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Quelle:SMA

Levelized cost of electricity of renewable and conventional energy sources in Germany and Senegal

2nd German-Senegalese Economic Summit

Prof. Dr.-Ing. Bernd Engel

Düsseldorf, November 7th, 2014

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Bernd Engel

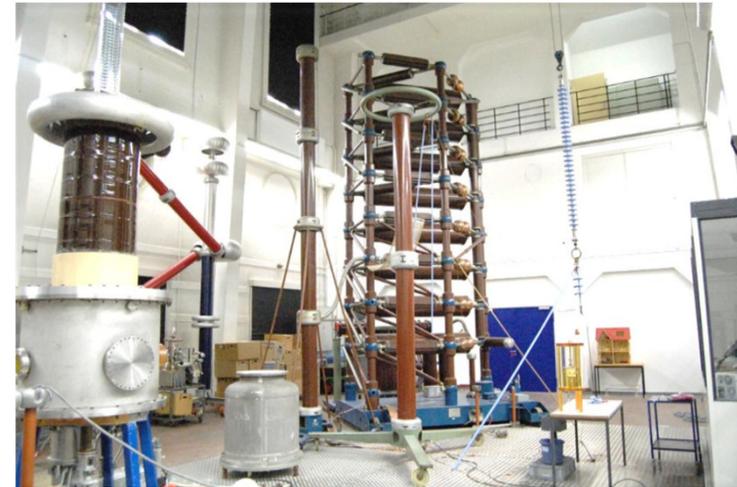
- Since 2011 Professor at Technical University Braunschweig for components for sustainable energy systems at the elenia institute
- Representative of the Board for grid integration at SMA Solar Technology AG
- Member of the WG system stability at the Federal Ministry for Economics and Energy (BMWi)
- Vice President of the Forum Network technology/Network operation (FNN) in VDE
- 2003 – 2011 Senior Vice President SMA Technology AG (solar inverter)
- 1996 – 2003 Site Engineering Director, Alstom Transport (trains)



elenia – Institute of High Power Technology and Electrical Power Systems

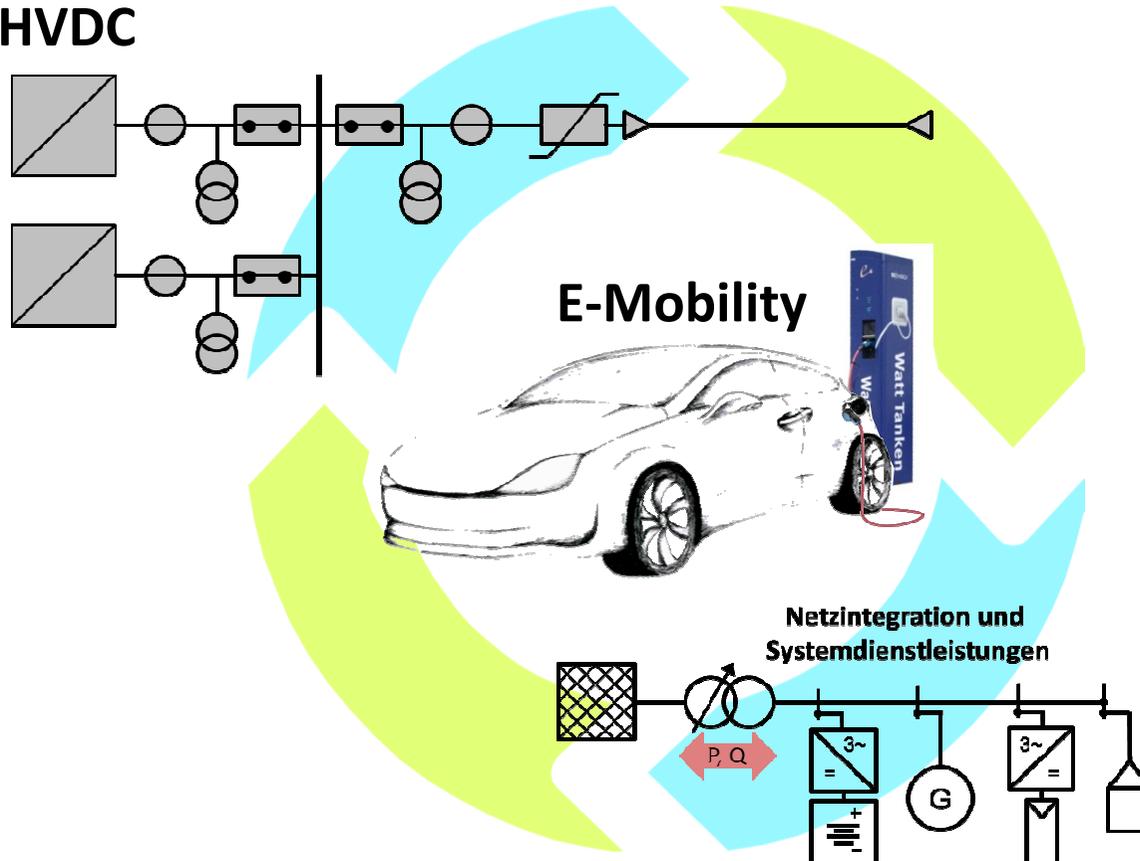
elenia in numbers

- 2 university professors
- 36 scientific employees
- 8 employees in administration/workshop
- approx. 70 bachelor/master theses per year
- approx. 75 student employees
- approx. 50 scientific publications per year



Research at elenia

Large Scale Integration Offshore Wind + HVDC



Active distribution network (Smart Grid)

Energy policy (1)

„Historical 20-20-20-20 decisions“ of the **European Council** dated March 8th/9th, 2007 under German Presidency, to limit the average global temperature rise to 2 °C

Until **2020...**

- **20 %** reduction of the **greenhouse gases emissions** compared with 1990
- **20 %** rise of the **Energy efficiency**
- **20 % share of the Renewable Energies** in the primary energy consumption



Energy policy (2)

After the nuclear disaster of the Fukushima nuclear power plant caused by earthquake and tsunami dated March 11th, 2011 shutdown of the seven oldest German nuclear power plants and of nuclear power plant Krümmel.



Quelle: Wikipedia

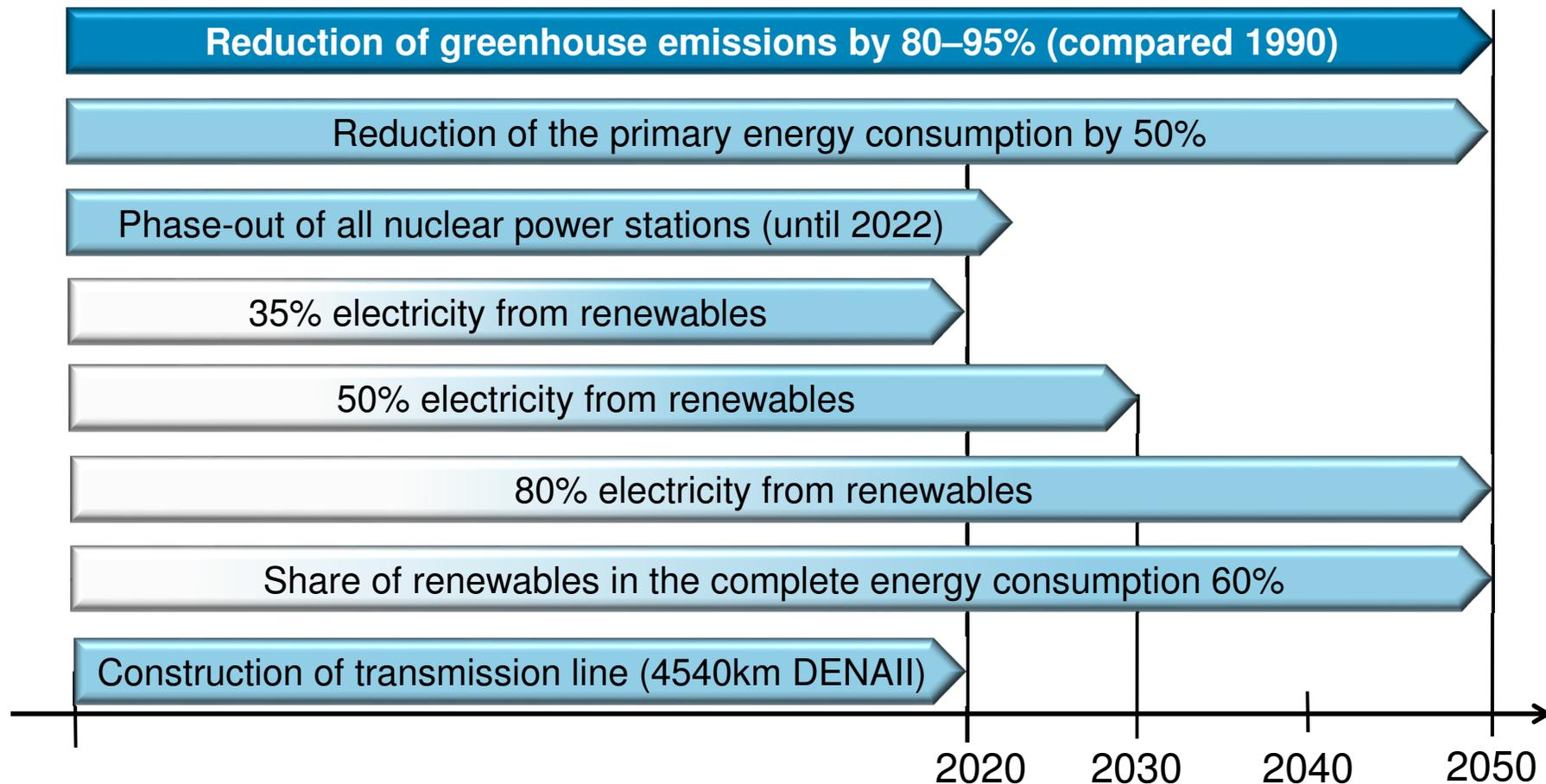
On June 30th, 2011 the German parliament decided on the „Energiewende“ (energy revolution), a package of 7 laws including the phase out of the nuclear power plants until 2022 and the development of the renewable energies, e.g.:

- *13. Change of the „nuclear law“*
- *Change of the renewable energy act*

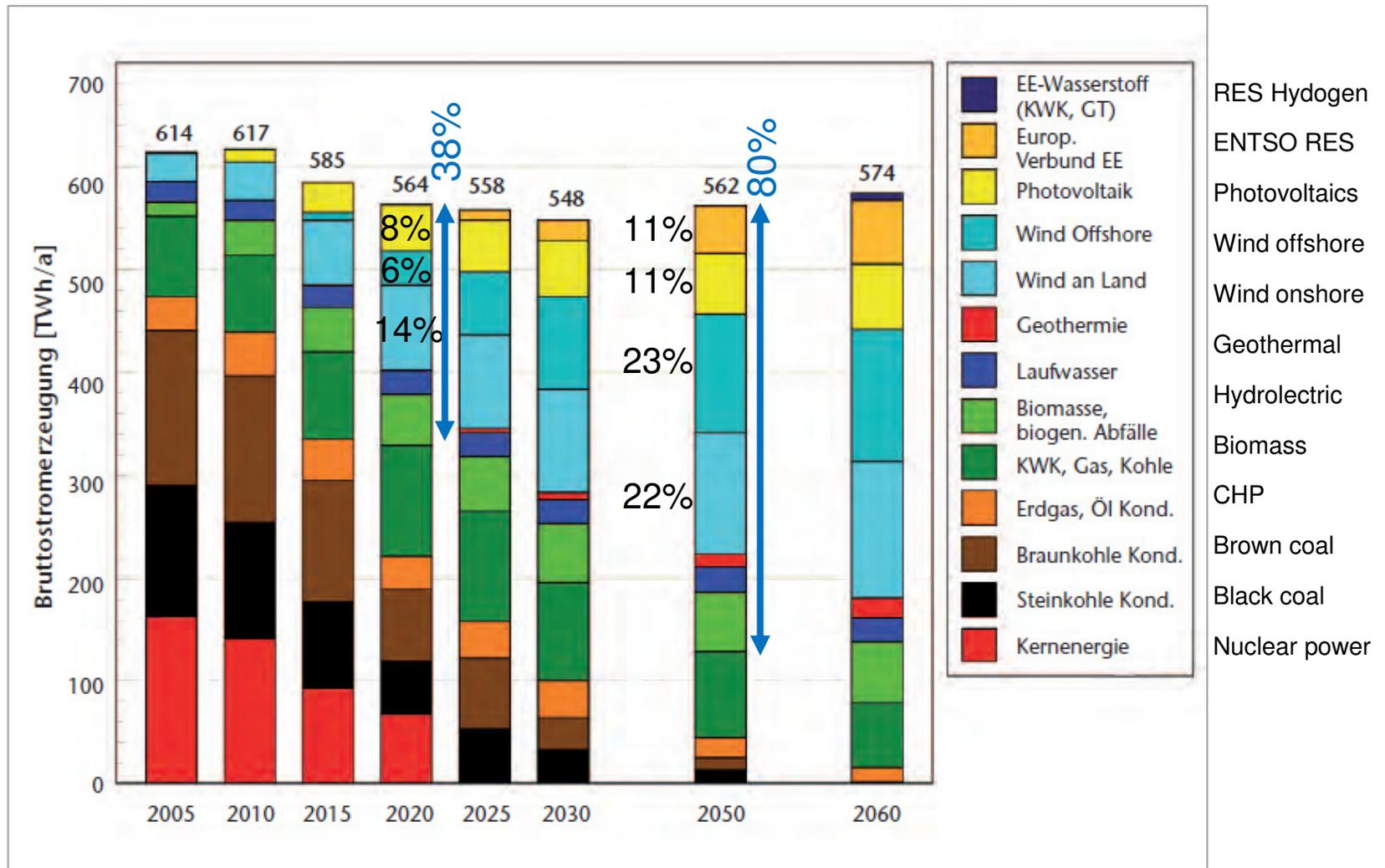


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Marc-Steffen Unger

Targets of the „Energiewende“ in Germany



Pilot study 2011 of the German Environment Ministry – Shares in the electricity production



Source: Nitsch 2011



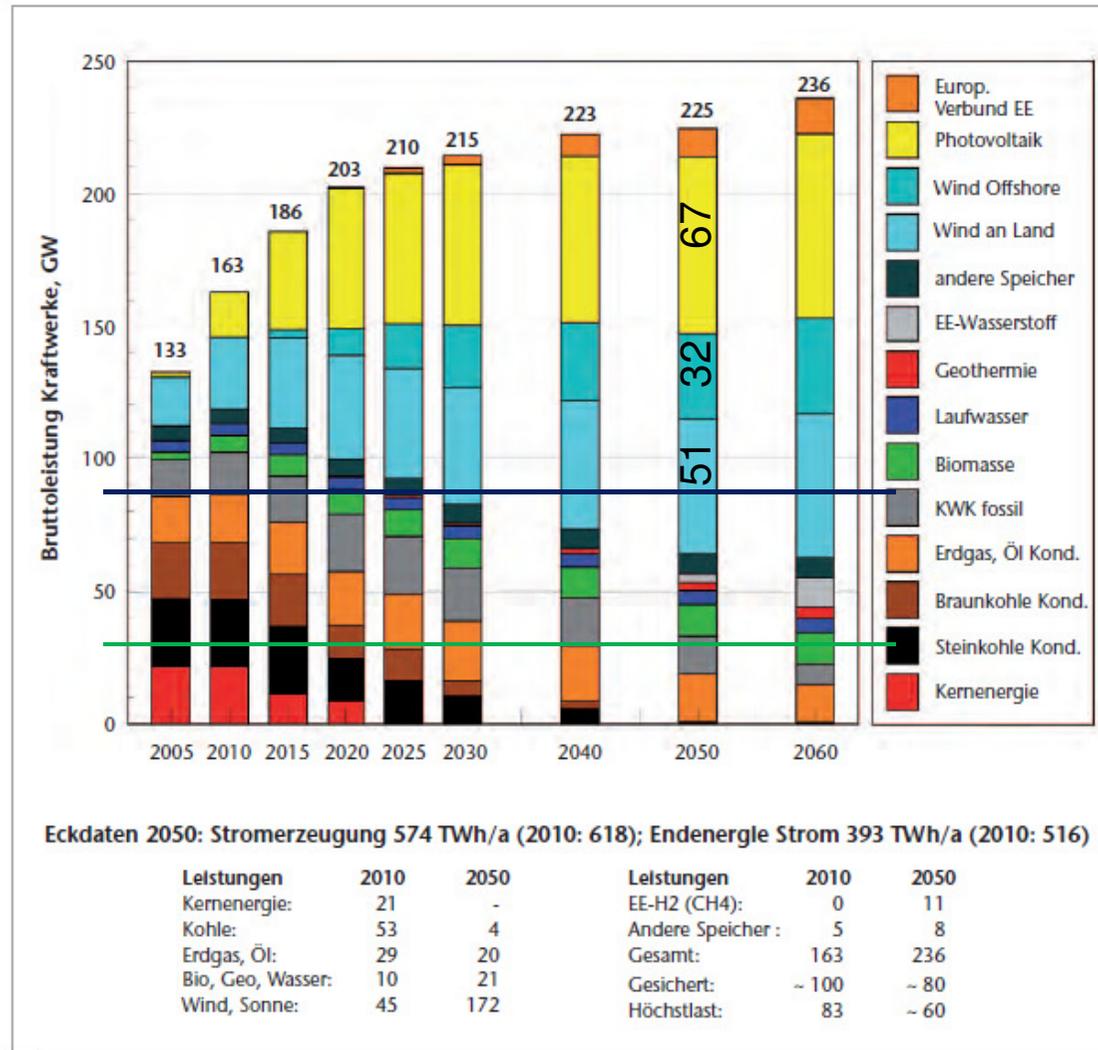
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Pilot study 2011

