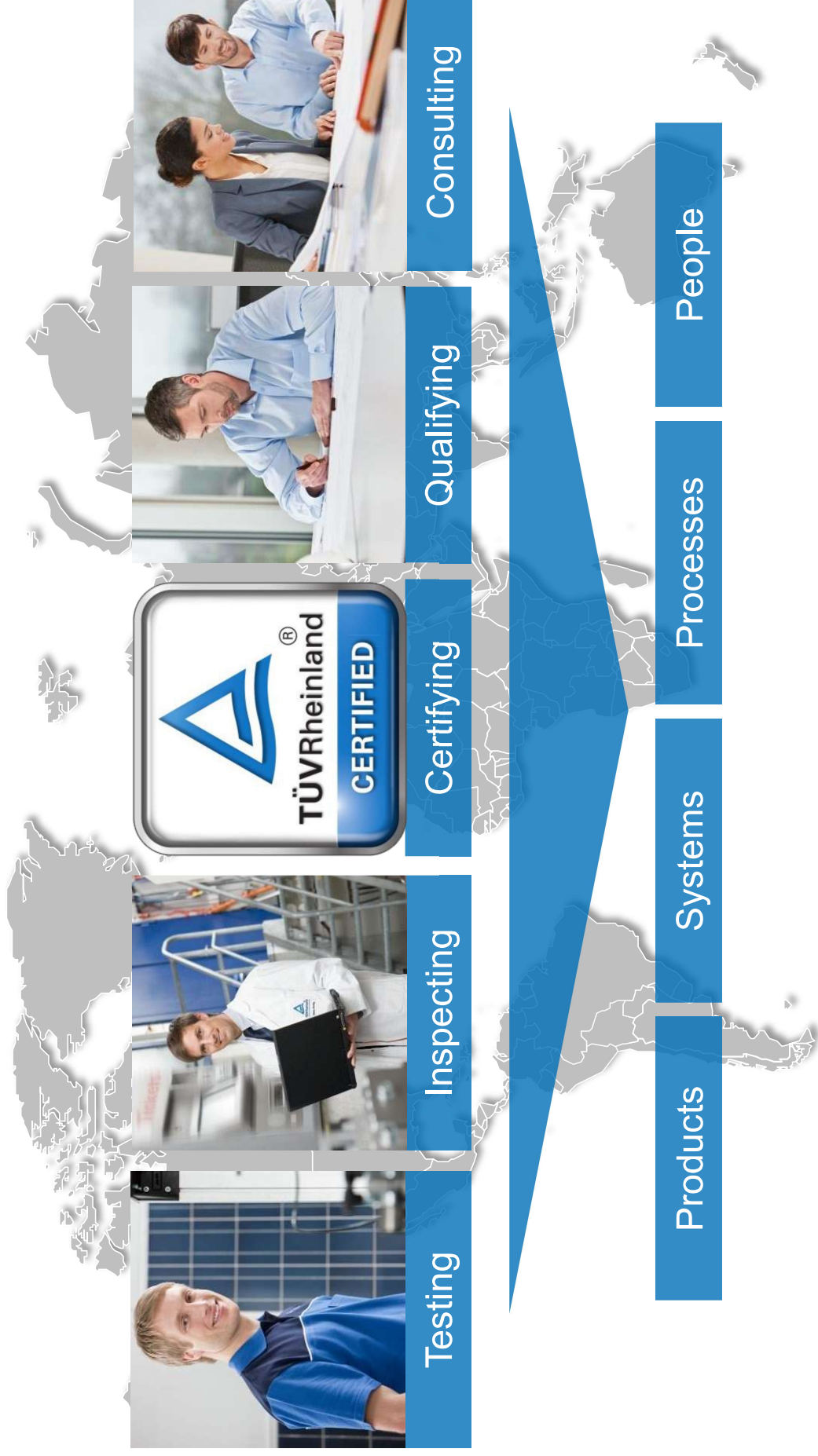


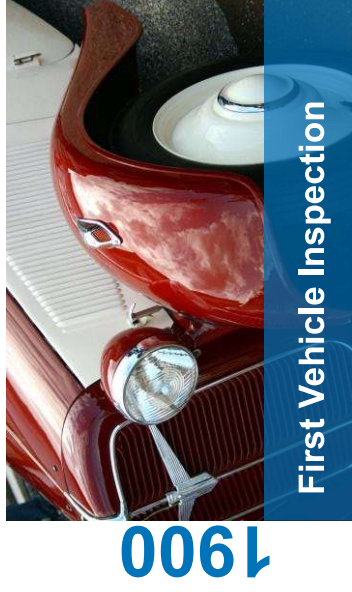
Introduction, Overview of PV Market and Technology

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Short Introduction. Our Services.



TÜV Rheinland – History.



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

Business Streams

Industry



Systems



Products



Academy & Life Care



Mobility



ICT & Business Solutions



TÜV Rheinland 2015 – Facts & Figures.

