Federal Ministry
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Energy

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

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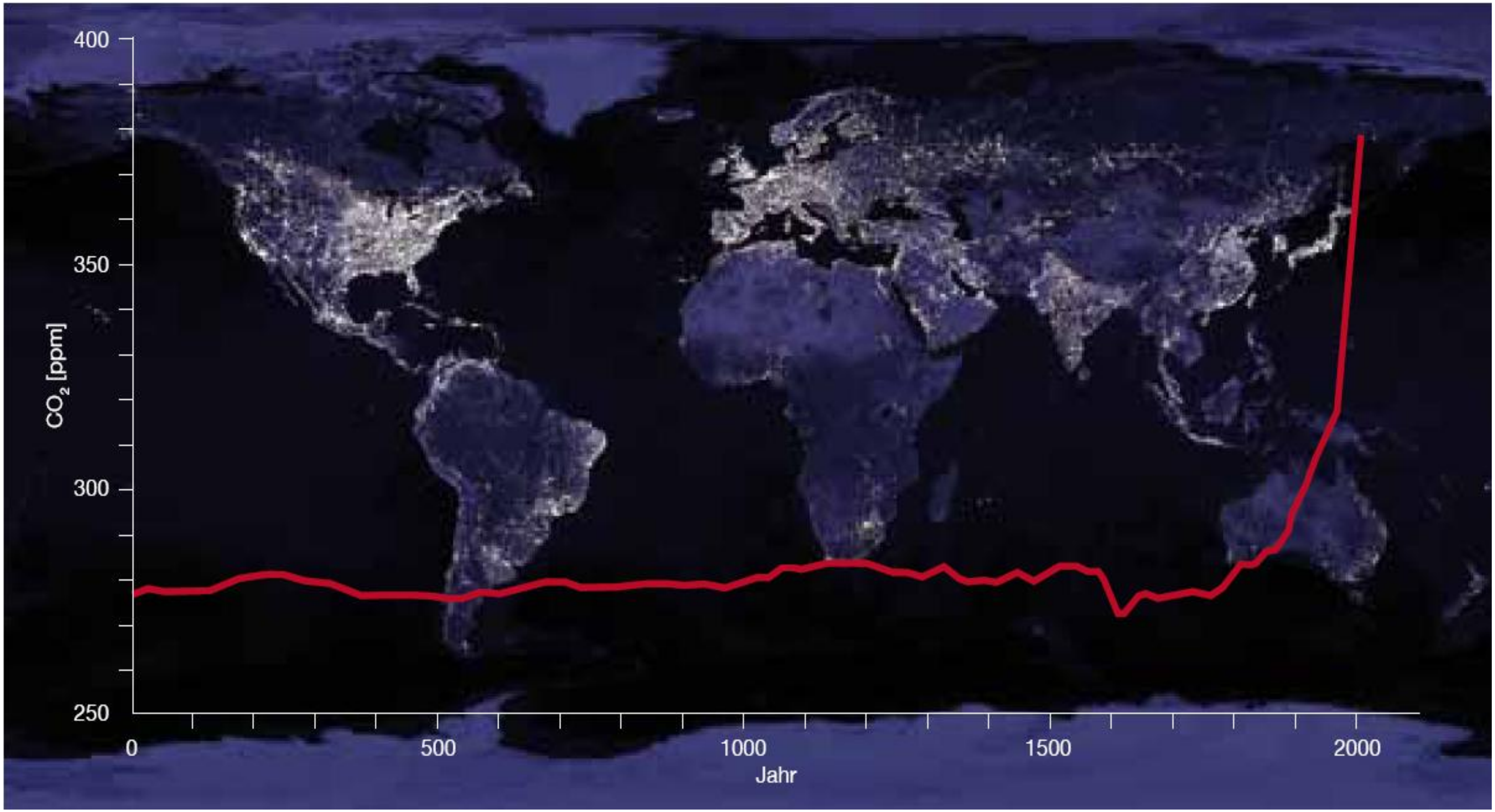
sustainable strategies, Berlin

8th Germany California Solar Day
October 30, 2012
Fort Mason Center, San Francisco, USA

renewables Made in Germany

sustainable strategies
ruggero schleicher-tappeser

energie waechter
efficient & renewable


400
350
300
250
CO2 [ppm]
0
500
1000
1500
2000
Jahr

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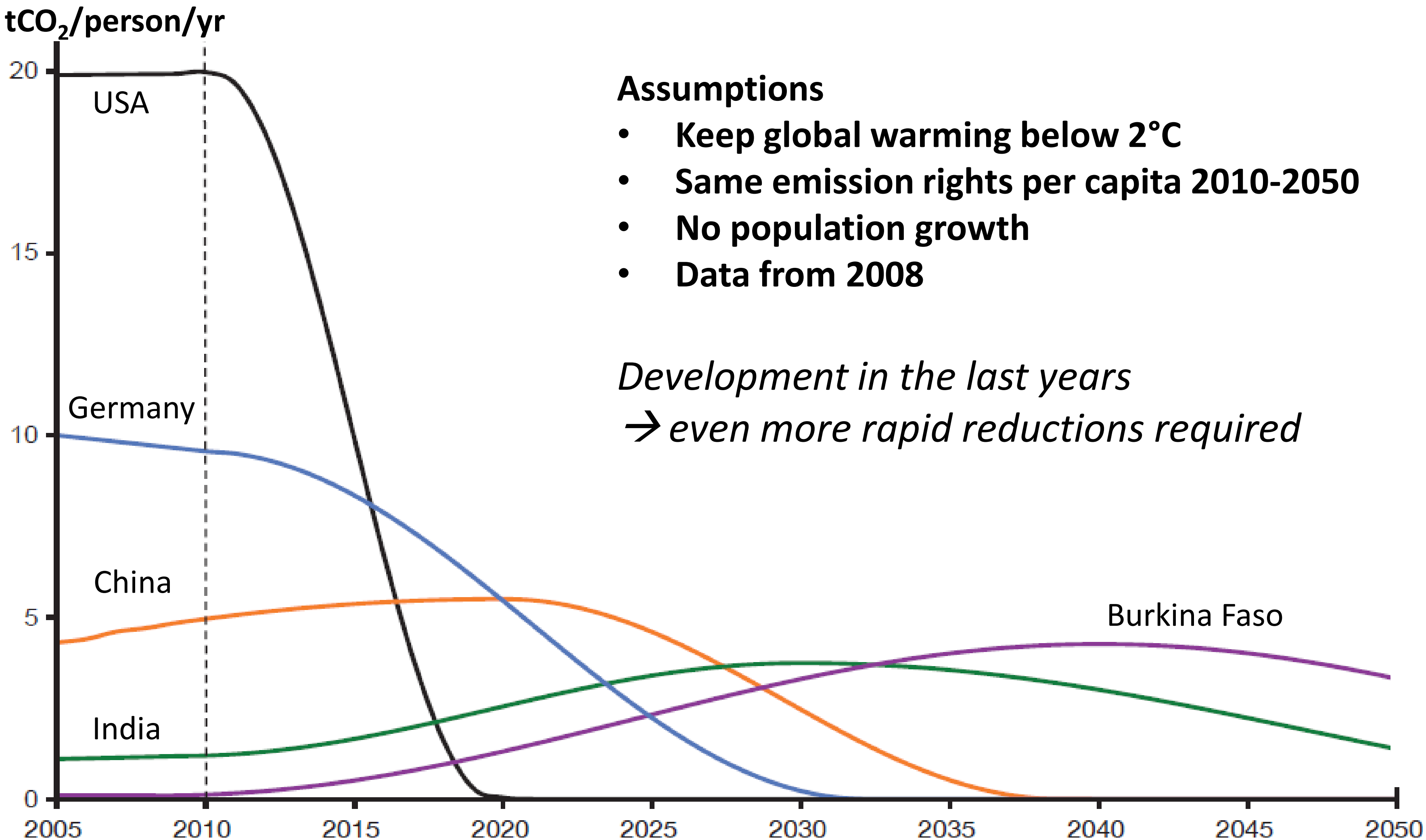
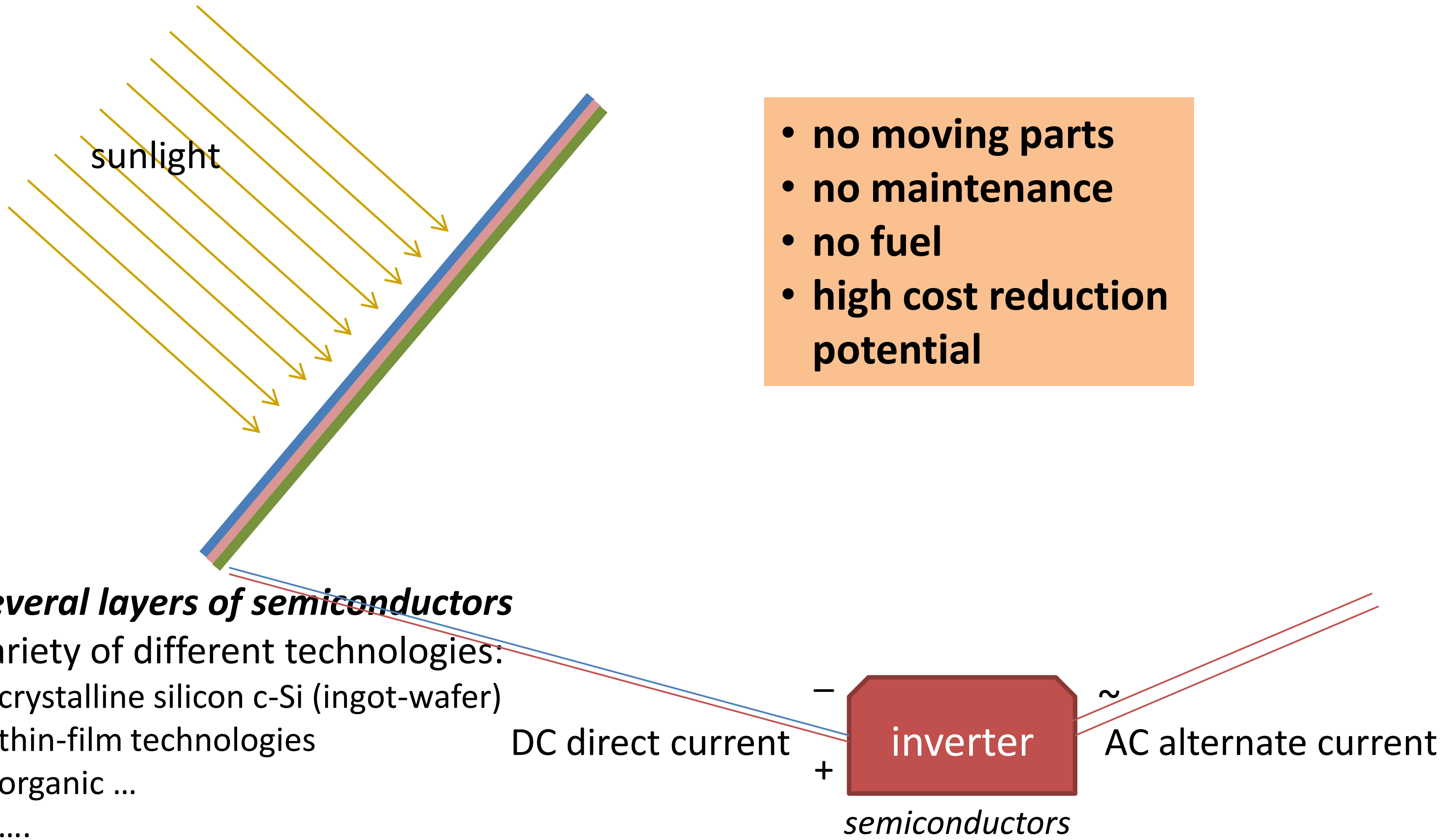