– capacity of the different sources

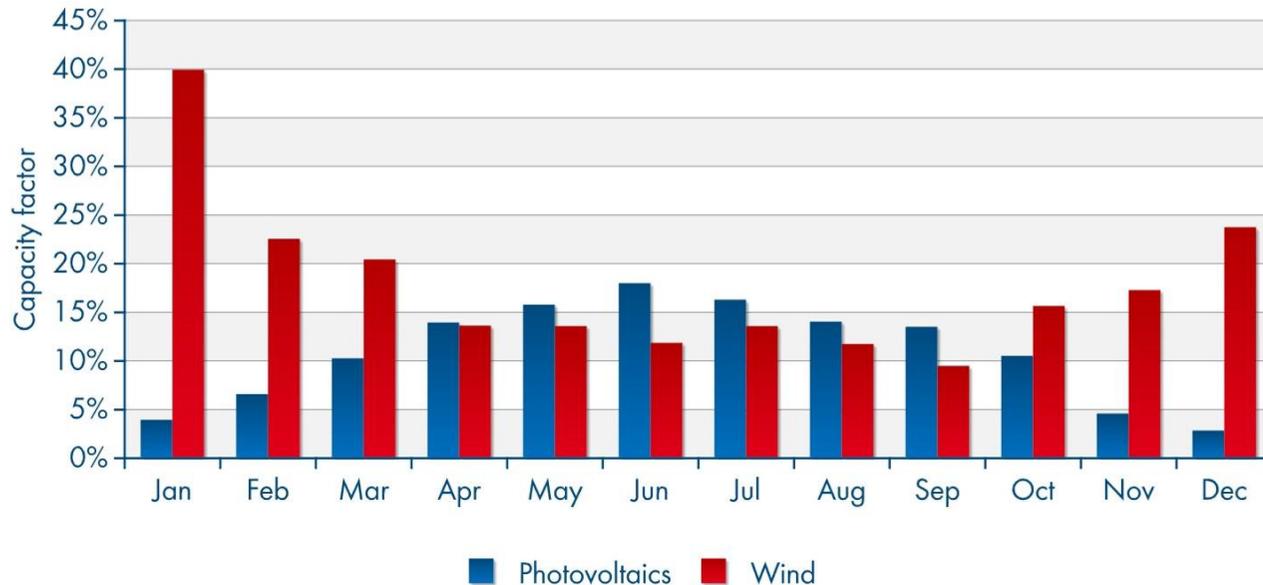
Peak load
83 GW

Low load 30 GW



Source: Nitsch 2011

Wind and PV complement one another



Quelle: ISET, Kassel

Average wind and PV feed-in, Germany, 2005



Quelle: LichtBlick AG

20 kW_{el} Mini-CHP from Volkswagen AG and LichtBlick AG

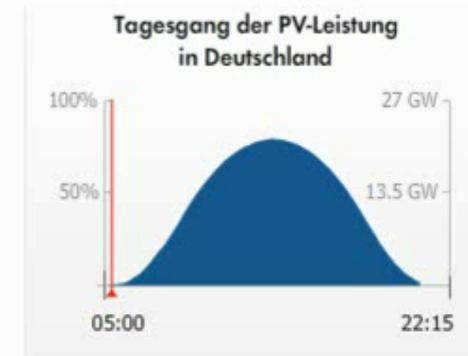
- ▶▶ **Wind** and PV complement one another during the 4 seasons
- ▶▶ Fluctuating renewable energies can be compensated by controlled, decentral **mini-CHP**



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Das leistet Photovoltaik in Deutschland

Relative Leistung vom 25.05.2012 - 5:30 Uhr



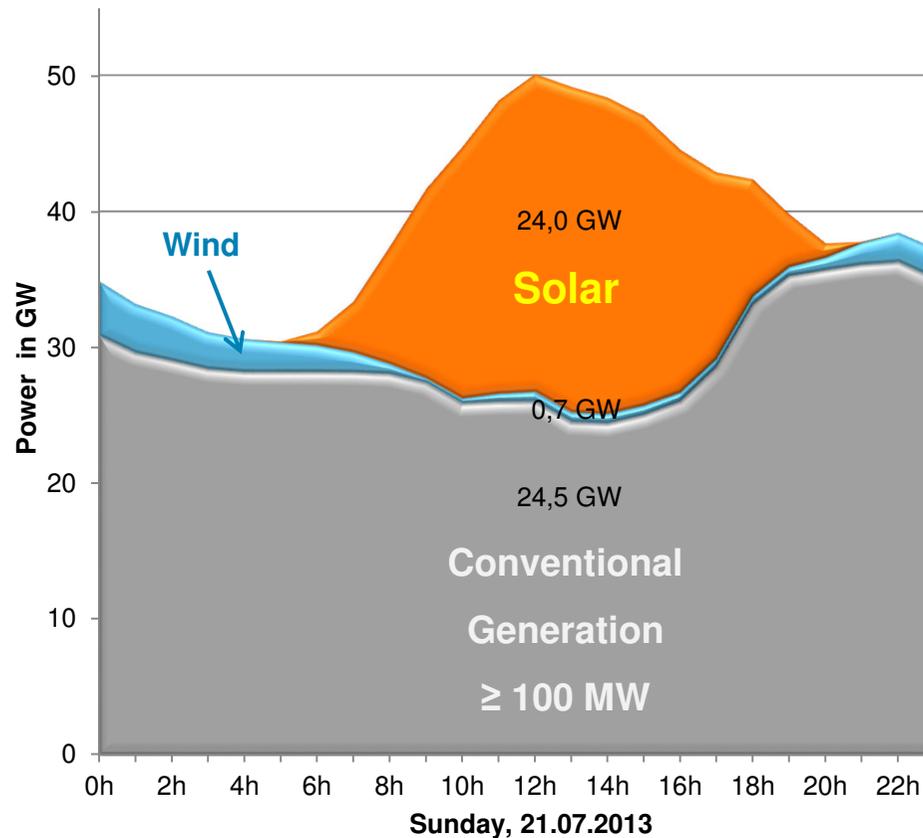
*Hochgerechnete Leistung

aller lt. Bundesnetzagentur am Stichtag
31.03.2012 installierten PV-Anlagen mit
insgesamt 26.63 GW Nennleistung.

(<http://www.sma.de/de/news-intos/pv-leistung-in-deutschland.html>)

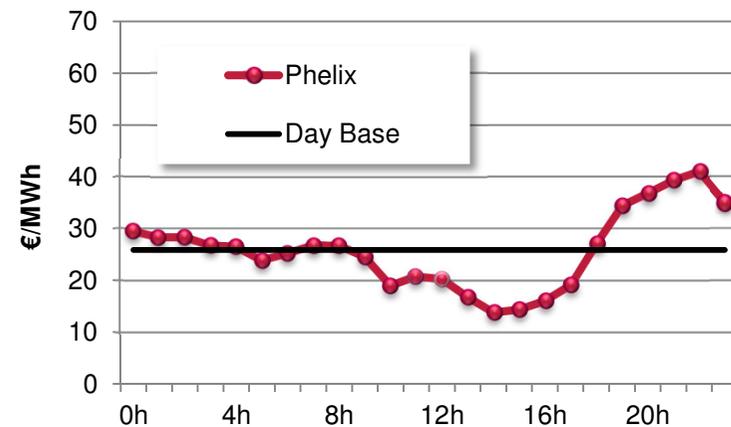
PV is now major column in the German generation mix

▶▶ PV replaces peak load generation



Daten: EEX-Transparenzplattform, Grafik: Soyck

- > 48,8 % PV share in Germany at a sunny Sunday at noon
- > 21,5% PV share in the day energy production (204 GWh)



Daten: EEX, Grafik: Soyck



Winter 2011/2012: Germany exports (PV) electricity to „nuclear“ France

ENERGIE - 06/02/2012 | 17:32 - 585 mots

L'Allemagne exporte de l'électricité vers la France

Tweet < 32

J'aime

Envoyer

47 « J'aime ». Inscription pour voir ce qu'aiment vos amis.



Copyright Reuters

Par Dominique Pialot

En dépit du froid et du nombre de centrales nucléaires divisé par deux, l'Allemagne résiste bien à la vague de froid grâce à ses centrales conventionnelles et à sa production d'énergie solaire. Et elle réussit à exporter de l'électricité vers la France.