EBIT in Mil. EUROS
5.4% Margin

101.4



HEADQUARTERS COLOGNE

1872



Founded in Germany

LOCATIONS/COUNTRIES

500



66



LABORATORIES

200



SALES IN BIL. EUROS

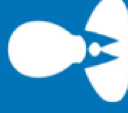
Growth 9%



1.88

EMPLOYEES

19,600



Solar Technology



World number **1** in PV plant assessment and component testing

More than **30** years experience in PV

Inspected PV portfolio > **20** GW

1990

Power plant inspections since

1982

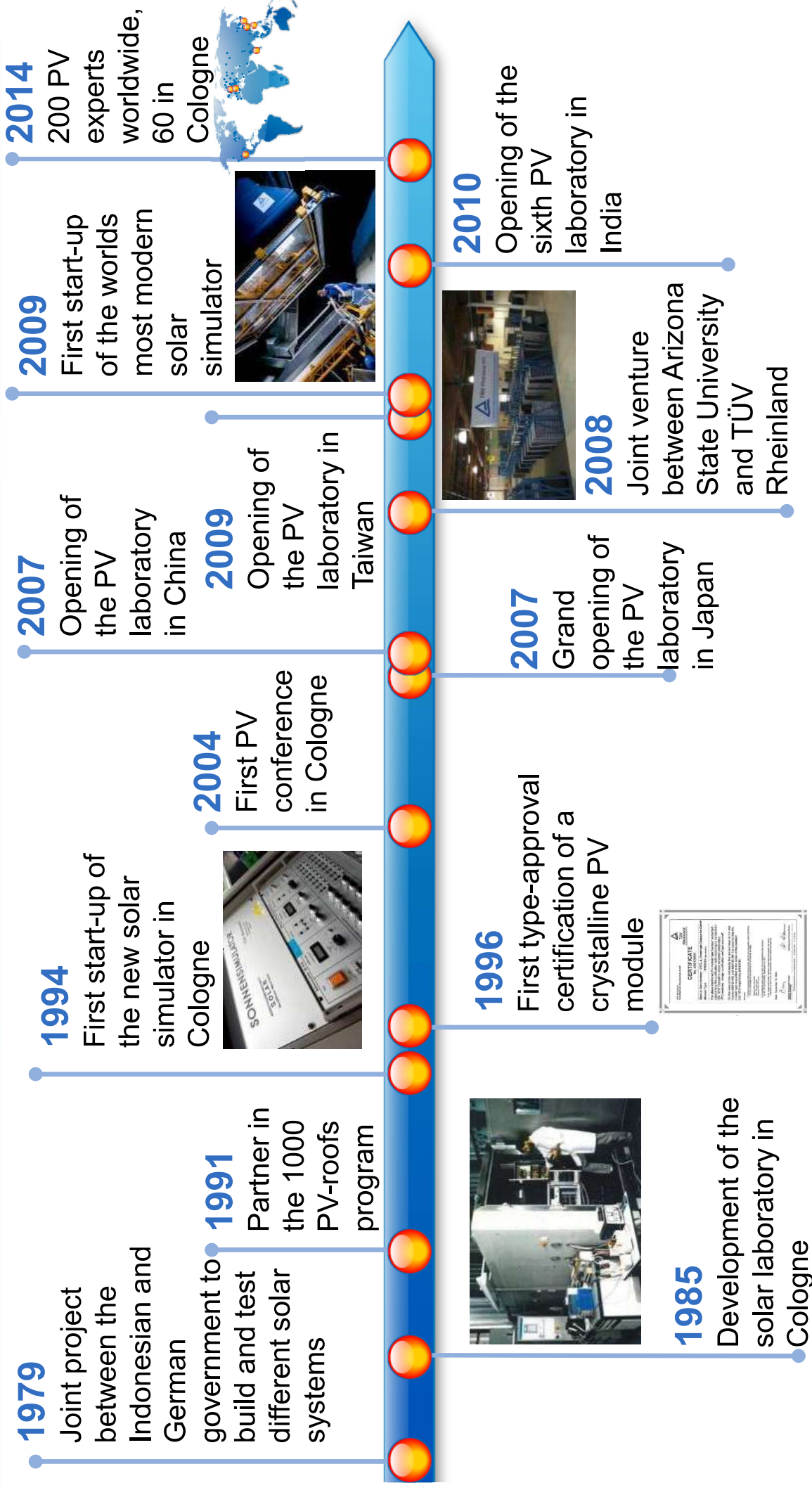
PV Product testing since

6 photovoltaic test centres worldwide

500

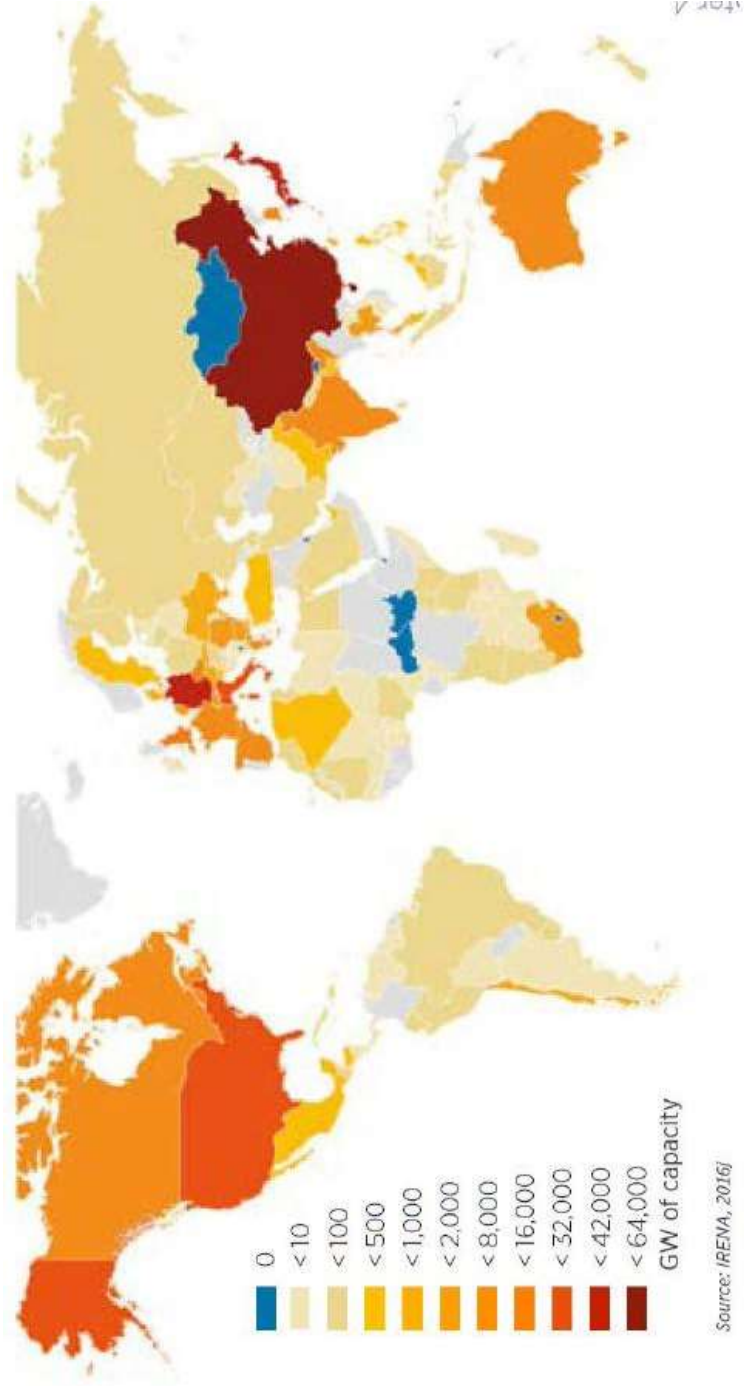
locations worldwide

History of TÜV Rheinland's Business Field Solar Energy



The current state of PV expansion

Global cumulative installed solar PV capacity by country, 2015

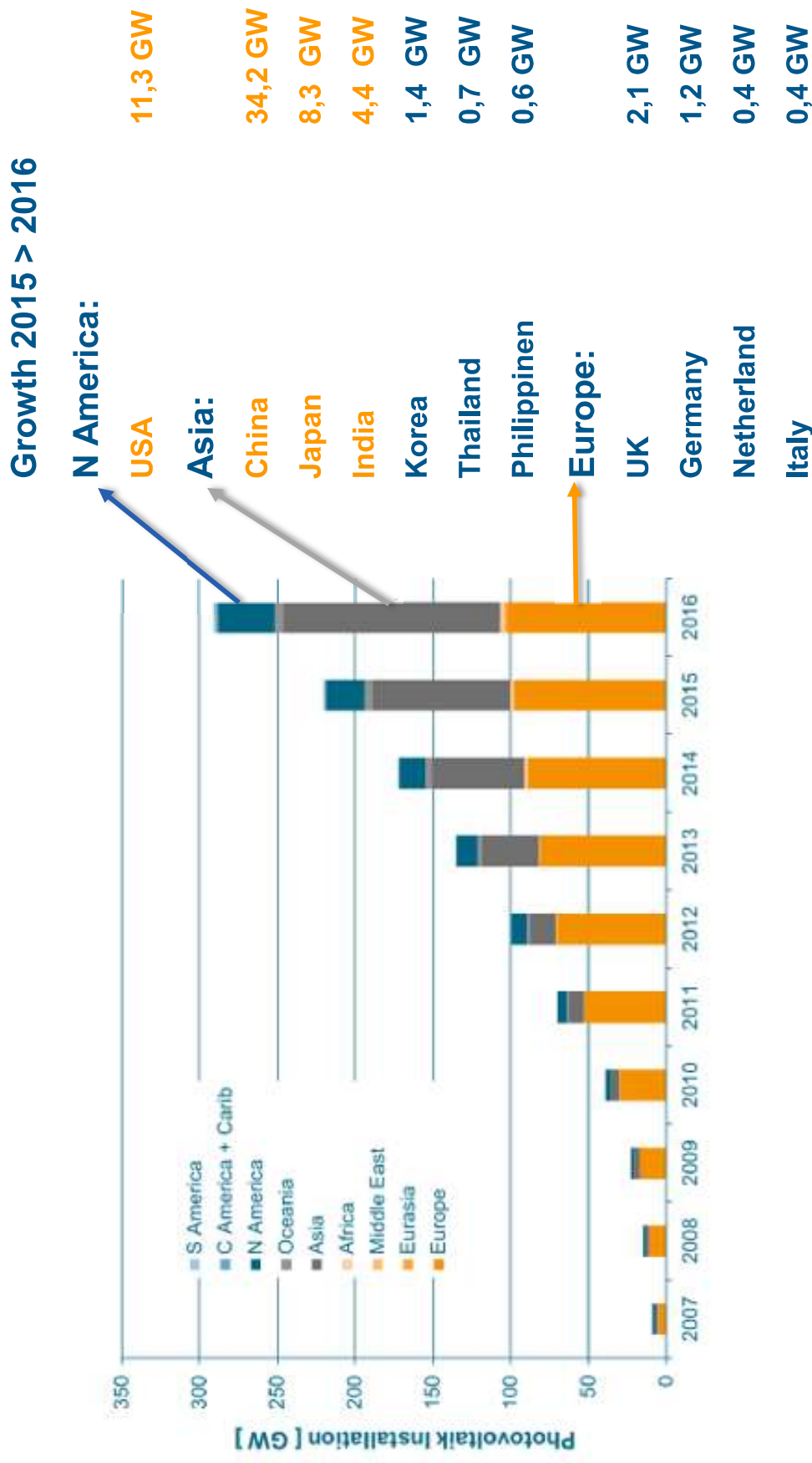


The End of 2016:

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

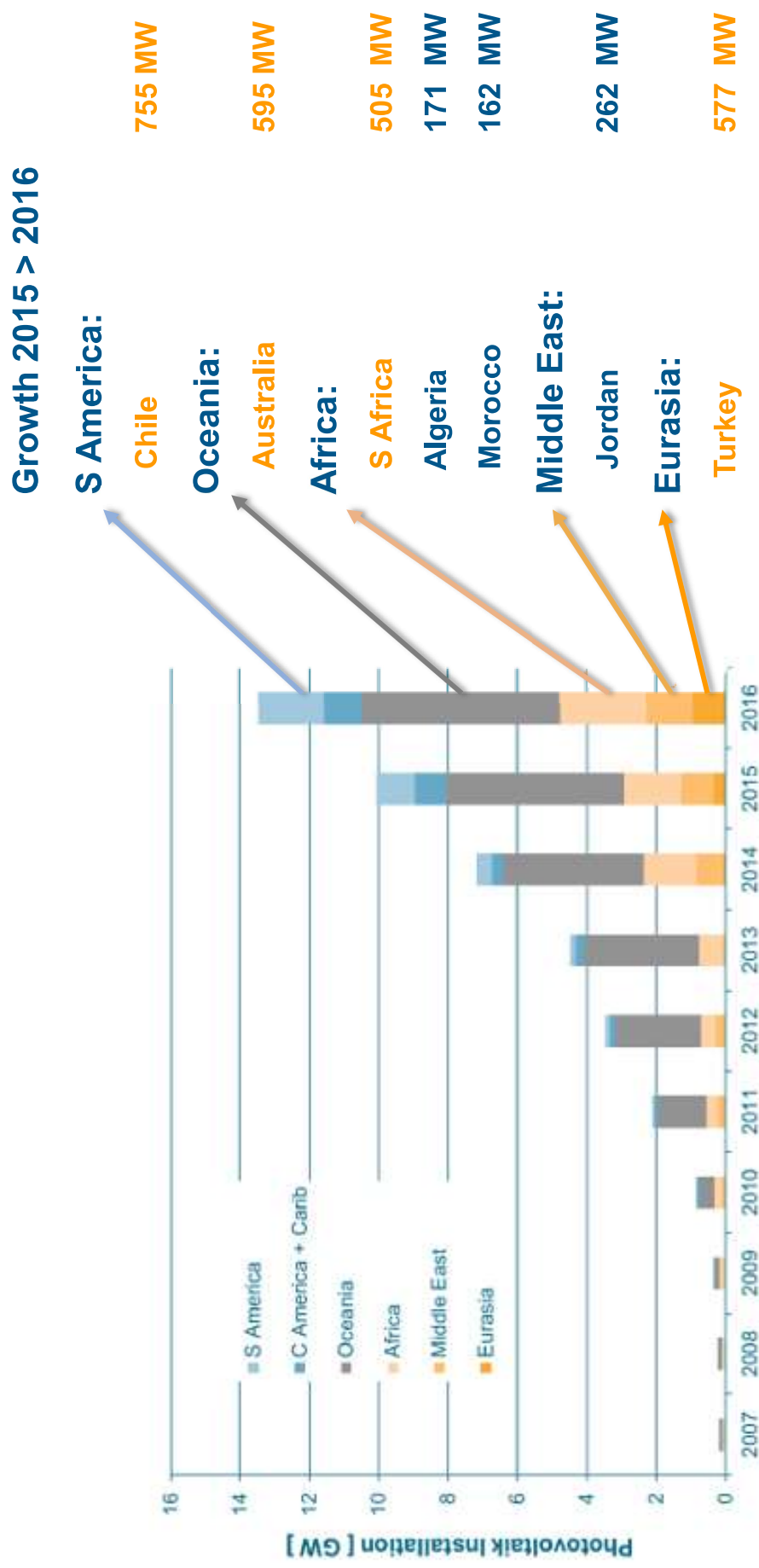
Source: VDMA

Where is the photovoltaic market growth ?



Source: VDMA

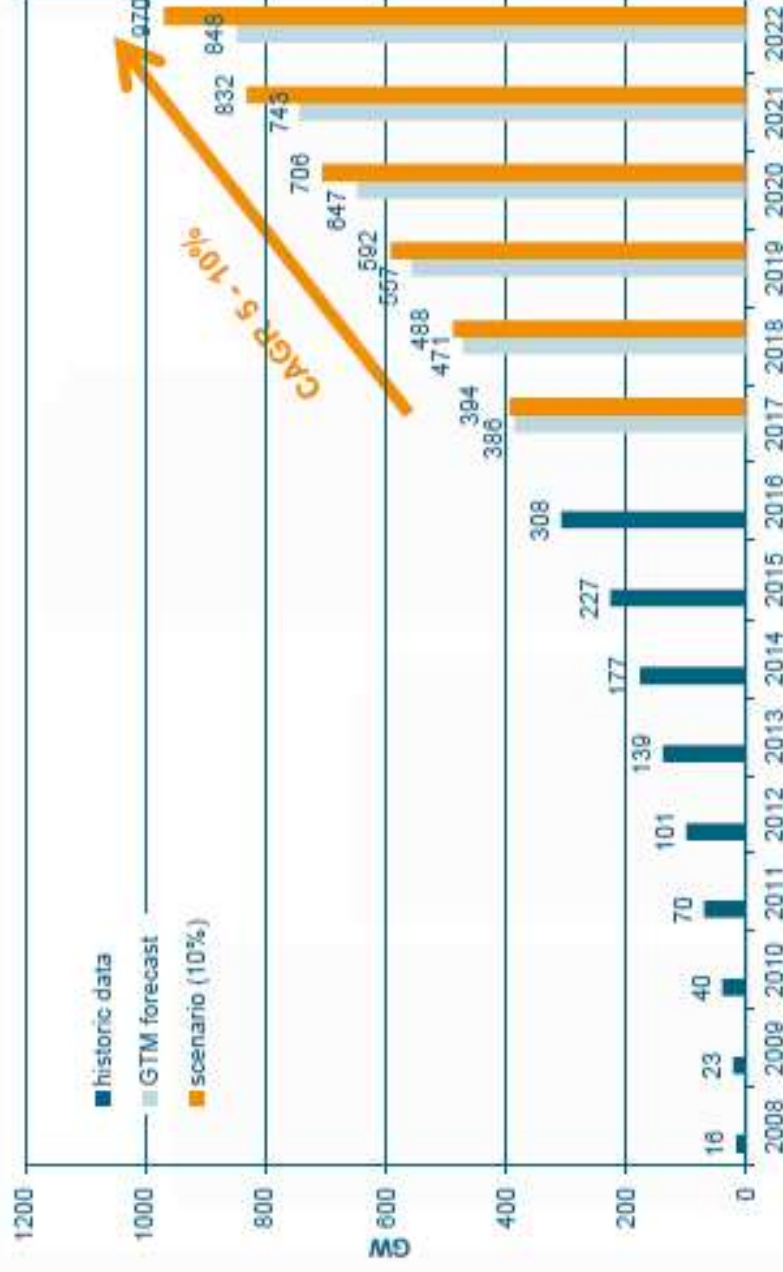
In which emerging countries is the solar PV market growing?



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**

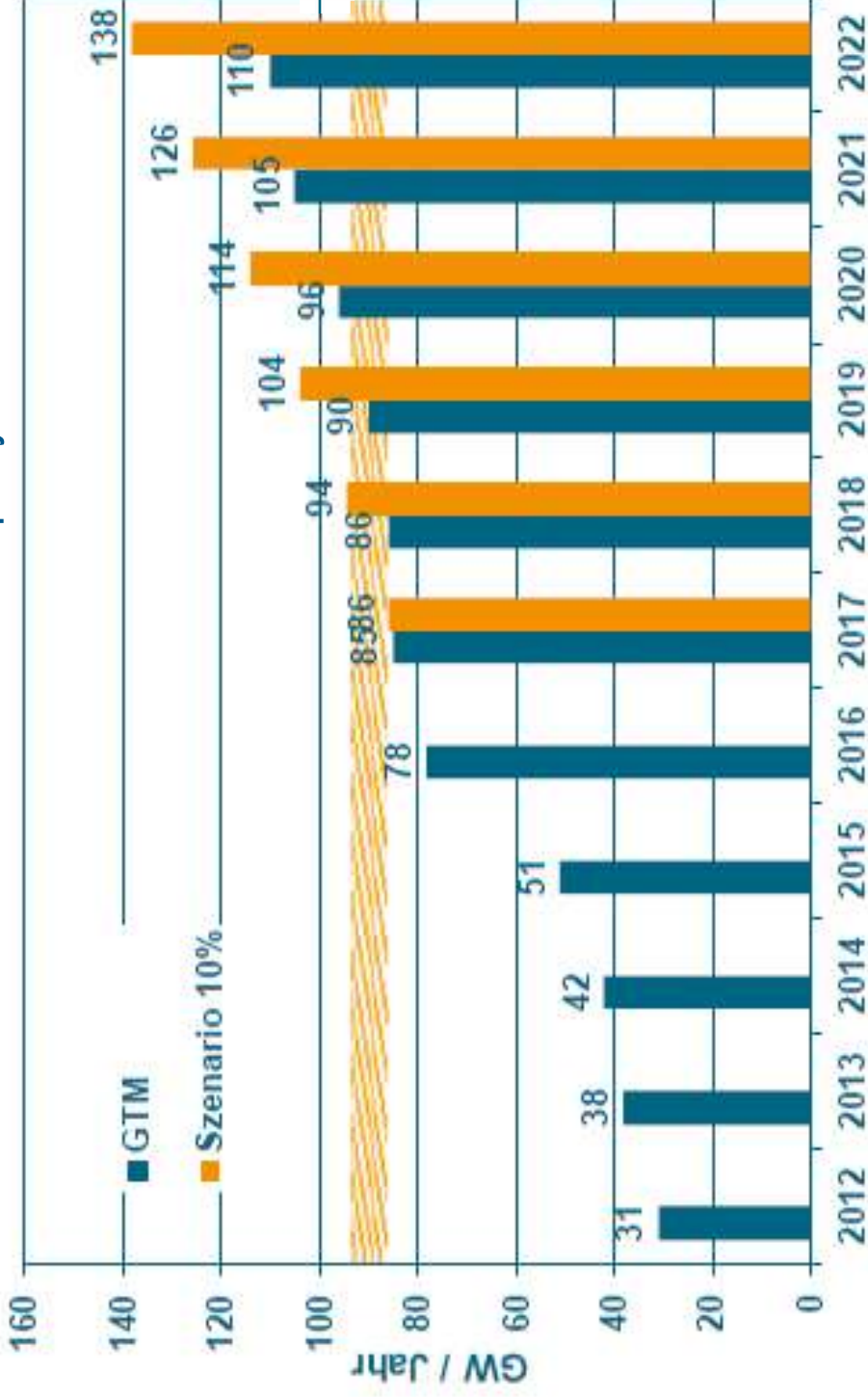
**The total installed PV
capacities with 308 GW
in 2016**

