The disruptive power of solar photovoltaics: What can be learned from 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 economies

► Rapid transformation of the energy system needed
  - *Political targets converge: 100% renewable electricity in 2050*

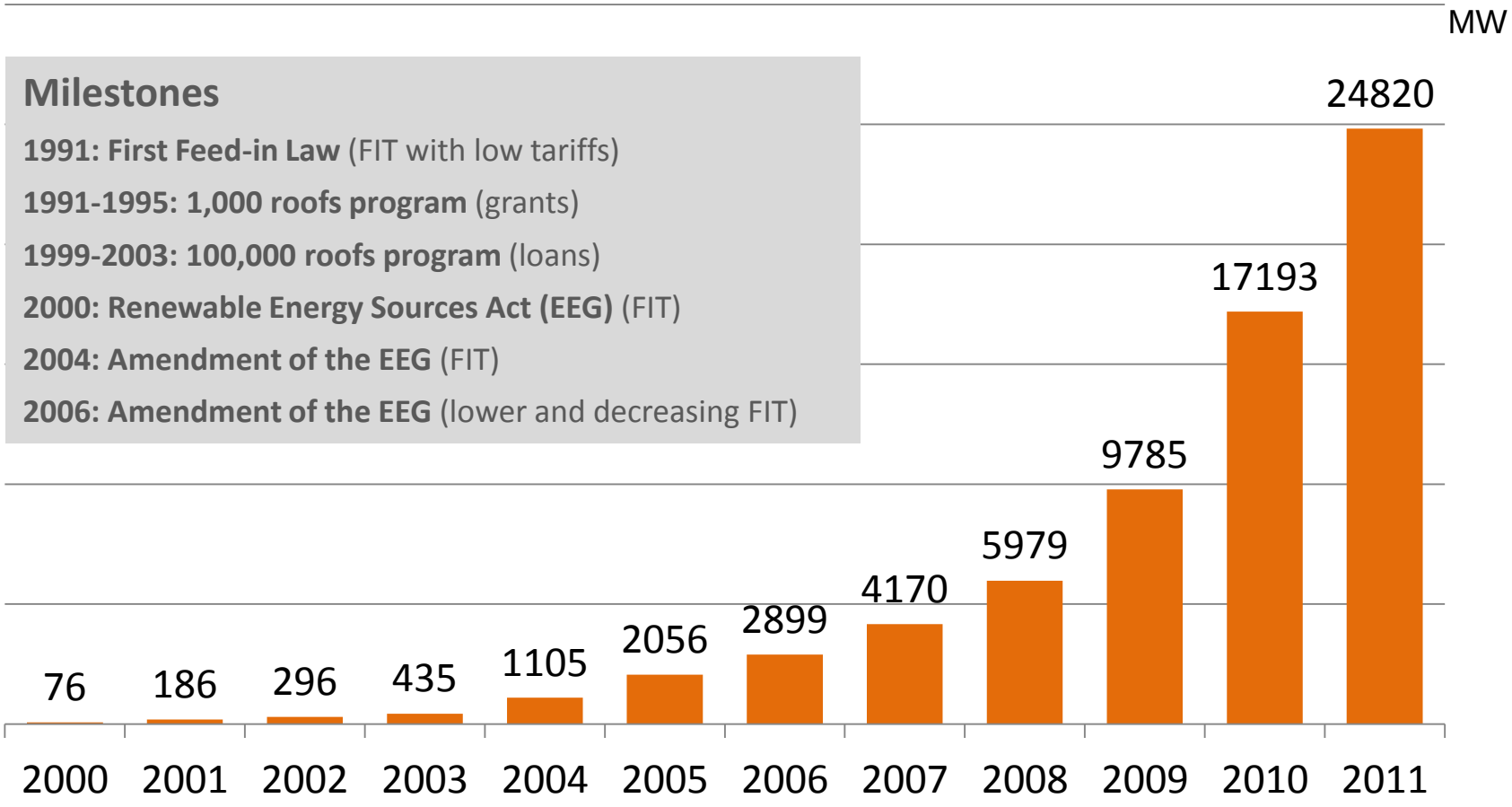
► Governments create markets for new technologies
  - *Global battle for leadership in new energy technologies*

► New technologies change the energy markets
  - *Incumbents try to delay the transformation*

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

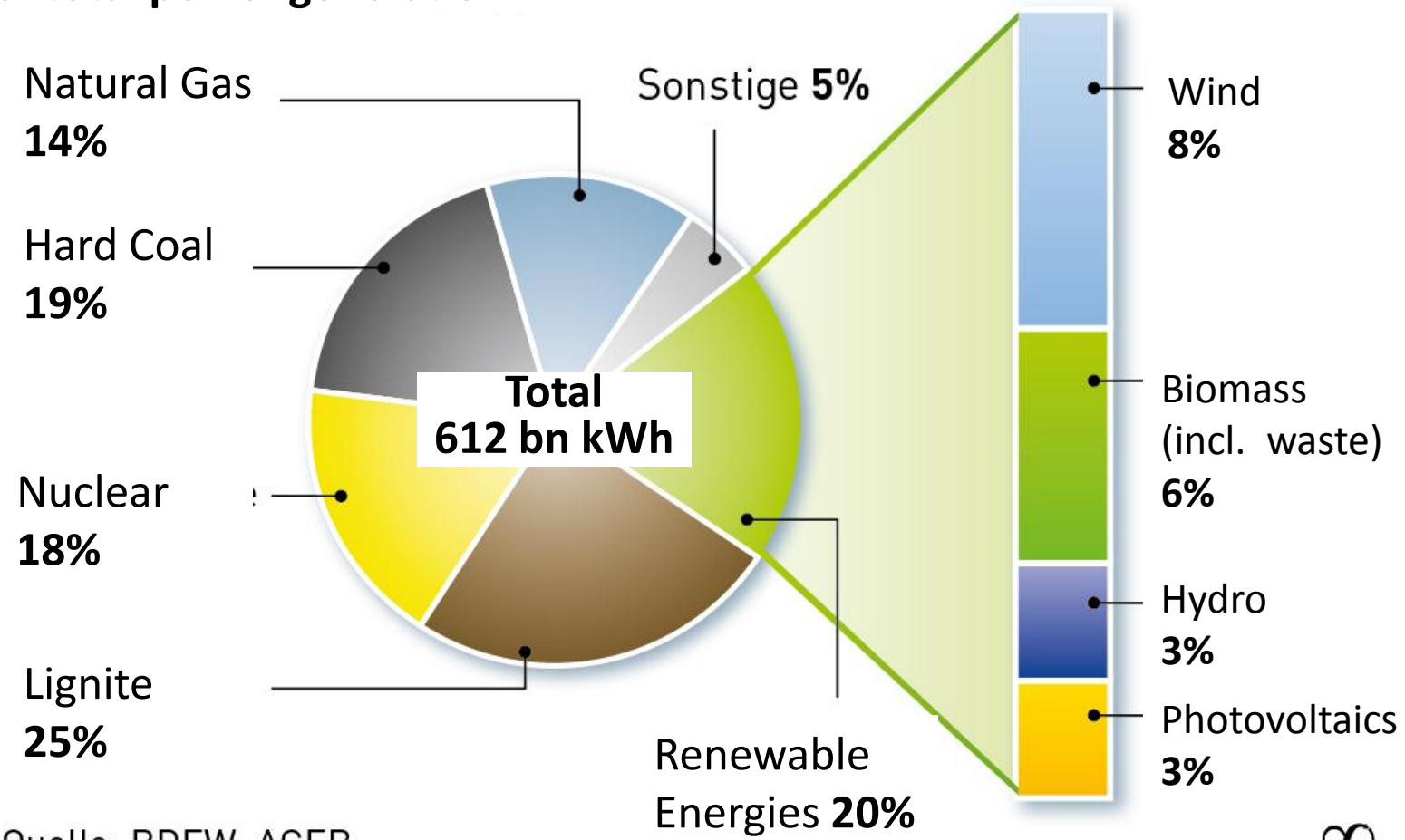
Germany has triggered the take-off of the world PV market