French Wallstreet Journal
La Tribune, Feb. 6th, 2012:

“Germany exports
electricity to France

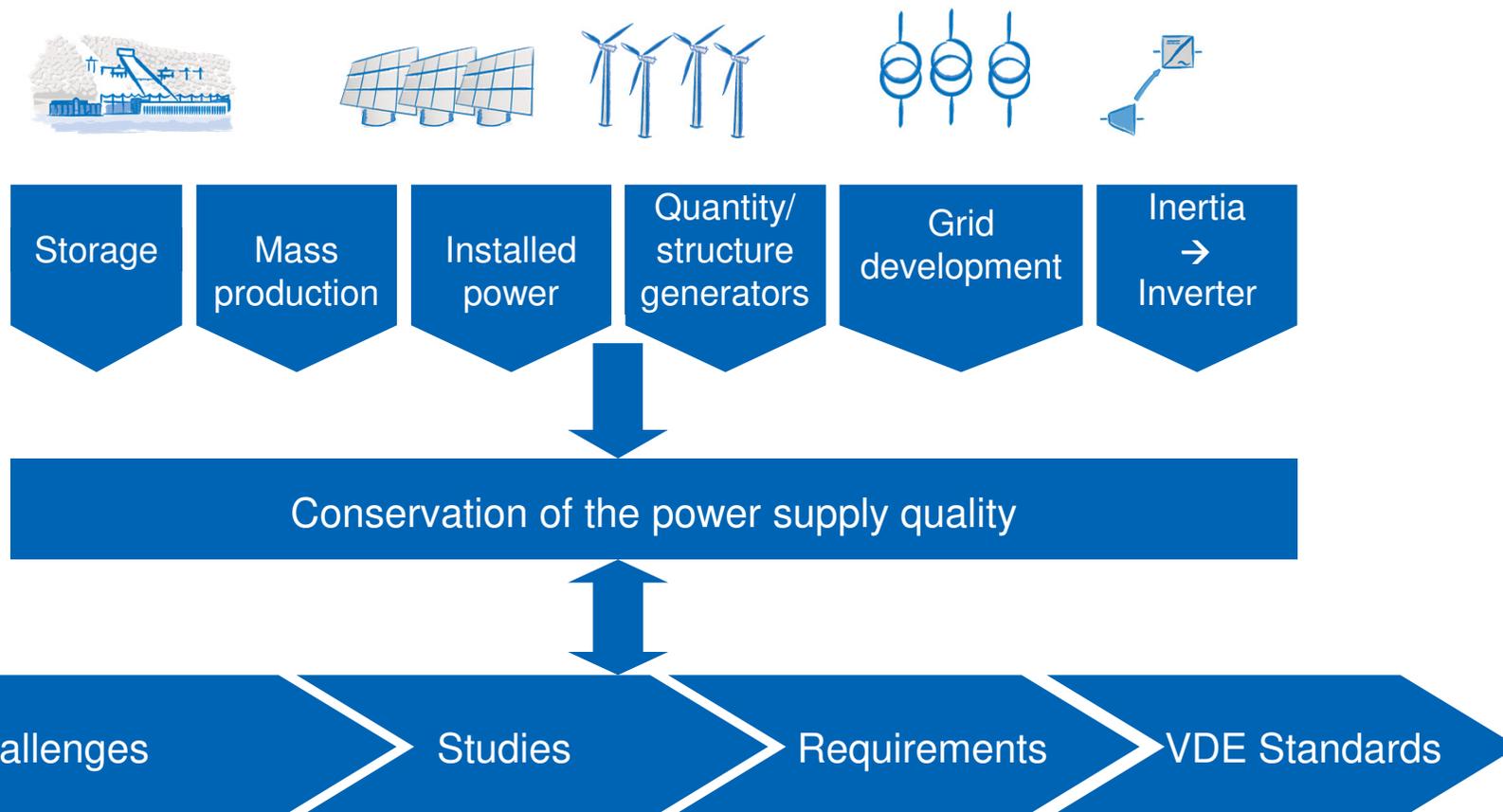
Despite of the cold and of halving the number of nuclear power stations Germany is resisting well the cold wave **thanks to** conventional power stations and **the solar energy**. And Germany manages to export electricity to France...”



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16.09.2013 | Prof. Bernd Engel | 7th PTB Seminar of Energy Seite 14

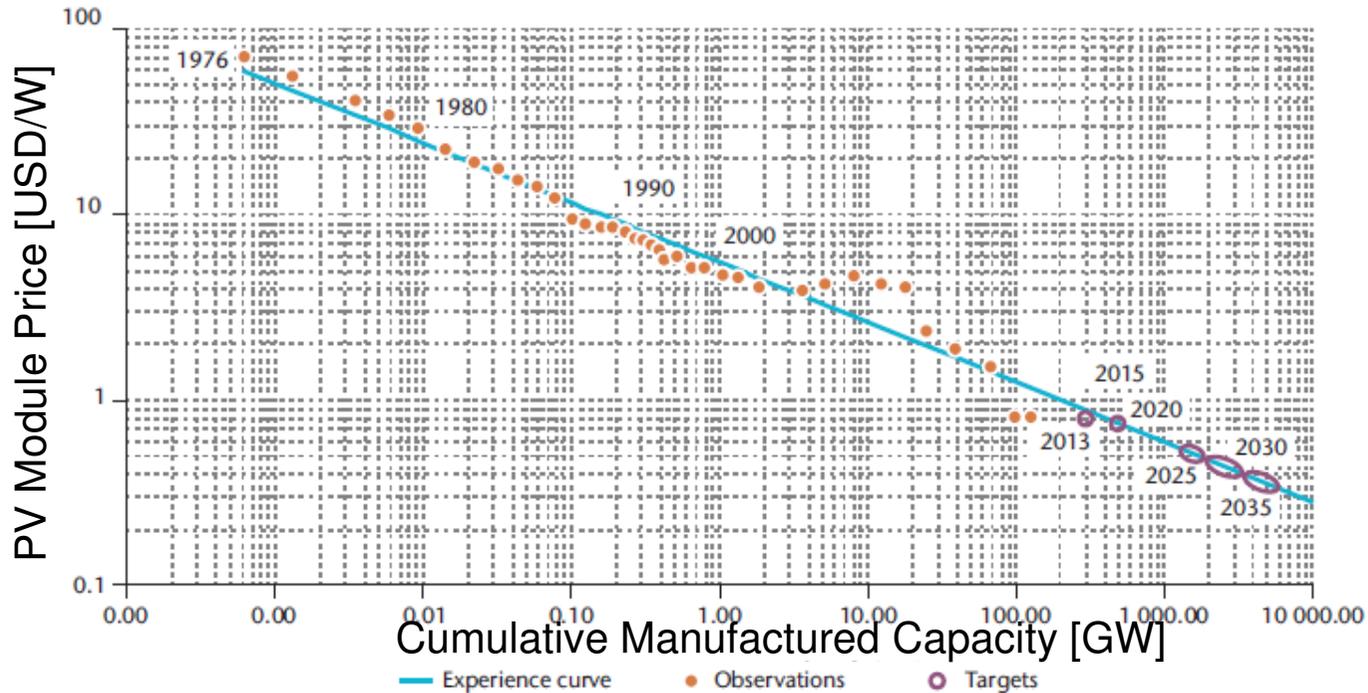
elenia
Institut für Hochspannungstechnik
und Elektrische Energieanlagen



- In FNN grid operators, the industry, scientists and authorities cooperate closely
- By law all VDE standards are mandatory in Germany

