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Energy

Photovoltaics – Turbulent Growth of a Disruptive Technology: Learning from the European Experience

Ruggero Schleicher-Tappeser, consultant, Berlin

Seminar on German Solar Technologies
Vivanta by Taj, M.G. Road, Bangalore, November 14, 2011

renewables Made in Germany

BSW

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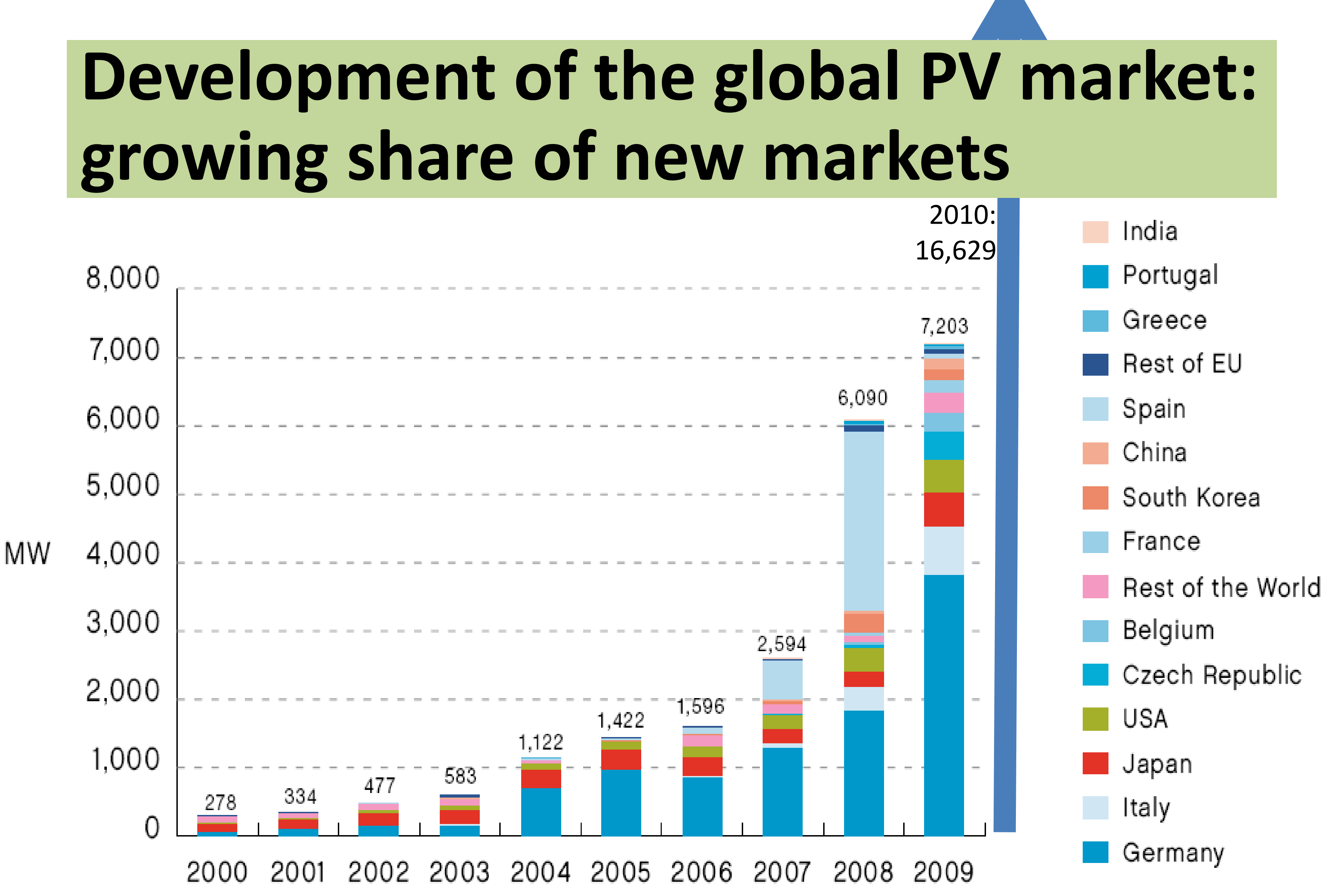
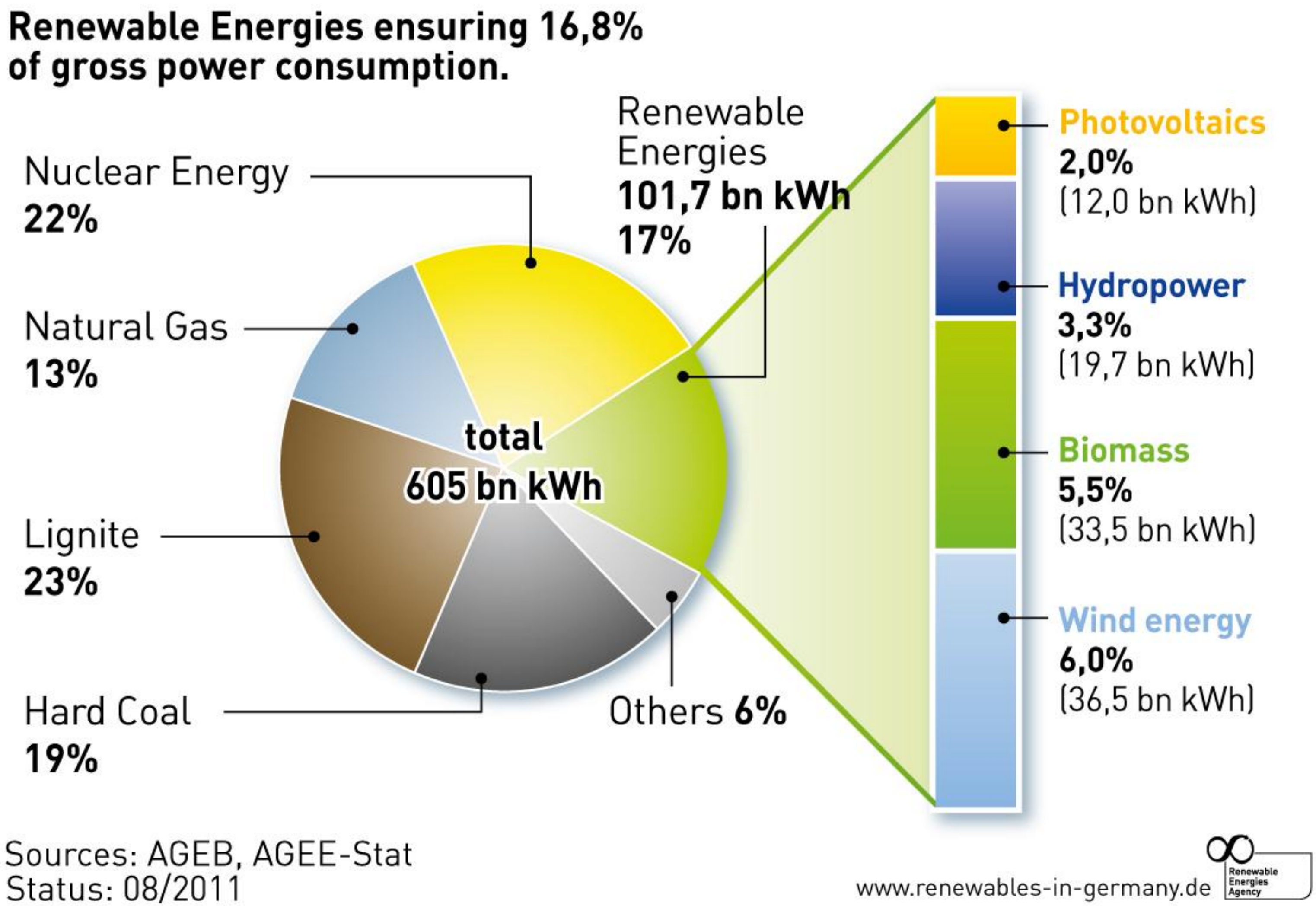
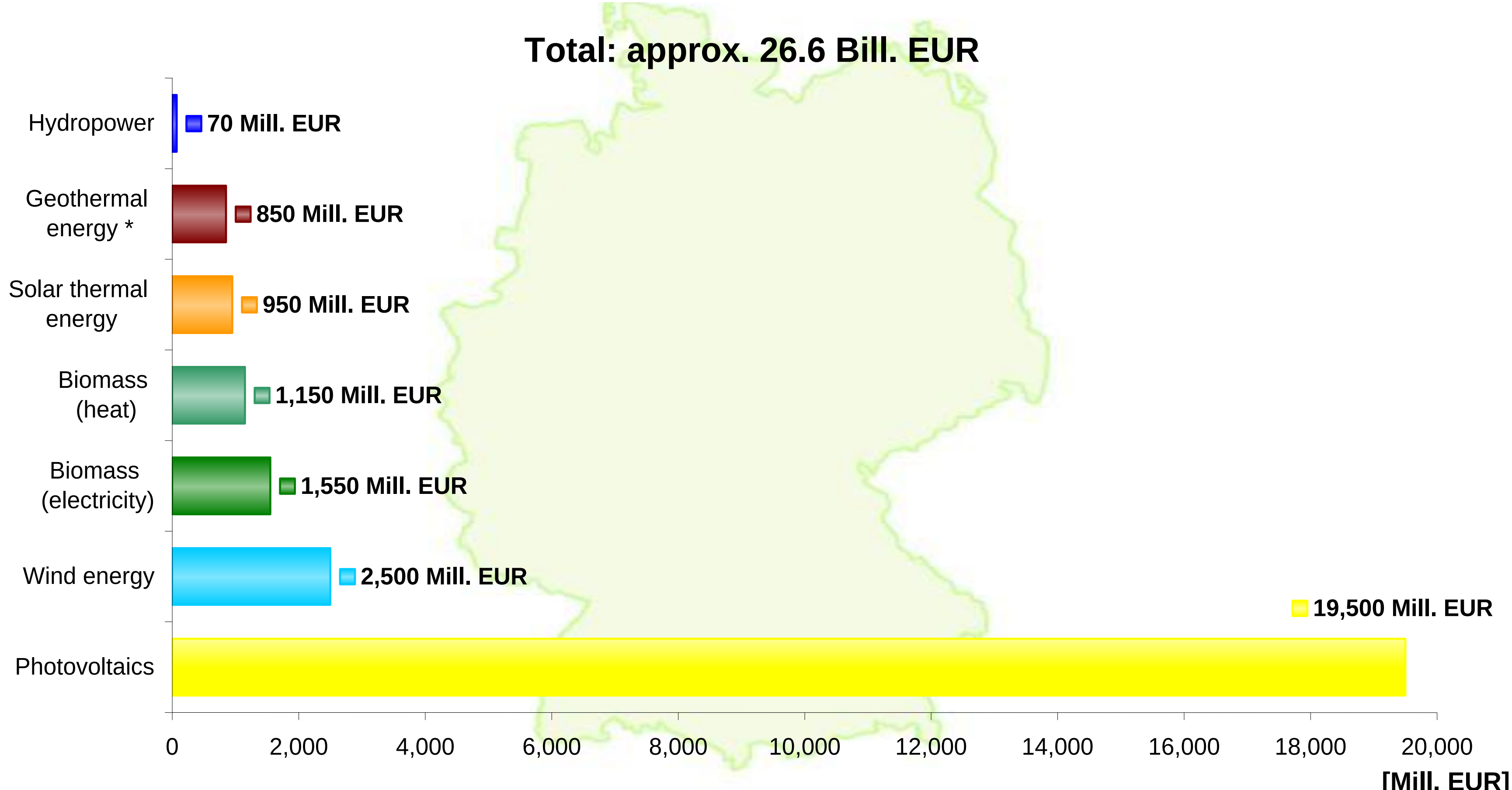
Development of the global PV market: growing share of new markets



Electricity production mix in Germany 2010



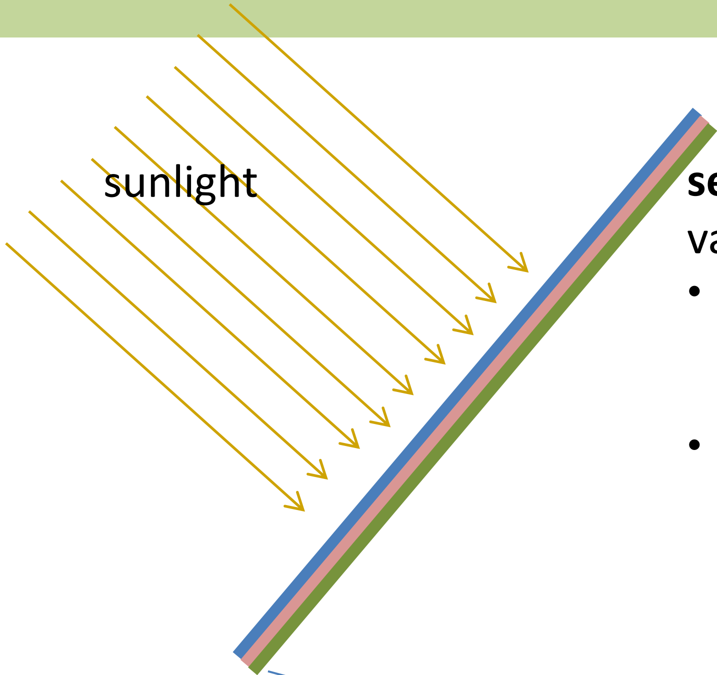
Investments in renewable energy installations in Germany 2010



