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Energy

Photovoltaics – Turbulent Growth of a Disruptive Technology: International Experiences and Development Perspectives for Portugal

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renewables Made in Germany

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Urging problems lead to a rapid paradigm change

- Accelerating climate change
- Depleting oil and gas resources
- Increasing energy demand in emerging and developing economies

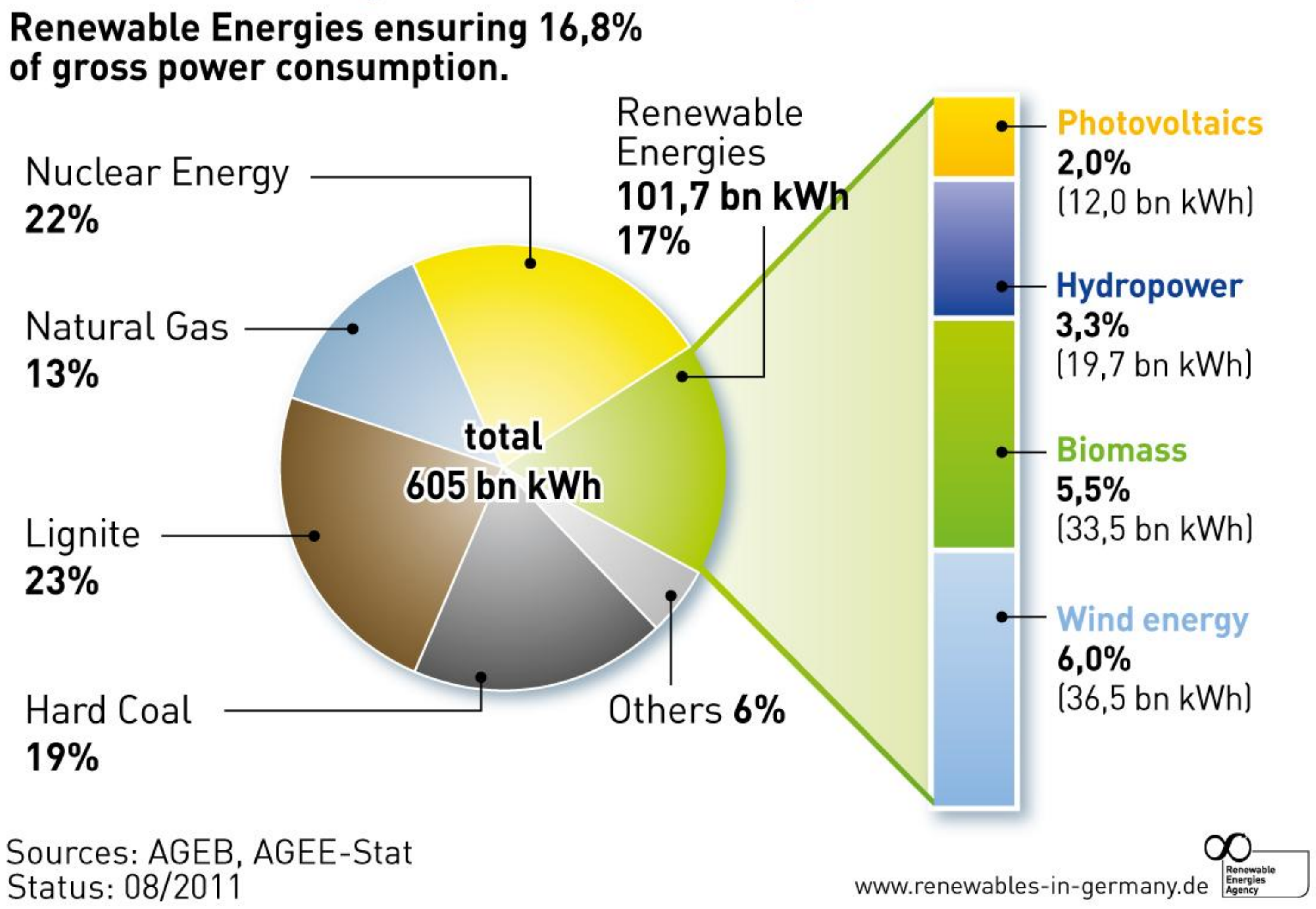
▶ Rapid transformation of the energy system needed
▶ Governments create markets for new technologies
▶ New technologies change the energy markets

- ***PV is the most disruptive of the new technologies***:
  - Fastest growth
  - steepest learning curve
  - biggest potential
  - but still small

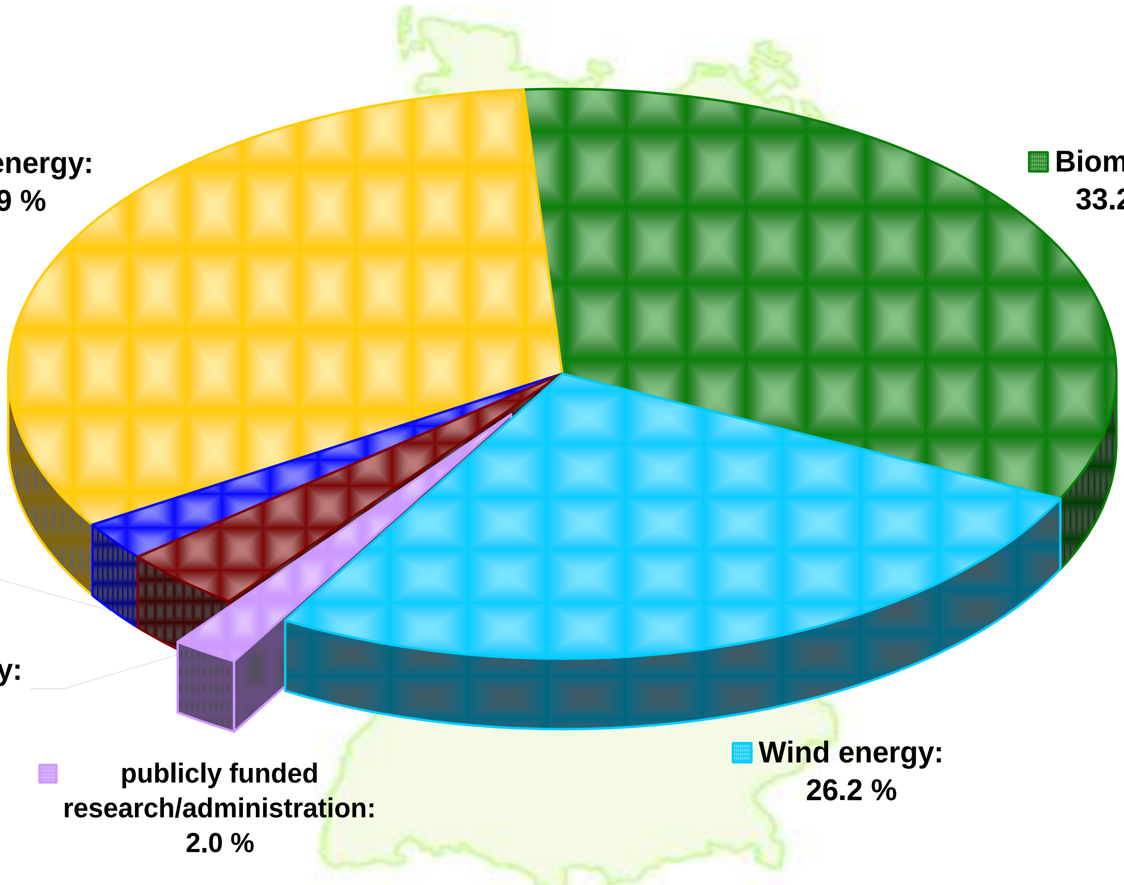
Converging political targets: ca. 100% renewable electricity by 2050

- EU decision in 2009, compulsory:
  <u>20% renewable energy in Europe 2020</u>
- German RE Industry Association 2008:
  47% renewable electricity in GER by 2020
- German environmental minister Röttgen 2010:
  his aim: 100% renewable electricity in GER 2050
- EREC (European RE Industry Association) 2010/11:
  100% renewable Energy in Europe 2050, 45% in 2030
- German Advisory Council on the Environment 2010:
  100% renewable electricity in Germany possible and necessary by2050
- European Climate foundation / PriceWaterhouseCoopers 2010:
  100% renewable electricity in Europe possible by 2050
- WWF 2011 worldwide scenarios:
  100% renewable Energy 2050
- EU Commission Energy scenarios 2011:
  ??? % renewable energy in Europe 2050

Electricity production mix in Germany 2010

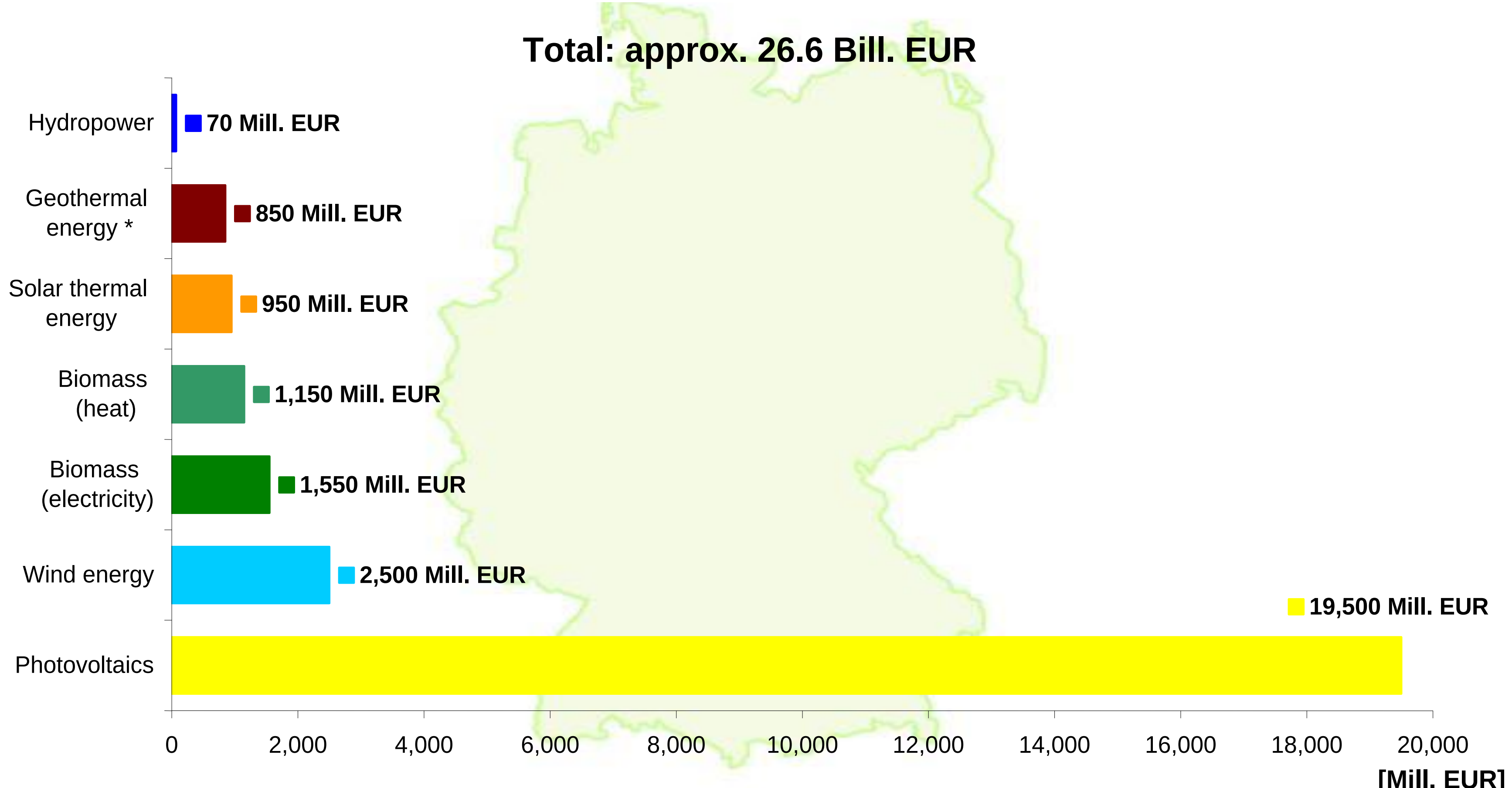


367,000 renewable energy jobs in Germany 2010



Figures for 2010 are provisional estimate; deviations in totals are due to rounding;
Source: O'Sullivan/Edler/van Mark/Nieder/Lehr: "Bruttobeschäftigung durch erneuerbare Energien im Jahr 20010 – eine erste Abschätzung", as at: March 2011; interim report of research project „Kurz- und langfristige Auswirkungen des Ausbaus erneuerbarer Energien auf den deutschen Arbeitsmarkt"

Investments in renewable energy installations in Germany 2010



* Large plants and heat pumps; deviations in the totals are due to rounding;
Source: BMU-KI III 1 according to the Centre for Solar Energy and Hydrogen Research Baden-Wuerttemberg (ZSW); as at: July 2011; all figures provisional

PHOTOVOLTAICS –
A DISRUPTIVE TECHNOLOGY

Germany has triggered the take-off of the world PV market

Total PV capacity installed in Germany

Milestones

1991: First Feed-in Law (FIT with low tariffs)

