THE TRANSFORMATION OF ENERGY SYSTEMS TOWARDS SUSTAINABILITY – EXPERIENCE GAINED IN GERMANY

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Benefits of an advanced energy system based on the sustainable use of renewable energy sources and energy efficiency, A

- Protection of the natural life support system
- Reduction of energy poverty in developing countries
- Promotion of peace, by reducing the dependence on regionally concentrated energy resource

Benefits of an advanced energy system based on the sustainable use of renewable energy sources and energy efficiency, B

- Increasing the security of energy supply
- Reducing uncertainties in cost of energy supply
- Promotion of future-compliant industries and jobs

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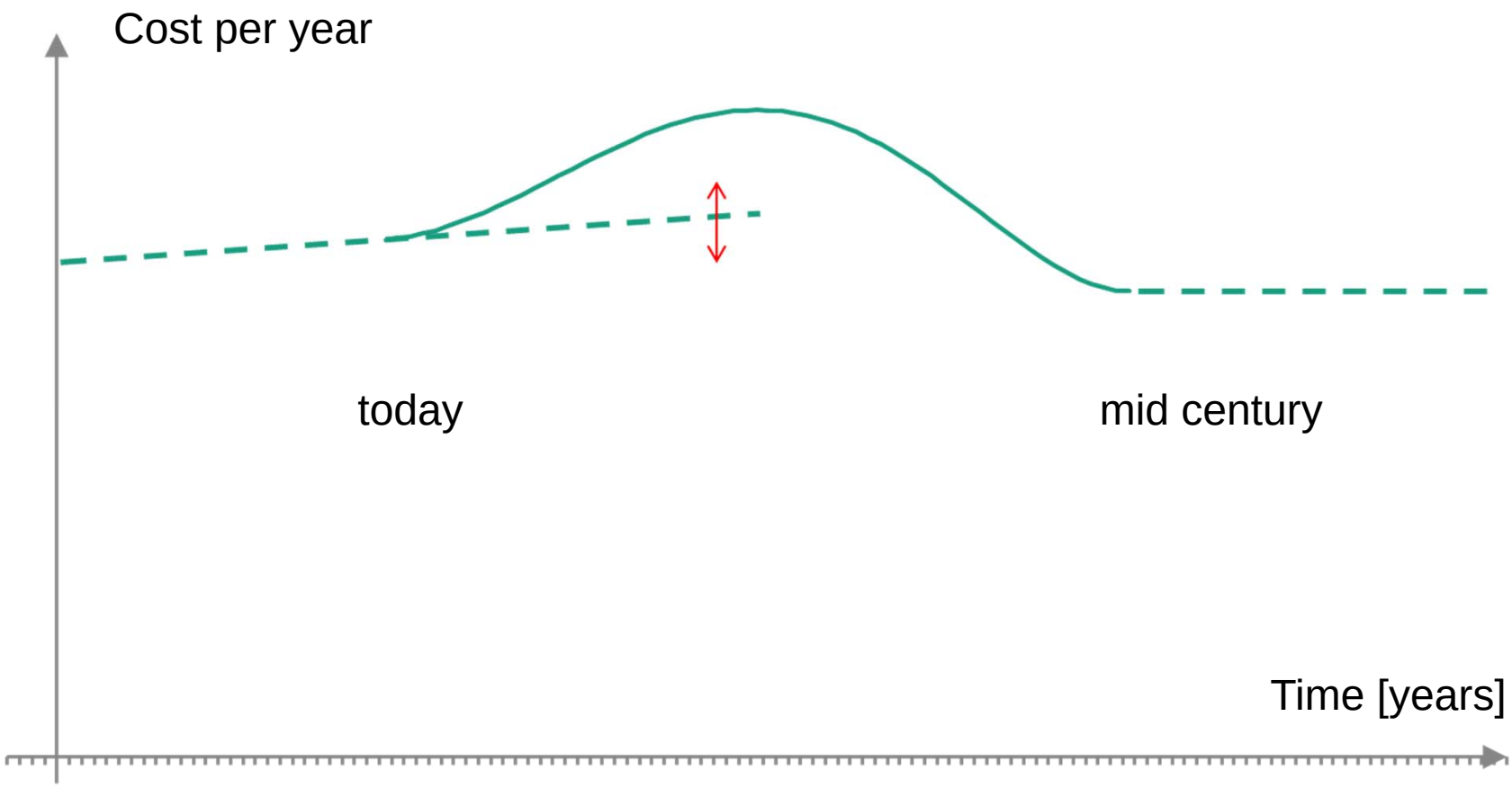
Transformation of the energy system,
annual cost of a complete energy supply system



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Renewable energies in Germany

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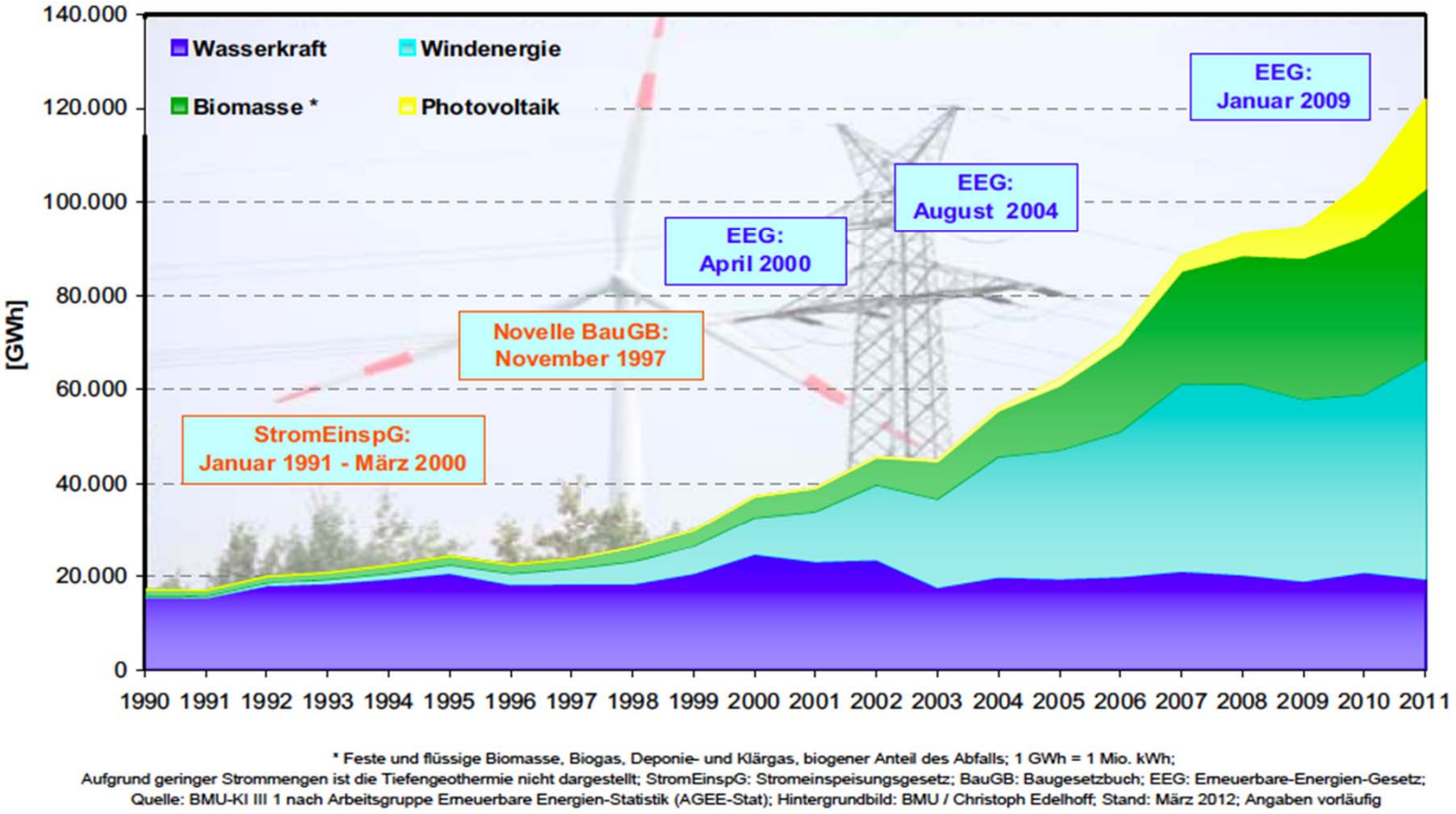
Electric energy from renewable sources, Germany