Assumptions
- **Keep global warming below 2°C**
- **Same emission rights per capita 2010-2050**
- **No population growth**
- **Data from 2008**

Development in the last years
→ *even more rapid reductions required*

PHOTOVOLTAICS –
A DISRUPTIVE TECHNOLOGY

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



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

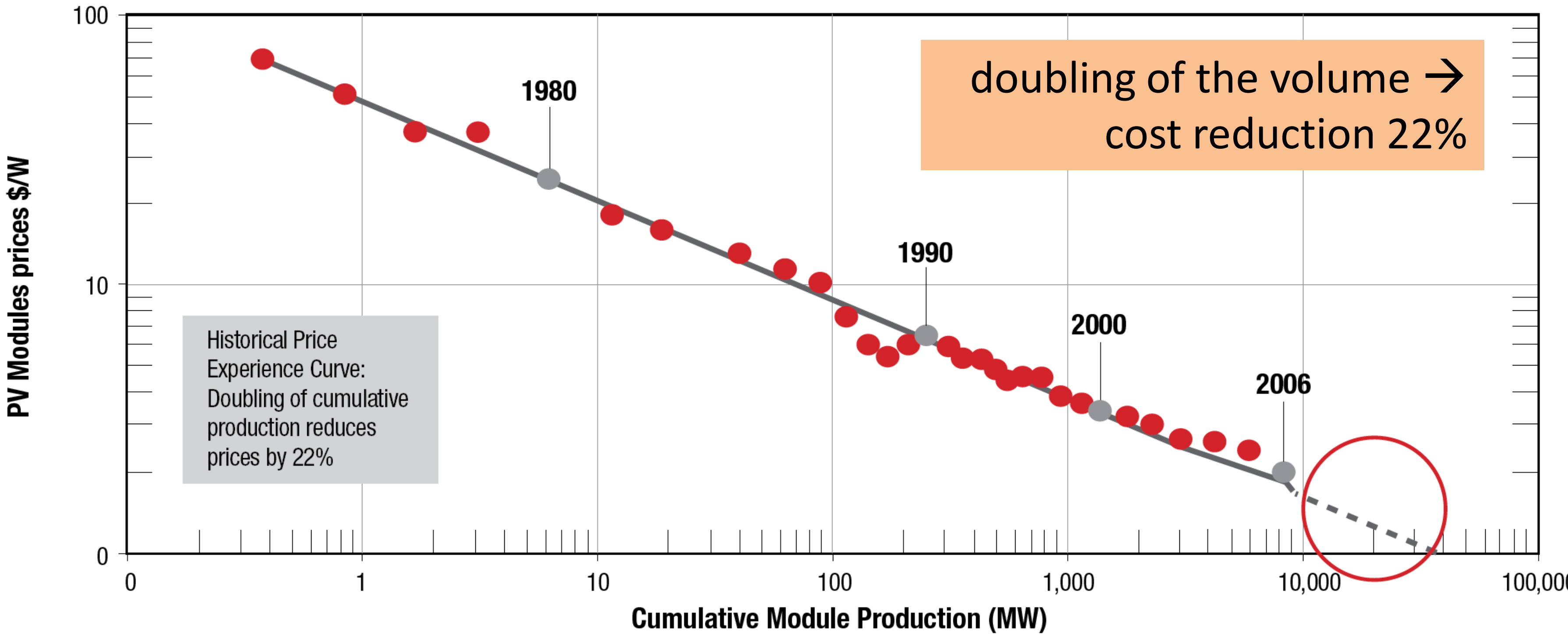
several layers of semiconductors

variety of different technologies:

- crystalline silicon c-Si (ingot-wafer)
- thin-film technologies
- organic …
- ….

PV is an extremely scalable technology: mass production of standardised cells

Rapidly decreasing Costs: The historical learning curve of PV

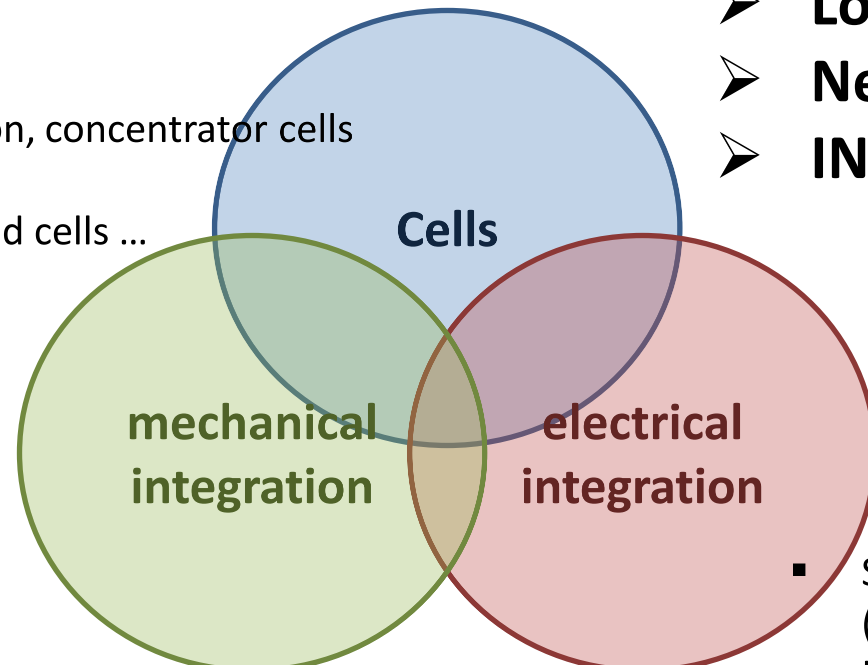


Sources: EU Joint Research Centre - EIA - National Renewable Energy Laboratory - A.T. Kearney analysis.

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 …

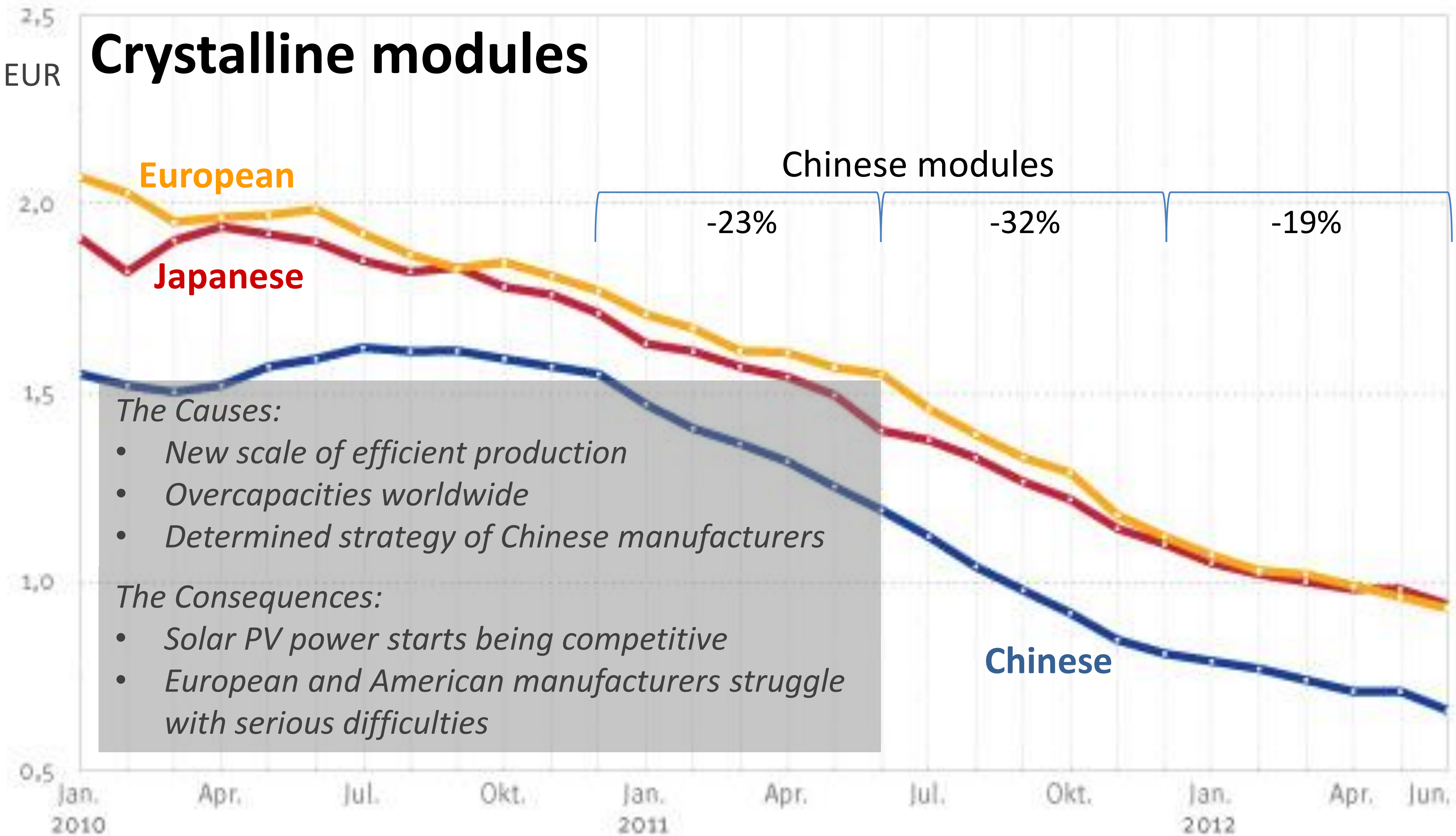
- ➢ **Higher efficiency**
- ➢ **Lower production costs**
- ➢ **New application fields**
- ➢ **INTEGRATION**



- 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

Heavy PV module price drop since 2010: - 45% in 12 months



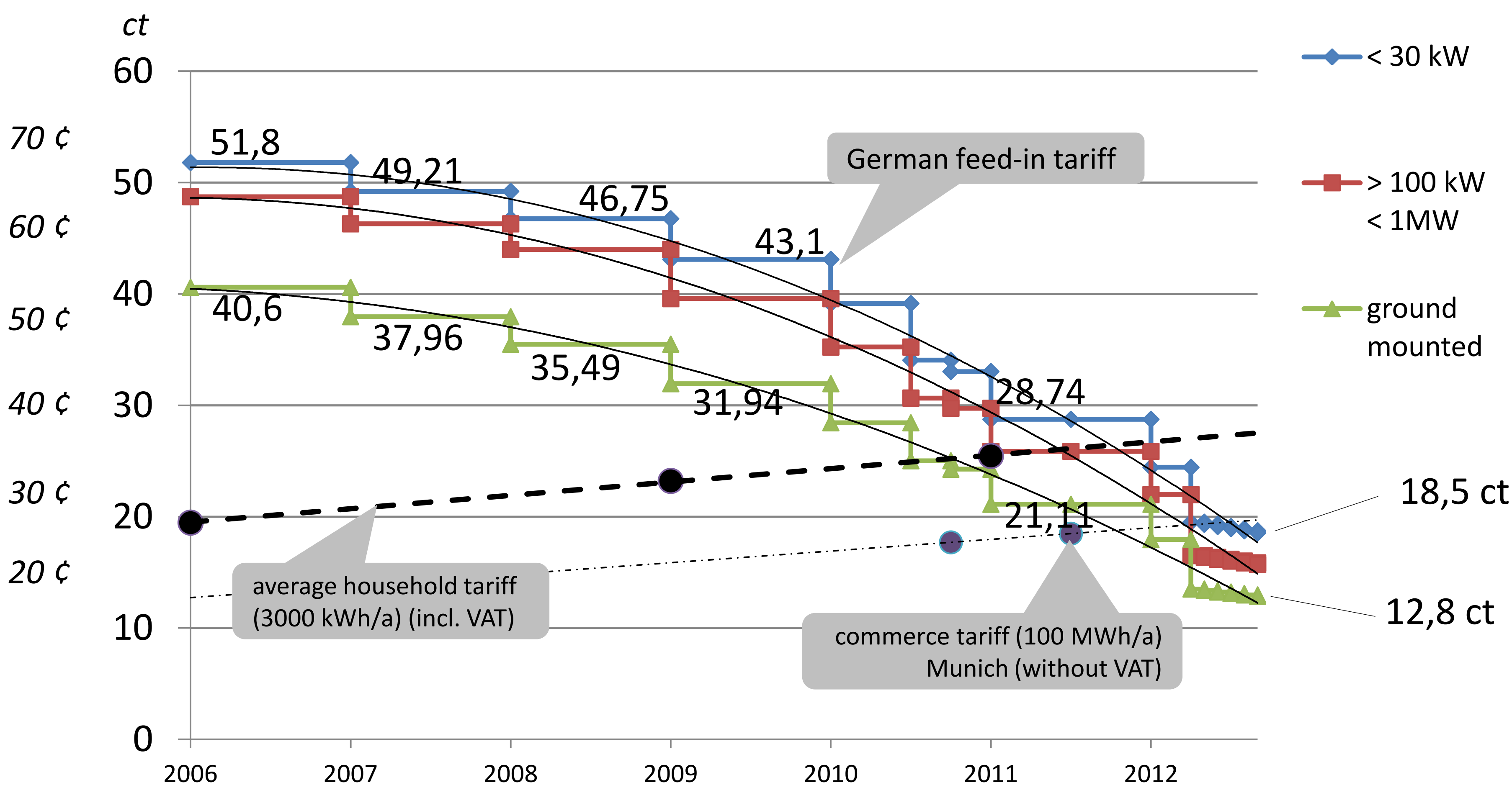
The Causes:

- *New scale of efficient production*
- *Overcapacities worldwide*
- *Determined strategy of Chinese manufacturers*

The Consequences:

- *Solar PV power starts being competitive*
- *European and American manufacturers struggle with serious difficulties*

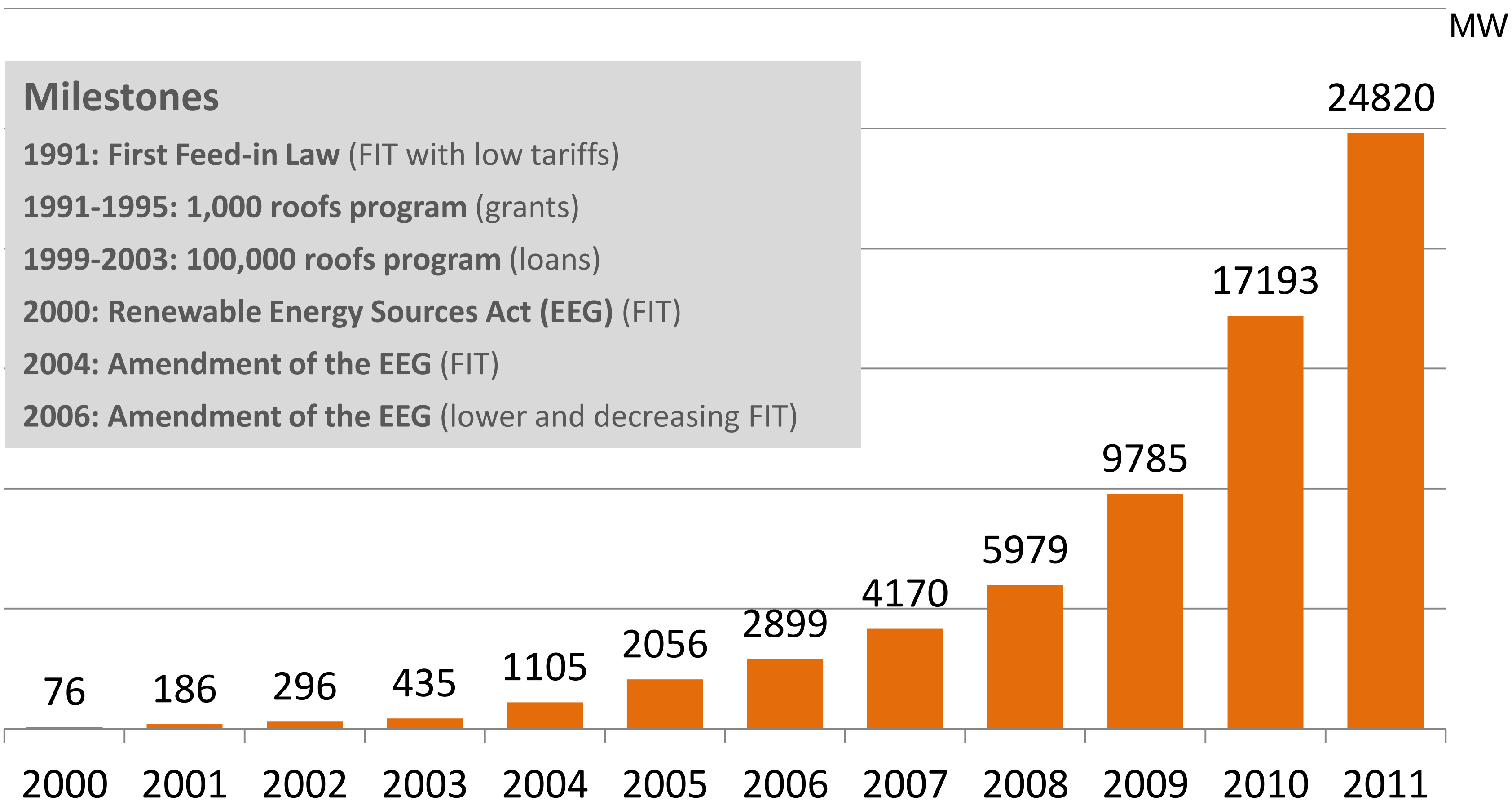
Rapidly decreasing German feed-in-tariffs: grid parity residential & commercial since 2012



DEVELOPING GLOBAL MARKETS

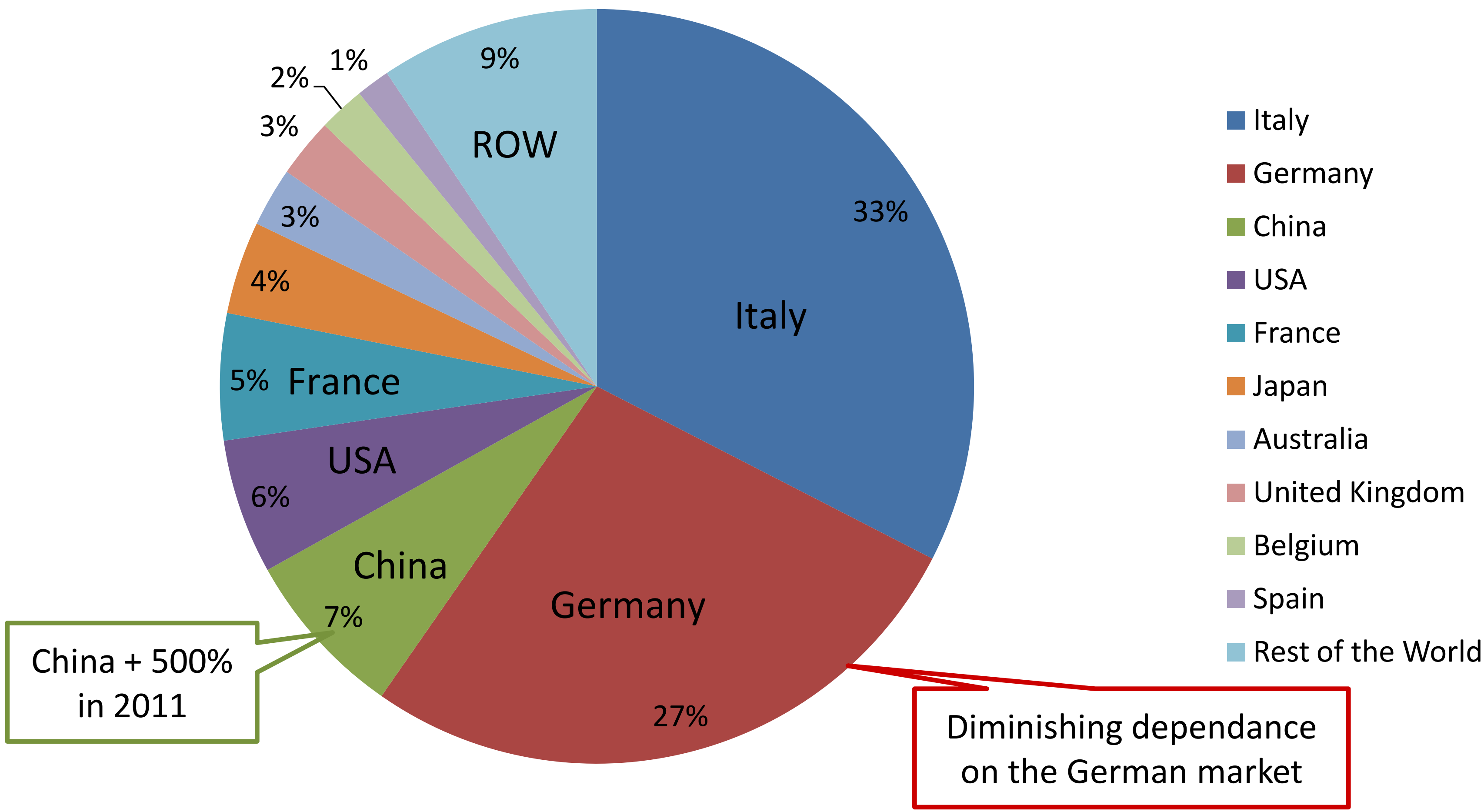
Germany has triggered the take-off of the world PV market

Total PV capacity installed in Germany



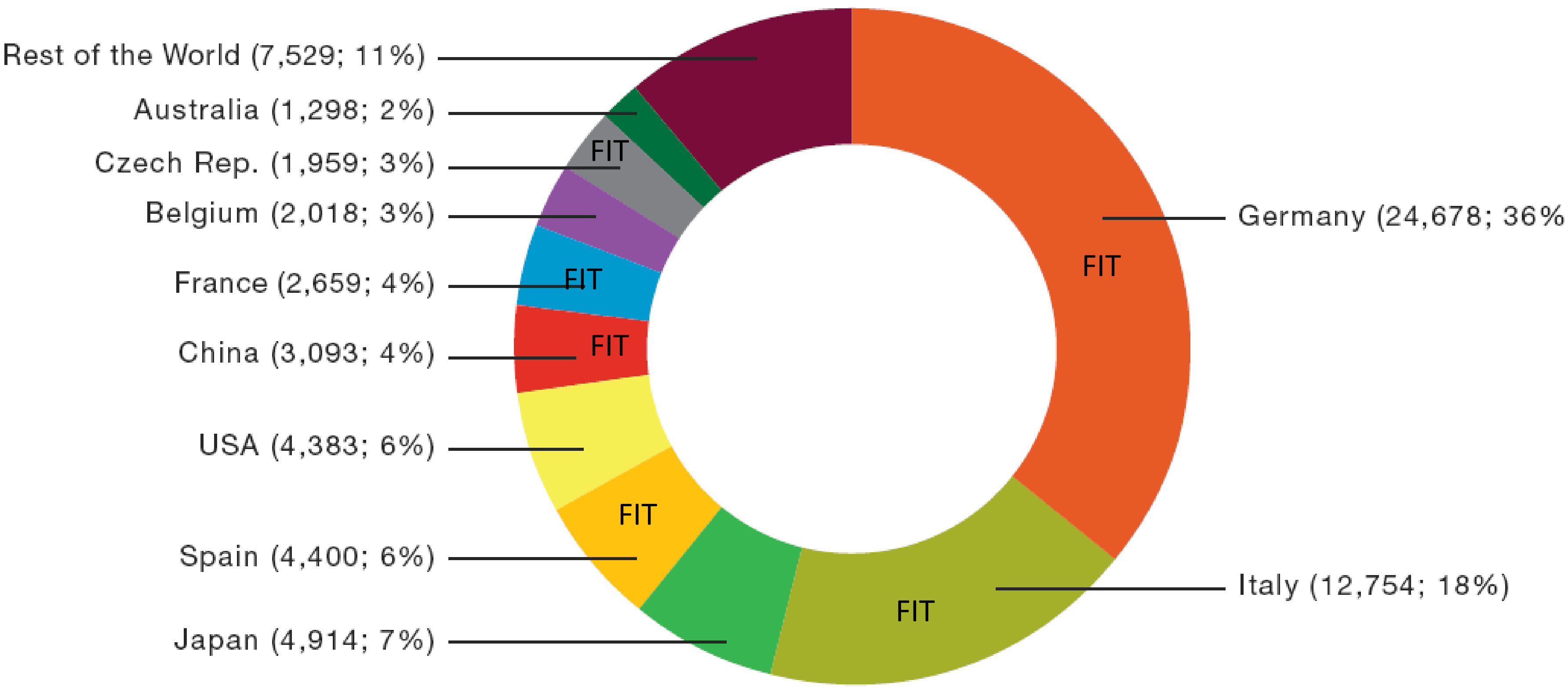
Source: BMU, BSW

The global PV market in 2011 (27.000 MW)