- Until 2022 the estimated installed PV-basis will increase to around 800 –1000 GW

Source: VDMA

The annual growth of the PV market

Additional installed GW per year



The current
production capacity

About 90 GW end
of 2016

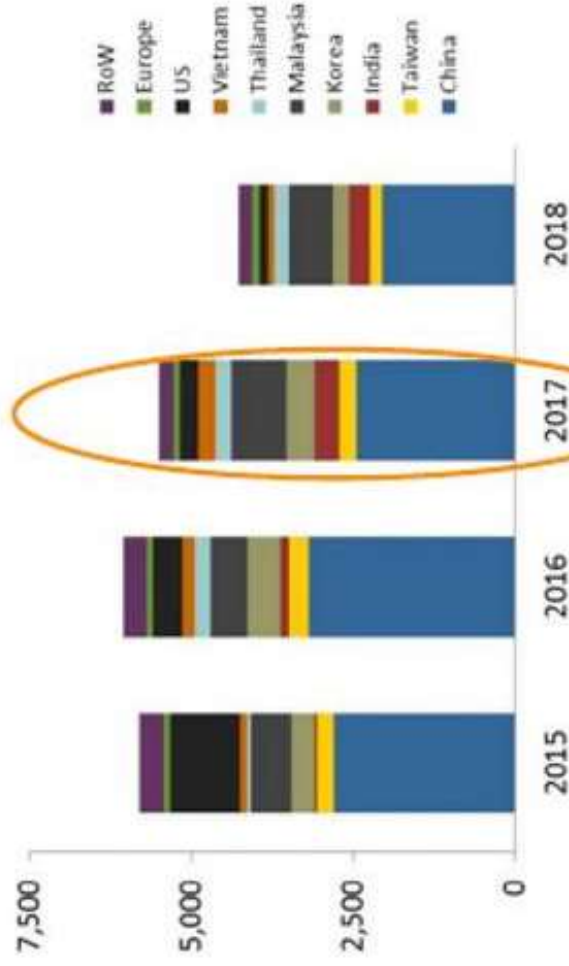
Untill 2022 necessary
production extension

5 – 15 GW per year

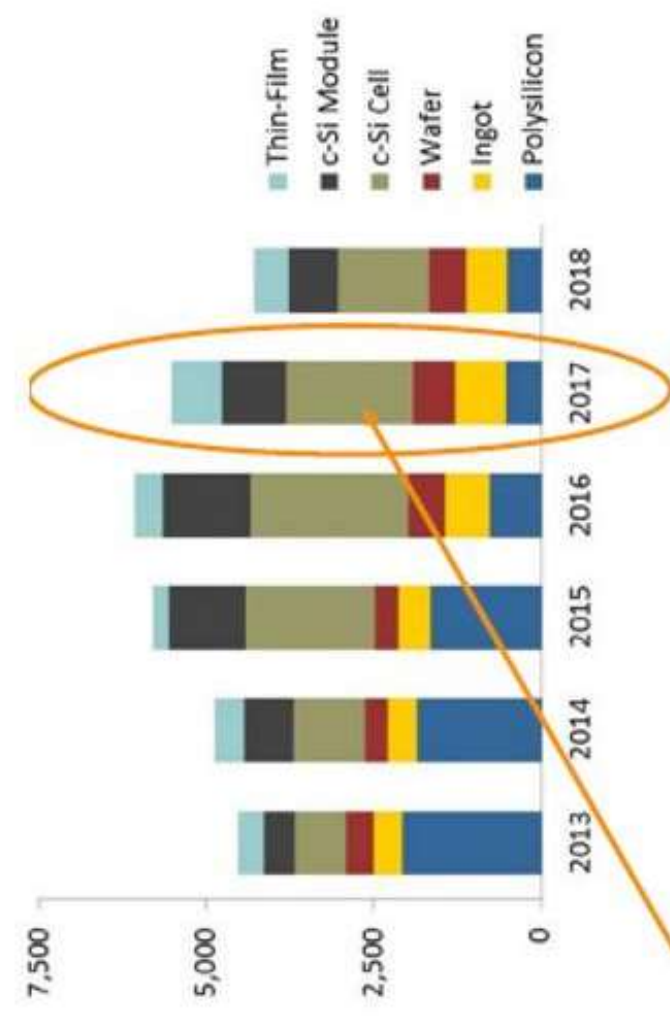
Source: VDMA

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

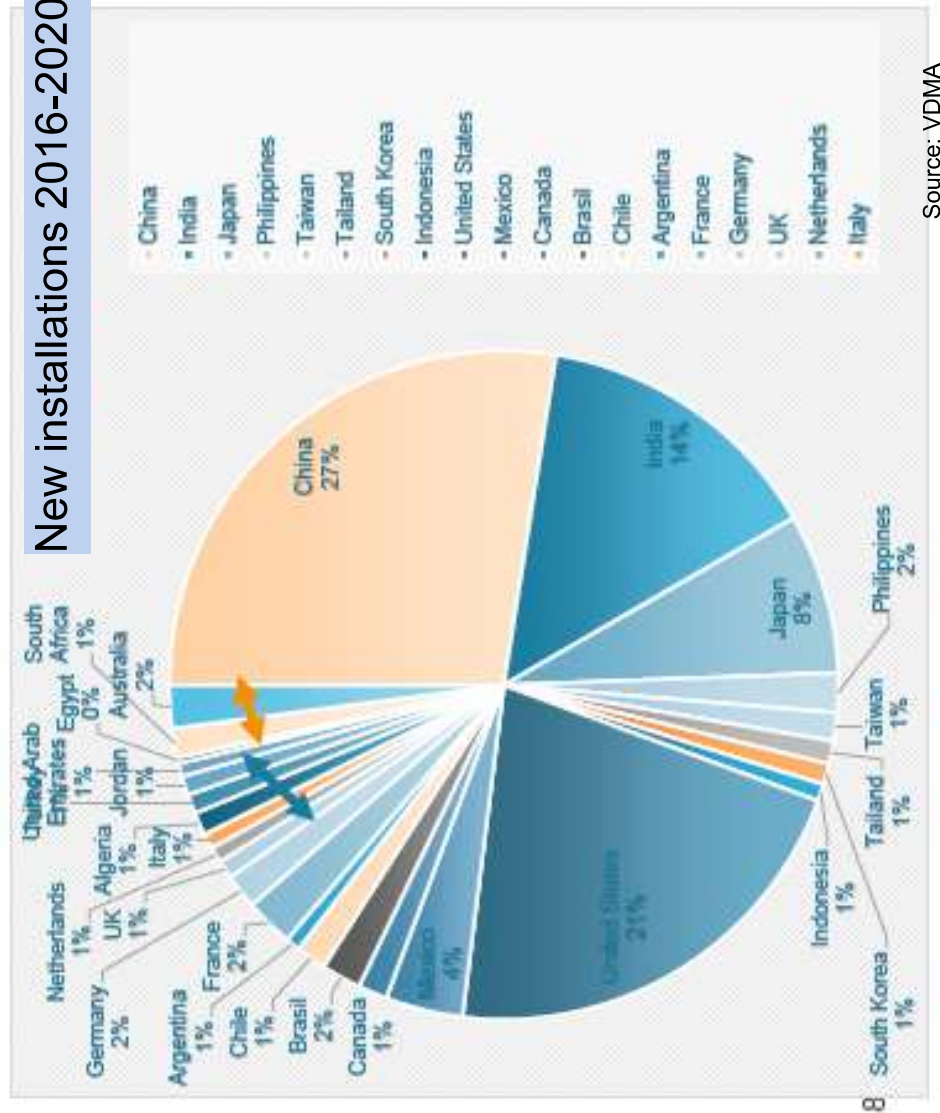
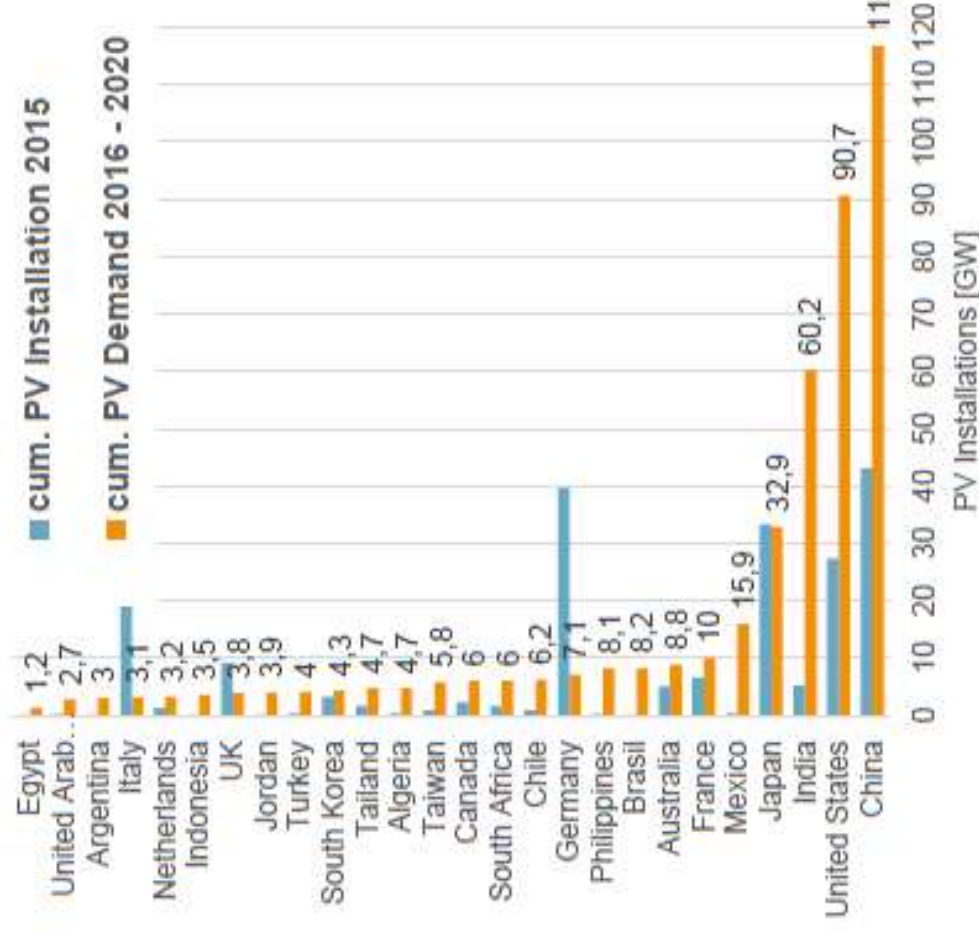
Source: PVTech