* Feste und flüssige Biomasse, Biogas, Deponie- und Klärgas, biogener Anteil des Abfalls; 1 GWh = 1 Mio. kWh;
Aufgrund geringer Strommengen ist die Tiefengeothermie nicht dargestellt; StromEinspG: Stromeinspeisungsgesetz; BauGB: Baugesetzbuch; EEG: Erneuerbare-Energien-Gesetz;
Quelle: BMU-KI III 1 nach Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat); Hintergrundbild: BMU / Christoph Edelhoff; Stand: März 2012; Angaben vorläufig

Annual electricity demand 604 TWh, Germany 2010

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Electricity from renewables first half-year 2012, Germany

Total **25,1%**
67,9 TWh

PV **5,3%**
14,4 TWh

Bio **6,6%**
17,8 TWh

Wind **9,2%**
24,9 TWh

Hydro **4,0%**
10,8 TWh

Annual electricity demand 604 TWh, Germany 2010

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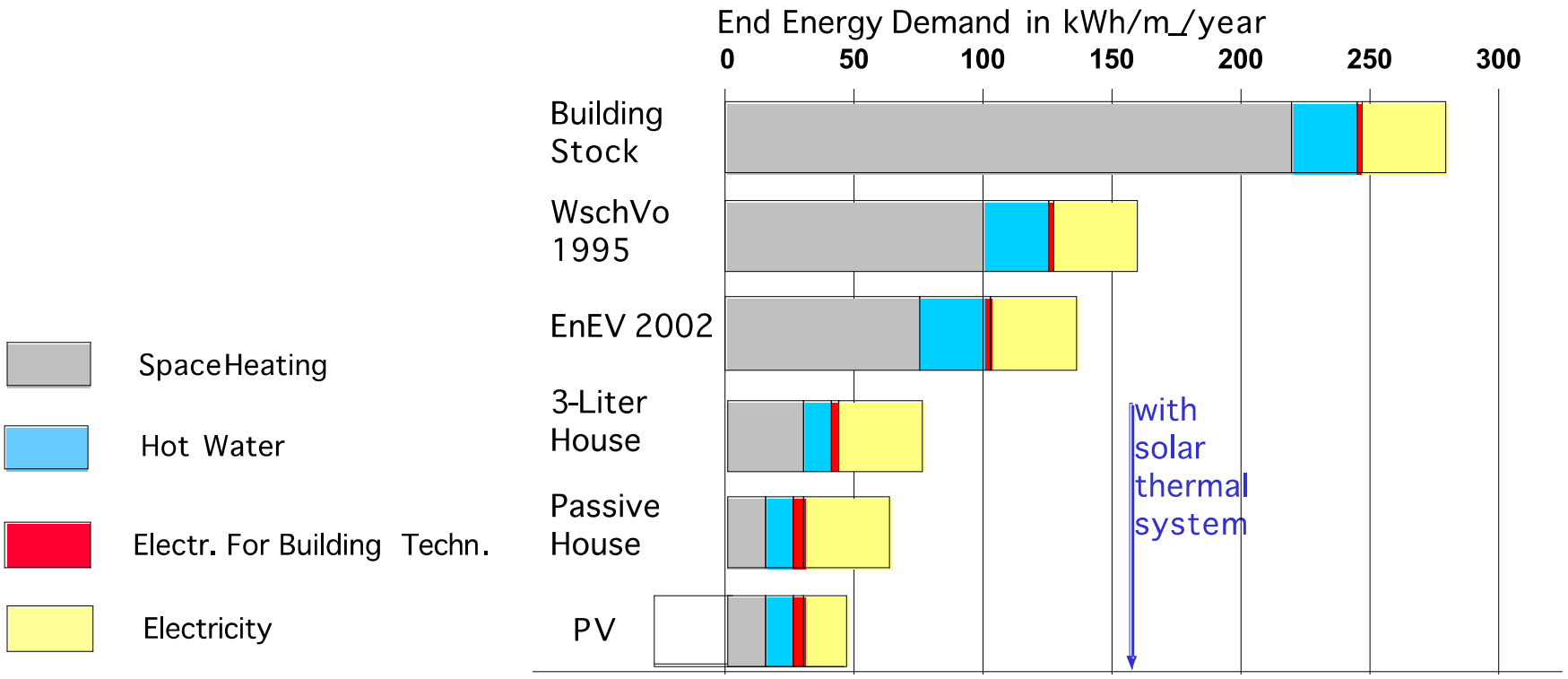
External end energy demand of residential buildings, buildings codes and innovative buildings



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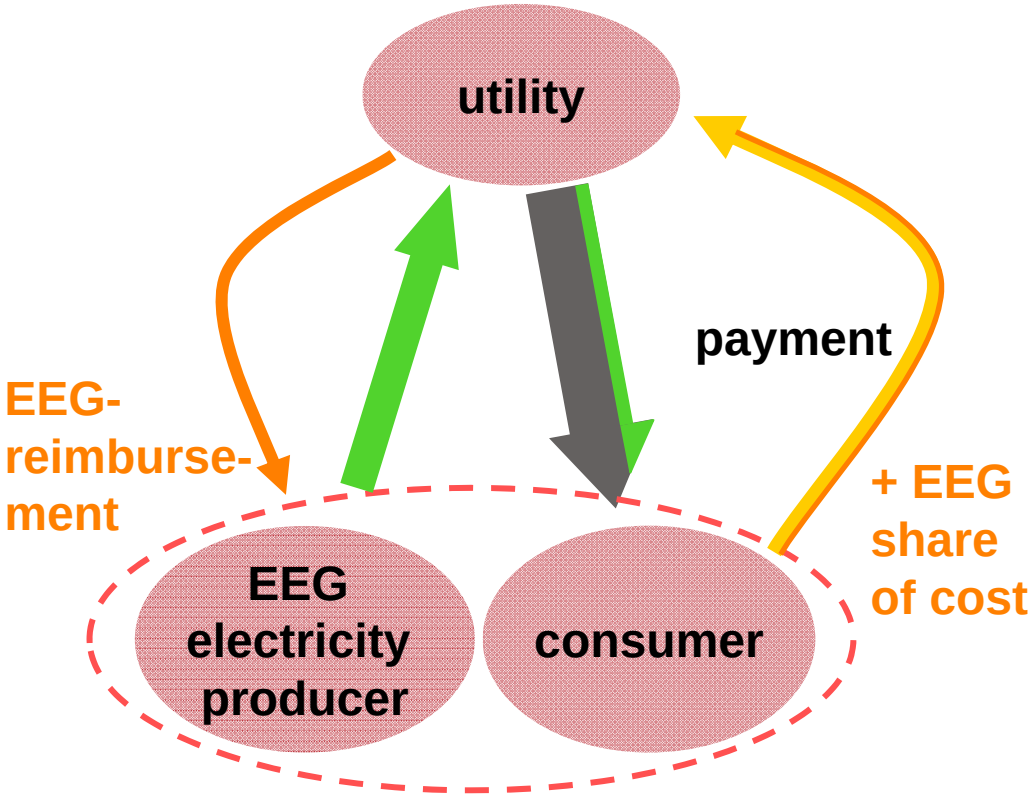
Energy policy - European and German targets