Photovoltaic has the highest cost reducing potential of all energies

Figure 10: Past modules prices and projection to 2035 based on learning curve



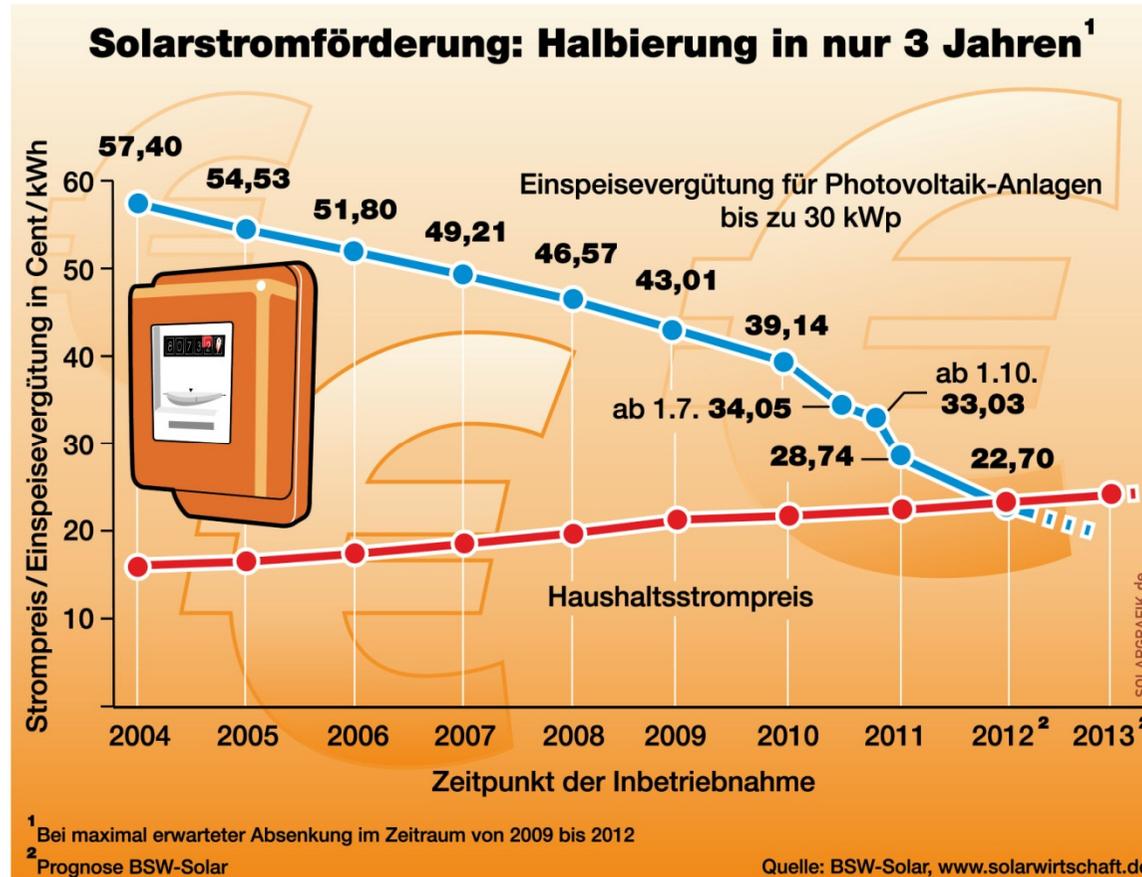
Notes: Orange dots indicate past module prices; purple dots are expectations. The oval dots correspond to the deployment starting in 2025, comparing the 2DS (left end of oval) and 2DS hi-Ren (right end).

KEY POINT: This roadmap expects the cost of modules to halve in the next 20 years.

» With each doubling of the installed power the prices fall by 25 %

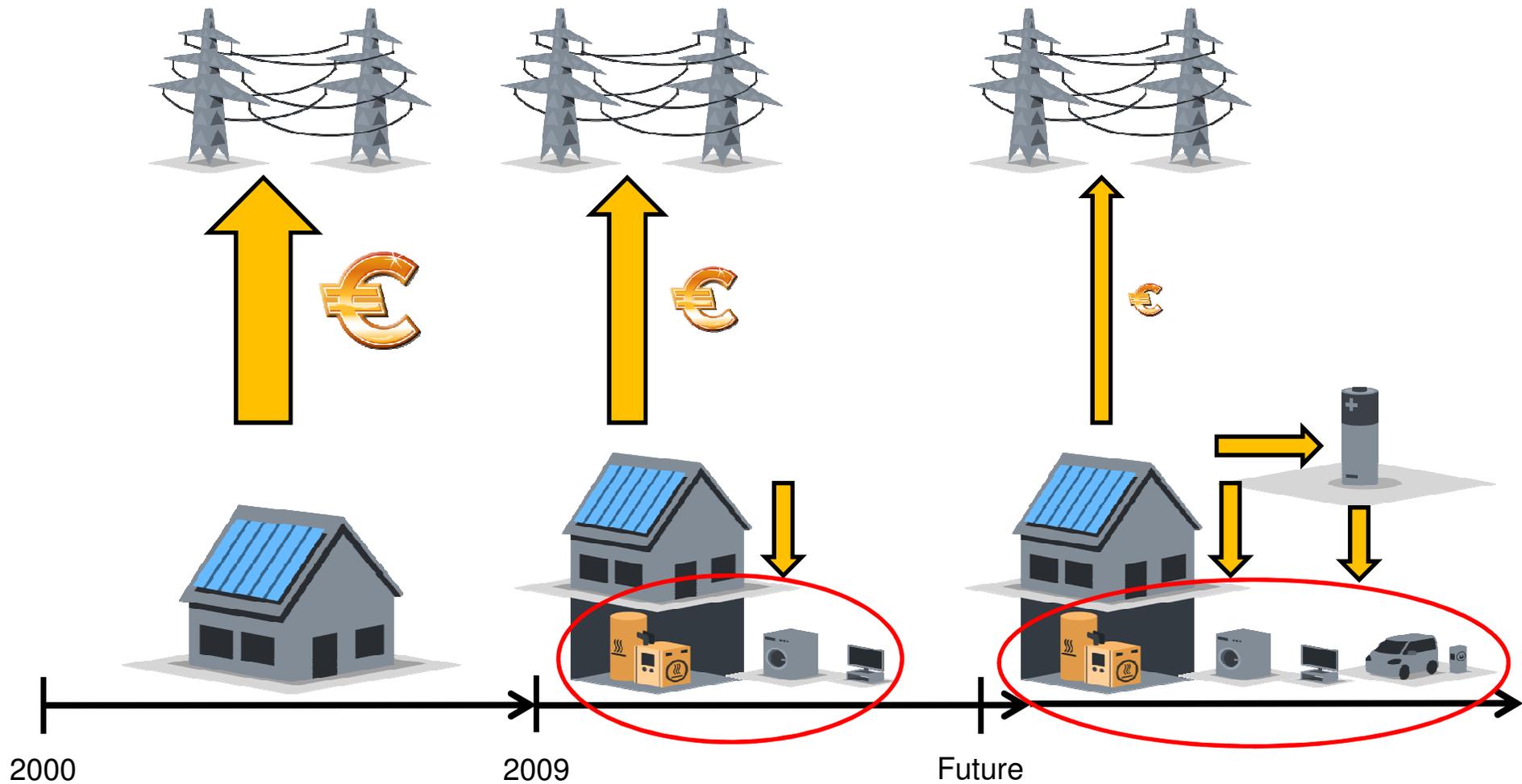
Source: IIEA Technology Roadmap Solar Photovoltaic Energy 2014 Edition

In 2012 Feed-in tariff is below the household tariff

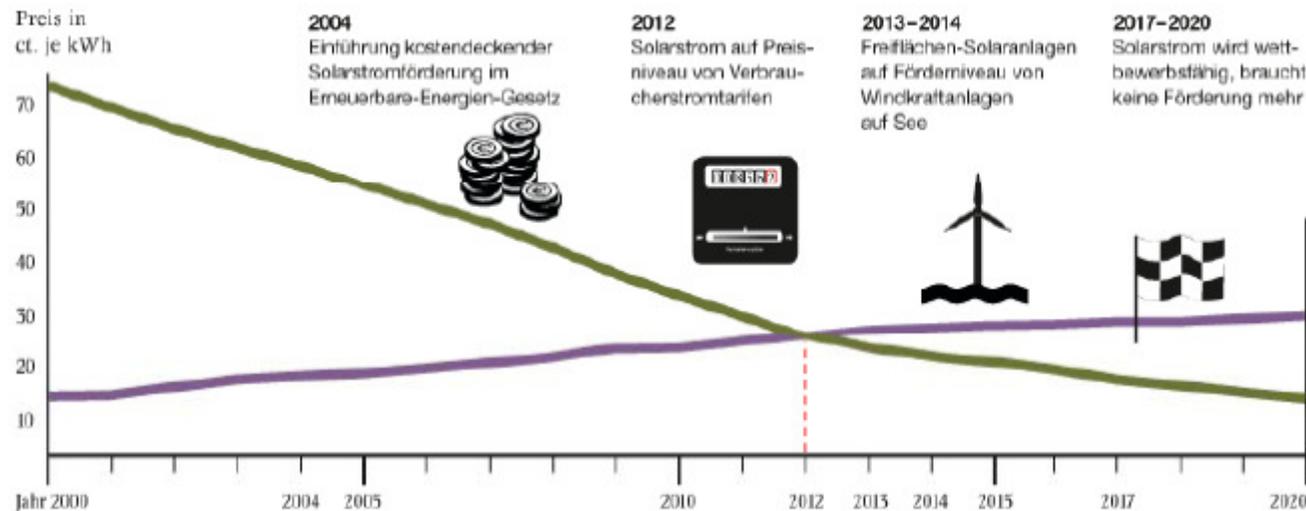


▶▶ In 2012 grid parity is reached

Paradigm Shift: From „Feed-in“ to „Self Consumption“



The new PV feed-in tariffs from 1.4.2012 are below Offshore-Wind feed-in tariff



- Solarstromerzeugungskosten (wie sie sich aufgrund fallender Preise für Solaranlagenssysteme entwickelt haben und voraussichtlich weiter entwickeln)
- Verbraucherstrompreis (wie er sich aufgrund steigender Kosten für fossile Kraftwerke entwickelt hat und voraussichtlich weiter entwickelt)