* 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

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%
  - …

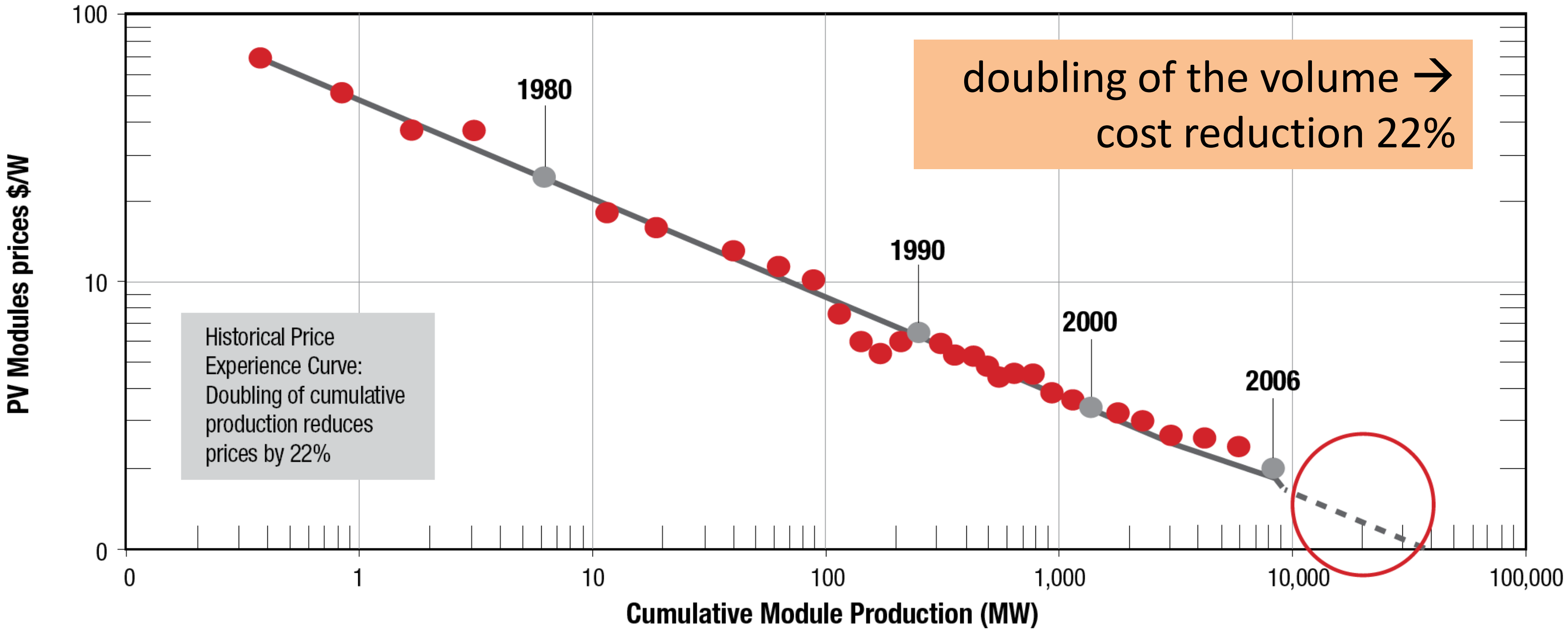
DC direct current – + inverter ~ AC alternate current

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

ruggero@schleicher-tappeser.eu

A modular, scalable technology: Typical photovoltaic systems

Rapidly decreasing Costs: The historical learning curve of PV

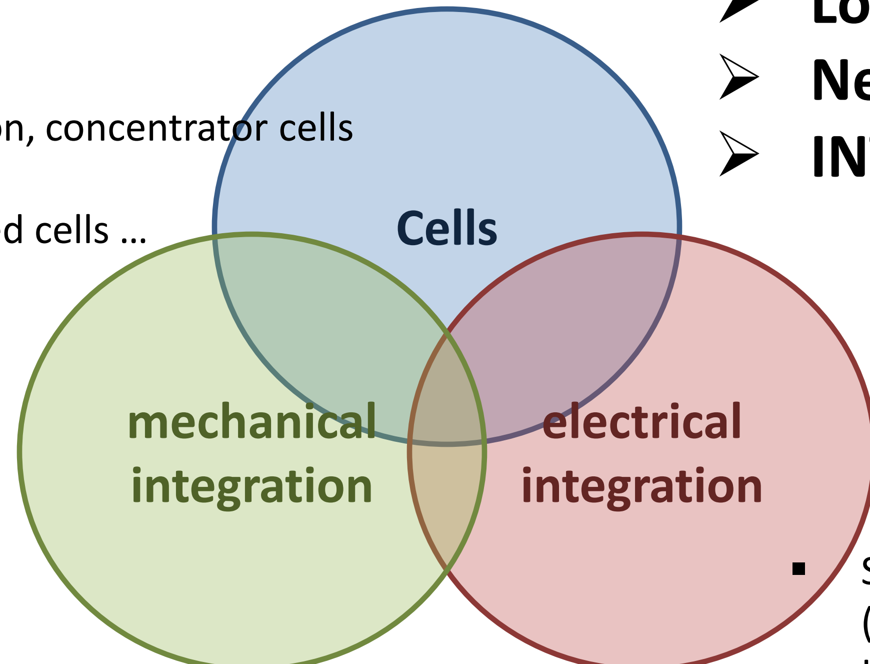


Sources: EU Joint Research Centre - EIA - National Renewable Energy Laboratory - A.T. Kearney analysis.

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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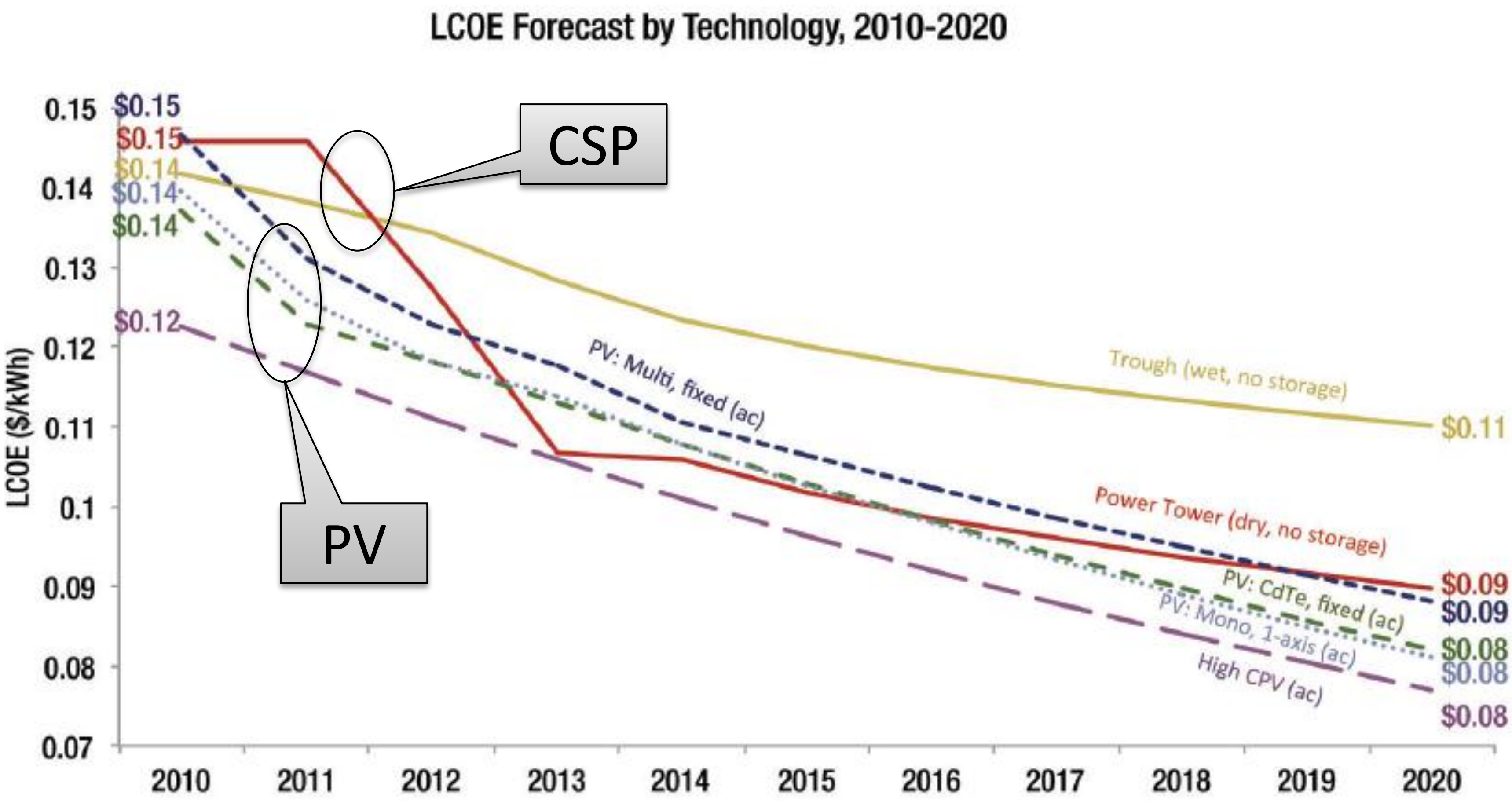
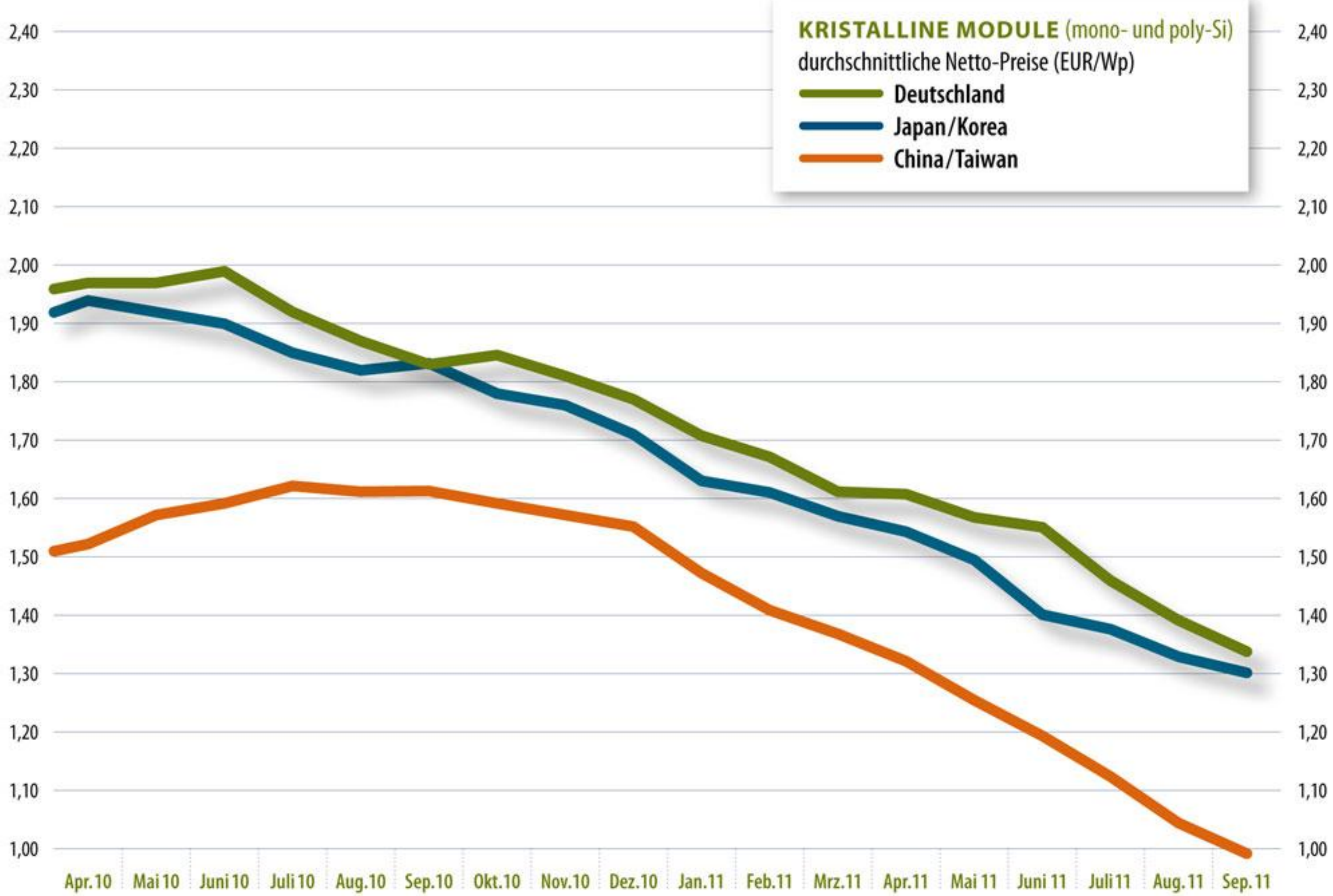
PV has a higher cost reduction potential than more conventional technologies