Feed-in-tariffs (FIT) have boosted markets globally

Global cumulative installed capacity share 2011



Success factors during the start-up phase 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

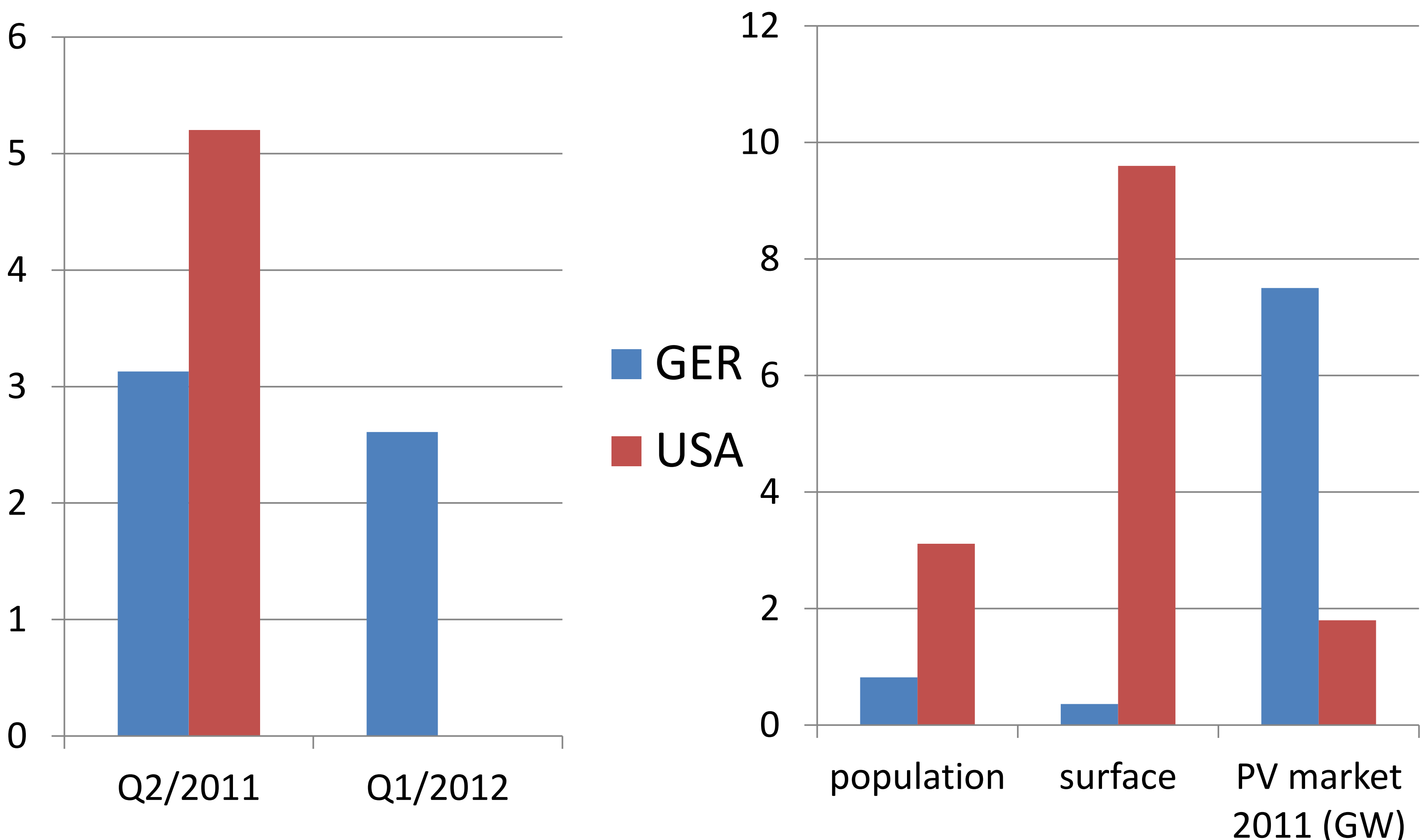
- ➢ Banks have learned that PV investments are low risk → low capital costs
- ➢ Industry and craftsmen have invested in production and training → reliable quality, low system price
- ➢ Hundreds of thousands of new private investors

Building the value chain takes time

↓ 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

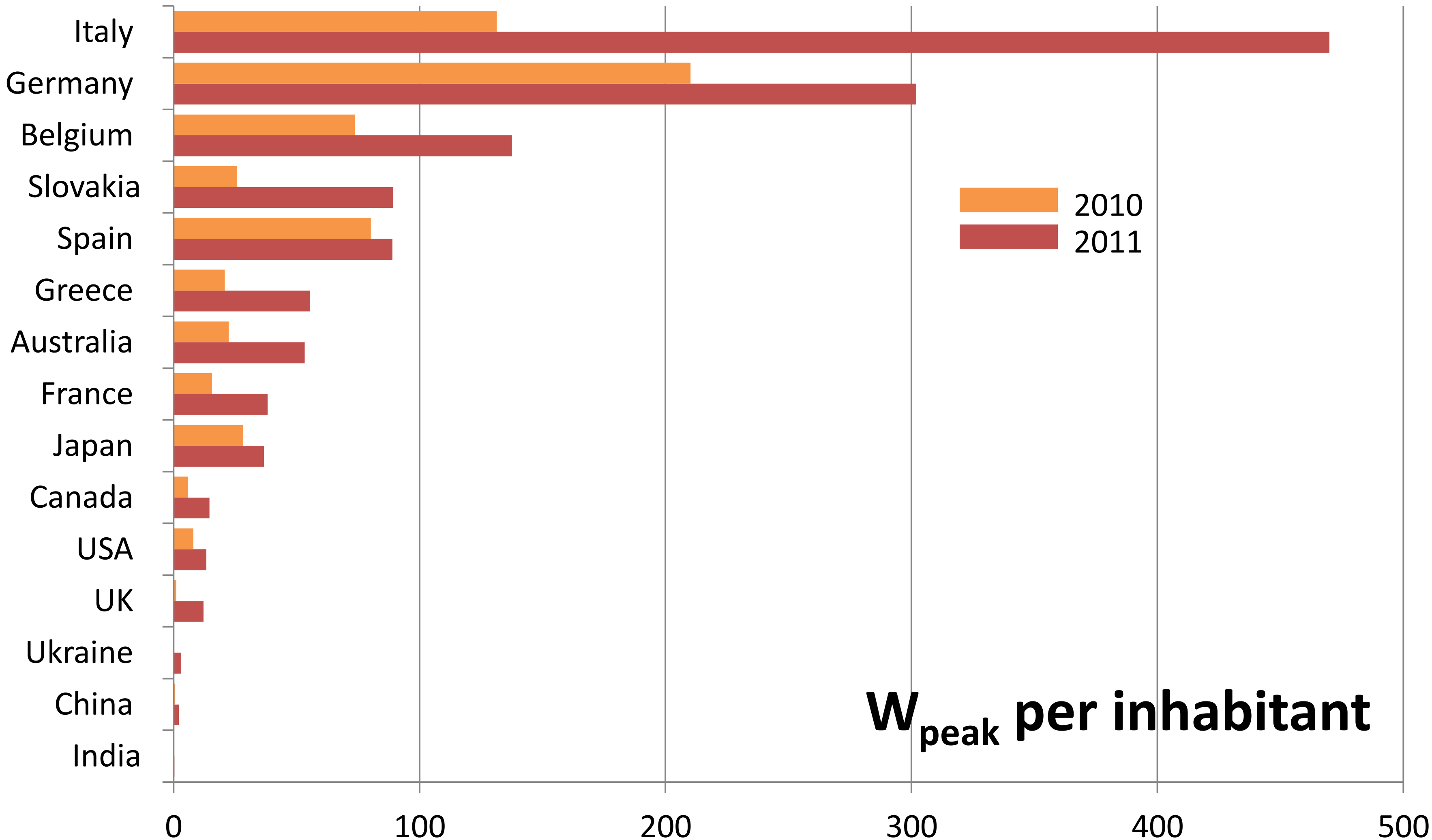
System prices depend on the maturity of the market



System prices ($/$W_p$)

