PV Grid Parity and Cheaper Storage bring Disruptive Change in Electricity Markets

Ruggero Schleicher-Tappeser

sustainable strategies, Berlin

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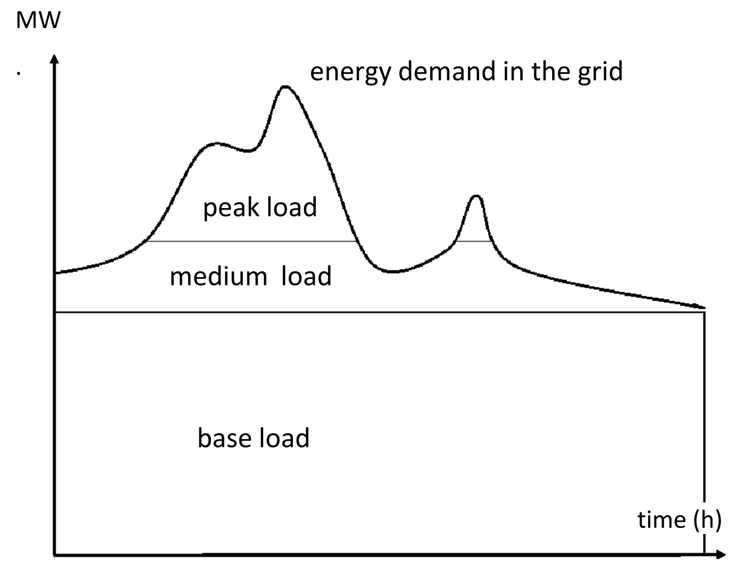
The main problem with high shares of wind and solar power: fluctuation

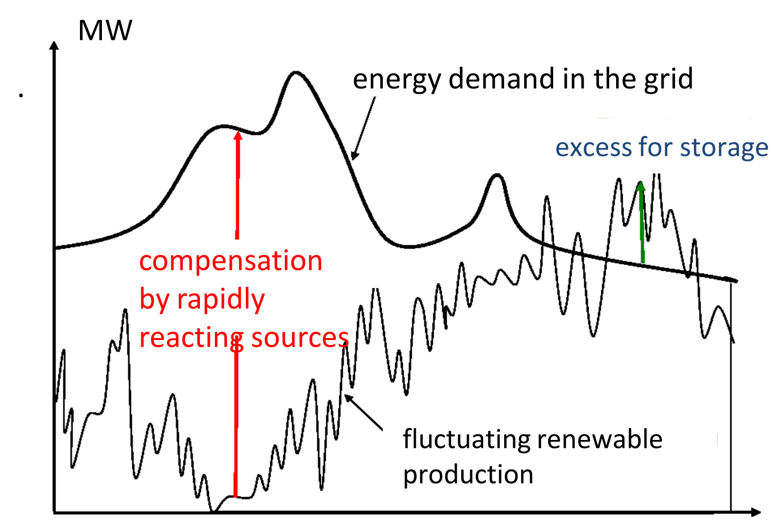
The old base load concept:

- 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)
- <u>Storage</u> becomes important
- <u>Load management</u> becomes important
- No need for baseload plants