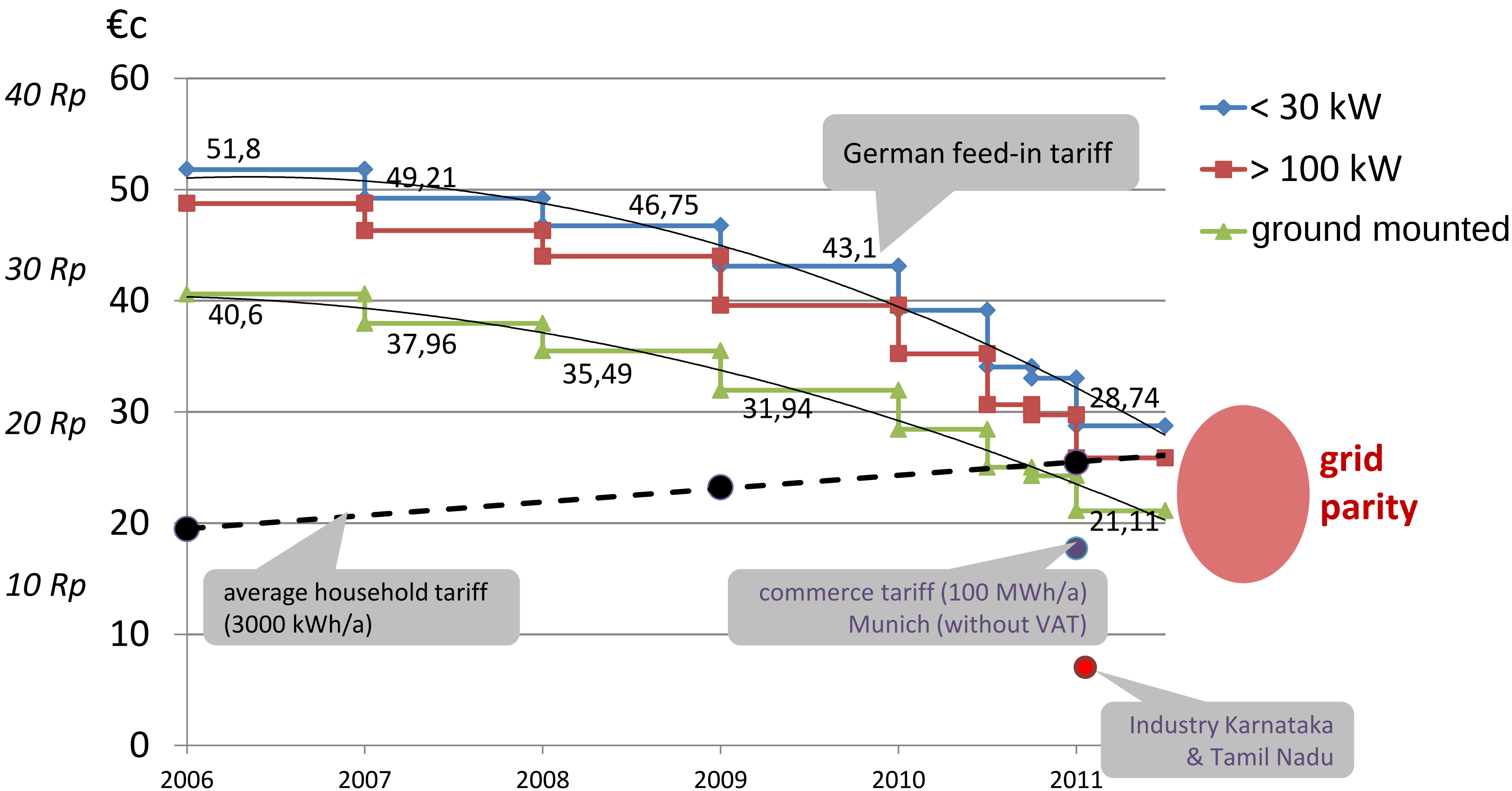


© GTM Research: Concentrating Solar Power 2011

PV prices continue to fall rapidly: by more than 30% in 12 months



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



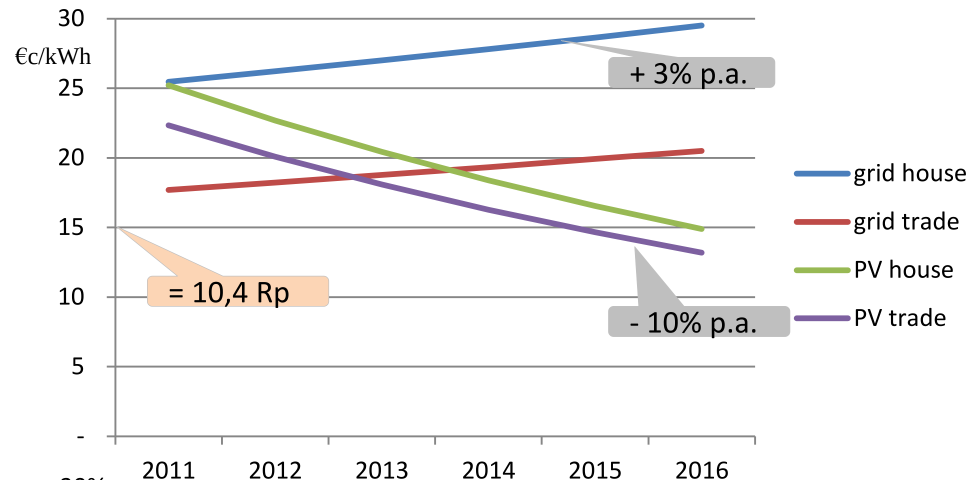
Attractiveness of captive power production in Germany: scenario for the next five years

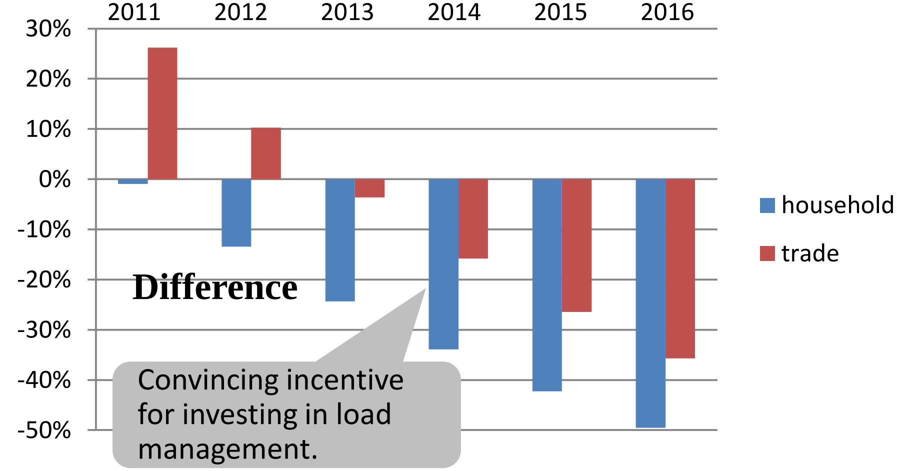
- In the last four years the average PV system price declined by 50% (3Q07-3Q11, <100kWp, Germany) corresponding to *-16% p.a*.

- 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)

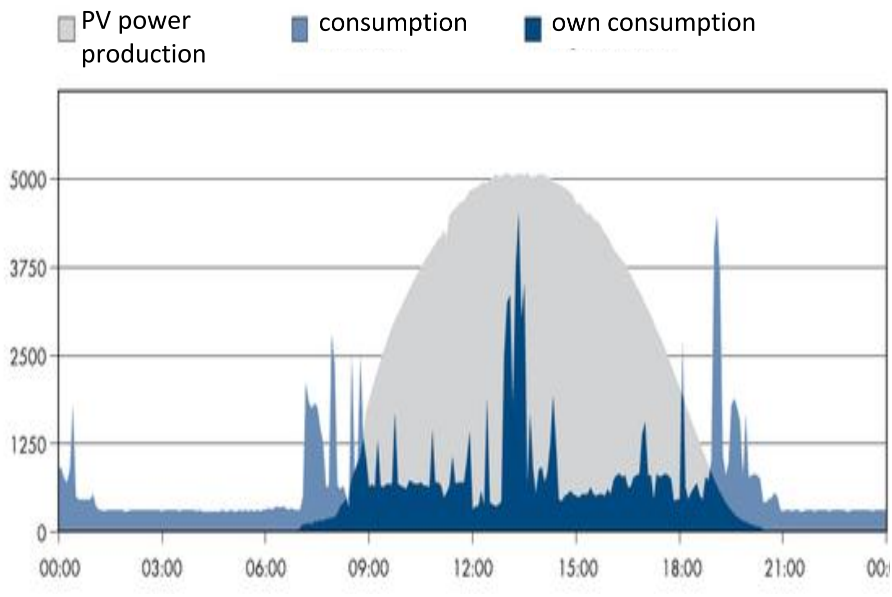
➢ In five years PV power from the roof could cost 40% less than power from the grid

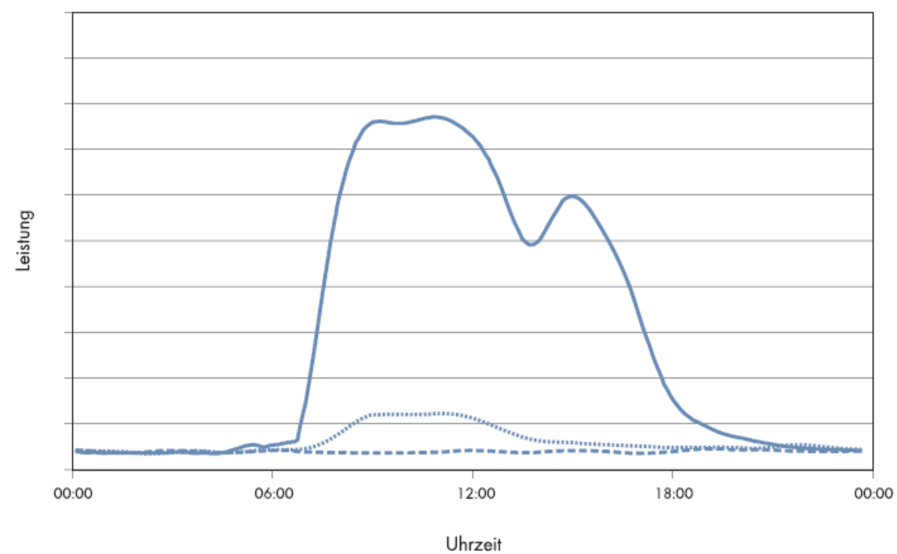
Evolution of the difference between grid tariffs and own PV power costs





