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The evolution of the renewable energy revolution

Dr. Radovan Kopecek

International Solar Energy Research Center Konstanz

News from Tuesday 23 May 2017

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Environment

India cancels plans for huge coal power stations as solar energy prices hit record low

'India's solar tariffs have literally been free falling in recent months'

Ian Johnston Environment Correspondent | @montaukian | Tuesday 23 May 2017 15:42 BST | 98 comments

219K shares

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A field of solar panels at Cochin International Airport in southern India *CIAL*

INDEPENDENT

India has cancelled plans to build nearly 14 gigawatts of coal-fired power stations – about the same as the total amount in the UK – with the price for solar electricity "free falling" to levels once considered impossible.

Analyst Tim Buckley said the shift away from the dirtiest fossil fuel and towards solar in India would have "profound" implications on global energy markets.

According to his article on the Institute for Energy Economics and Financial Analysis's website, 13.7GW of planned coal power projects have been cancelled so far this month – in a stark indication of the pace of change.

News from Tuesday 23 May 2017

tional Solar Energy
Center Konstanz

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PV cheaper as coal energy

agenda

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- **ISC Konstanz:** international PV institute performing technology transfer

- **Renewables:** past, present, future

- **PV:** how to reach 1USct/kWh?

ISC Konstanz

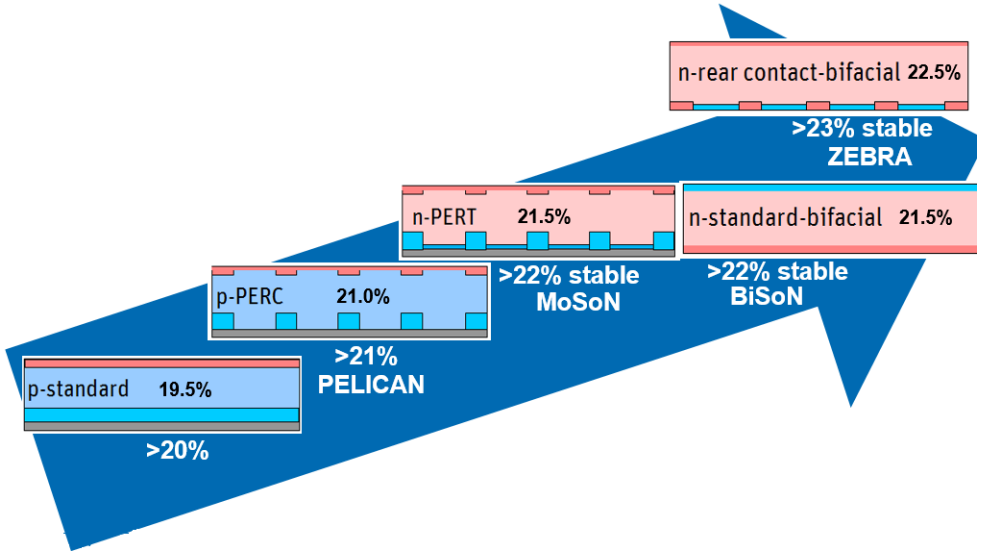
ISC Konstanz: who we are

International Solar Energy Research Center Konstanz

International Solar Energy Research Center e.V.

– a nonprofit organization
– Founded in 2005
– R&D on c-Si solar cells, modules and systems
– **Technology transfer**

– About 50 employees
– Turnover about 5 Mio€/a



cells

modules

systems

12.12.2005

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12.12.2005

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10 years later

12.12.2015

top PV research institutes world wide

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Fraunhofer ISE

ISC

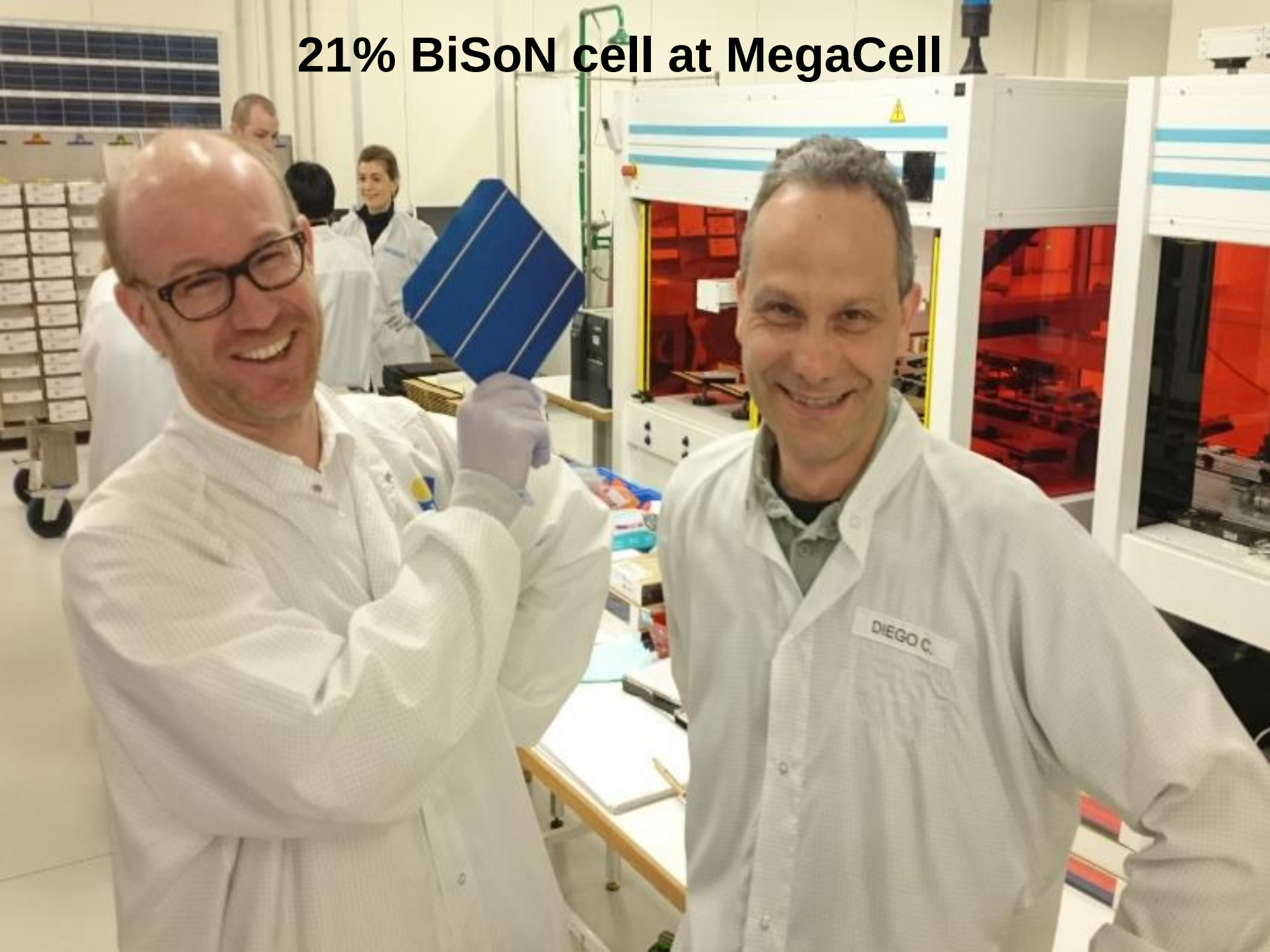
ISFH

ines INSTITUT NATIONAL DE L'ENERGIE SOLAIRE

THE UNIVERSITY OF NEW SOUTH WALES

ECN › TNO

21% BiSoN cell at MegaCell



All technology transfers 2015-

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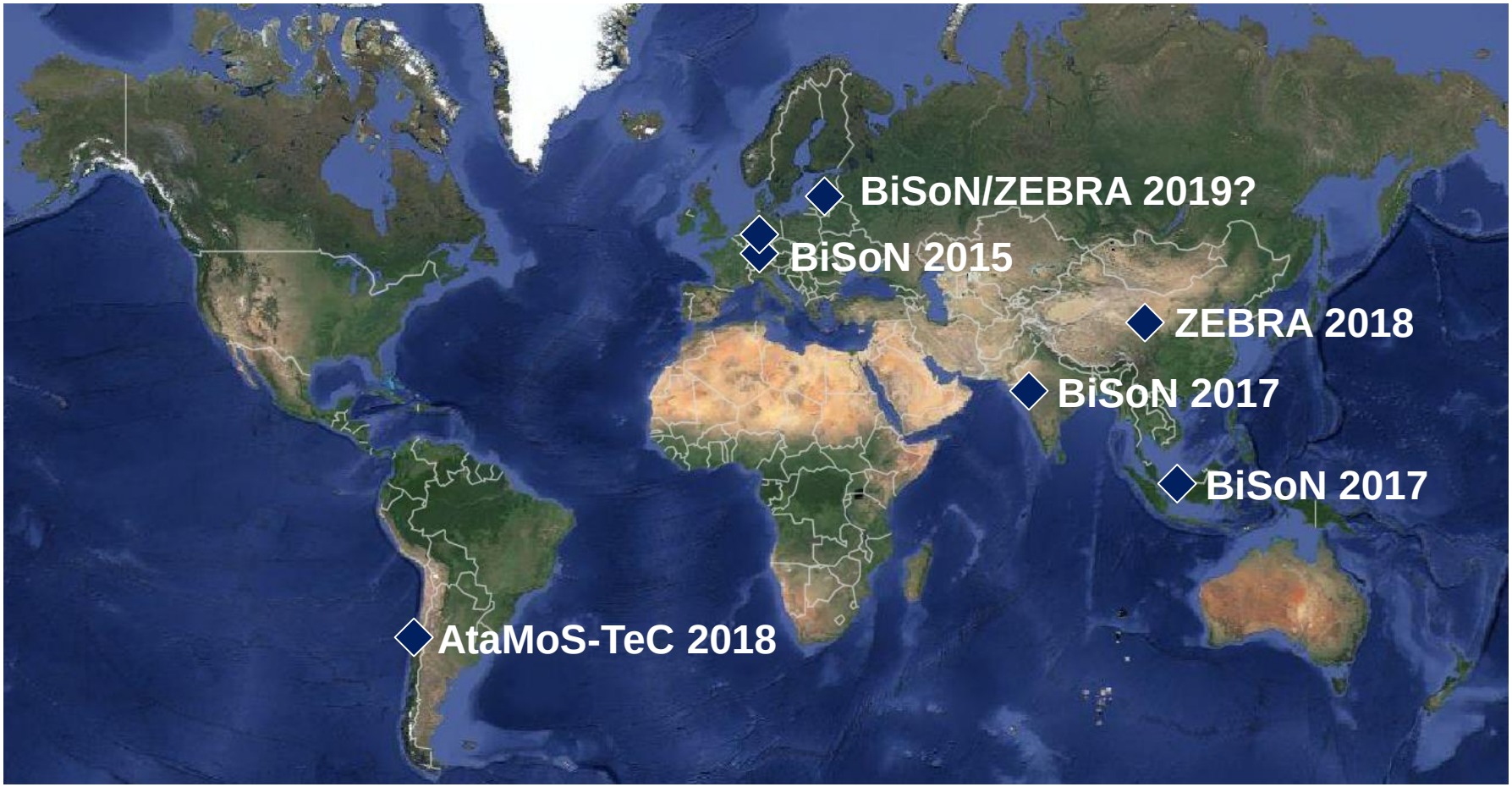

The planning 2017

The fab 2018
adani

The defense

Solar cell production site 2018

AtaMoS-TeC consortium 2018

PSDA in Atacama desert

Department of energy in Washington 2018

Education/Development cooperation

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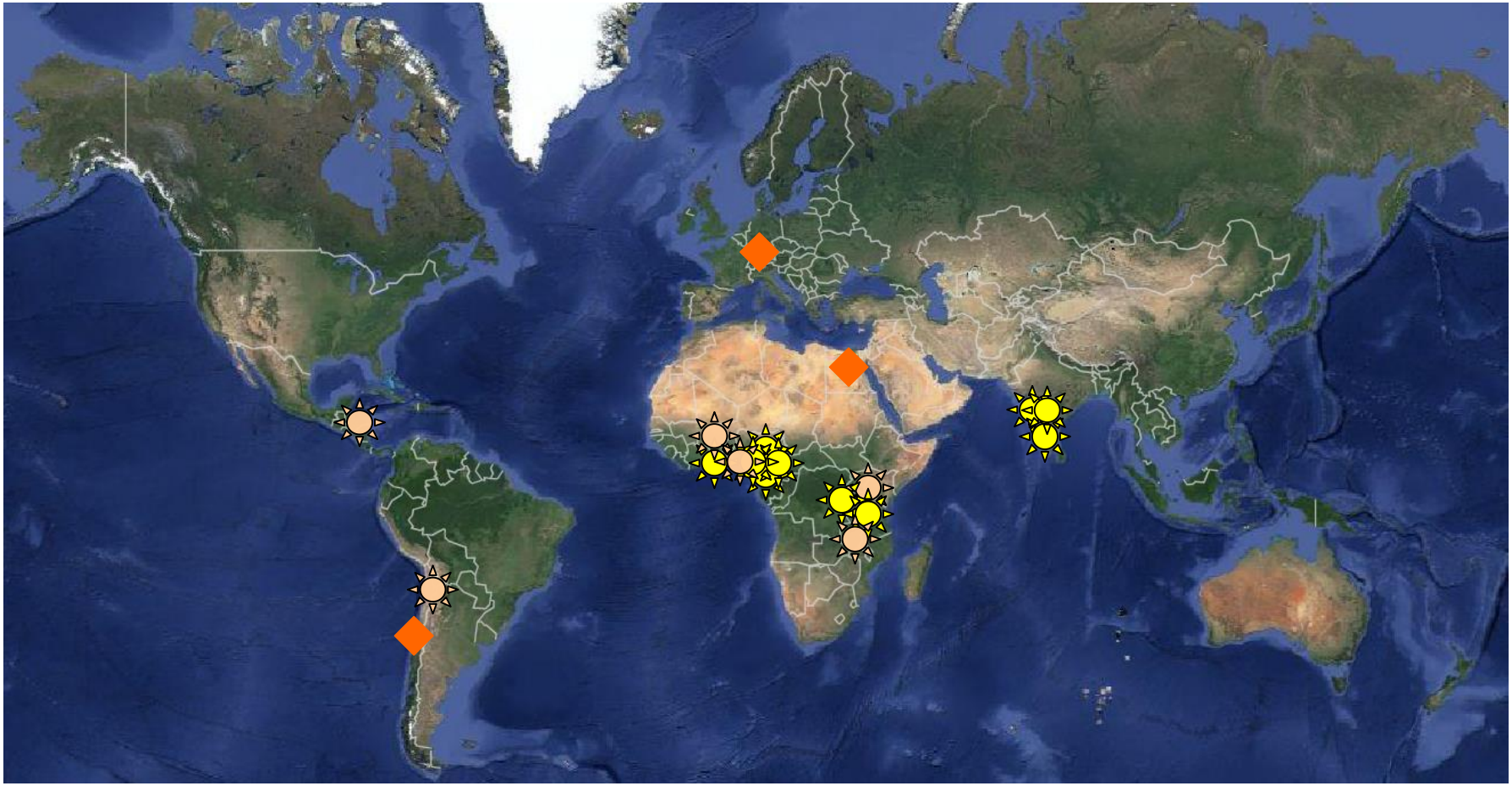
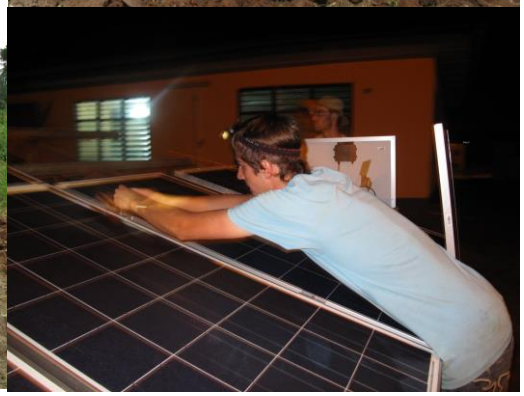
Educationcooperation Electrification project Module donation