Total PV capacity installed in Germany



Electricity production mix in Germany 2011

Renewable Energies provided 20% of total power generation

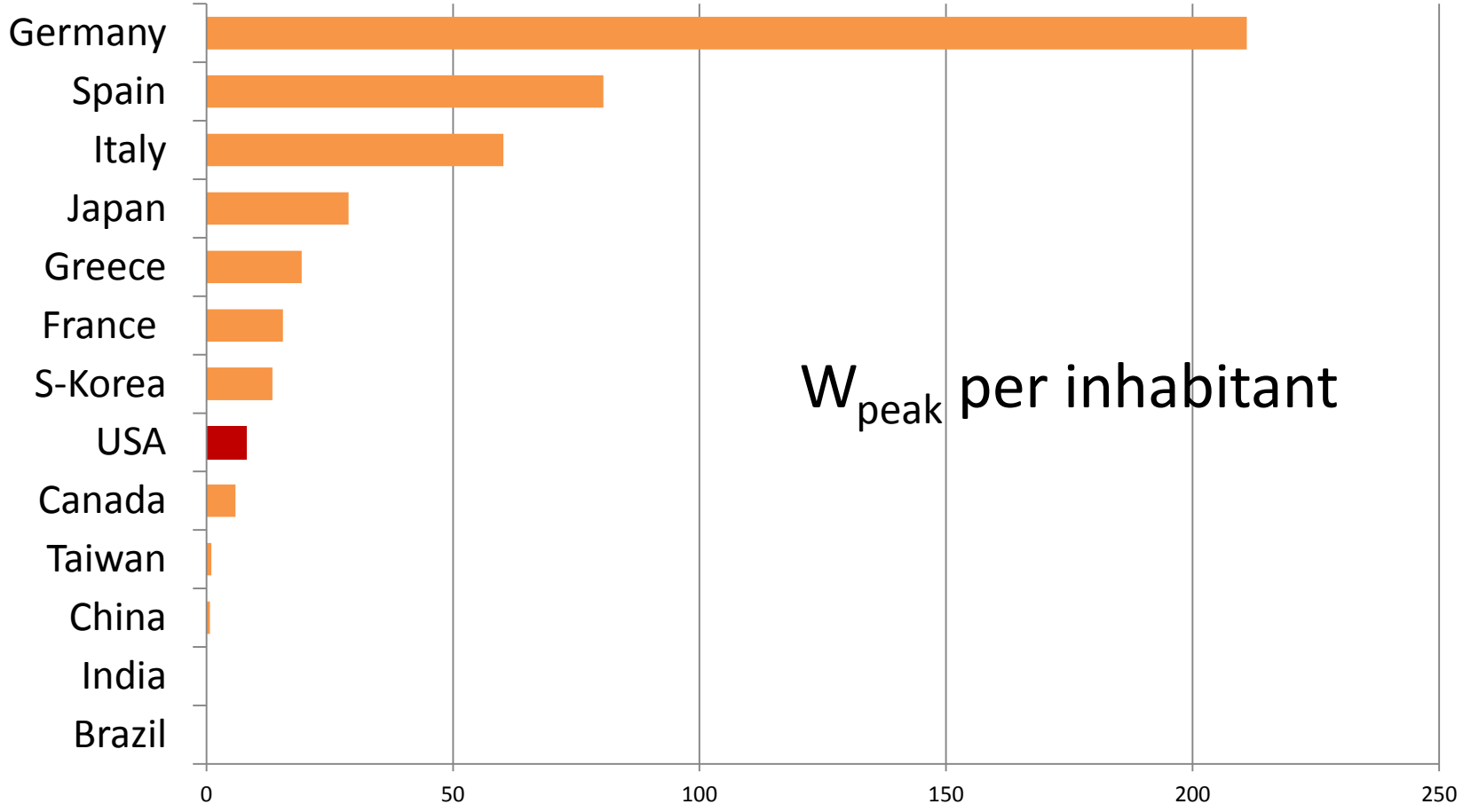


Quelle: BDEW, AGEB
Stand: 12/2011

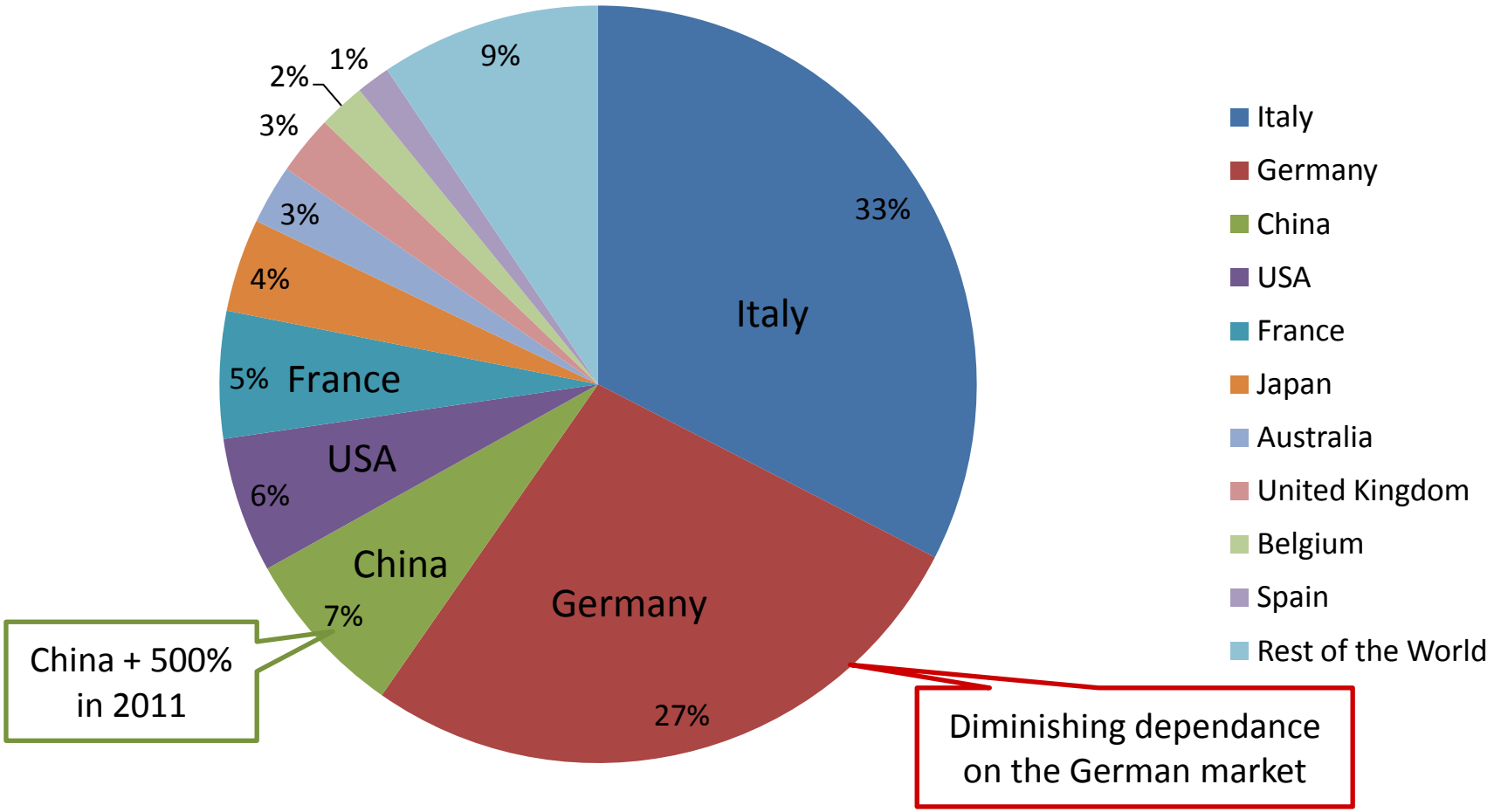
www.unendlich-viel-energie.de

Agentur für Erneuerbare Energien

Cumulative PV installations per capita in 2010

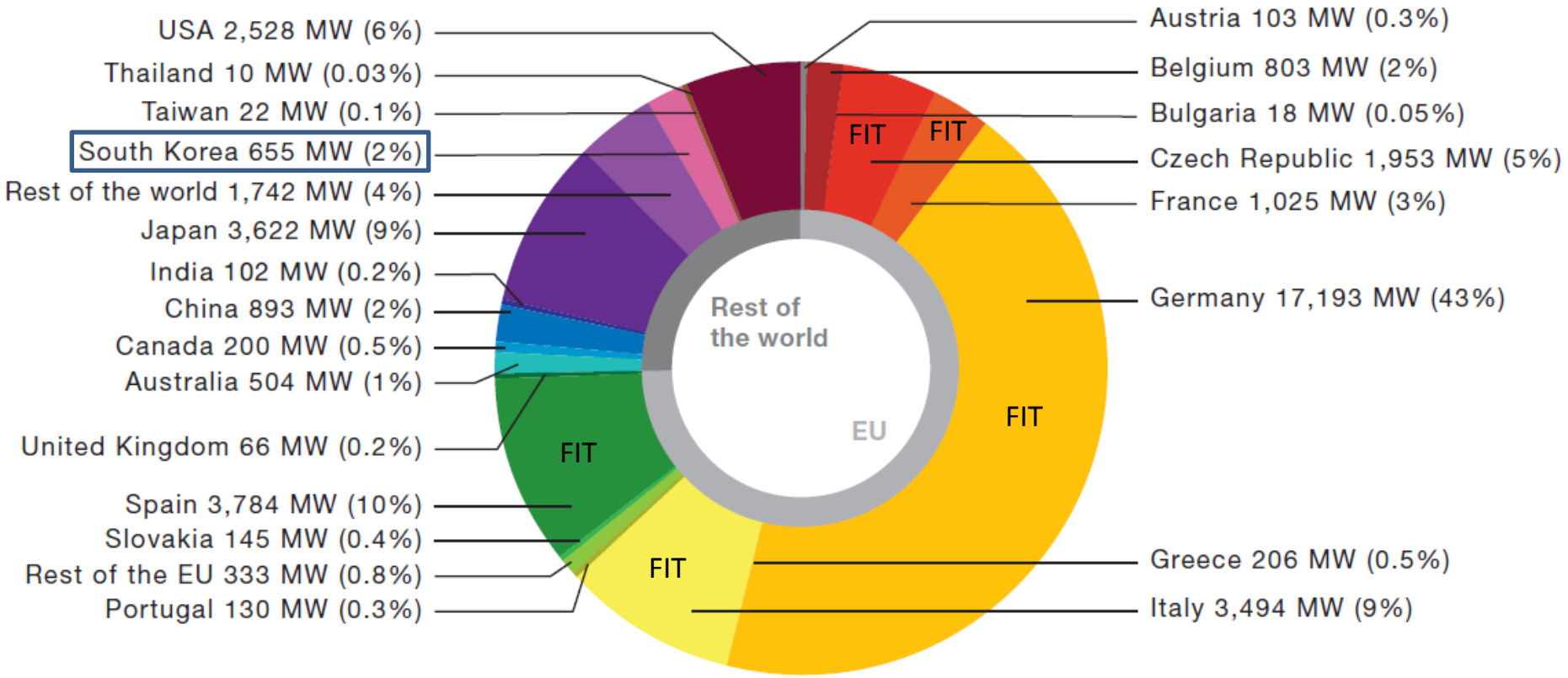


The global PV market in 2011 (27.000 MW)



Feed-in-tariffs have boosted markets globally

Global cumulative installed capacity share 2010



Success factors in Germany

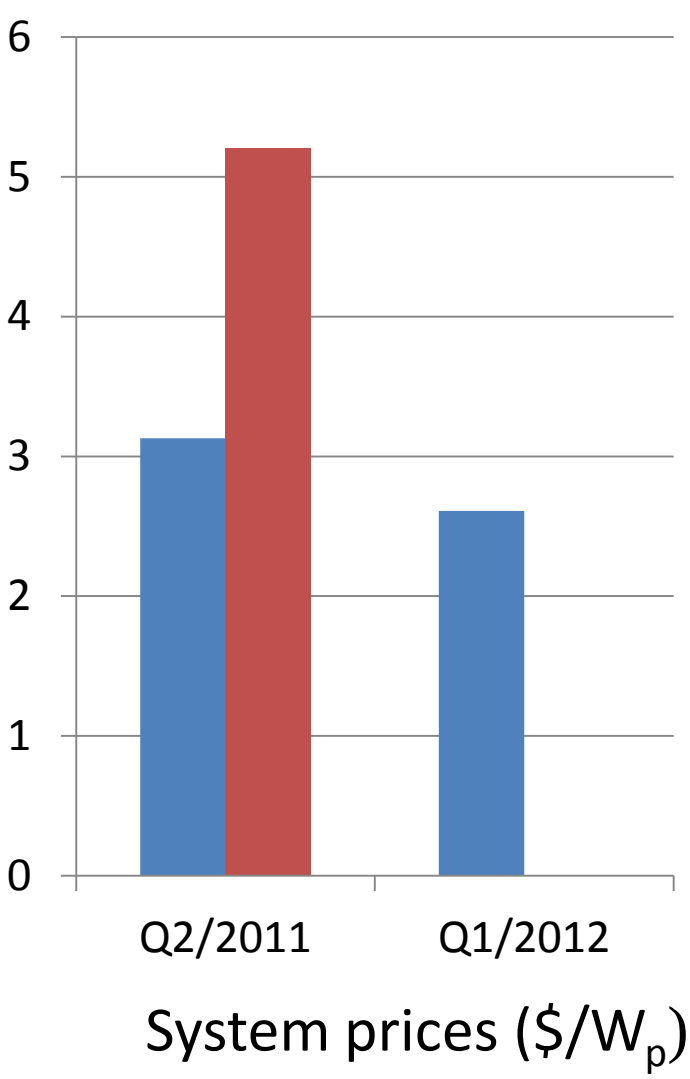
- A reliable investment context with guaranteed feed-in tariffs for 20 years after installation
- Continuous adaptation of the FIT for new systems to market development → steady growth
- A simple scheme: no other incentives, just FiT
- No complicated permitting procedures

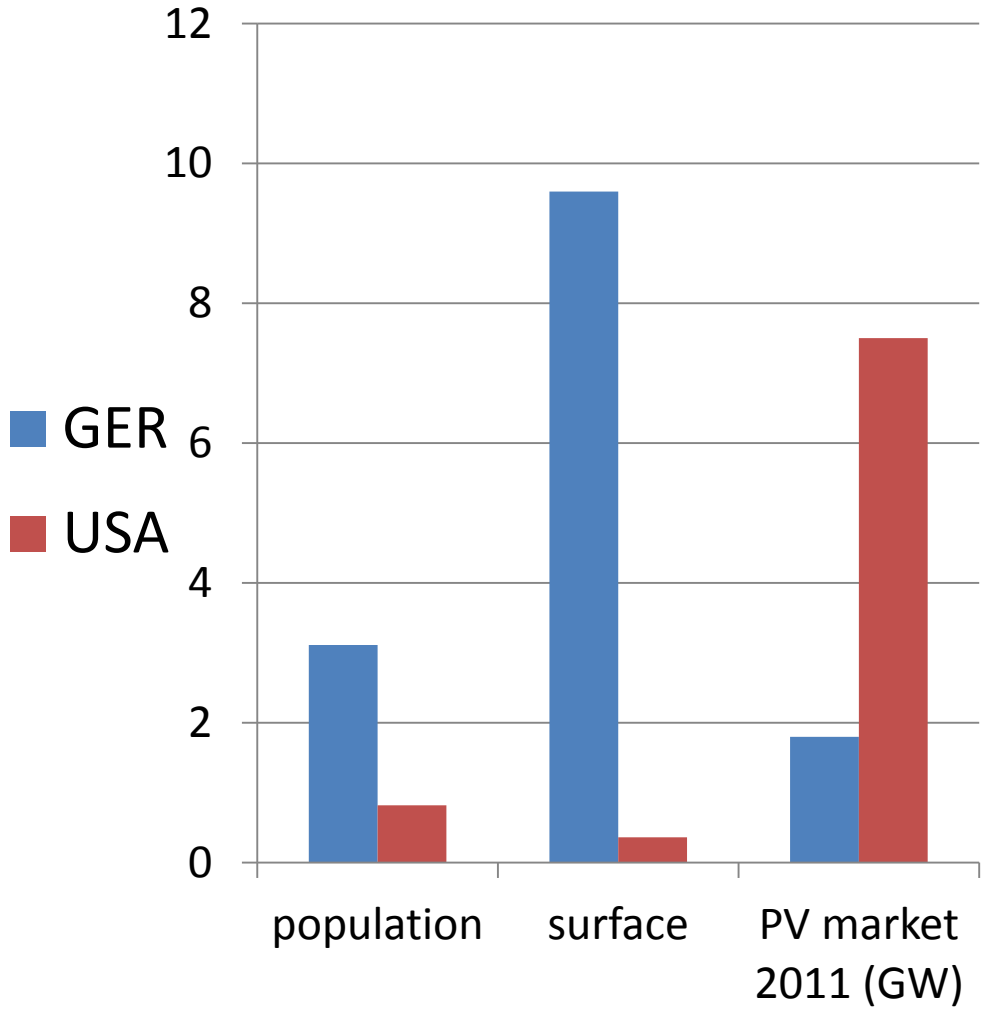
➢ Banks have learned that PV investments are low risk → low capital costs

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

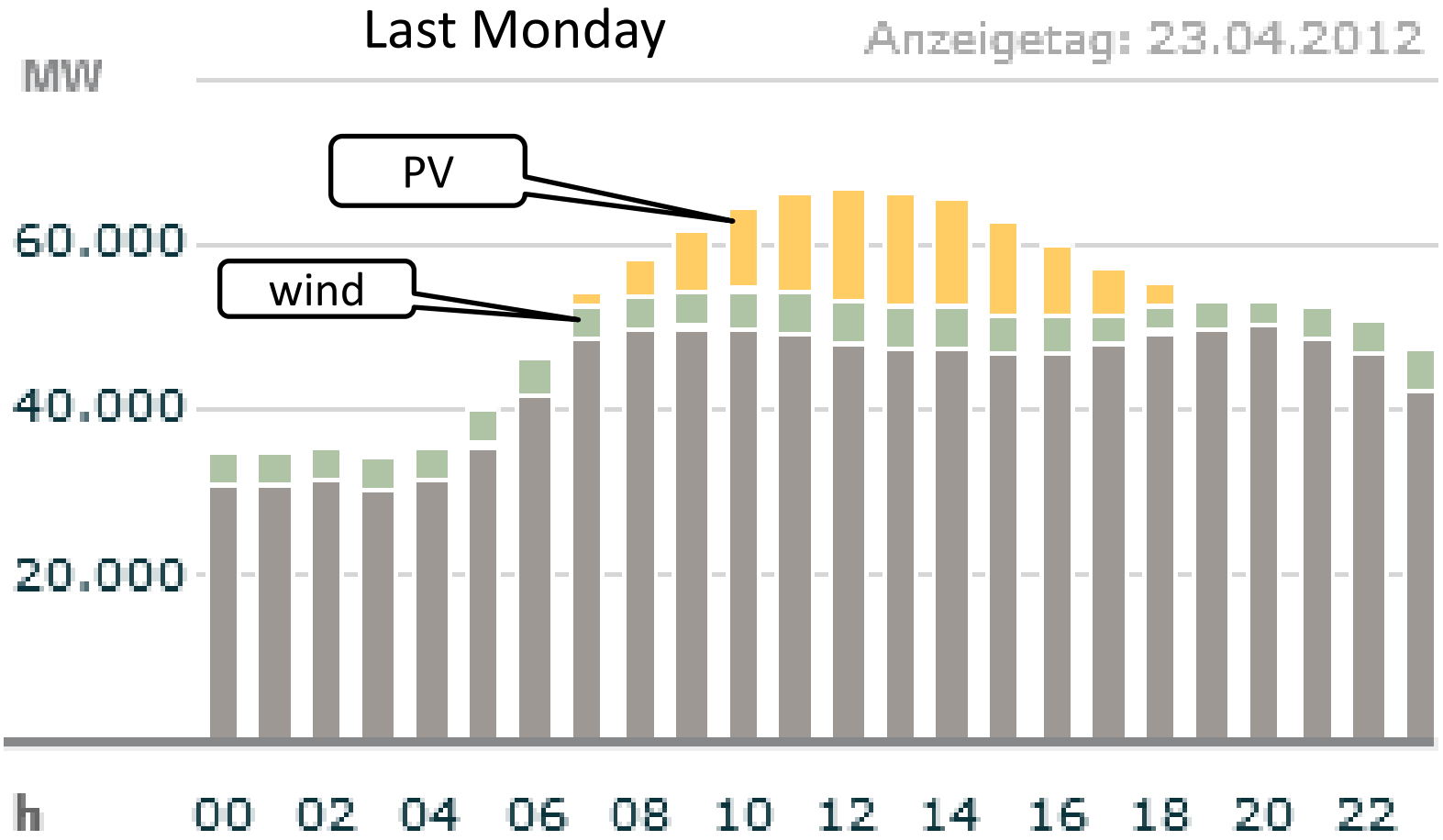
➢ Hundreds of thousands of new private investors