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





Private household, Germany

cloudless summer day, 4 persons,

PV installation 5 kWp

→ Efforts needed for > 30% of own consumption

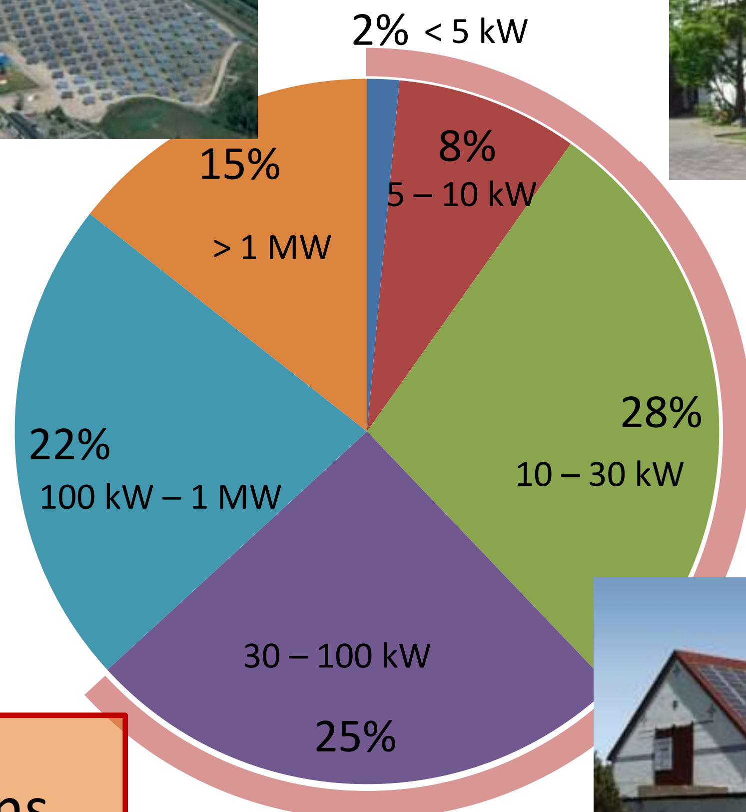
Commerce

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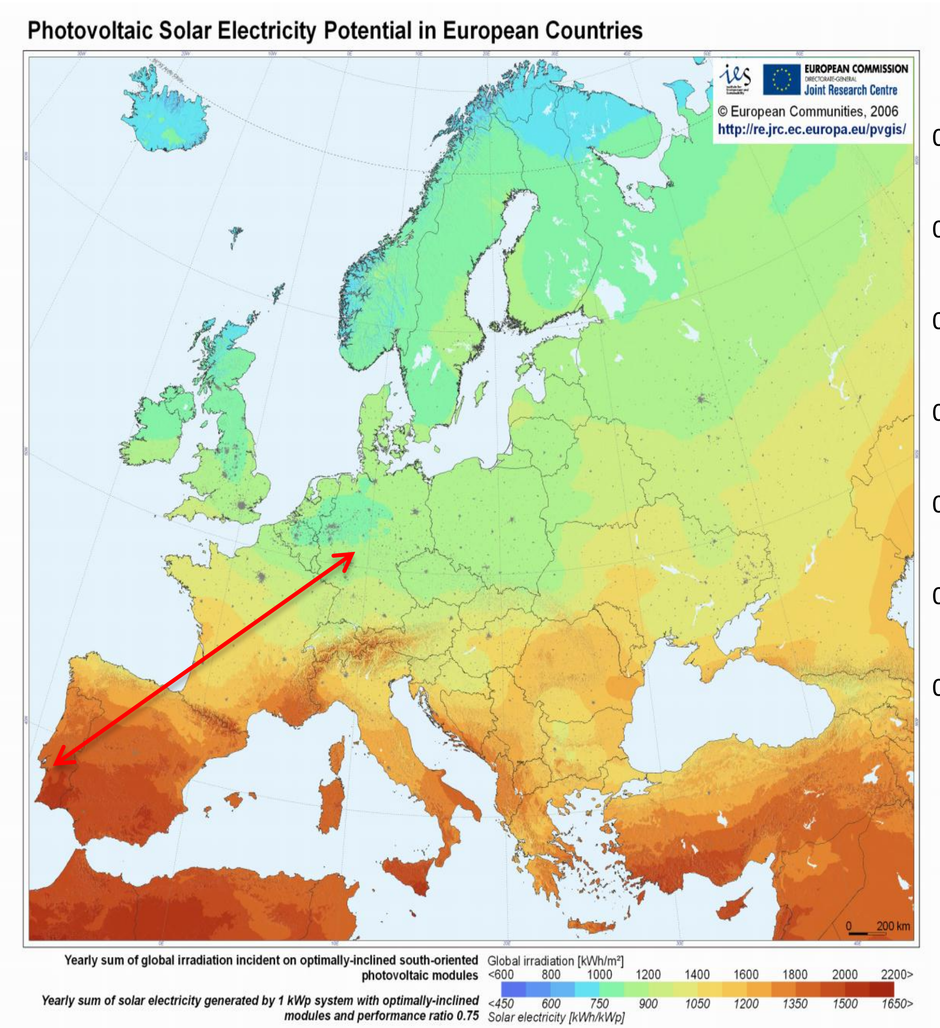
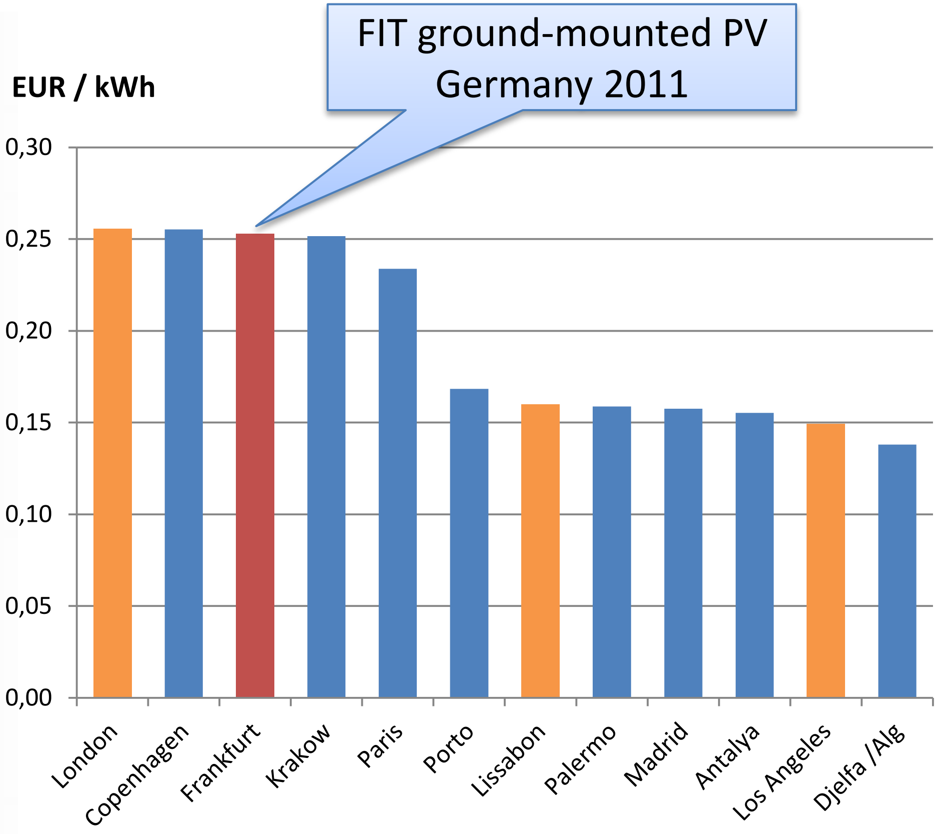
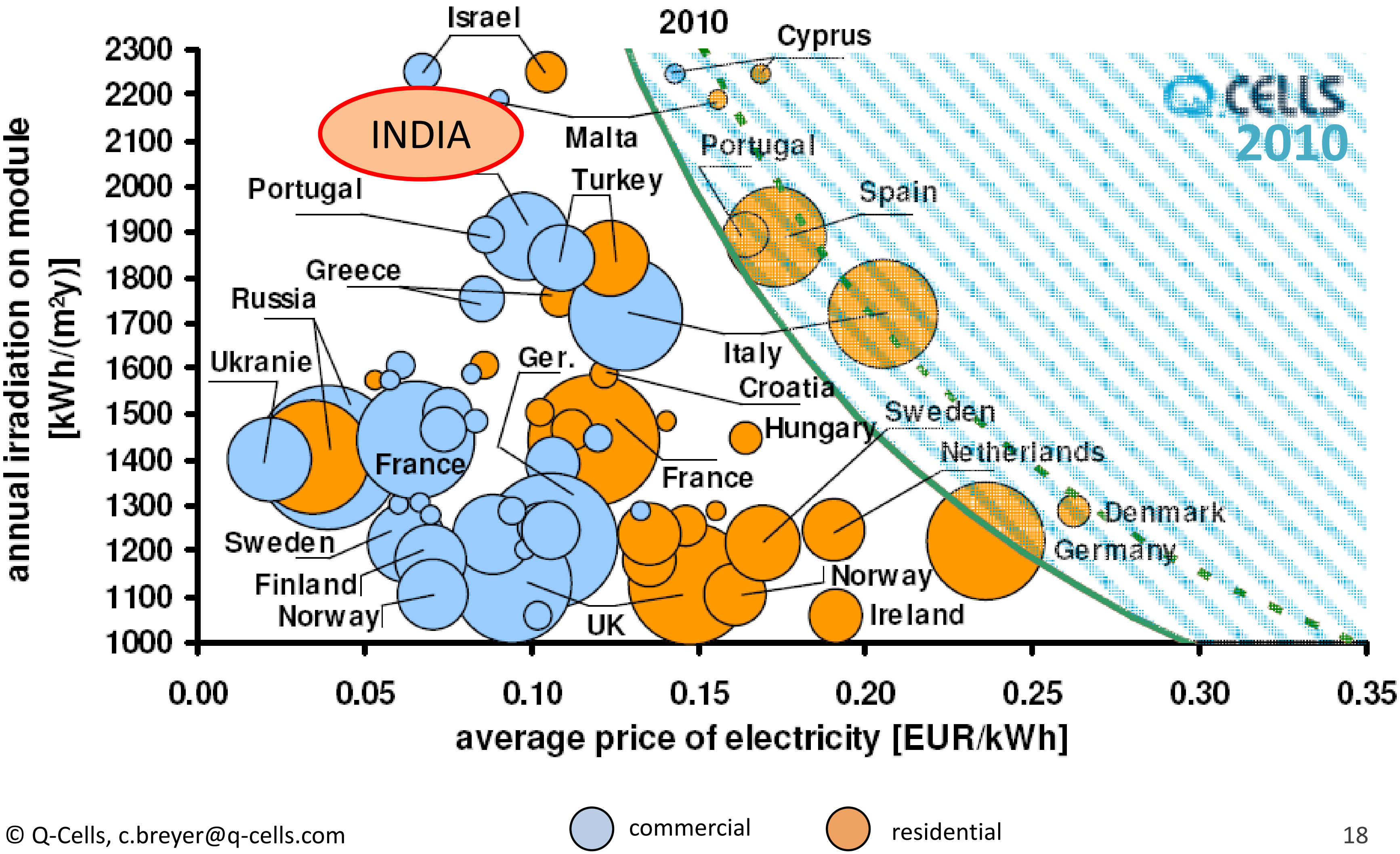
The influence of differences in solar radiation on the LCOE (levelised cost of electricity)

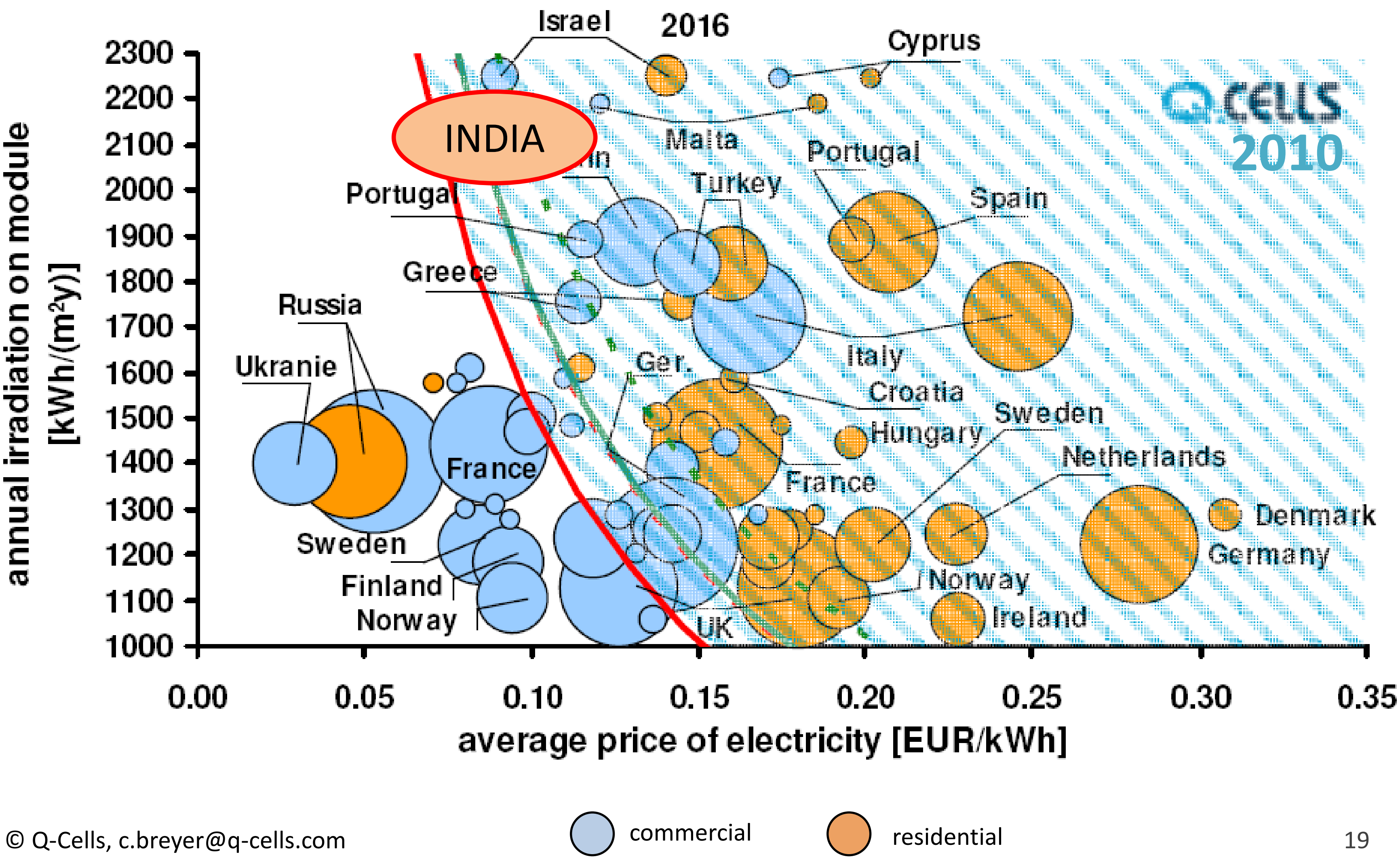




Grid parity in Europe 2010



Grid parity in Europe 2016
(forecast in 2010)