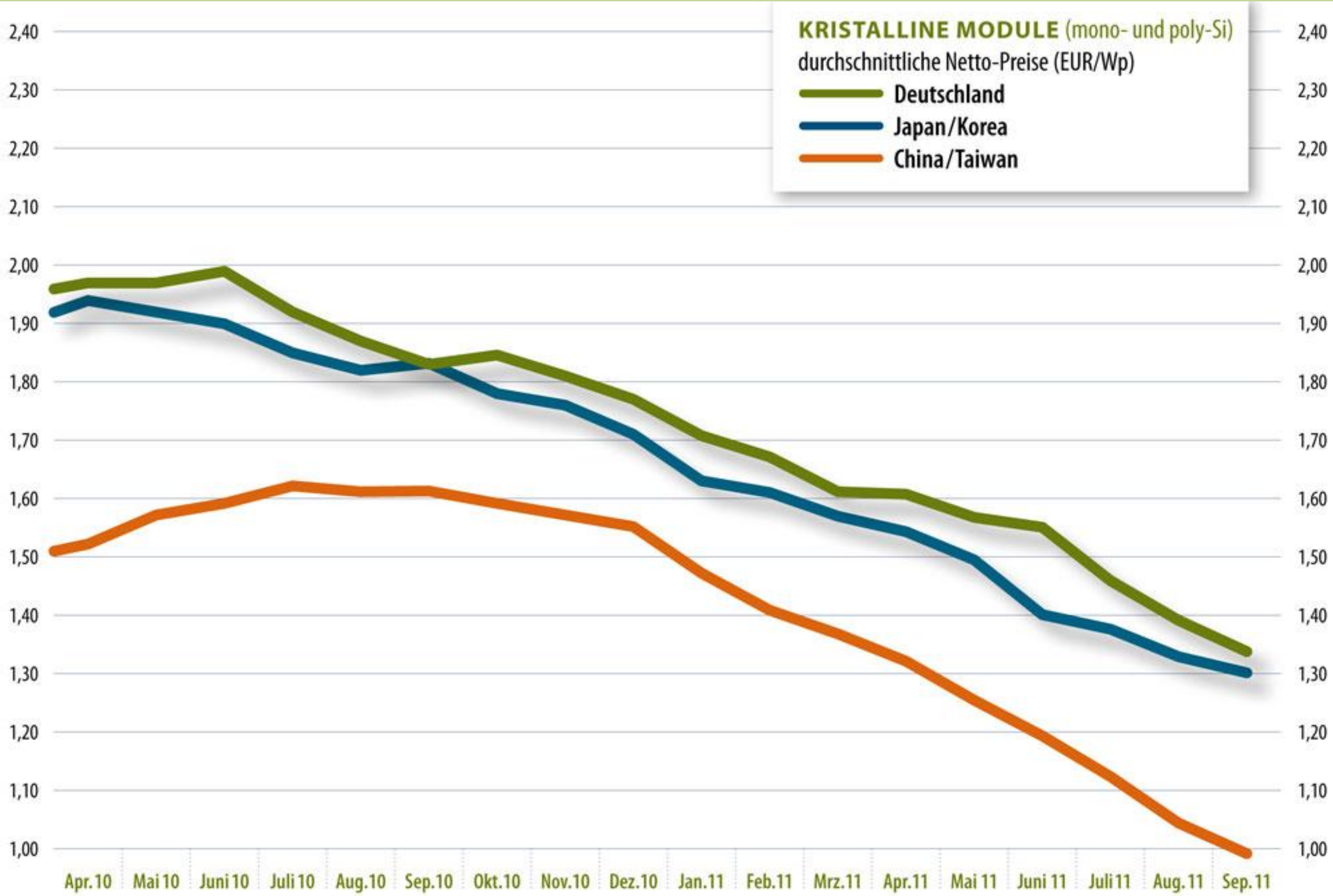
Transformation of electricity markets: strong drivers for change requiring storage

1. End of nuclear, climate change, ↗ energy prices
   → accelerated switch to renewables
2. Wind & solar depend on weather, no variable costs – need to cope with fluctuating production
3. The disruptive character of photovoltaics – steadily falling prices, modularity, prosumers
4. ICT conquers traditional grids –
   old top-down logic challenged by new concepts

→ Complexity increases, present regulation inadequate, new wave of innovations, rapid & turbulent change