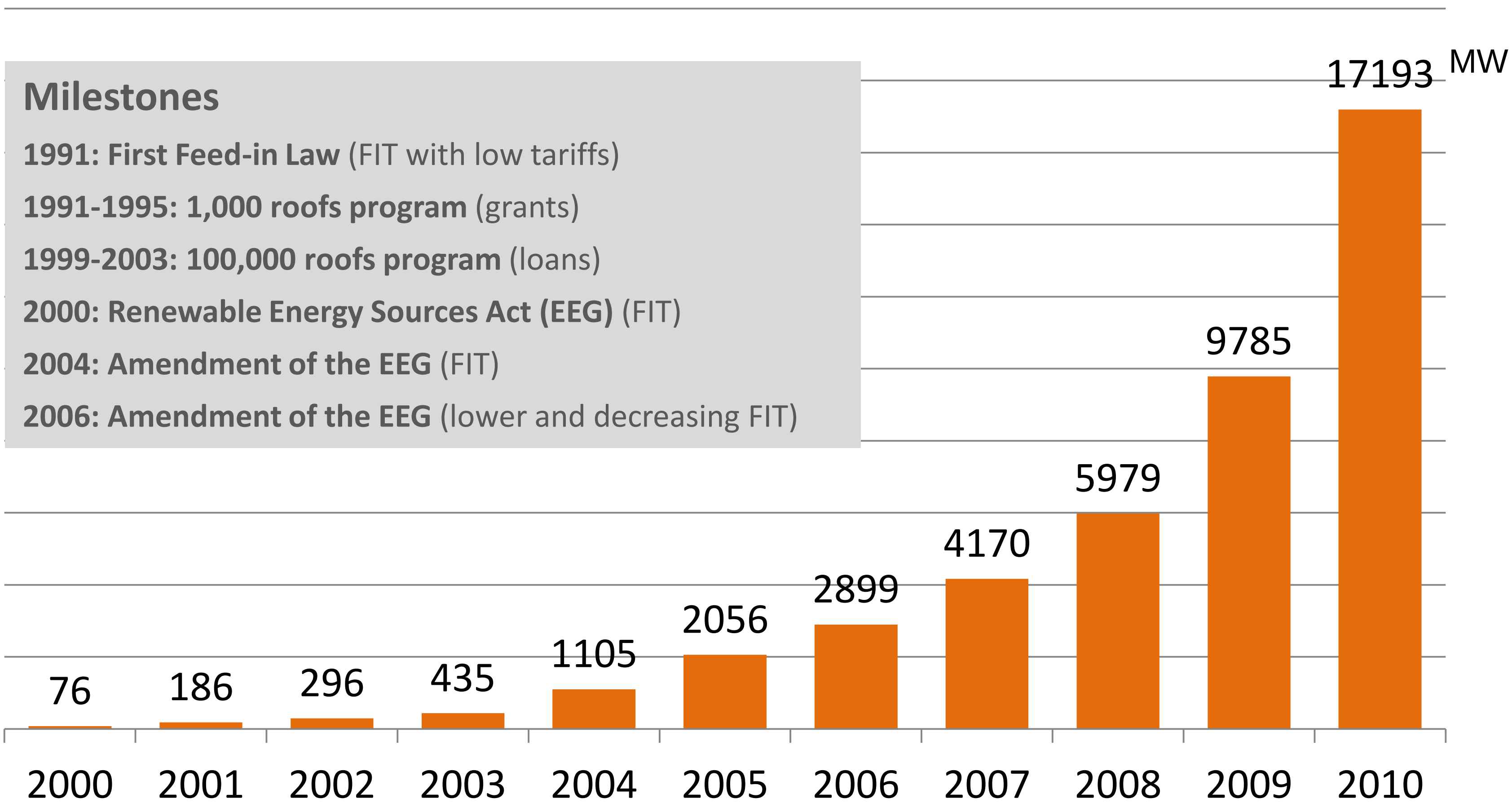
1991-1995: 1,000 roofs program (grants)

1999-2003: 100,000 roofs program (loans)

2000: Renewable Energy Sources Act (EEG) (FIT)

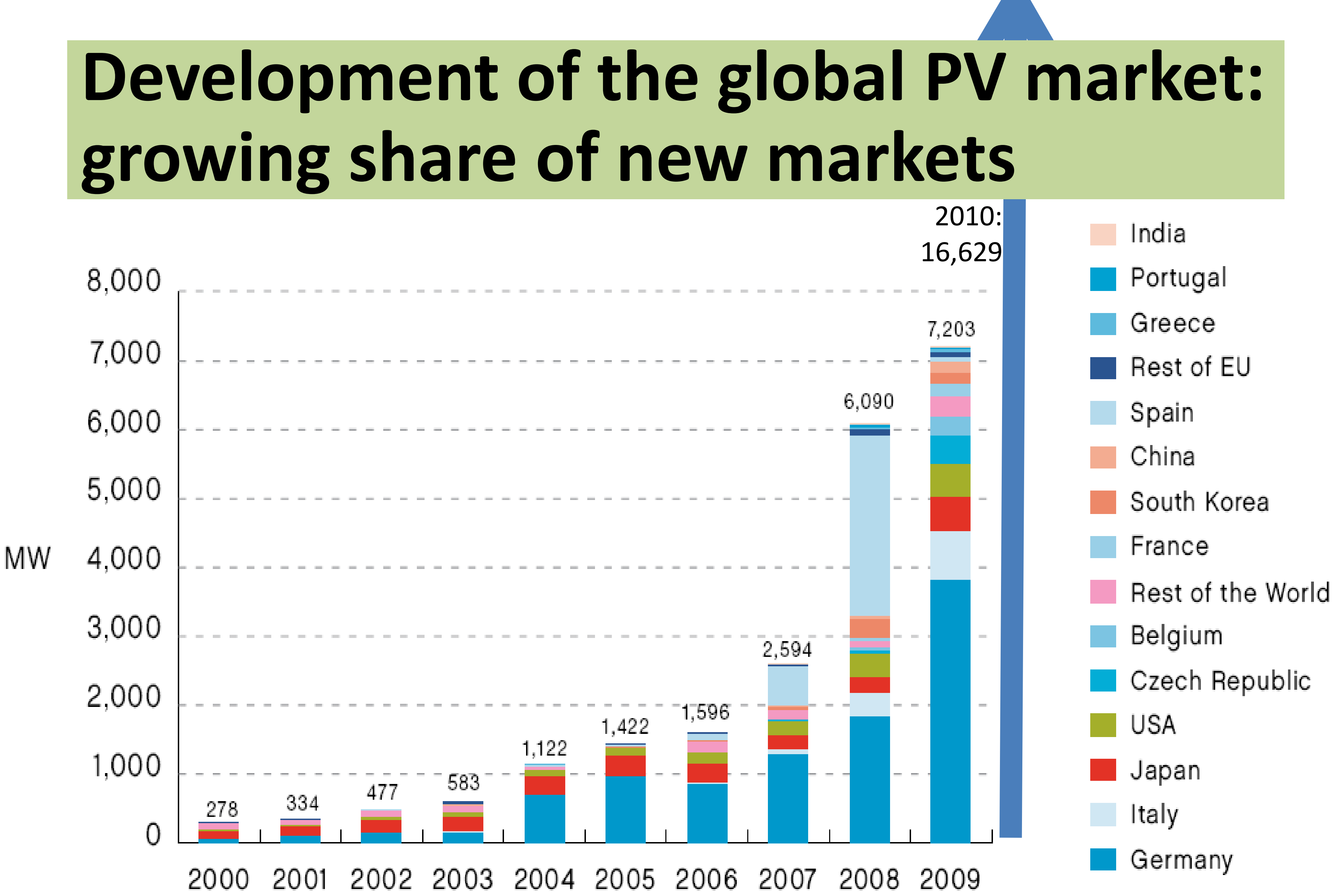
2004: Amendment of the EEG (FIT)

2006: Amendment of the EEG (lower and decreasing FIT)



Source: BMU, BSW

Development of the global PV market: growing share of new markets



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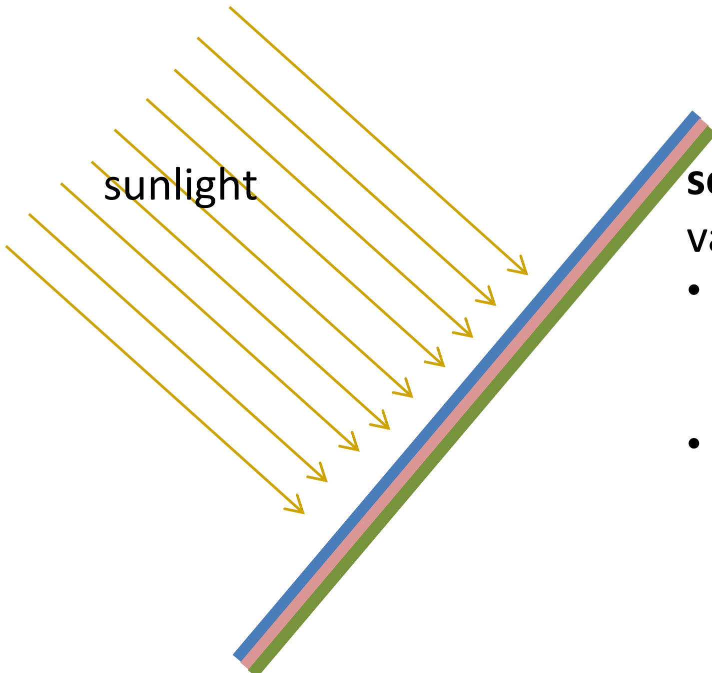
PV is a Semiconductor technology: Direct transformation of sunlight into electricity



several layers of semiconductors

variety of different technologies:

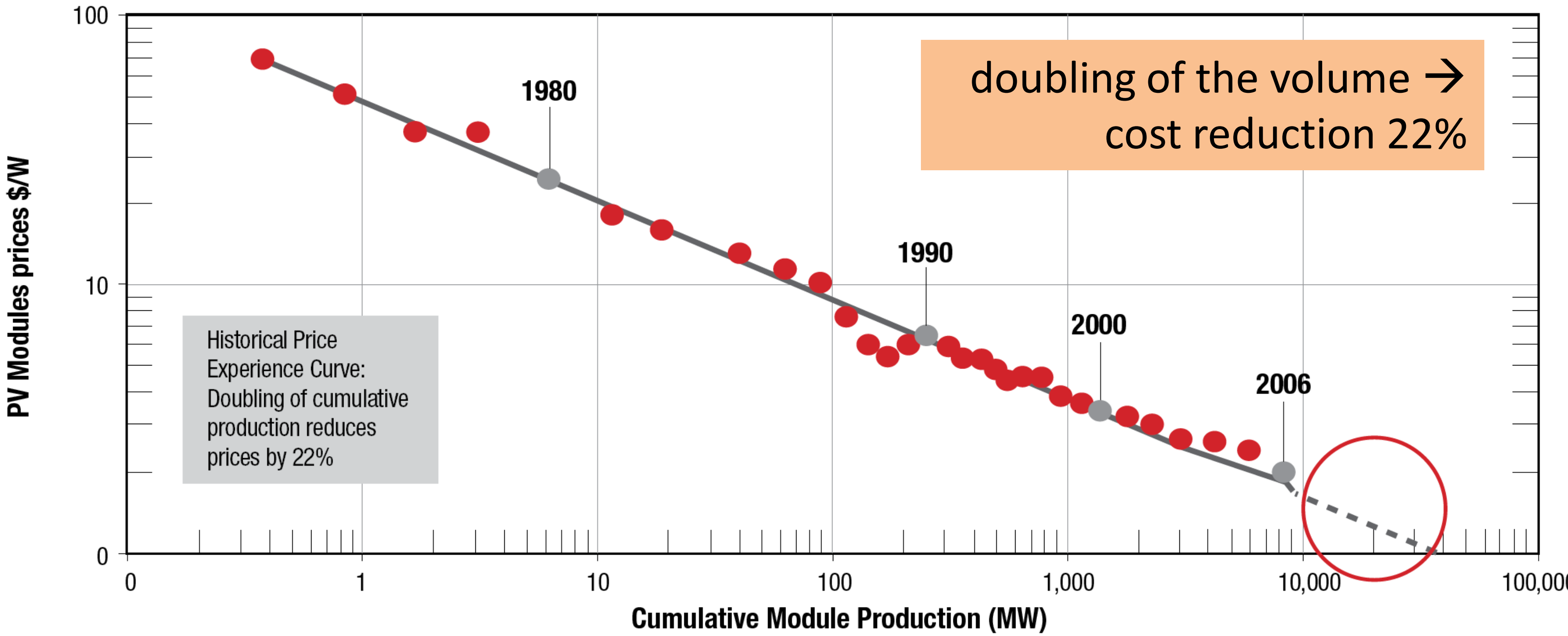
- crystalline silicon c-Si (ingot-wafer)
  - monocristalline < 24% efficiency
  - polycristalline < 20%
- thin-film technologies
  - amorphous Silicon a-Si, also comb. < 12%
  - CdTe Cadmium-Telluride < 16%
  - CIGS, different combinations < 20%
  - GaAs, Gallium-Arsenide < 24%
  - poly-junction < 41%
  - …

DC direct current – + inverter ~ AC alternate current

- **no moving parts**
- **no maintenance**
- **no fuel**
- **high cost reduction potential**

A modular, scalable technology: Typical photovoltaic systems

Rapidly decreasing Costs: The historical learning curve of PV

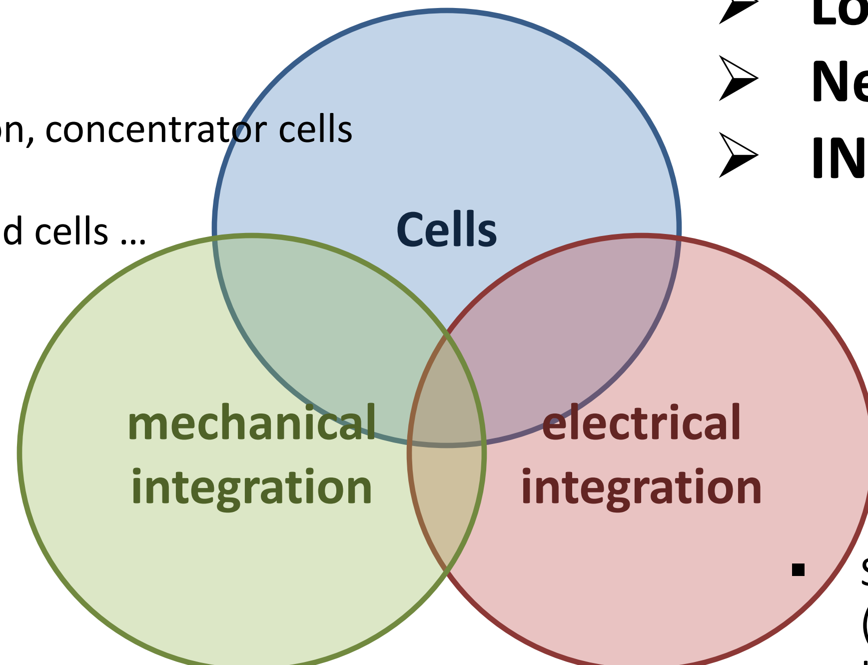


Sources: EU Joint Research Centre - EIA - National Renewable Energy Laboratory - A.T. Kearney analysis.