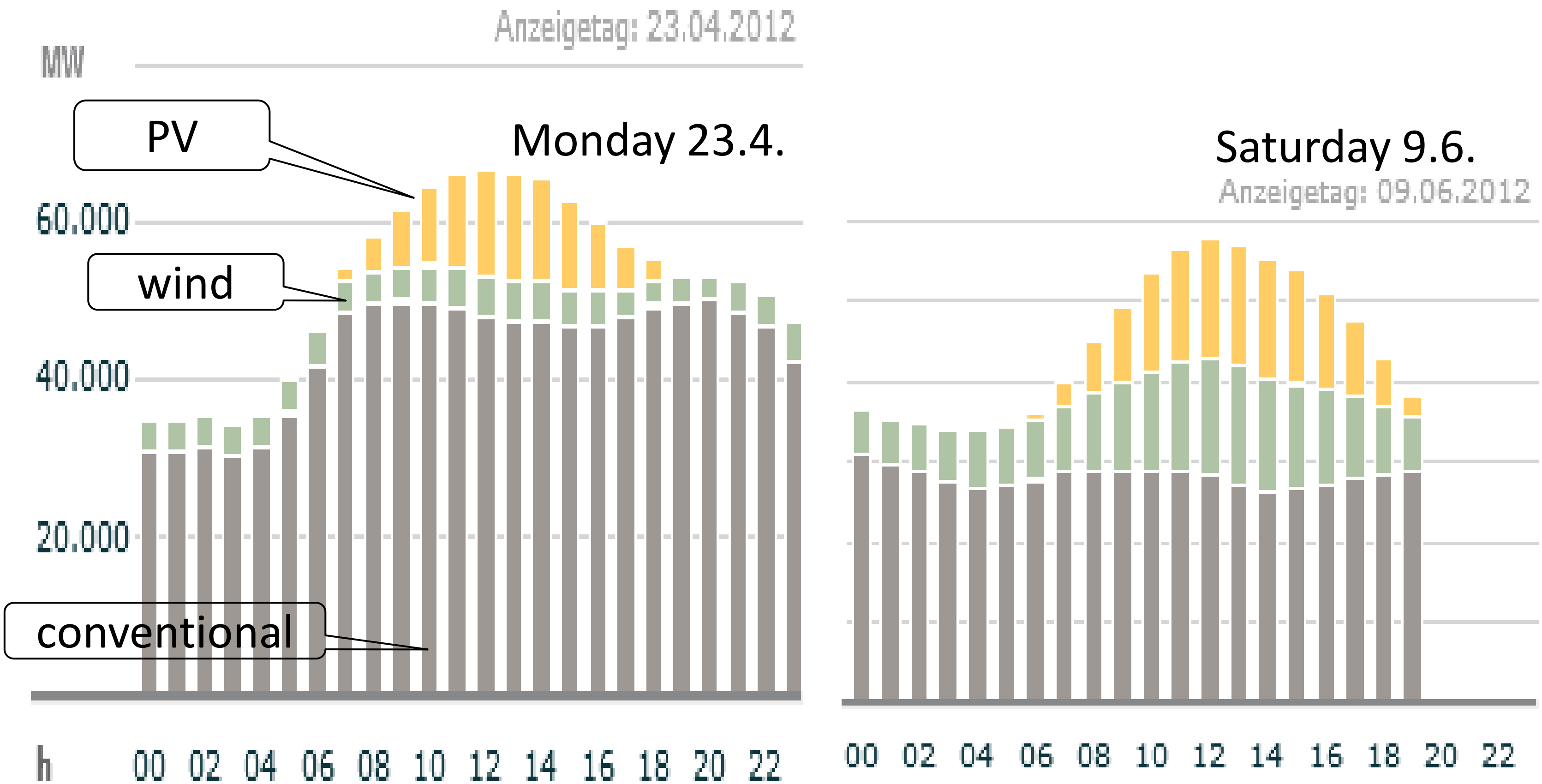
AN UNPRECEDENTED CHALLENGE FOR THE ELECTRICITY SYSTEM

Germany one of the first countries to experience major effects of PV in the grid



Data: EPIA 2011

PV covers consumption peak
→ declining prices at the power exchange



→ Billions lost for conventional power producers

The three key challenges of solar and wind power

1. Fluctuating power generation:
   Power generation directly depends on changing natural input
   - Forecasting production is a challenge
   - Flexible compensation needed
2. No marginal costs:
   Wind and solar power need no fuel
   - Dispatch priority
3. Distributed generation:
   Photovoltaics and onshore wind: essentially distributed
   - “Distribution” grid changes role
   - Captive power generation: Prosumers emerge as new actors

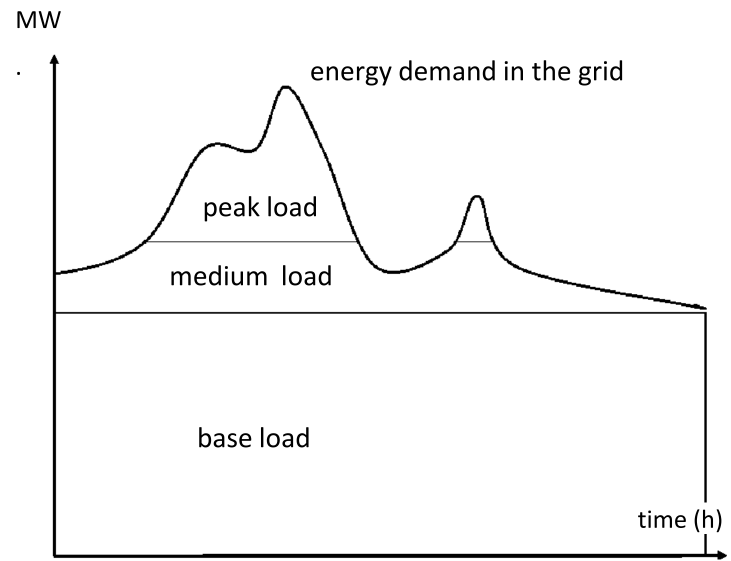
Fluctuation of wind and solar power requires flexibility instead of base load

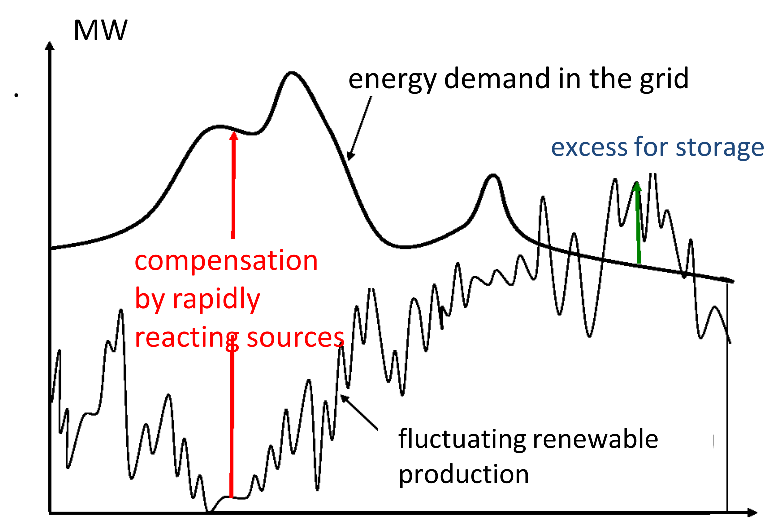
The old base load concept:

- 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

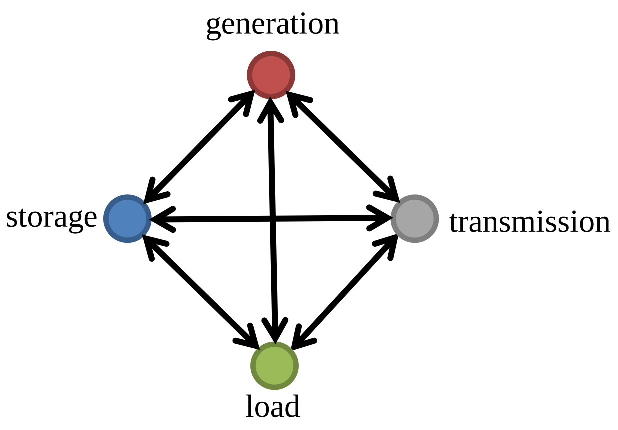




The system gets much more complex: more flexibility – four options

Generation, load, storage and exchange must be balanced at each point in time – all four can be managed:

1. Flexible backup generation
   - traditional approach, limited when needing fossil fuel
   - old technologies not flexible enough
   - new technologies: gas turbines, distributed CHP, fuel cells
   - today: natural gas, tomorrow: renewable fuel – SNG
2. Increased transmission
   - compensates local fluctuations over distance
   - requires additional transmission capacities
   - cannot compensate daily and seasonal cycles
3. Storage of electricity
   - intuitively the easy solution, but costly
   - different technologies for different time horizons, scales
4. Adapting demand
   - up to large extents cheaper than other solutions
   - nearly untapped: regulatory barriers, new opportunities with ICT



Business and government grappling with 5 to 10 times shorter innovation cycles

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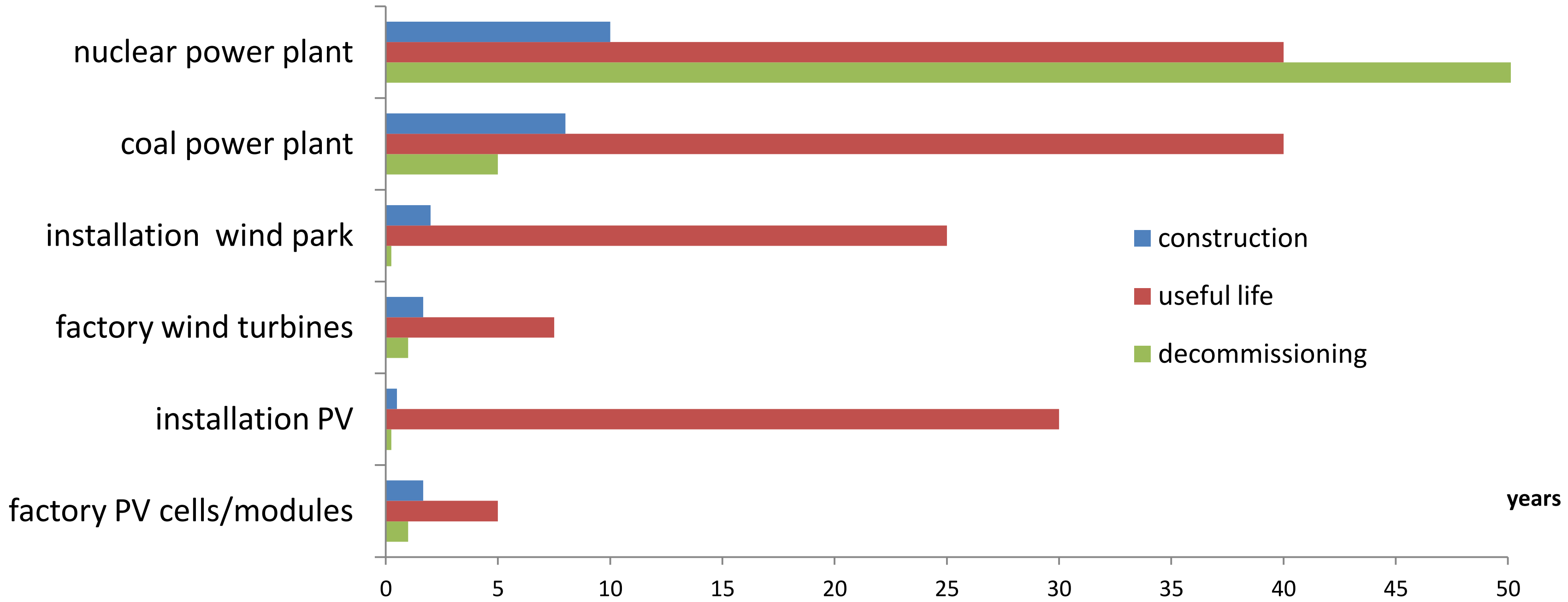
→ More rapid build-up of capacities (e.g. Dec. 2011 in Germany: 3,5 GW PV)