Quellen: Bundesumweltministerium (Leitstudie 2010), BSW-Solar (PV-Roadmap)

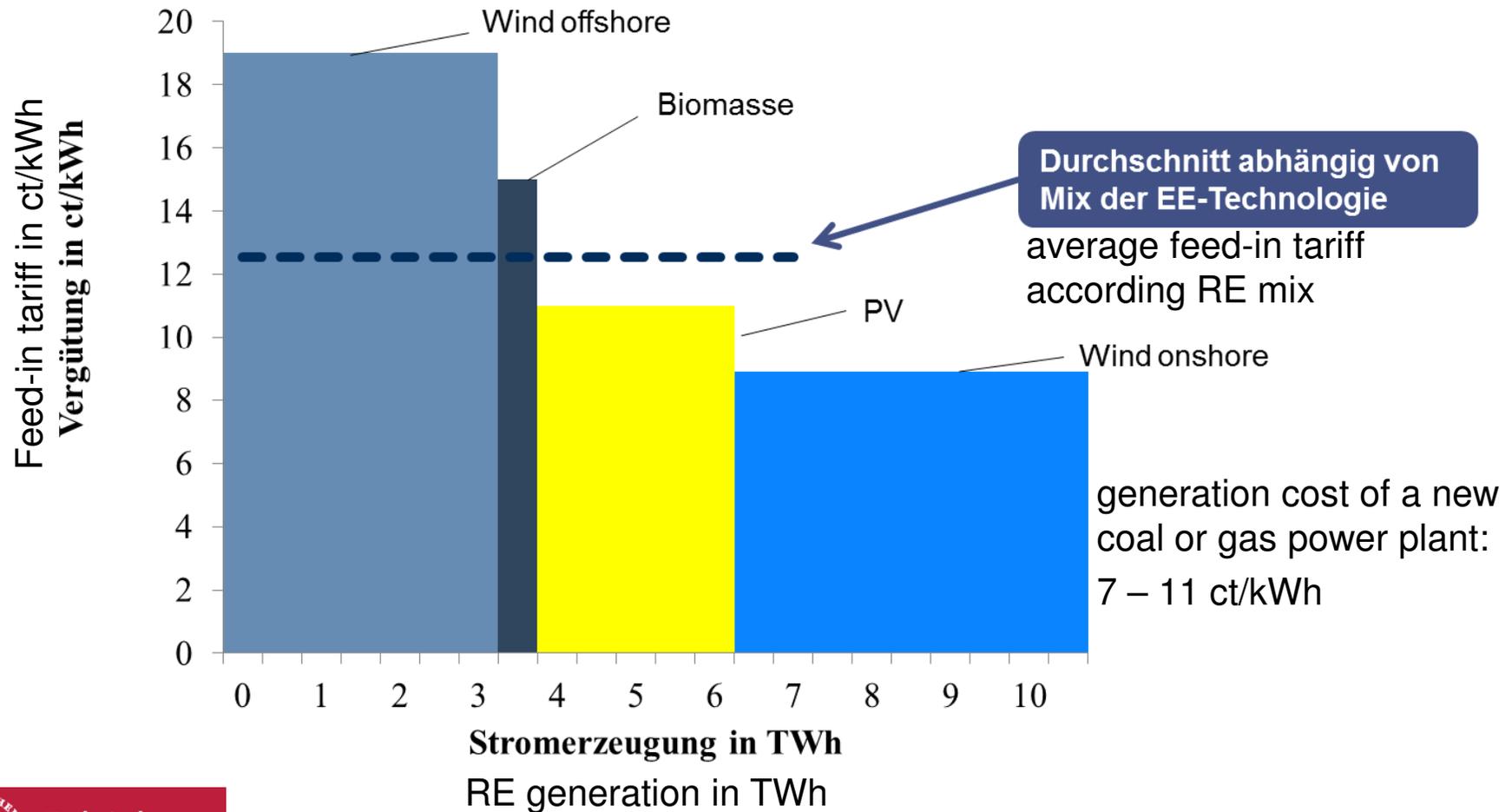
Feed-in Tariff PV for 20 years:

- 0-10 kWp: 12.65 ct/kWh
- >1000 kWp: 8.76 ct/kWh

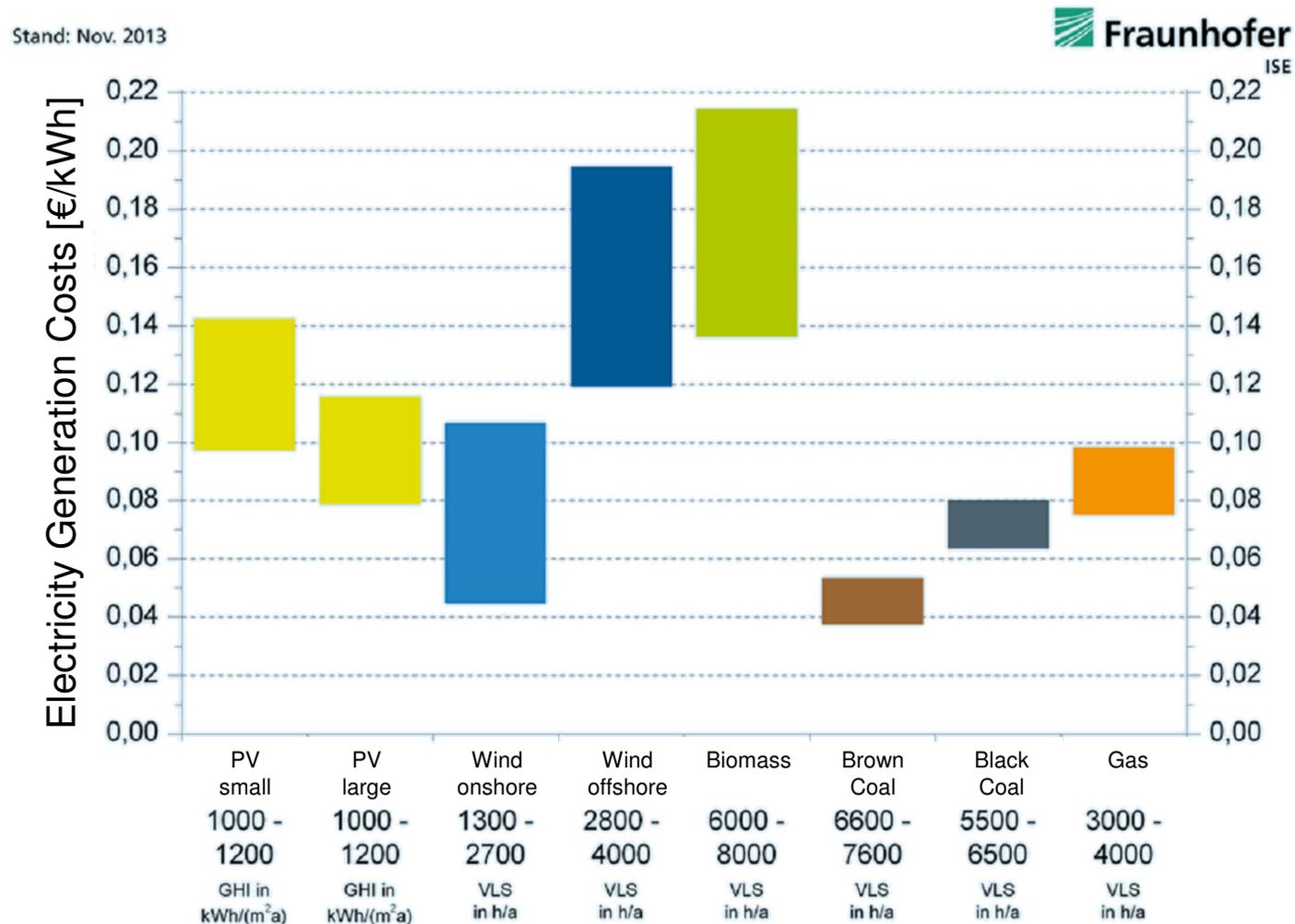
Comparison Offshore-Wind:

19 ct/kWh (for 8 years)
 then 15 ct/kWh
 (for e.g.. 4-5 years)
 then 3.5 ct/kWh for the remaining time

New guideline German Government 01/2014 for next years: Distinction cheap and expensive renewable energies

