Photovoltaics: A Disruptive Technology
The European Experience

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sustainable strategies, Berlin

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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

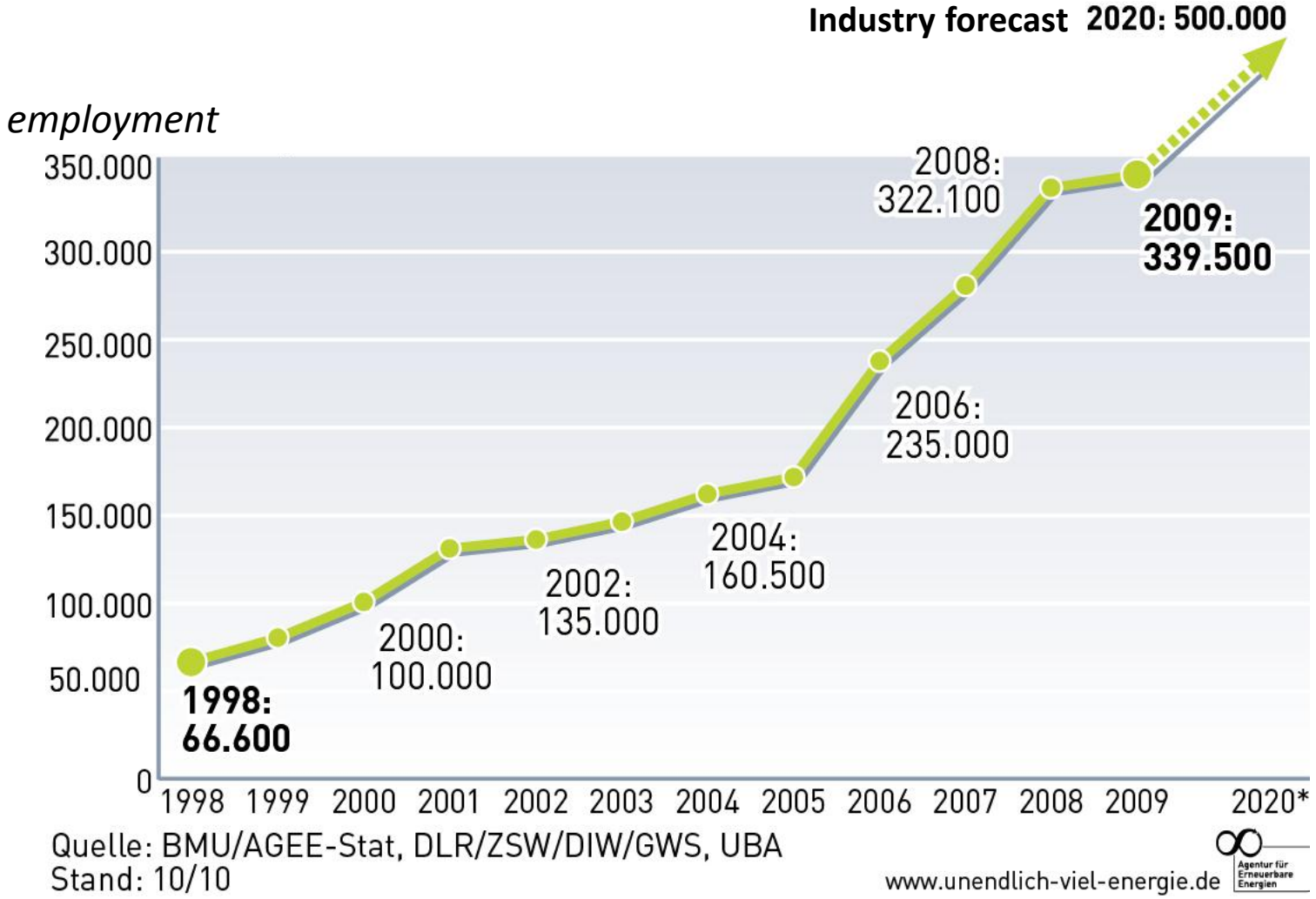
► Rapid transformation of the energy system needed
► Governments create markets for new technologies
► New technologies change the energy markets

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

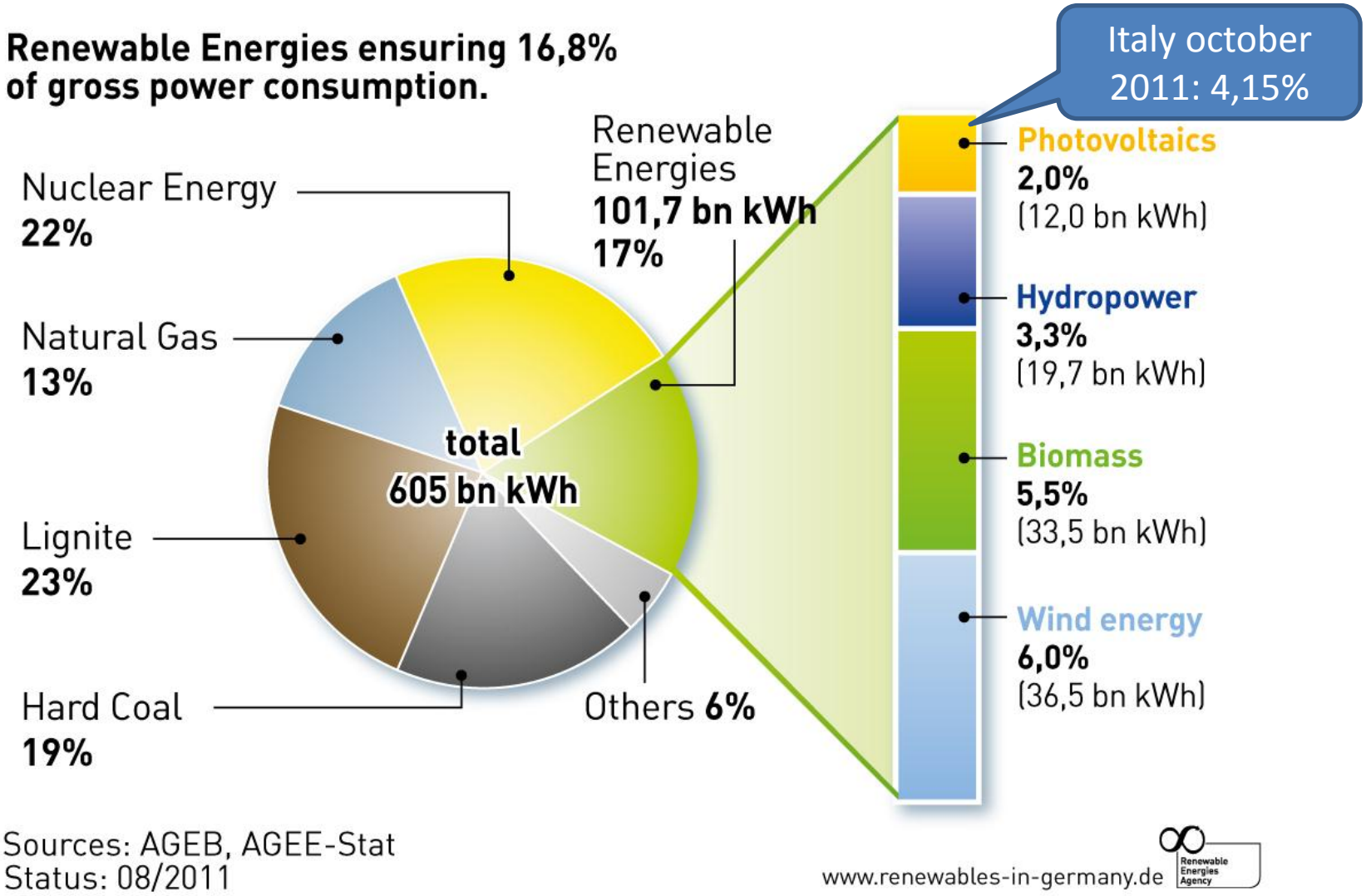
Converging political targets in Europe: 100% renewable electricity by 2050

- EU decision in 2009, compulsory:
  20% renewable energy in Europe 2020 → ca. 35% renewable electricity
- German RE Industry Association 2008:
  47% renewable electricity in Germany by 2020
- German environmental minister Röttgen 2010:
  his aim: 100% renewable *electricity* in Germany 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

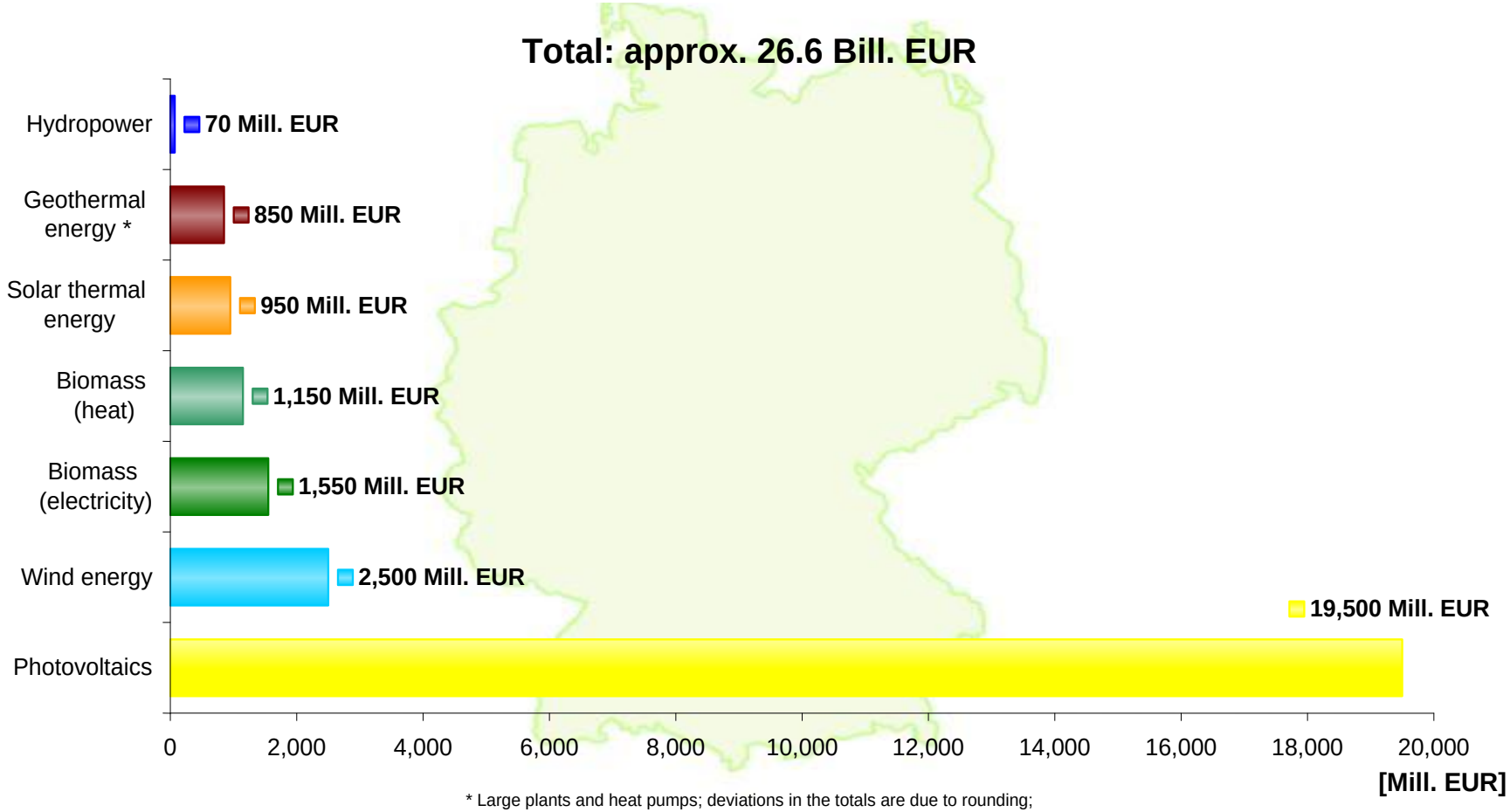
Employment in renewable energies in Germany



Electricity production mix in Germany 2010



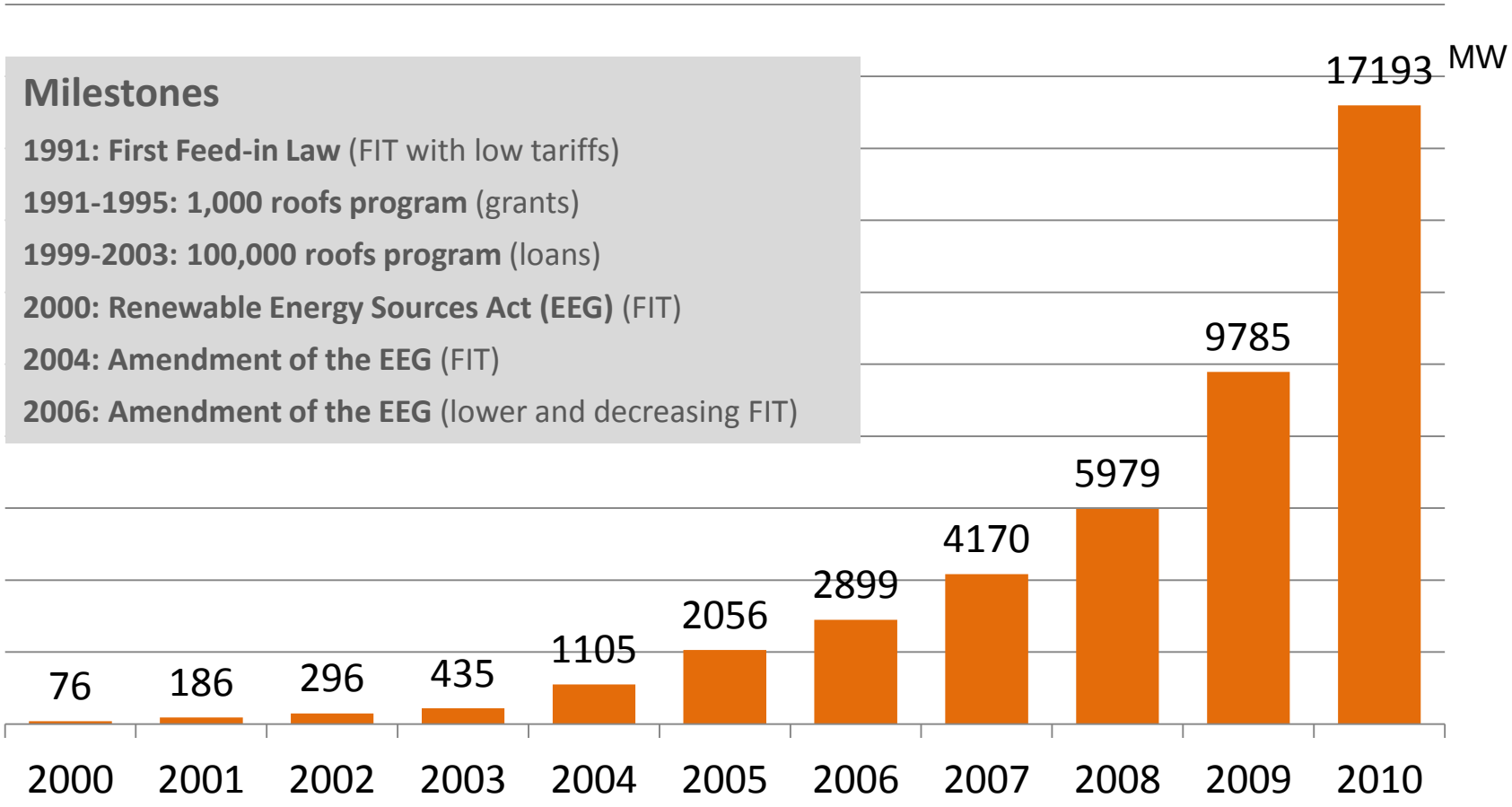
Investments in renewable energy installations in Germany 2010