E/D cooperation: GhanSol



Nyakrom school

Nachhaltigkeit lernen

Weltdekade der Vereinten Nationen 2005-2014

Bildung für nachhaltige Entwicklung

UNESCO

Offizielles Projekt der Weltdekade 2014

E/D cooperation: SLAK5

Nachhaltigkeit lernen

Weltdekade der Vereinten Nationen 2005-2014

Bildung für nachhaltige Entwicklung

UNESCO

Offizielles Projekt der Weltdekade 2014

till 2020
ENERGY TRANSITION
20-20-20

Energy transition

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Energy ~~transition~~ transformation

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Potential of renewables

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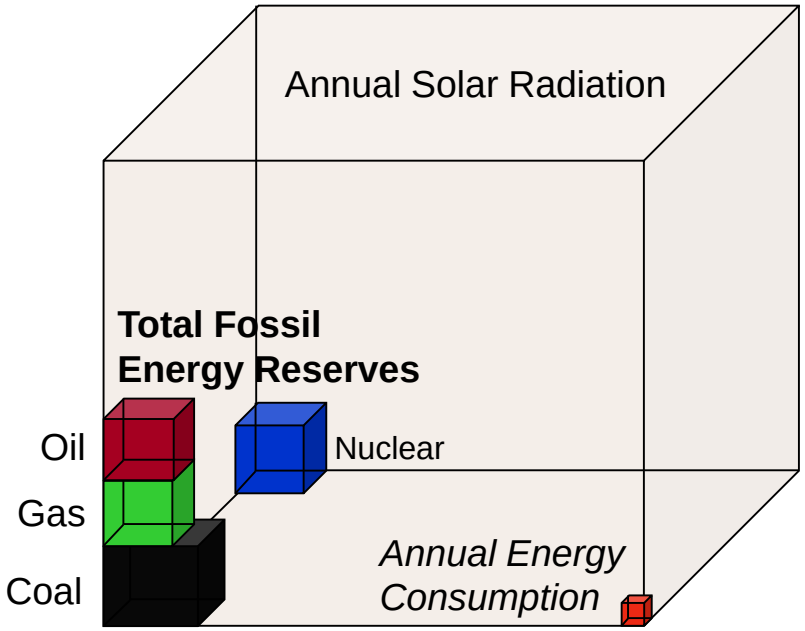
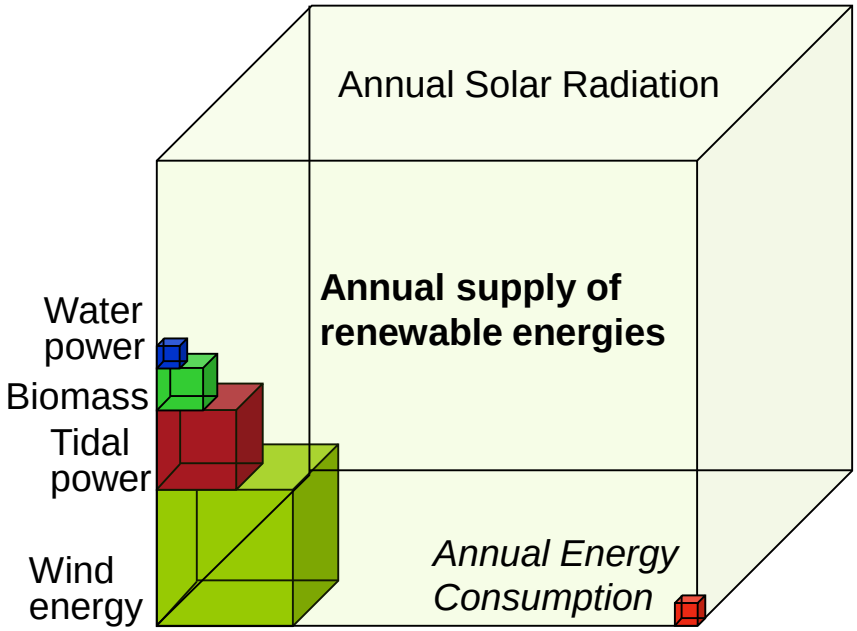
world energy consumption/potential

Traditional energy sources



Renewable energy sources



Eurec Agency/ Eurosolar, WIP: Power for the World – A Common Concept.

Potential of renewables (forecast 2002)

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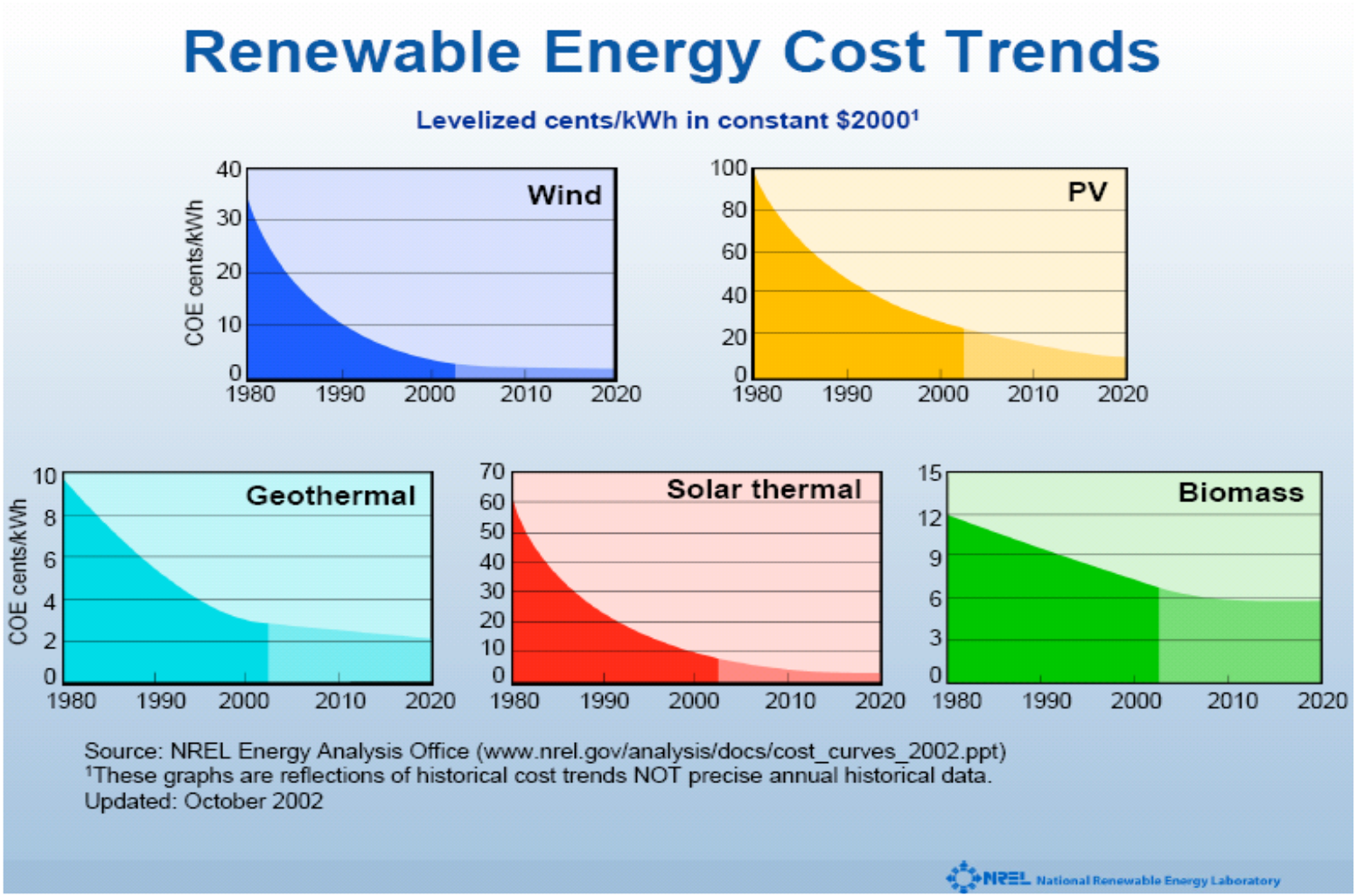

Potential of renewables (forecast 2002)

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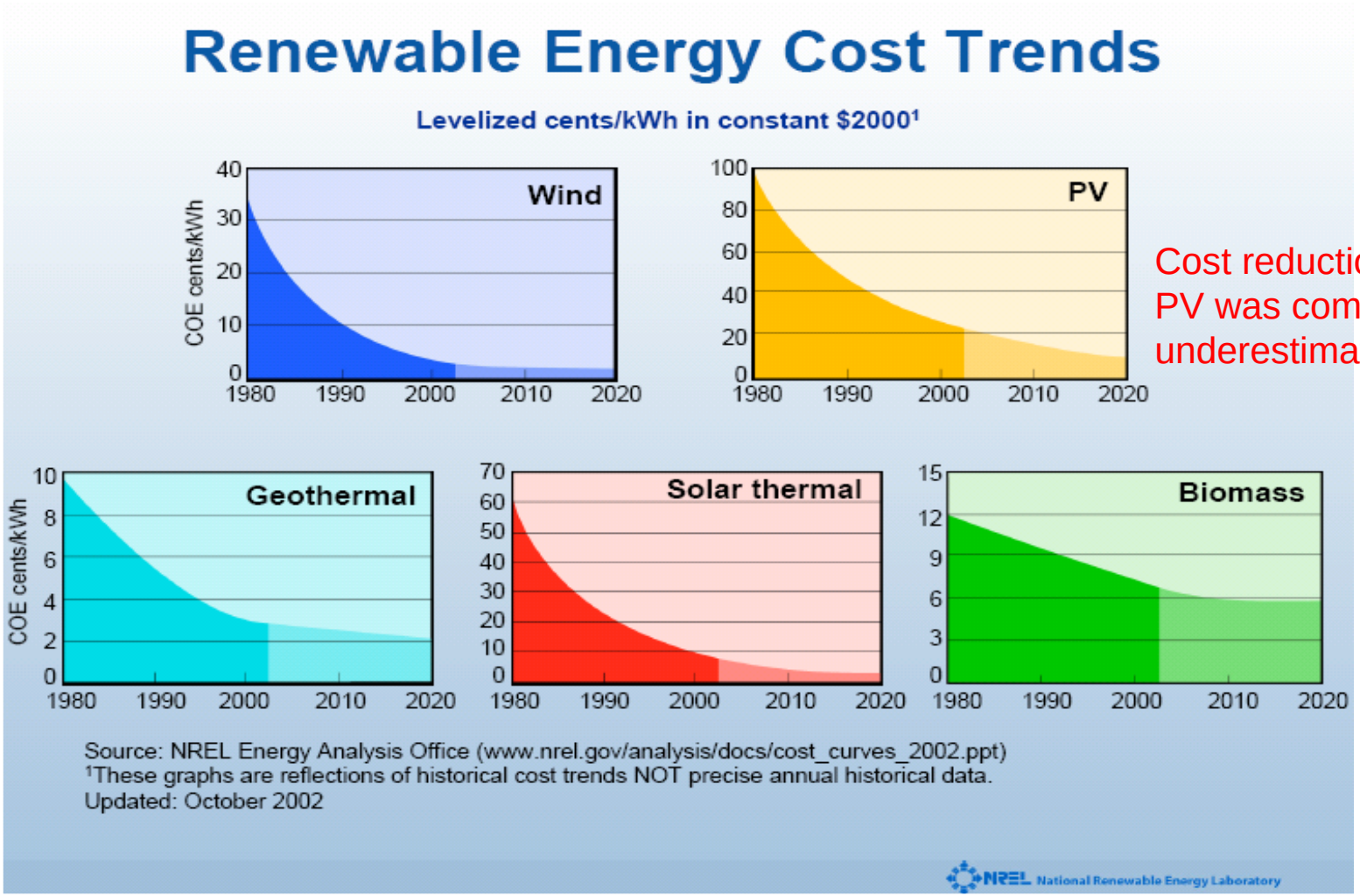

Cost reduction of PV was completely underestimated

Hermann Scheer (1944 - 2010)

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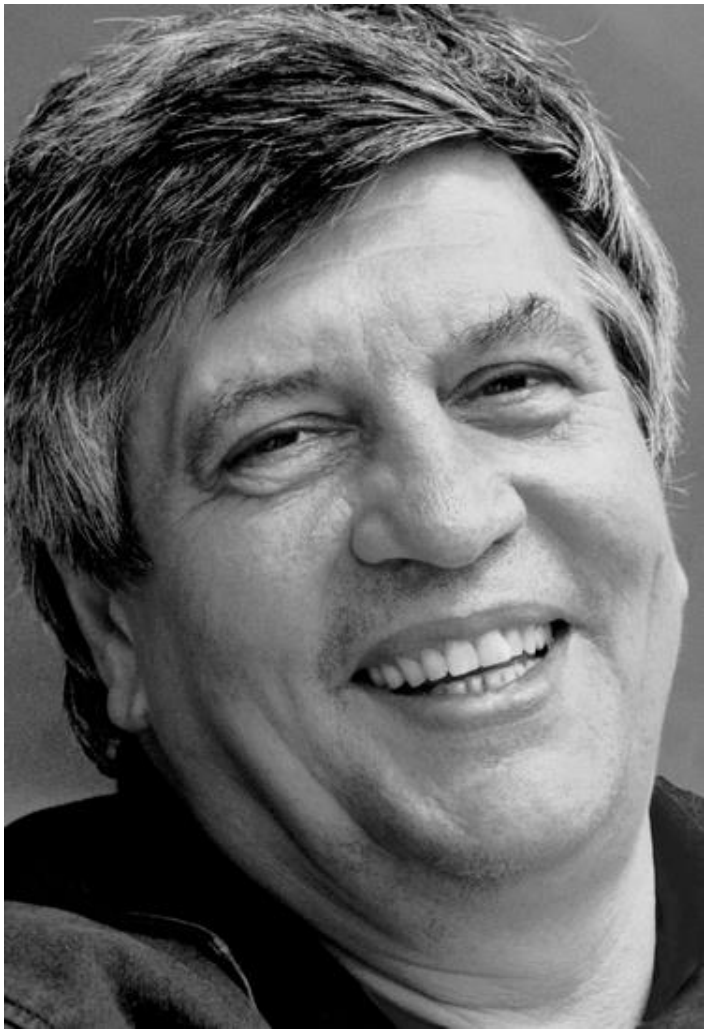