<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 & Technology Quarterly report, Jan 2017

Cumulative PV installations 2015 vs. Demand 2016-2020

Shift also to the new market

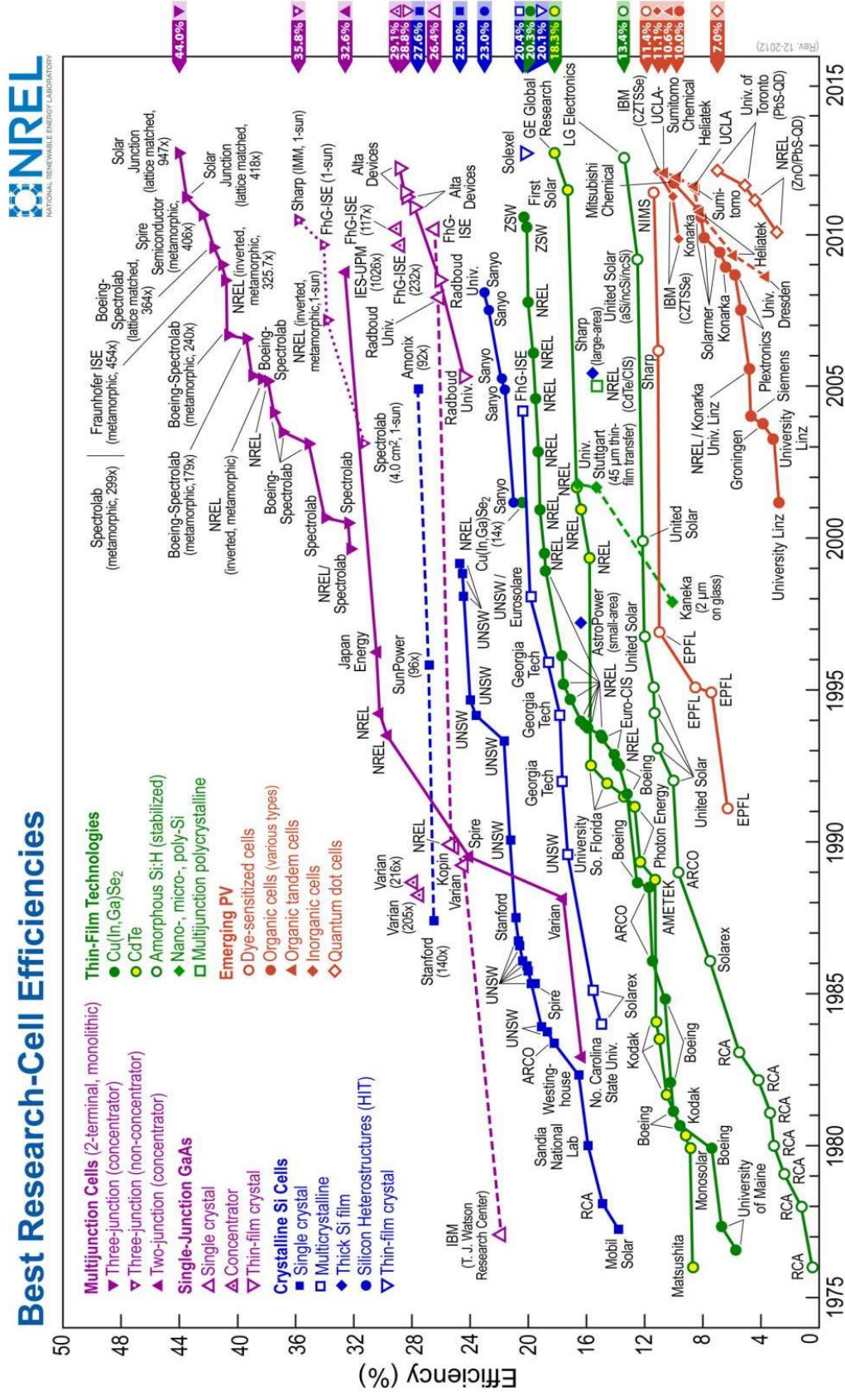


Source: VDMA

PV Module

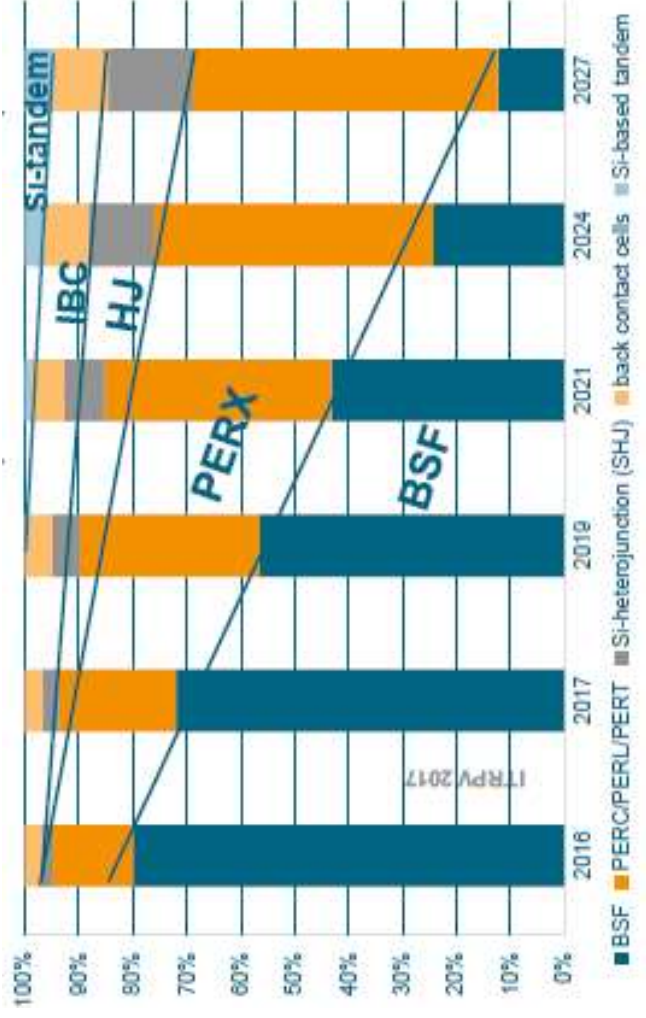
Technologies, Efficiencies

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

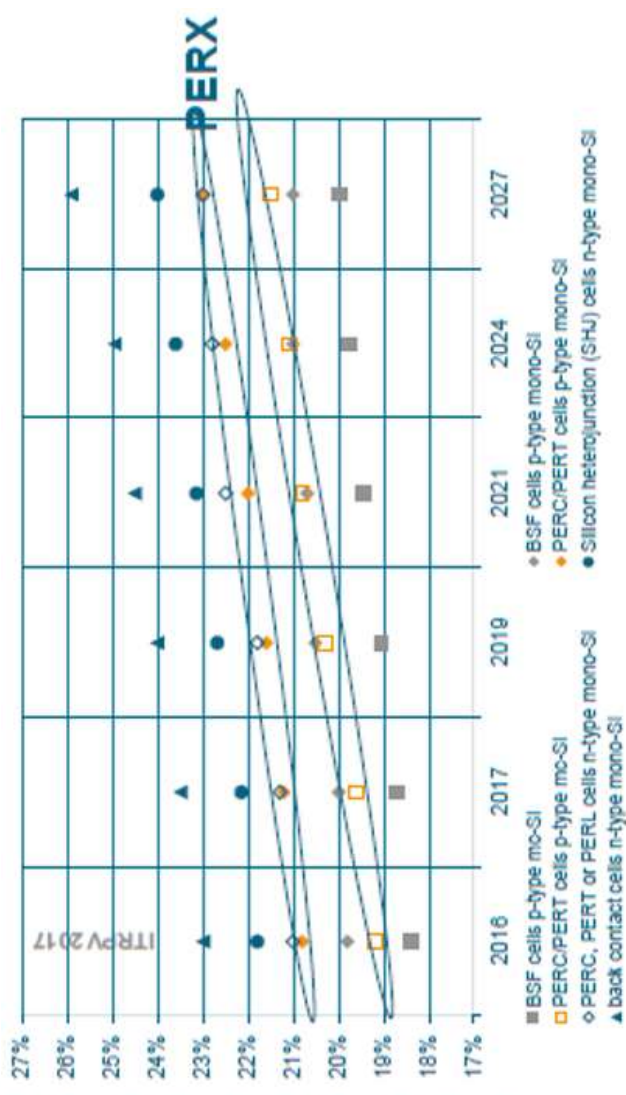


Cell Production: technologies / efficiency trends

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)