→ More rapid decrease of costs

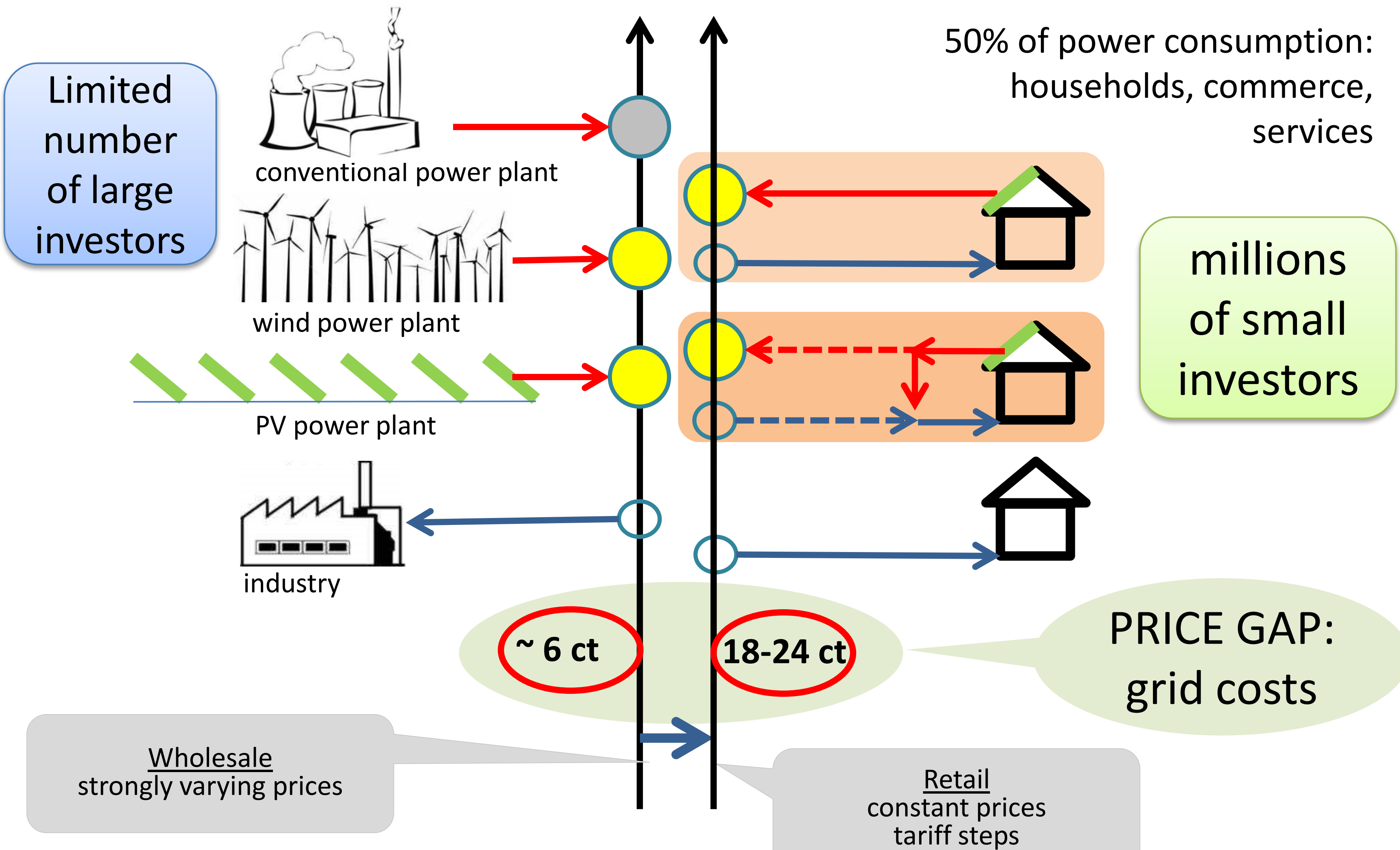
→ More rapid transformation of the electricity sector

Dramatic acceleration compared to traditional energy technologies

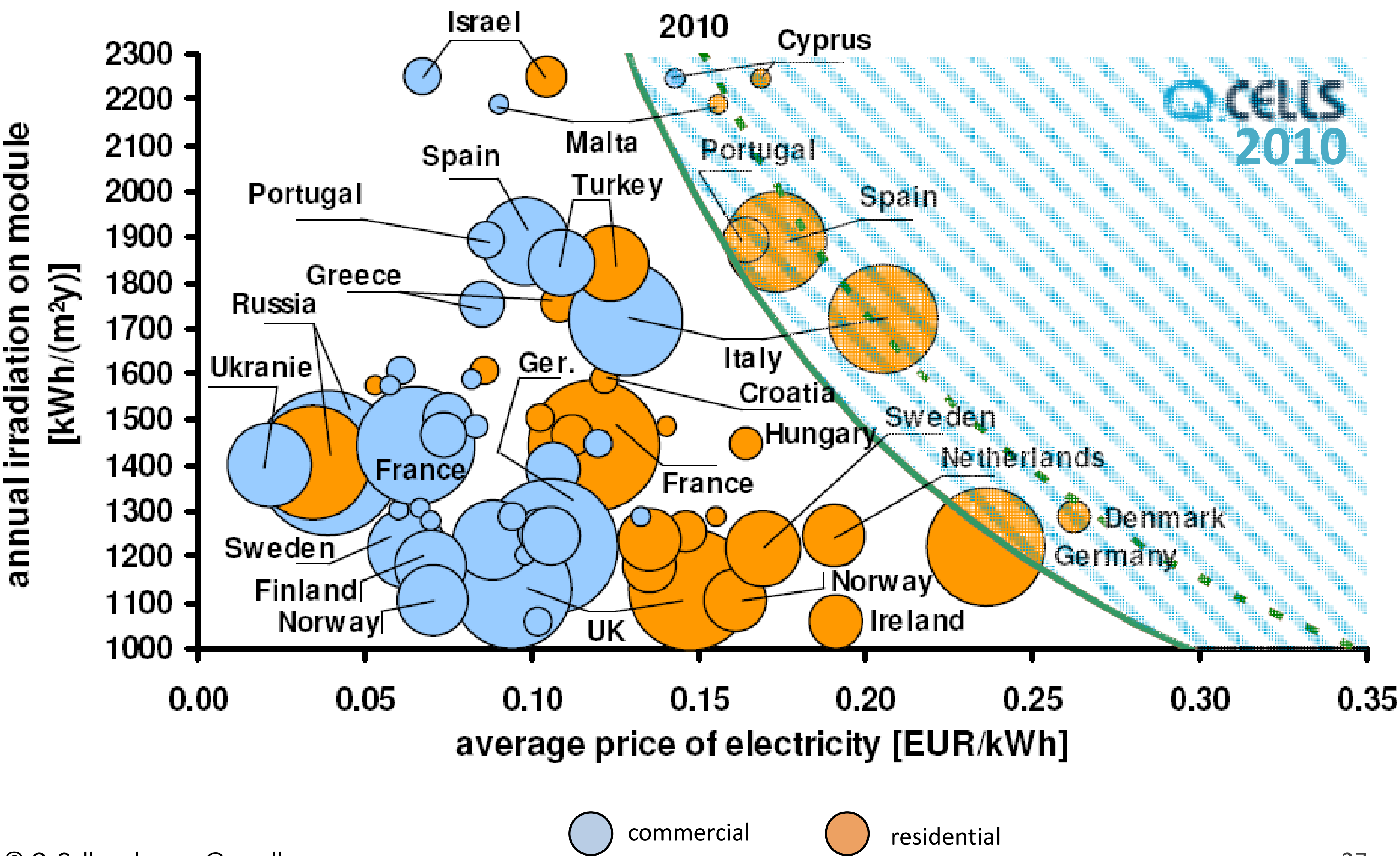


CAPTIVE POWER GENERATION CHANGES THE GAME

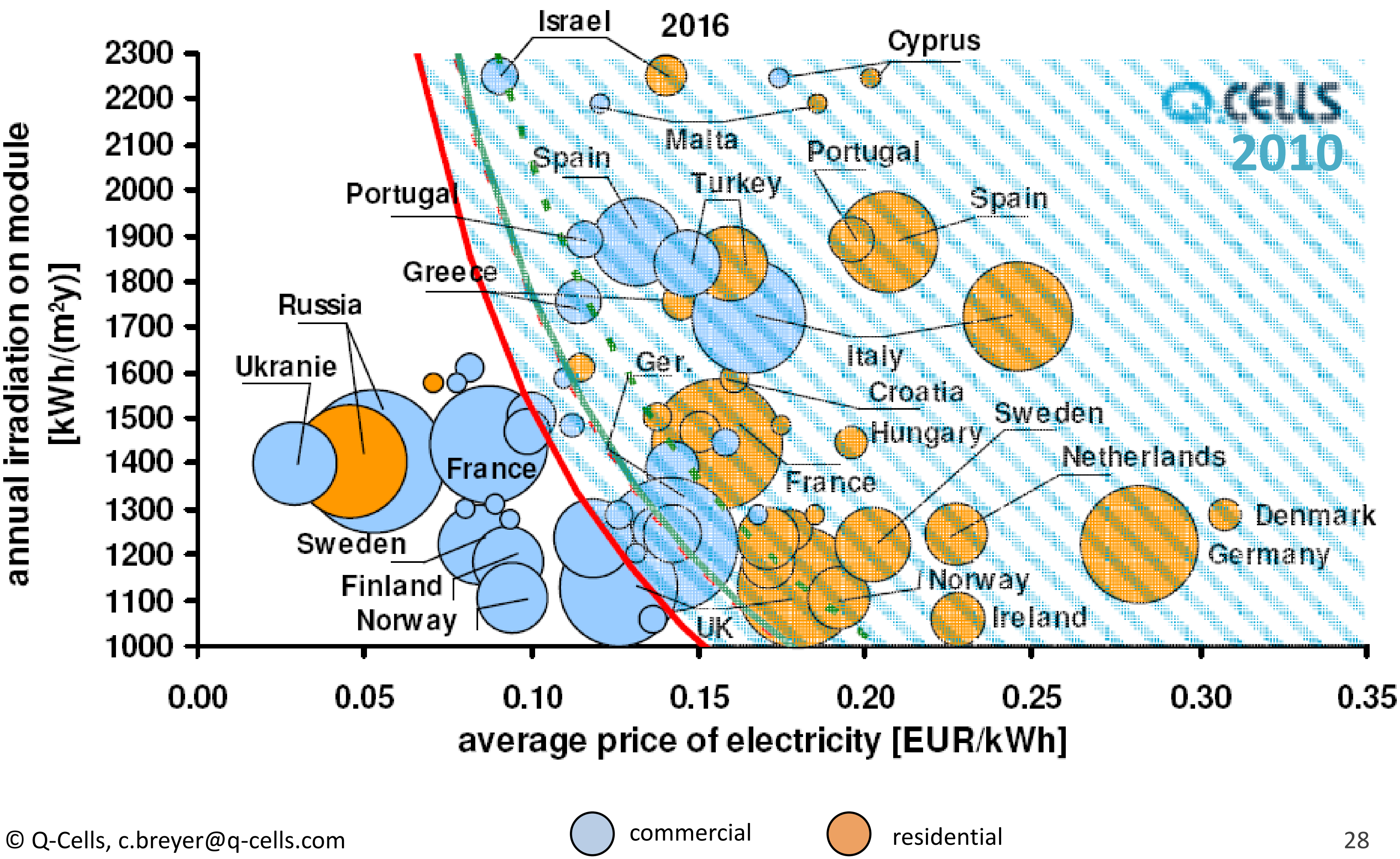
Photovoltaics is a modular technology: competing on the retail side