Innovations in PV development: large variety guarantees further cost reductions

- Silicon, improvement c-Si cells
- Thin film:
  - Si,
  - CIGS,
  - CdS, …
- Multi-junction, concentrator cells
- Organic cells
- Dye sensitised cells …

- **Higher efficiency**
- **Lower production costs**
- **New application fields**
- **INTEGRATION**



- Storage technologies (stationary, mobile, off-grid, grid)
- Intelligent inverters
- System design
- Hybrid systems, mini-grids
- Grid concepts, grid steering
- Regulation, markets

- Carrying materials, module design
- Concentrators, tracker systems
- BIPV: integration in buildings, construction elements
- in appliances, in vehicles
- Free space, traffic areas, roofing

Building Integrated PV (BIPV)

- Whole roofs as a first step
- Other components of the building shell require more sophisticated solutions / integration with
  - standard building components
  - planning and building processes
  - construction industry
- Very high potential but little commercial progress in the last years
- New opportunities with thin film products

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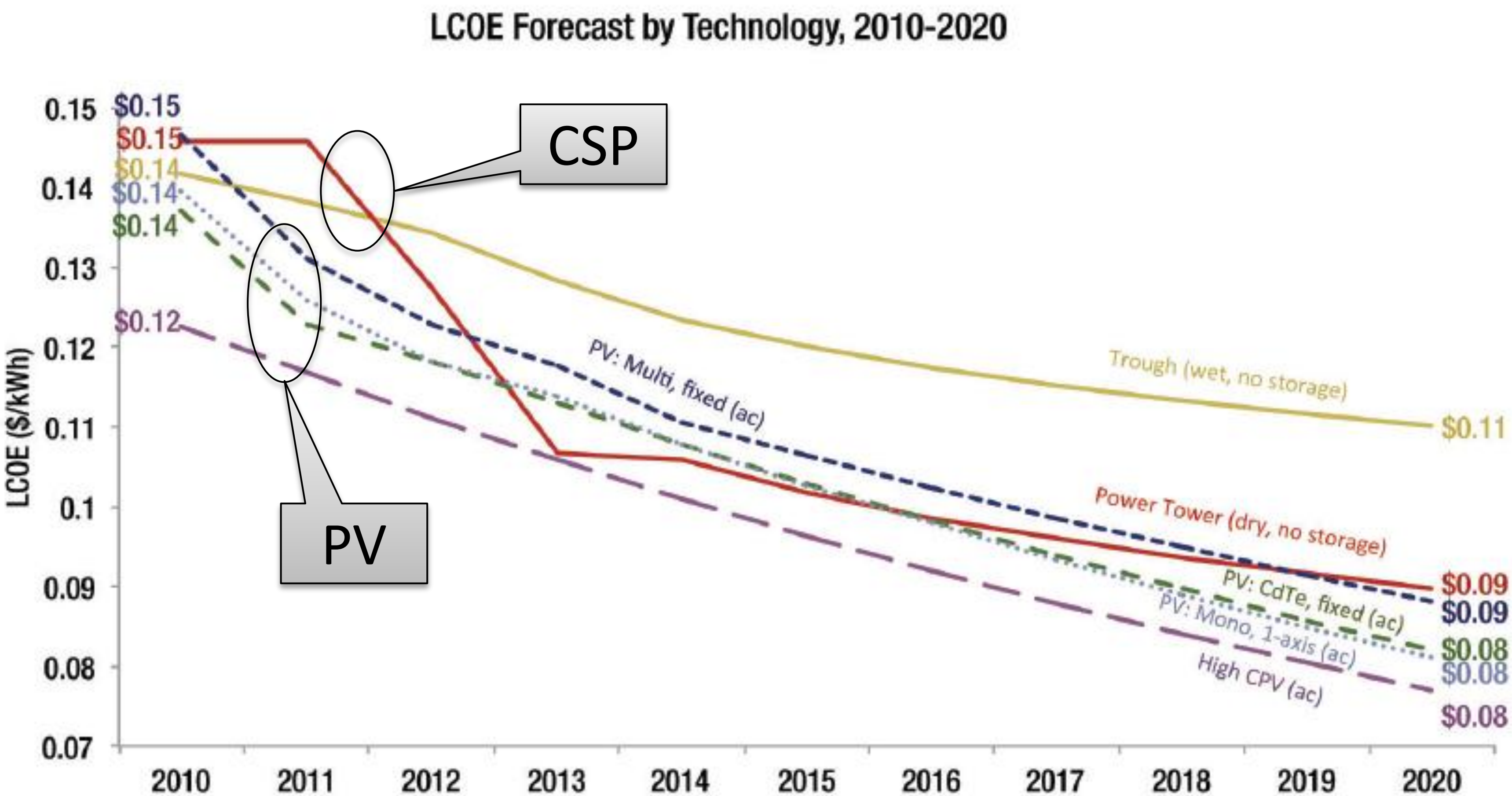
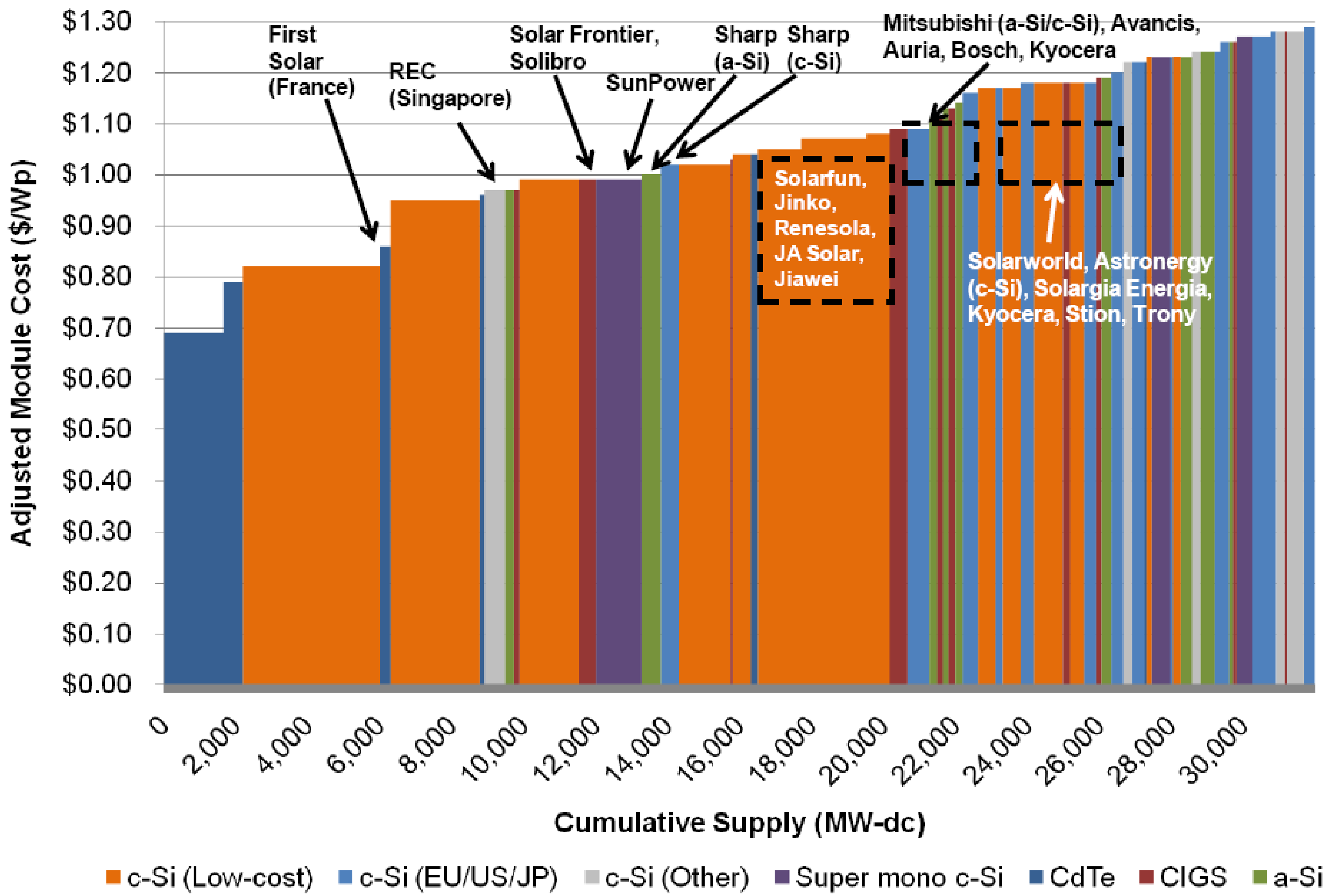
PV has a higher cost reduction potential than more conventional technologies



© GTM Research: Concentrating Solar Power 2011

Offer in 2013: costs adjusted for efficiency, bankability



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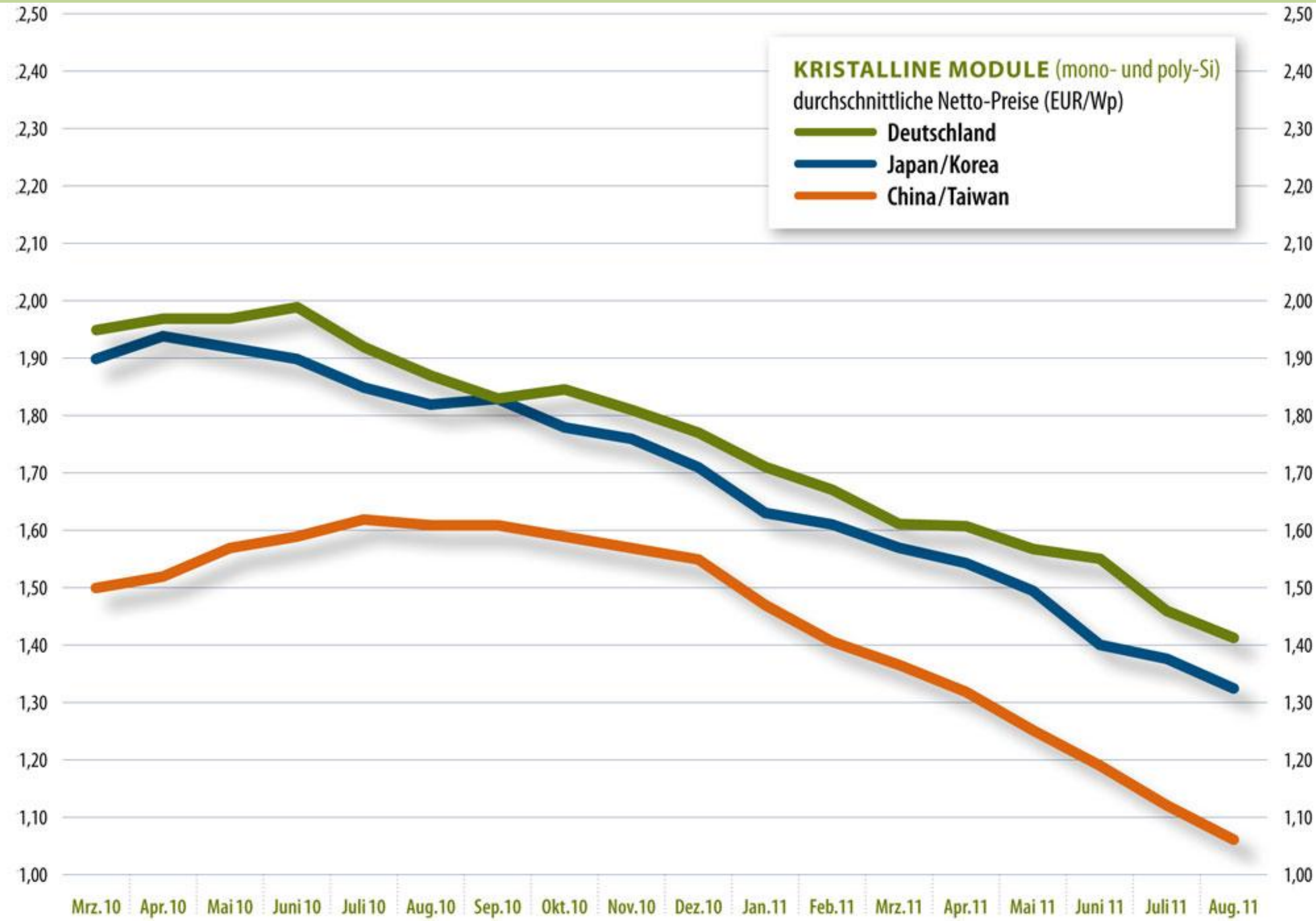
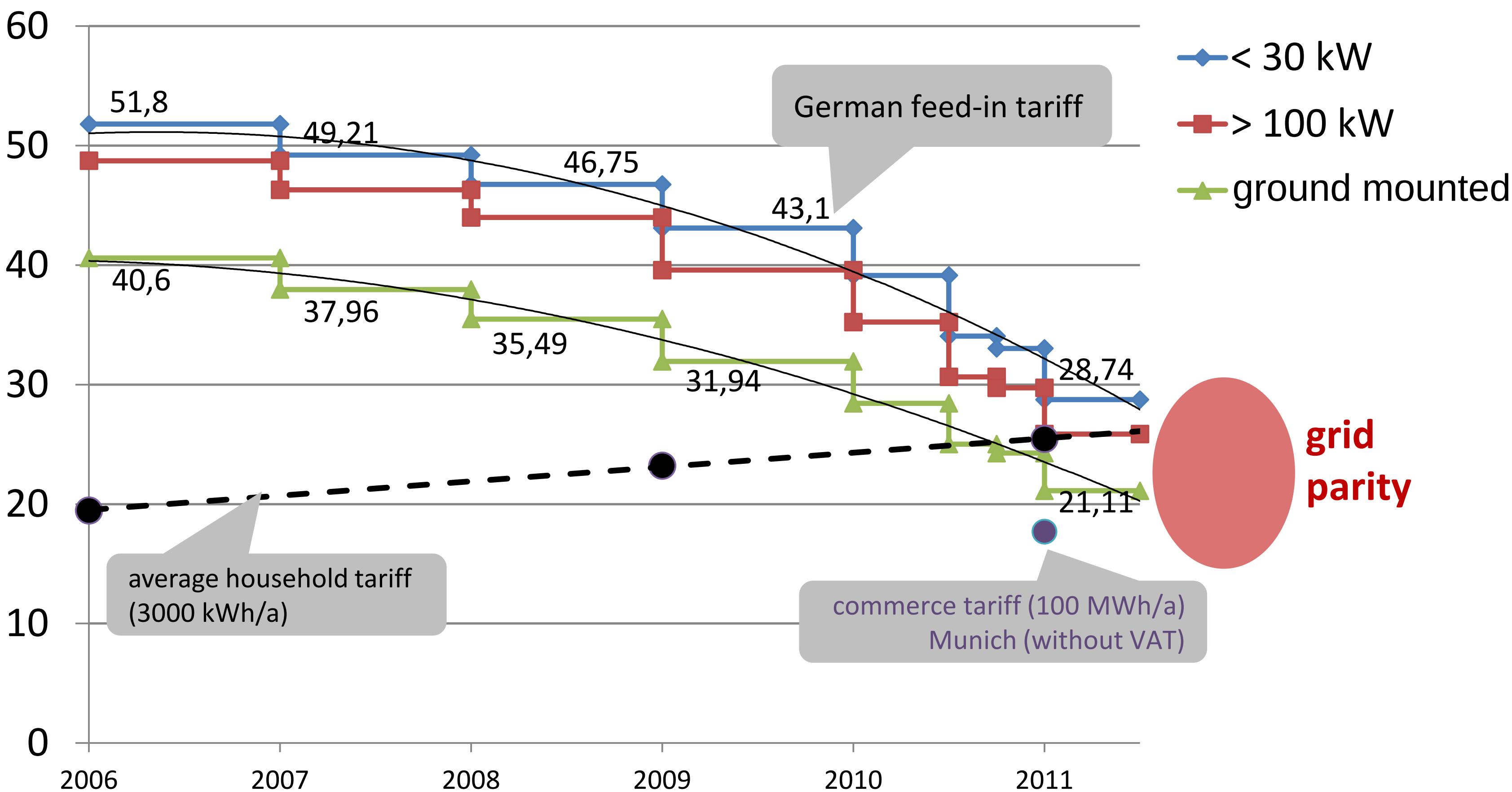
PV prices continue to fall rapidly: -30% in 12 months