	base year	2020	2050
EU			
Reduction of green house gas emissions	1990	20%	min. 80%
Increase in energy efficiency	1990	20%	
Fraction of renewables	2009: 11,6%	20%	
Germany			
Reduction of green house gas emissions	1990	40%	80-95%
Increase in energy efficiency	2008	20%	50%
Fraction of renewables, total energy	2011: 12,2%	18%	60%
Fraction of renewables, electricity	2011: 20,0%	35%	80%

The feed-in tariff, the Renewable Energy Sources Act (EEG)

Renewable Energy Sources Act (EEG)



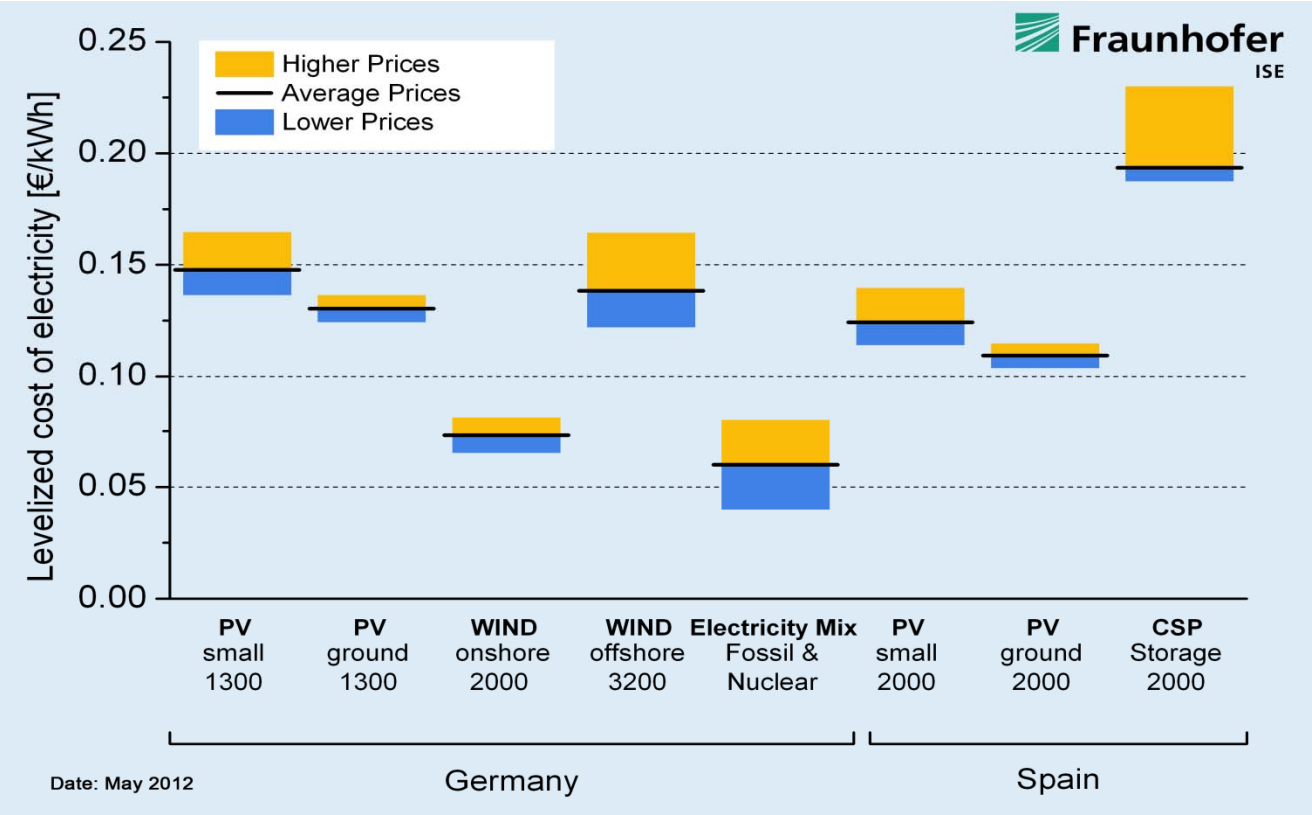
Electricity from renewable sources:

- Priority, connection to the grid
- Priority, supply of electricity to the grid
- Fixed feed-in tariff over 20 years
- Yearly decrease of feed in tariff

Source: www.bmu.de

Levelised cost of electricity generation (LCOE)

Germany and Spain, May 2012



Feed-in tariff Germany:

small PV
0.189 €/kWh

PV ground mounted
0.130 €/kWh

<- kWh/(m^2 a); h/a

Source: Fraunhofer ISE 2012, C. Kost, T. Schlegl

1 € = 1.3 AUD

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Levelised cost of PV electricity*
September 2012

- Module prices, Germany 0.7 €/ W_p
- System prices (10 kW), Germany 1.5 €/ W_p
- LCOE Southern Germany (1 300 kWh/(m^2 a) 0.12 €/ kWh
- LCOE at 2 500 kWh/(m^2 a) 0.06 €/ kWh
- LCOE at 3 400 kWh/(m^2 a) 0.05 €/ kWh

- **Near future** system price one €/ W_p
- LCOE 0.08 €/ kWh
  0.05 €/ kWh - 0.03€/kWh