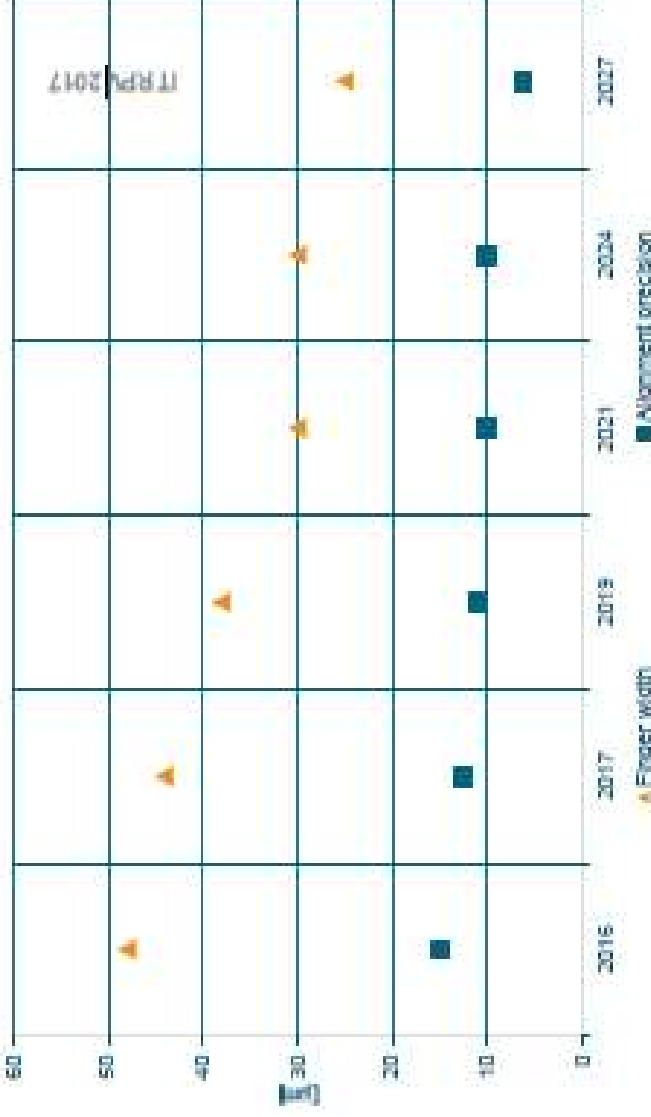
- **Back Surface Field** share is shrinking
- **Back contact + HJ**: slow increase in share
- **Si tandem**: under development

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

Source: VDMA | International Technology Roadmap PV, ITRPV 2017

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

→ Selective emitters + Bifacial cells require good alignment

→ Bifacial cells will increase market share

Trend: number of bus bars (BB)



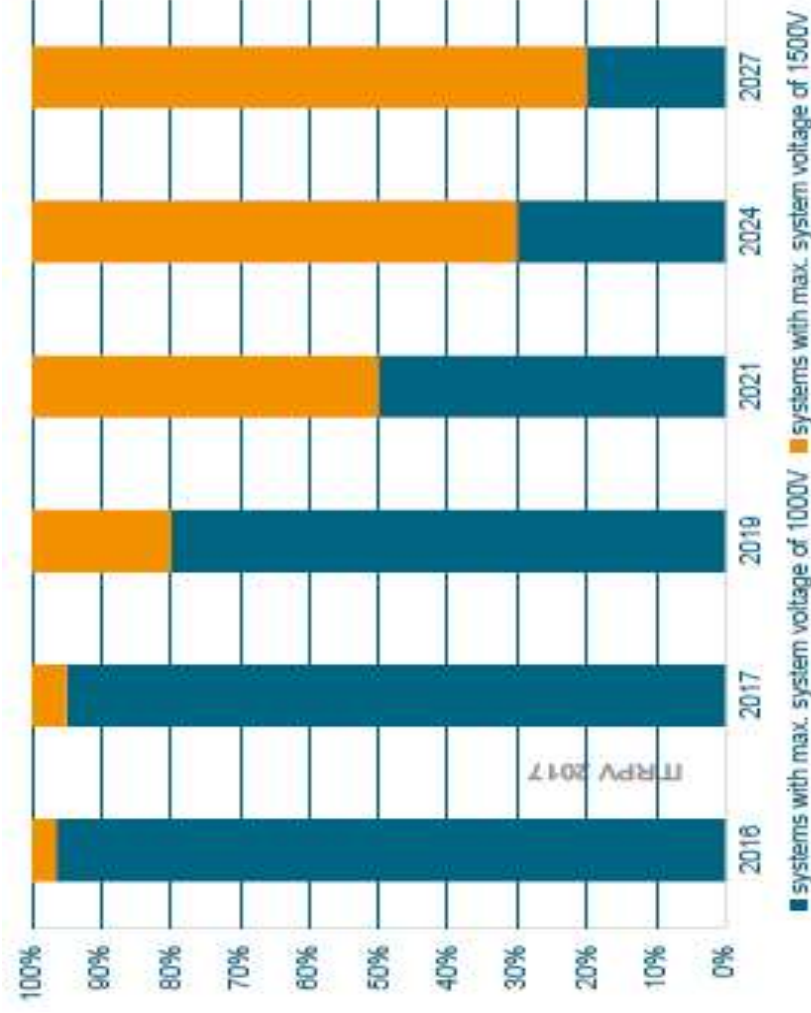
Trend: market share of bifacial cells



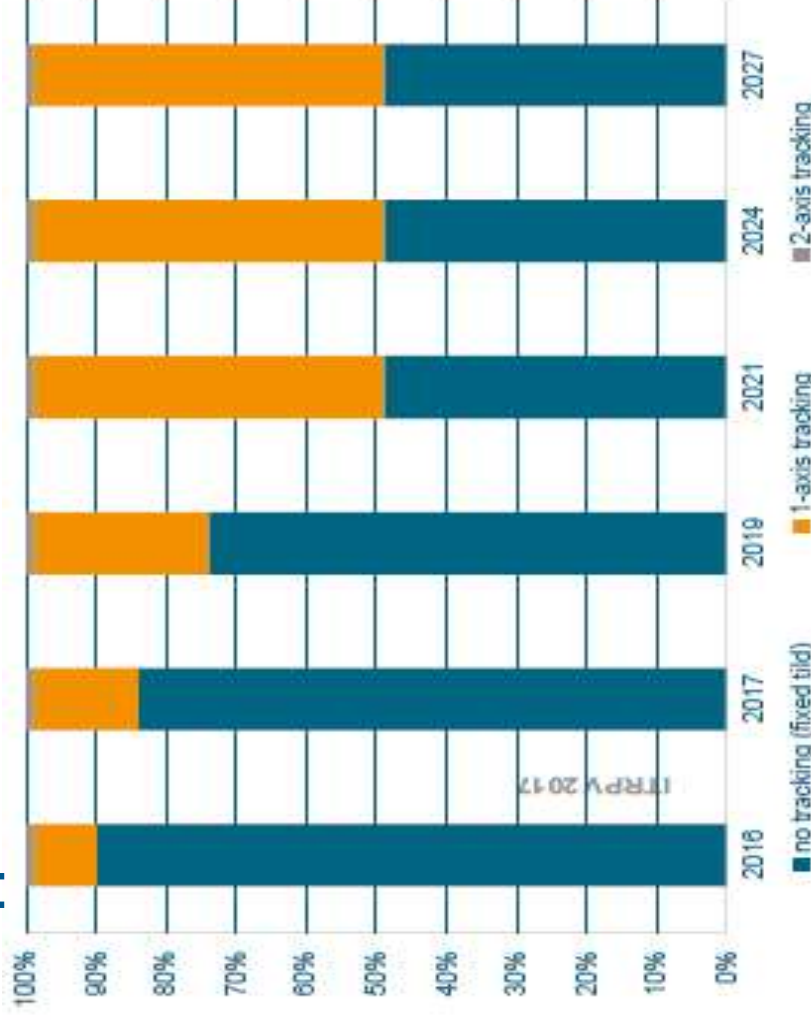
Source: VDMA | International Technology Roadmap PV, ITRPV 2017