Structural Change in the PV Industry

- To a large extent PV industry becomes a mature semiconductor industry based on standardised mass products
- Strong competition leads to market shakeout
- Large European producers are revising their business model and start mass production in Asia (Q-Cells, Solon, REC)
- Increasing importance of large players with strong capital basis (Bosch, Schott, Sharp, SunPower/Total, General Electric)
- European PV manufacturers will have to develop system competence and provide integrated solutions
- European manufacturers of production equipment deliver integrated solutions and maintain leaders in technology
- Larger industrial units require more international co-operation

Rapidly decreasing German feed-in-tariffs: grid parity next year (2012)



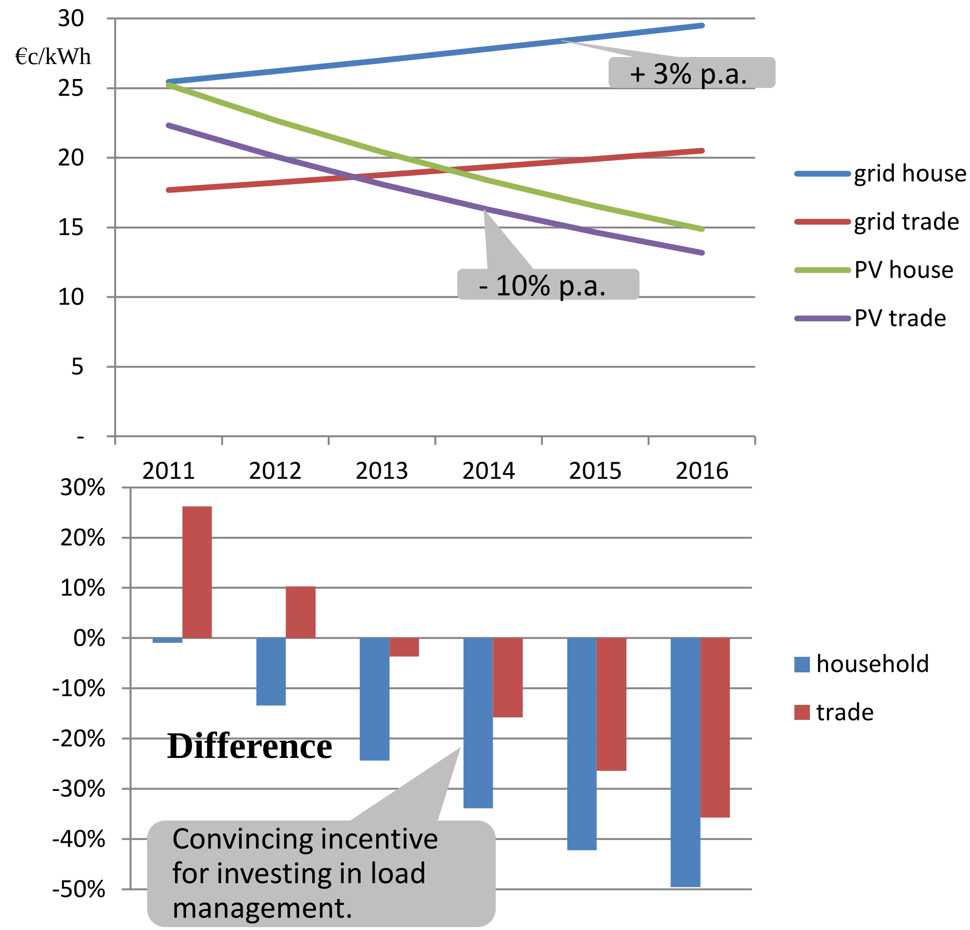
Attractiveness of captive power production in Germany: scenario for the next five years

- In the last four years the average PV system price declined by 50% (3Q07-3Q11, <100kWp, Germany) corresponding to *-16% p.a*.

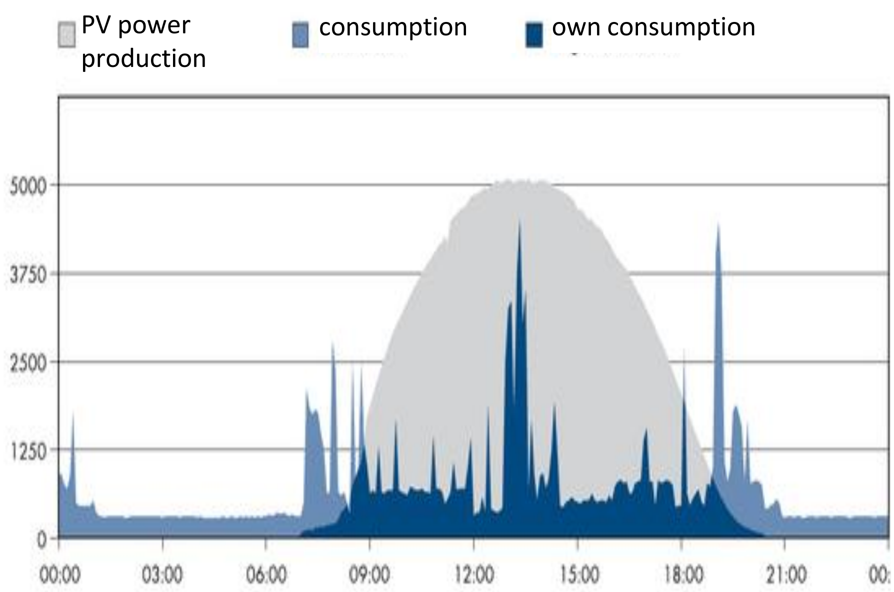
- Scenario assumptions
  - System price development: *-10% p.a*.
  - Power from the grid: + 3% p.a.
  - PV power cost: based on the relation between FiT and system price in 2008 (steady growth conditions)

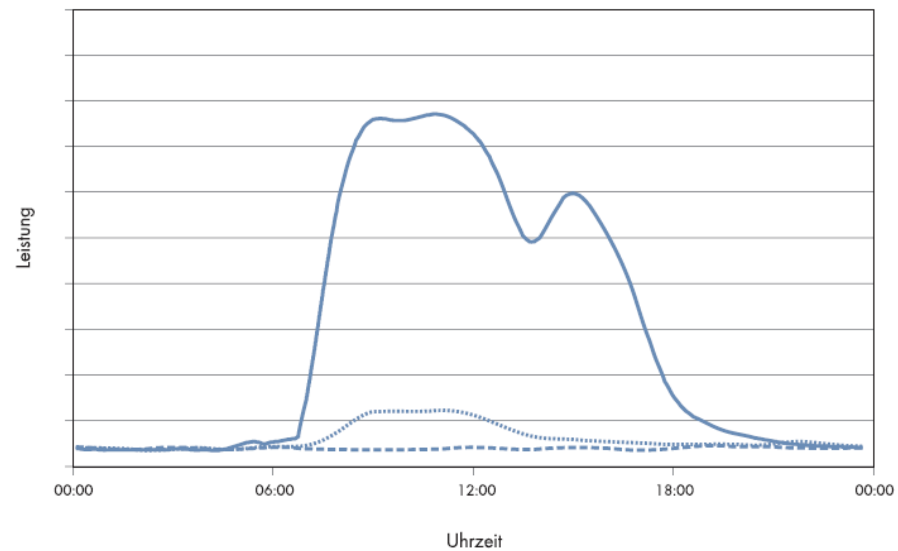
➢ In five years PV power from the roof could cost 40% less than power from the grid

Evolution of the difference between grid tariffs and own PV power costs



Power need when the sun does not shine: different potentials for own consumption





Private household

clouless summer day, 4 persons,

PV installation 5 kWp

→ Efforts needed for > 30% of own consumption

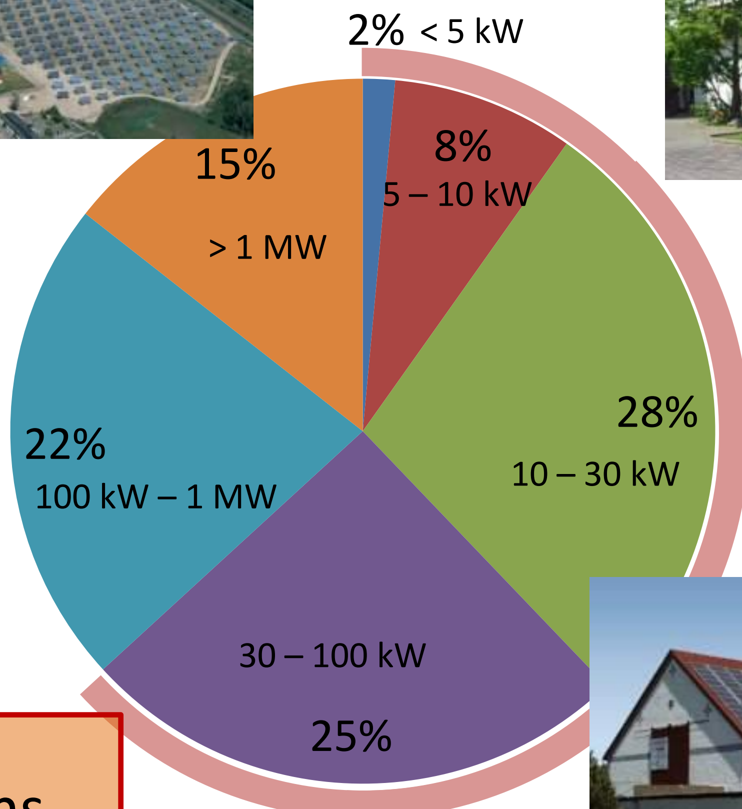
Commerce

working day 8-18h

BDEW Lastprofil G1

→ Good conditions for high share of own consumption

From 2013: large shares of the German PV market interesting for own consumption



Installations
january – september **2010**

60% of
new installations
< 100 kW

data: BNetzA 2010

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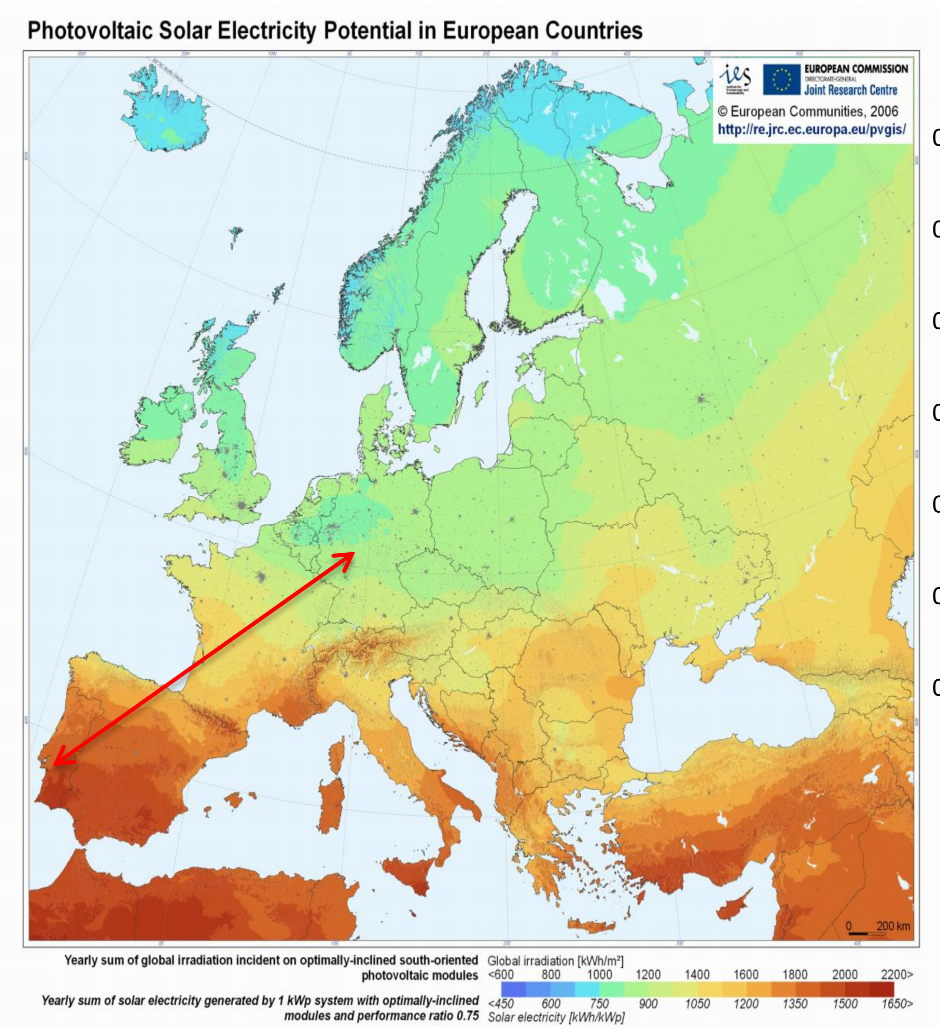
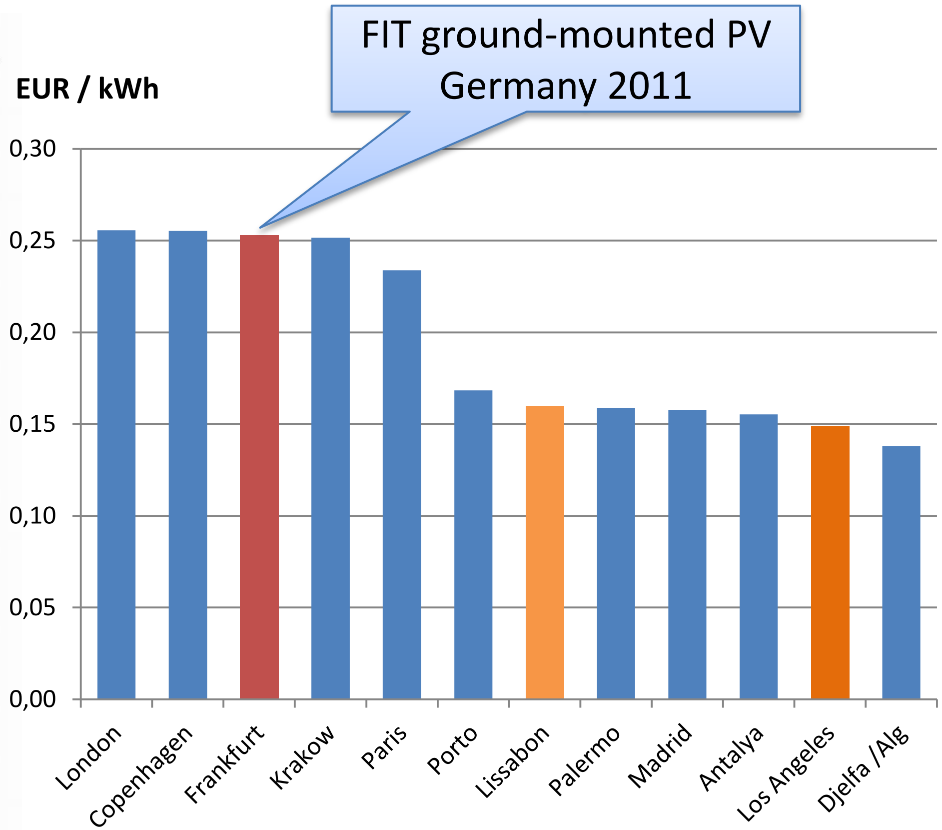
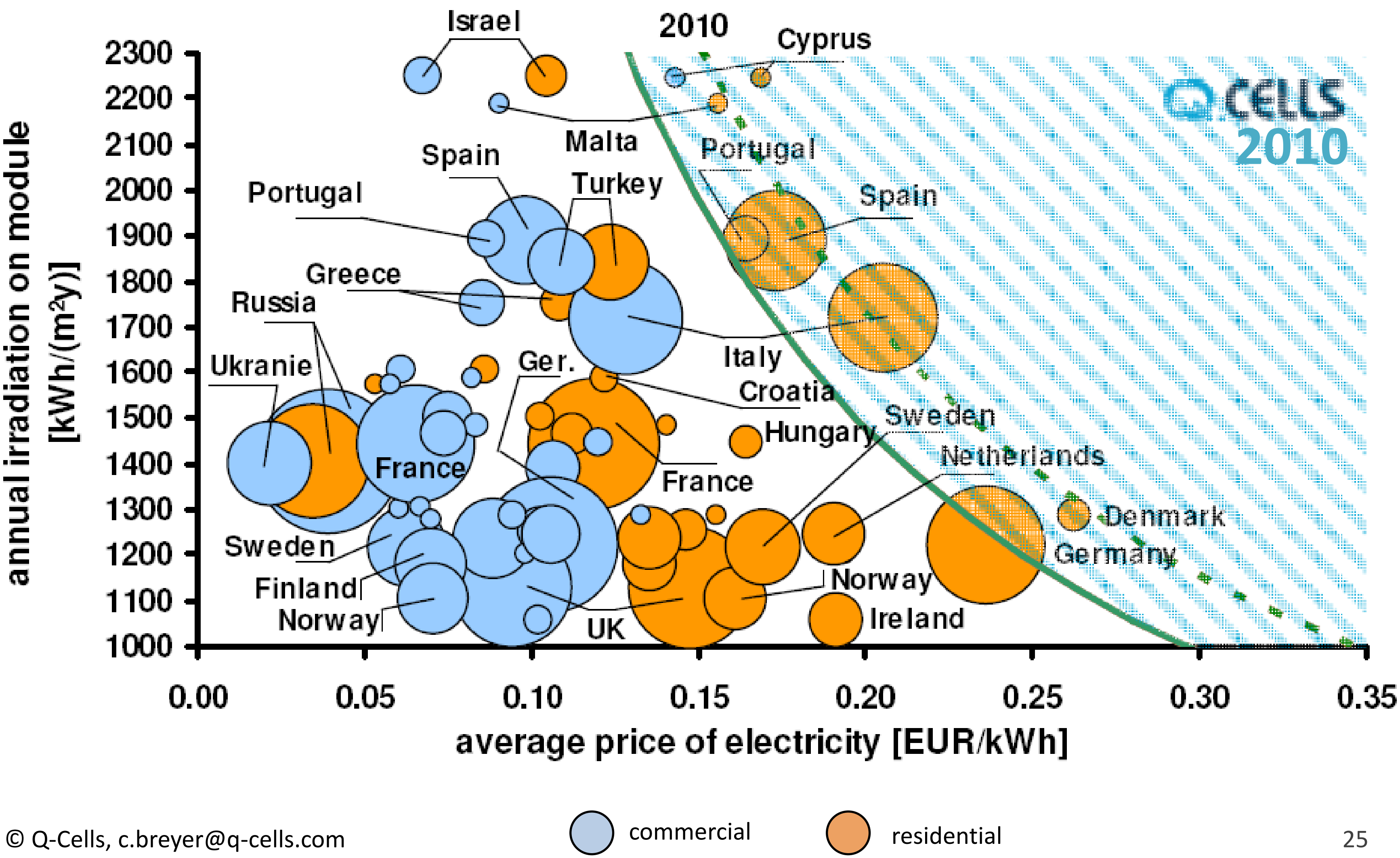
Typical system in Spain (Menorca): 3.2 MWp