* Applying the rule of proportion

1 € = 1.3 AUD

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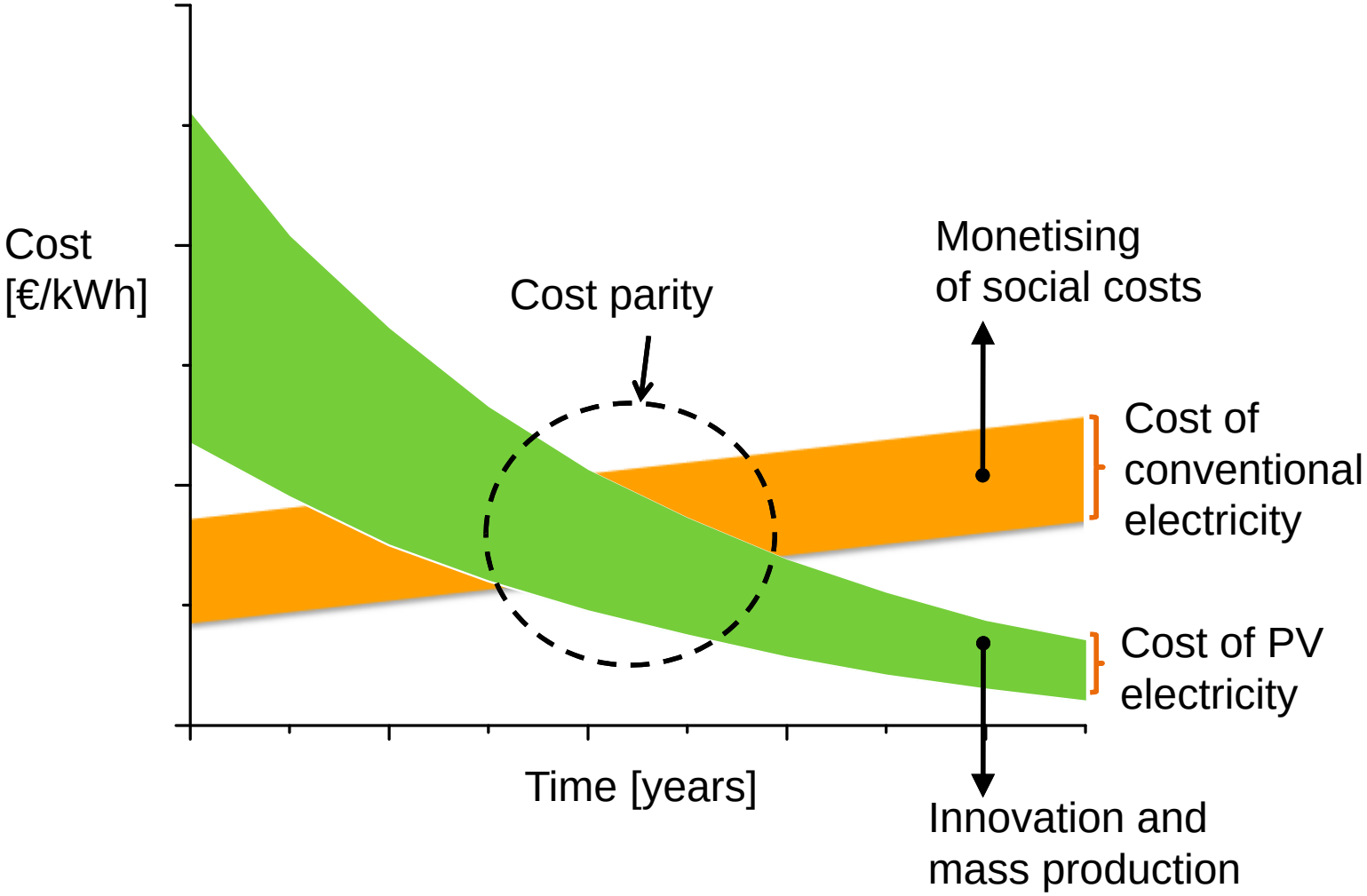
Levelised cost of electricity* (LCOE)
Caveats

- The comparability between different types of energy generation is enabled through the concept of LCOE

- But the LCOE is not a direct measure for the value of electricity. The value is determined by
  - The LCOE
  - The time pattern of load and generation
  - The predictability of the electricity generation
  - Political boundary conditions, market schemes

* LCOE = (present value of expenditures)/(present value of electricity generated)

Cost parity between conventional and photovoltaic electricity generation



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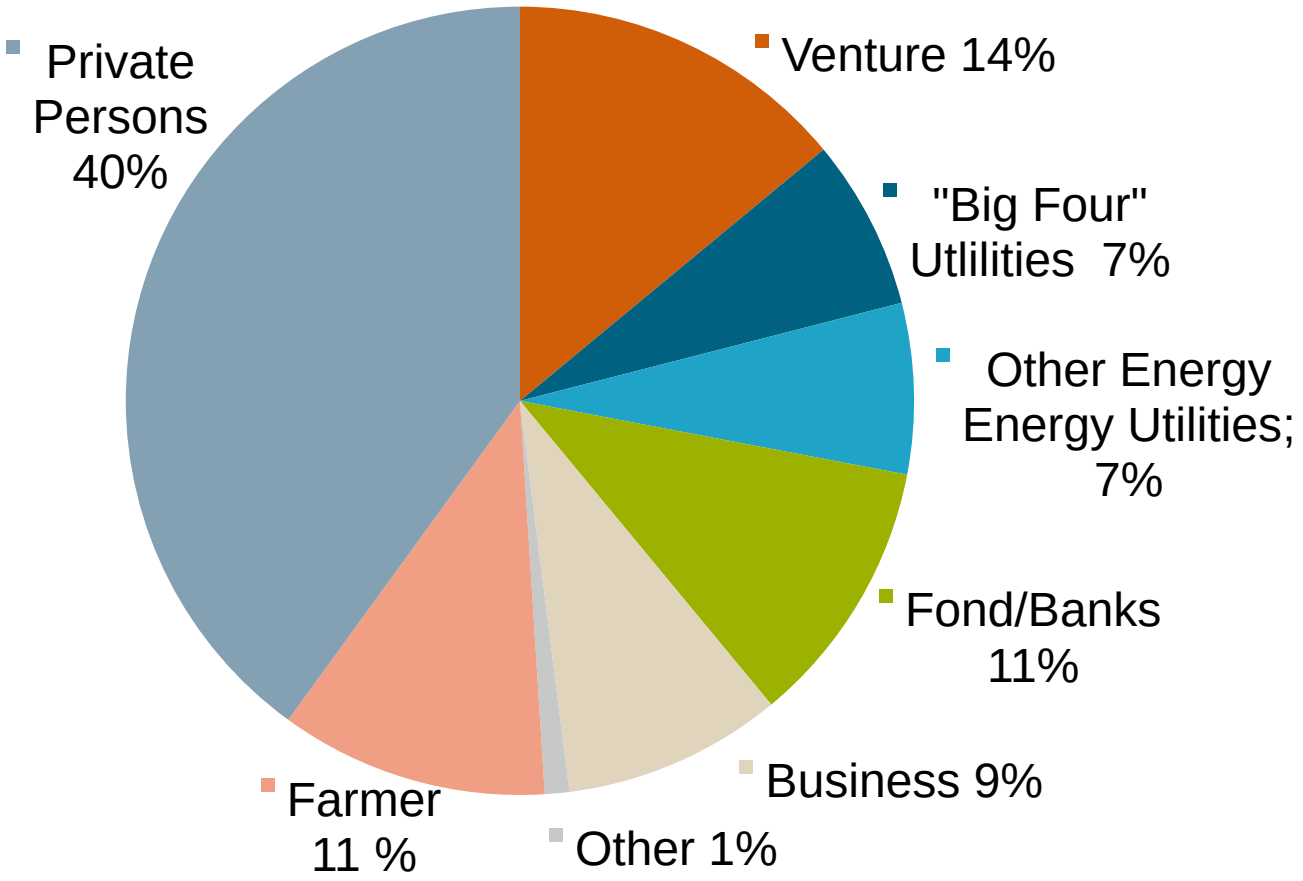
Financing of renewable energy installations,
Germany 2011