System Components: System voltage / tracking

Trend: system voltage



Trend: tracker systems in power plant applications



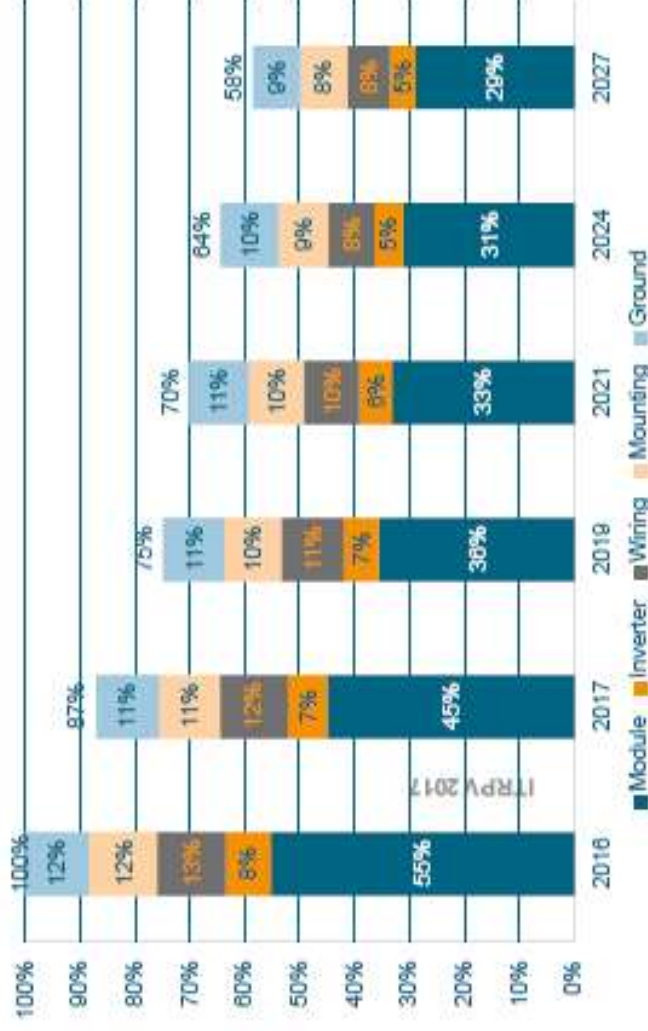
1500V are the future

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

Evolution of the PV bid prices utility-scale



Factor 2,5 in solar radiation

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

Source: VDMA

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 :

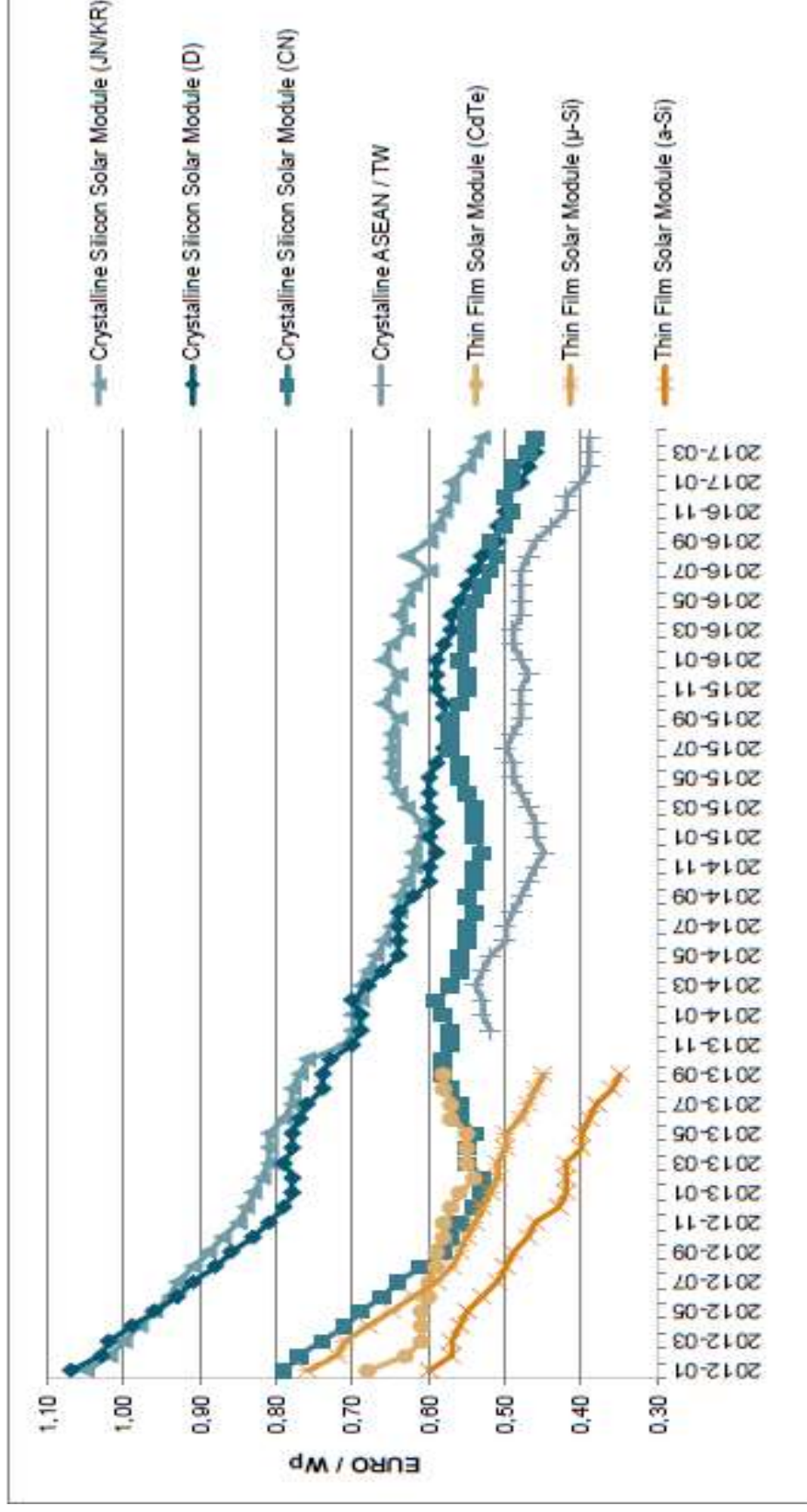
Investment 34% lower (Comparison of 2015 and 2016)

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:

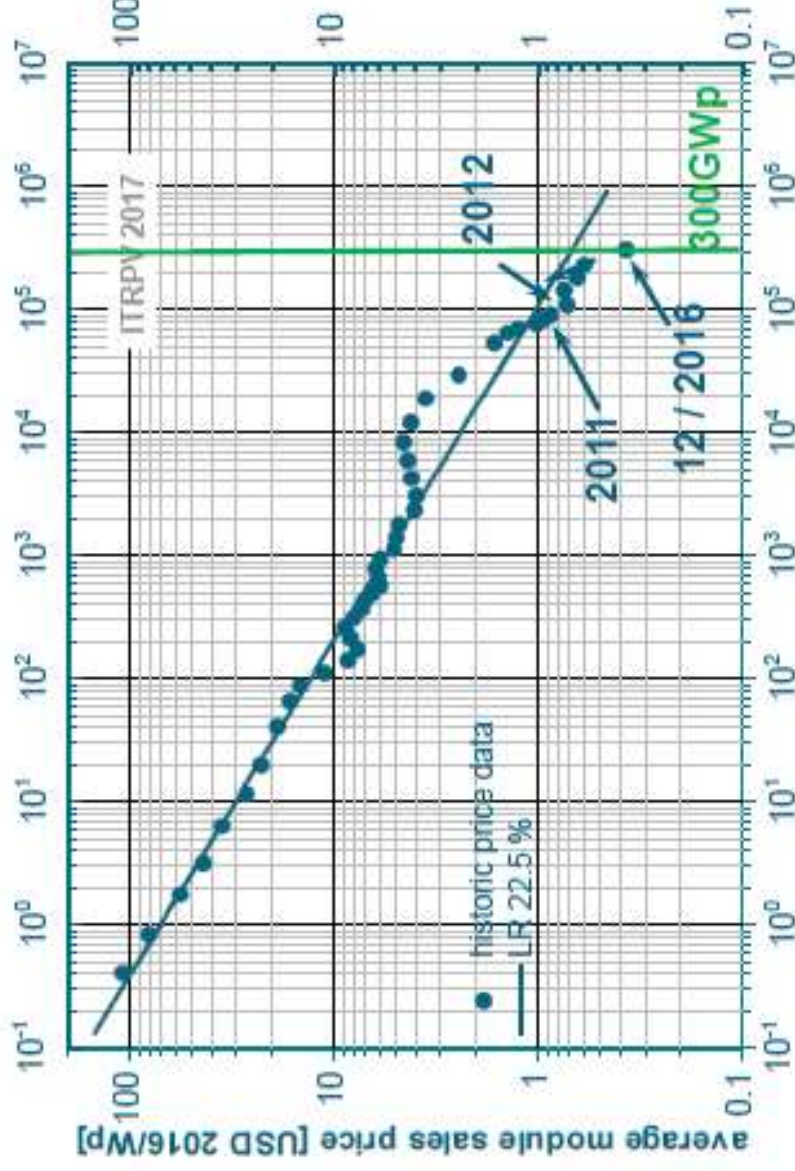
2016: 75 GWp / 0,37 US\$/Wp
 o/a shipment: ≈ 308 GWp
 o/a installation: ≈ 300 GWp