The influence of differences in solar radiation on the LCOE (levelised cost of electricity)

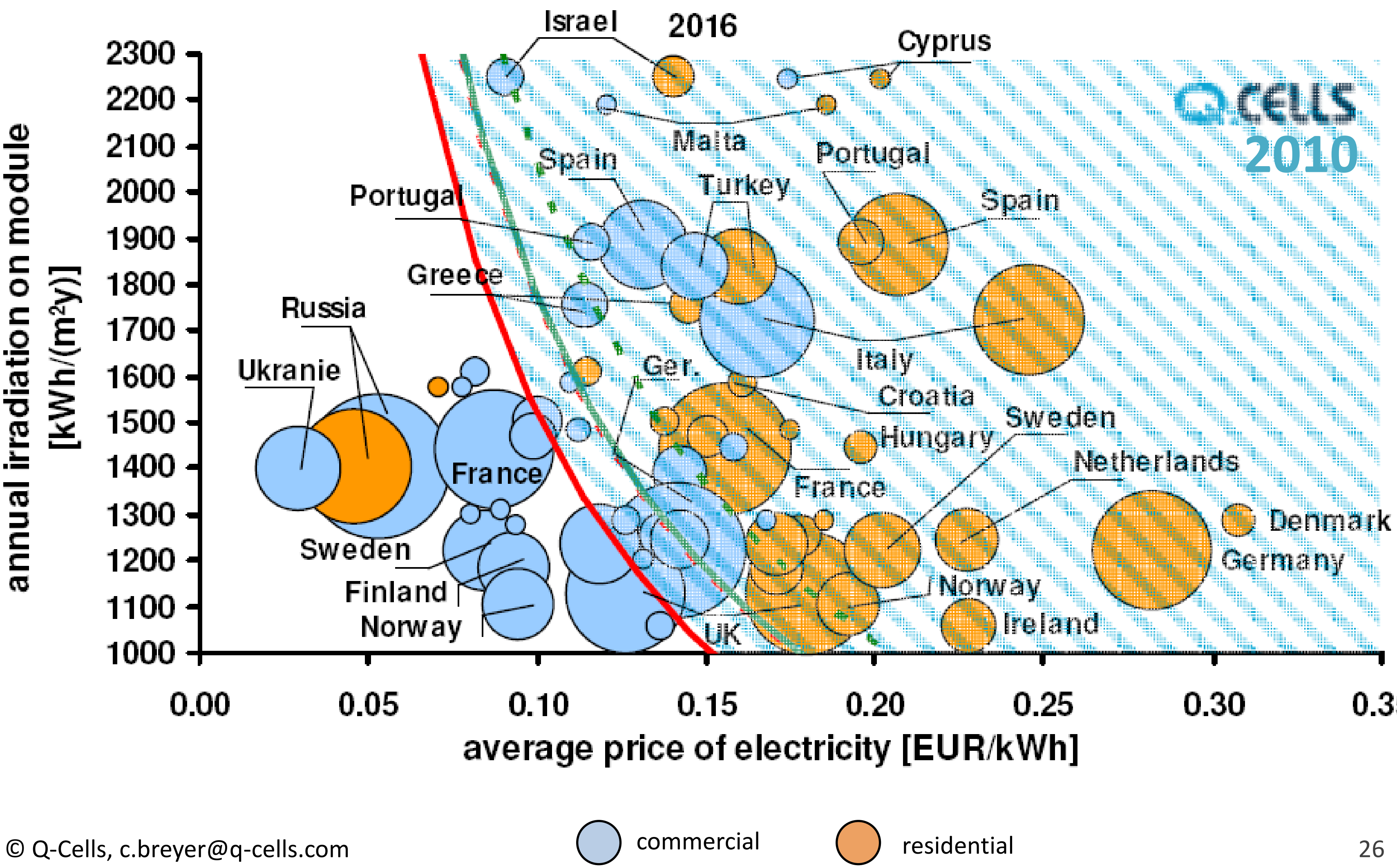




Grid parity in Europe 2010



Grid parity in Europe 2016
(forecast in 2010)



The coming boom: captive power generation

Attractive investments even without incentives:

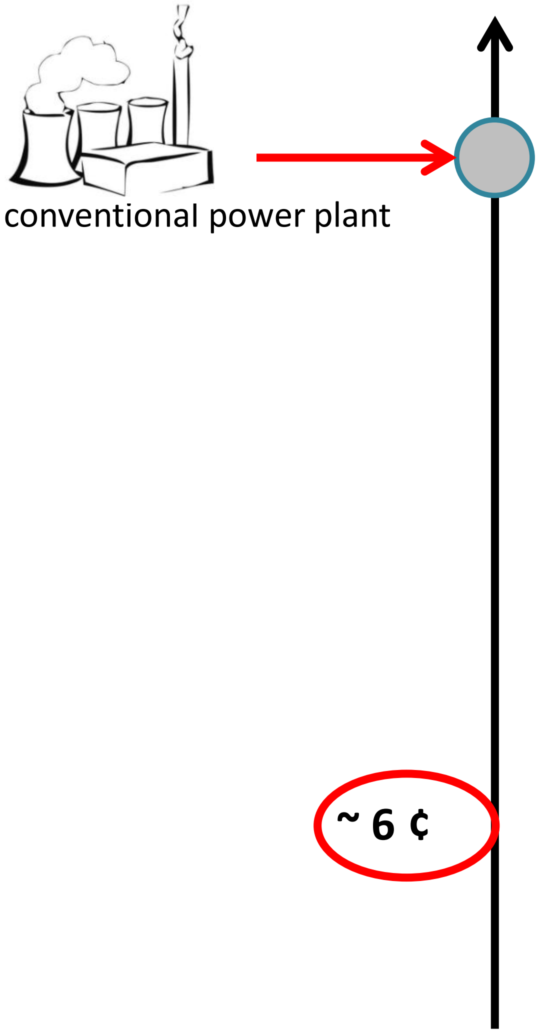
- In two years: PV power for own consumption in commerce and services
- In three years: Supplementary investments for increasing the share of own consumption