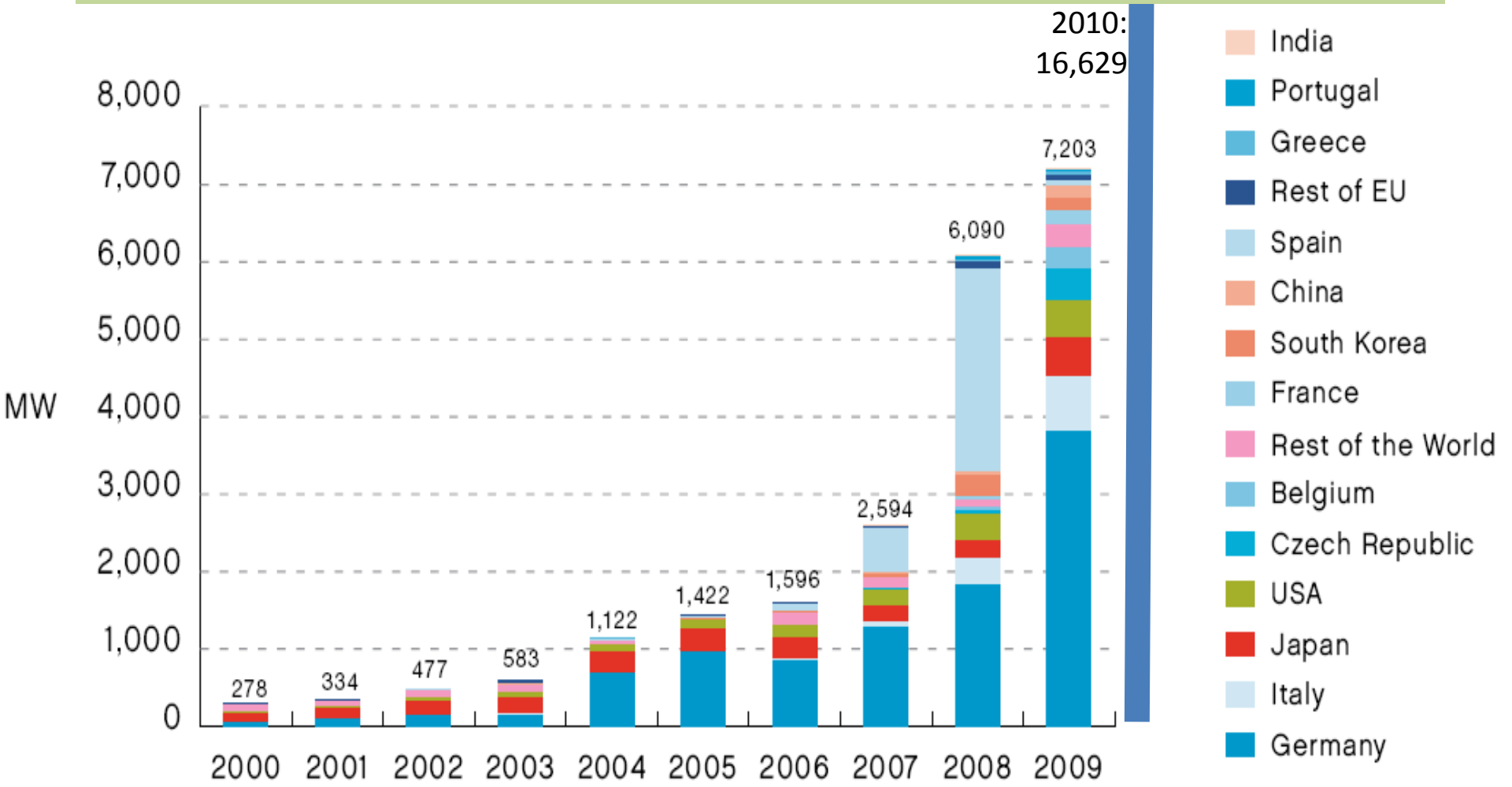
* Large plants and heat pumps; deviations in the totals are due to rounding;
Source: BMU-KI III 1 according to the Centre for Solar Energy and Hydrogen Research Baden-Wuerttemberg (ZSW); as at: July 2011; all figures provisional

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

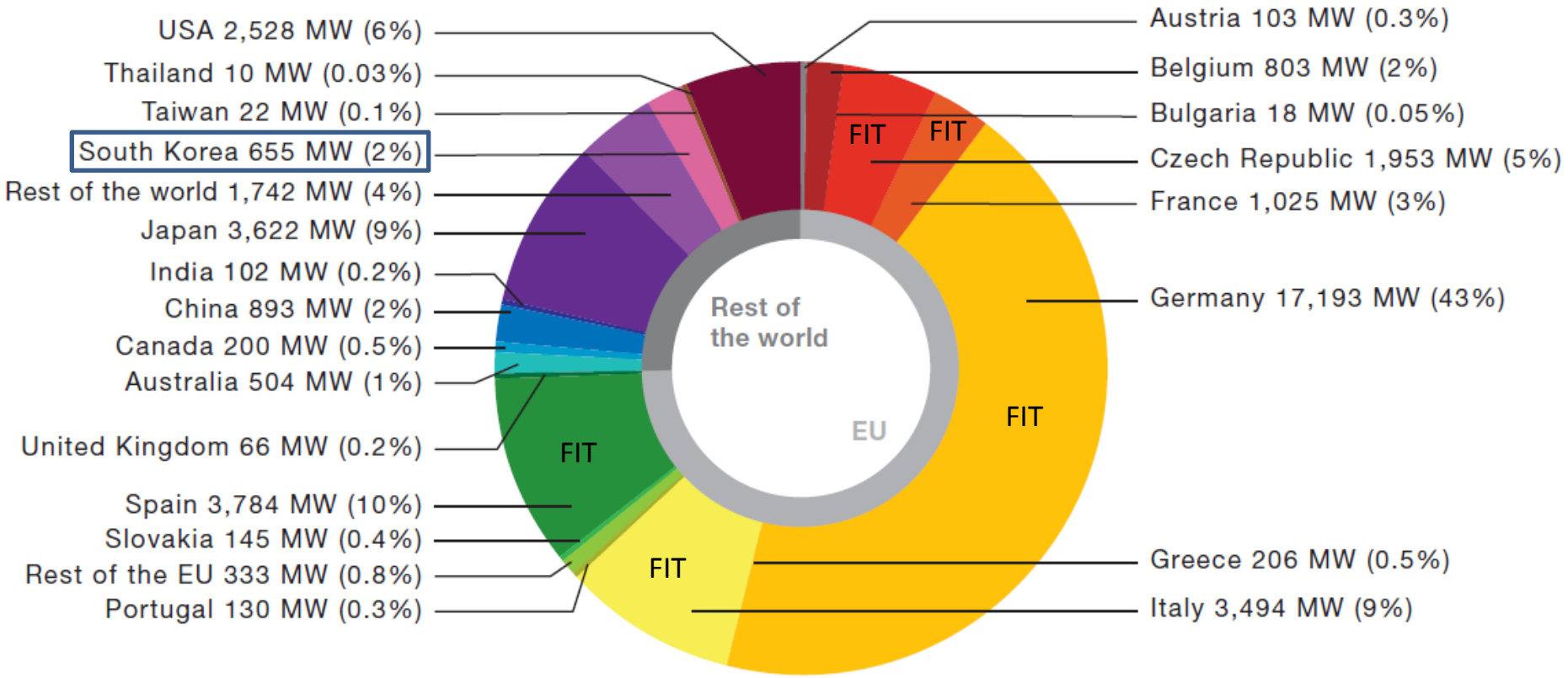
Total PV capacity installed in Germany



Global PV deployment: new markets stabilise growth path



Global cumulative installed capacity share 2010



Success factors in Germany

- A reliable investment context with guaranteed feed-in tariffs for 20 years after installation
- Continuous adaptation of the FIT for new systems to market development → steady growth
- A simple scheme: no other incentives, just FiT
- No complicated permitting procedures

➢ Banks have learned that PV investments are low risk → low capital costs

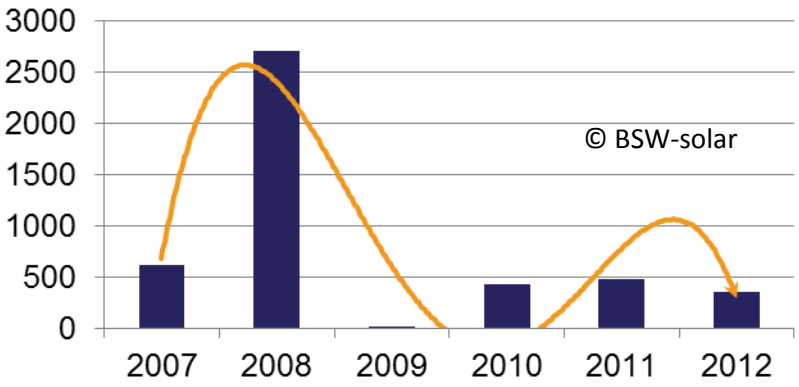
➢ Industry and craftsmen have invested in production and training → reliable quality, low system price

➢ Hundreds of thousands of new private investors

Creating a stable market with feed-in-tariffs

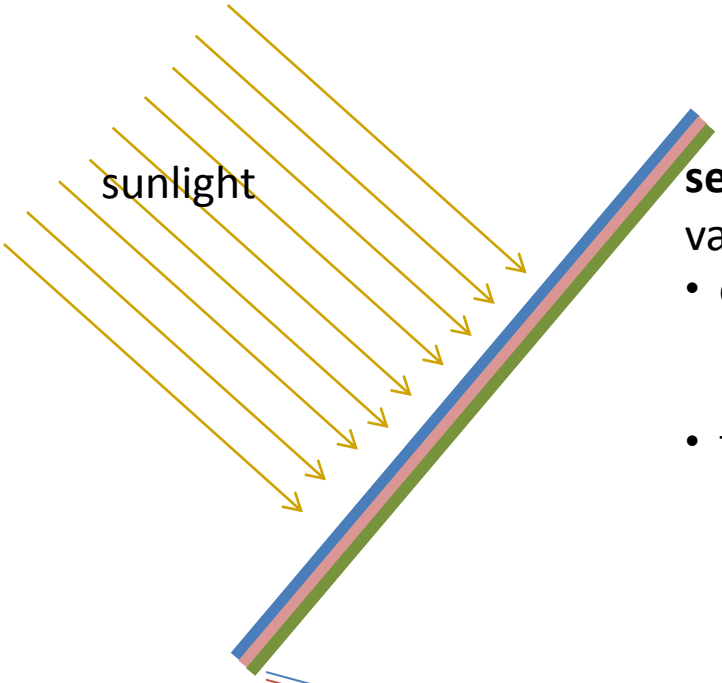
- Earlier promising PV programmes pushed by the USA (President Carter) in the early eighties, then by Japan in the nineties were less transparent and terminated to early
- The feed-in-tariff has become an international success story: 61 countries with FiT. They have strongest PV growth
- Pitfalls to be avoided:
  - Unsustainable high tariffs (Spain, Czech Republic, UK)
  - Unbalanced market without small players (Spain)
  - Slow FiT adaptation
  - Complicated, permitting procedures (Greece, Portugal)
  - Retroactive changes (Czech Republic)

Market development in Spain



PHOTOVOLTAICS –
A DISRUPTIVE TECHNOLOGY

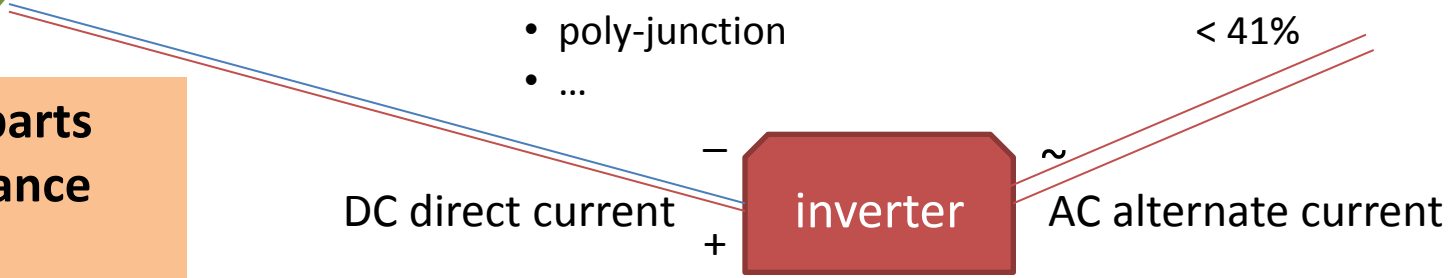
PV is a Semiconductor technology: Direct transformation of sunlight into electricity



several layers of semiconductors

variety of different technologies:

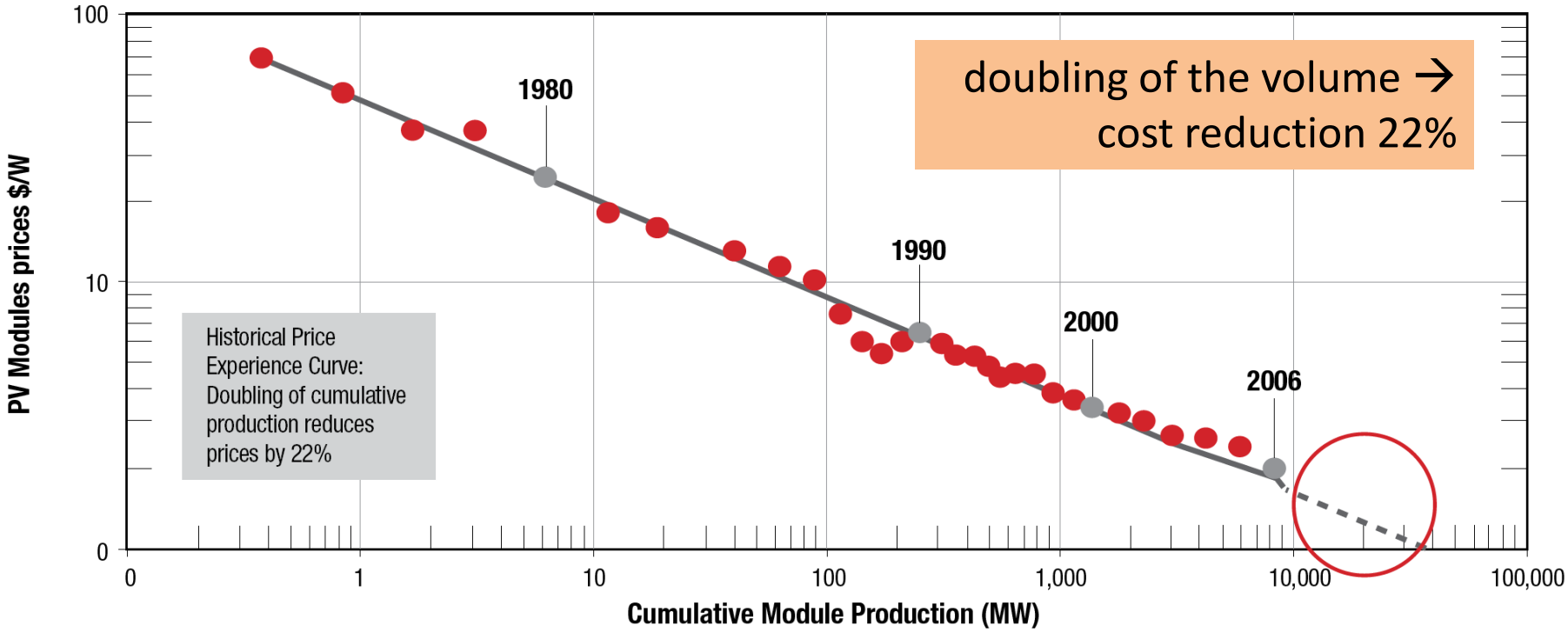
- crystalline silicon c-Si (ingot-wafer)
  - monocristalline < 24% efficiency
  - polycristalline < 20%
- thin-film technologies
  - amorphous Silicon a-Si, also comb. < 12%
  - CdTe Cadmium-Telluride < 16%
  - CIGS, different combinations < 20%
  - GaAs, Gallium-Arsenide < 24%
  - poly-junction < 41%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



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

A scalable technology: mass production of standardised cells

Rapidly decreasing Costs: The historical learning curve of PV

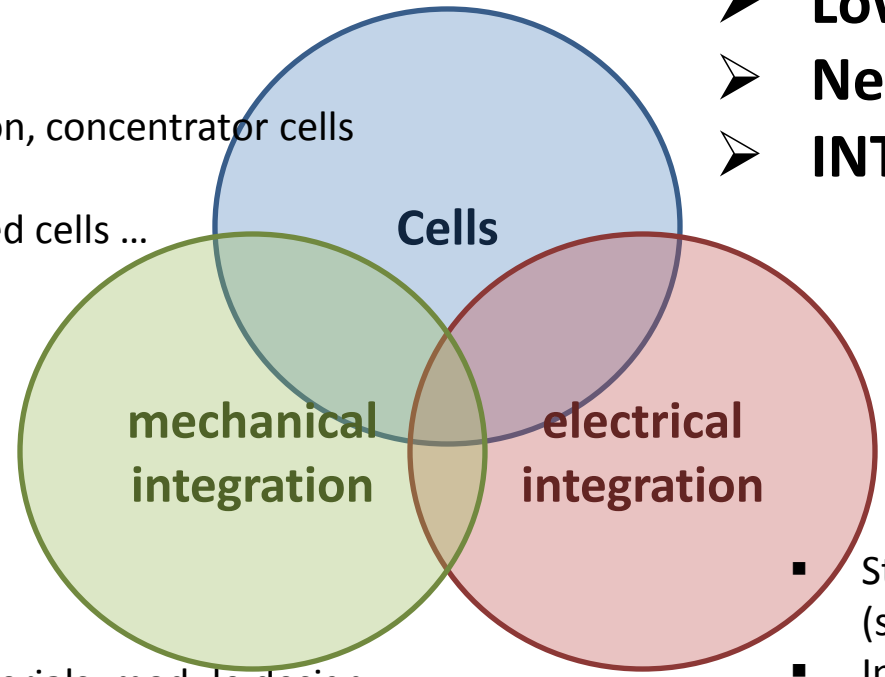


Sources: EU Joint Research Centre - EIA - National Renewable Energy Laboratory - A.T. Kearney analysis.

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 …

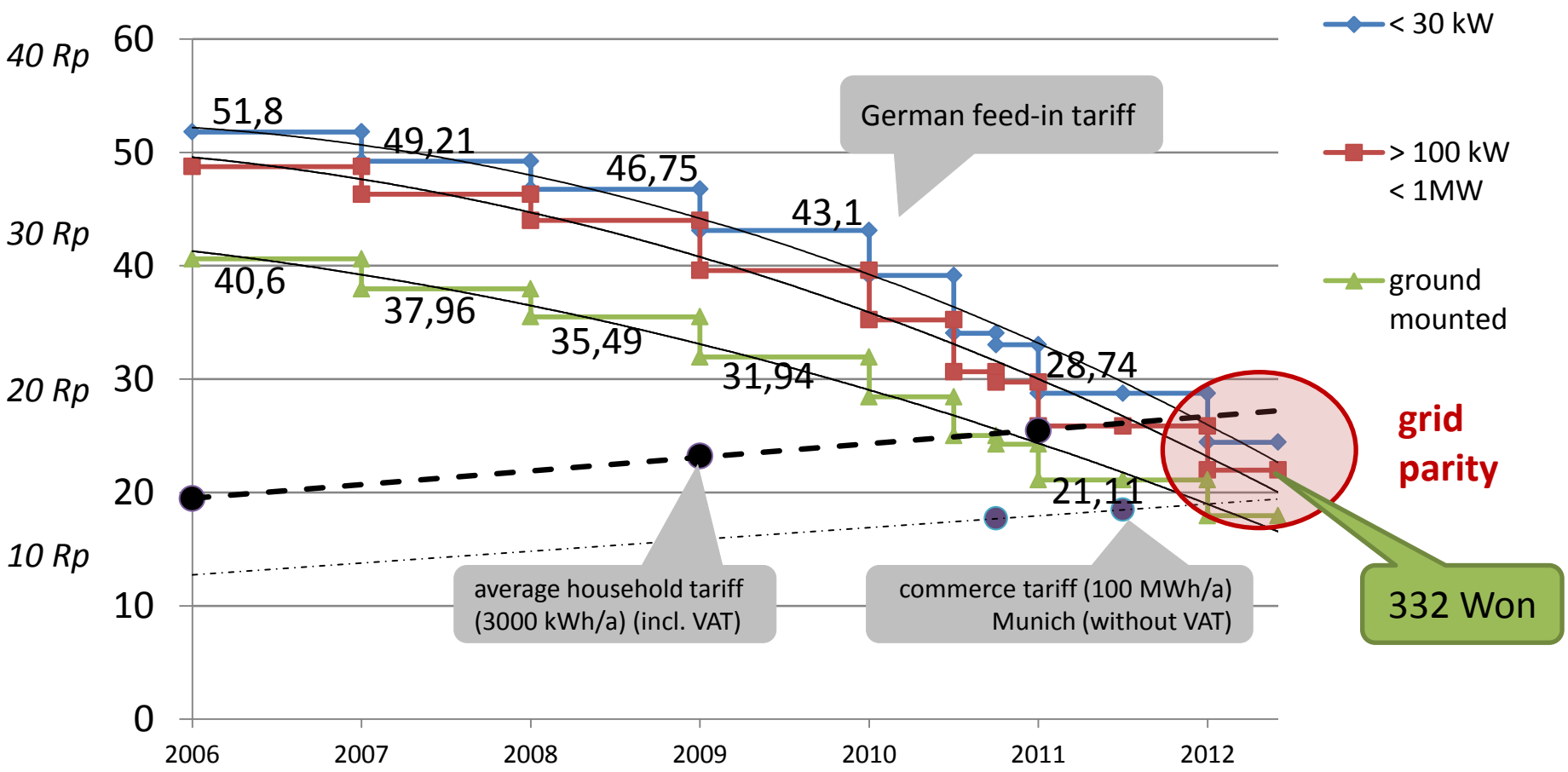
- **Higher efficiency**
- **Lower production costs**
- **New application fields**
- **INTEGRATION**



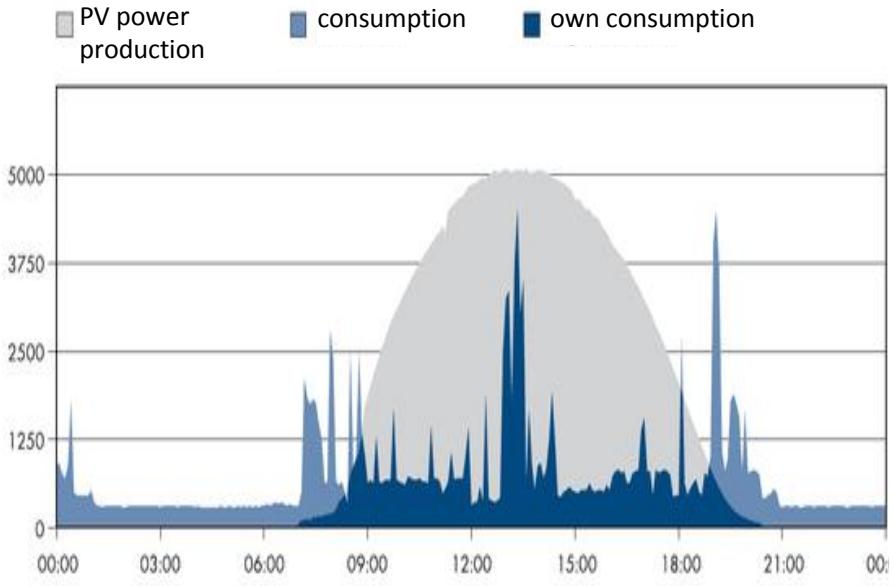
- Carrying materials, module design
- Concentrators, tracker systems
- BIPV: integration in buildings, construction elements
- in appliances, in vehicles
- Free space, traffic areas, roofing

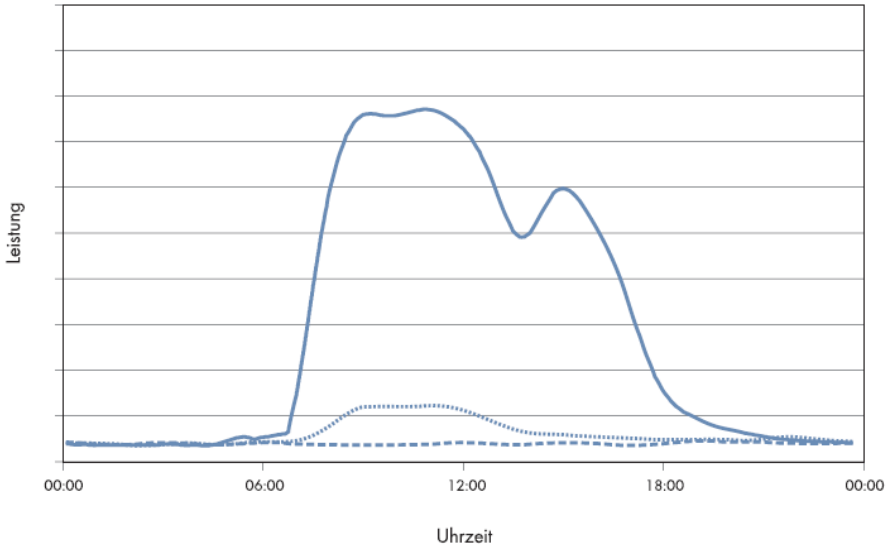
- Storage technologies (stationary, mobile, off-grid, grid)
- Intelligent inverters
- System design
- Hybrid systems, mini-grids
- Grid concepts, grid steering
- Regulation, markets

Rapidly decreasing German feed-in-tariffs: grid parity residential in 2012



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





Private household in Germany

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

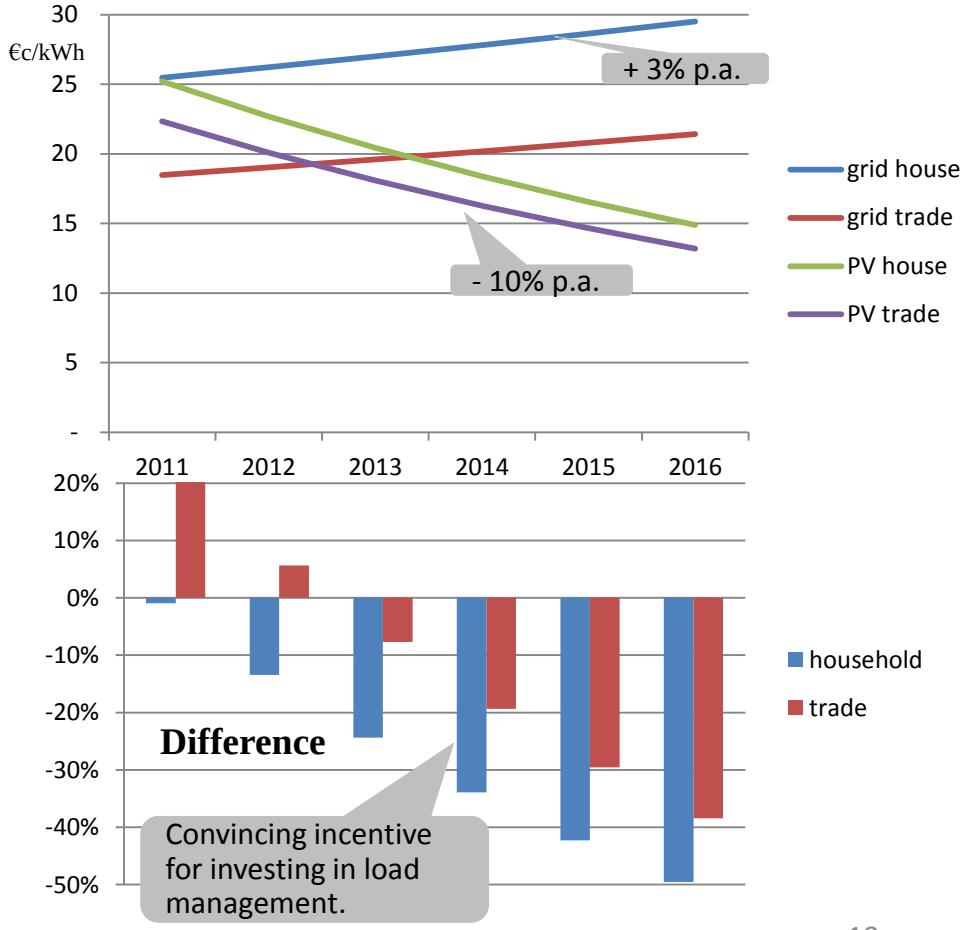
Attractiveness for own power production: Germany - Scenario for the next five years