300 GWp landmark was passed!

LR 21,5% (1976...2016)

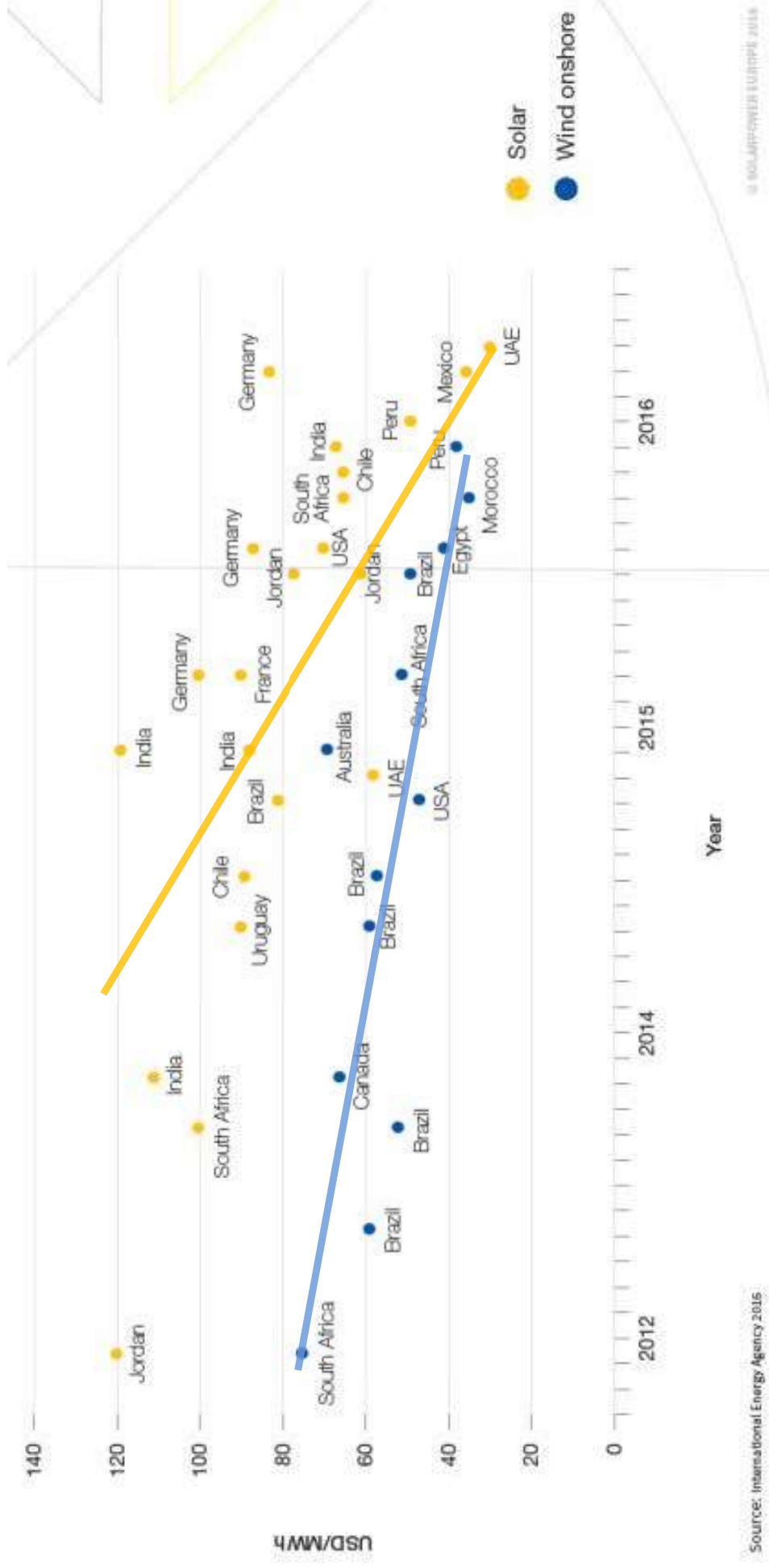
Dramatic price drop due to market situation

➤ Comparable to 2011/2012, but faster



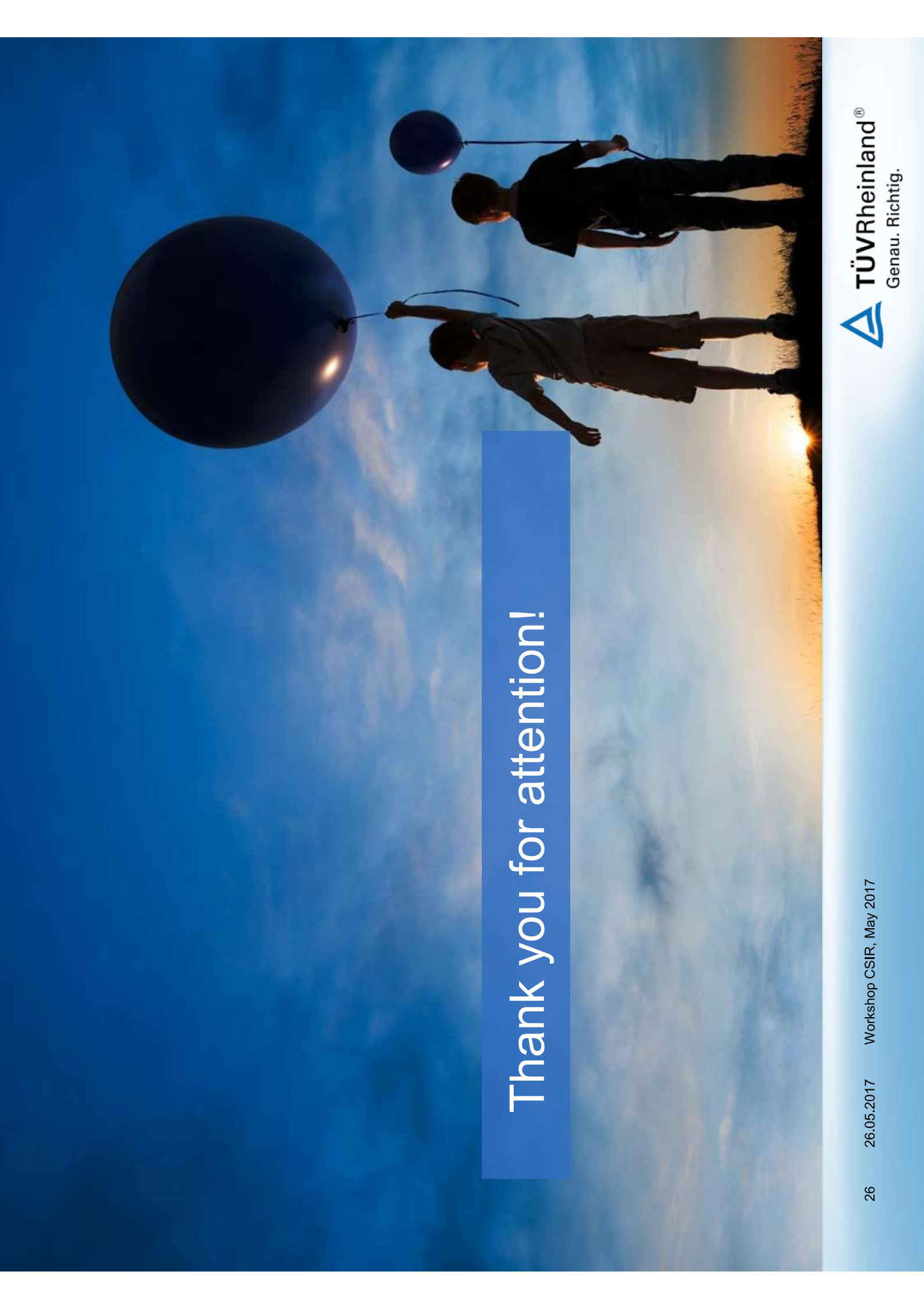
Source: VDMA | ITRPV 2017

Comparison of price degression PV - Wind



A fast PV learning curve

Source: VDMA

A photograph of two children standing on a grassy field at sunset. The child on the left is holding a large, dark blue balloon, and the child on the right is holding a smaller, dark blue balloon. The sun is low on the horizon, creating a warm orange glow. The sky is a deep blue with some light clouds. A blue rectangular box is overlaid on the image, containing the text "Thank you for attention!".

Thank you for attention!