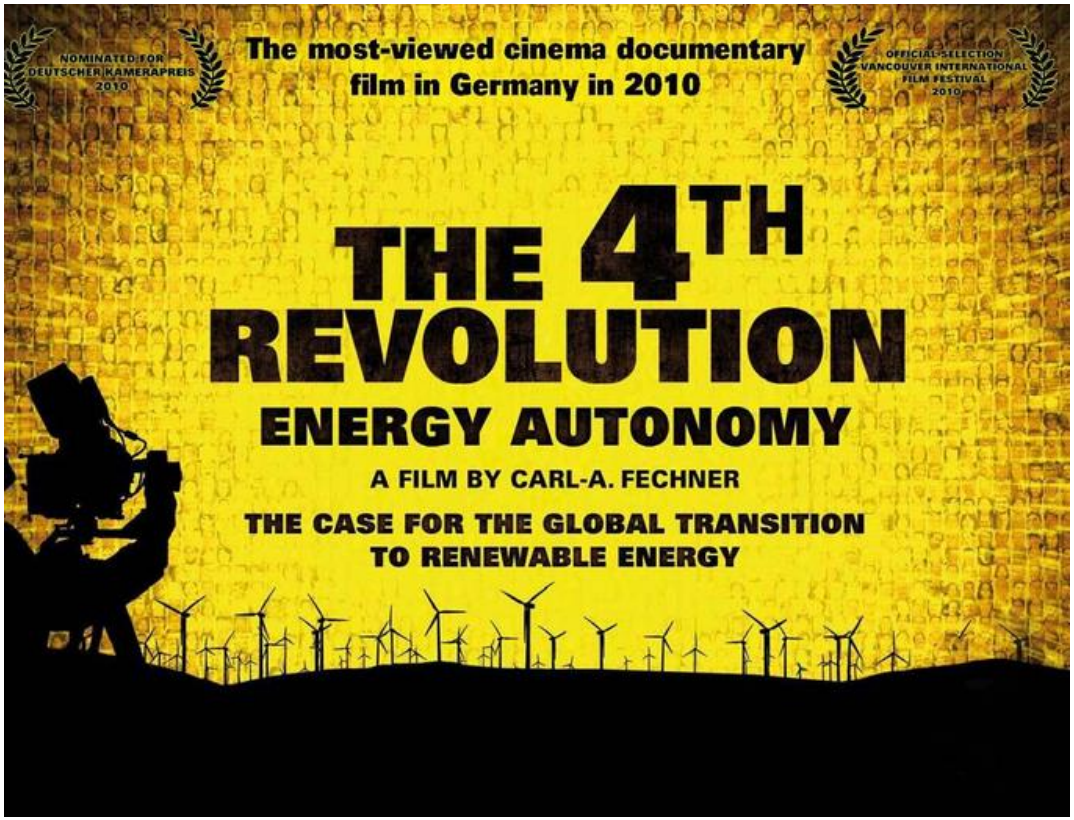

He had a dream!

The dream is today reality!

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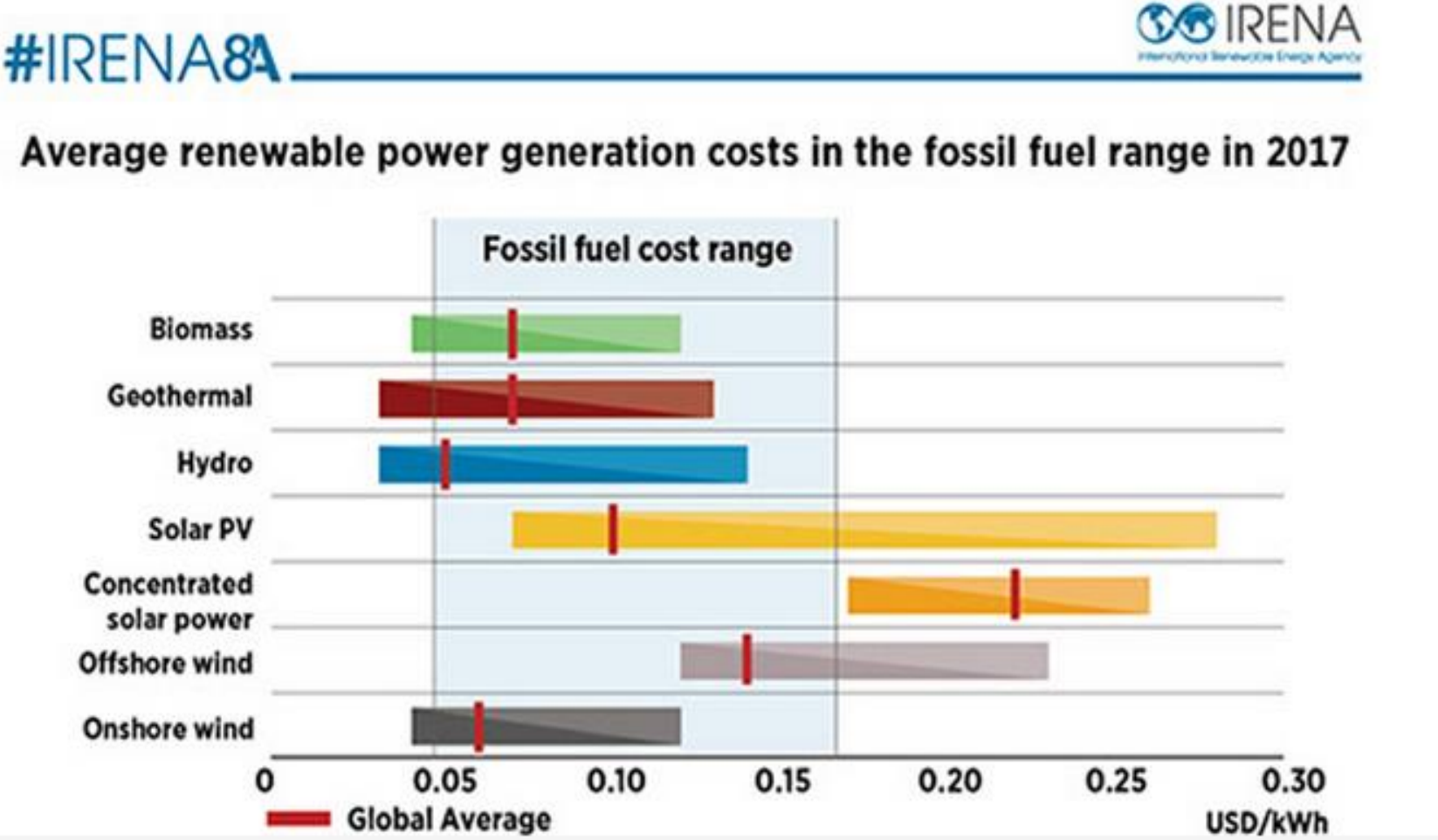
#IRENA8A

IRENA



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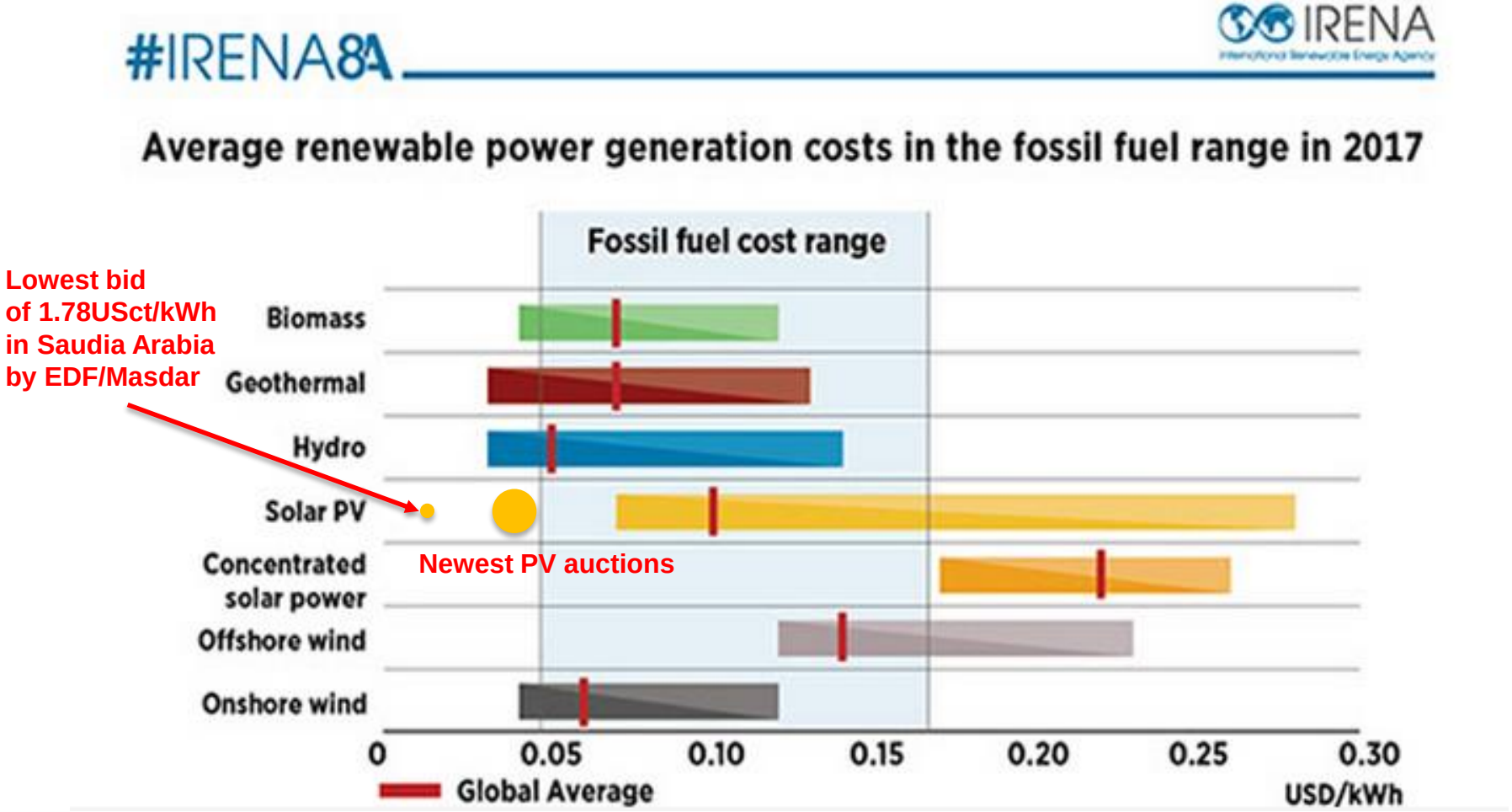
#IRENA8A

IRENA



Onshore wind and PV costs

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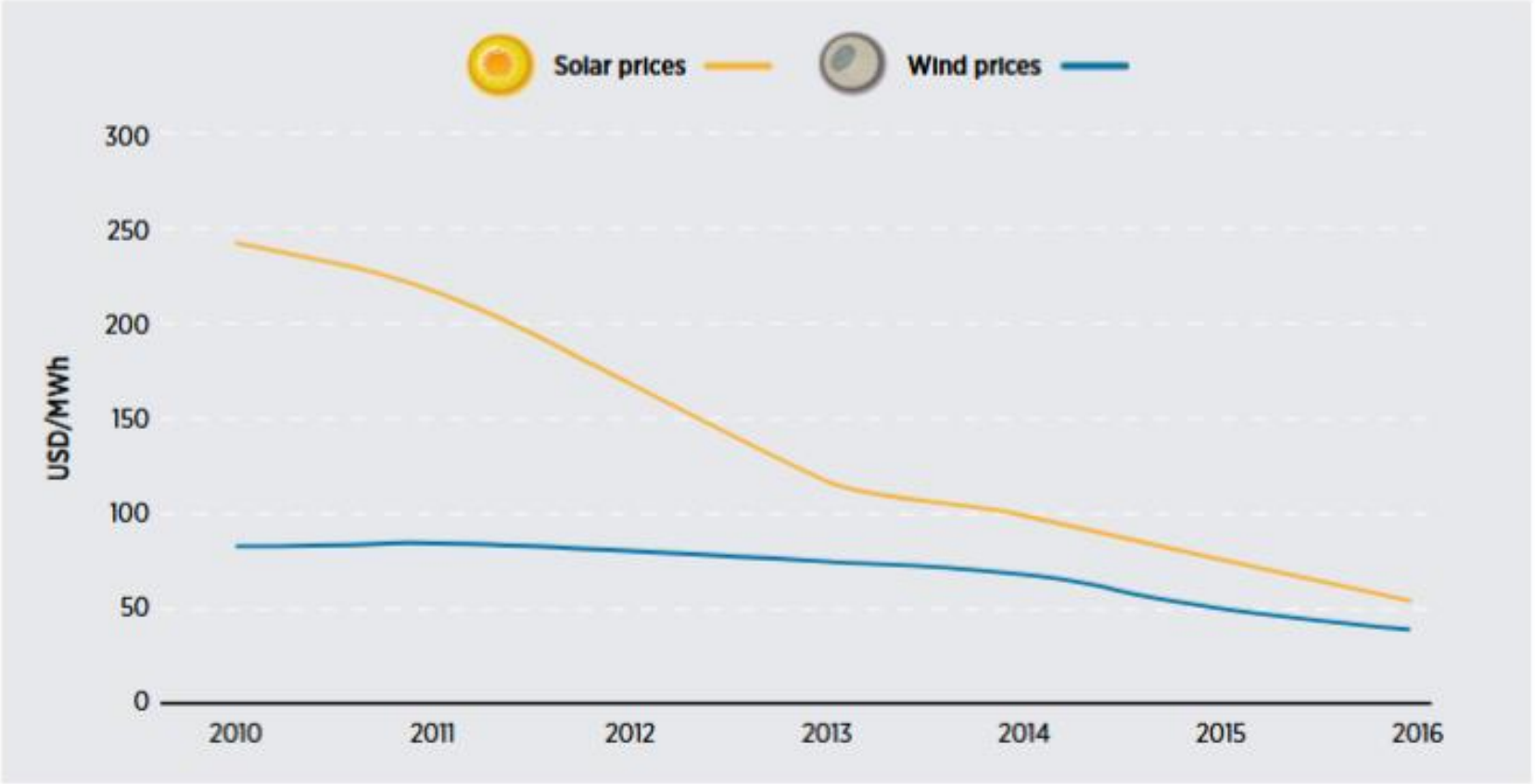
Figure 1 Average prices resulting from auctions, 2010-16



Source: IRENA, 2017.