Source: trend research 2011, Deutschland hat unendlich viel Energie

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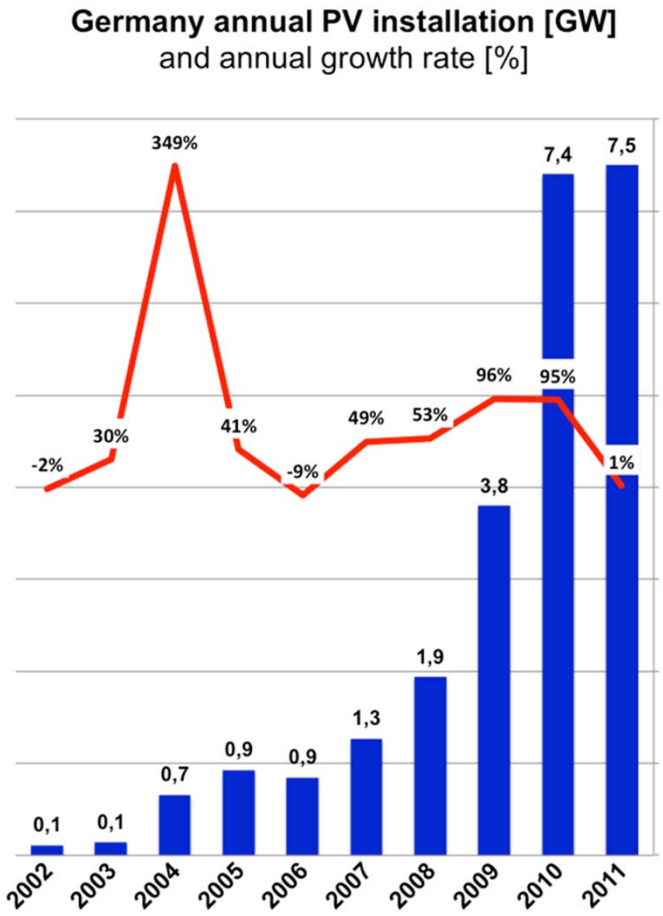
Annual PV installations [GW] and growths rates, Germany



Source: BSW 2012

EEG support for PV will run out at a cumulative
PV capacity of 52 GW

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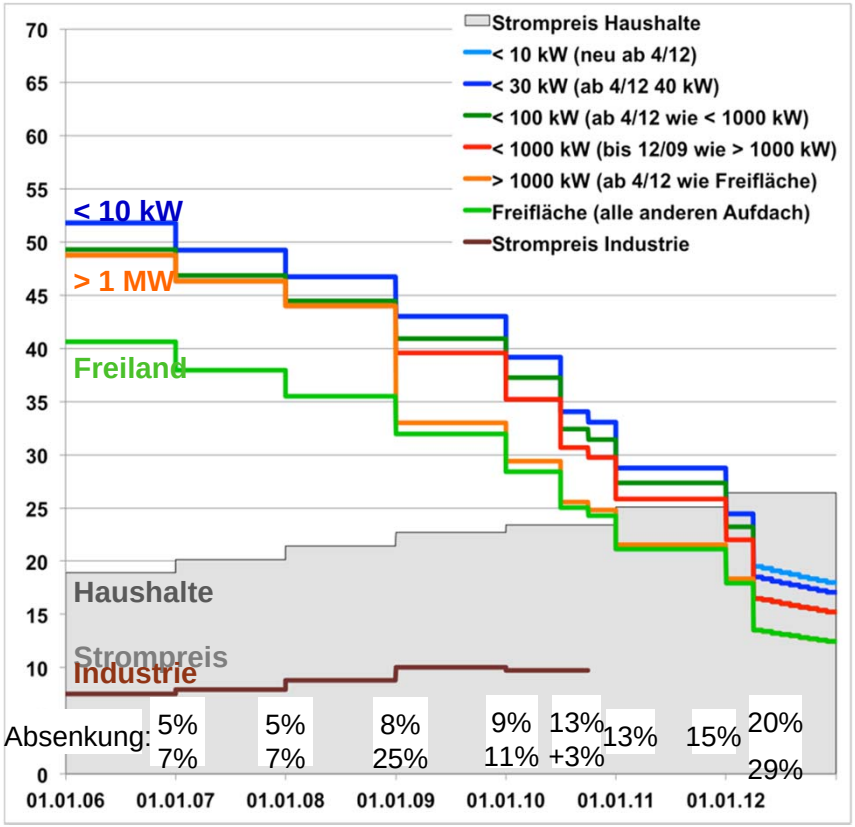
Evolution of the feed-in tariff



Light blue	< 10 kWp
Red	0.1 -1.0 MWp
Light green	ground based systems

Residential electricity prices

Industry prices

Reduction of the feed-in tariff

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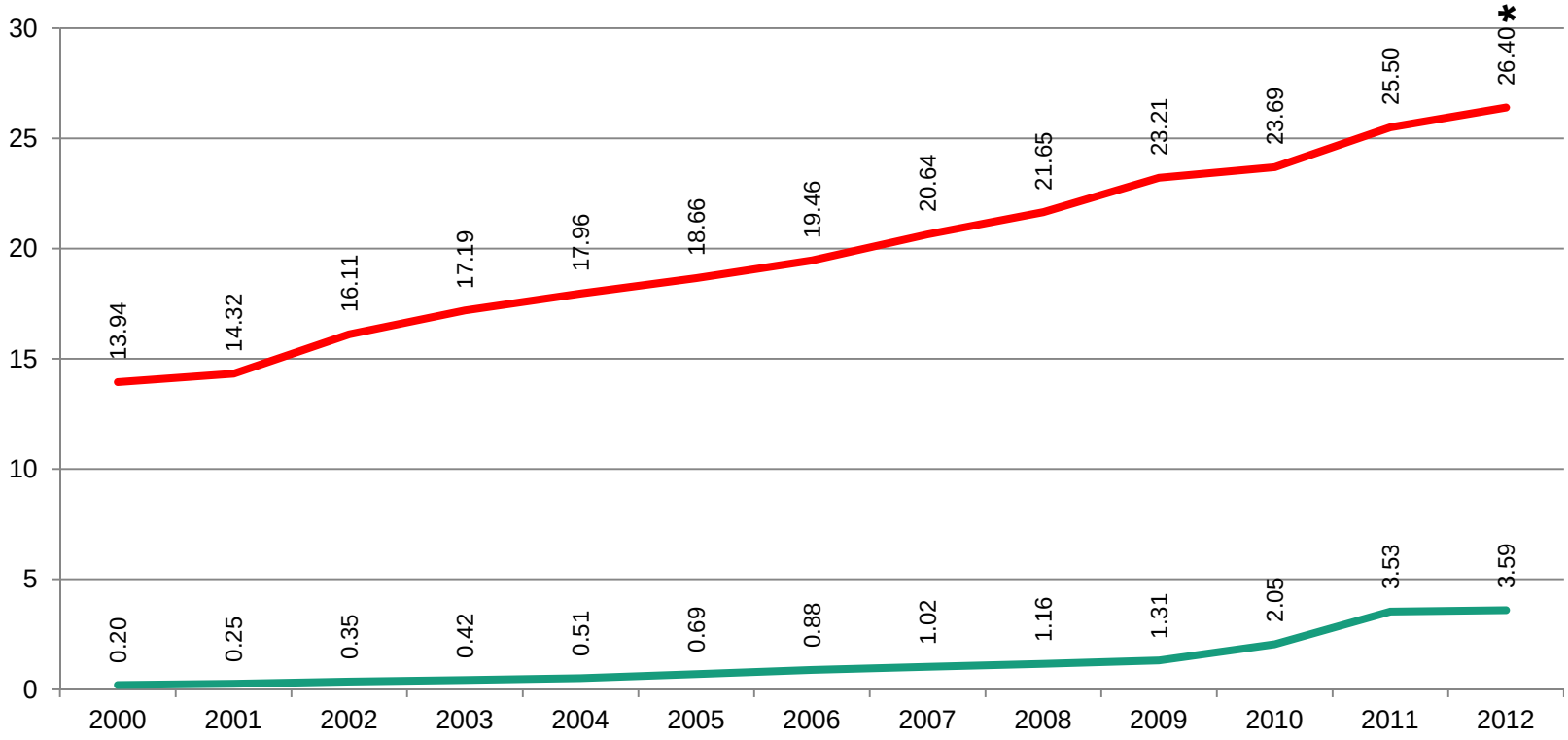
Average residential electricity price (Germany) and fraction due to the feed-in scheme