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

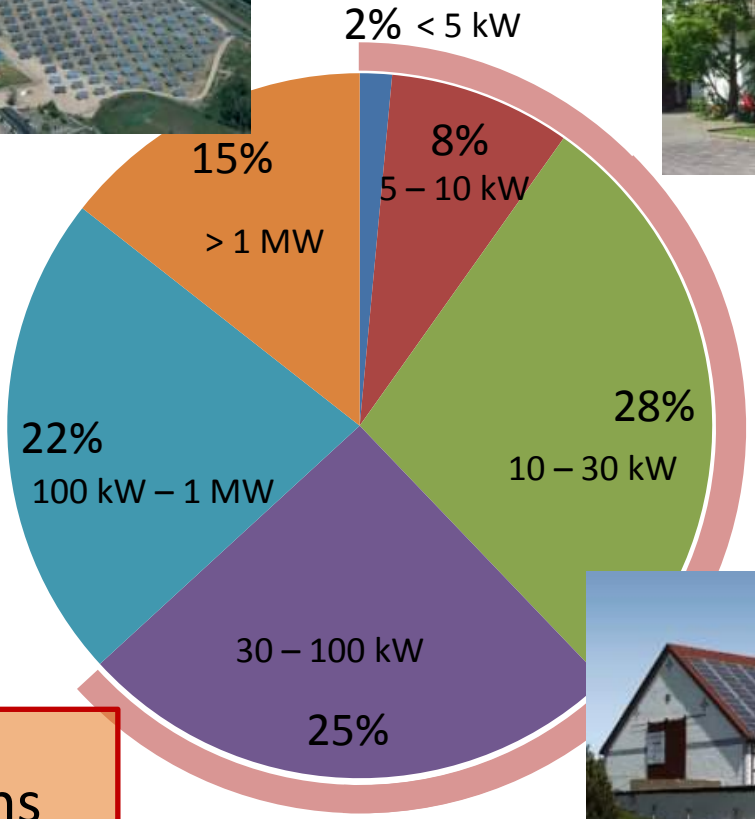
- Scenario assumptions
  - System price development: *-10% p.a*.
  - Power from the grid: + 3% p.a.
  - present FIT in Germany represent present PV power costs

➢ 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



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

The coming boom: captive power generation

Attractive investments even without incentives

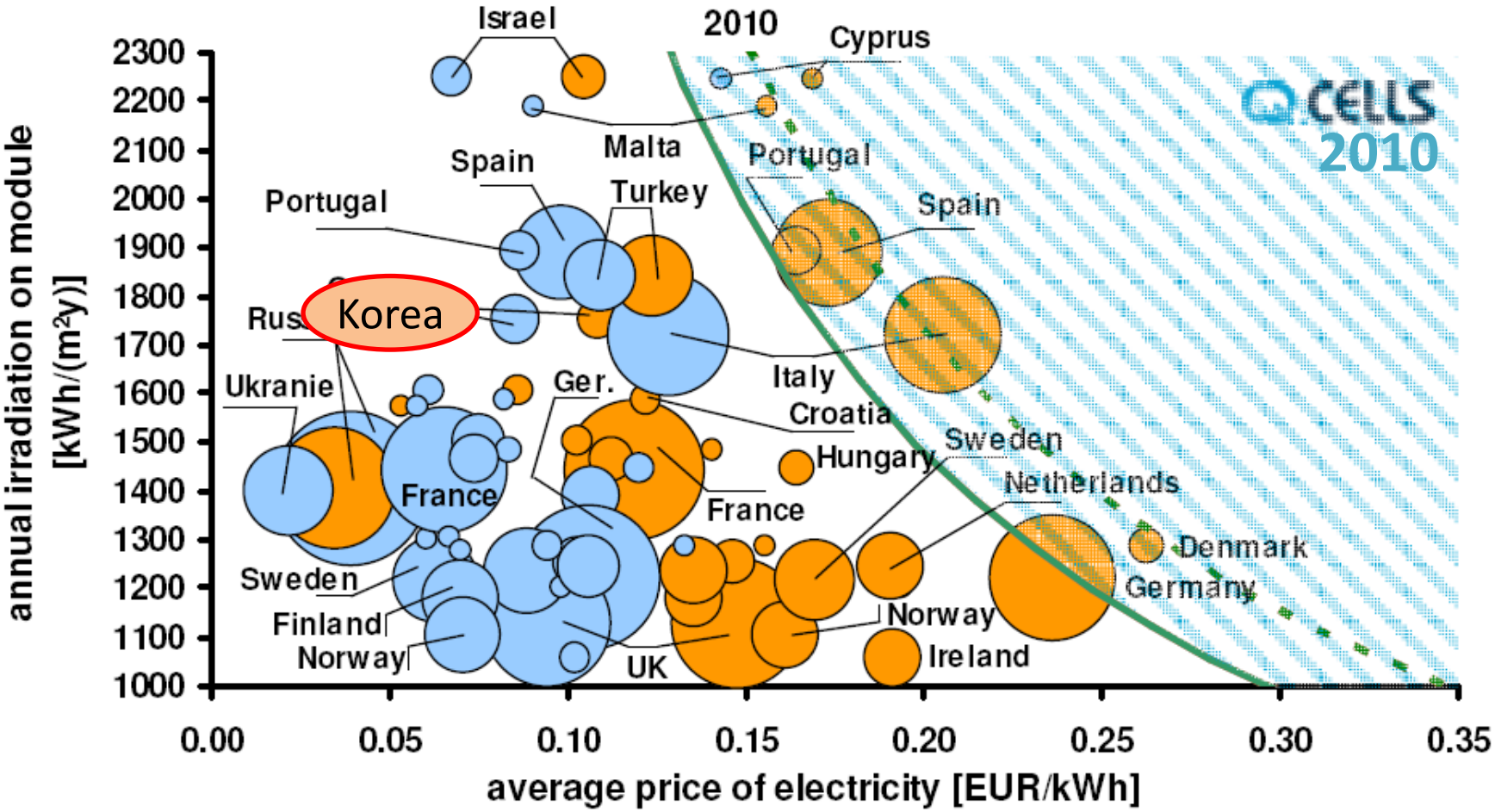
Timeline in Germany:

- 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

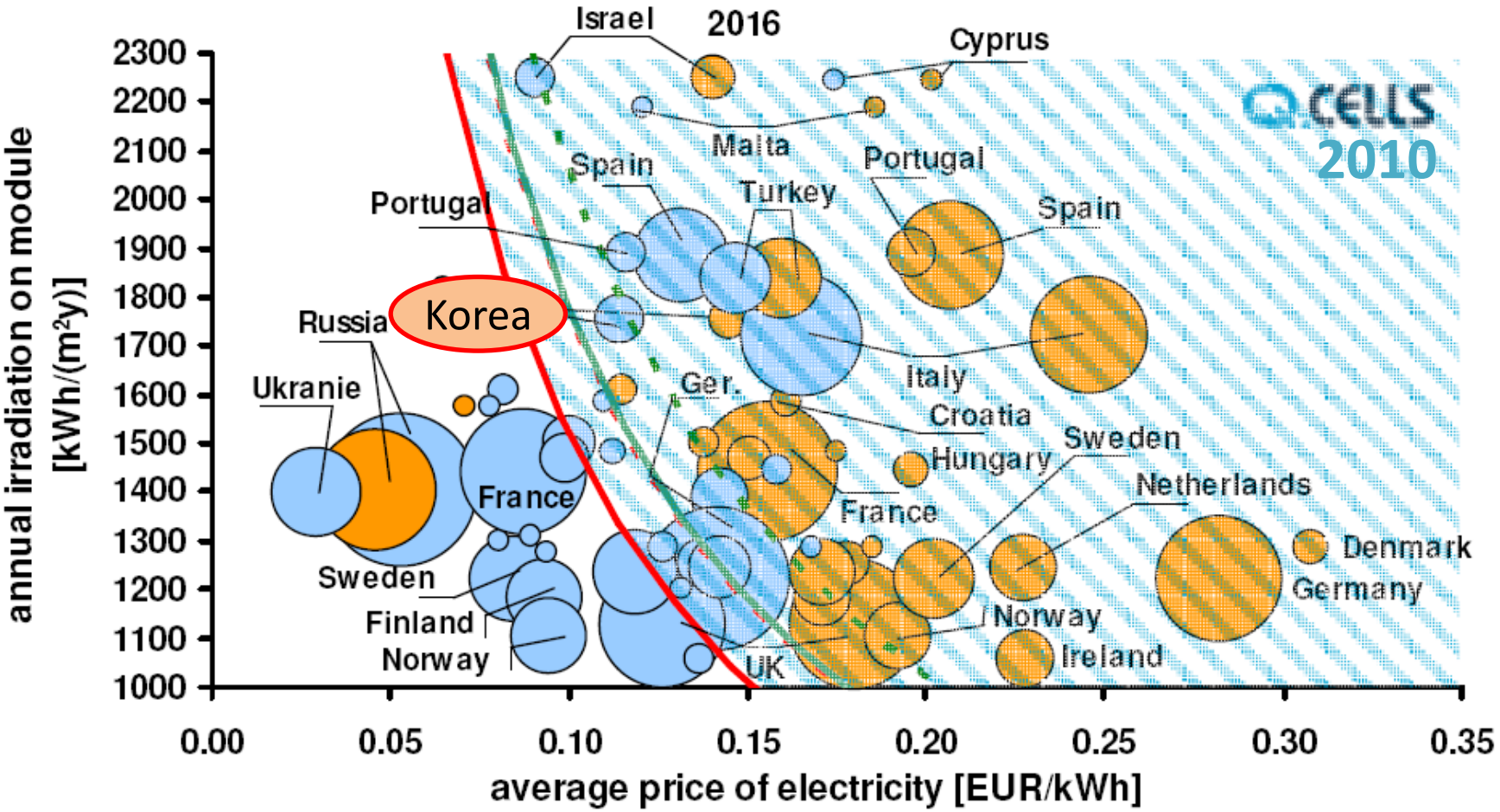
➢ Boom in power management technologies

Grid parity in Europe 2010



commercial residential

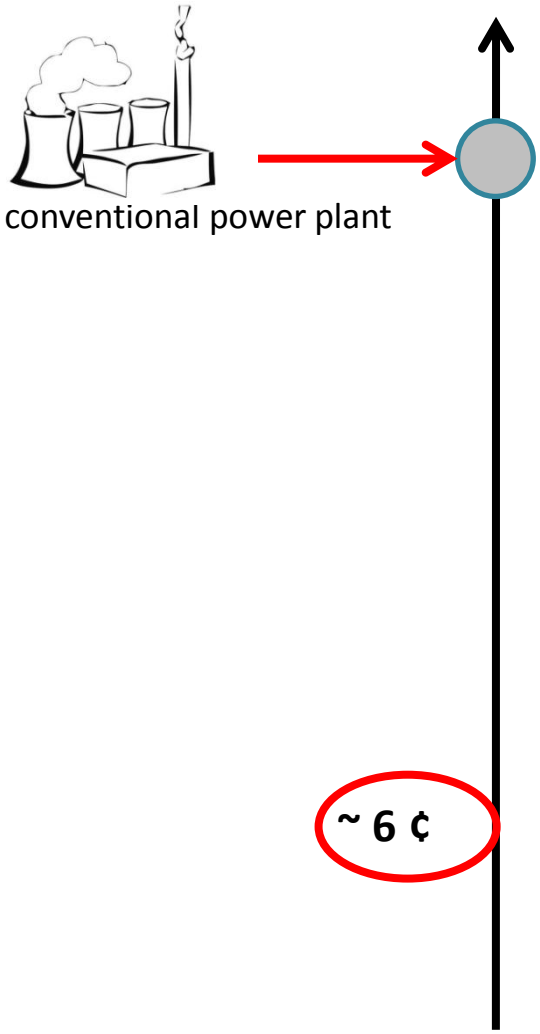
Grid parity in Europe 2016
(forecast in 2010)



commercial residential

TOWARDS A NEW CONTROL LOGIC OF THE ELECTRICITY SYSTEM

Photovoltaics is a modular technology: competing on the retail side



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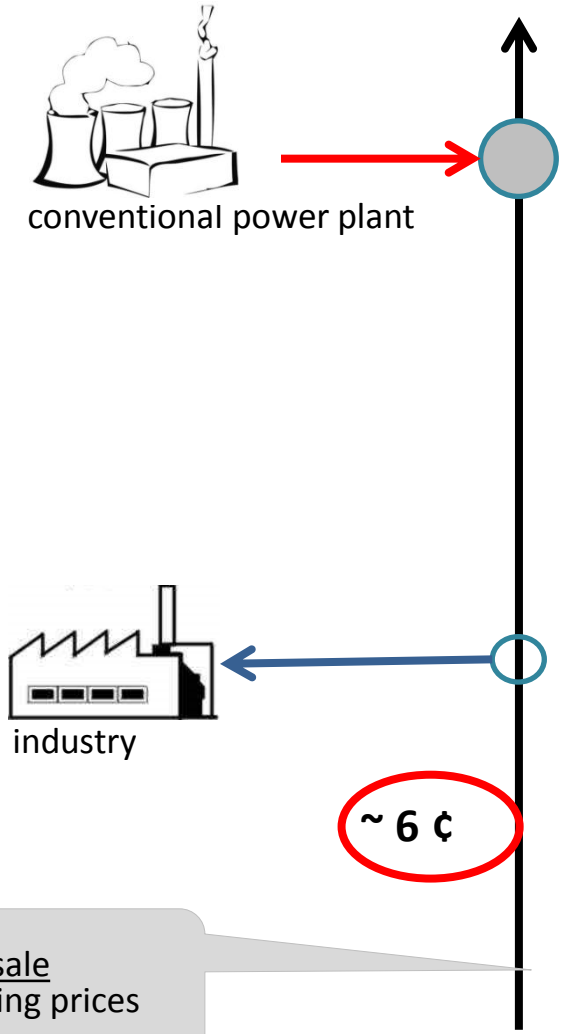