➢ PV growth independent from incentives

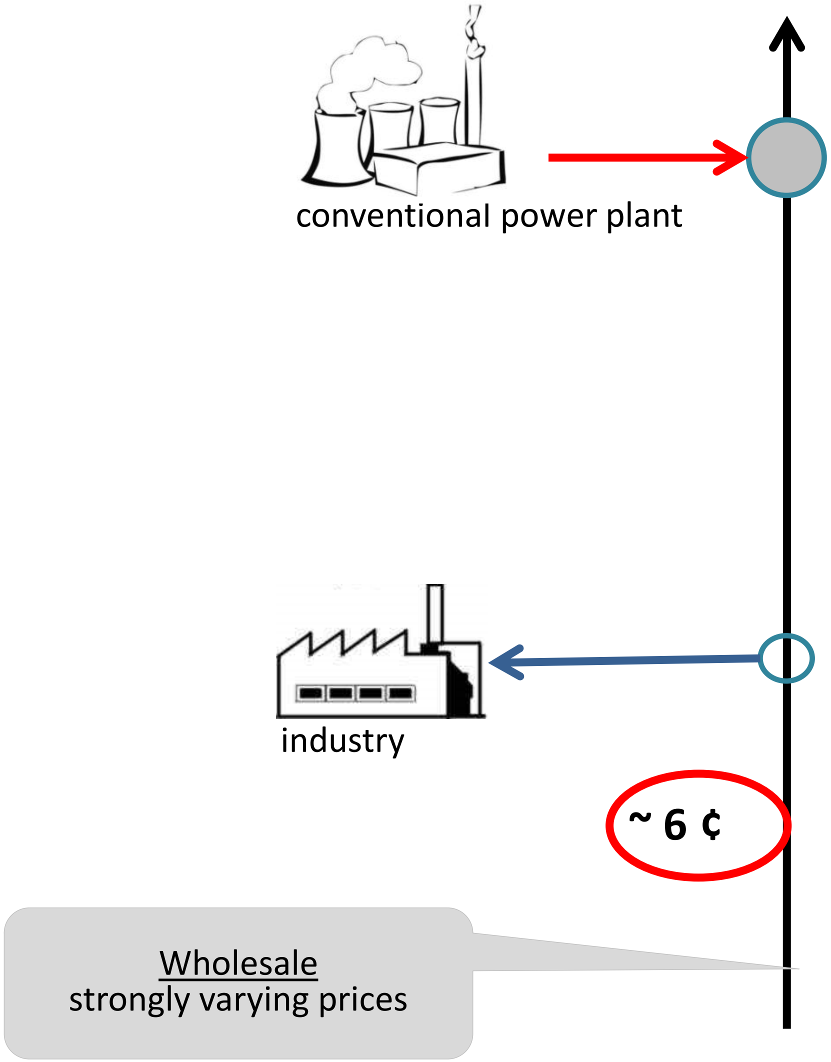
➢ Boom in power management technologies

THE BIG CHALLENGE: COPING WITH A TURBURLENT TRANSFORMATION

Photovoltaics is a modular technology: competing on the retail side

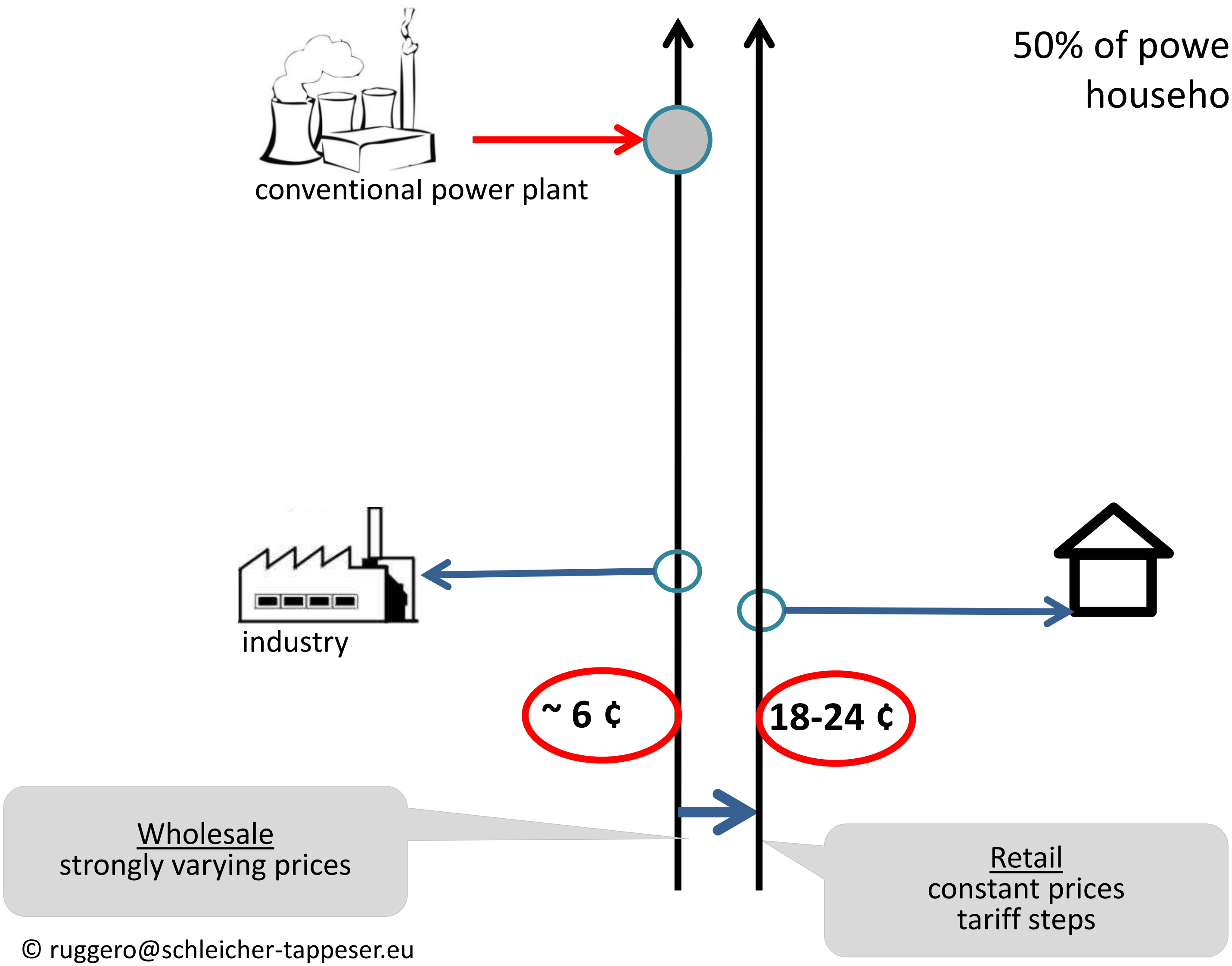


Photovoltaics is a modular technology: competing on the retail side



Photovoltaics is a modular technology: competing on the retail side

50% of power consumption:
households, commerce,
services



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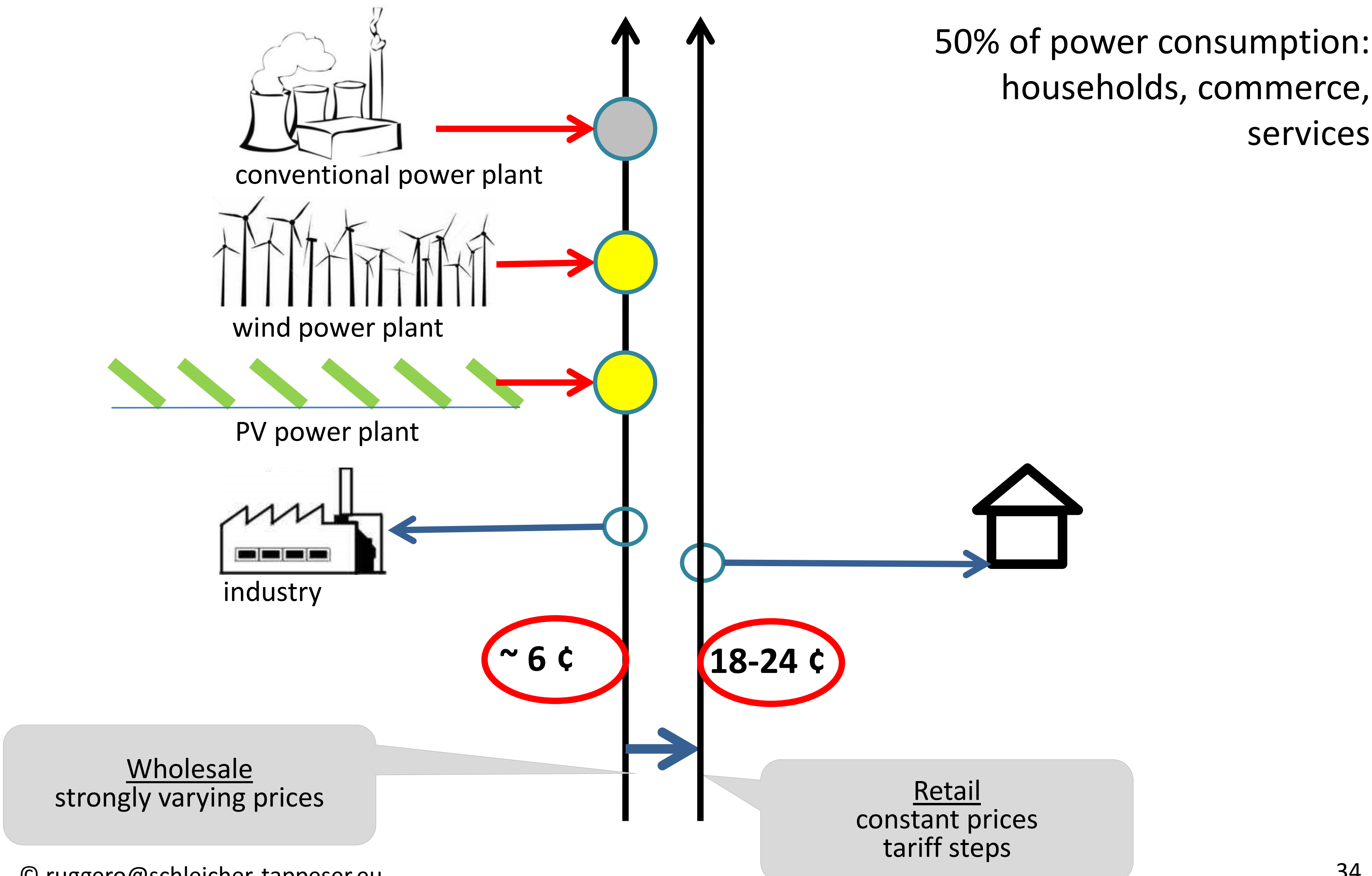

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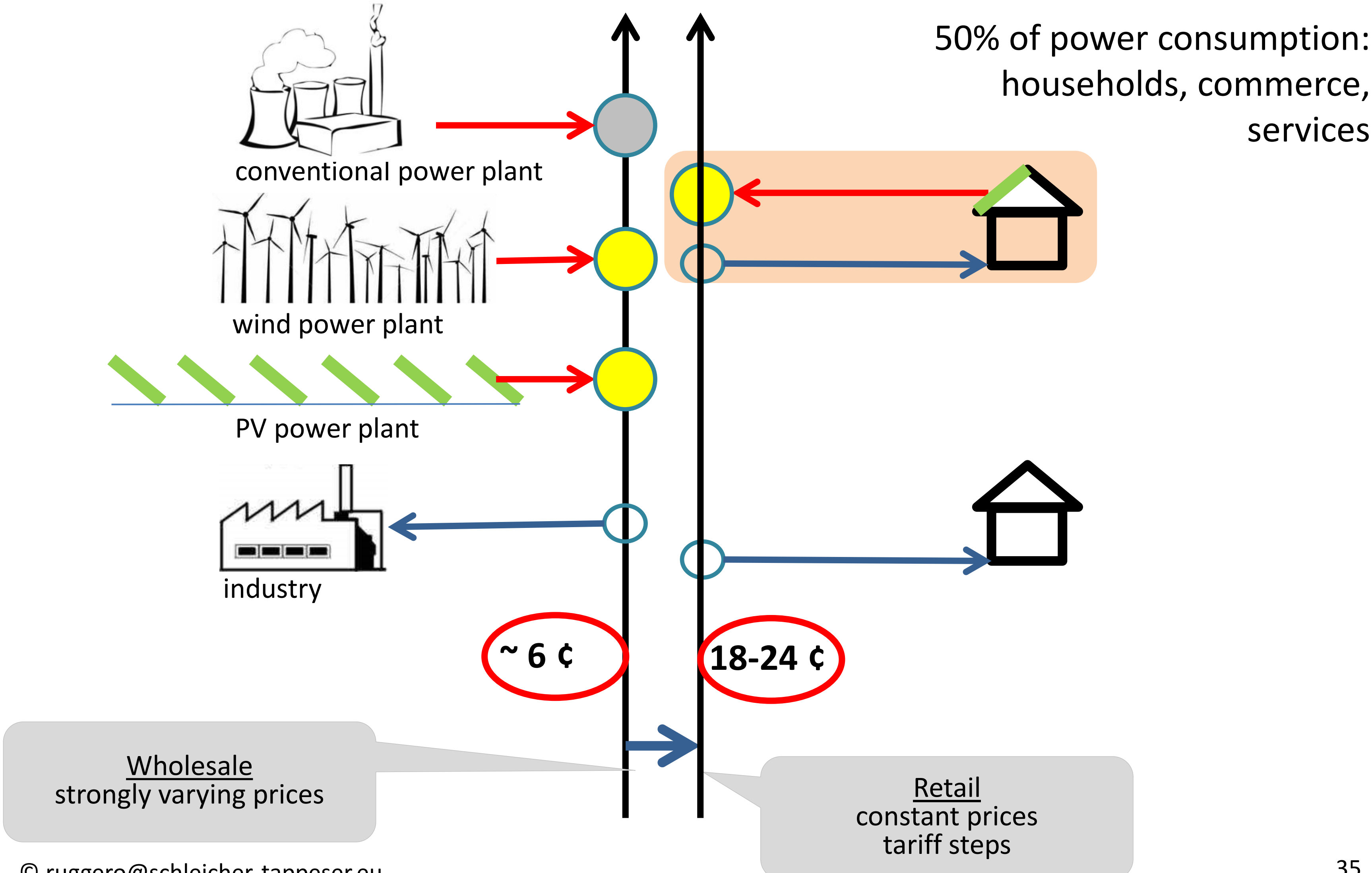

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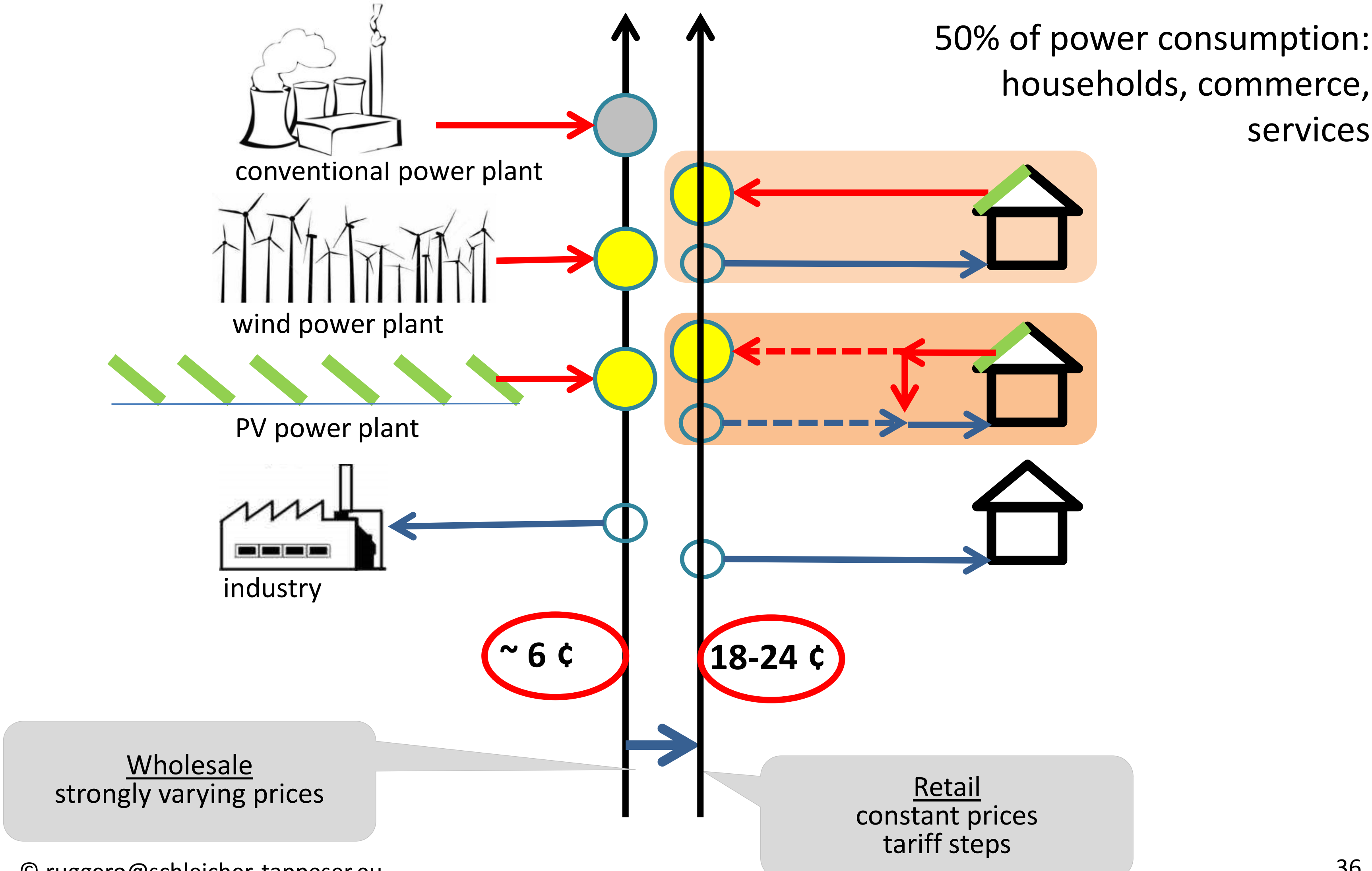