Source: German Federal Network Agency, 2011

* = expected

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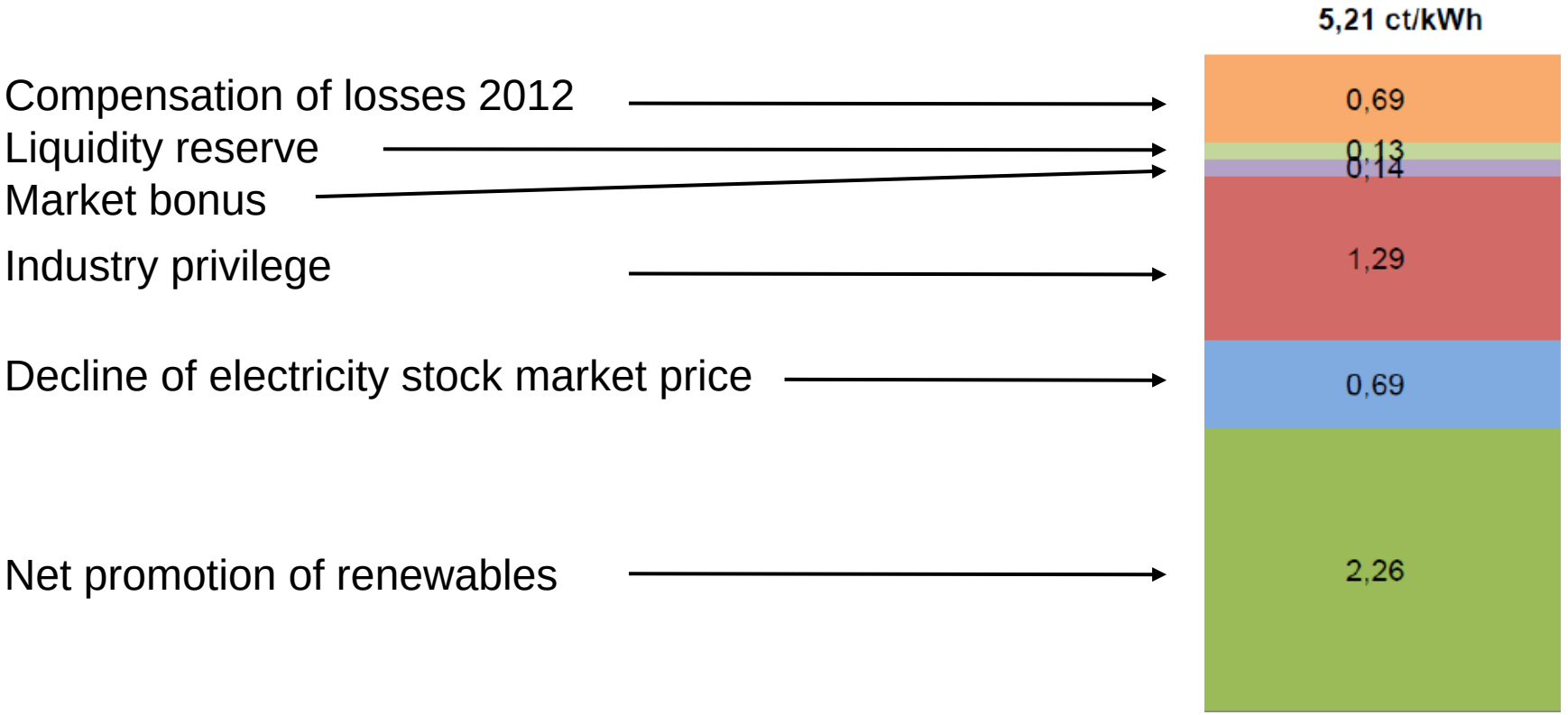
Allocation of costs, feed-in tariff, Germany 2013



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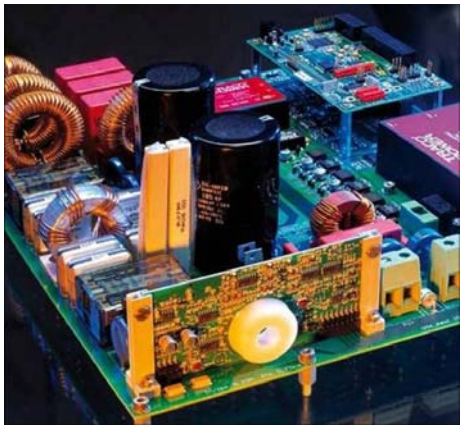
Integration of fluctuating renewable electricity into power supply structures

Smart grids,
merging energy and information technologies

- Matching demand and generation on the local and central level
  - Control of non time-sensitive loads
  - Control of the energy demand through variable tariffs
  - Control of renewable and conventional electricity generation
  - Energy weather forecast
  - Energy storage
- Large area (inter-) continental grids



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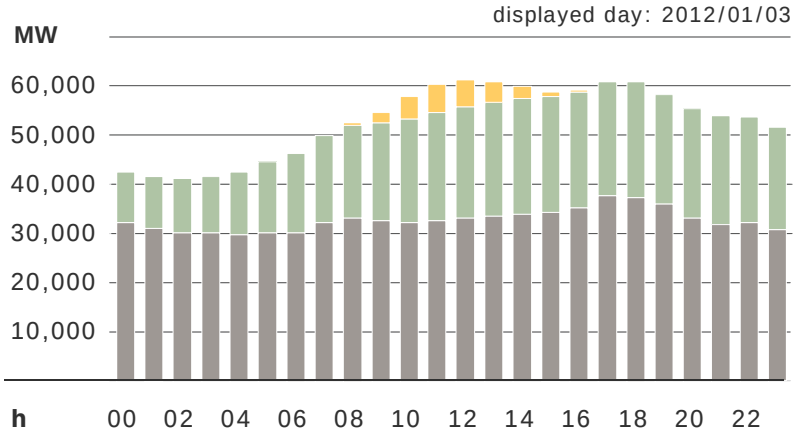
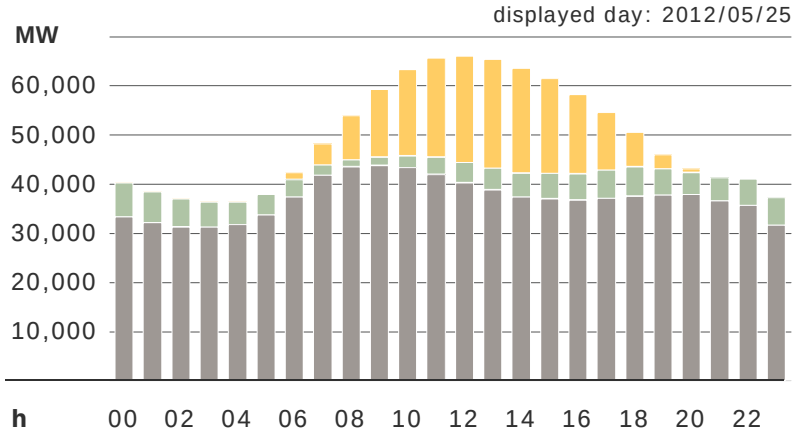
Electricity generation in Germany, selected days