System prices depend on the maturity of the market





Peak shaving with PV cuts conventional peak profits



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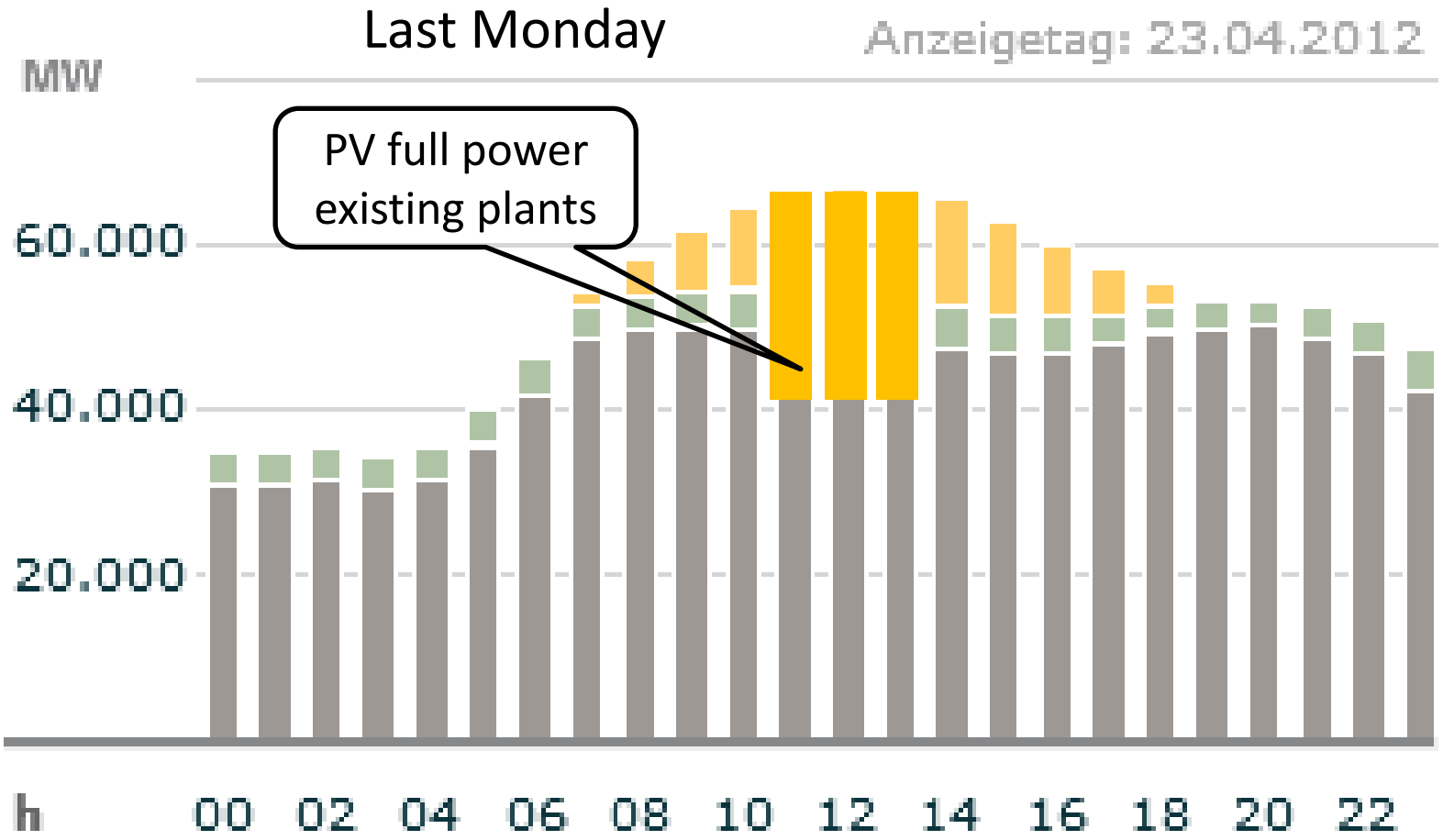
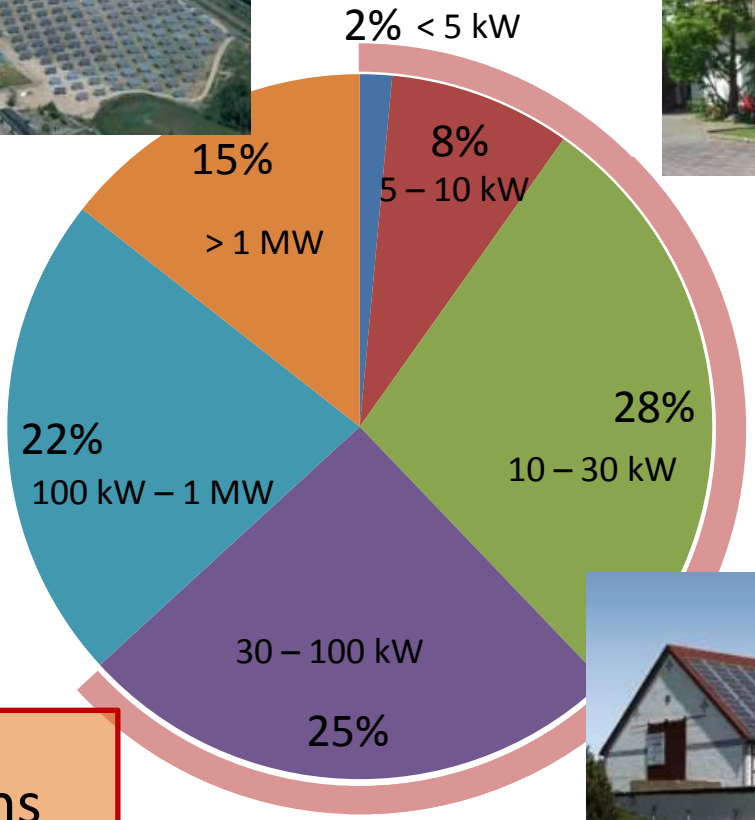


Germany: The lions share of the installed capacity is on roofs



Installations
january – september **2010**

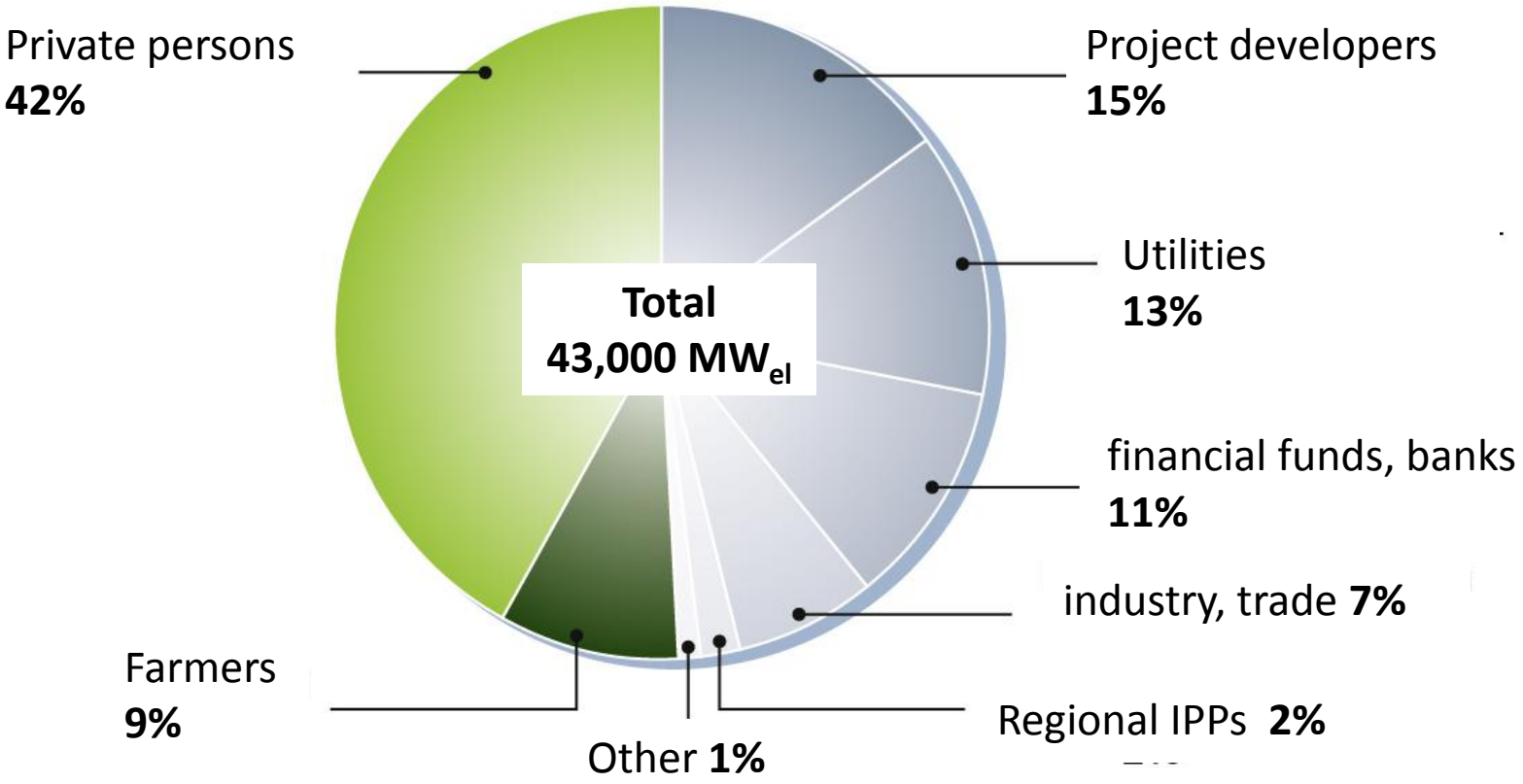
60% of
new installations
< 100 kW

data: BNetzA 2010

ruggero@schleicher-tappeser.eu

Citizens participation: Distribution of ownership

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



Quelle: trend research 2010; Stand: 10/2010

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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

300,000 PV related jobs in Germany in 2010

smaller installations – more local content

- ↓ Research institutes — international
- ↓ Manufacturers (32,000 plants) — international
- ↓ Banks and financing companies — can be local
- ↓ Manufacturers (18,000 jobs)
  - silicon — international
  - wafers, cells — international
  - modules — can be local
- ↓ Traders — can be local
- ↓ System integrators, EPC contractors — can be local
- ↓ craftsmen in the (36,000 business) — local
- ■ operating company — can be local

Pre-products 43,000

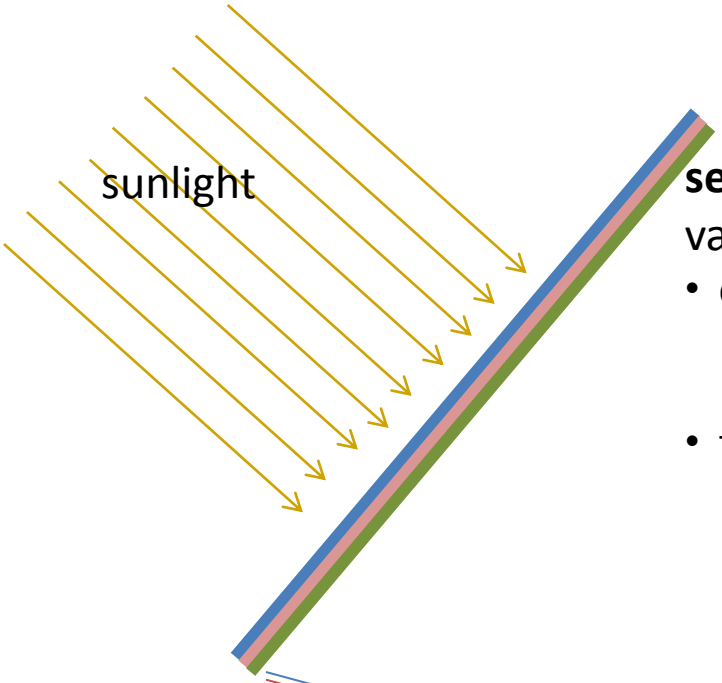
smaller installations – more opportunities for local added value

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 …)

HOWEVER, the incumbent large utilities fear to lose their dominant role. After years of indulgence they have discovered the potential of PV and started heavy attacks since 2010.

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



several layers of semiconductors

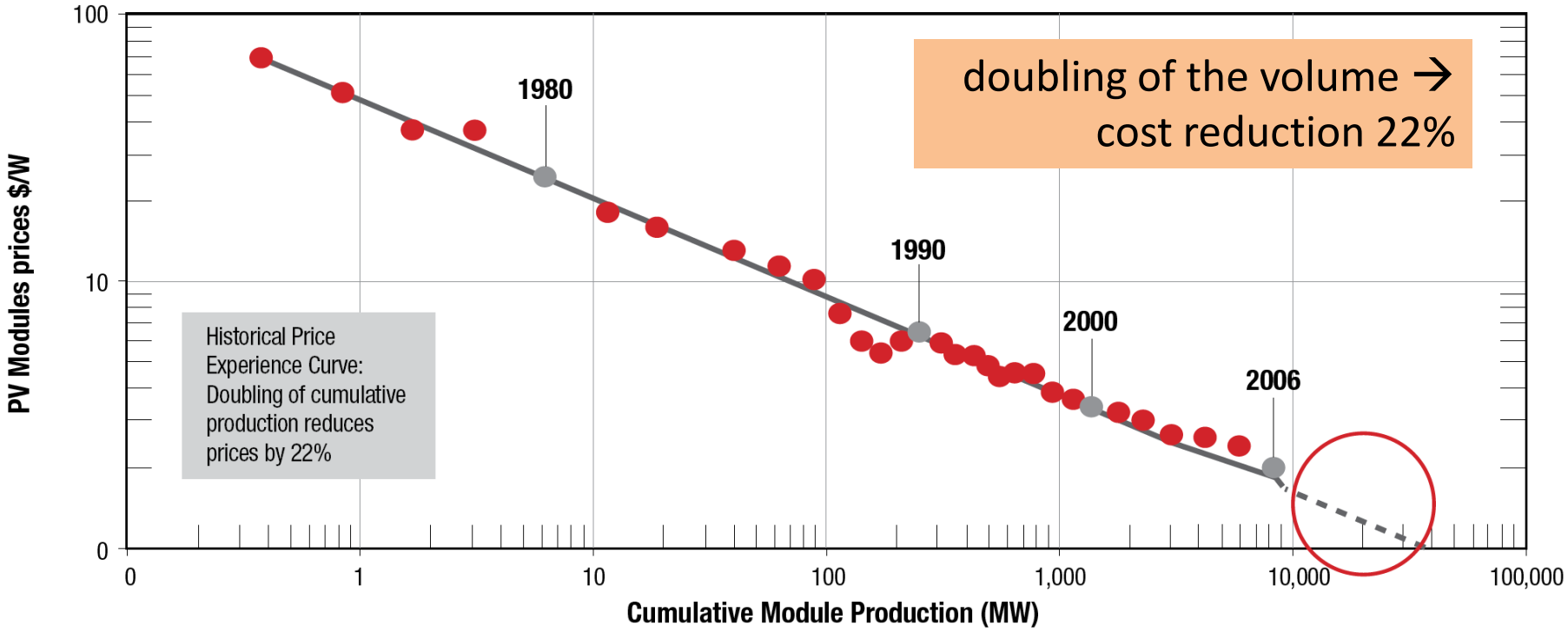
variety of different technologies:

- 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

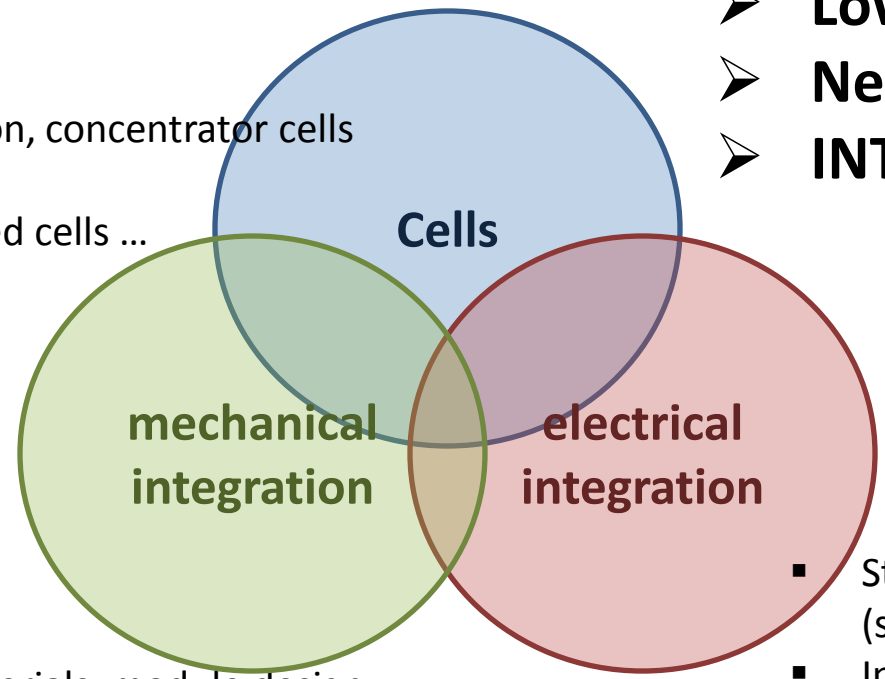


Sources: EU Joint Research Centre - EIA - National Renewable Energy Laboratory - A.T. Kearney analysis.