Onshore wind and PV costs

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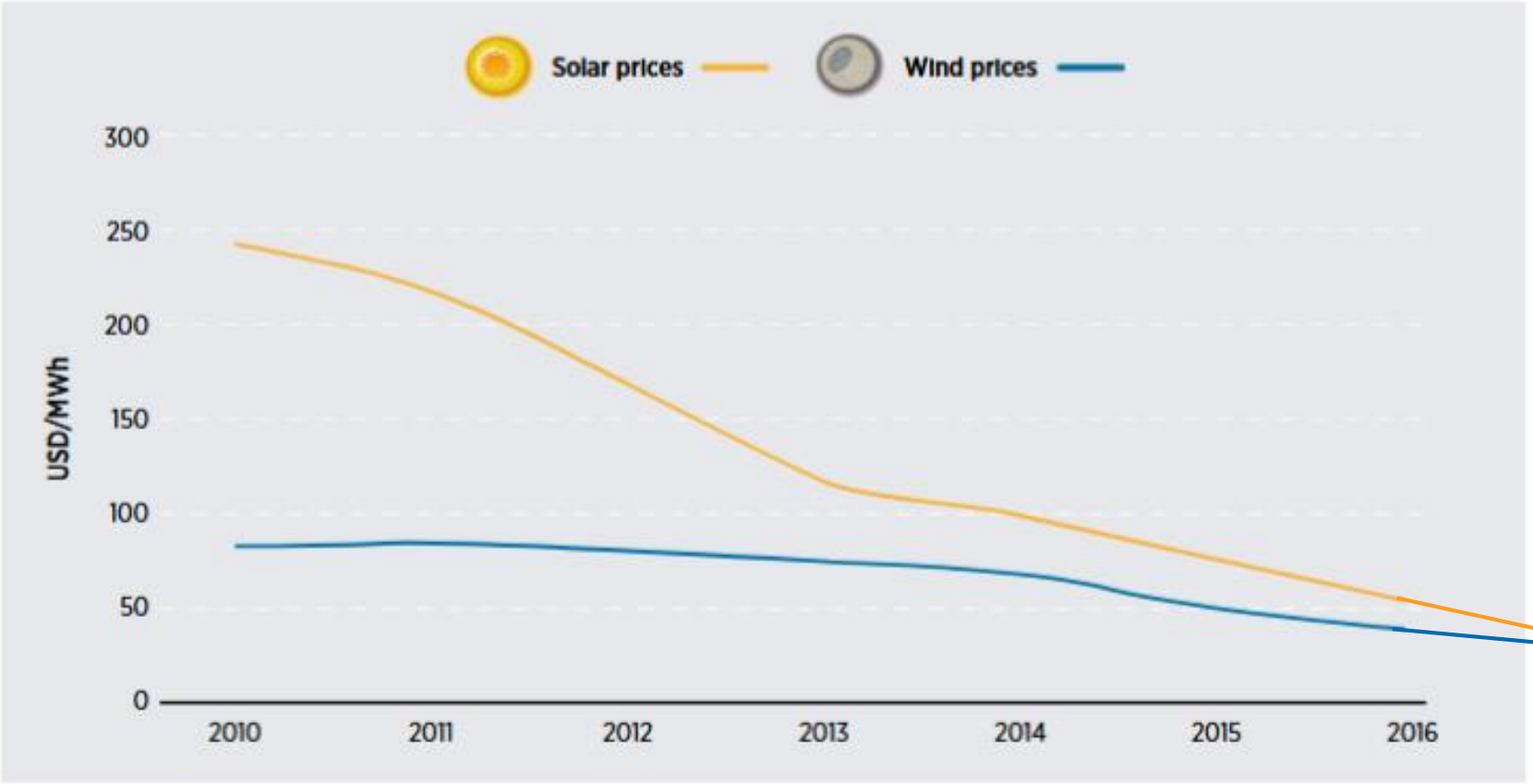

Source: IRENA, 2017.

Onshore wind and PV costs

International Solar Energy Research Center Konstanz

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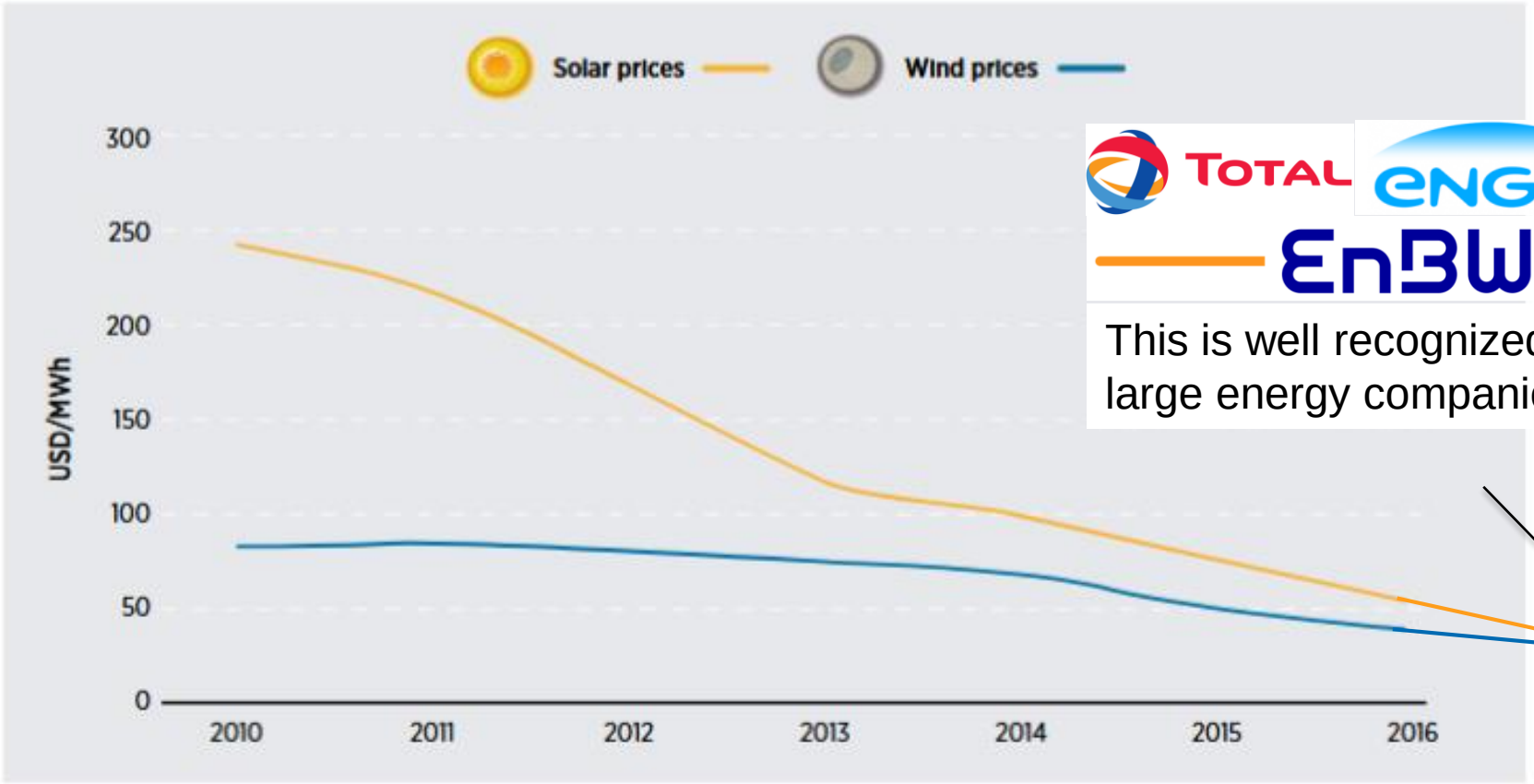

Source: IRENA, 2017.

TOTAL ENGIE EnBW

This is well recognized by large energy companies

Onshore wind and PV markets 2018

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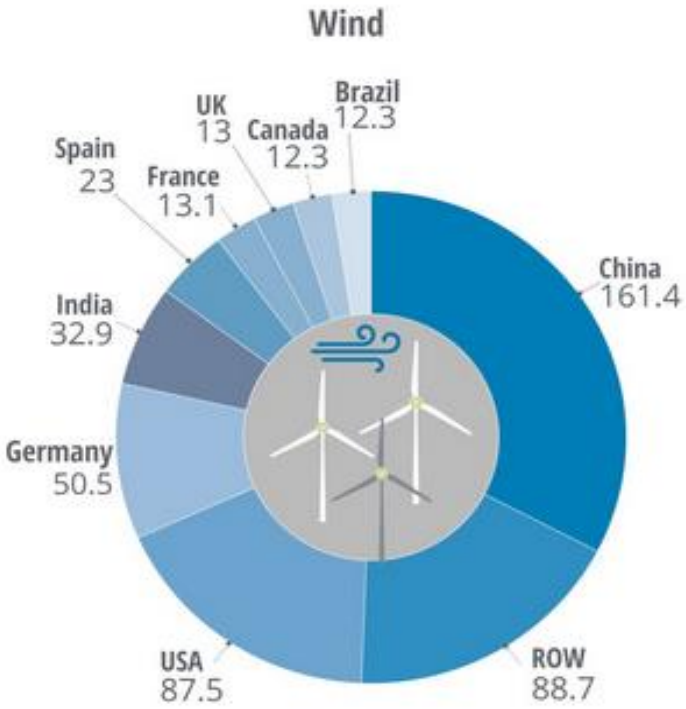

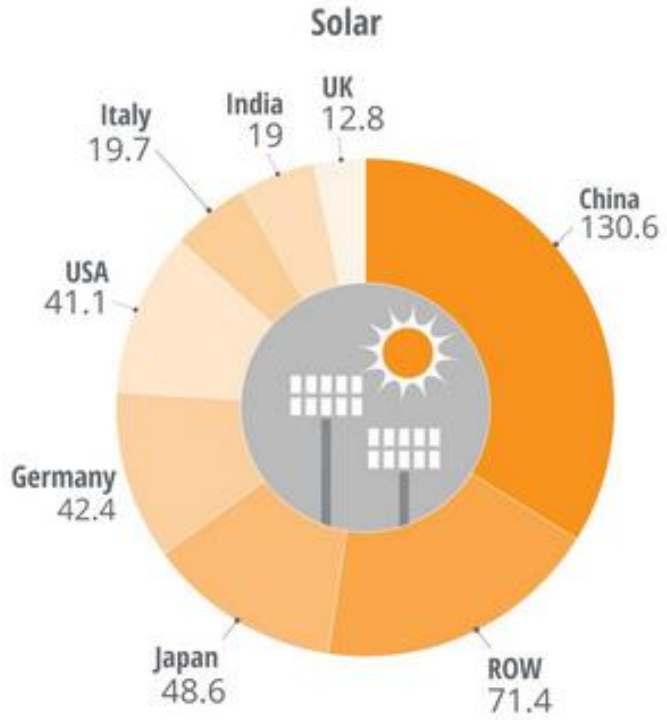

Note: Unit = GW

Source: IRENA, *Renewable capacity statistics 2018.*

Deloitte Insights | deloitte.com/insights

Electricity mix in Germany 2017

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Bloomberg´s forecast in 2015

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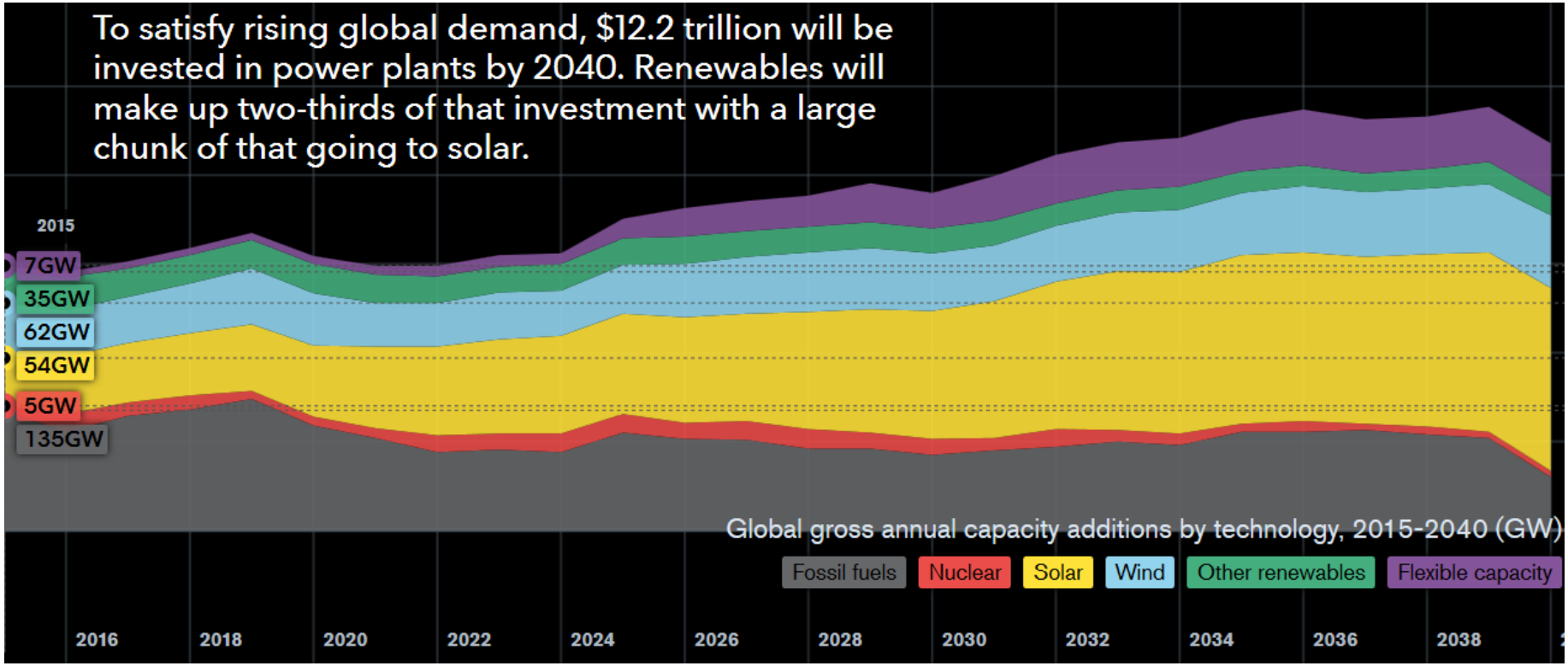

https://www.bnef.com/dataview/new-energy-outlook/index.html

Bloomberg´s forecast in 2015

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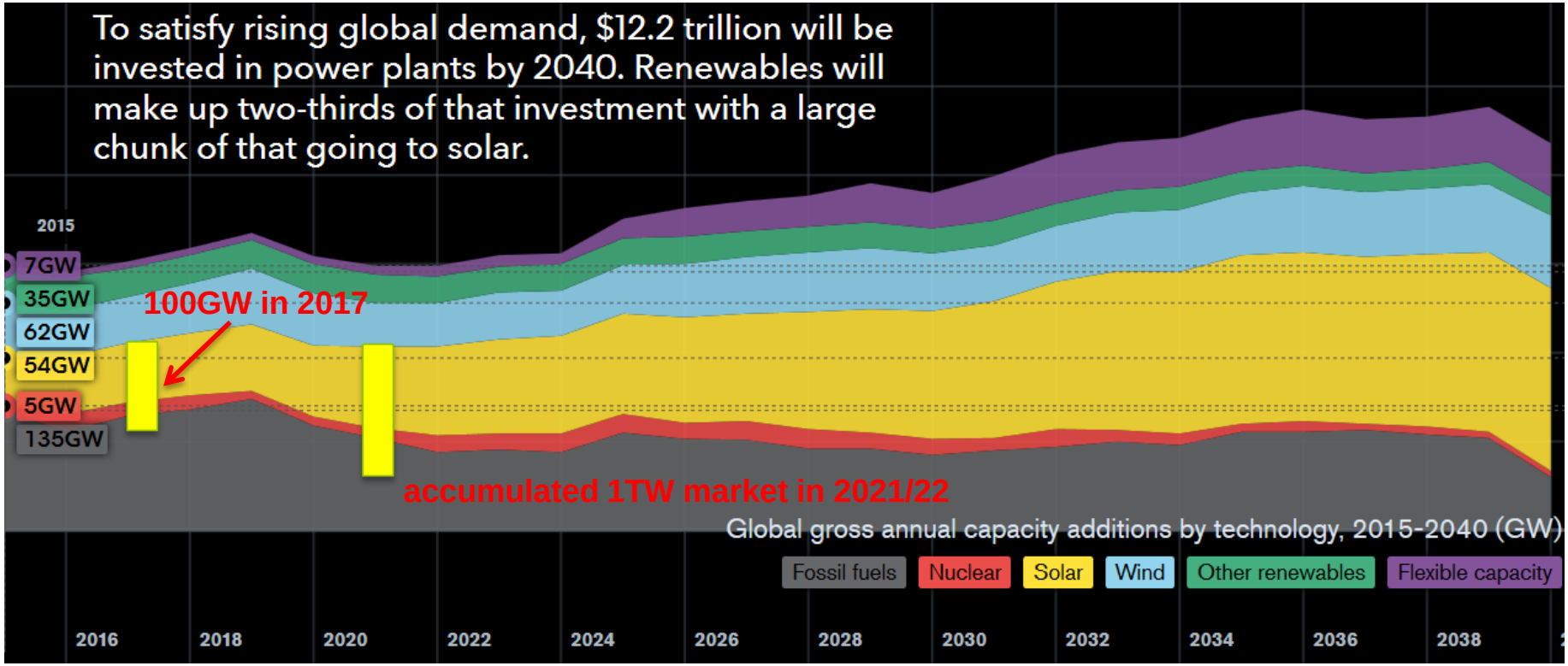

