GWp / 0,37 US$/Wp

o/a shipment: ≈ 308 GWp
o/a installation: ≈ 300 GWp

300 GWp landmark was passed!

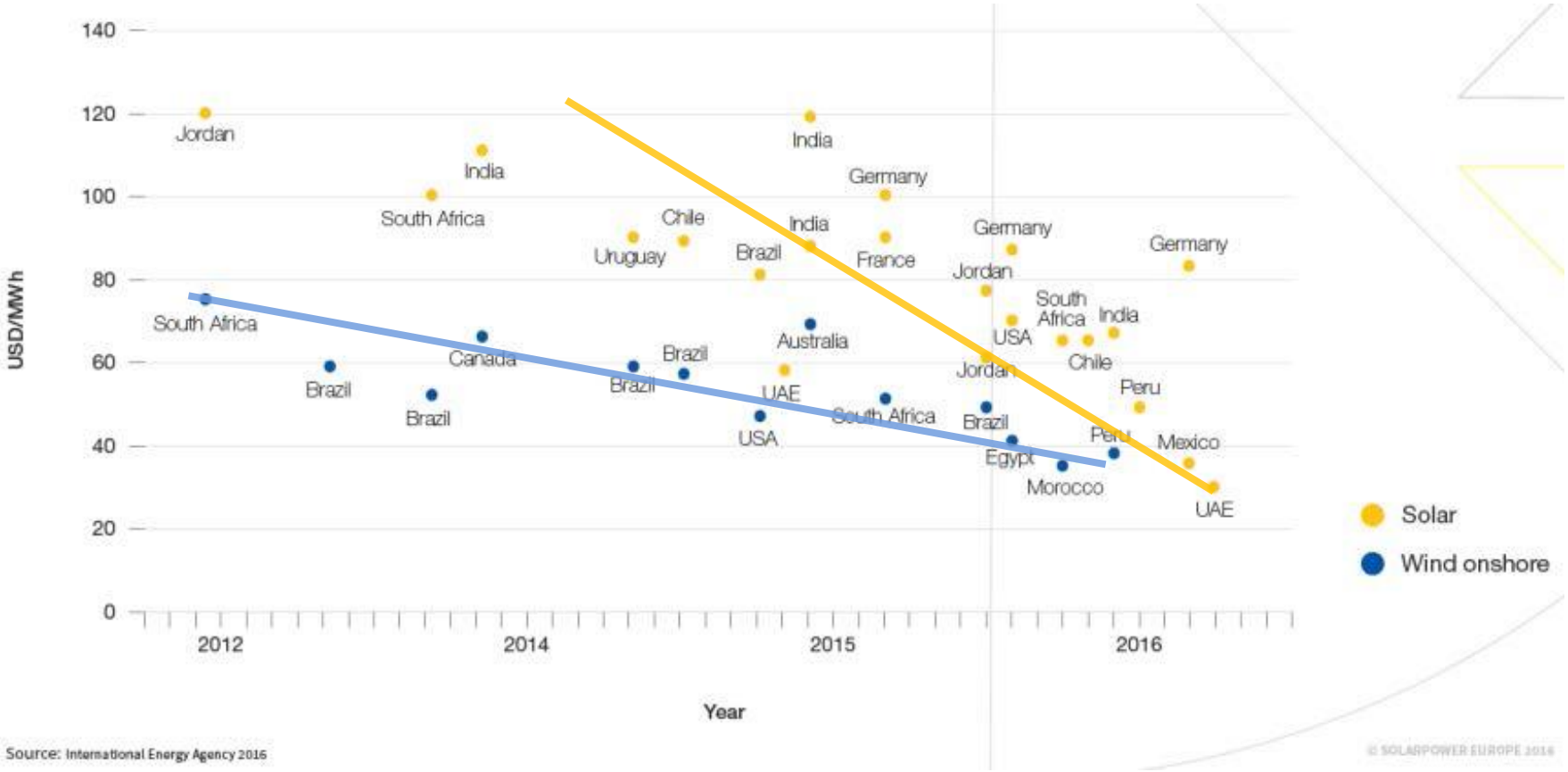
LR 21,5% (1976…2016)

Dramatic price drop due to market situation

- **Comparable to 2011/2012, but faster**

Source: VDMA | ITRPV 2017

Comparison of price degression PV - Wind



A fast PV learning curve

Source: VDMA

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