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

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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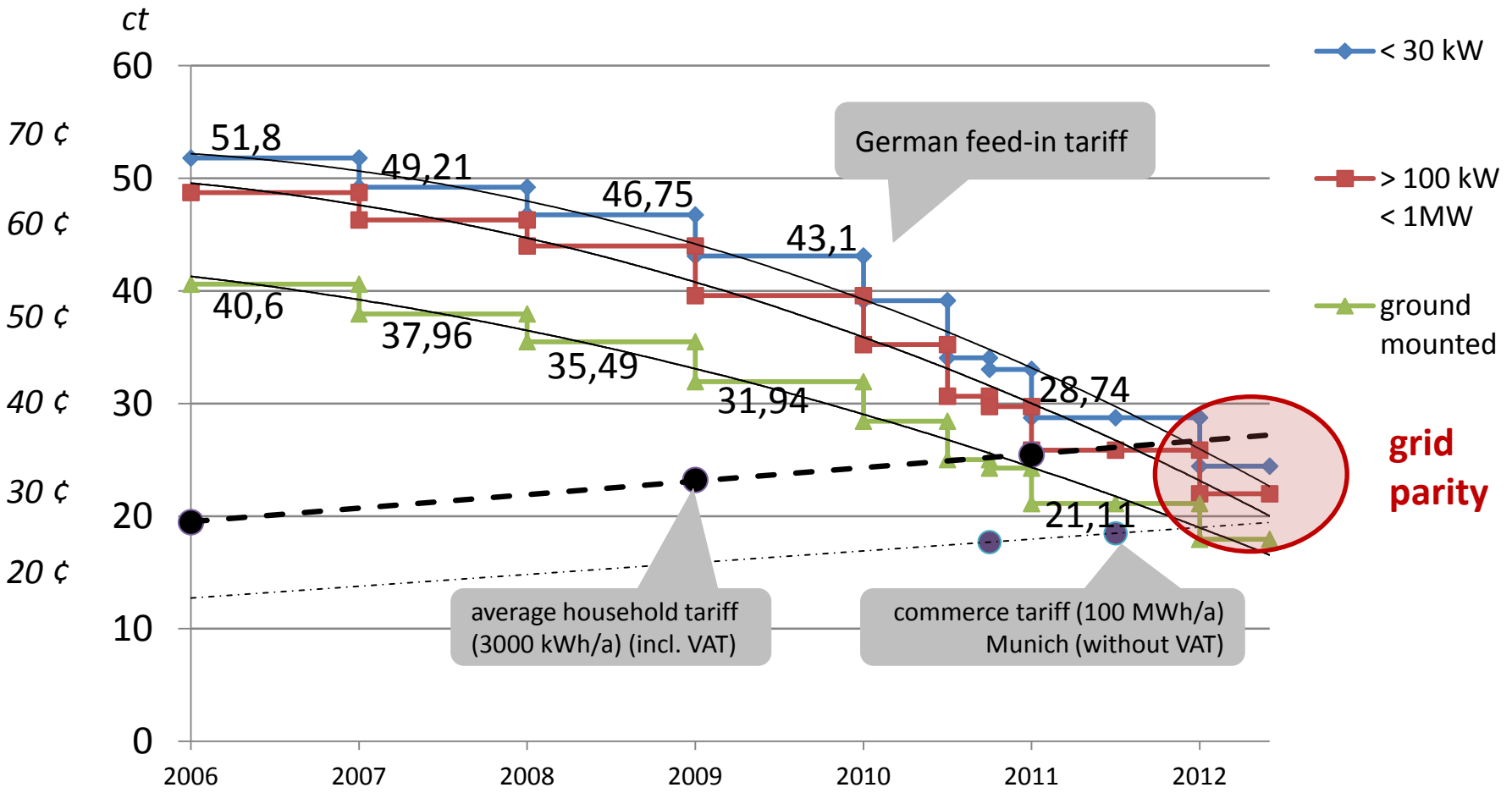
transport

electric car with PV

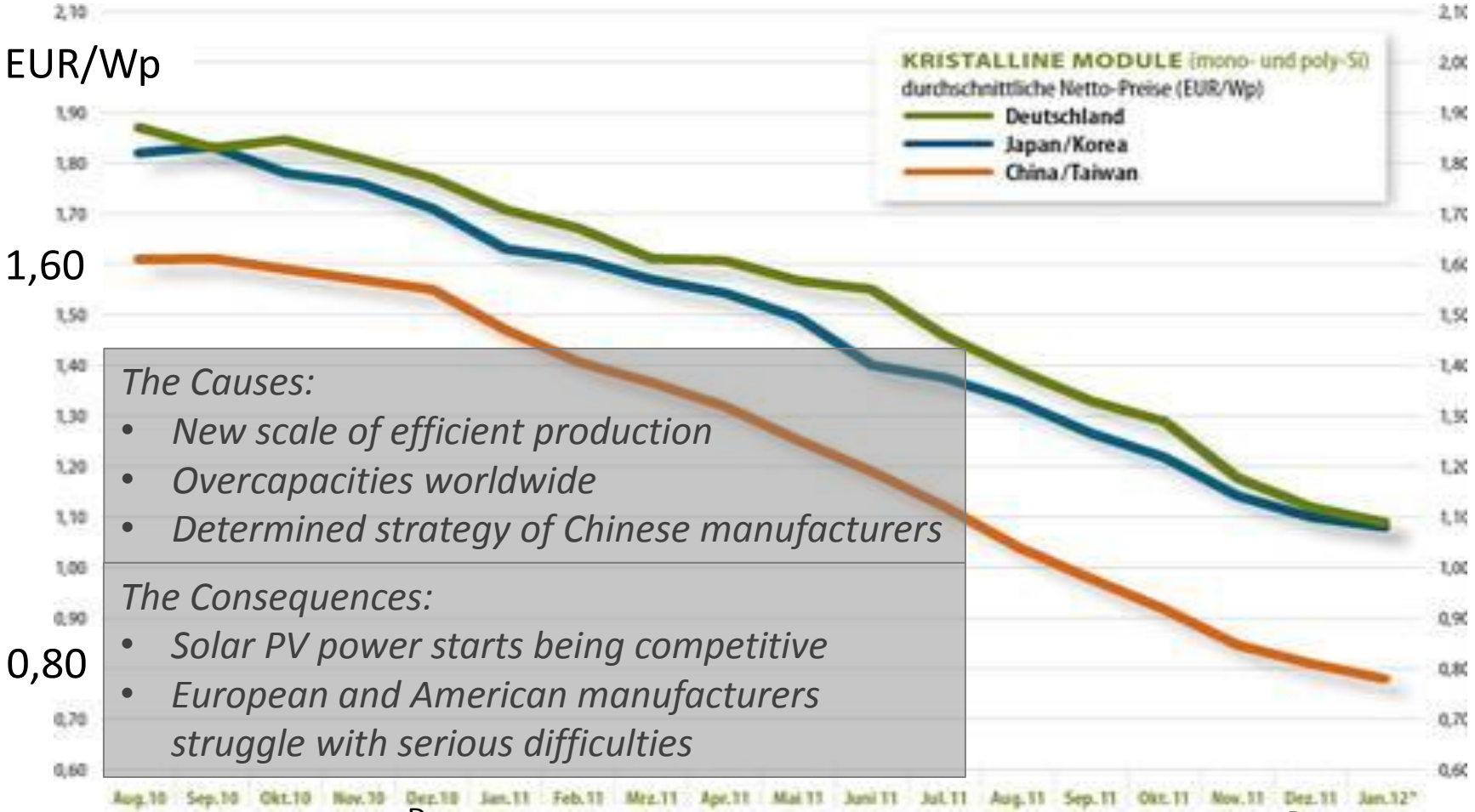
conventional car with biofuel

factor 250

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



Heavy PV module price drop in 2011: - 45% in 12 months



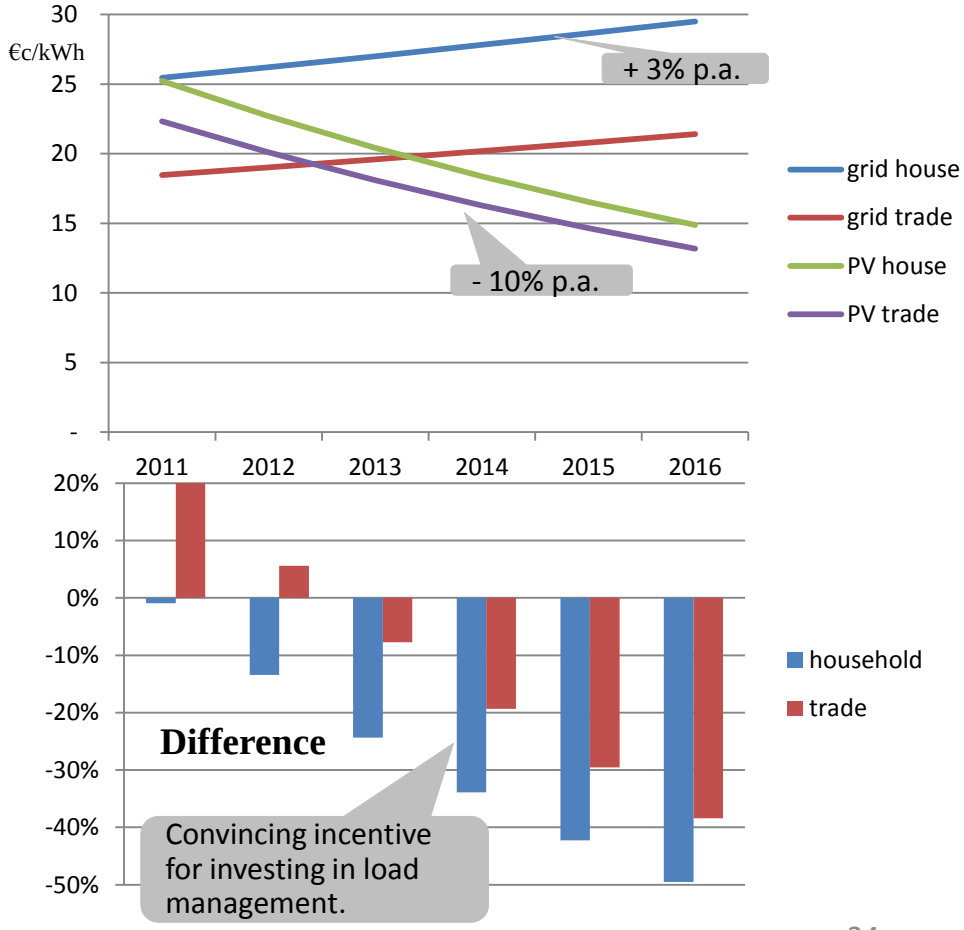
Attractiveness for own power production: Germany - Scenario for the next five years

- 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



The coming boom: captive power generation

Attractive investments even without incentives

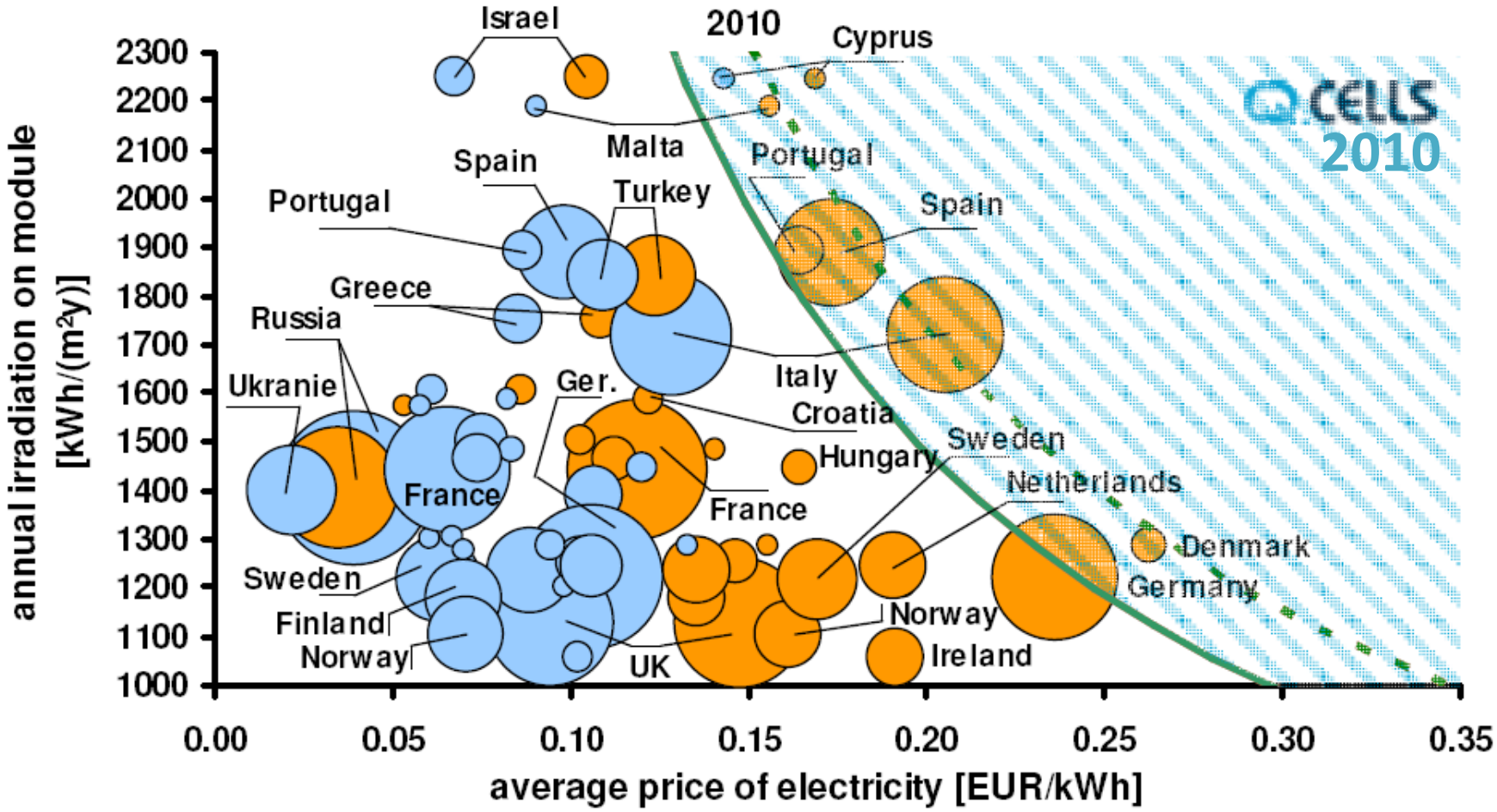
Timeline in Germany:

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

➢ PV growth independent from incentives

➢ Boom in power management technologies

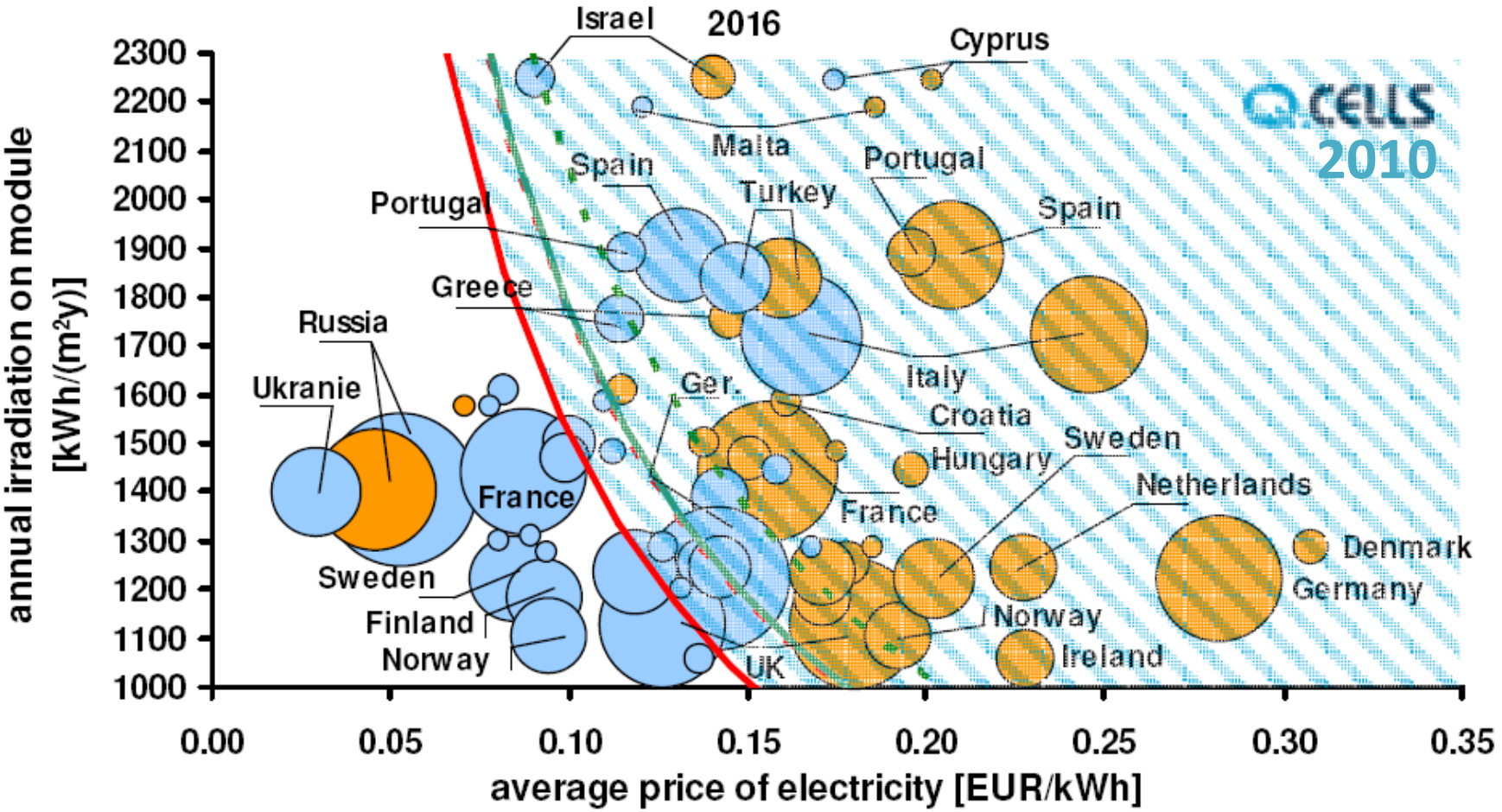
Grid parity in Europe 2010



commercial residential

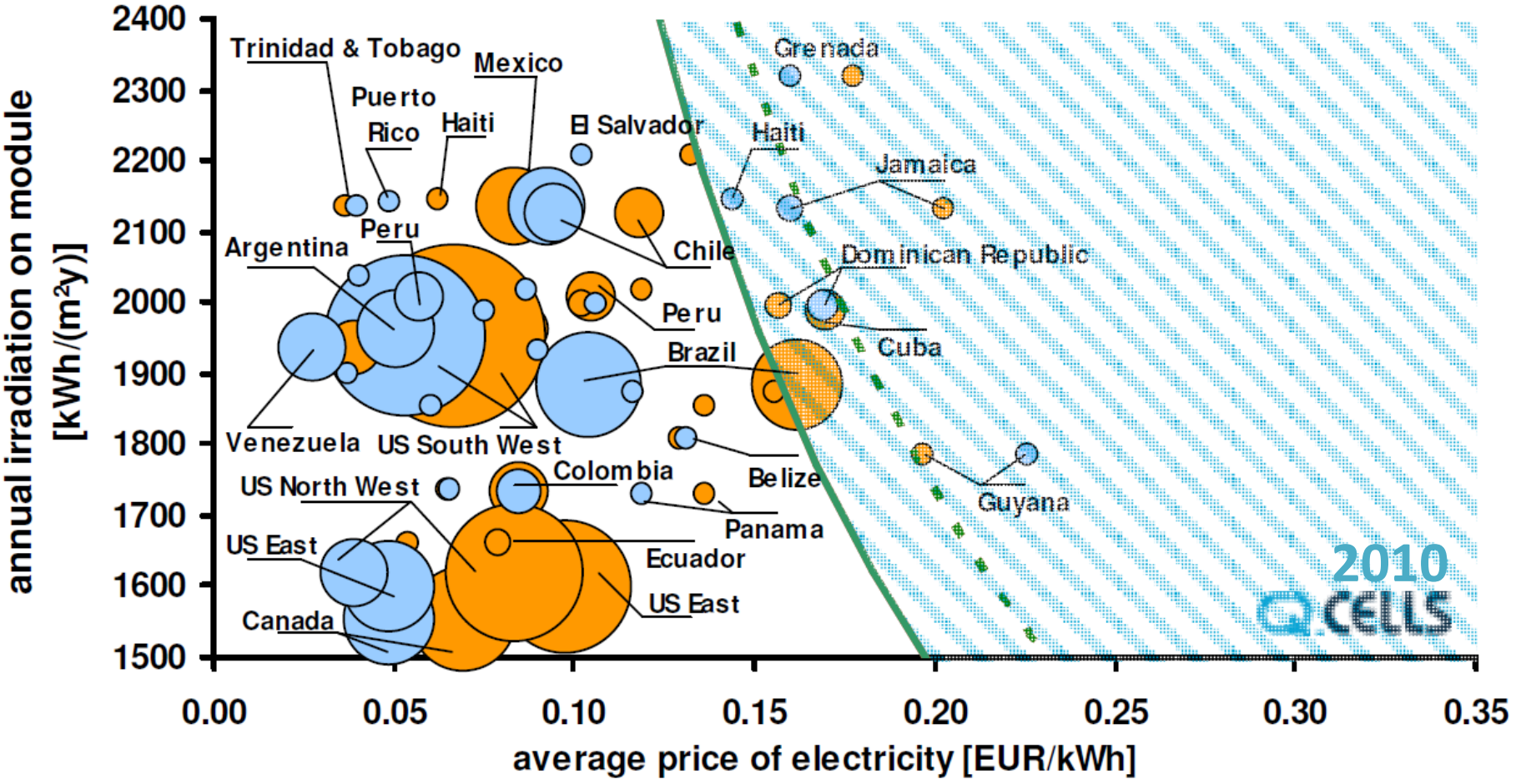
Grid parity in Europe 2016

(forecast in 2010, might be reached already in 2013)



commercial residential

Grid parity in the Americas 2010



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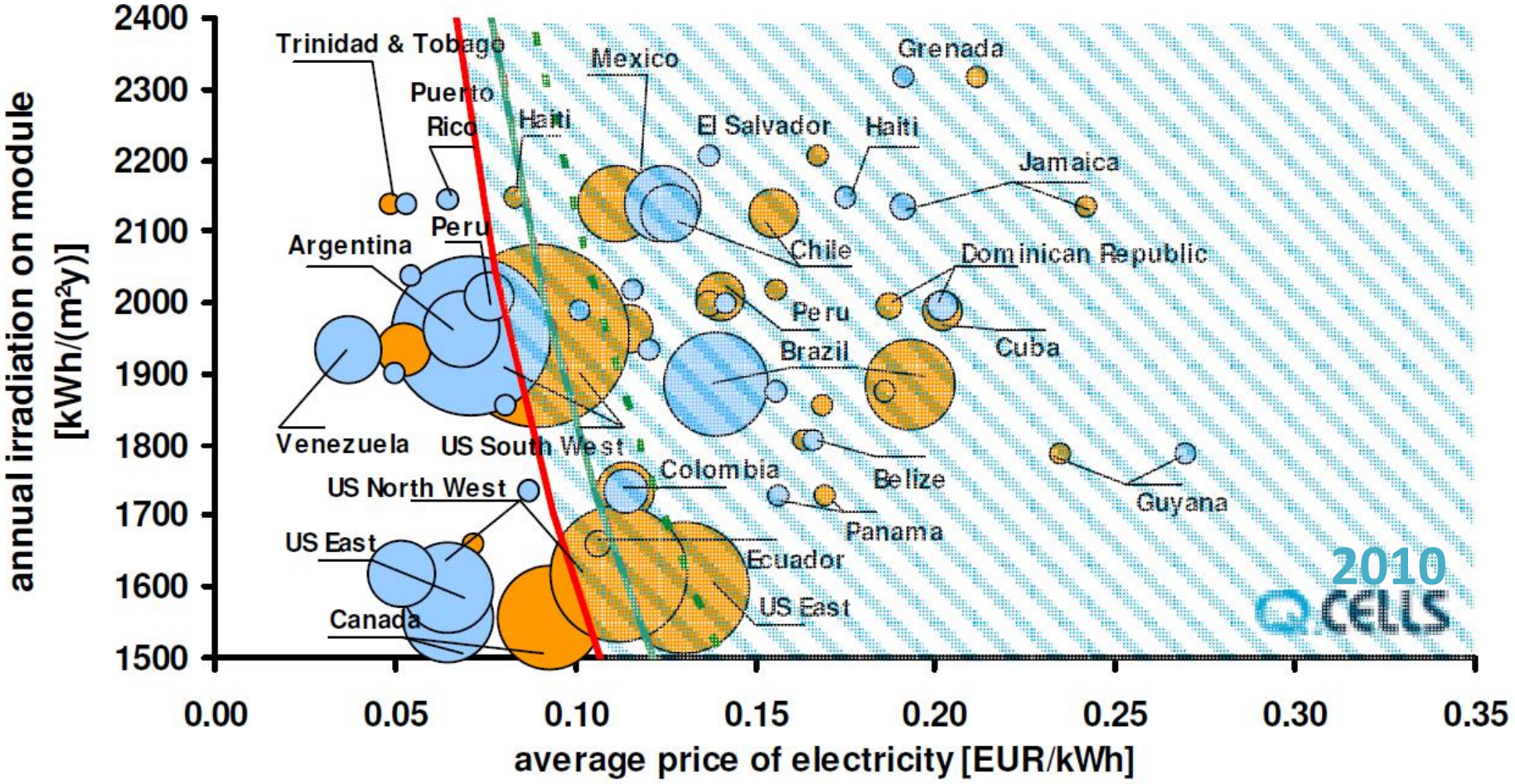
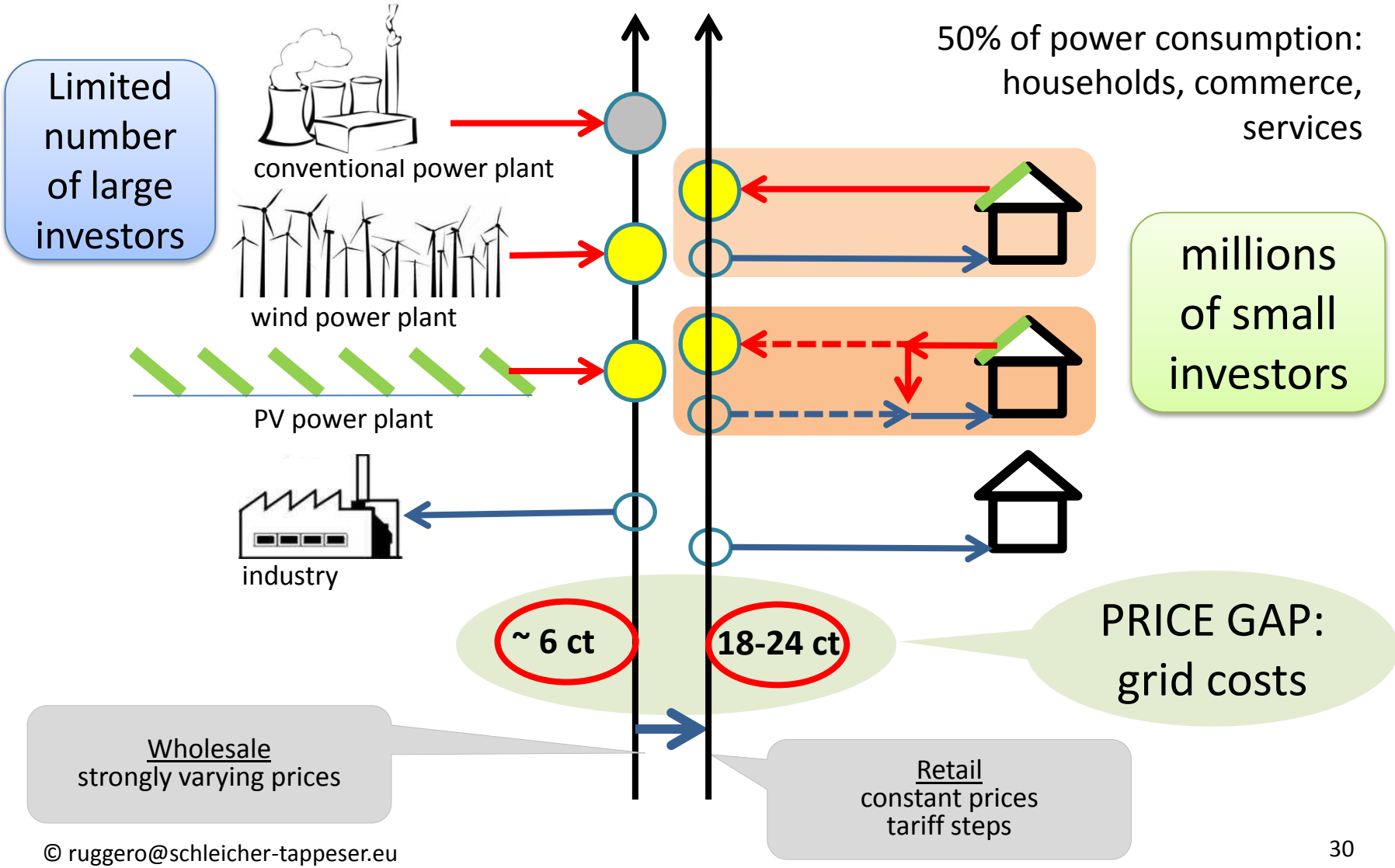
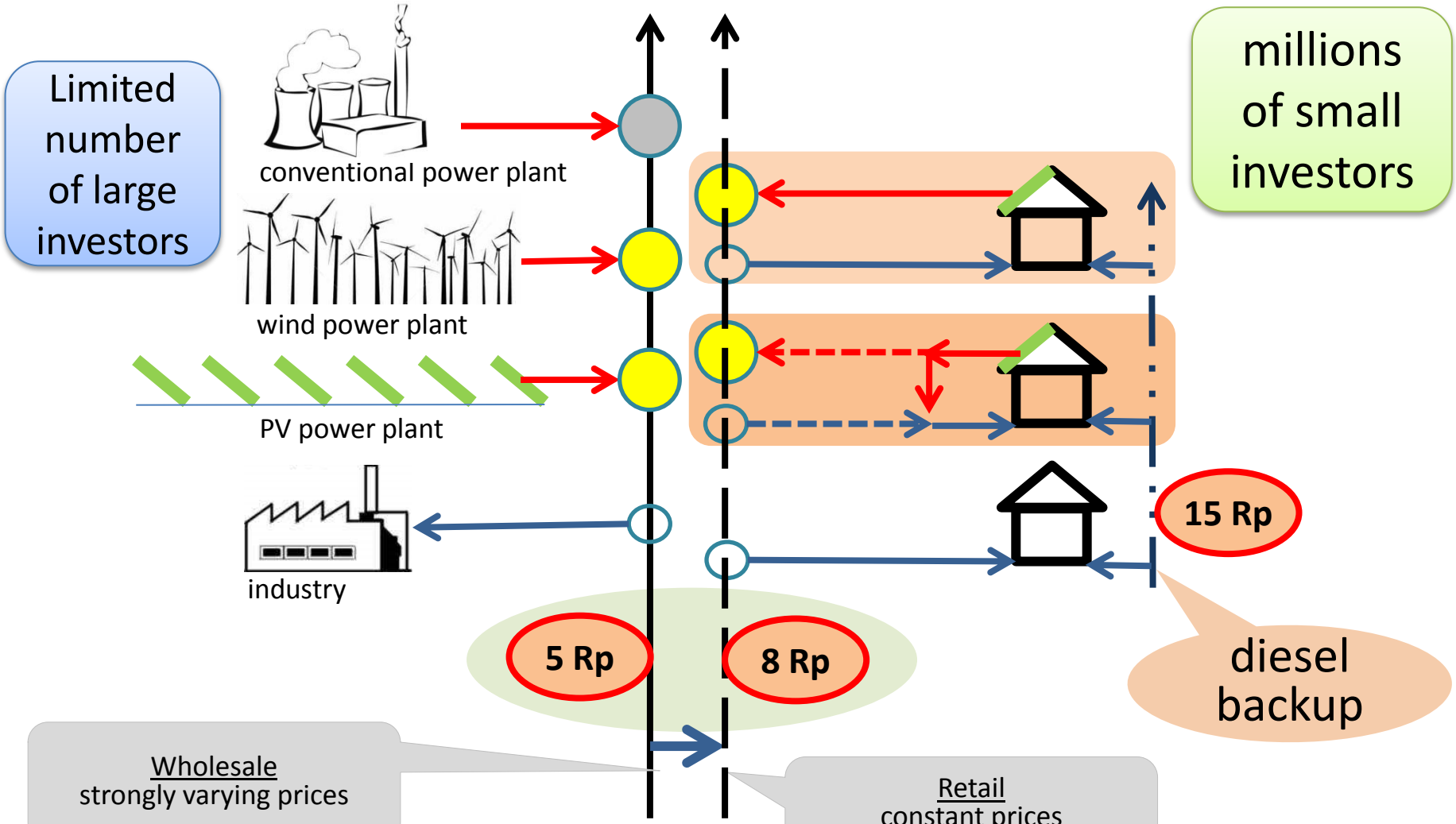