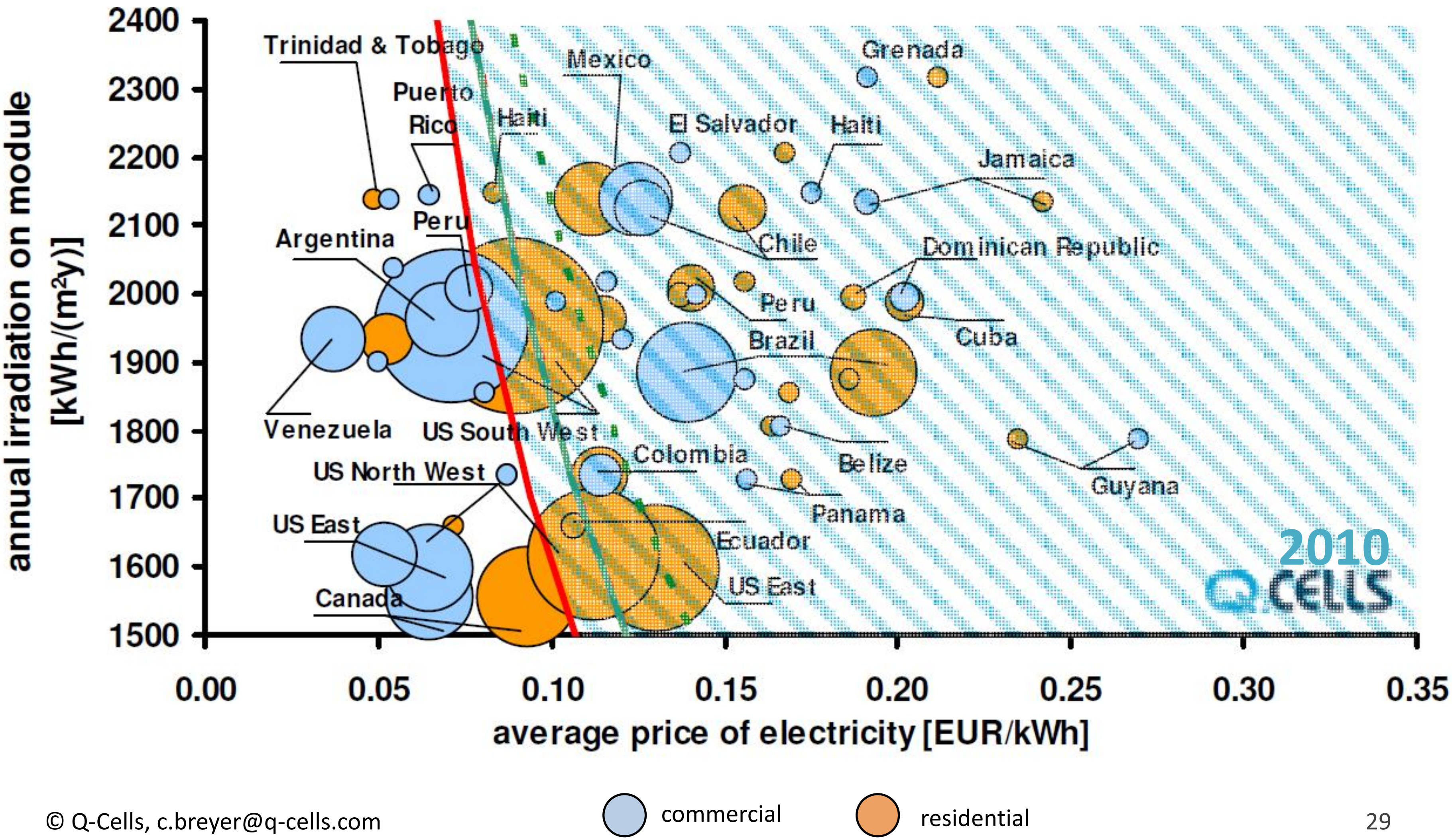
Grid parity in Europe 2010



Grid parity in Europe 2013?
(forecast in 2010 for 2016)



Grid parity in the Americas 2013?
(forecast in 2010 for 2016)



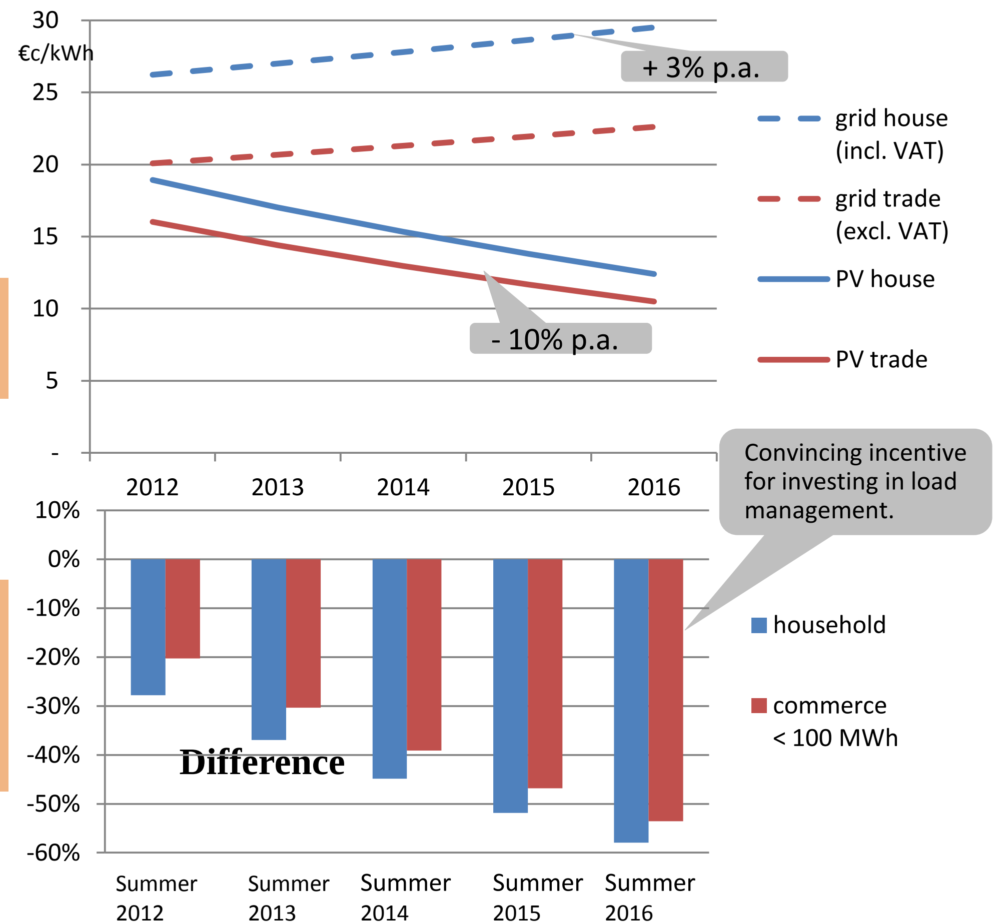
Attractiveness for own power production: Germany - Scenario for the next four years

- <u>In the last six years the average PV system price declined by 65%</u> (3Q06-3Q12, <100kWp, Germany) corresponding to <u>*-16% p.a*</u>.

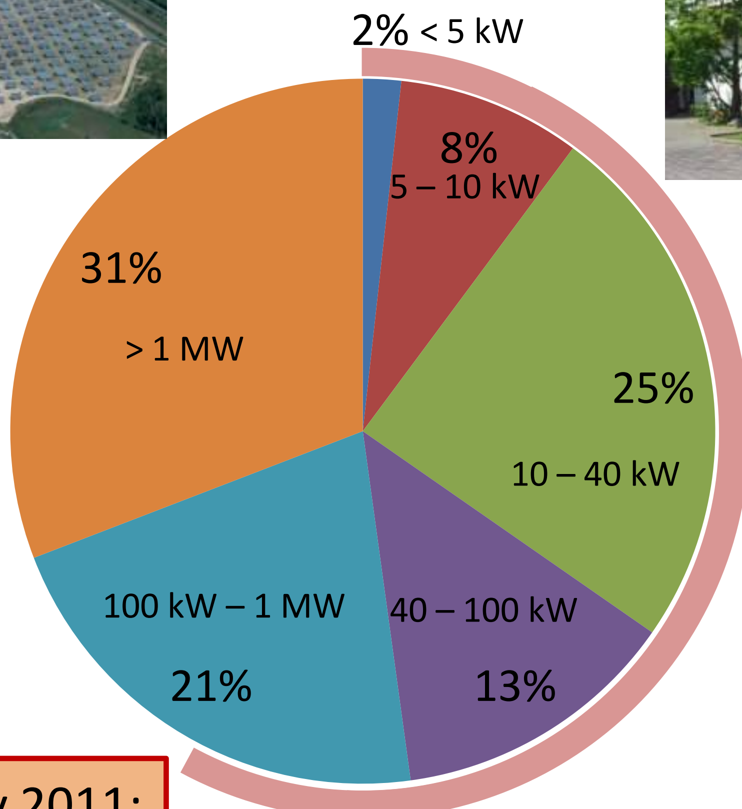
- Scenario assumptions
  - <u>System price development: *-10% p.a*</u>.
  - Power from the grid: + 3% p.a.
  - FIT July 2012 in Germany represents present PV power costs

➢ In four years PV power from the roof may cost 50% less than power from the grid

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



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

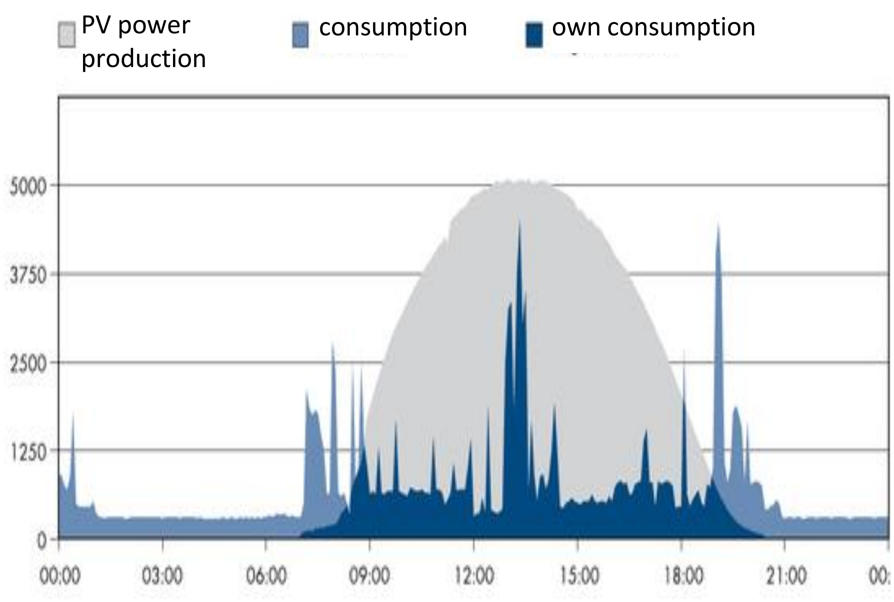


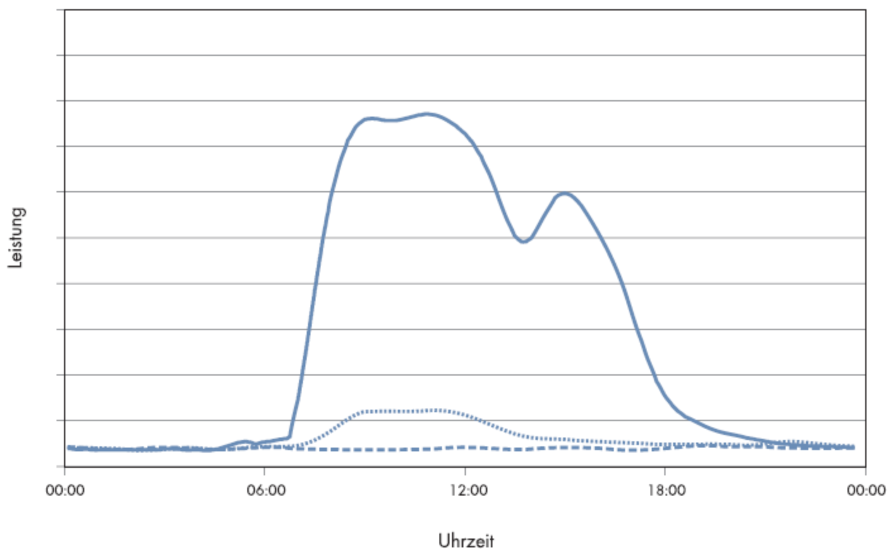
Installations **2011**

New installed capacity 2011:
48% < 100 kW

data: BNetzA 2010

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

Prosumers start to shift their load into sunshine hours, dealing with fluctuation locally

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- Storage of electricity
  - Batteries
  - Flywheels…
- Load management
  - 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
- Additional, non time-critical loads
  - Loading electrical vehicles
  - Heat pumps: substitution of other kinds of heat production
  - Production of synth. methane or hydrogen (larger plants)

Cheaper than electricity storage

➢ Flexibility of the user system increases

The coming boom: captive power generation

Attractive investments even without incentives

Timeline in Germany:

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

➢ PV growth independent from incentives

➢ Boom in power management technologies

Still missing but slowly emerging: appropriate business models

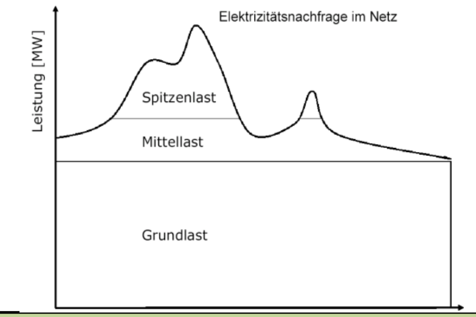
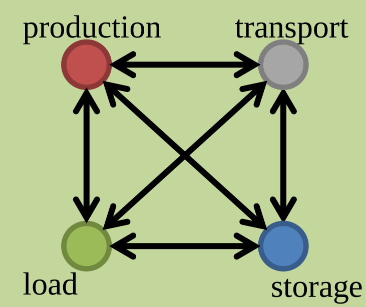
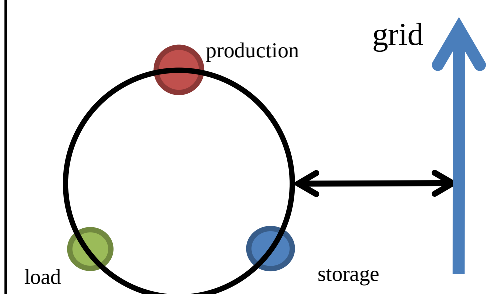
- Dealing with high upfront costs
- Structuring of risks
- Segmentation of markets
- Distribution of roles
- Development of step by step approaches

Where will we see them first at large scale?