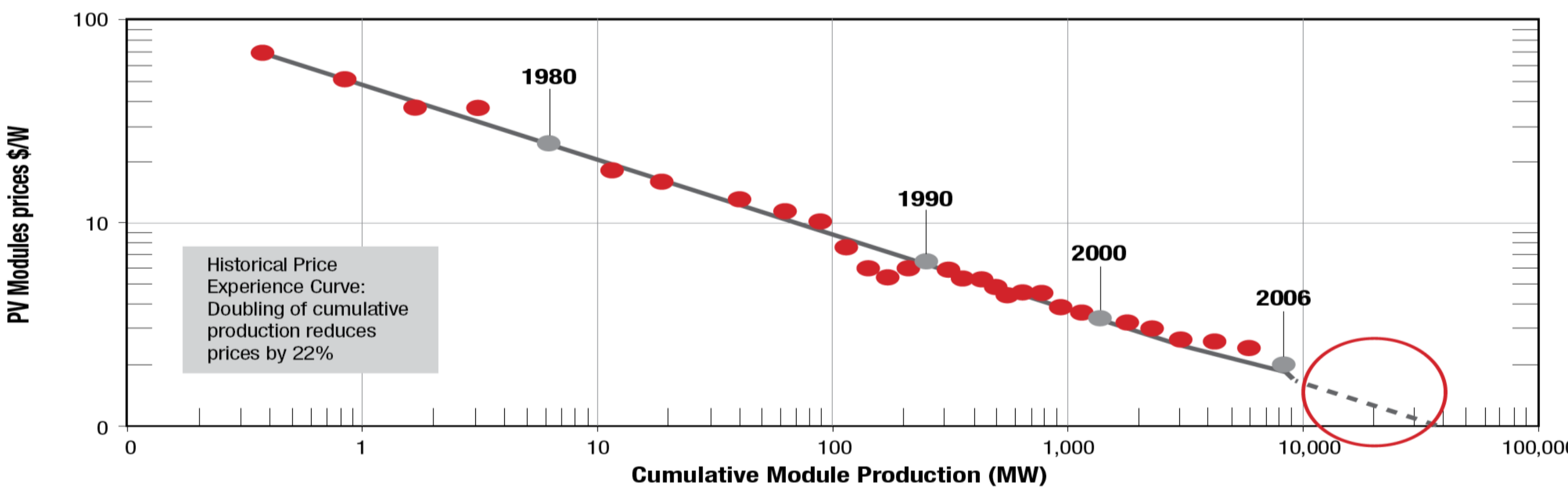
THE DISRUPTIVE CHARACTER OF PHOTOVOLTAICS

PV prices continue to fall rapidly: - ⅓ in 12 months



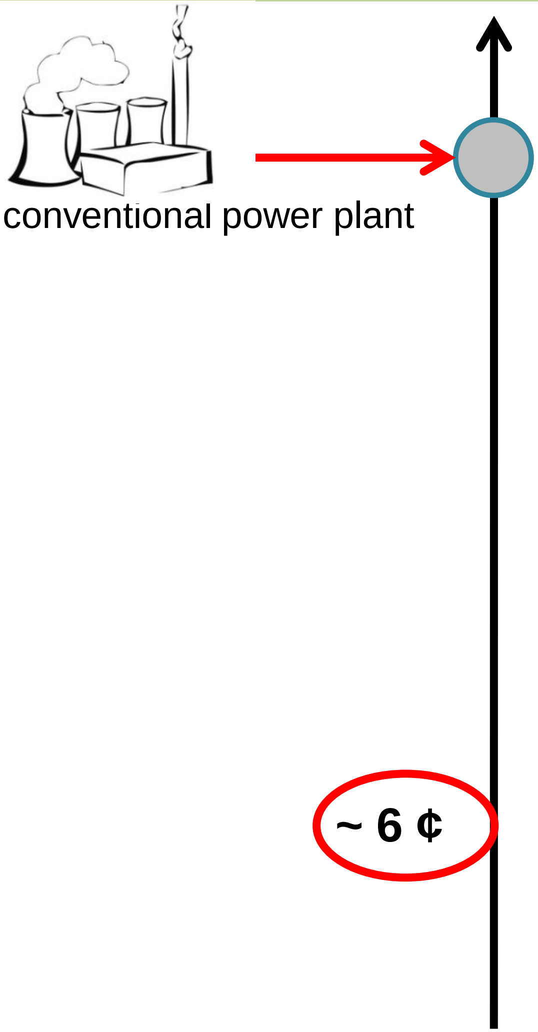
Price decline will go on

- Learning curve similar to other semiconductor technologies
- 22% cost reduction for every doubling of production
- Plenty of cost-reducing innovations in preparation
- Several competing technologies
- Accelerated growth of markets → accelerated cost reduction



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

Modular PV technology: competing on the retail side



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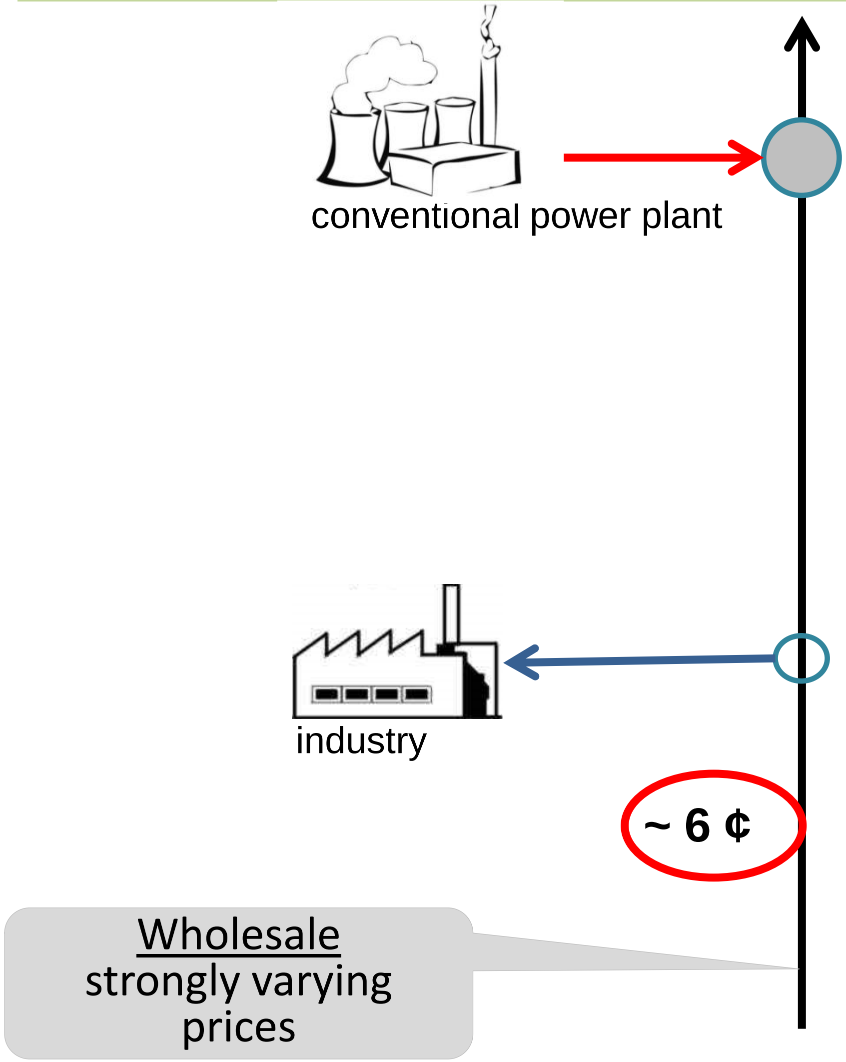