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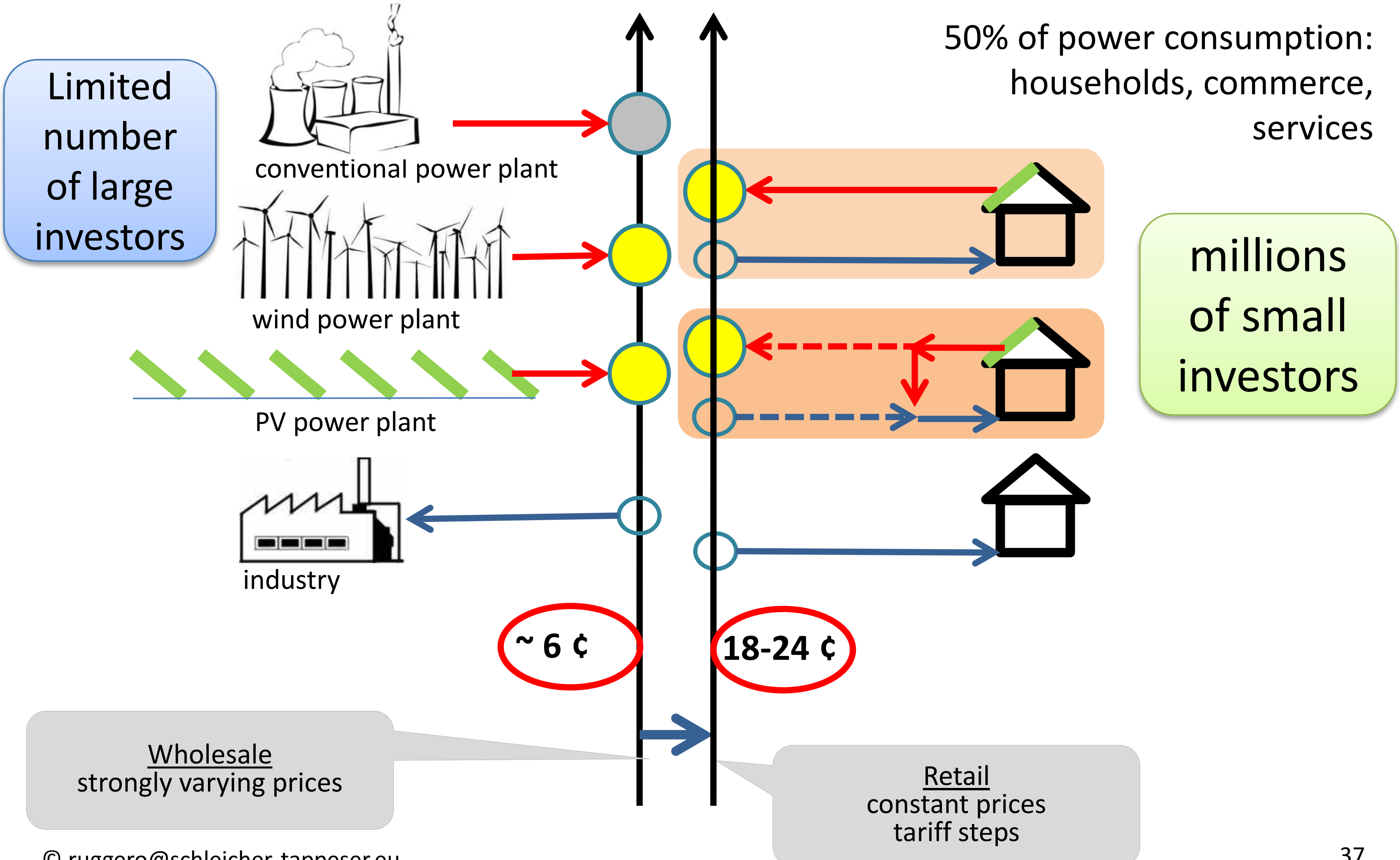

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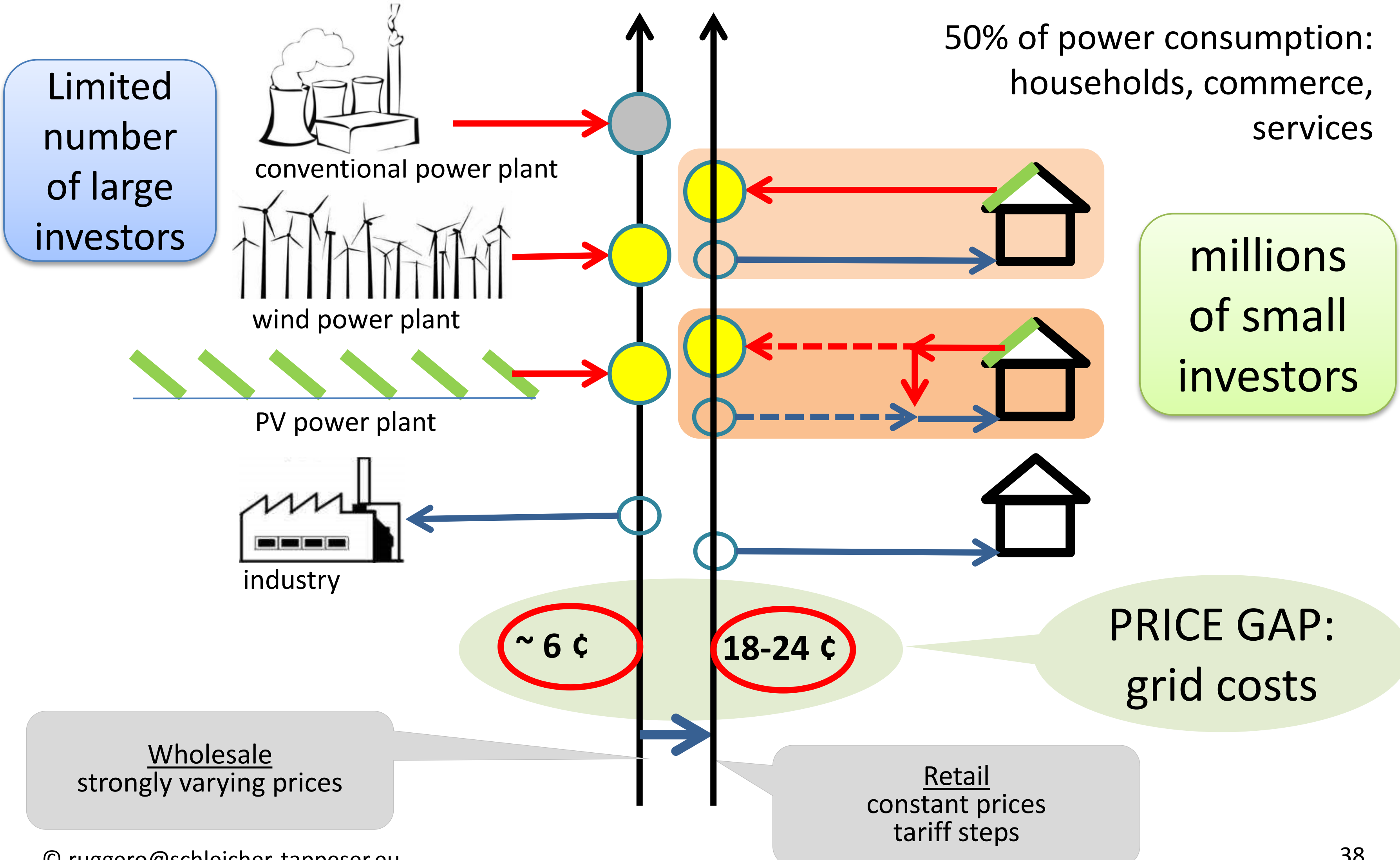


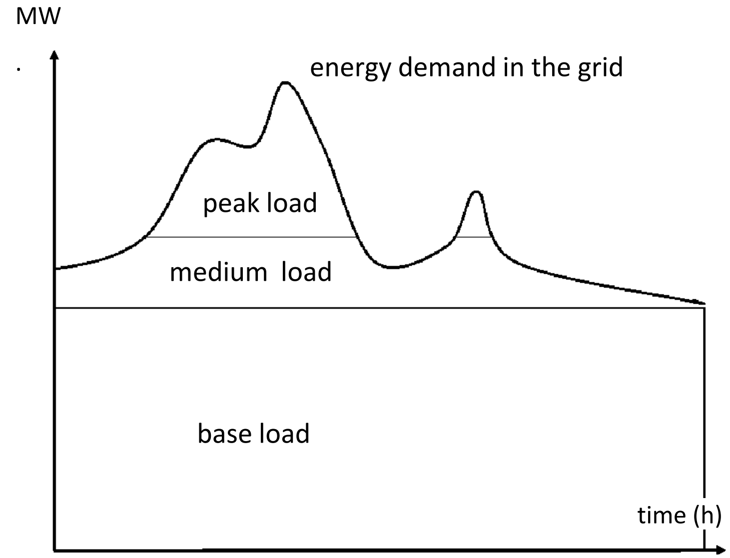
The main problem with high shares of wind and solar power: fluctuation

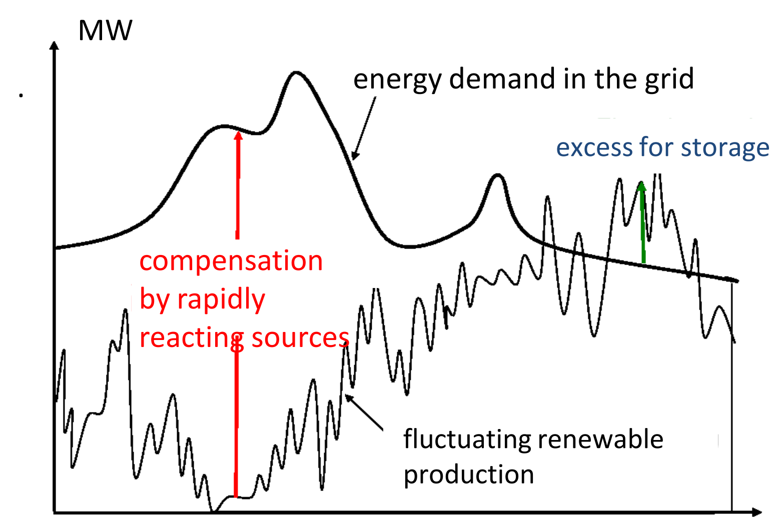
The old base load concept:

- cheap base load electricity from large plants
- expensive peak load from more variable sources

The new paradigm:

- Variable production from re-newables with zero marginal cost
- Compensation with rapidly reacting sources (hydro, gas turbines)
- Storage becomes important
- Load management becomes important (smart grid)
- No need for baseload plants





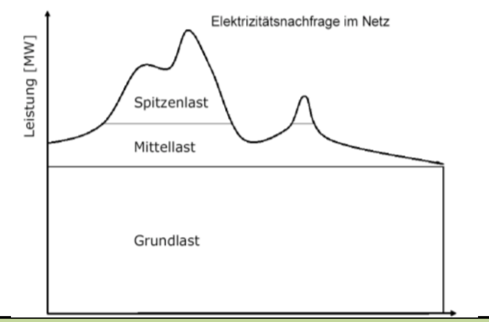
Increasing the share of own consumption: dealing with fluctuation locally

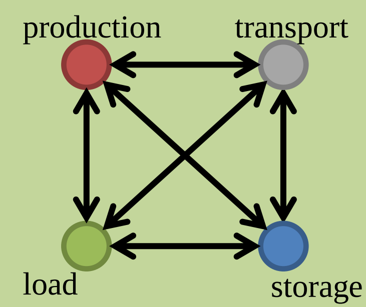
- <u>Load management</u>
  - Temporal shift of operation
  - Thermal storage in heating and cooling applications (cooling, air conditioning, warm water, space heating, process heat)
  - Storage of compressed air for mechanical applications
  - Combination of different users
- <u>Additional, non time-critical loads</u>
  - Loading electrical vehicles
  - Heat pumps: substitution of other kinds of heat production
  - Production of synth. methane or hydrogen (larger plants)
- <u>Storage of electricity</u>
  - Batteries
  - Flywheels

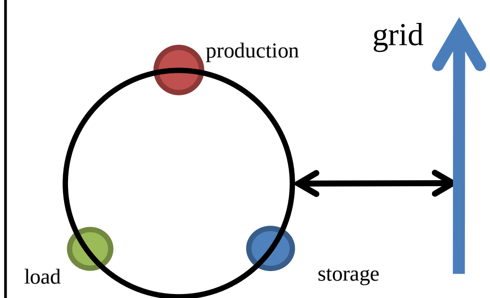
➢ Flexibility of the user system increases

Change of the control logic of the electricity system

Traditional Large power plants fossil and nuclear Transformation	• Production follows demand: base / middle / peak load • Load management only with large consumers • Central control
Supply 100% REN Integrated optimisation of the whole system	• Fluctuating production with wind and sun dominates • Load management, storage • Complexity requires optimisation on several levels
Contribution ***Captive power production*** *Optimisation on the consumption level*	• Optimisation subsystem • Partial buffering of fluctuations at the local level • Facilitation of optimisation at higher levels







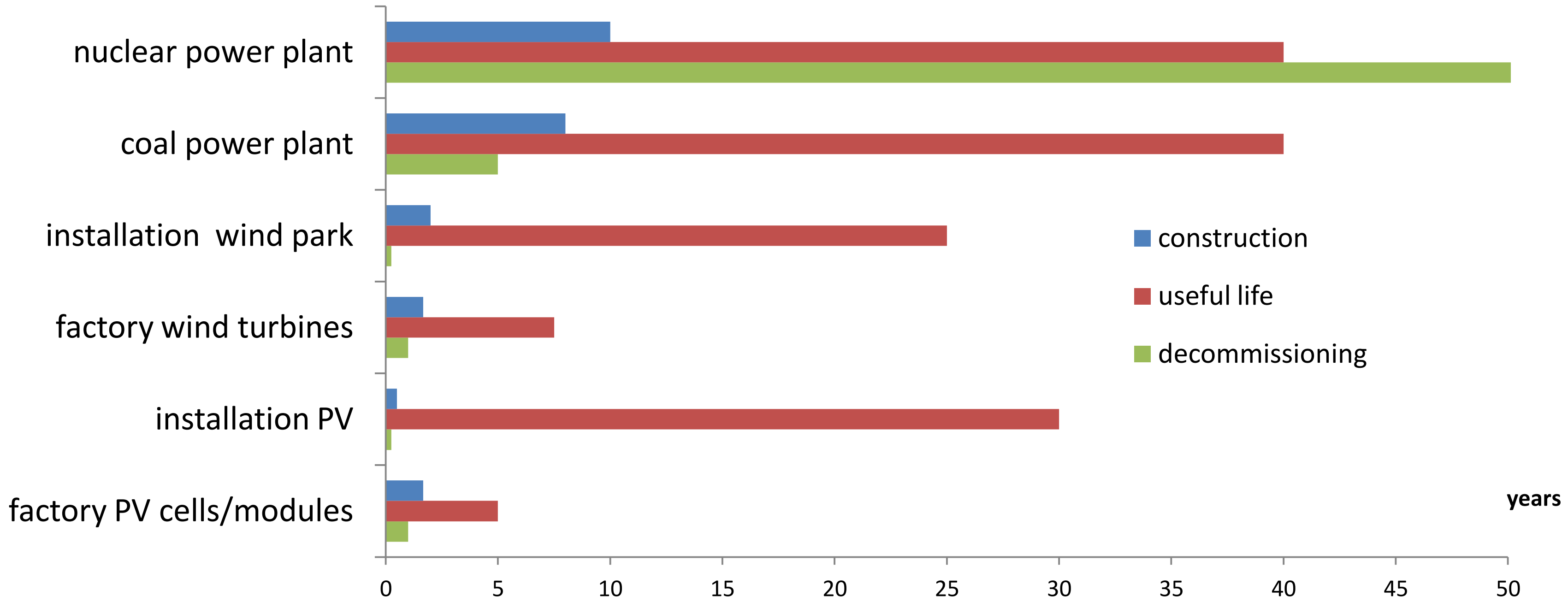
Unfamiliar to energy business: 4 to 10 times shorter innovation cycles