Photovoltaics is a modular technology: competing on the retail side



India: Photovoltaics in weak grids competing against diesel backup



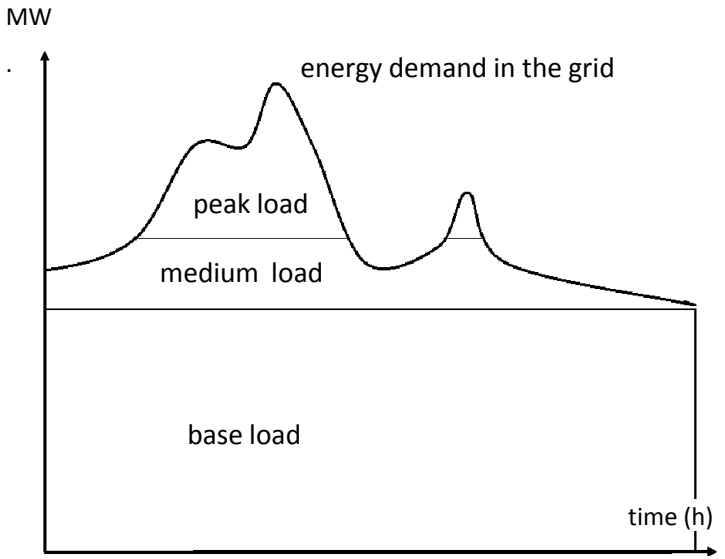
The main problem with high shares of wind and solar power: fluctuation

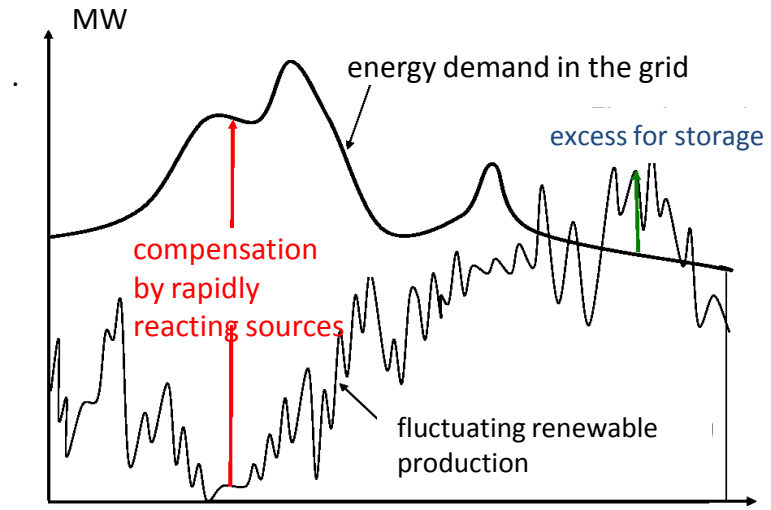
The old base load concept:

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

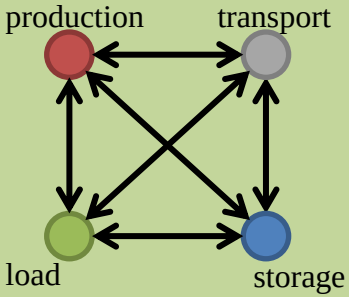
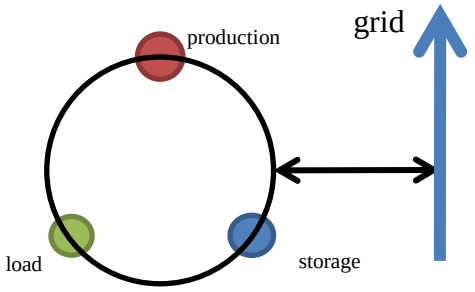
The new paradigm:

- 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





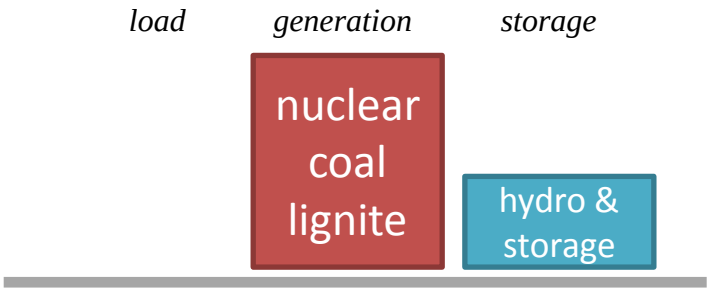
Captive PV Power can support the change of the control logic of the electricity system

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	

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

load *generation* *storage*

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



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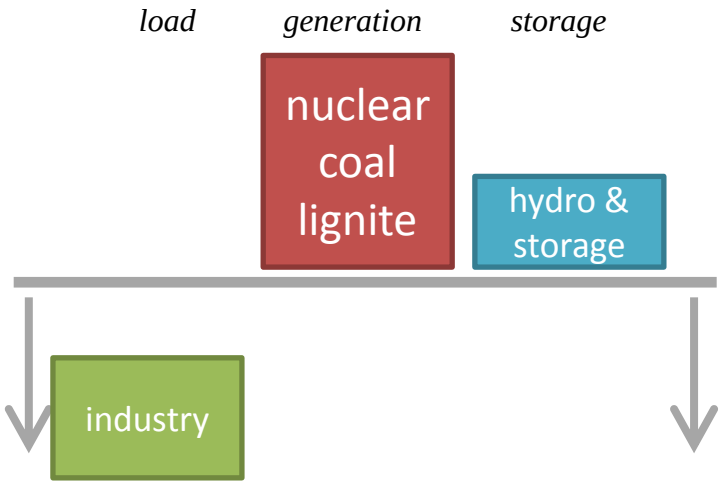

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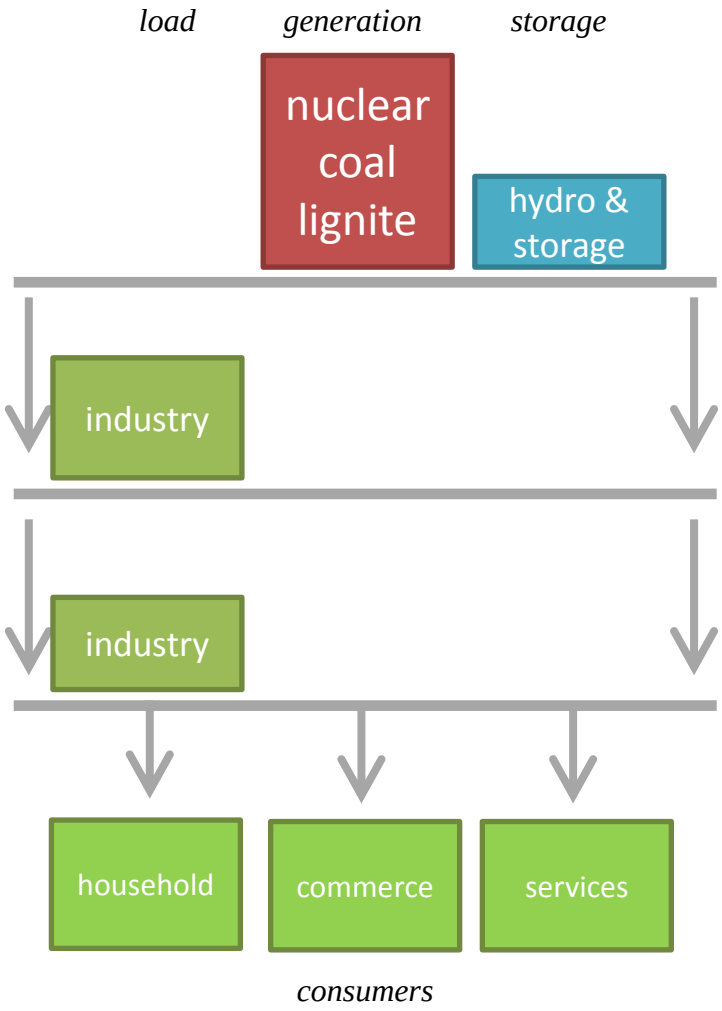

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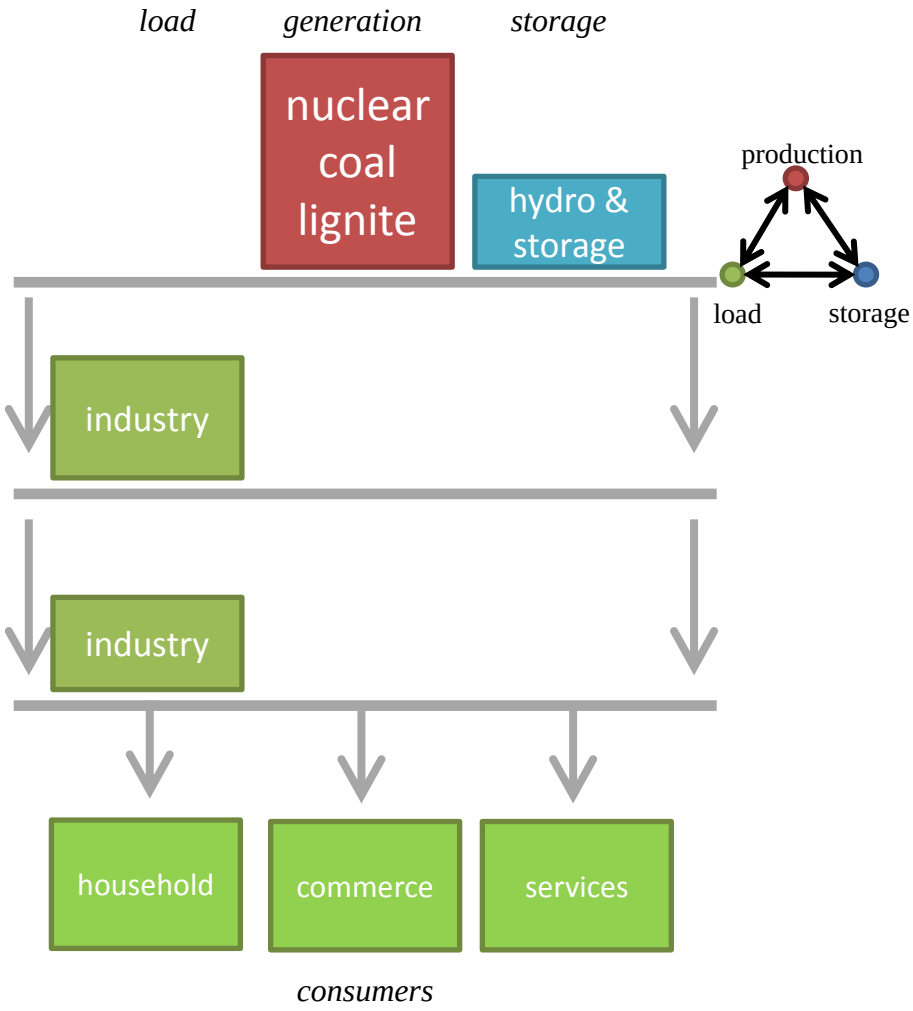