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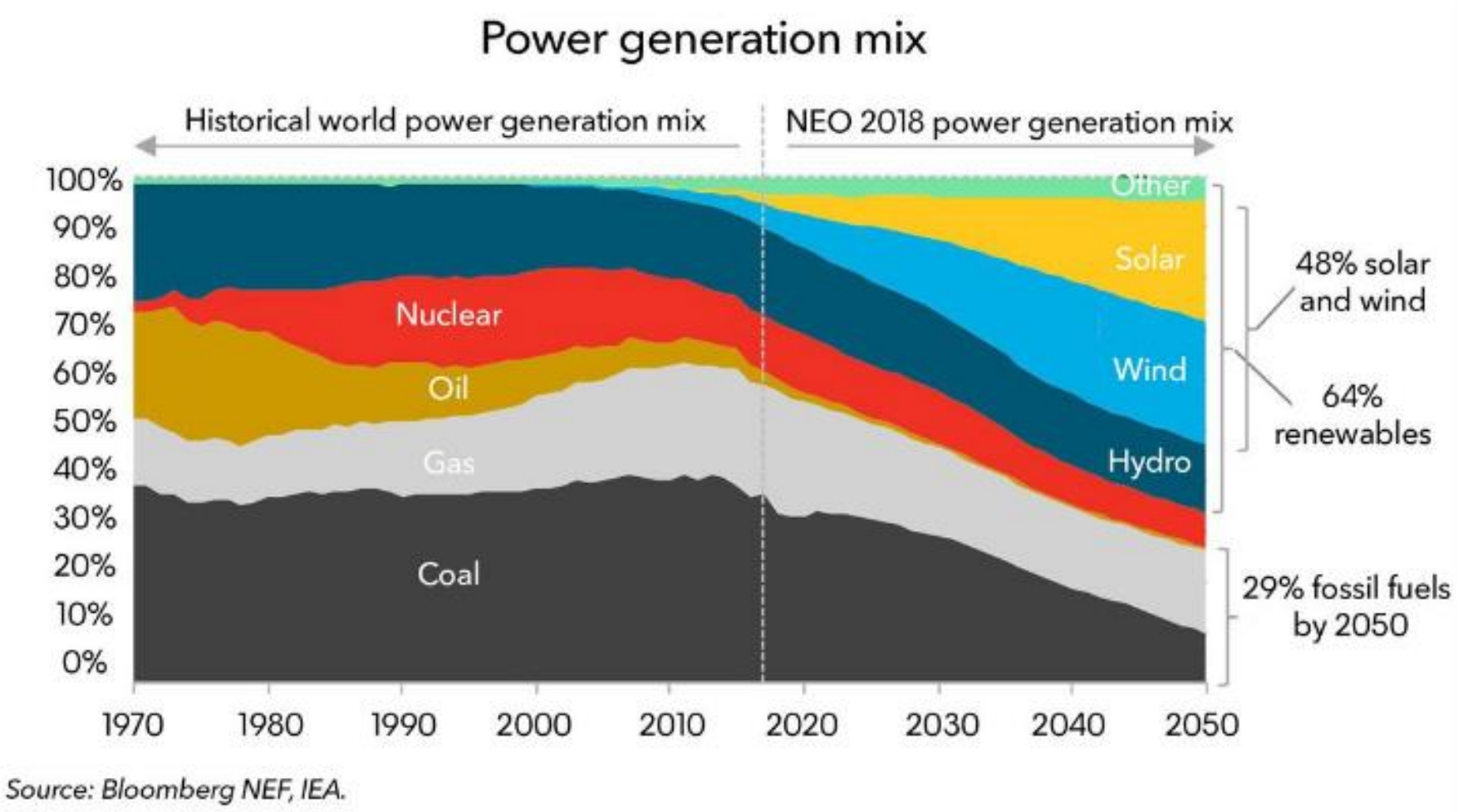
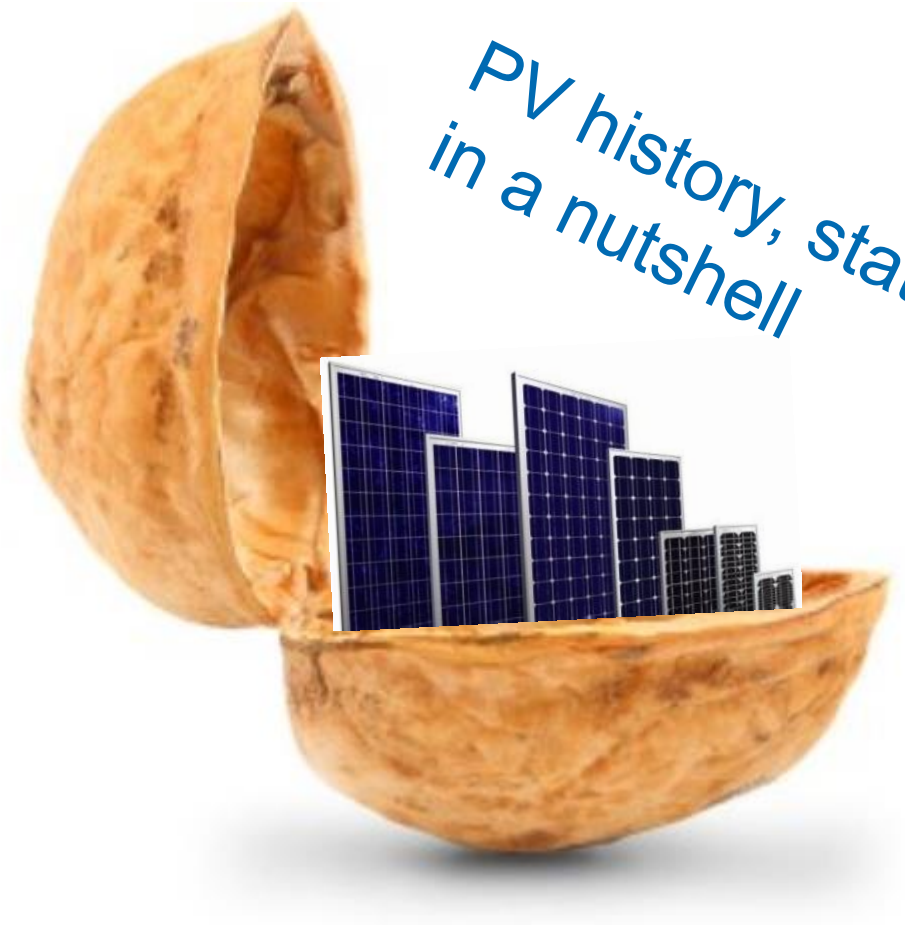


Source: Bloomberg NEF, IEA.

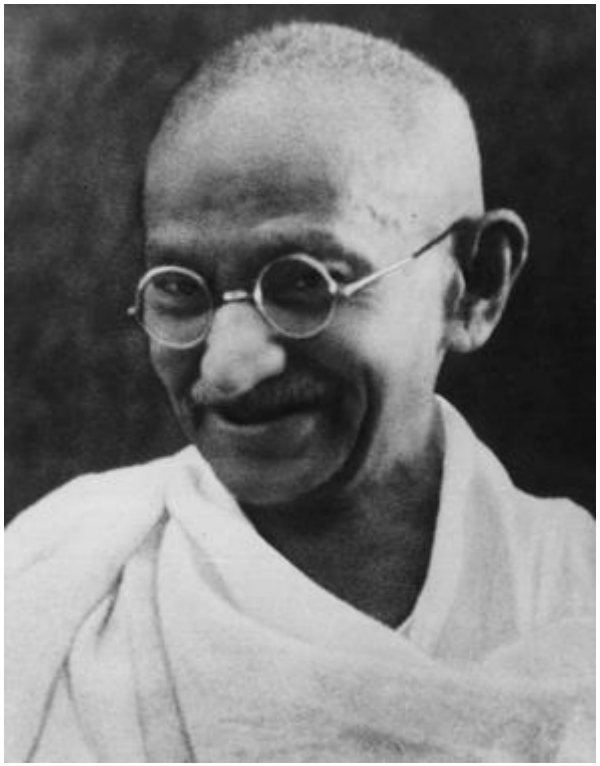
PHOTOVOLTAICS
history, present and future

History, status and future of PV



PV history, status and future in a nutshell

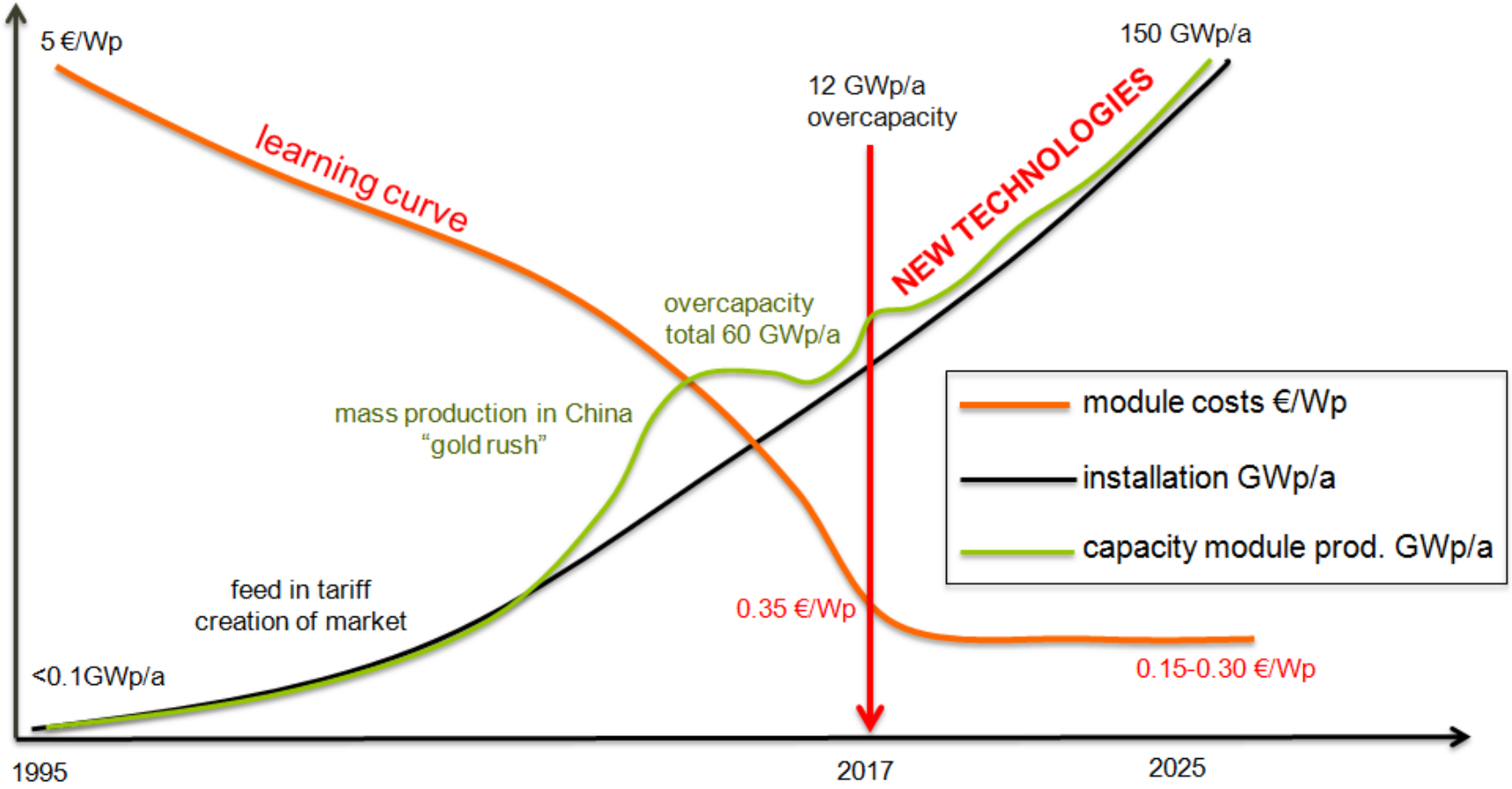
History, status and future of PV



First they ignore you then they laugh at you then they fight you and then you win.