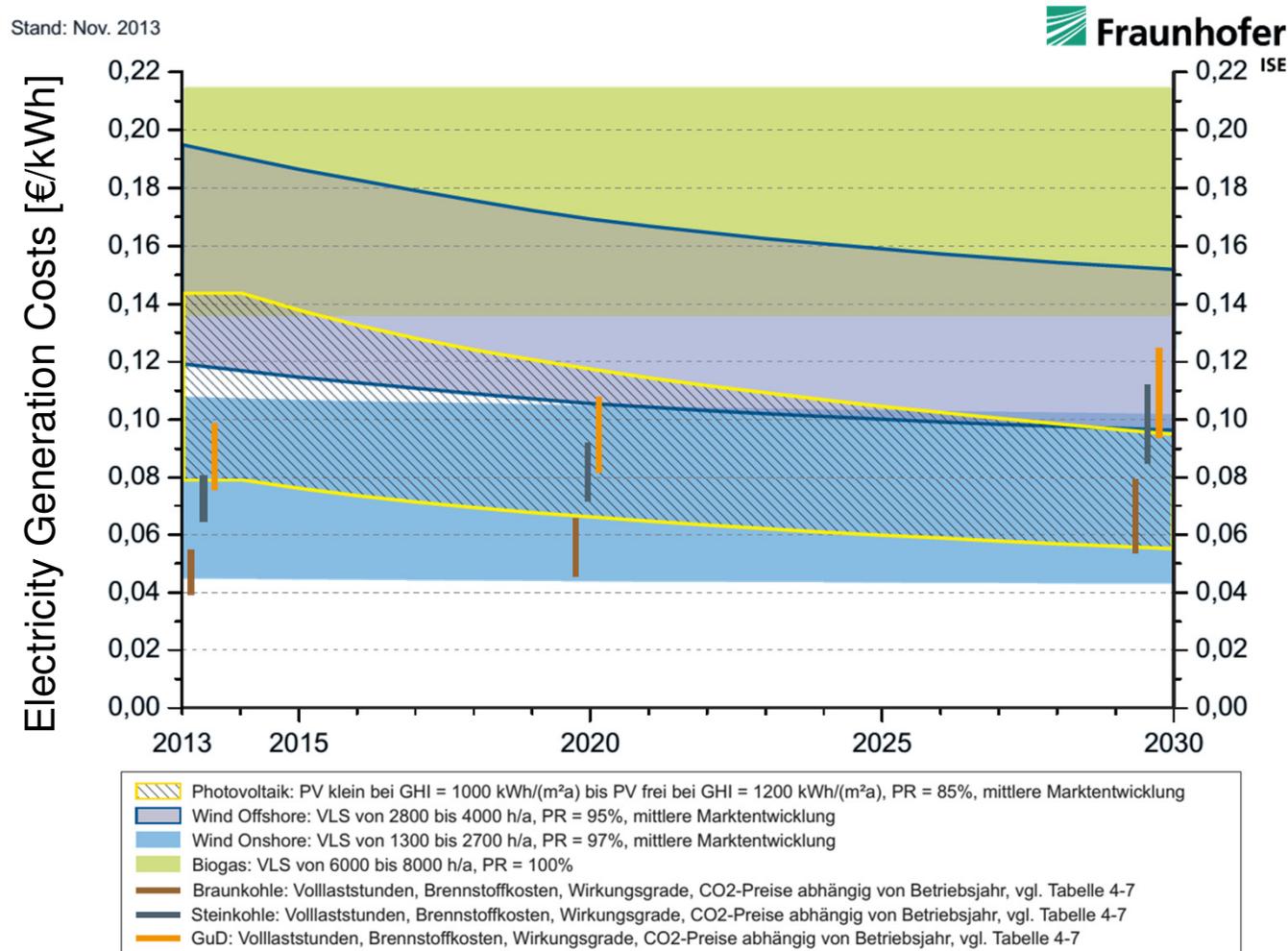


Electricity generation costs for renewable energies and conventional power plants in Germany (2013)



Source: Fraunhofer ISE

Prediction of electricity generation costs based on the learning curve in Germany until 2030

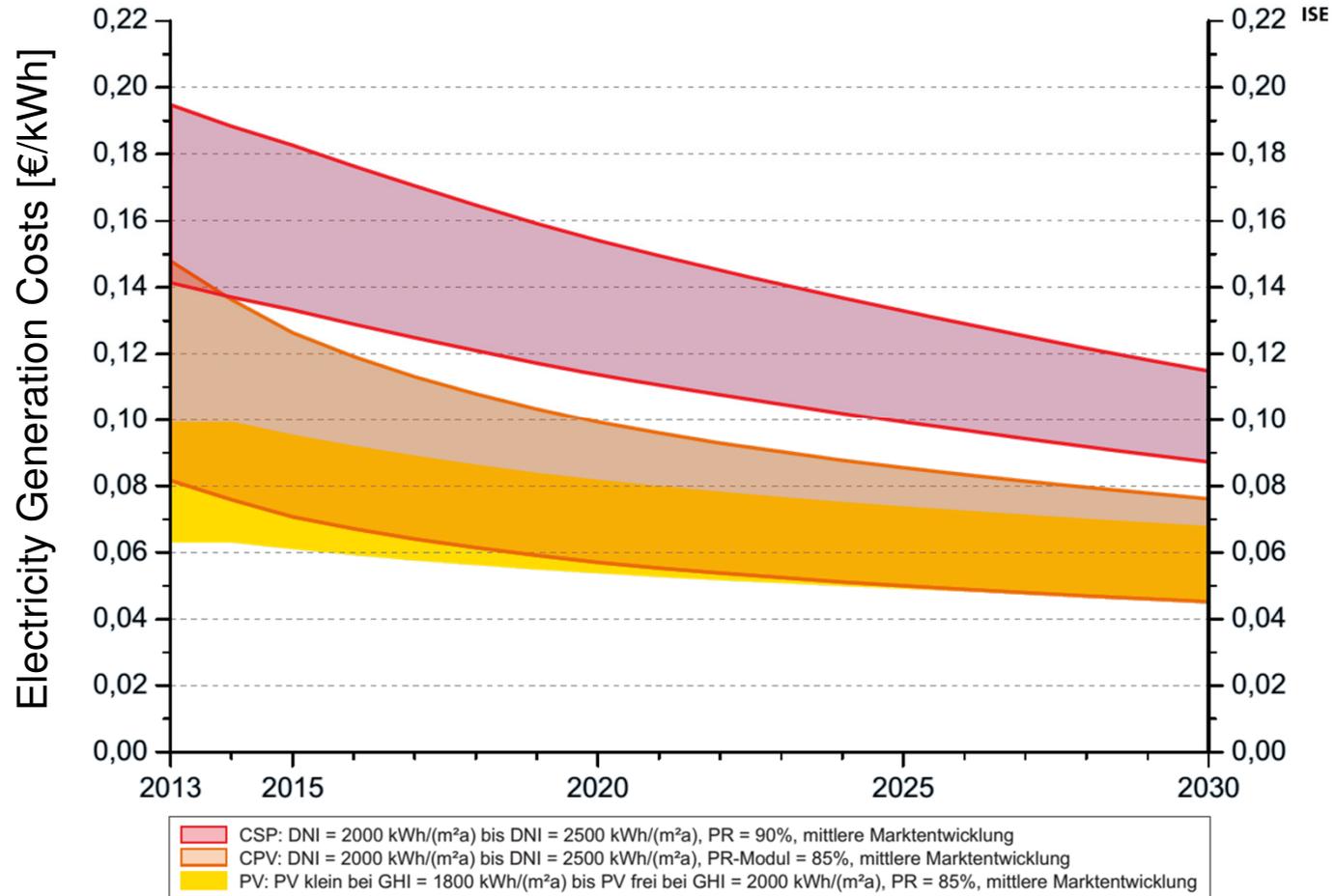


Source: Fraunhofer ISE

Prediction of electricity generation costs of different solar technologies based on the learning curve at places with high solar radiation until 2030