The coming boom: captive power generation

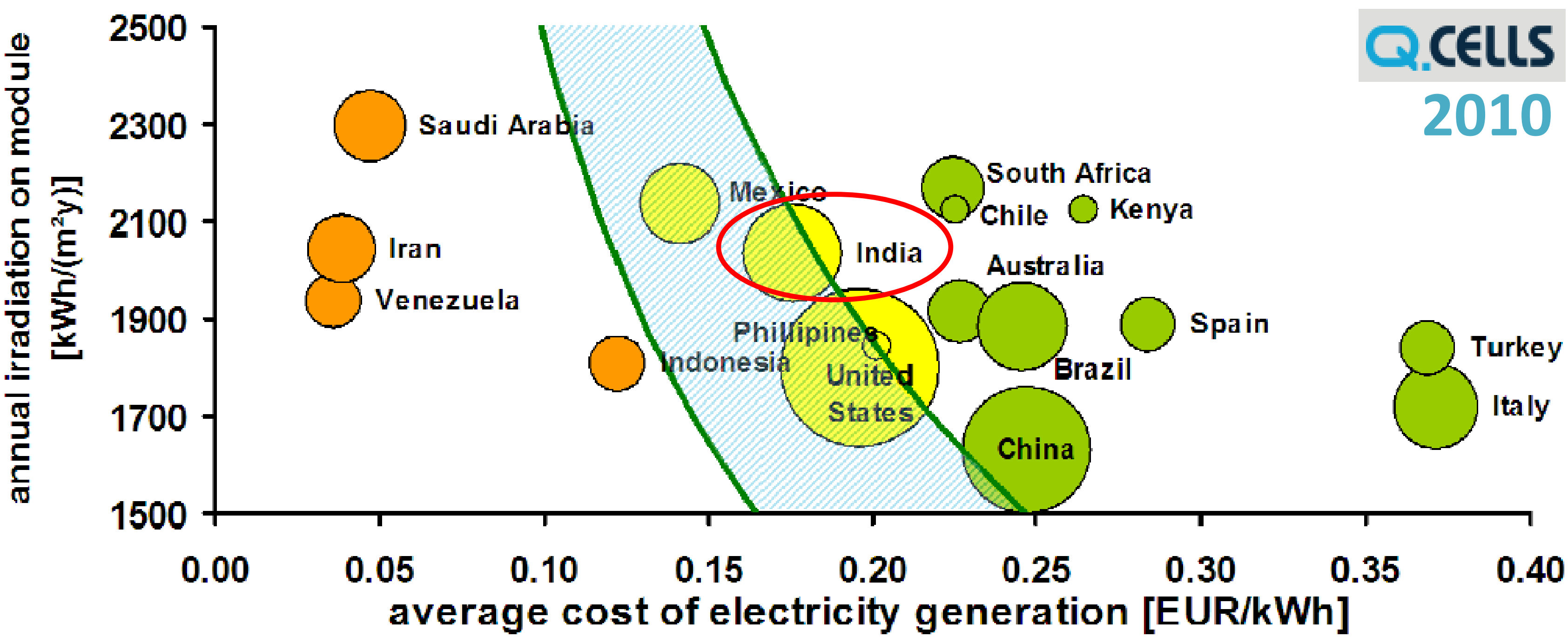
Attractive investments even without incentives:

- 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

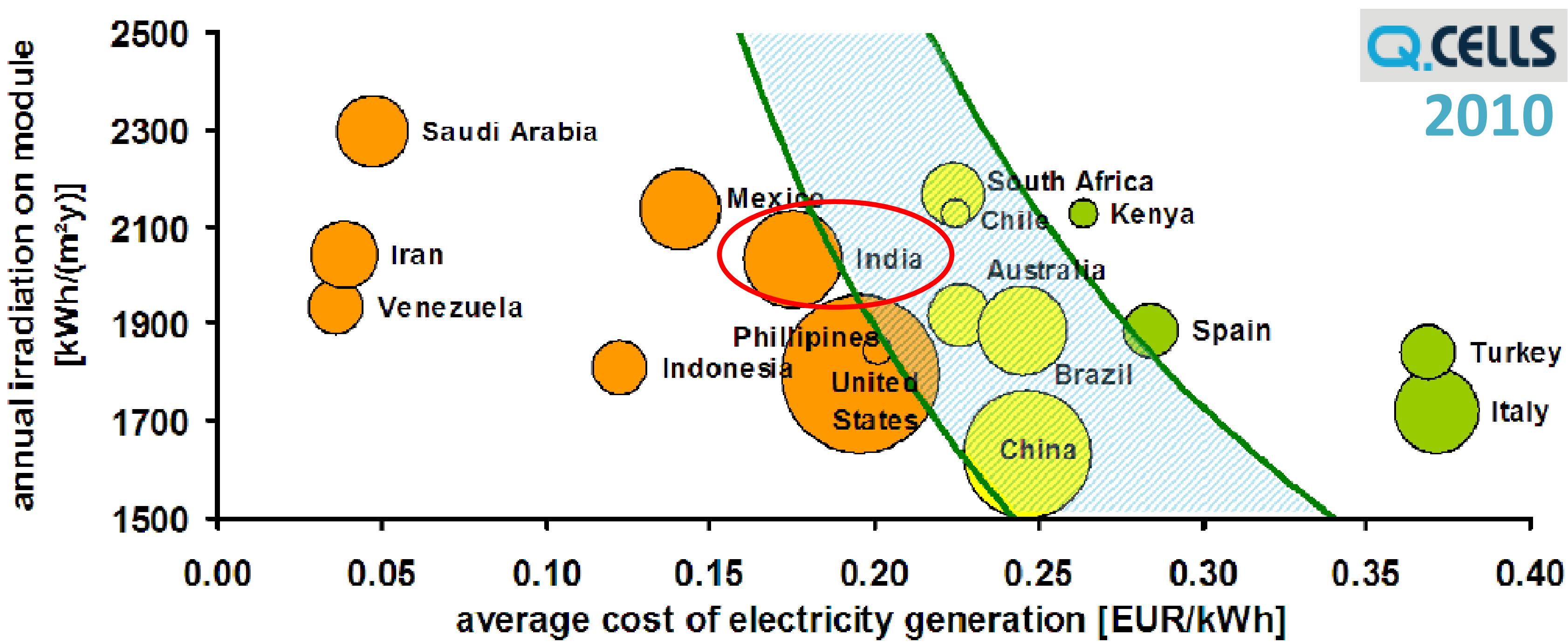
➢ Boom in power management technologies

Decisive where grids are weak: Fuel Parity – PV vs Diesel Generators



assumptions: 2.0...3.0 €/Wp Capex, 6.4% WACC, 25 years lifetime, 75% performance ratio, Diesel full load hours analogue PV, 35% Diesel efficiency, 1.4 $/€, Diesel price data of GTZ

PV+ Storage versus Diesel Generators

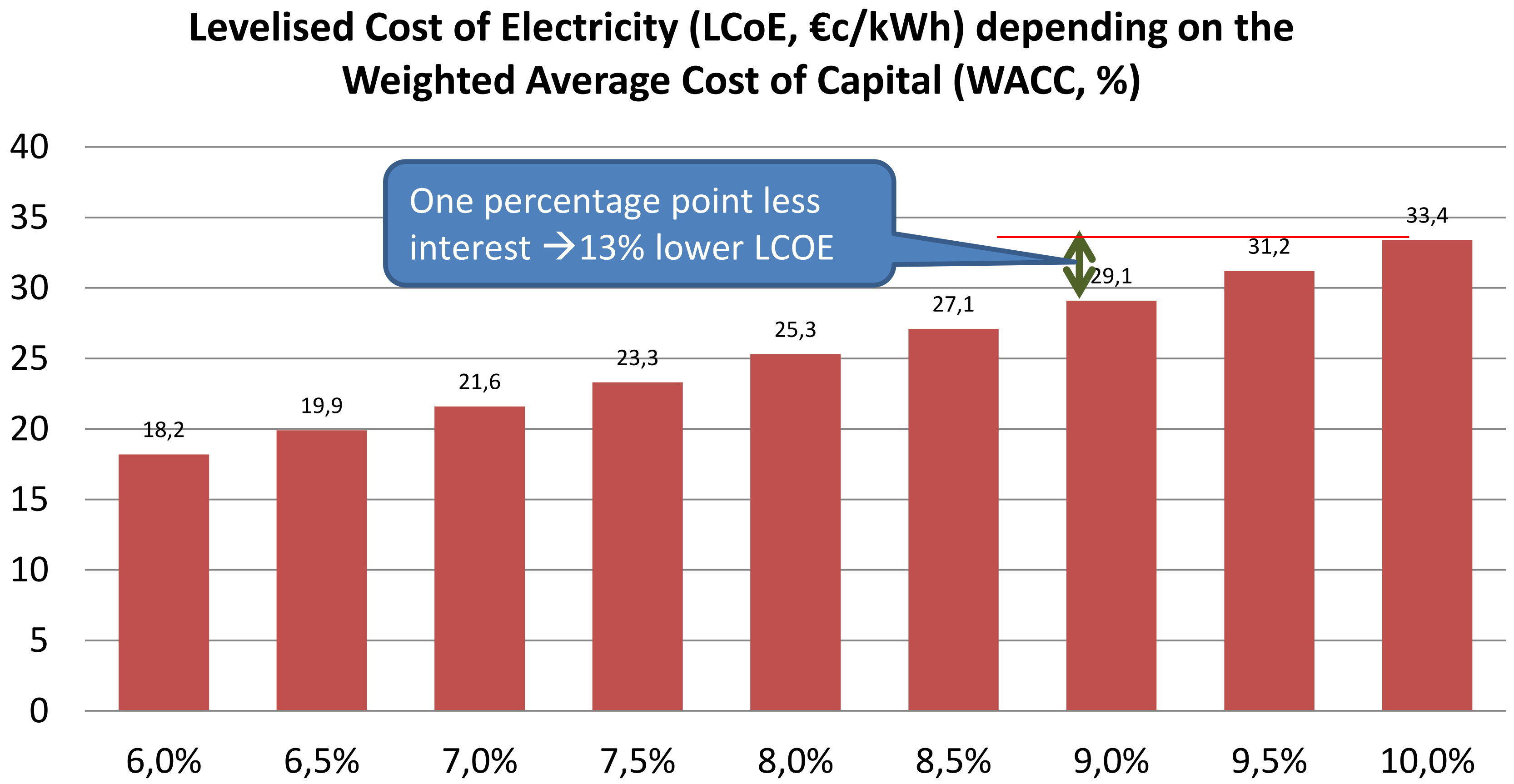


assumptions: 2.0...3.0 €/Wp Capex, 6.4% WACC, 25 years lifetime, 75% performance ratio, redox-flow storage, 150 $/kW and 150 $/kWh Capex, 73% full cycle storage, 50% direct PV power supply and 50% storage, 150% of annual mean day storage size, 1.4 $/€, Diesel price data of GTZ

Growing opportunity: Captive Power Generation in India

- Wind power market mainly driven by captive power for manufacturing industries (70% of customers in 2008)
- 30% of industrial consumption: in-house power plants
- Example: factories in a central Indian city (2010)
  - Highly dynamic economic development
  - 12-14h power cuts per day unscheduled for longer periods
  - Electricity tariff: 6 Rp/kWh (→ 8)
  - Cost of back-up diesel power 9 Rp/kWh (→ 11) (10-12h/day in process industries)
  - High indirect costs and efficiency losses due to power cuts
  - Many factories working at night for avoiding power cuts
- High reliability of sunshine during most of the year

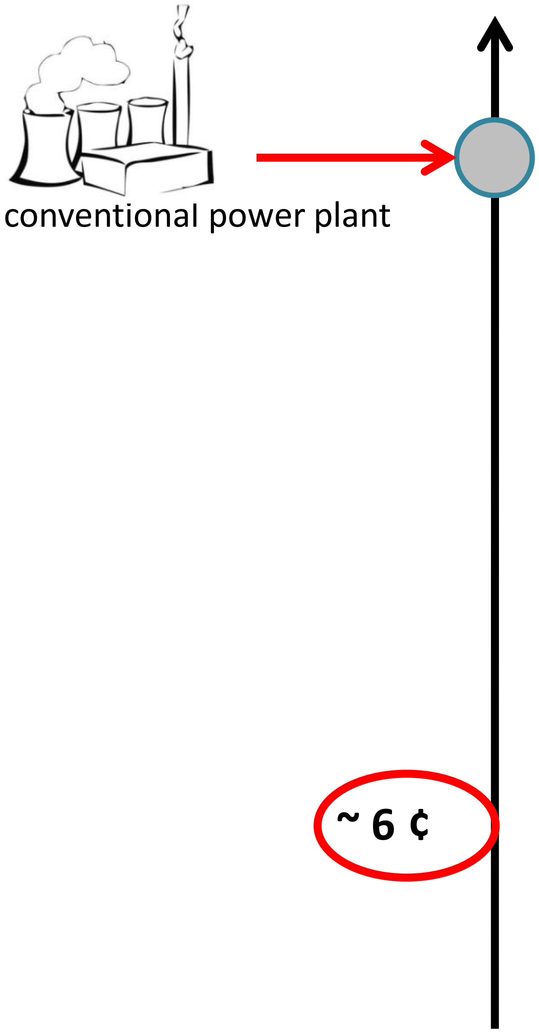
Strong influence of capital costs → important to keep risks low