- in Germany?
- in Italy?
- in Spain?
- in Turkey?
- in India?
- in the US?

TOWARDS A NEW CONTROL LOGIC OF THE ELECTRICITY SYSTEM

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	

…but without an appropriate framework private optimisation can destabilise the whole system

- Who pays the grid costs not covered by self-supplying ex-consumers?
- What happens if prosumers dump generation peaks into the grid when their storage is full?
- …

➢ Time-dependent feed-in and supply tariffs must set incentives for system-stabilising exchange with the grid

➢ System needs may vary from place to place as the production-consumption mix varies

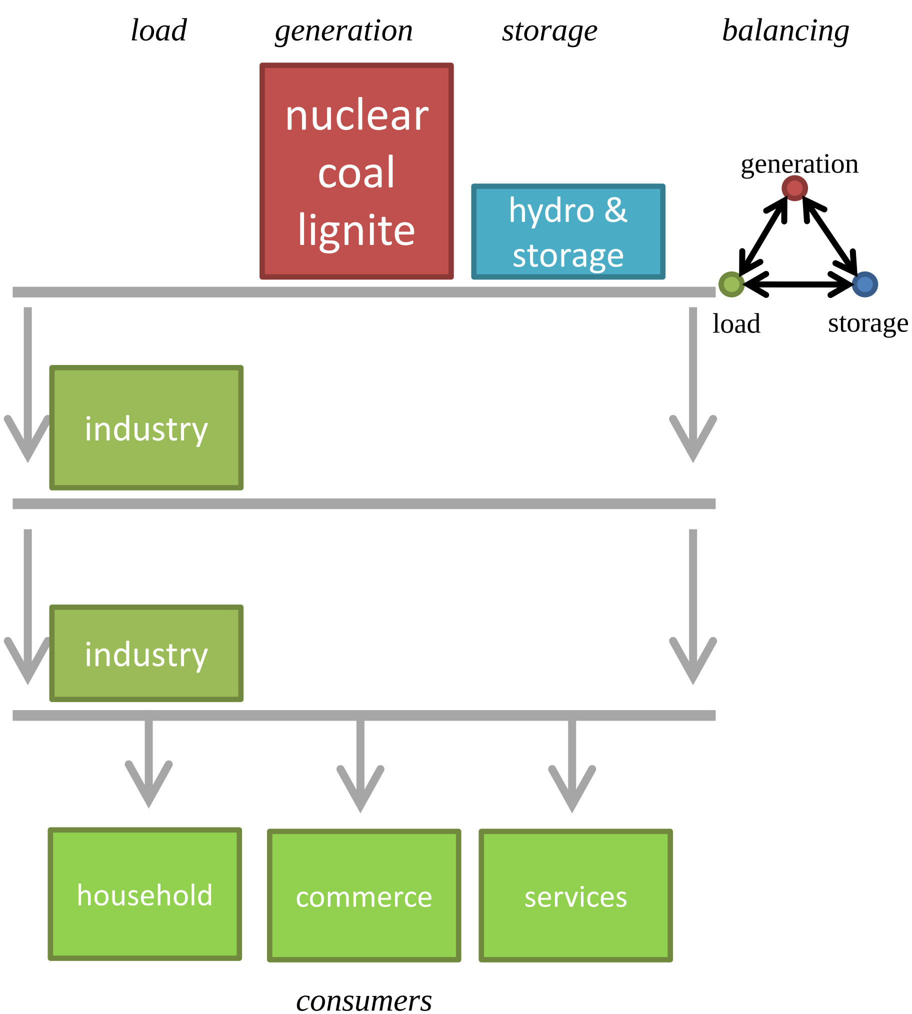
➢ System responsibility must be decentralised

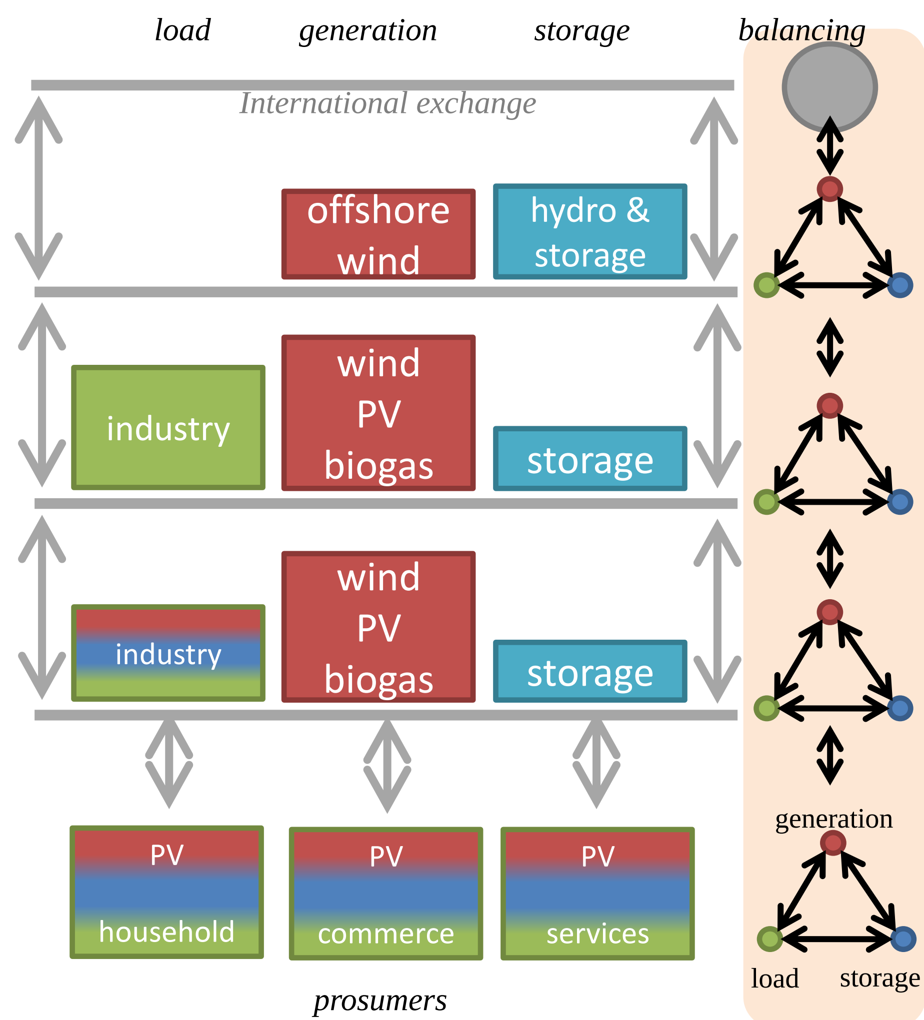
→ **A more differentiated approach in time and space**

→ **We will need local electricity markets**

Top-down supply system
(central control)

Multi-level exchange system
(subsidiarity, shared responsibility)





Navigating through a turbulent transformation period

Business and government grapple with the speed & uncertainties of change, but slowing down the transition is no option

- Accept the challenge of competitive distributed power generation
- Flexible optimisation → targeted use of market mechanisms, local flexible pricing
- Integrated energy management at the building level becomes interesting as load flexibility gets important
- Building up the solar value chain takes time: start immediately
- Strive for steady development and reliable frame conditions despite a turbulent environment: stable sub-systems

The semiconductor revolution reaches the power sector: We need flexible multi-level governance

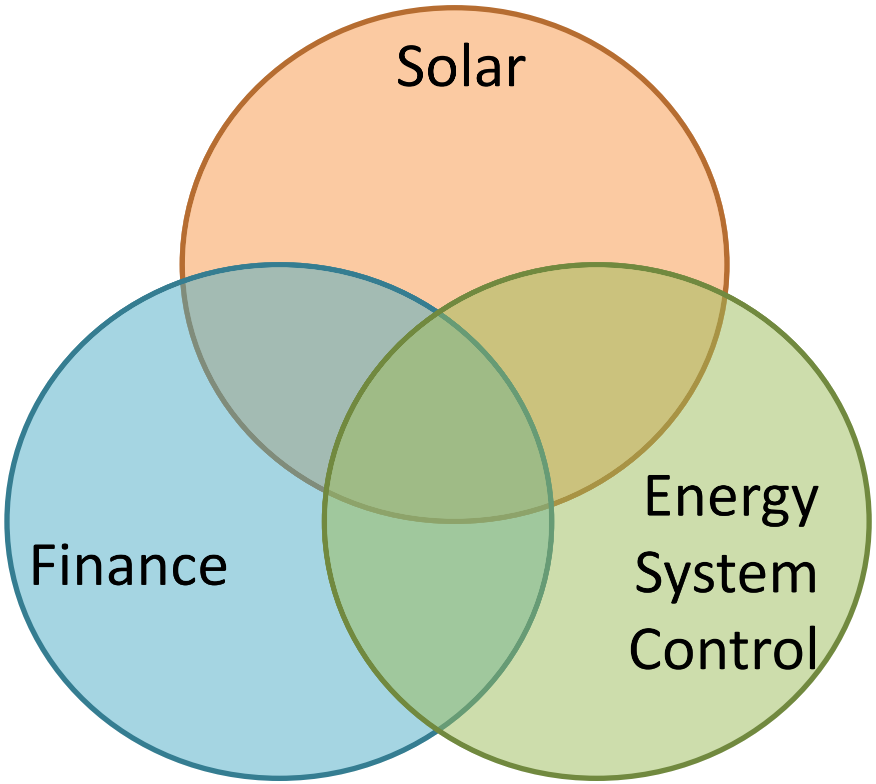
New dimensions emerge:

- new qualities of time and space (fluctuation, storage, grids)
- new kinds of actors (prosumers, new system roles)
- accelerated change with differing innovation speeds
- highly scalable modular generation technologies
- flexible smart grid infrastructures

For a pragmatic transition we need strategic visions

- re-definition of the role of actors at several levels
- re-definition of markets
- Industry policy and industry strategies

Strategies for the industry: Solar is not enough – Clients want solutions



attractive packages require system competence

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Energy

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You will find this presentation and more on my website
www.sustainablestrategies.eu

See article:
„How renewables will change electricity markets in the next five years"
Energy Policy 2012 http://bit.ly/L27haO

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