Stand: Nov. 2013

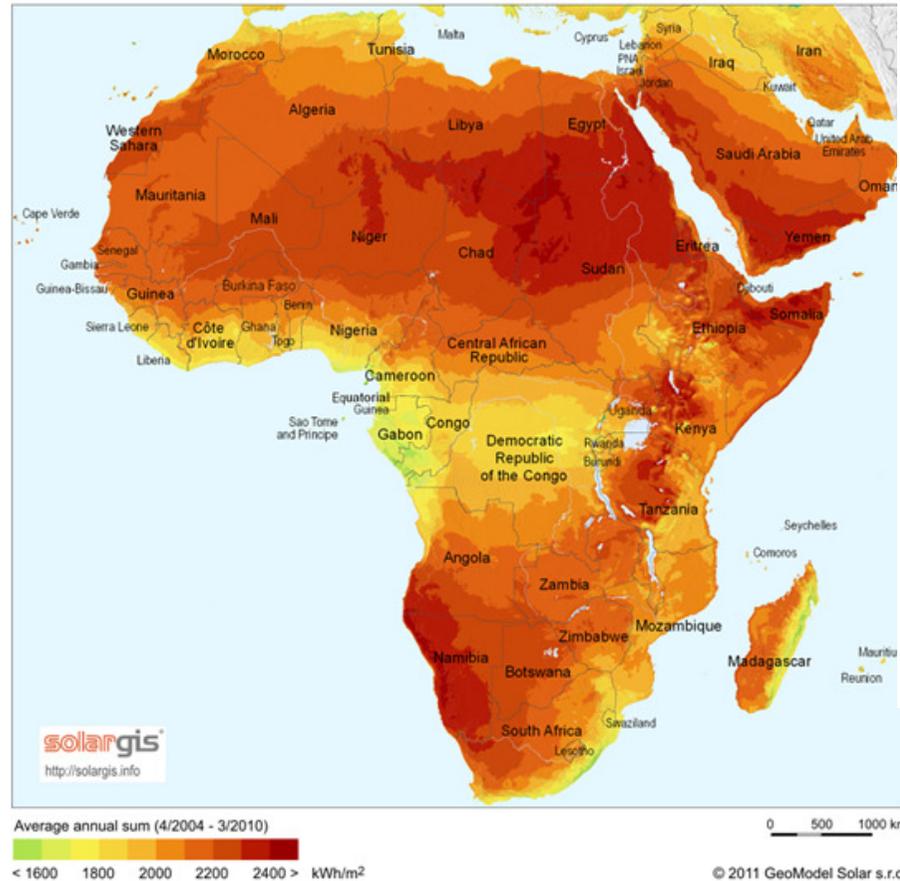
Fraunhofer ISE



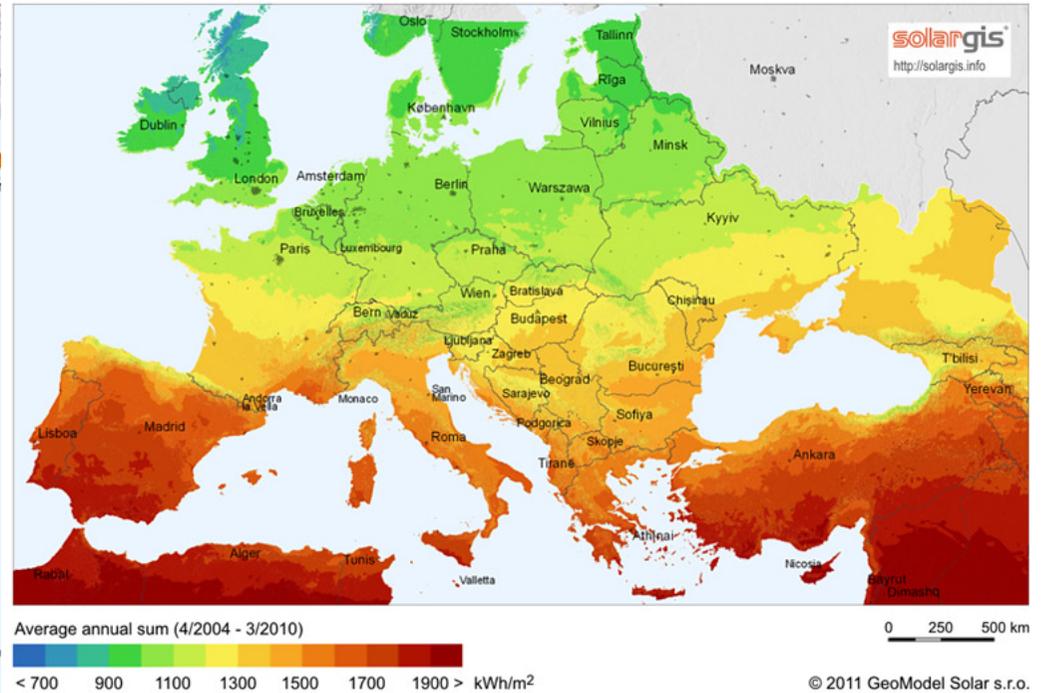
Source: Fraunhofer ISE

Senegal has nearly twice the solar irradiation than Germany

Global horizontal irradiation



Africa and Middle East Global horizontal irradiation

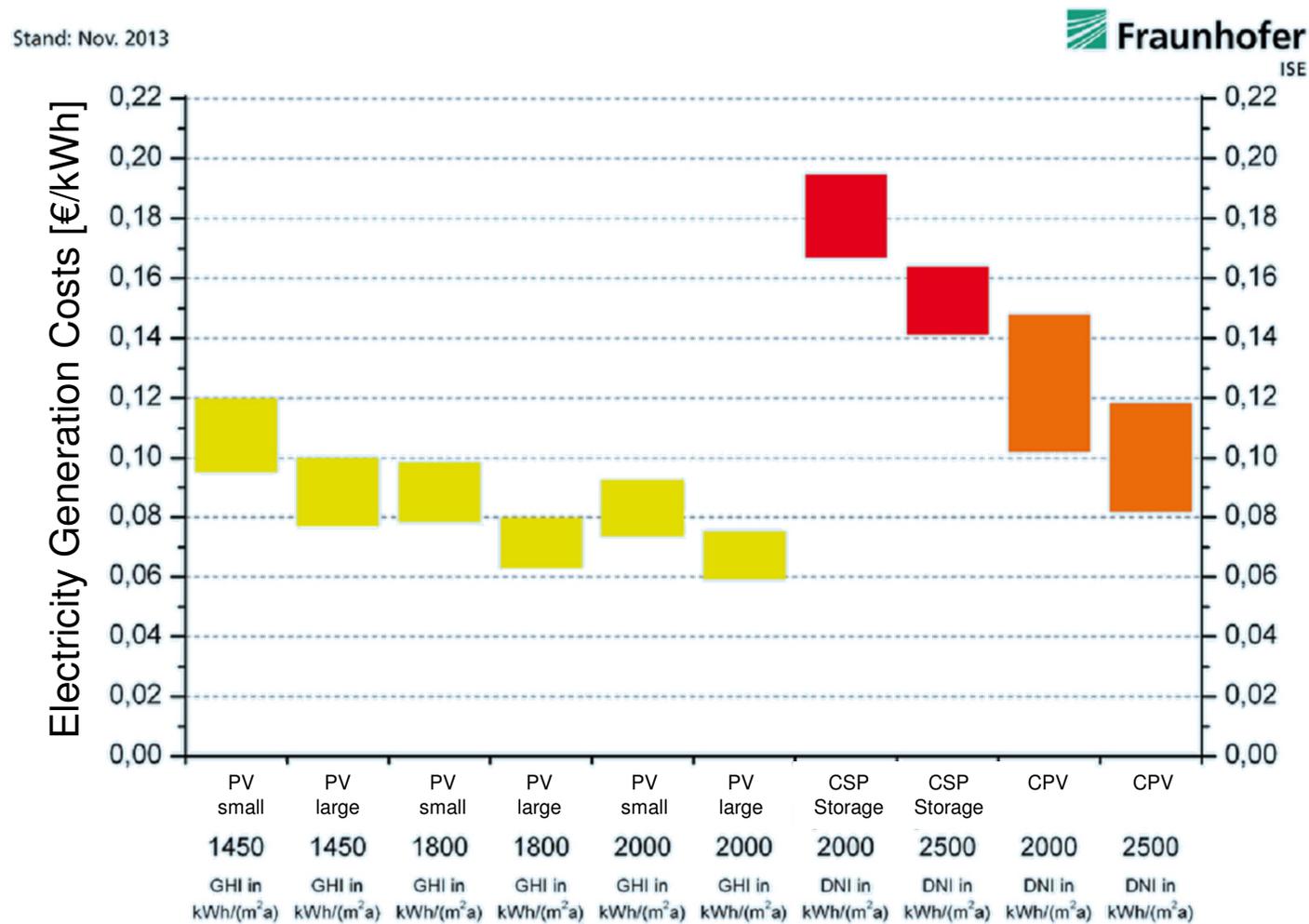


Europe

Germany: 900 – 1200 kWh/m² year

Senegal: 1600 – 1800 kWh/m² year

Electricity generation costs for renewable energies at places with high solar radiation (2013)



Source: Fraunhofer ISE



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Projections for LCOE for new-built utility-scale PV plants to 2050 (USD/MWh) in the hi-Ren Scenario

	2013	2020	2025	2030	2035	2040	2045	2050
Minimum [€/MWh]	95	77	57	45	38	36	34	32
[USD/MWh]	119	96	71	56	48	45	42	40
Average [€/MWh]	142	107	77	65	58	54	47	45
[USD/MWh]	177	133	96	81	72	68	59	56
Maximum [€/MWh]	255	200	144	111	95	87	83	78
[USD/MWh]	318	250	180	139	119	109	104	97

Note: All LCOE calculations in this table rest on 8% real discount rates as in ETP 2014 (IEA, 2014b). Actual LCOE might be lower with lower WACC.

Conversion: 1.000 EUR = USD 1.248

Conclusion



- The experience curve of PV shows the highest cost reduction potential of all energy sources
- The German consumers have made PV cheap enough for world wide application now
- Senegal has nearly twice the irradiation than Germany

▶▶ Photovoltaic will be more and more competitive compared with conventional and other renewable energy sources – especially in Senegal





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Thank you for your attention!
Please feel free to ask questions

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