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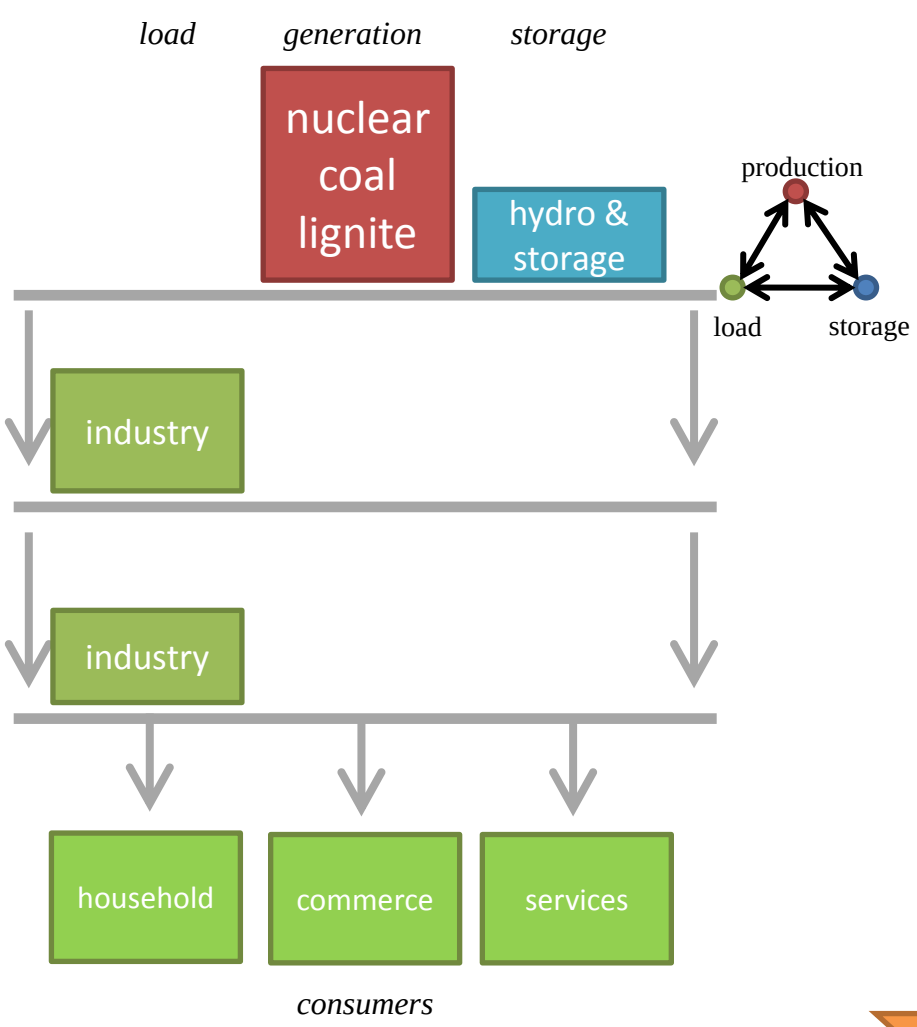
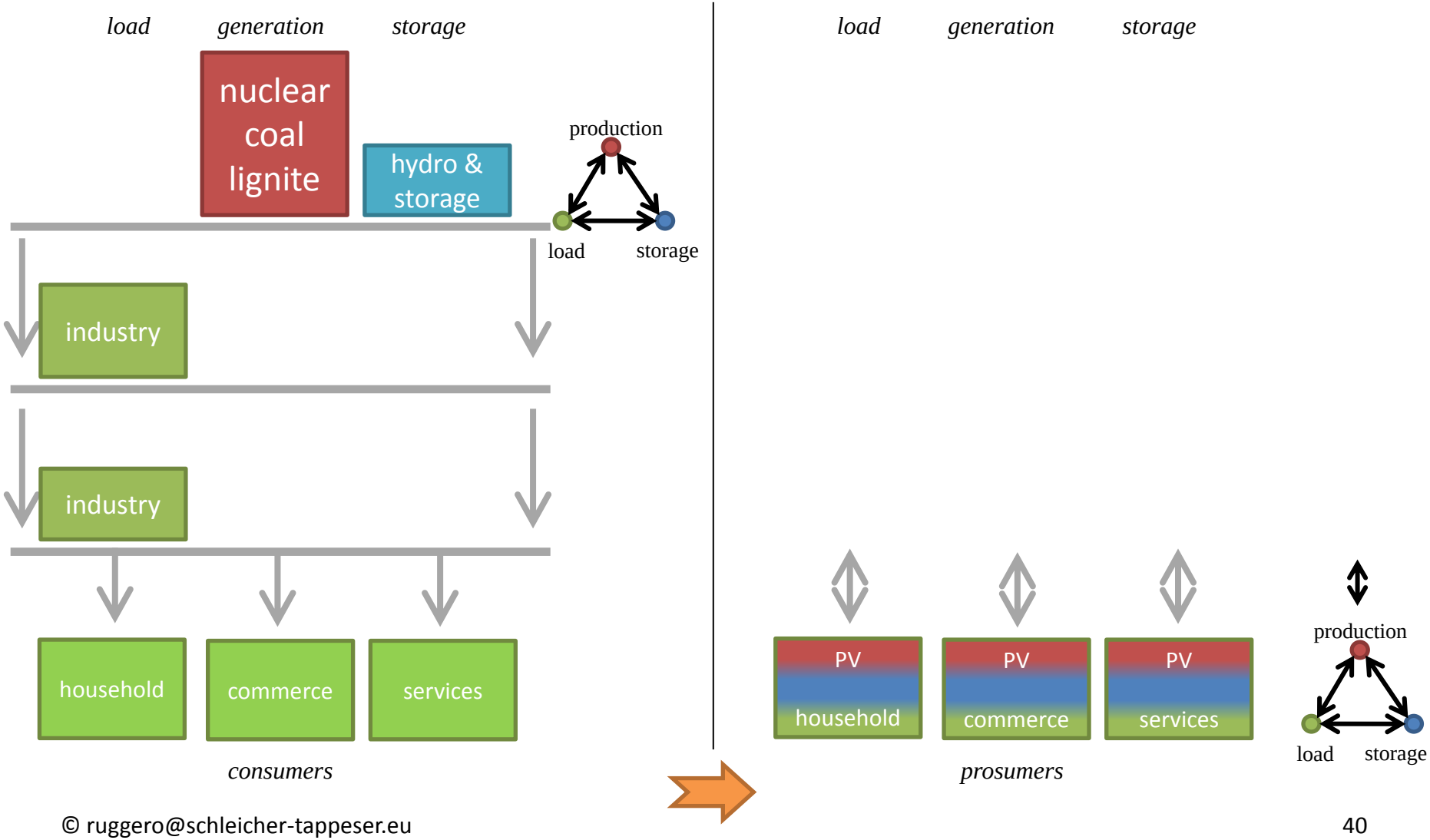


load generation storage

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



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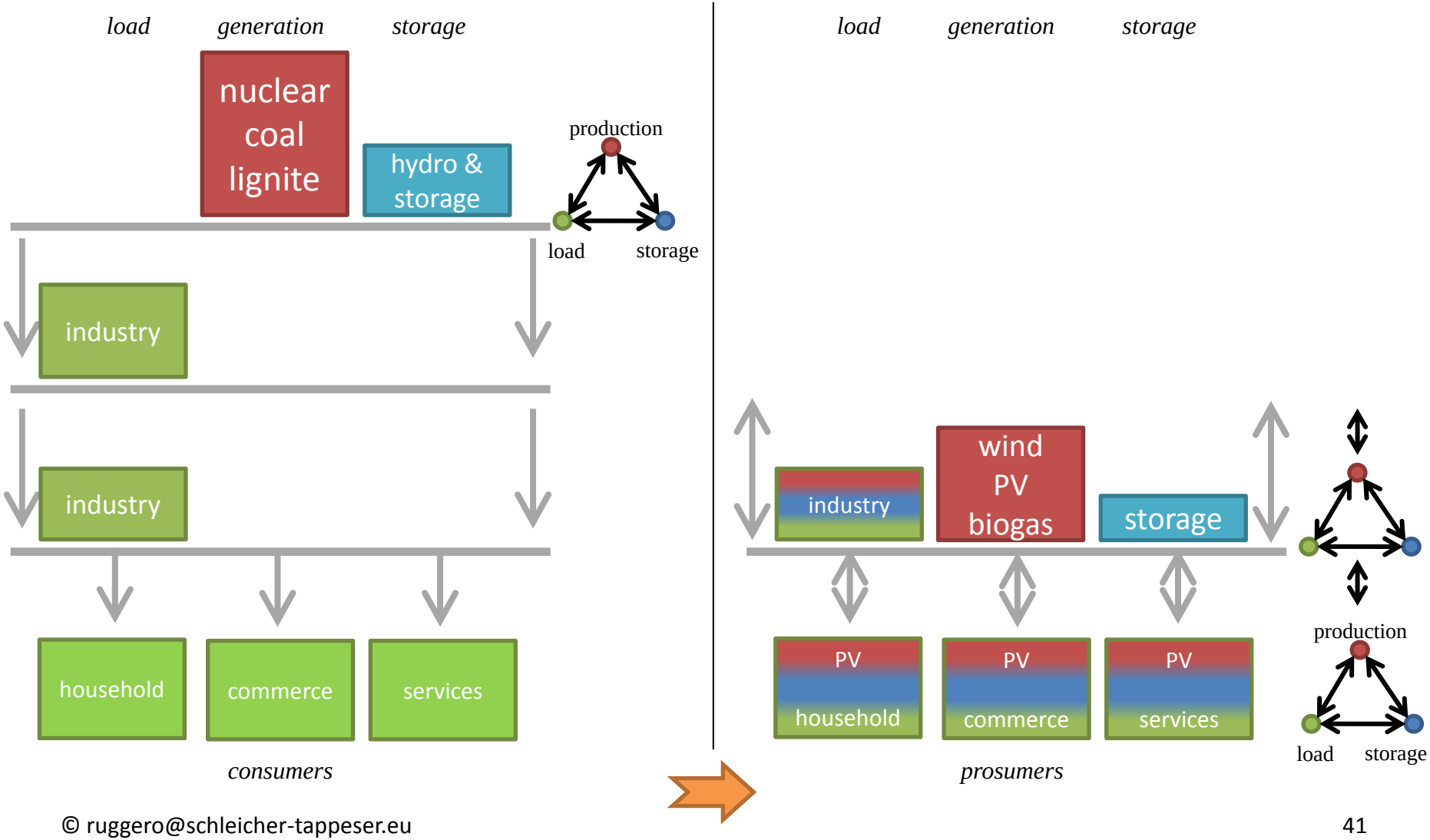

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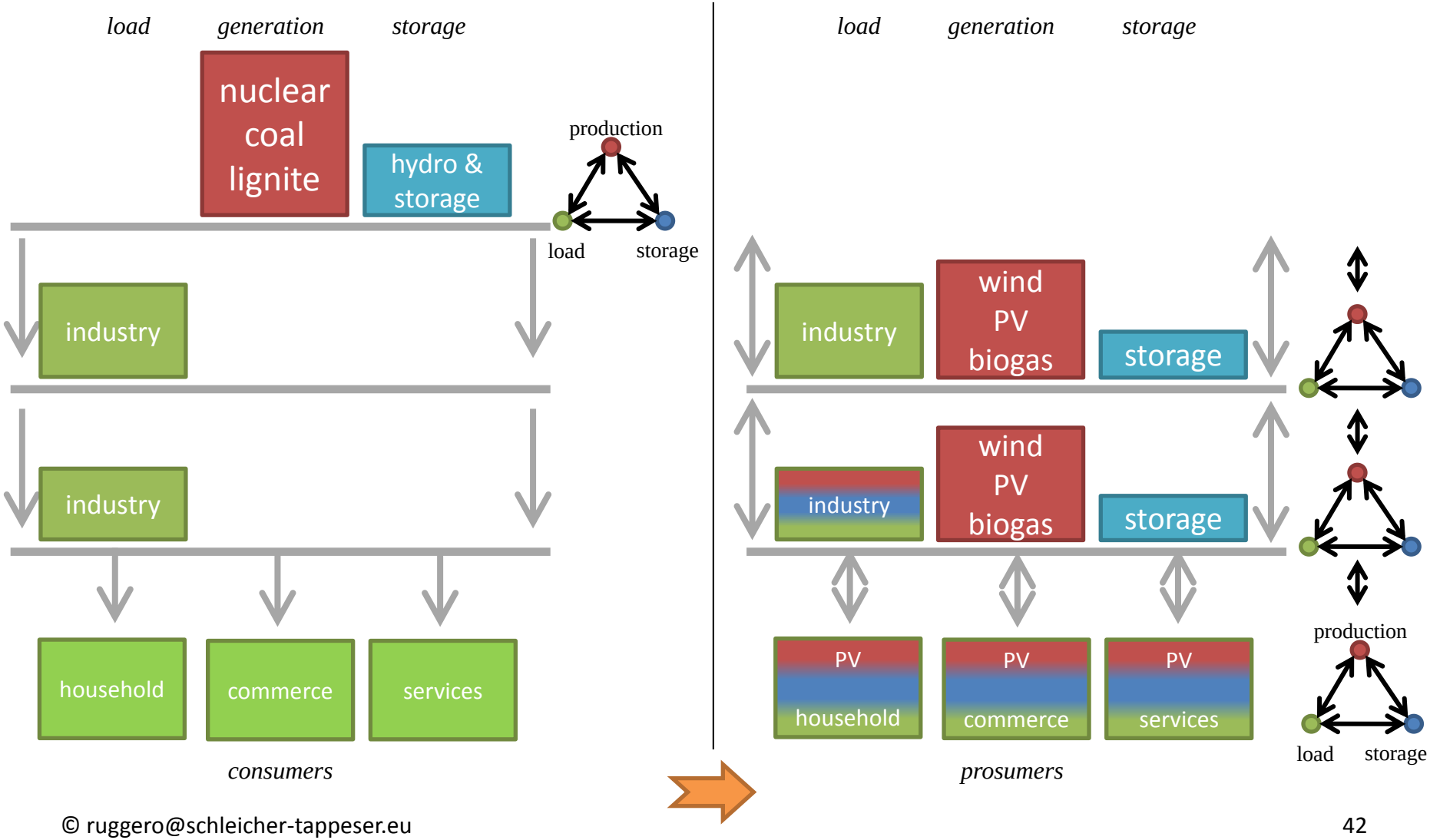

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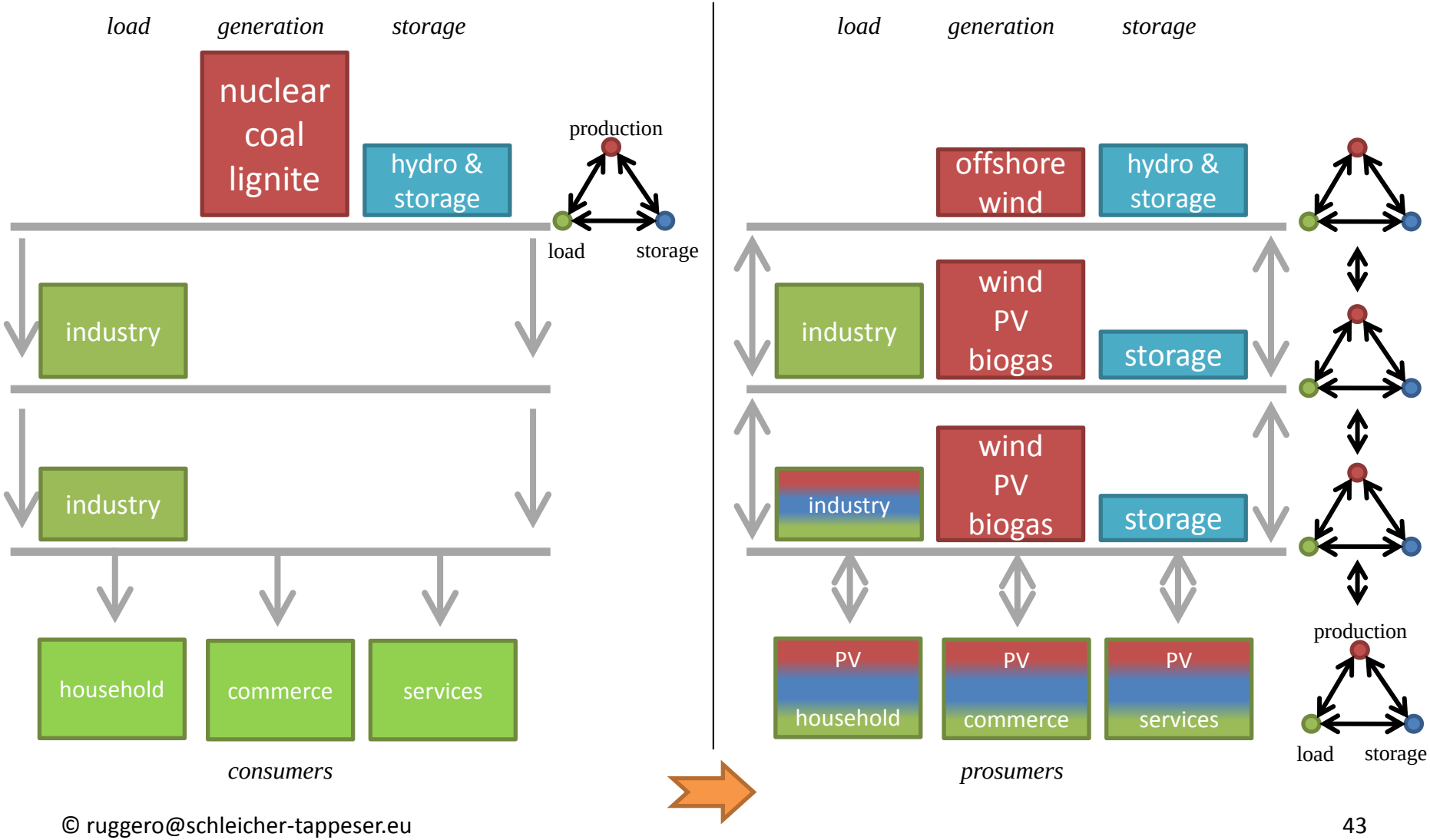