03.01.2012 und 25.05.2012

Actual production



Actual production



Renewables, installed (rated) power, August 2012

PV 30 GW, wind 29 GW

Source: B. Burger, Fraunhofer ISE, 2012

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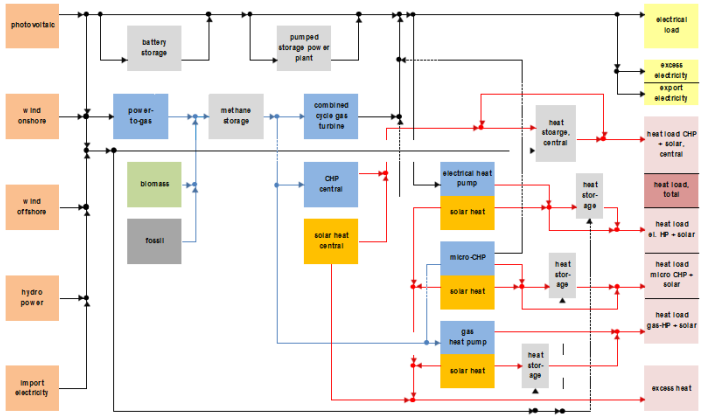
An extreme model of a future German energy system*

energy sources: 100% from wind, solar, hydro, biomass; no import/export

PV	220 GW,	214 TWh
Wind	253 GW,	596 TWh
Hydro	5 GW,	21 TWh
Bio		50 TWh
Energy efficient buildings		-50%



Peak load 132 GW
Max. generation 321 GW

Source H. Henning, A. Palzer, Fraunhofer ISE 2012

*heat and electricity; liquid fuels not included

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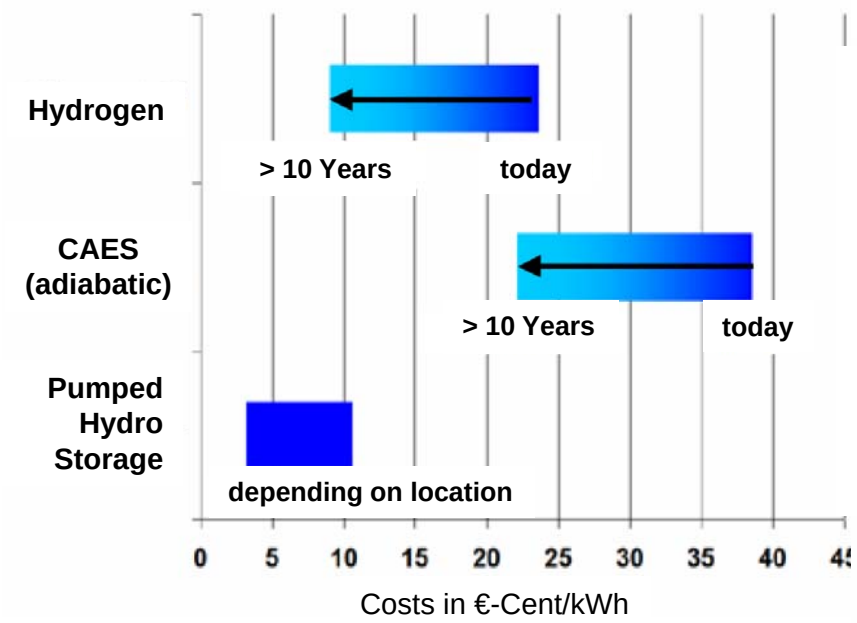
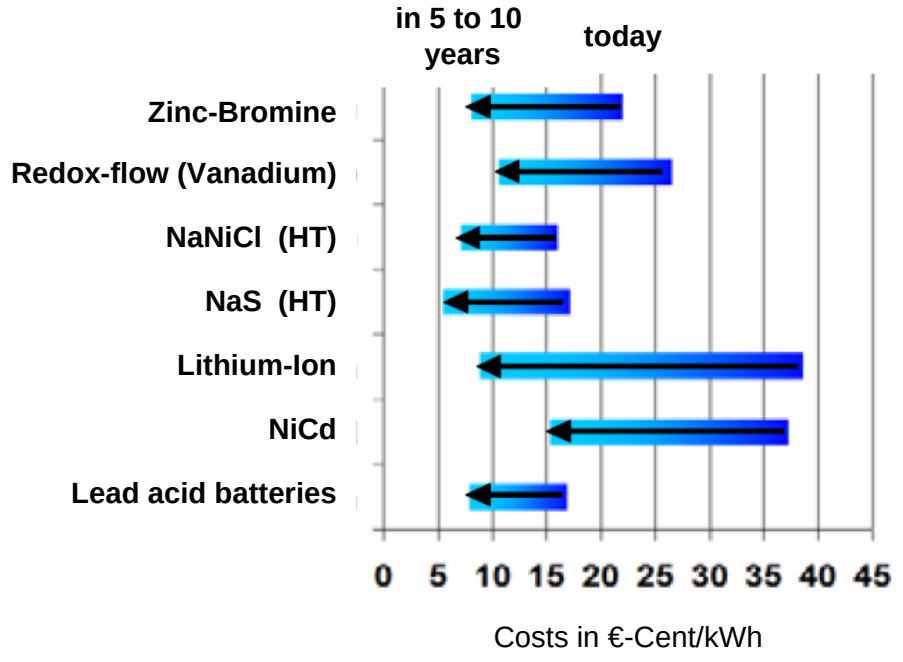
Handling excess electricity generation from solar and wind - examples

- Load management
- Large area electricity exchange (export/import)
- Energy storage electricity
  - Hydro, pressurised air
  - Batteries
- Energy storage - heat
  - Water, building components
- Energy storage – gas
  - Methane, Hydrogen
- Energy storage – transport
  - Batteries