History, status and future of PV

International Solar Energy Research Center Konstanz

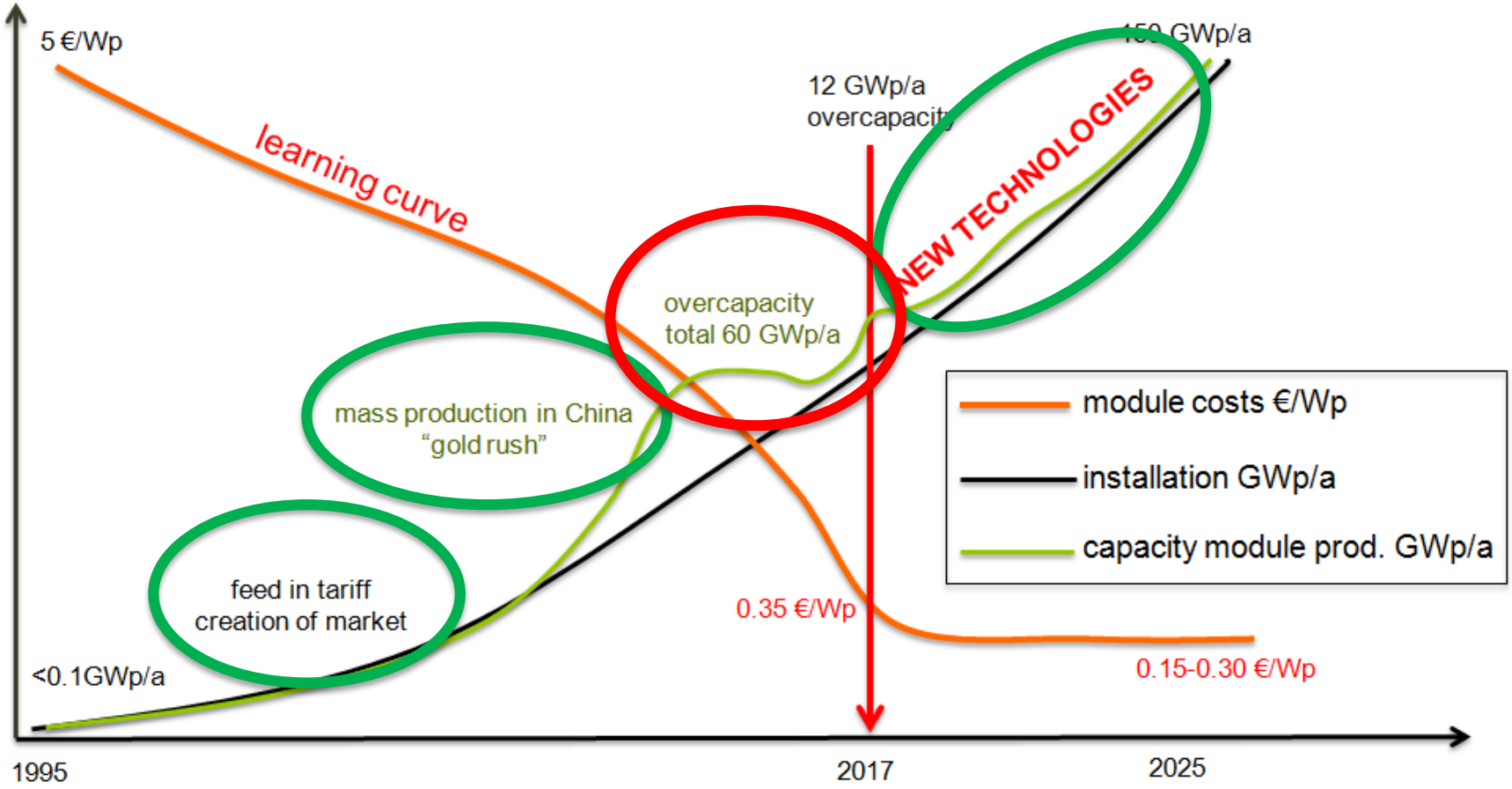


"First they ignore you, then they laugh at you, then they fight you, then you win."

Kopecek et al., PV international, issue 21, 2013 (updated for bifacial book 2018)

History, status and future of PV

International Solar Energy Research Center Konstanz



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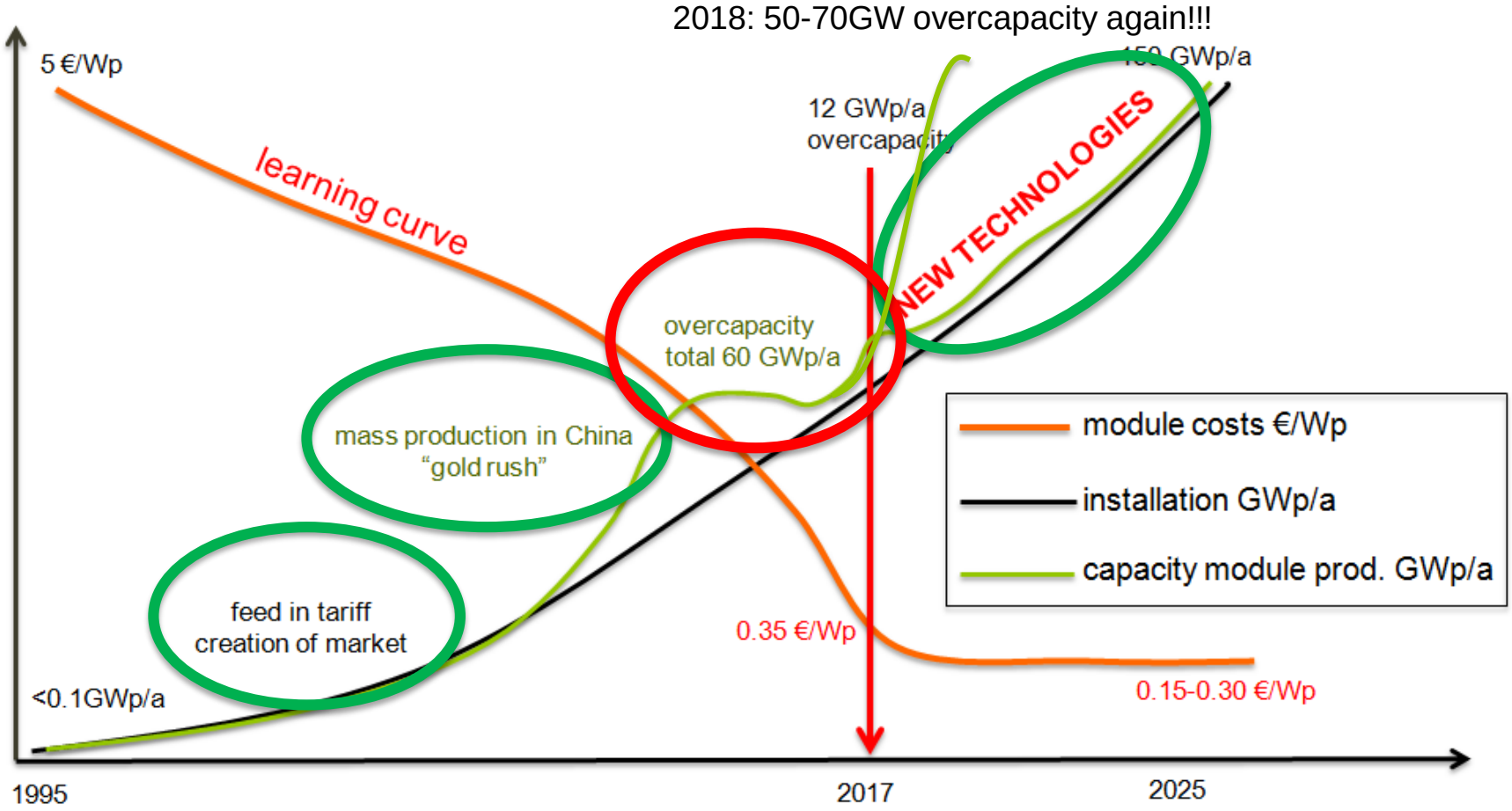
International Solar Energy Research Center Konstanz



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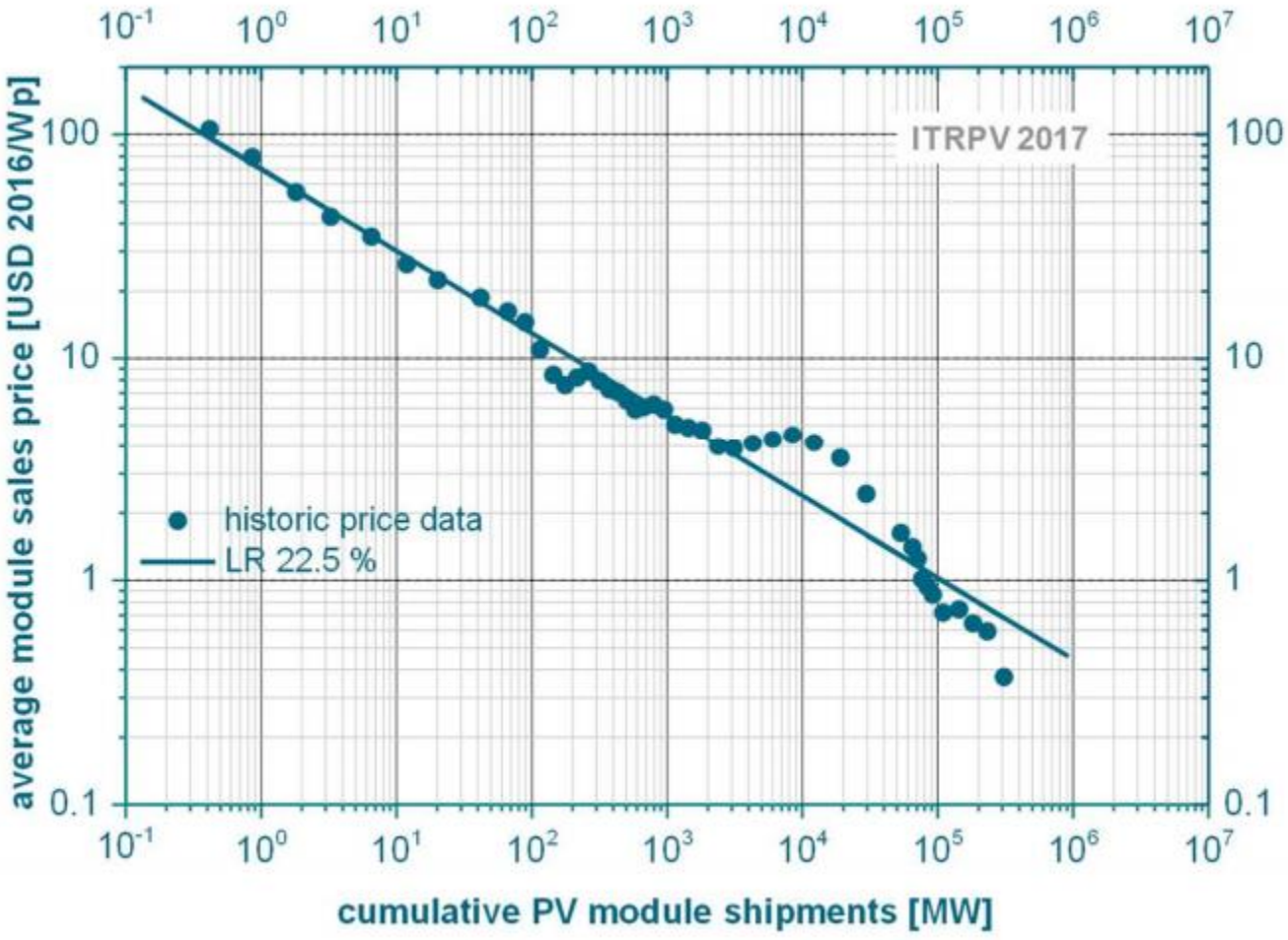
status of PV 2017: learning curve

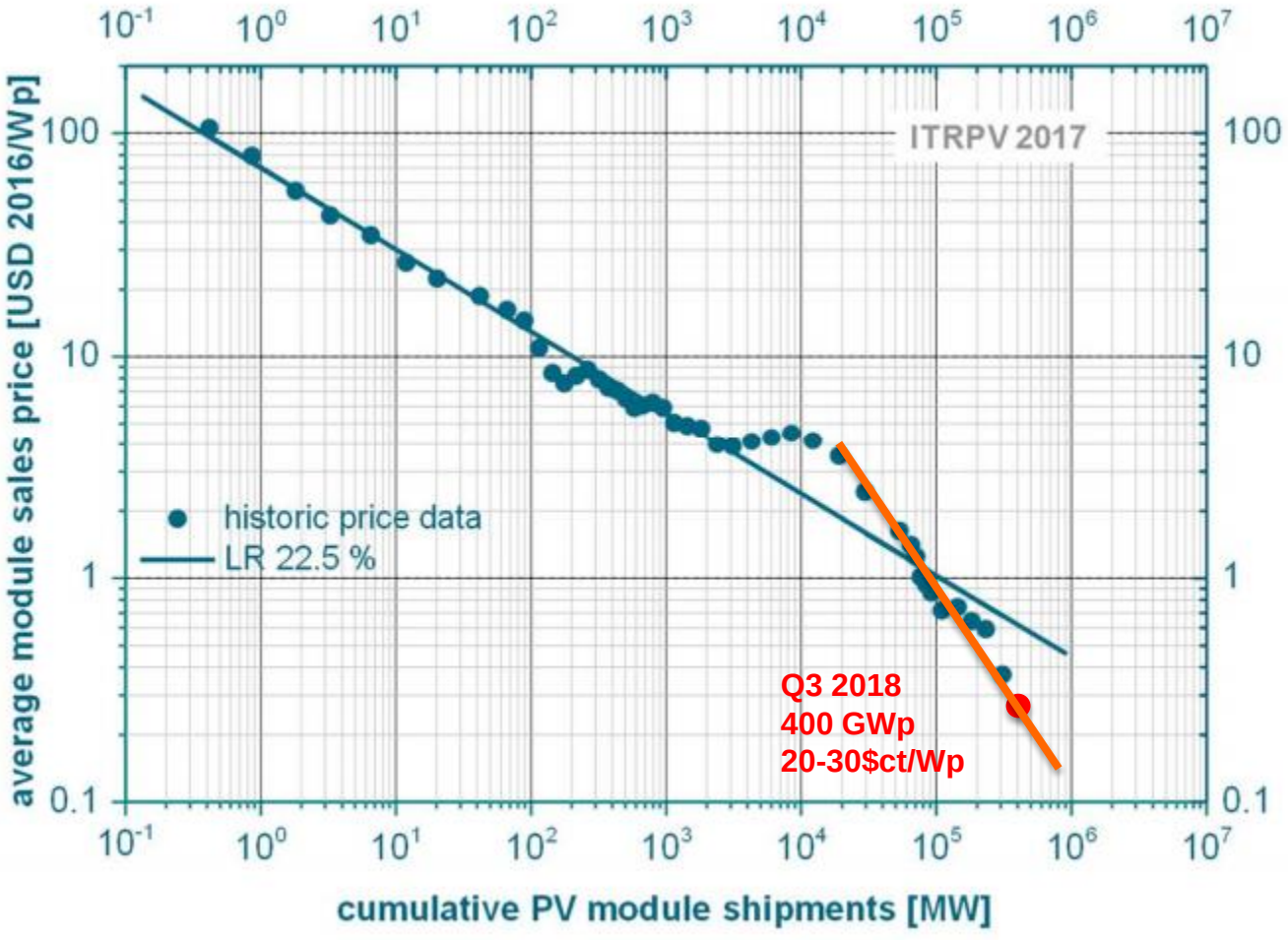
International Solar Energy Research Center Konstanz