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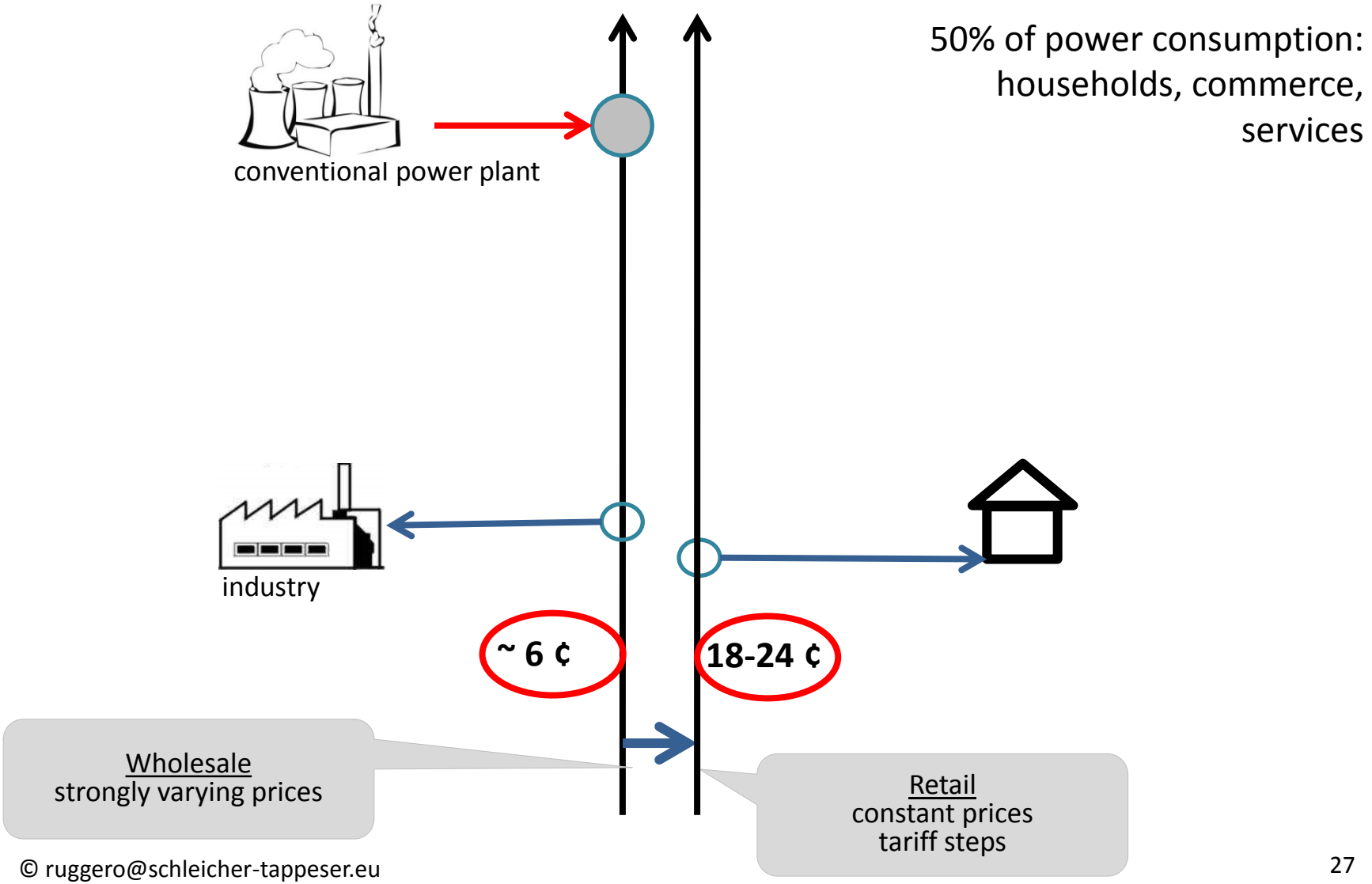

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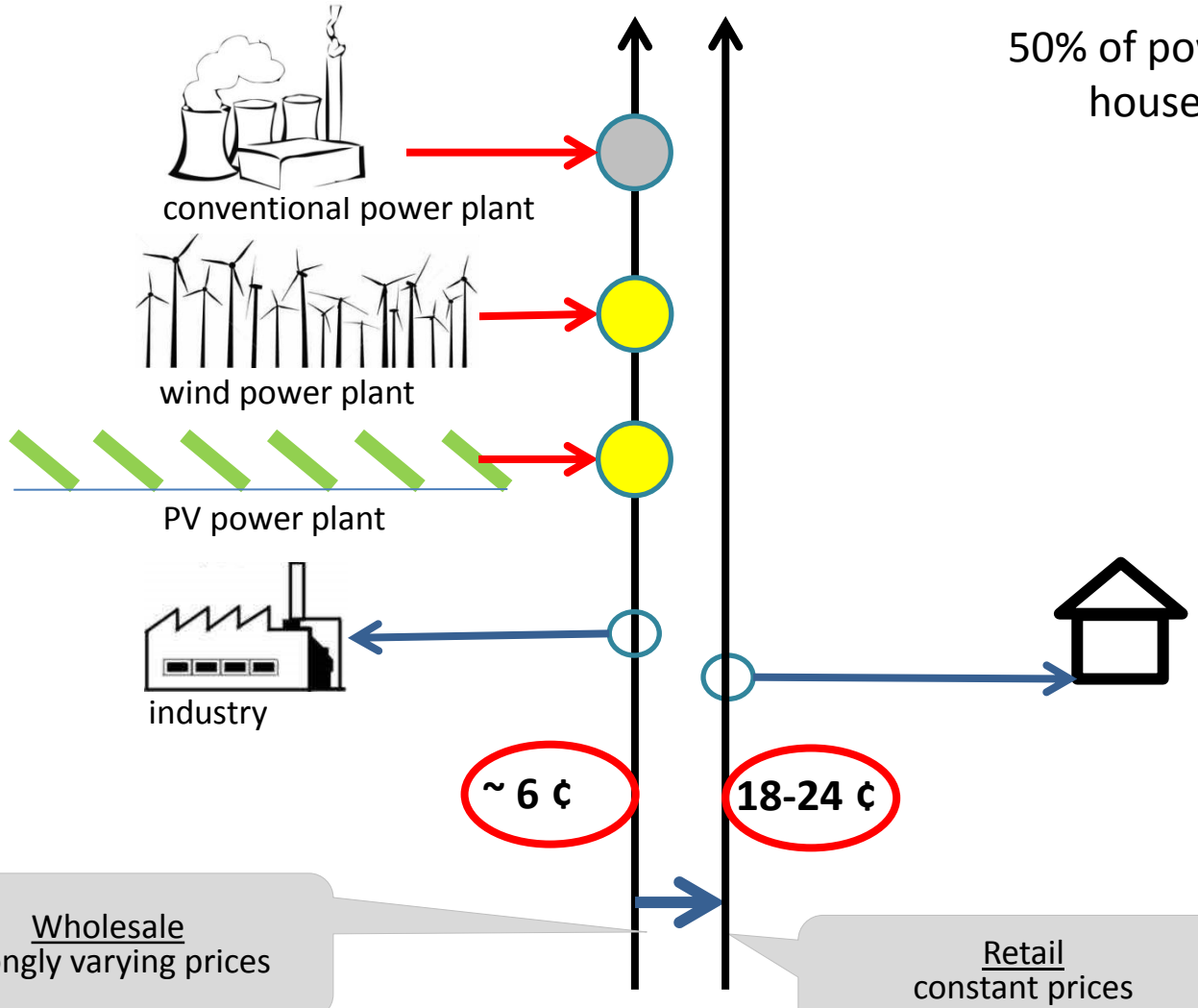
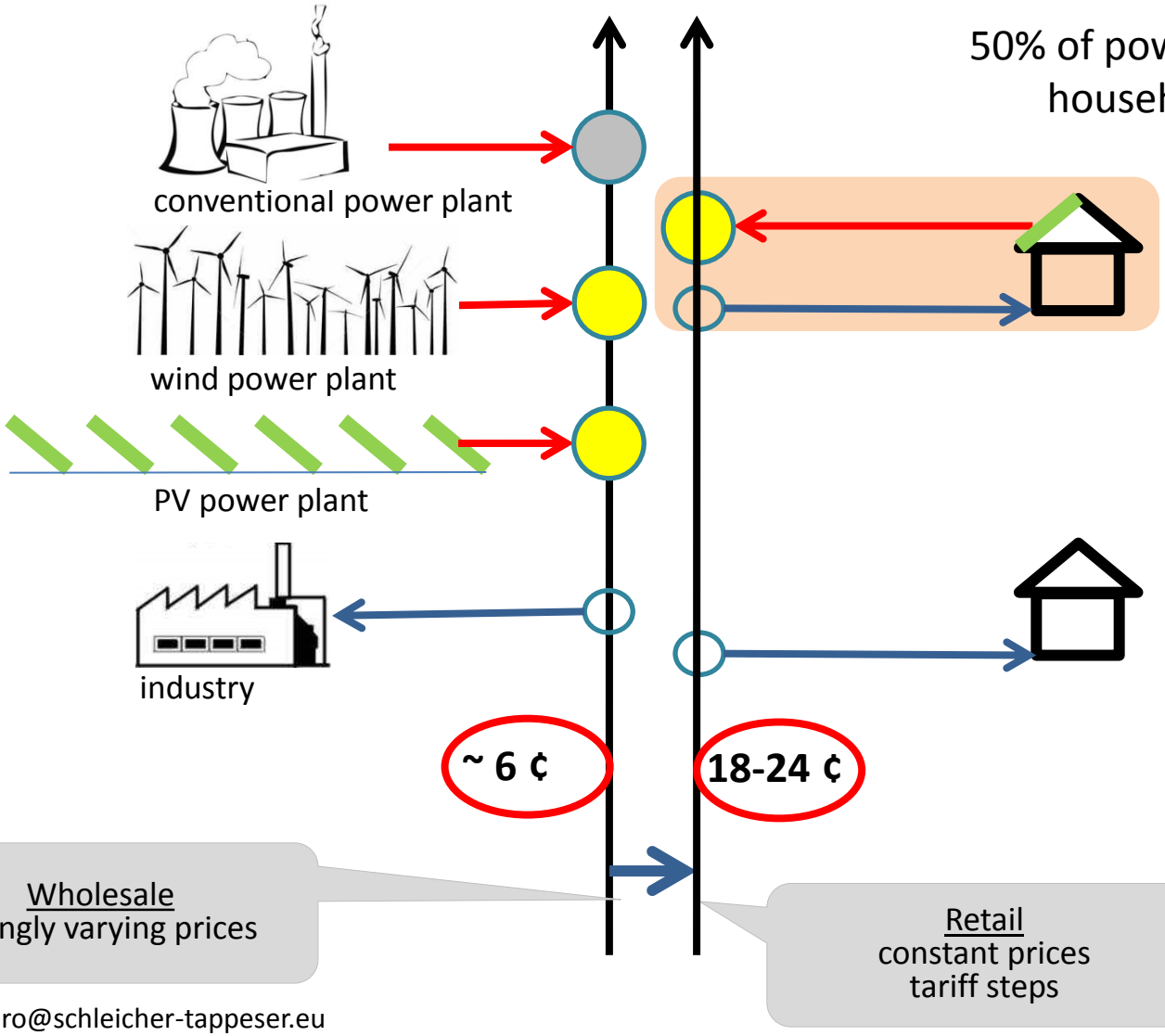


50% of power consumption:
households, commerce,
services

Photovoltaics is a modular technology: competing on the retail side



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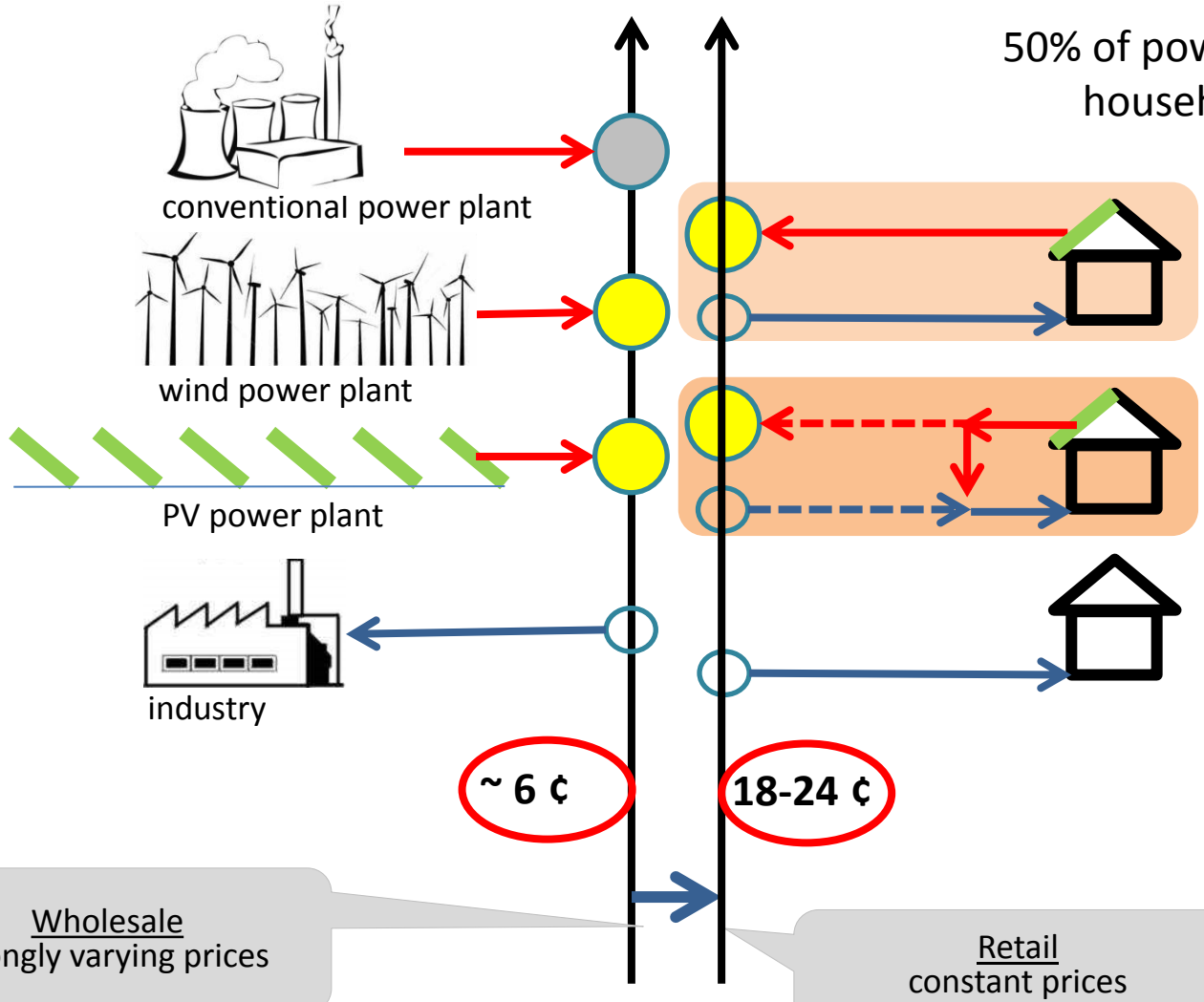