Cost of electrical energy storage
Examples





Load levelling:
1 GW for 8h, 1 cycle per day

Load levelling and peak shaving:
100 kW for 2.5 h, 2 cycles per day

Source: VDE ETG, 2008

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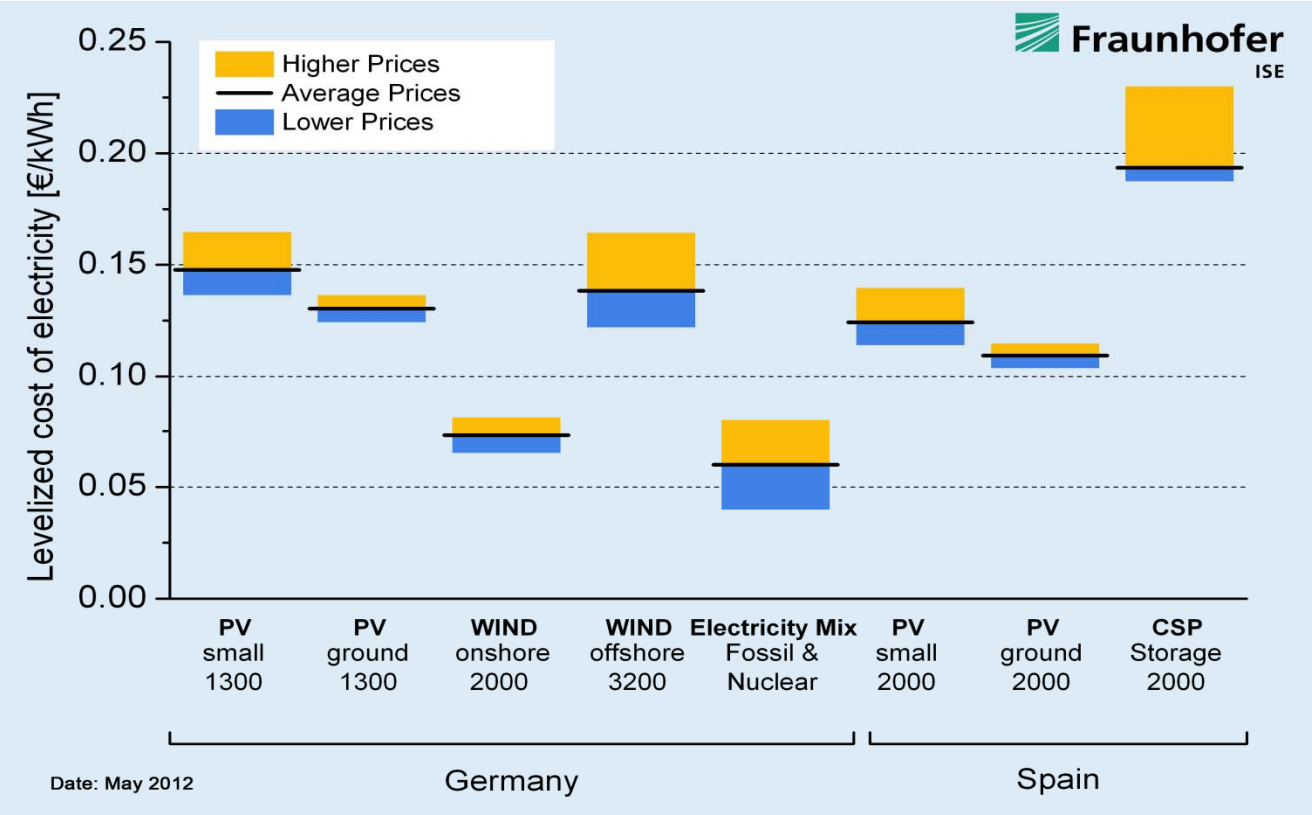
Levelised cost of electricity generation (LCOE)

Germany and Spain, May 2012



Residential electricity price Germany:

~ 0.25 €/kWh

Source: Fraunhofer ISE 2012, C. Kost, T. Schlegl

1 € = 1.3 AUD

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Final remarks

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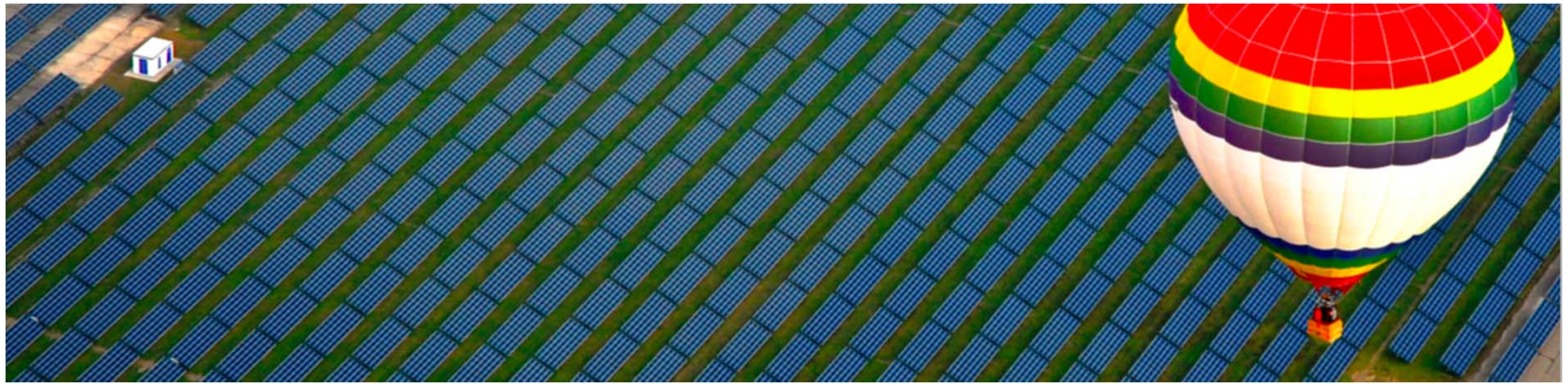
Prerequisites for an effective transformation of our energy systems towards sustainability

- Low cost generation of energy from renewable sources
- Sustainable production, installation and recycling of components and systems
- Efficient integration of fluctuating renewable energies into electricity supply systems – empowering grids, integration of storage systems
- In all sectors: efficient use of energy
- Smart financing, market design, emission trading
- International co-operation



Thank you for your attention

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Parameters for cost calculations

	Germany				Spain		
	PV Klein	PV Groß/Fläche	Wind Onshore	Wind Offshore	PV Klein	PV Groß/Fläche	CSP
Betriebsdauer	**25 Jahre**	**25 Jahre**	**20 Jahre**	**20 Jahre**	**25 Jahre**	**25 Jahre**	**25 Jahre**
Eigenkapital-Anteil	20,0%	20,0%	30,0%	40,0%	20,0%	20,0%	30,0%
Fremdkapital-Anteil	80,0%	80,0%	70,0%	60,0%	80,0%	80,0%	70,0%
Eigenkapital-Rendite	6,0%	7,5%	9,0%	14,0%	9,0%	10,5%	12,0%
Fremdkapital-Zins	4,0%	4,5%	4,5%	7,0%	7,0%	7,5%	9,0%
WACC (Weighted Average Cost of Capital)	**4,4%**	**5,1%**	**5,9%**	**9,8%**	**7,4%**	**8,1%**	**9,9%**
Jährliche Betriebskosten	**30 €/kWp**	**30 €/kWp**	**0,015 €/kWh**	**0,030 €/kWh**	**30 €/kWp**	**30 €/kWp**	**0,025 €/kWh**
Jährlicher Anstieg der Betriebskosten	2,00%	2,00%	2,00%	2,00%	2,00%	2,00%	2,00%
Jährliche Degression Stromoutput	0,20%	0,20%	0,00%	0,00%	0,20%	0,20%	0,20%

Source: Fraunhofer ISE 2012, C. Kost, T. Schlegl

Investments, different technologies

Investition in Euro/KW in 2012					
Technologie	Anlagen	Mittlerer Wert	Untere Grenze	Obere Grenze	Quellen
Photovoltaik	Kleinanlagen bis 10 kWp	1900	1700	2200	*BSW Preimonitor (2012), Fraunhofer ISE (SCost-System)*
	Großanlagen bis 1000 kWp	1700	1500	1800	
	Freiflächen ab 1000 kWp	1600	1500	1700	
CSP	Parabol 100 MW ohne Speicher	4700	3600	5000	*Nevada One, Acciona (Majadas de Tietar)*
	Parabol 100 MW mit 8h-Speicher	5400	5200	6600	*Andasol1-3 (ES)*
	Fresnel 100 MW ohne Speicher	3700	3400	4000	*PE2 power station (ES)*
	Turm 100 MW mit 8h-Speicher	6500	6000	9000	*Crescent Dunes (US), Abengoa (RSA)*
Wind	Onshore (1,5 – 2 MW)	1200	1000	1350	*EWEA (2009)*
	Onshore (2 – 3 MW)	1400	1200	1600	*Windguard (2011)*
	Offshore (3 – 5 MW)	3200	2700	4000	*EWEA (2009), Gerdes (2006), Krewitt (2009), Projekte: Borkum West 2, Baltic1*

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