ITRPV

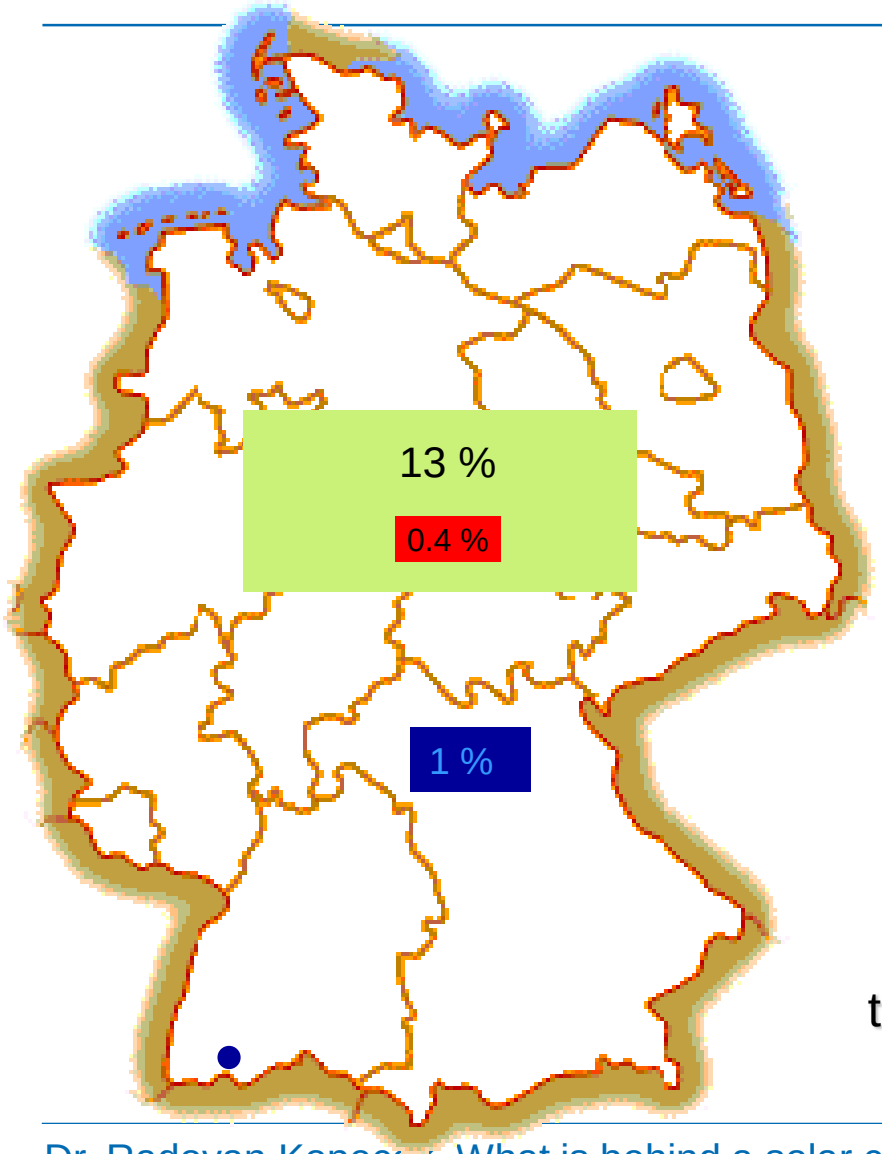
status of PV 2018: learning curve

International Solar Energy Research Center Konstanz



ITRPV

PV area needed for 100% solar electricity



356 970 km² Germany

45 000 km² built area

1 500 km² useful area on houses

3 500 km² for 100% solar electricity

today: ca. 245 km² 7% solar electricity

100% Renewable in Germany?

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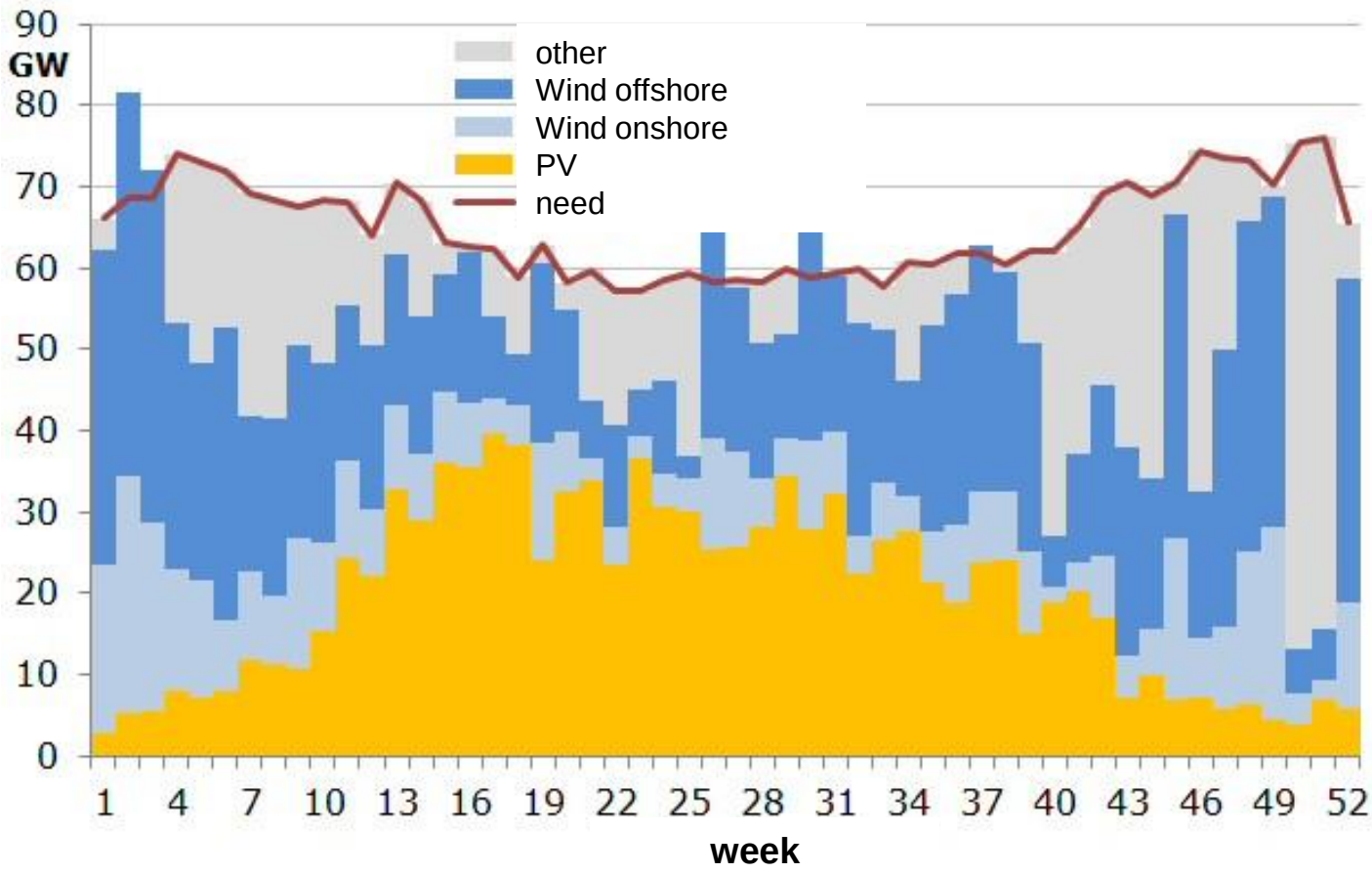

source: volker-quaschning.de

weekly electricity power need and production in Germany

200 GW PV, 100 GW wind power

Past and current situation in Germany

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- **2000: introduction of EEG with feed in tariff**

>> Market was created

>> 7GWp installations yearly resulted in >40GWp total PV power

>> German PV sector (also cell production) was booming

- **2013/2014: Cap and introduction of taxes on self consumption**

>> reduction to 1.5GWp installations in Germany yearly (goal 2,5 GW)

>> shakes out because of overcapacity

- **2018: Drop of import taxes on PV in EU**

>> more challenging for PV manufacturing in EU but possible

>> good for EPCs

>> installations in Germany >2GWp in 2019

- **2019: Drop of feed-in: 10,26 €ct/kWh to 8,33 €ct/kWh (roof-top)**

>> Reduction of installations in 2019 again

Current situation in Germany

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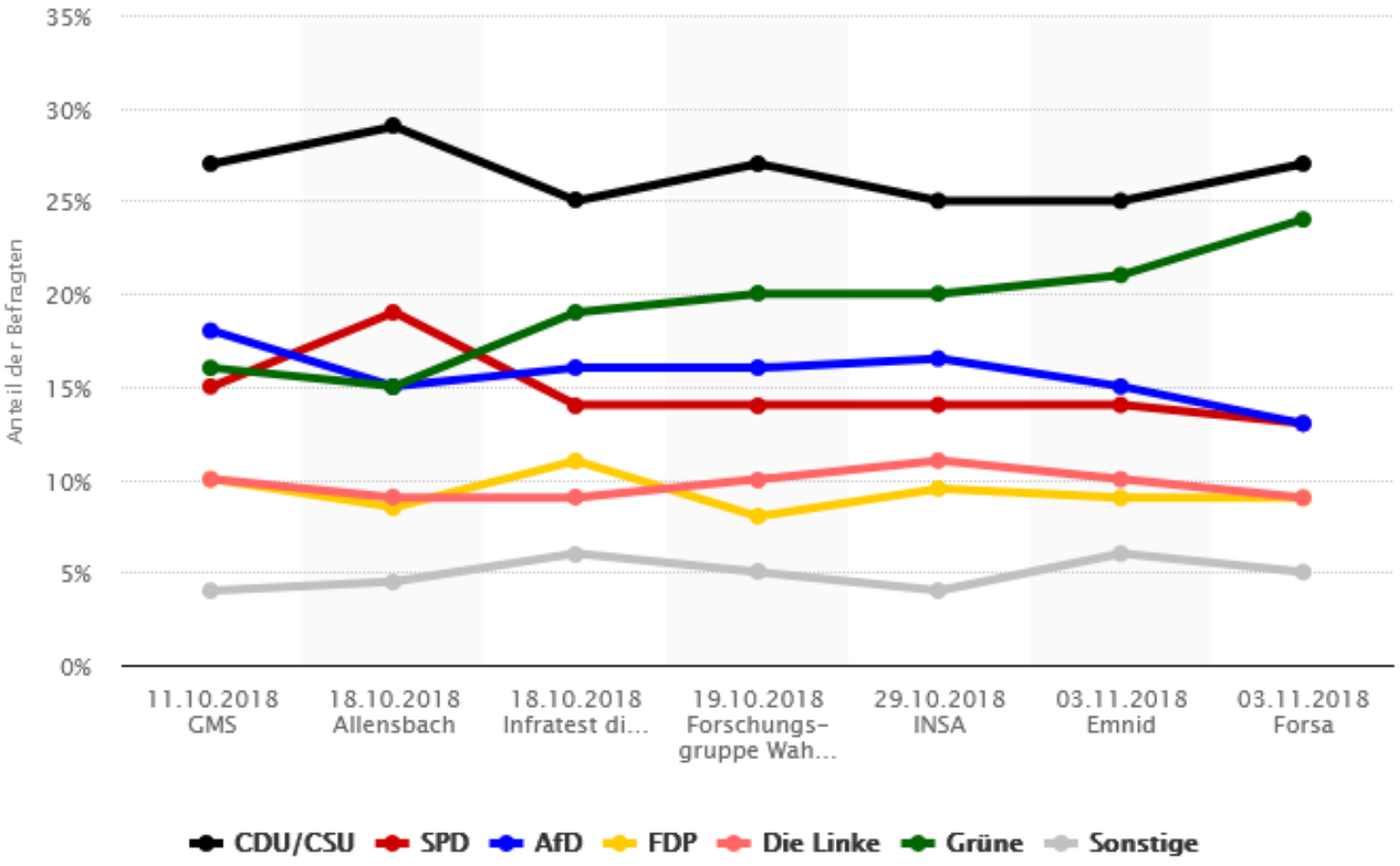

Current situation in Germany

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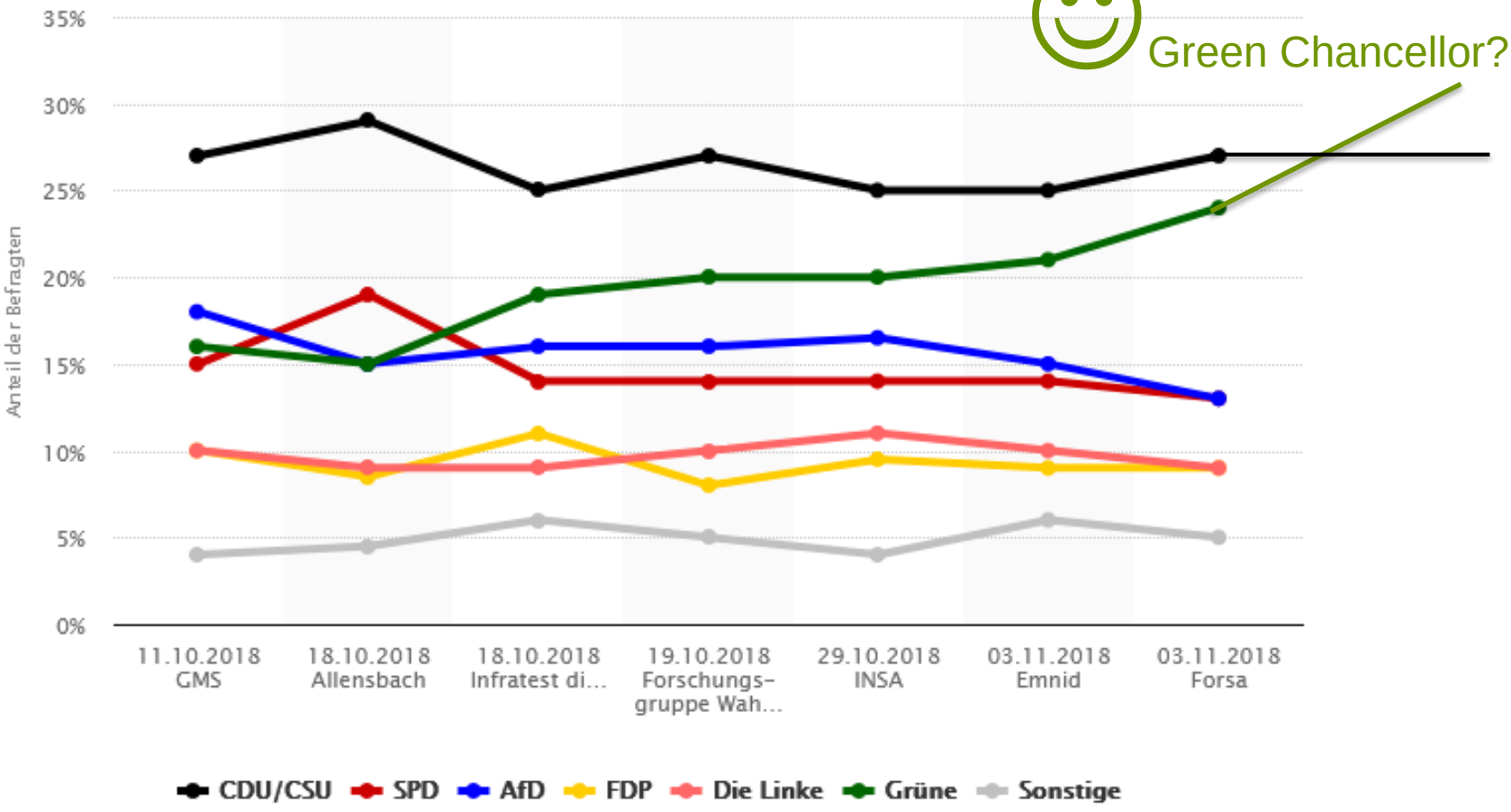
Green Chancellor?