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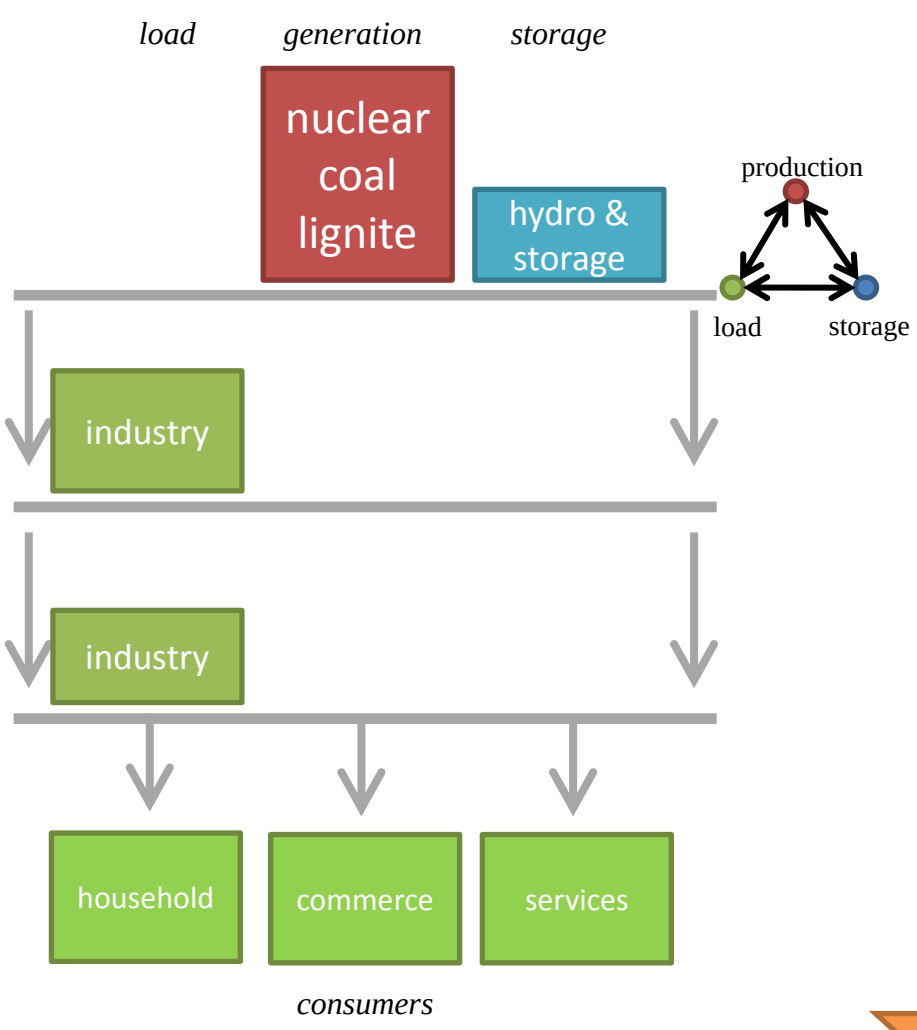

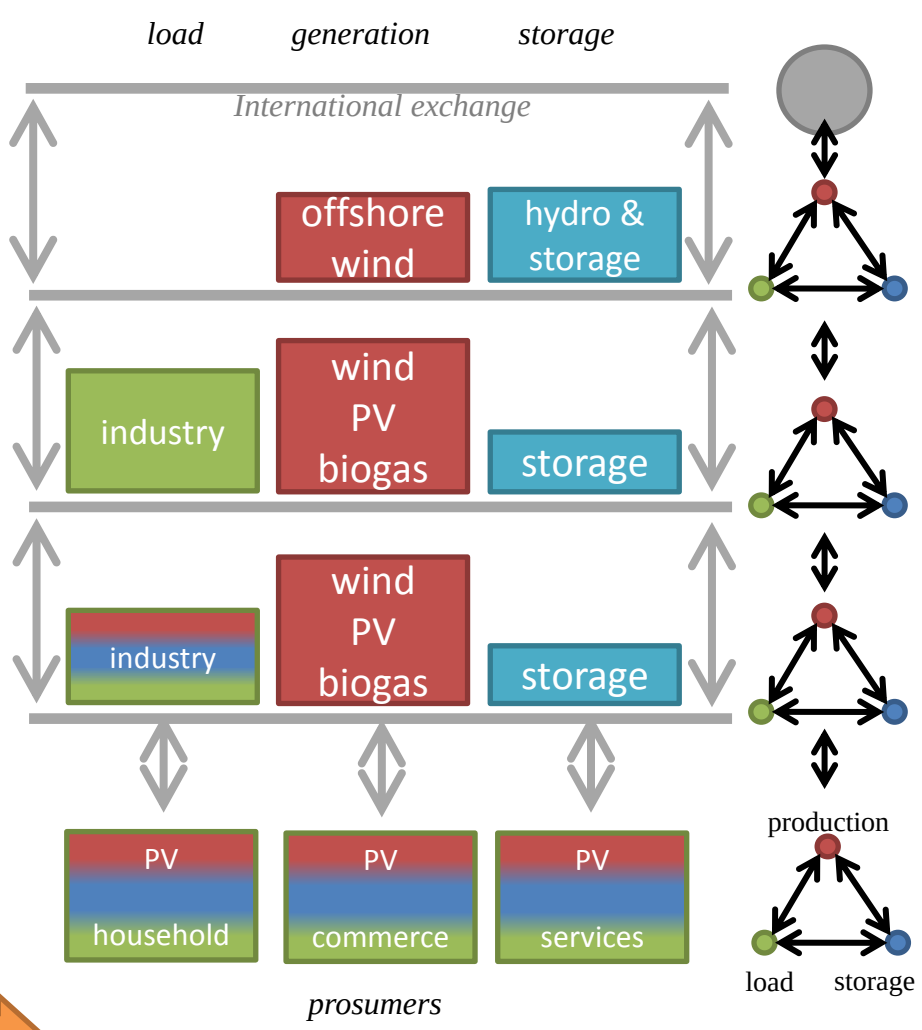

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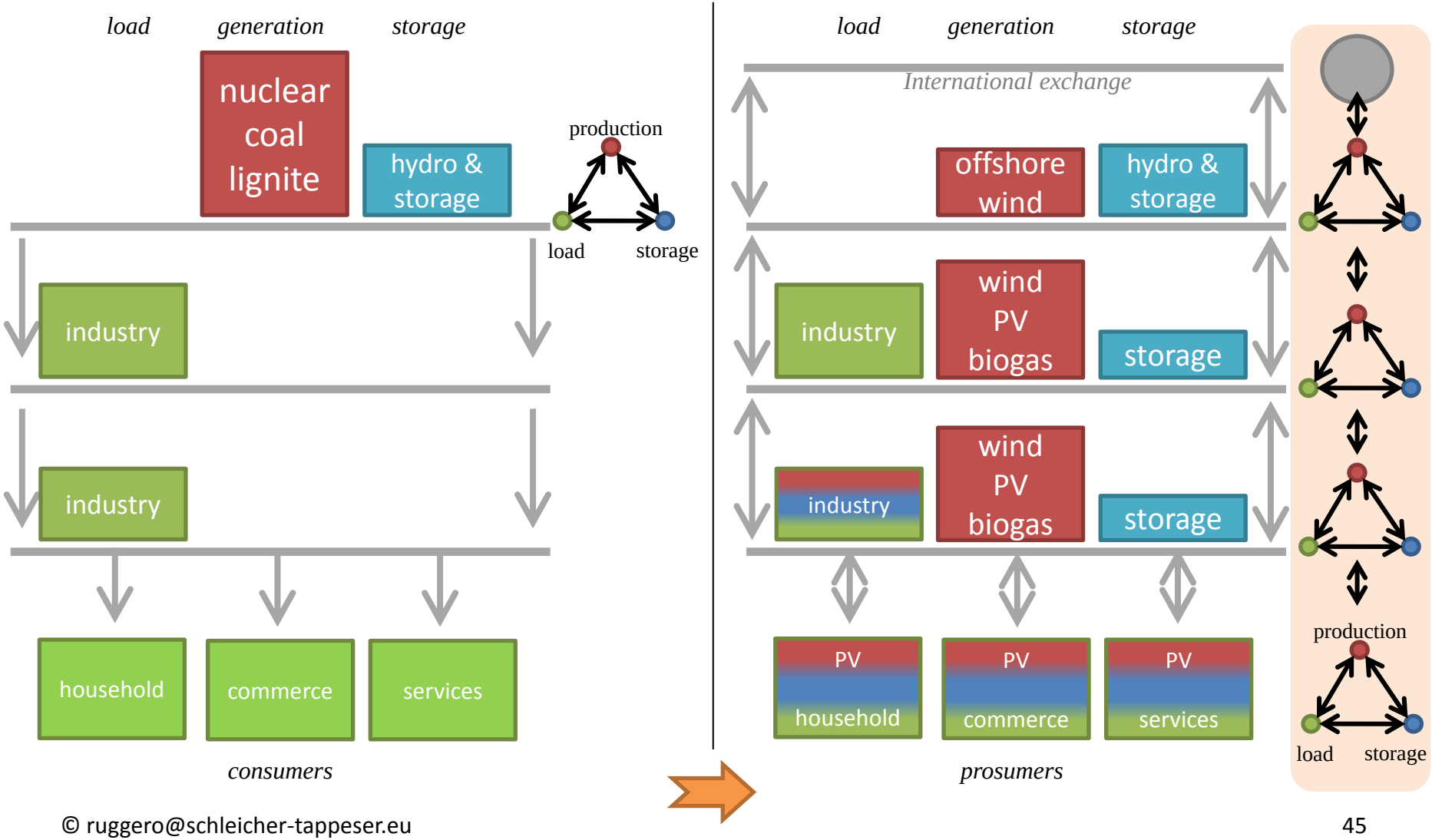


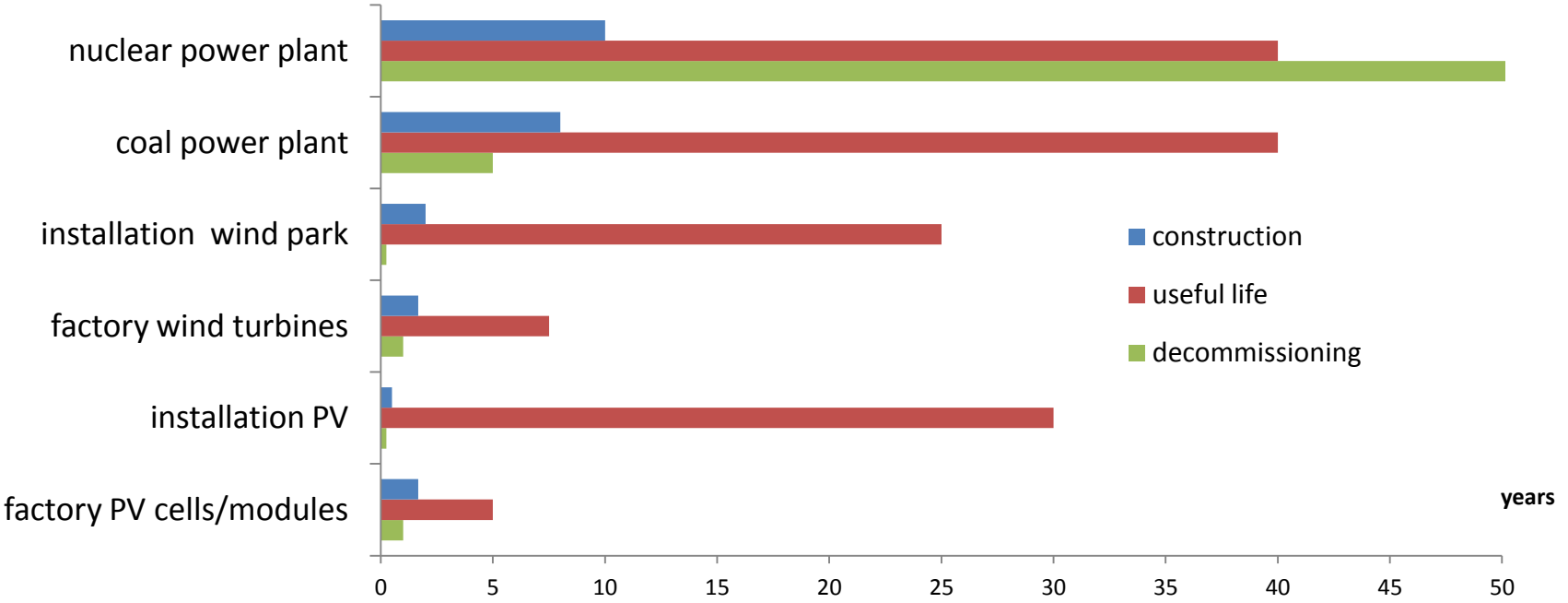
Unfamiliar to energy business: 4 to 10 times shorter innovation cycles

→ More rapid build-up of capacities (e.g. Dec. 2011 in Germany: 3,5 GW PV)

→ More rapid decrease of costs

→ More rapid transformation of the electricity sector

Dramatic acceleration compared to traditional energy technologies



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

What can be learned from the European experience?

1. PV is a disruptive technology – distributed power generation will fundamentally change electricity markets
2. FiT is an excellent tool for early market development, developing an efficient broad PV market takes many years
3. System aspects have been neglected for too long from all sides, a new market architecture is urgently needed
4. The attempt of incumbent powers to delay system transformation results in economic disadvantages
5. Manufacturing of standard PV components is only a small part of a much larger emerging industry
6. For surviving, EU and US PV industry must develop system solutions

THANK YOU FOR YOUR INTEREST

You will find this presentation and more on my website

www.sustainablestrategies.eu

Look for my forthcoming article in the journal Energy Policy:
„How renewables will change electricity markets in the next five years“

Ruggero Schleicher-Tappeser

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