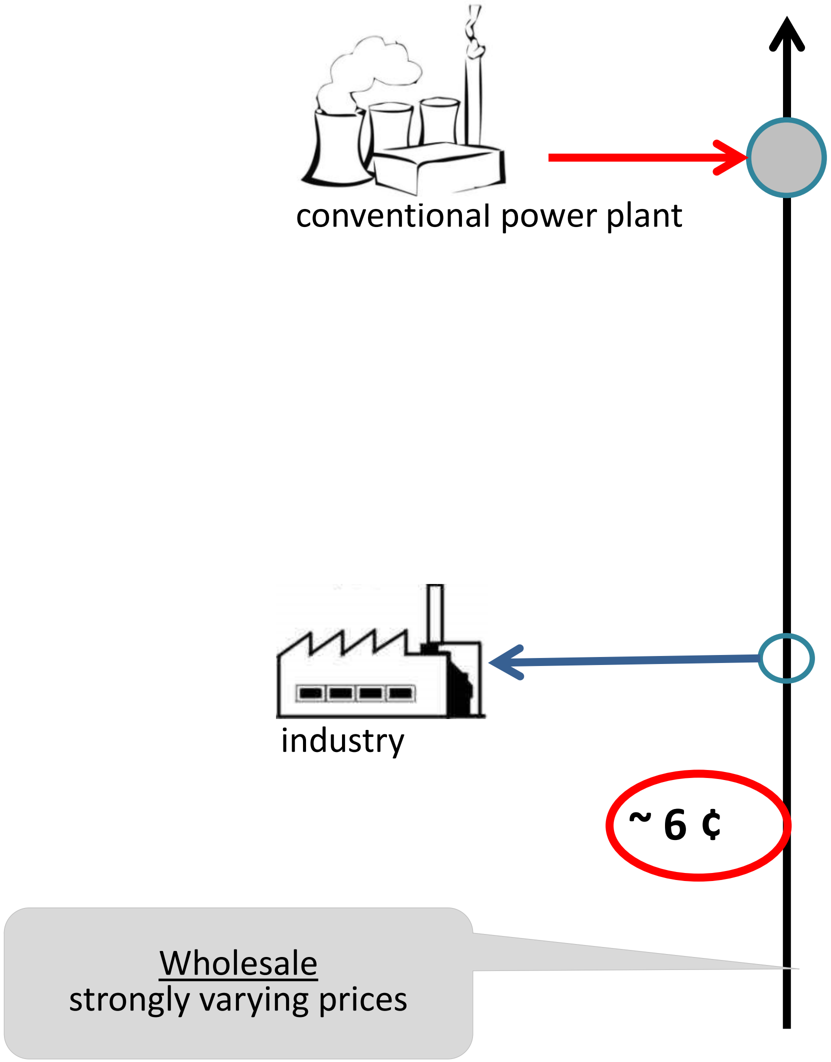
Example for a PV plant costing 3,43 USD/Wp

PV ENFORCES TRANSFORMATION OF THE POWER BUSINESS

Photovoltaics is a modular technology: competing on the retail side

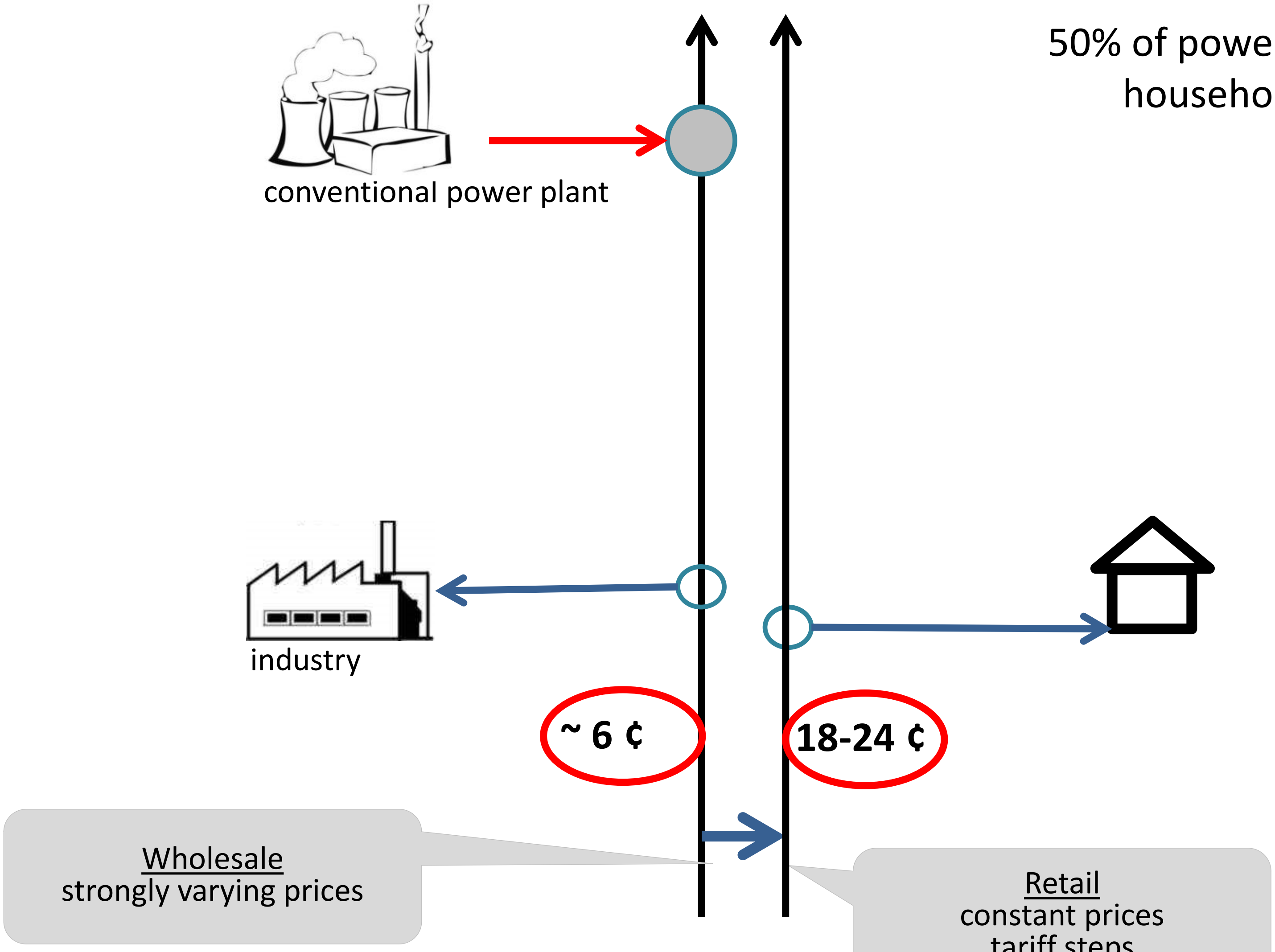


Photovoltaics is a modular technology: competing on the retail side



Photovoltaics is a modular technology: competing on the retail side

50% of power consumption:
households, commerce,
services



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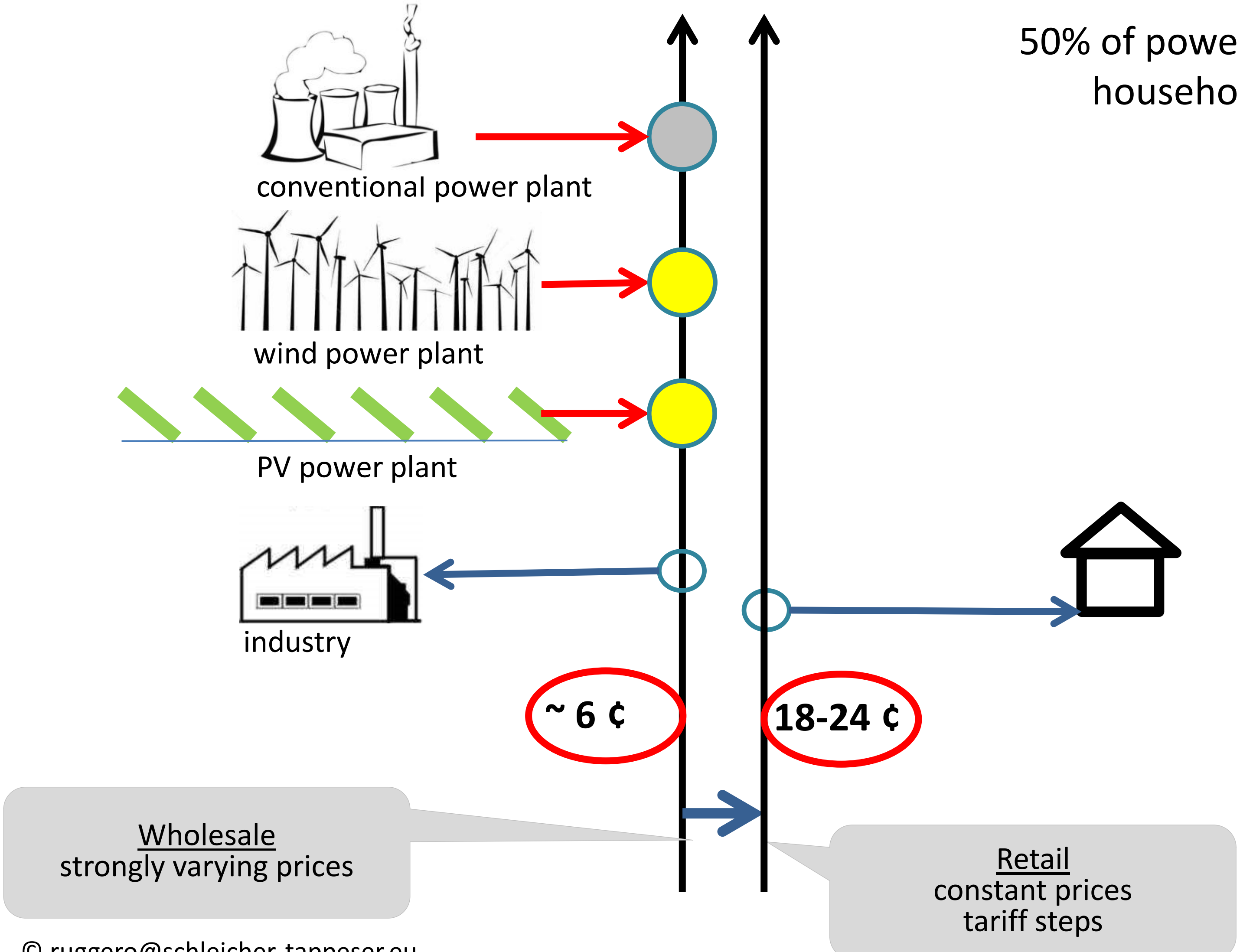

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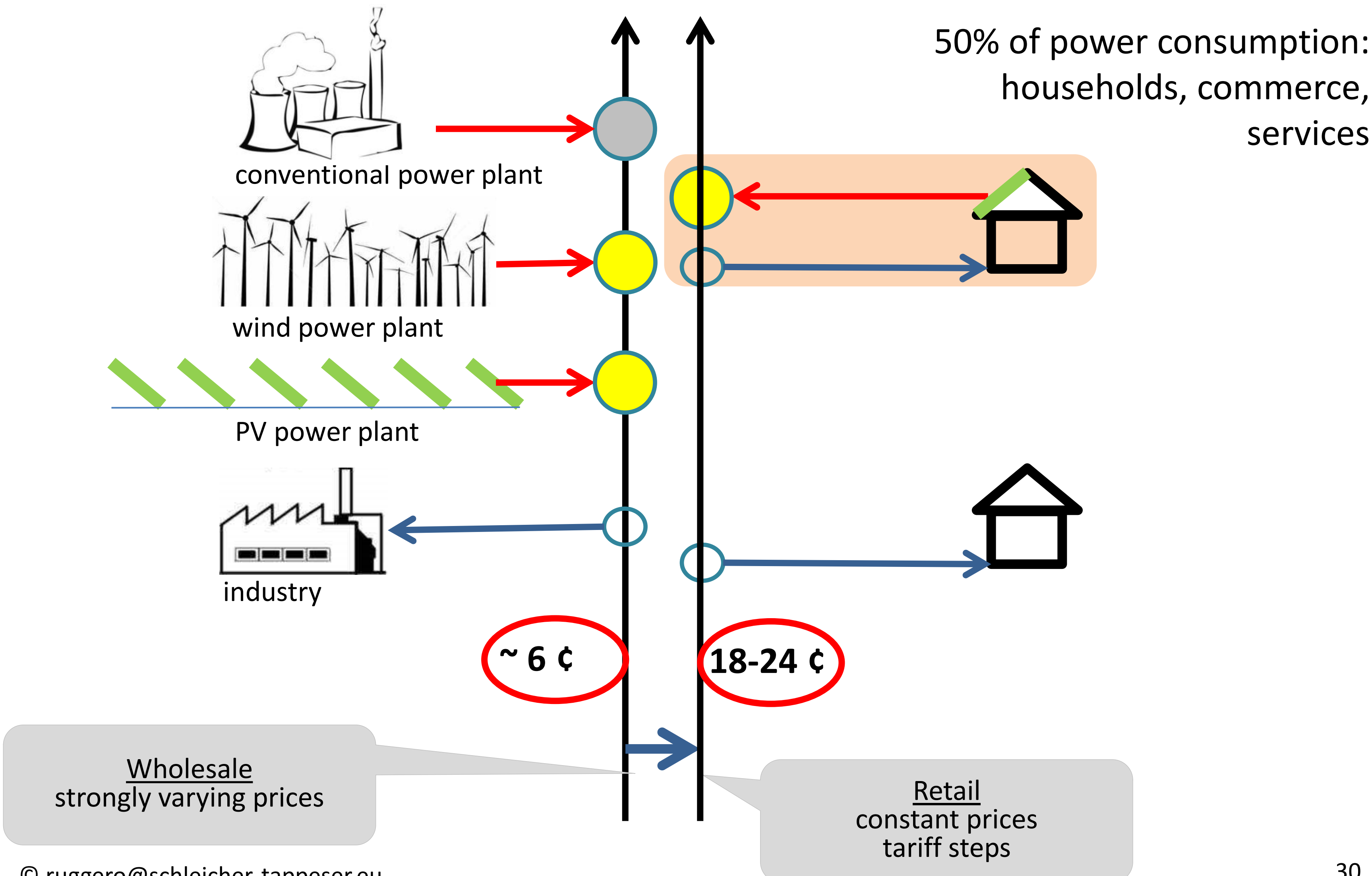