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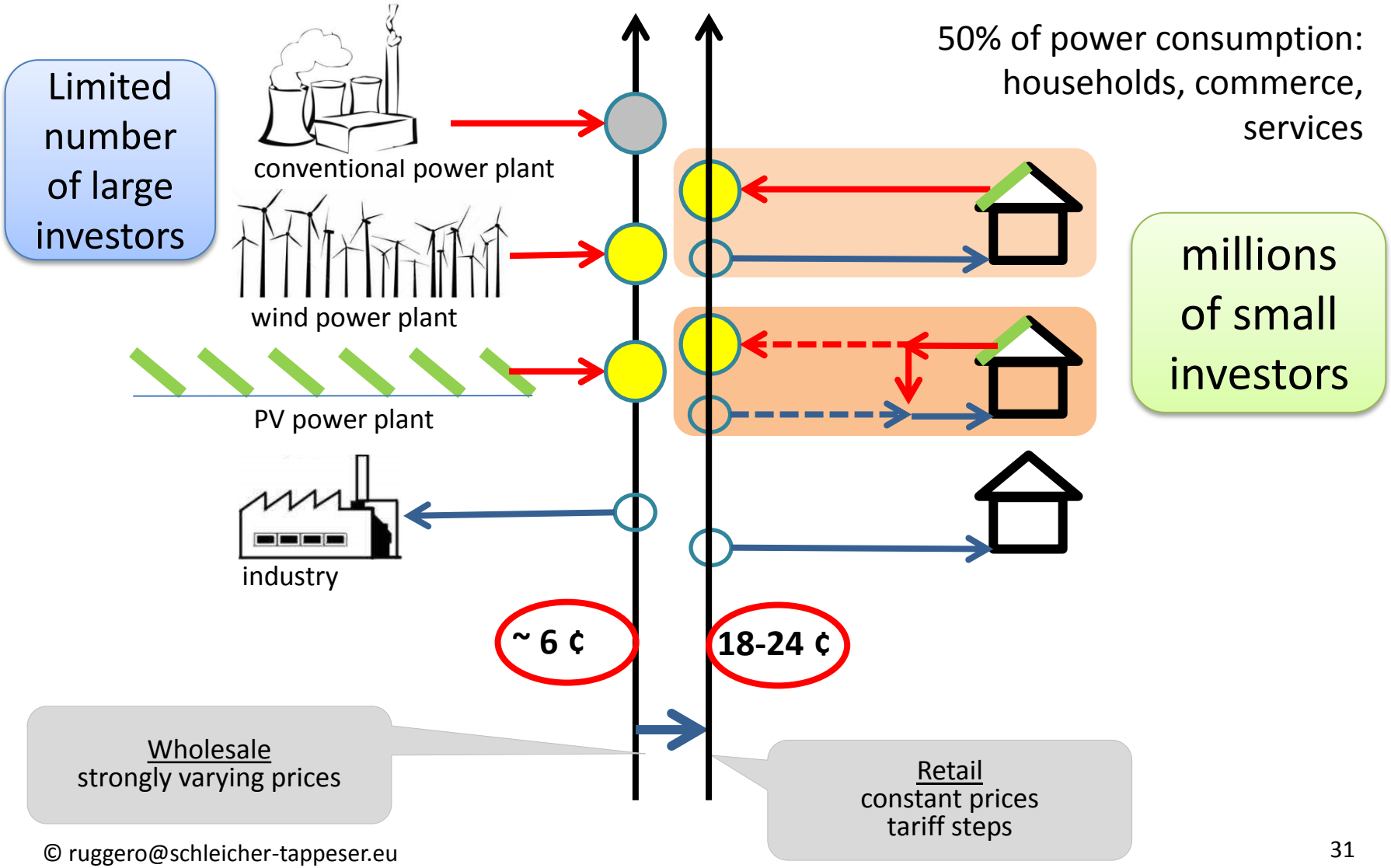
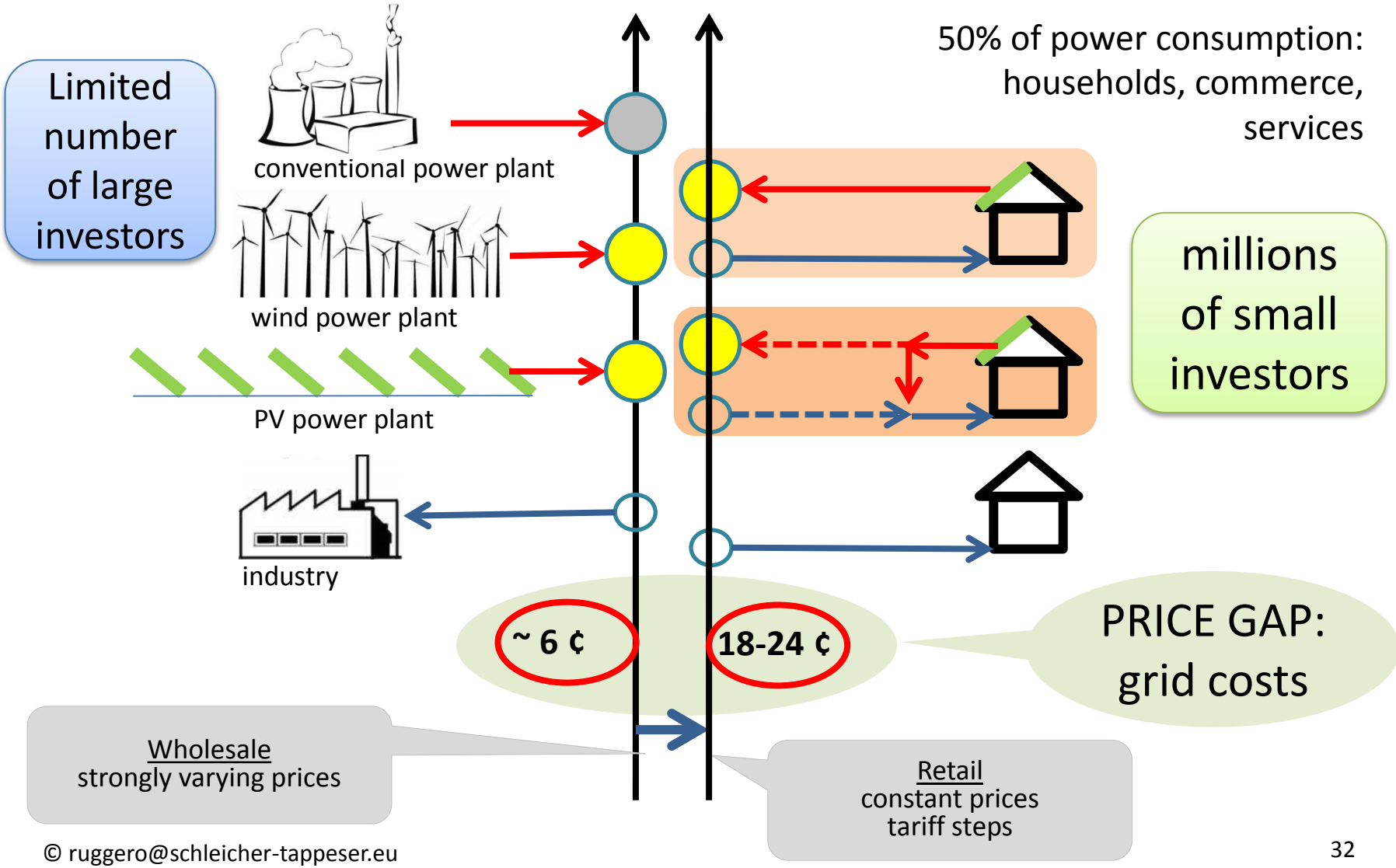
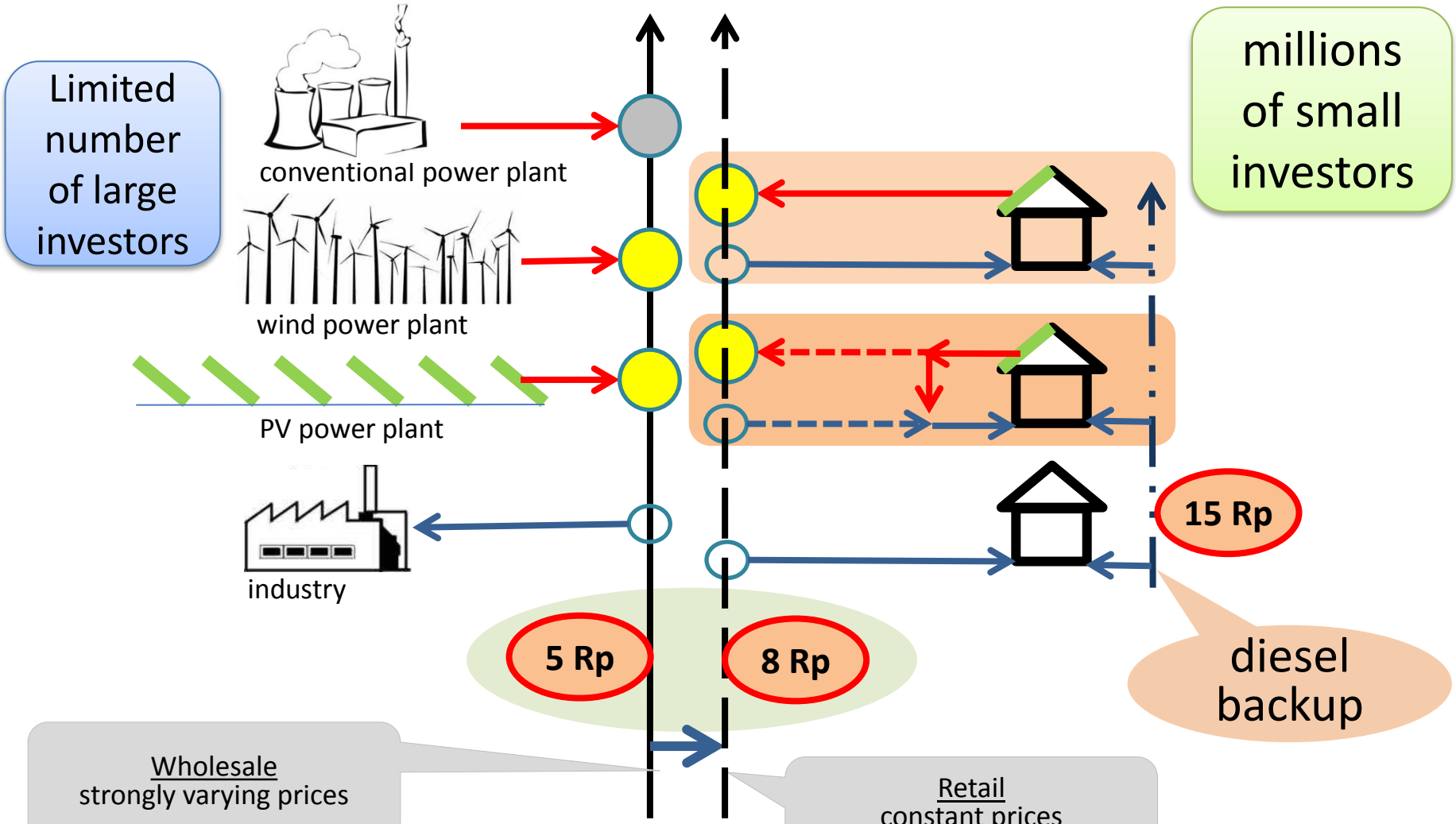


Photovoltaics is a modular technology: competing on the retail side



India: Photovoltaics in weak grids competing against diesel backup



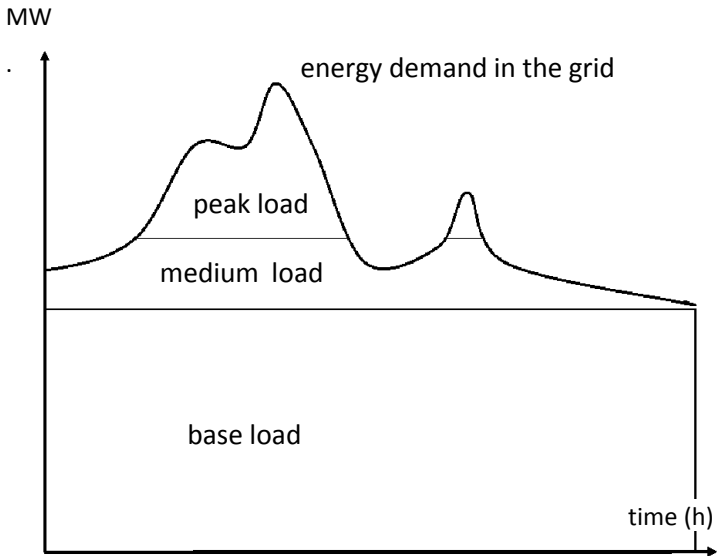
The main problem with high shares of wind and solar power: fluctuation

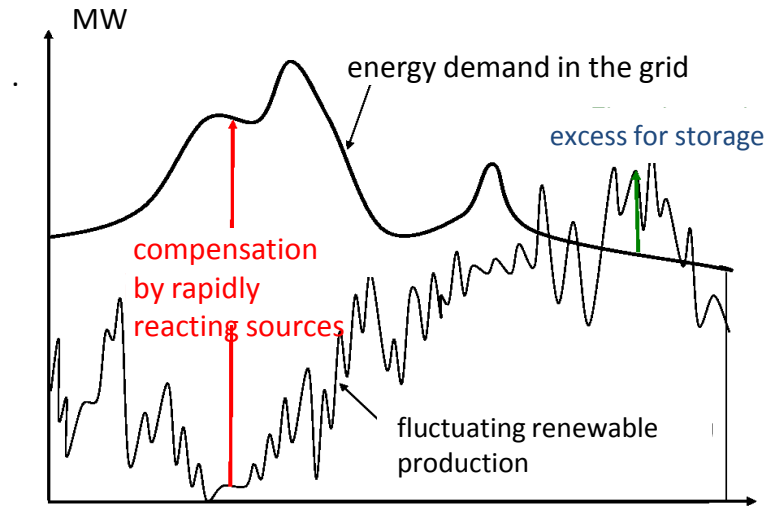
The old base load concept:

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

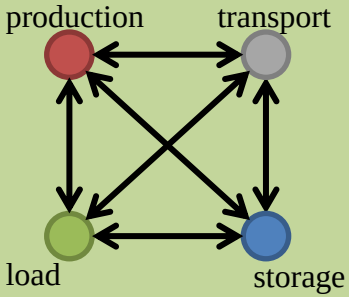
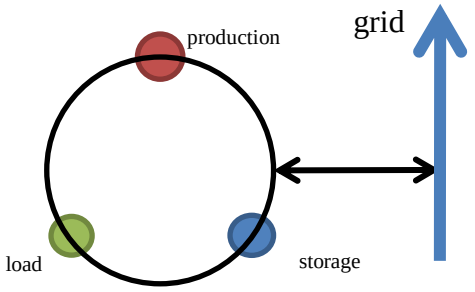
The new paradigm:

- Variable production from renewables 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





Captive PV Power can support the 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	

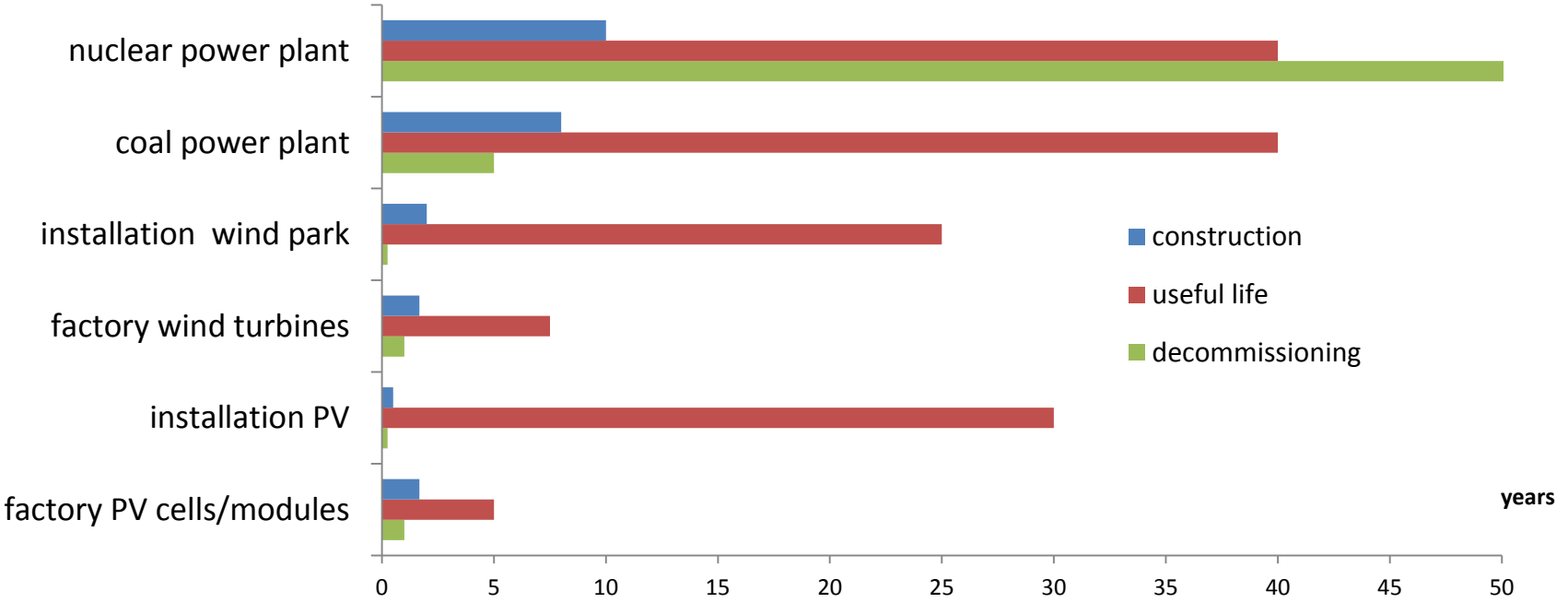
Unfamiliar to energy business: 4 to 10 times shorter innovation cycles

→ 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



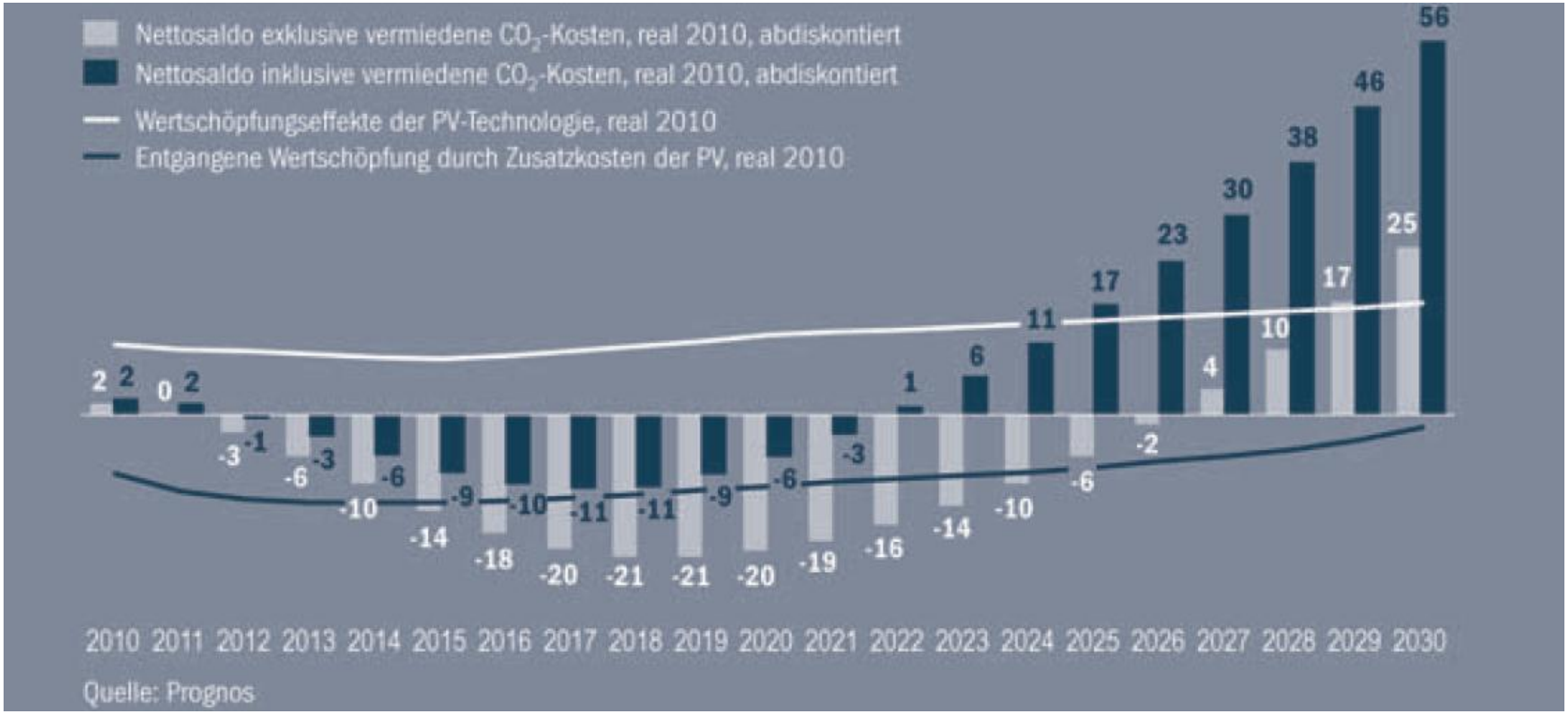
ECONOMIC IMPACTS

PV brings important economic advantages for 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 paid 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

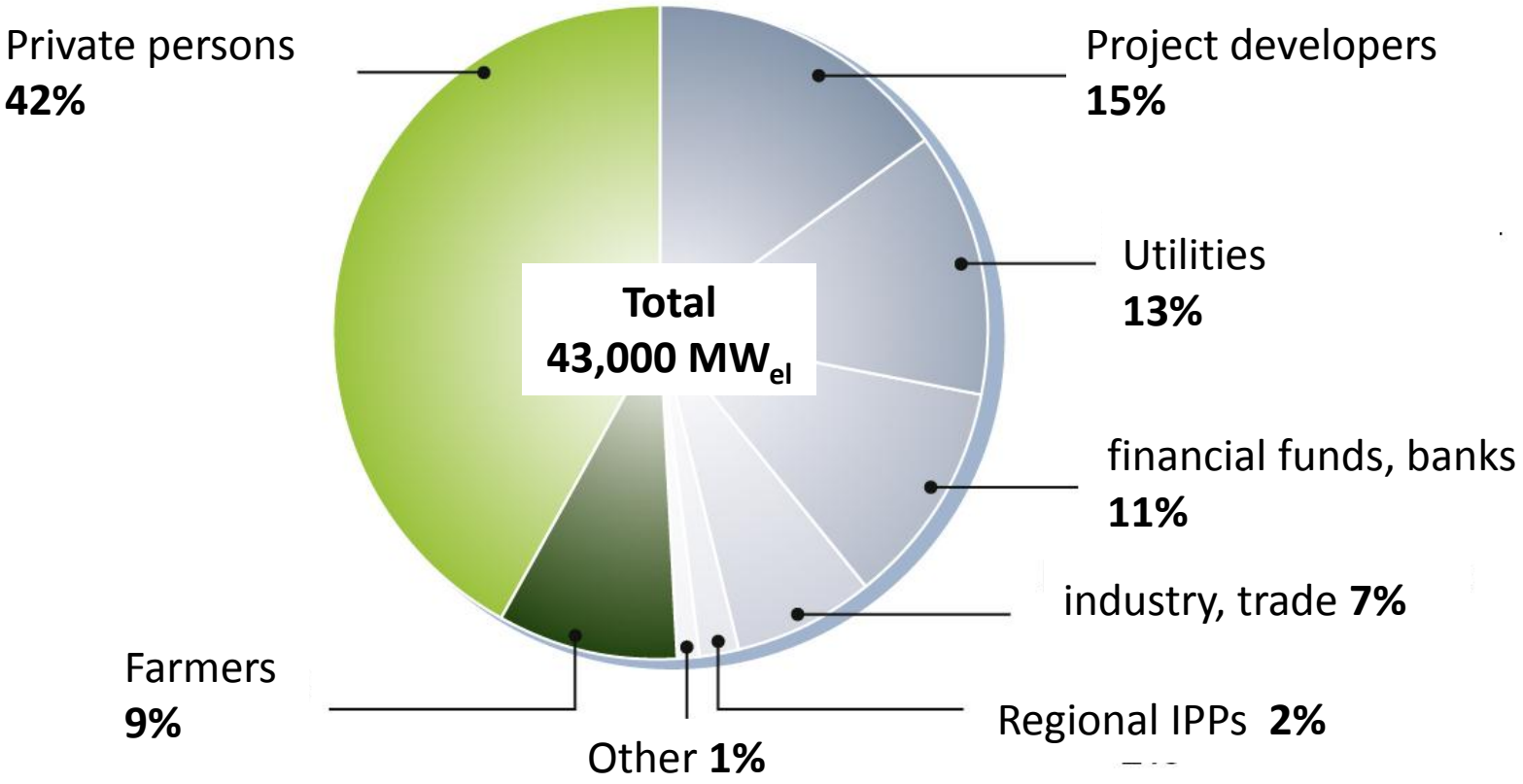
- Roland Berger / PROGNOS 2010 with very prudent assumptions:



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

Citizens participation: Distribution of ownership

Ownership of installations for renewable electricity production in Germany (2010)



Quelle: trend research 2010; Stand: 10/2010

www.unendlich-viel-energie.de

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

PROJECT EXAMPLES

Rooftop plant on historical protected house in Italy 2011

- Modena / Italy. 6 kW. 2011
- Built by CoEnergia
- modules: Q-Cells thin-film

Plus-Energy-Houses in Freiburg / Germany

Agricultural building in central Germany

- 23,10 kWp , St. Goar-Werlau / Germany, 2009
- Modules SolarWorld, monocrystalline
- In operation since 30.9.2009
- Produced until end Nov 2011: 46‘000 kWh

Using the whole roof of a small industry building

- Sasbach / southern Germany
- 267 kWp
- yield 254 MWh/yr
- modules: Solon

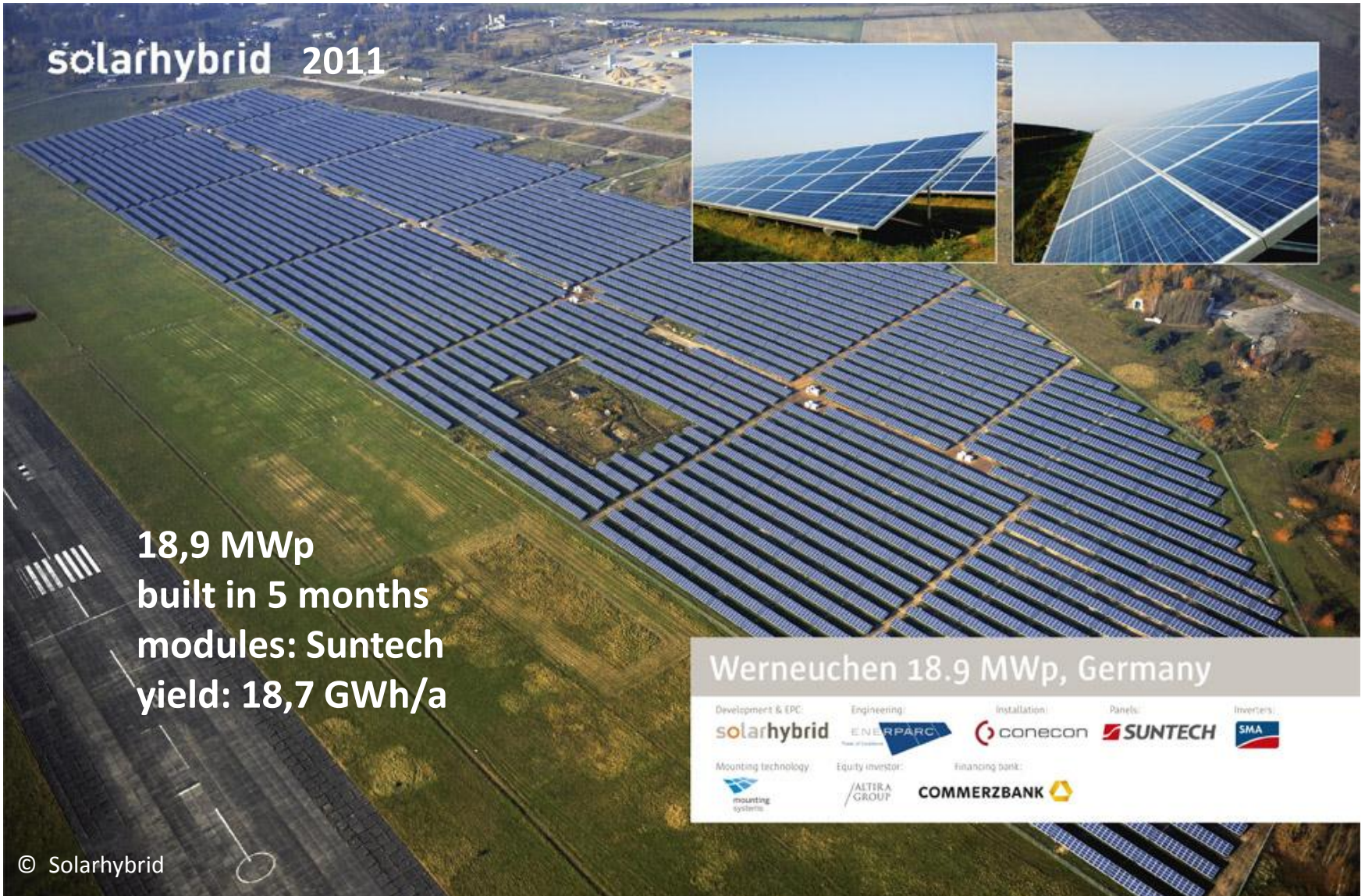
MW-plant on a logistics centre

- Lodi / Italy, flat roof, 1‘699 kWp
- built by Solon
- yield 1‘800 MWh/yr

Large plant built on greenfield site 2009 would not be allowed today

- Strasskirchen / Germany. 53 MW. 2009.
- built in 5 months by Q-Cells
- modules: Q-Cells polycrystalline