Current situation in Germany: Hambacher Forst

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1970-2011

2018

Bifacial PV for lowest costs electricity

nature energy: bifaciality

International Solar Energy Research Center Konstanz

comment

Towards large-scale deployment of bifacial photovoltaics

Low photovoltaic module costs imply that increasing the energy yield per module area is now a priority. We argue that modules harvesting sunlight from both sides will strongly penetrate the market but that more field data, better simulation tools and international measurement standards are needed to overcome perceived investment risks.

R. Kopecek and J. Libal

Since the implementation of the feed-in tariff in Germany in 2000 and the mass production of solar cells and modules in China from 2005, photovoltaic (PV) module costs have decreased so steeply that monofacial modules are more than ten times cheaper today (0.35 US$ per watt peak, Wp, which is calculated using the power at standard measurement conditions) than they were in 2000 (6–8 US$ Wp^{-1})[1]. By the end of 2017, the accumulated PV system installation reached 386 GWp worldwide[2], and from 2022 onwards, it is expected that we will enter a TWp PV era[3] — PV will then be the leading energy technology across all types of electricity generation in terms of yearly installations[3].

While PV modules have become more cost-effective in the past 15 years, the balance of system (BOS) costs (including racking, cables, inverters, installation) and the maintenance costs have stagnated. A large part of these costs is proportional to the total area of the installed PV modules.

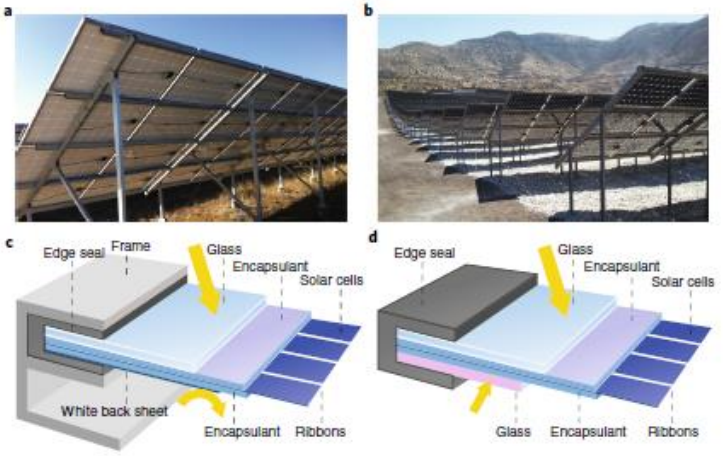

Fig. 1 | Monofacial and bifacial systems and modules. a–d, Pictures of monofacial (**a**) and bifacial (**b**) systems and cross sections of monofacial (**c**) and bifacial (**d**) modules. In the monofacial module, the solar cells are sandwiched by an encapsulant covered by glass on the front side and a non-transparent white

nature energy: bifaciality

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comment

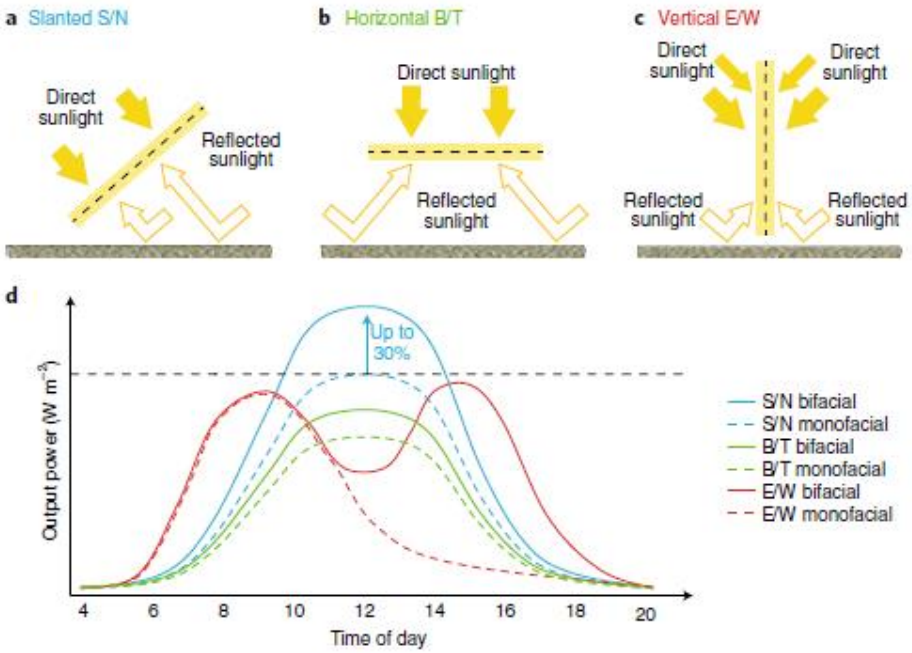

Fig. 2 | Most promising configurations for bifacial installations. a, Fixed-tilt module, slanted towards the Equator (S/N, South/North). Depending on the latitude of the installation, the inclination and row-to-row distances are optimized to provide the highest daily and yearly electricity generation. In the case of flat roof installations, the roof is often painted white (for example, for heat management of the building), which leads to high albedo values of 60–70%. In desert areas the natural albedo is around 25–40%, which can already lead to a bifacial gain of 15%. **b**, Horizontal (B/T, bottom/top) configuration, used for example for car ports. **c**, Vertical (E/W, East/West) geometry, used for example in sound blocking barriers. **d**, Resulting daily power generation curves compared to monofacial installations in the same configuration.

bifacial book

International Solar Energy Research Center Konstanz

Bifacial Photovoltaics: Technology, applications and economics

Editors: Radovan Kopecek and Joris Libal

Bifacial Photovoltaics: Technology, applications and economics provides an overview of the history, status and future of bifacial PV technology with a focus on crystalline silicon technology, covering the areas of cells, modules, and systems. In addition, topics like energy yield simulations and bankability are addressed. Illustrations are in full color.

Bifacial photovoltaic (PV) modules are able to utilize light from both sides and can therefore significantly increase the electric yield of PV power plants, thus reducing the electricity cost and improving profitability. Bifacial PV technology has a huge potential to reach a major market share, in particular when considering utility scale PV plants. In combination with simple tracking technology the total energy output of a PV power plant can be boosted to up to 50% compared to standard monofacial fixed tilt systems at about 10-20% additional costs. In addition different application fields are waiting for bifacial modules such as facades, car-ports, green-houses and other glass-intensive structures. Accordingly, bifacial PV is currently attracting increasing attention from involved engineers, scientists and investors.

Publication date: October 2018

Retail price: £115 / $150

Hardback: 300pp

ISBN: 978-1-78561-274-9

Product code: PBPO107

In 2016 the largest bifacial PV plant in Chile with ISC´s technology

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nominal power: 2.5MWp
effective power: 3.3MWpe

In 2016 the largest bifacial PV plant in Chile with bifacial tracking wit ISC´s technology

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In 2018 the largest bifacial PV plant in EU with 3MWp vertical installations

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In 2017 the lowest PV bid ever

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electricity costs from PV (utility scale)

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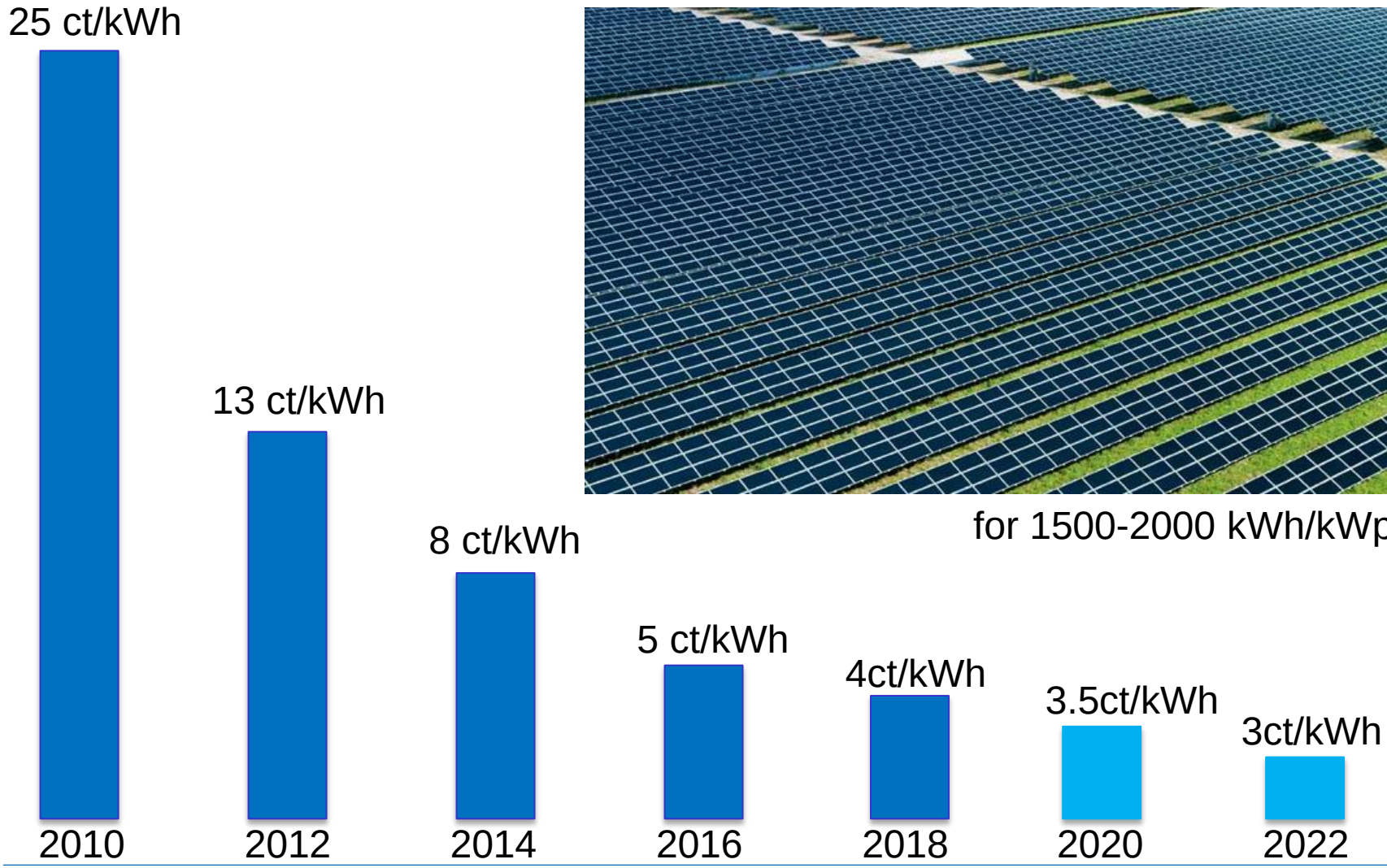
for 1500-2000 kWh/kWp



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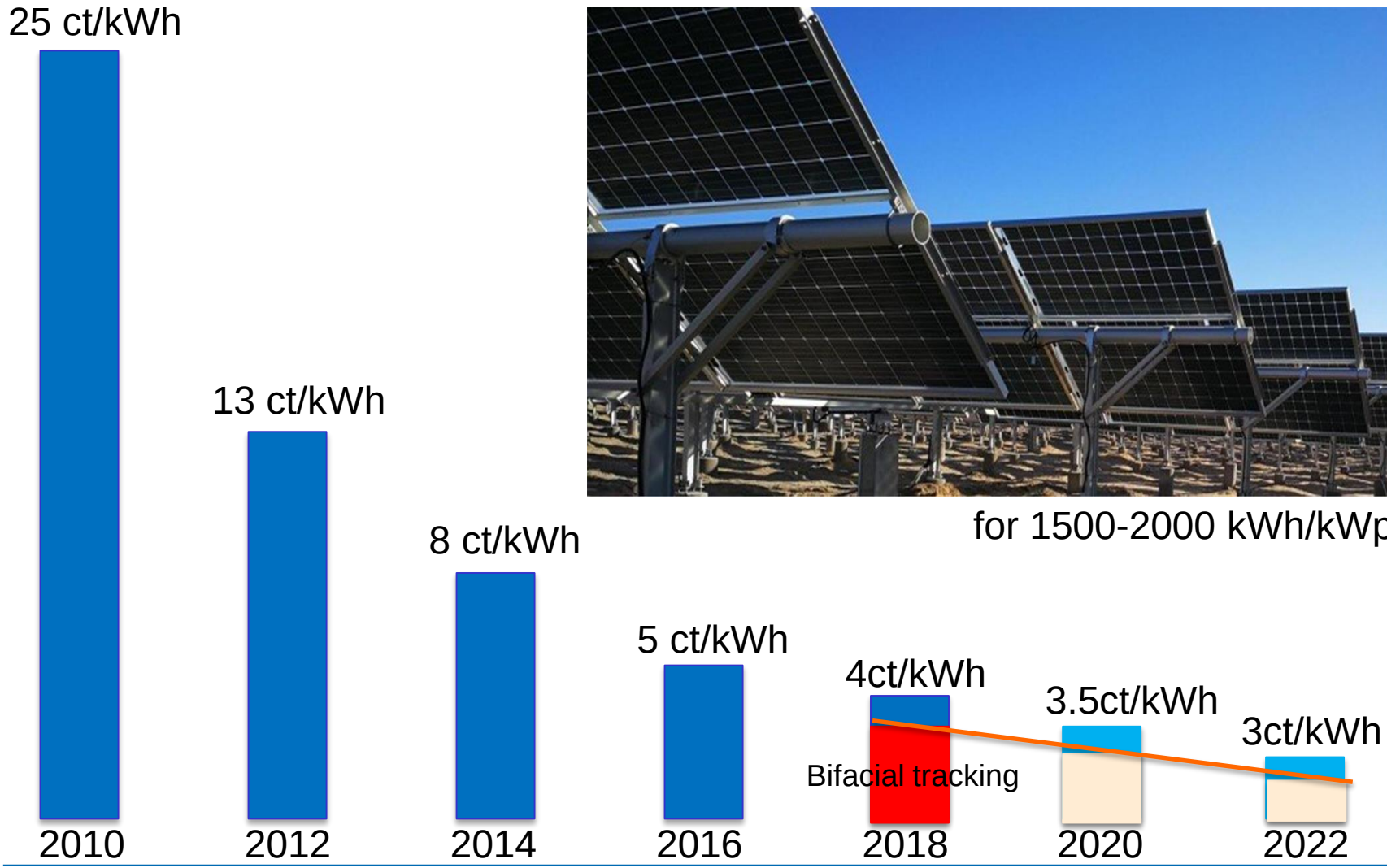

summary

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- Renewables are coming with huge impact as costs are dropping rapidly and environmental awareness is increasing
- PV, wind, biomass, water and thermal energy applications will win (Hermann Scheer:“From buried energies to energies above the ground!“)
- With different mix of renewables a 100% energy supply is possible: in addition power to gas and other storages (water, batteries) are to be further developed
- PV always was and still is underestimated in terms of growth and cost reduction potential
- In 2021/22 we will enter 1TW PV era and reach in some places costs of around 1USct/kWh >> then everyone can afford electricity
- Bifacial PV will lead as first technology to costs of 1USct/kWh

Let us move together to
costs below 1USct/kWh