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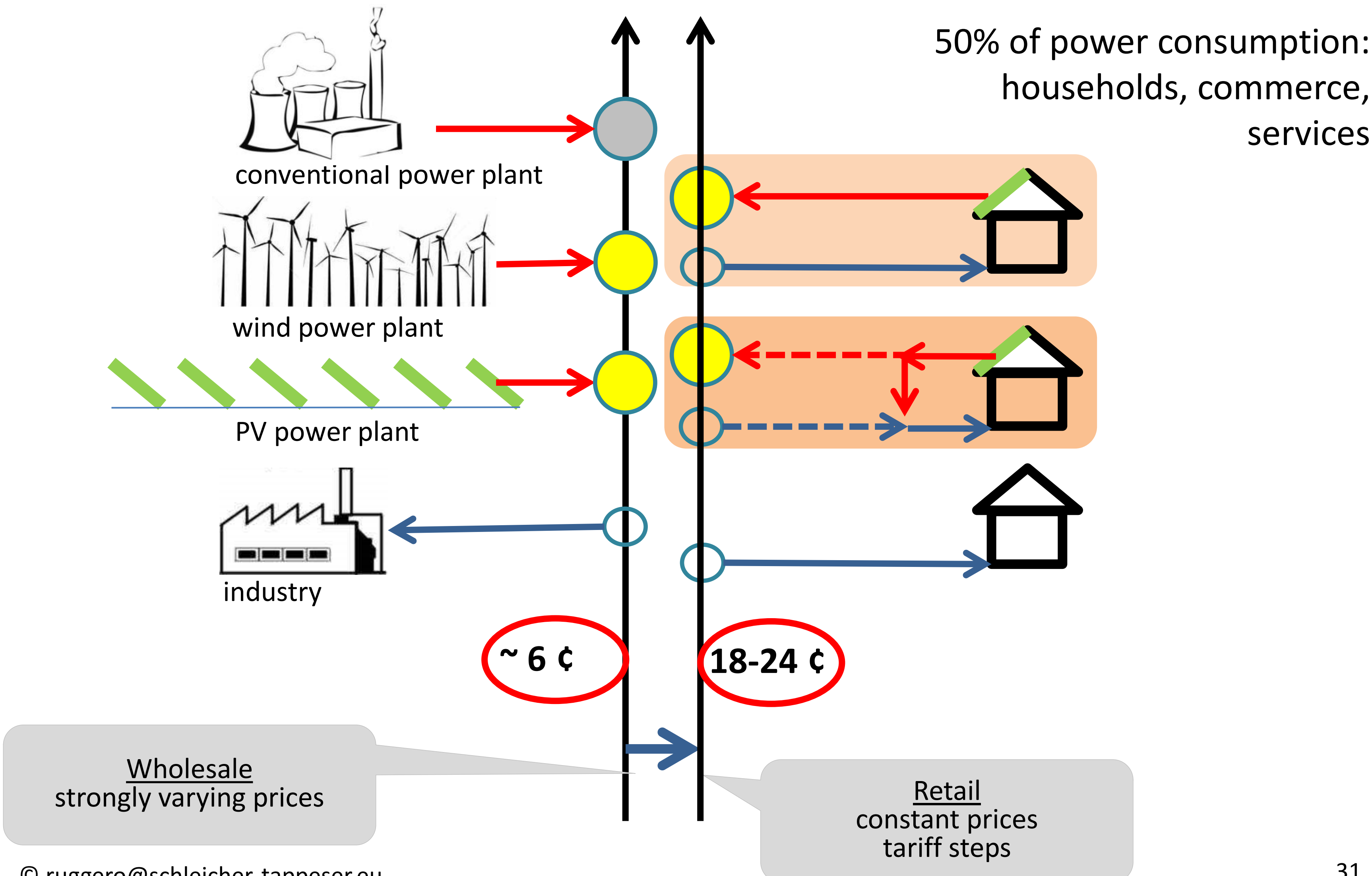

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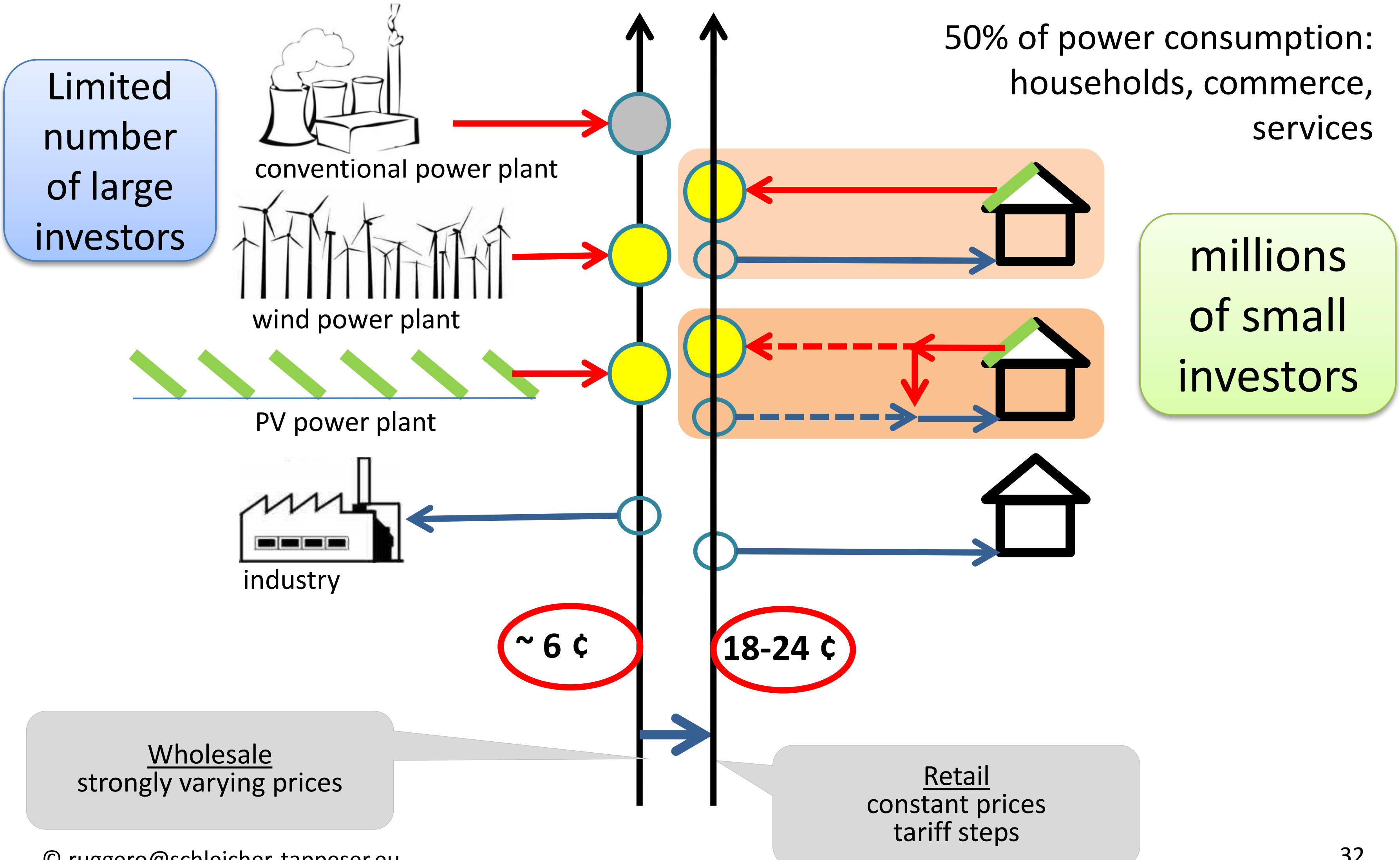

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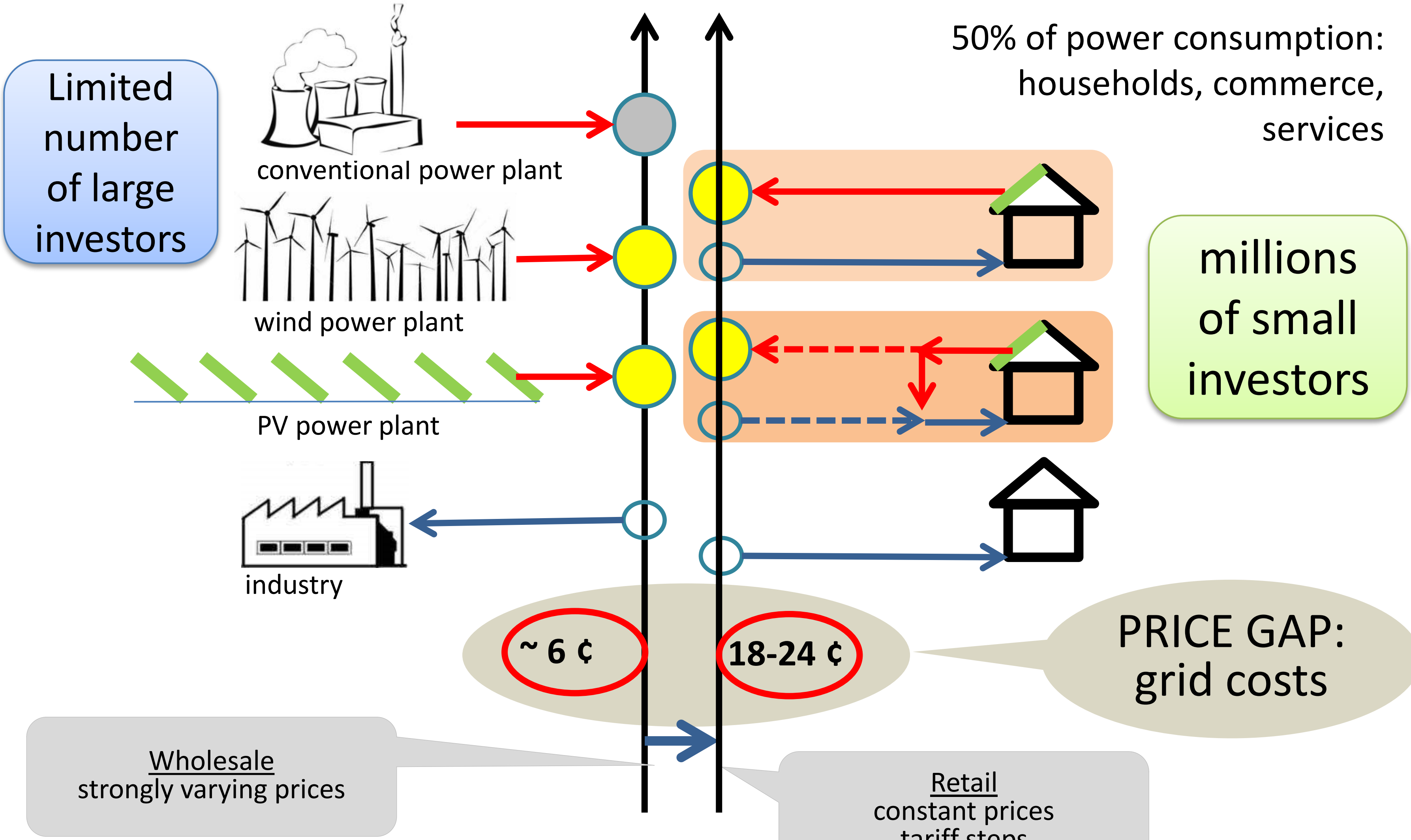
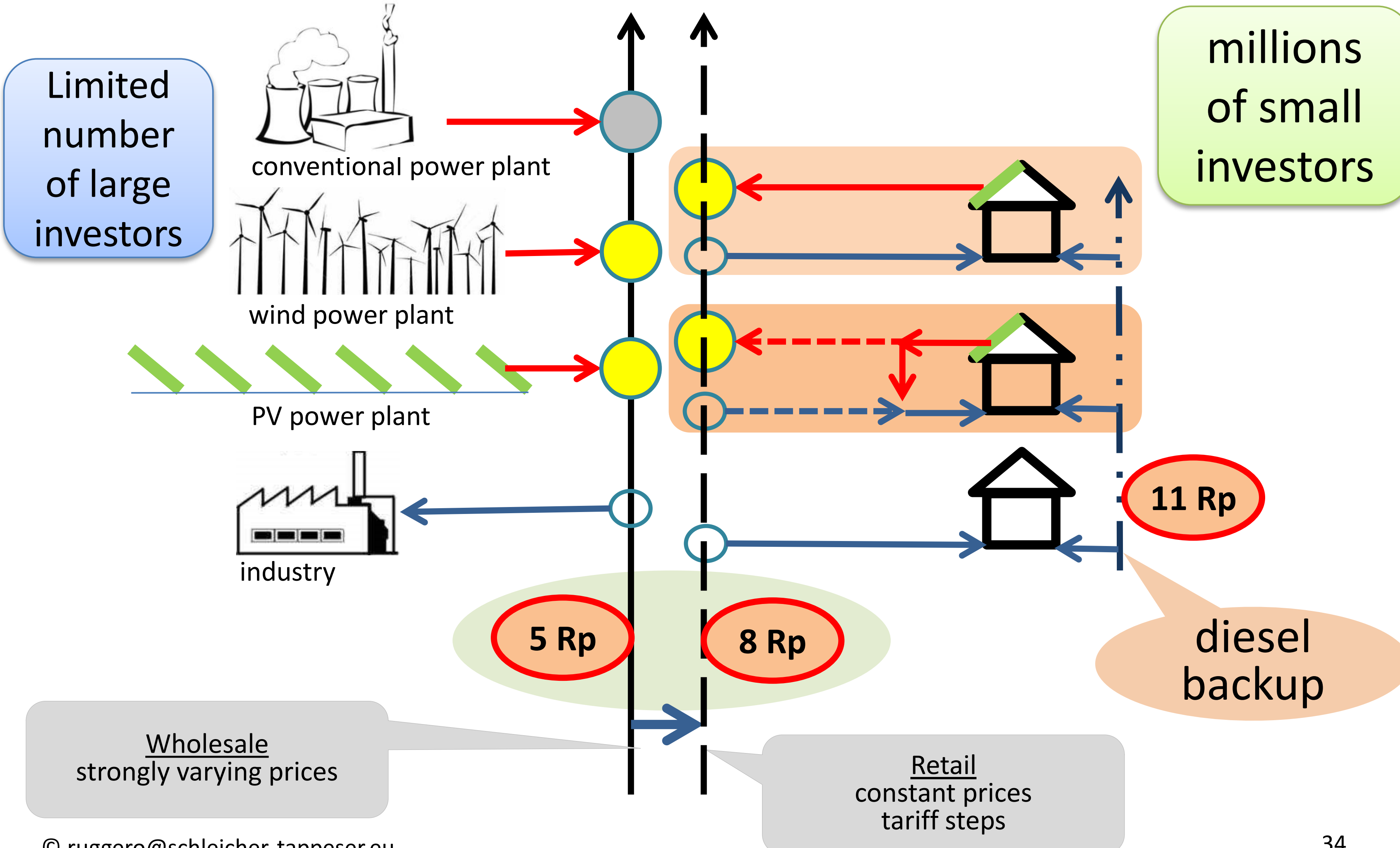
Photovoltaics is a modular technology: competing on the retail side