Large plant on former military site 2011



Surface requirements of different renewable technologies in Germany

electricity

photovoltaics: < 10 m²/MWh/yr

wind : < 10 m²/MWh/yr
surface: (3 x rotor diameter)²

Where applicable, CSP needs about the same surface as PV

Biomass (corn)
> 200 m²/MWh/yr

factor 20 - 100

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transport

electric car with PV

conventional car with biofuel

factor 250

CONCLUSIONS

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

Building blocs for a PV strategy

- Structures of electricity markets
- Financial support
- Technical aspects of grid connection
- Permitting procedures
- Industry policy, innovation policy
- Training, ensuring quality
- Financing and insurance
- Mobilisation of final customers, local gov.

THANK YOU FOR YOUR INTEREST

You will find this presentation and more on my website

www.sustainablestrategies.eu

sustainable strategies
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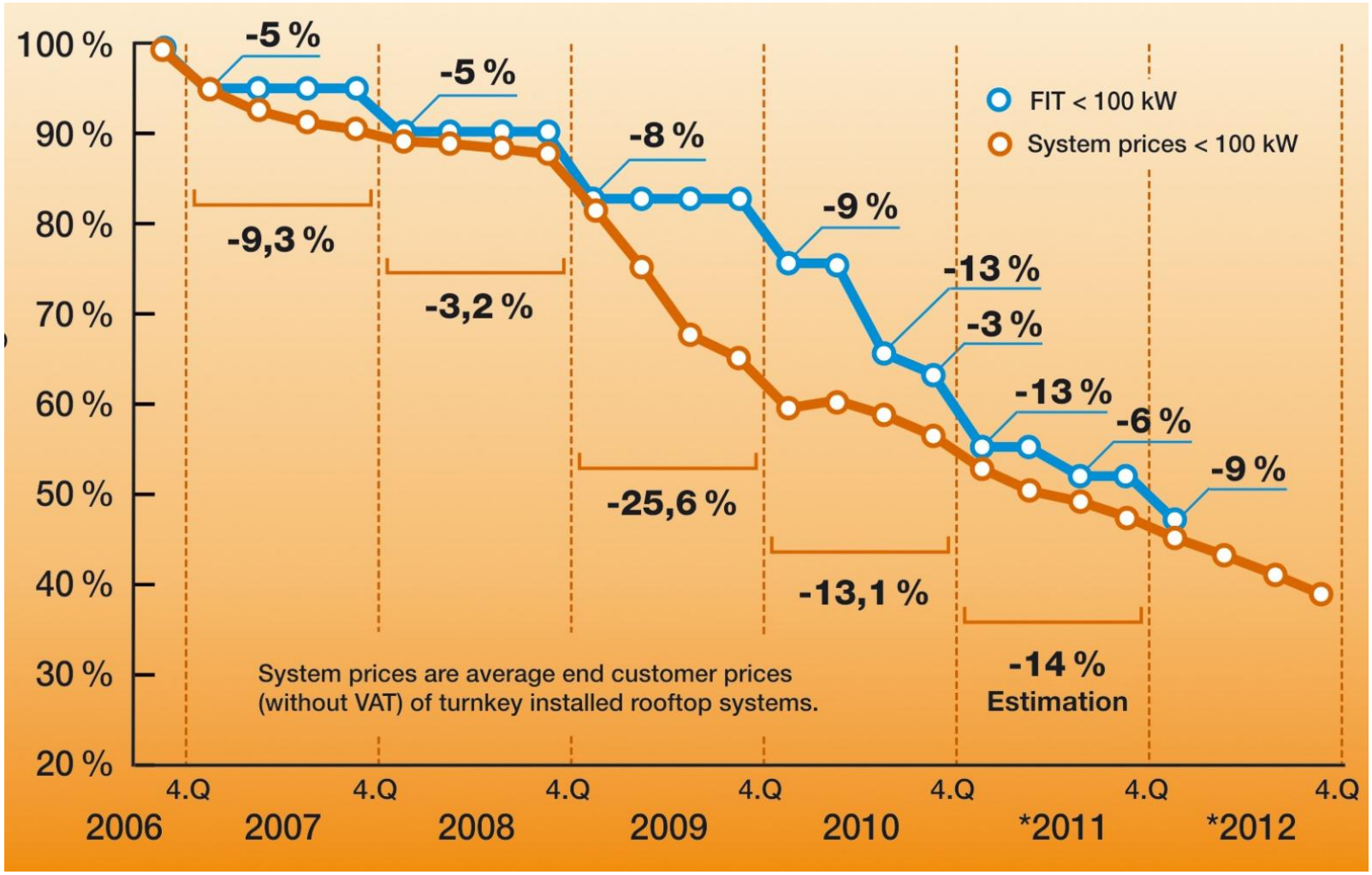
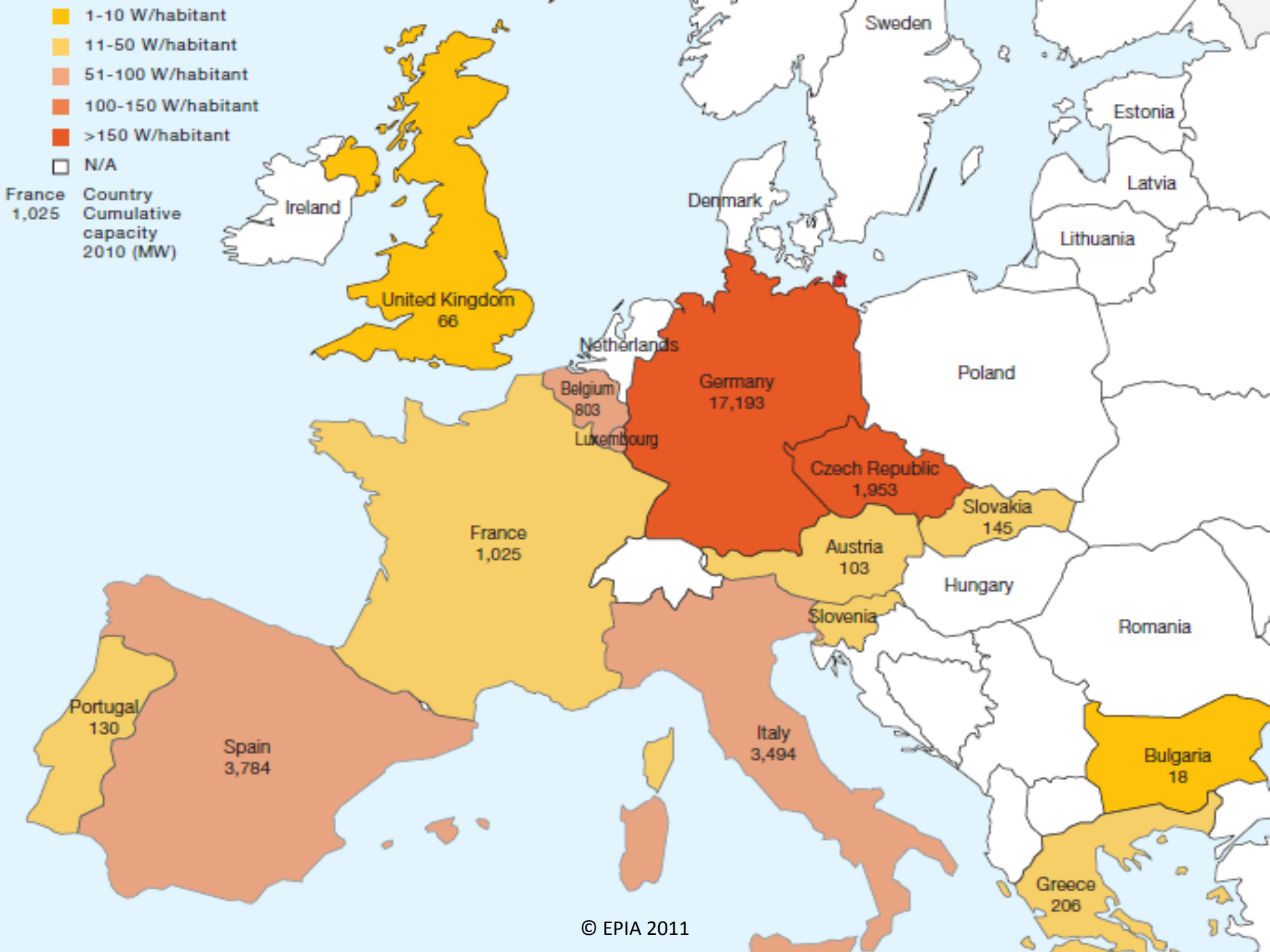
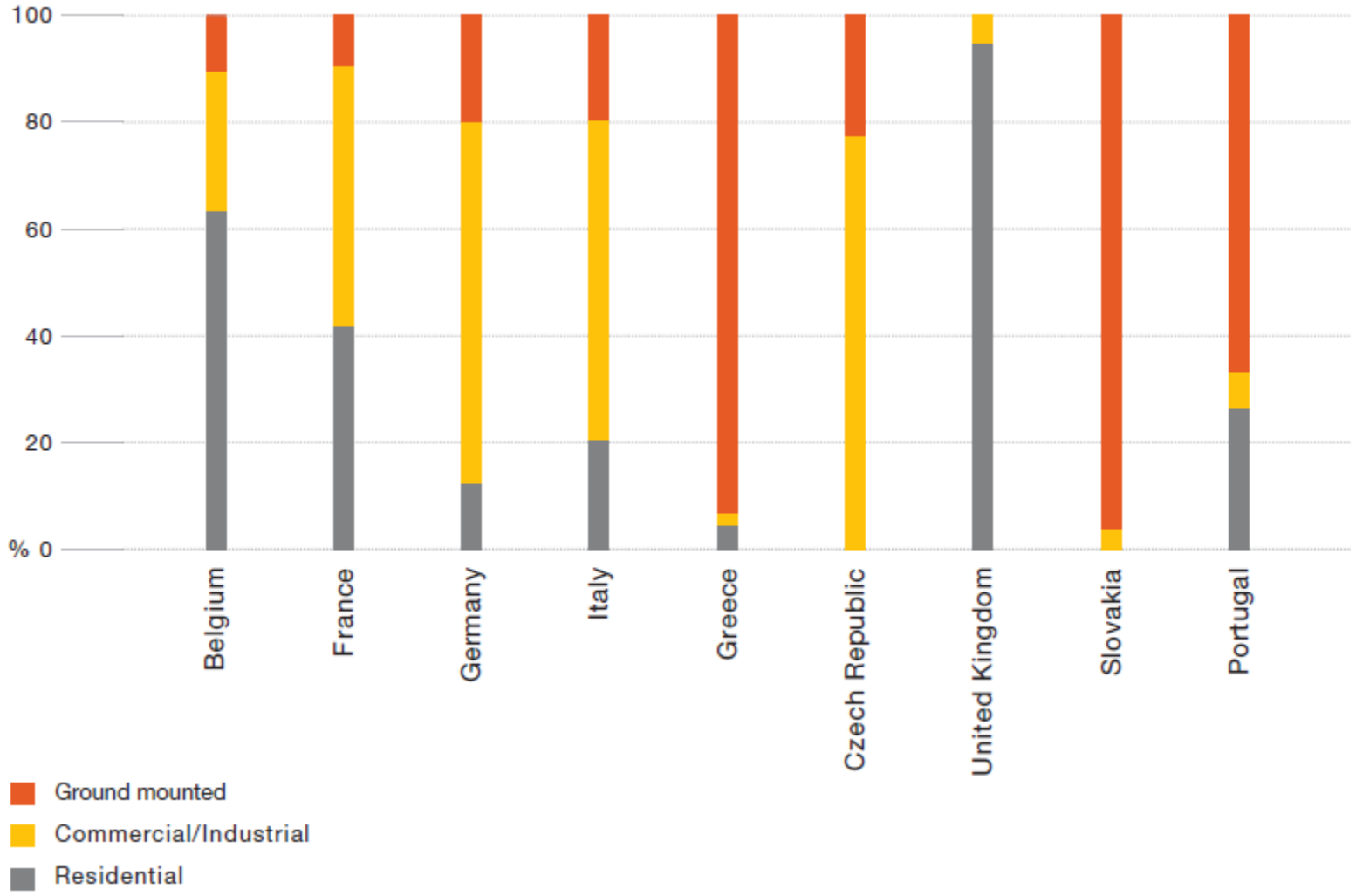
Germany: Adapting the feed-in-tariff to market volumes → steady market




1-10 W/habitant
11-50 W/habitant
51-100 W/habitant
100-150 W/habitant
>150 W/habitant
N/A
France 1,025
Country Cumulative capacity 2010 (MW)
Sweden
Estonia
Latvia
Lithuania
Denmark
Ireland
United Kingdom 66
Netherlands
Belgium 803
Luxembourg
Germany 17,193
Poland
Czech Republic 1,953
Slovakia 145
France 1,025
Austria 103
Hungary
Slovenia
Romania
Portugal 130
Spain 3,784
Italy 3,494
Bulgaria 18
Greece 206

PV market structure in different EU countries 2010



Cumulative PV installations per capita in 2010