→ More rapid build-up of capacities

→ More rapid decrease of costs

→ More rapid transformation of the electricity sector

Dramatic acceleration compared to traditional energy technologies



Main economic advantages for the society

- No fuel imports
- High value added at the regional level: employment, profits, taxes
- Several value-added steps with a broad variety of qualifications required
- Overall balance soon positive: start-up financing payed back rapidly
- High security of supply, avoidance of international conflicts
- No follow-up costs for future generations (e.g. climate damages, pollution, waste …)

The value chain:
smaller installations – more local content

↓ Research institutes	international
↓ Manufacturers of production plants	international
↓ Banks and financing companies	can be local
↓ Manufacturers	
– silicon	international
– wafers, cells	international
– modules	can be local
↓ Traders	can be local
↓ System integrators, EPC contractors	can be local
↓ craftsmen in the construction business	local
▪ operating company	can be local

smaller installations – more opportunities for local added value

The semiconductor revolution is reaching the power business – new strategies needed

- Renewables to take over: after market creation by politics, industrial dynamics and technology innovation now push for change
- semiconductor technologies transform power generation, energy management and the grids at unprecedented speed
- Distributed solar power generation will play an important role
- System competence will become most important at all levels, new players are entering the game
- New business models and adapted regulatory frameworks are urgently needed
- A collective international learning process is needed for managing the transition

The most important CHALLENGES

- For the Industry:
  - To develop new knowledge and capacities in time
  - To cooperate internationally while creating local added value
  - To cooperate for reaching system competence finding innovative and strong partners
  - To develop new business models, e.g. for captive power generation
- For the utilities:
  - To integrate a large and increasing share of fluctuating electricity production
  - To strive for an integrated management of energy production and consumption
  - To develop new business models, cooperating with partners at different levels
- For government and administration
  - To develop a vision for the future of the energy system
  - To create stable investment conditions, and ensure steady market growth for a new renewable energy industry by transparently adapting a few key parameters and reducing subsidies for conventional energies
  - To support the transformation of the control logic of the electricity system developing a transparent multi-level governance and market system

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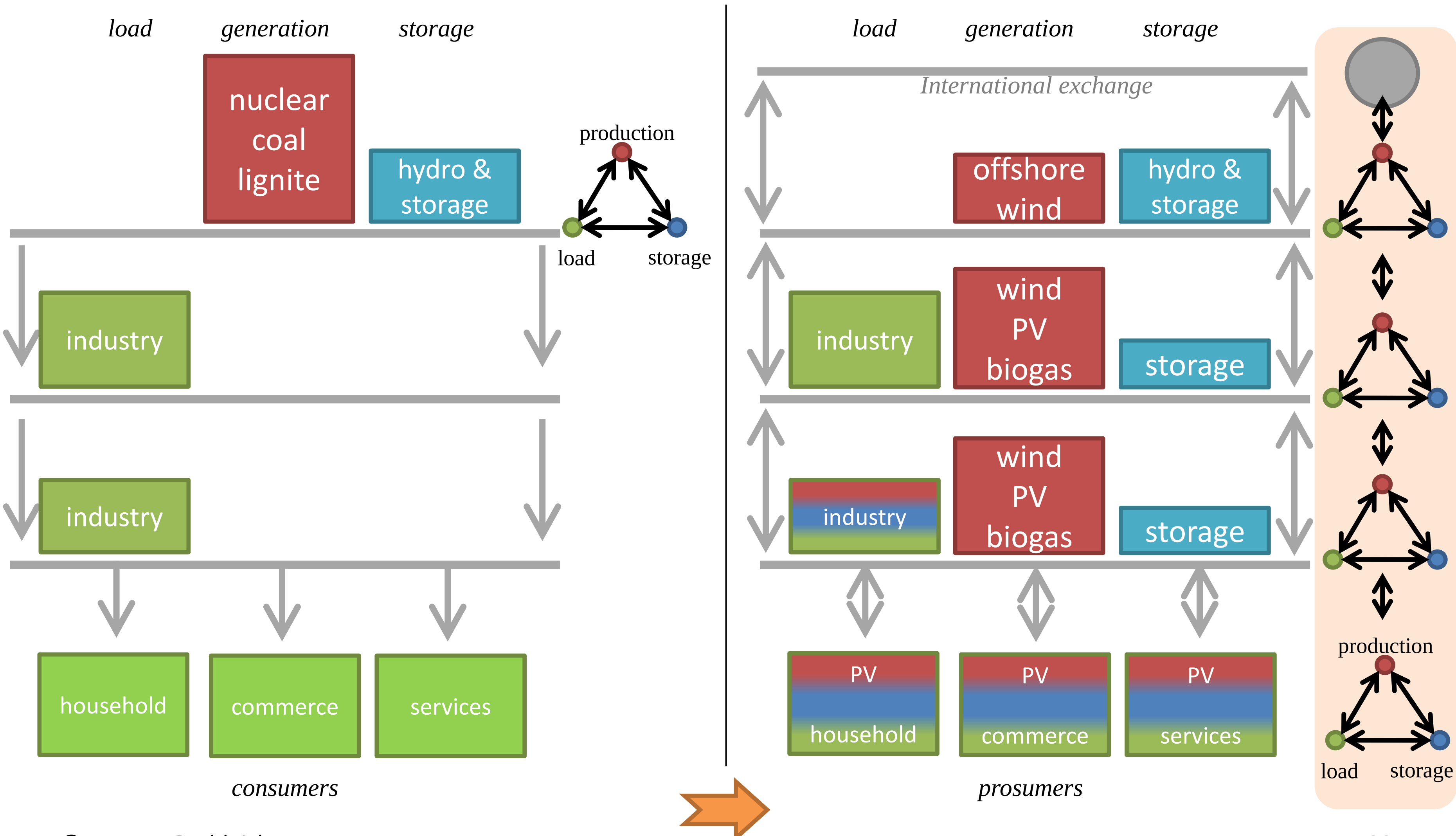
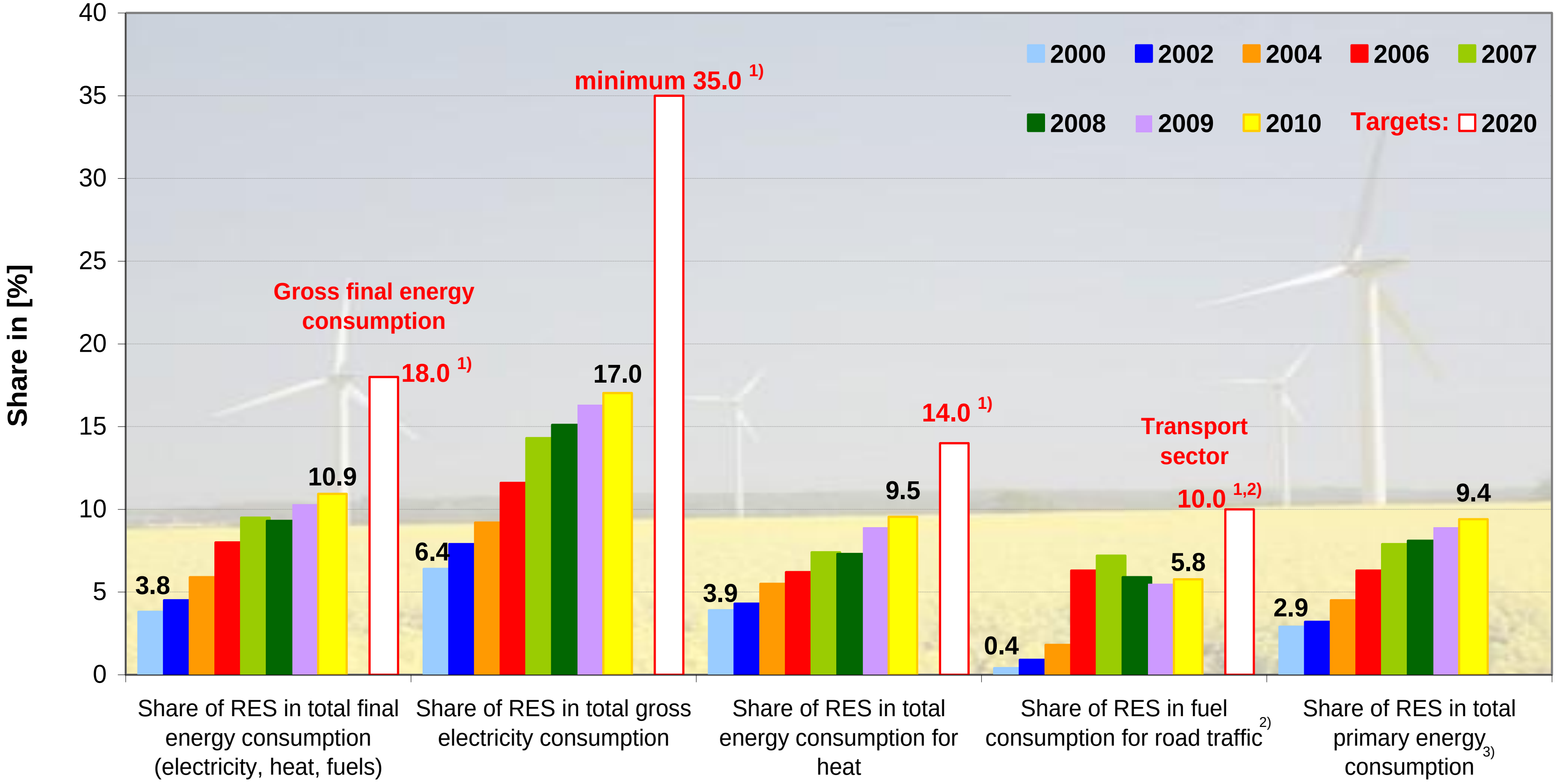
From top-down command to multi-level co-ordination

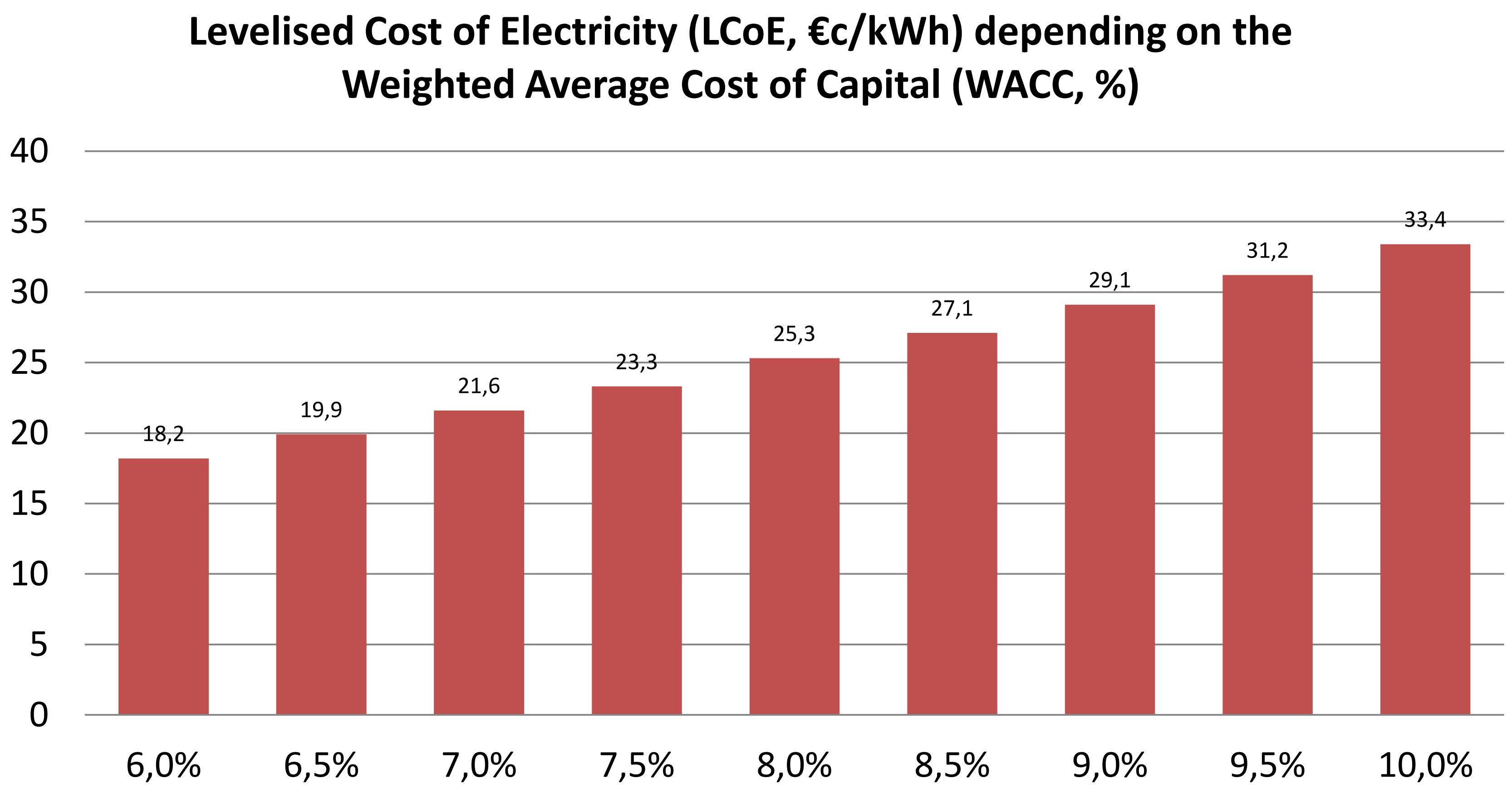


Renewable energy sources as a share of energy supply in Germany



1) Sources: Targets of the German Government according to Energy Concept, Renewable Energy Sources Act (EEG); Renewable Energy Sources Heat Act (EEWärmeG), EU-Directive 2009/28/EC;
2) Total consumption of engine fuels, excluding fuel in air traffic; 3) Calculated using efficiency method; Source: Working Group on Energy Balances e.V. (AGEB);
RES: Renewable Energy Sources; Source: BMU-KI III 1 according to Working Group on Renewable Energy-Statistics (AGEE-Stat); image: BMU / Brigitte Hiss; as at: July 2011; all figures provisional

Strong influence of capital costs



Example for a PV plant costing 3,43 USD/Wp