India: Photovoltaics in weak grids competing against diesel backup



Increasing the share of own consumption → dealing with fluctuation locally

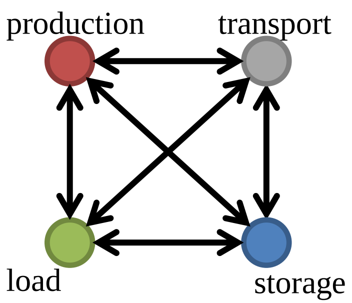
- <u>Load management</u>
  - Temporal shift of operation
  - Thermal storage in heating and cooling applications
  - Storage of compressed air for mechanical applications
  - Combination of different users
- <u>Additional, non time-critical loads</u>
  - Loading electrical vehicles
  - Heat pumps: substitution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

➢ Innovation wave in Energy management

➢ Flexibility of the user system increases

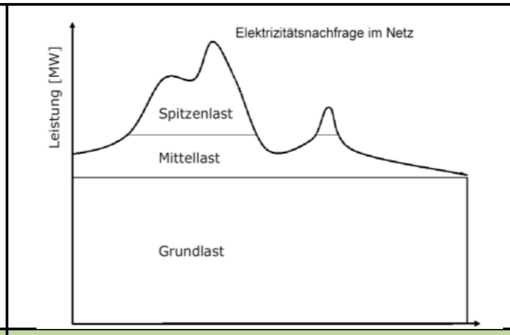
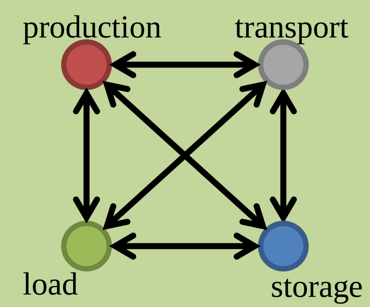
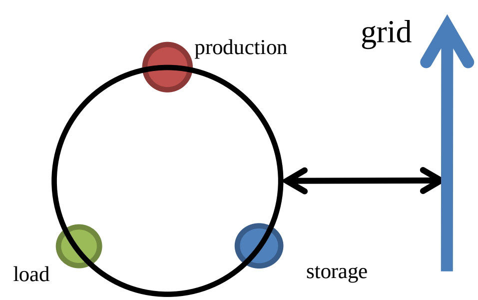
Captive power production can facilitate the system change and stabilise grids…

- The critical challenge for the whole system: fluctuating power supply with sun and wind



- Captive power production brings flexibility
- Captive power production can
  - unburden the grids
  - contribute to load management
  - contribute to security of supply
  - strengthen competition
- For this to happen, frame conditions must set appropriate incentives

… but this implies a 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	

Approaches for matching production and consumption of electricity

	conventional approach **central power plants**	**future approach ?** **fluctuating renewables**
Production management	central management	only in extreme cases, leads to losses
Spatial compensation over grids	central approach: predictable average loads	long distances: weather variations less important
Demand side management	widely abandoned, nearly no incentives	at all levels huge innovation potential
Storage	Central pump storage for buffering baseload nuclear	at all levels high innovation potential

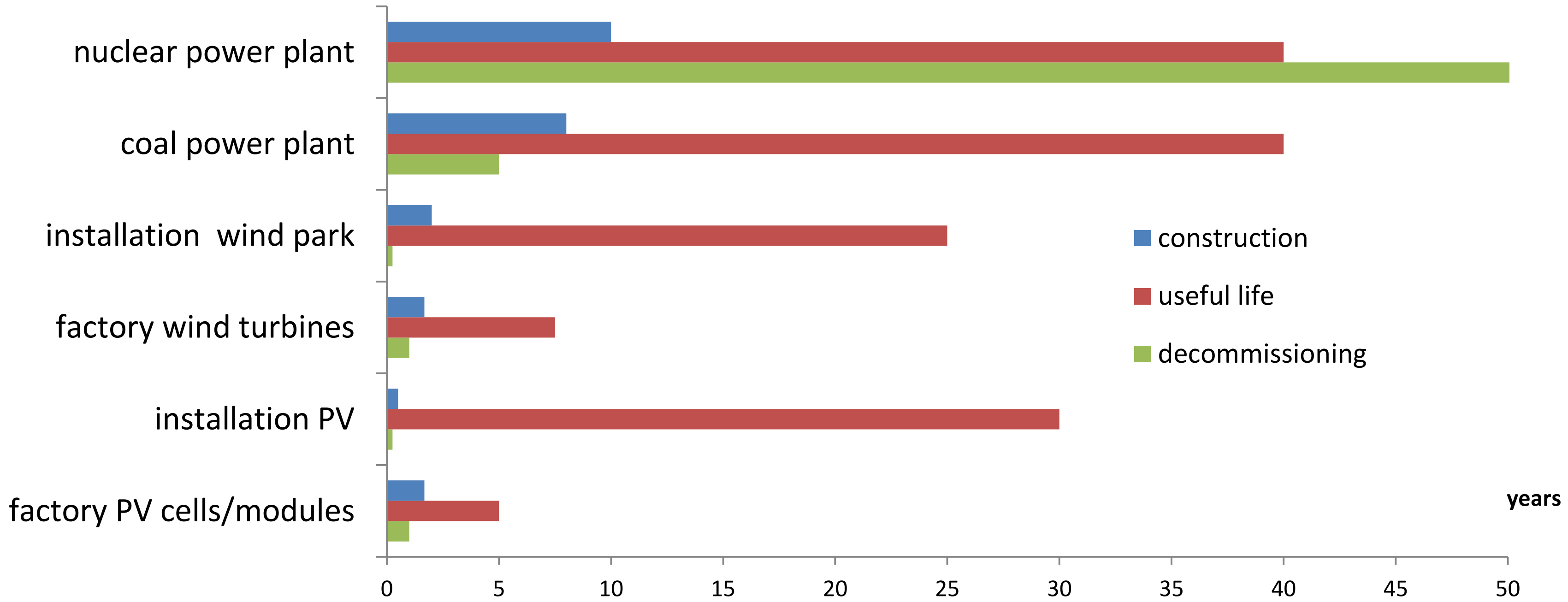
Unfamiliar to energy business: 4 to 10 times shorter innovation cycles

→ 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



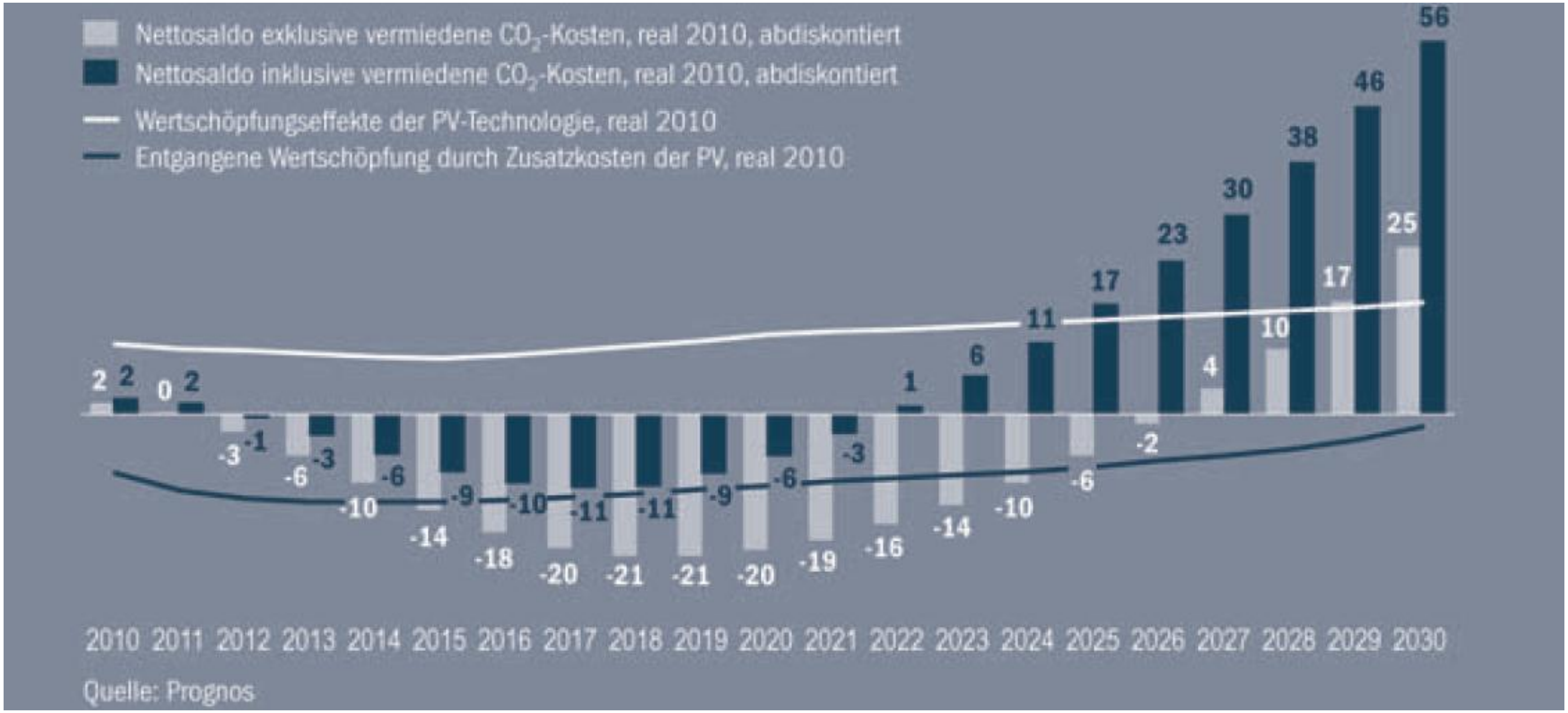
ECONOMIC IMPACTS

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 …)

Economic balance in Germany: despite expensive start phase positive before 2022

- Roland Berger / PROGNOS 2010 with very prudent assumptions:



- ATKearney 2010: <u>positive balance already in 2012</u>

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 BIG CHALLENGE: COPING WITH A TURBURLENT TRANSFORMATION

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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