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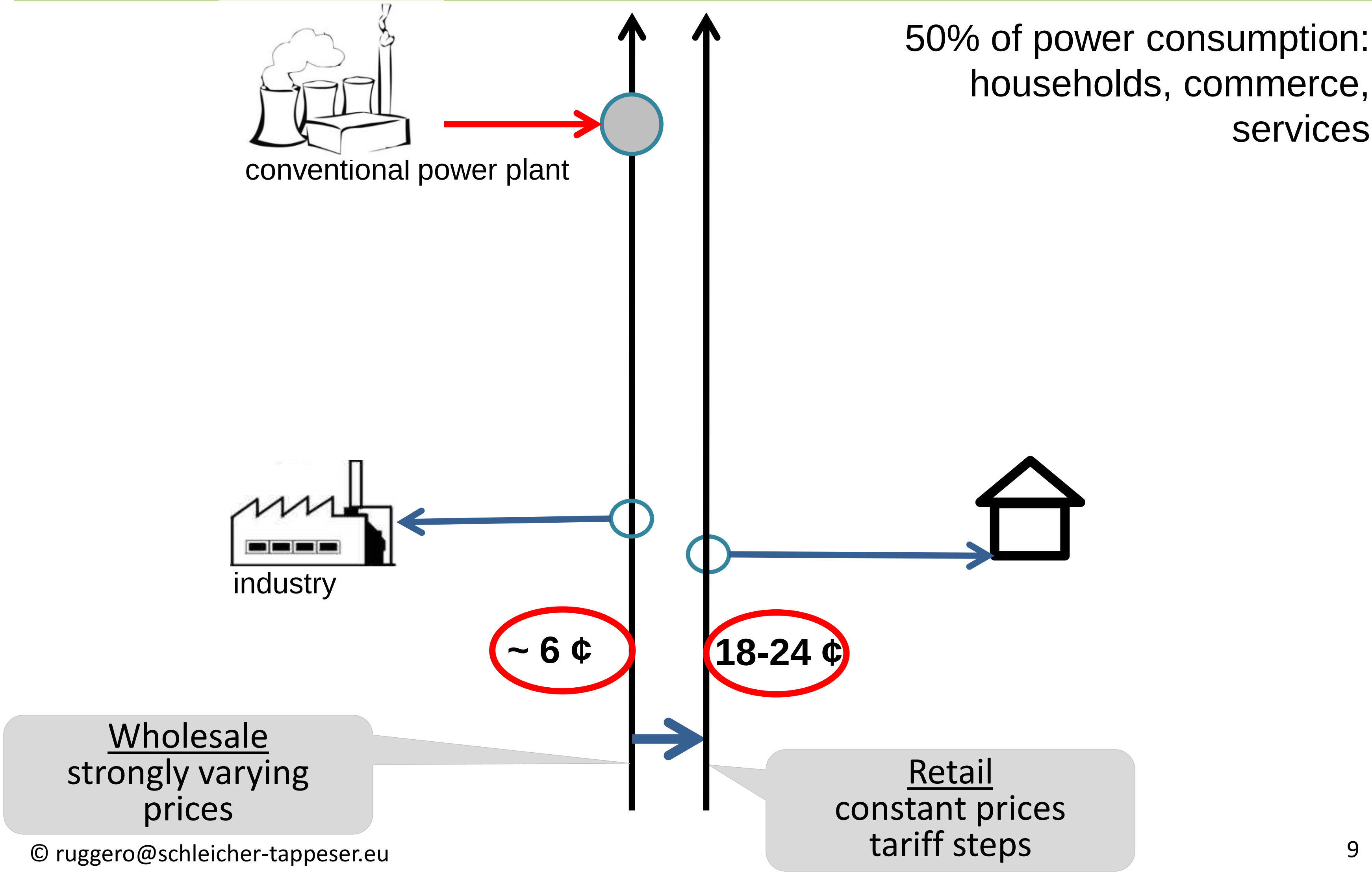

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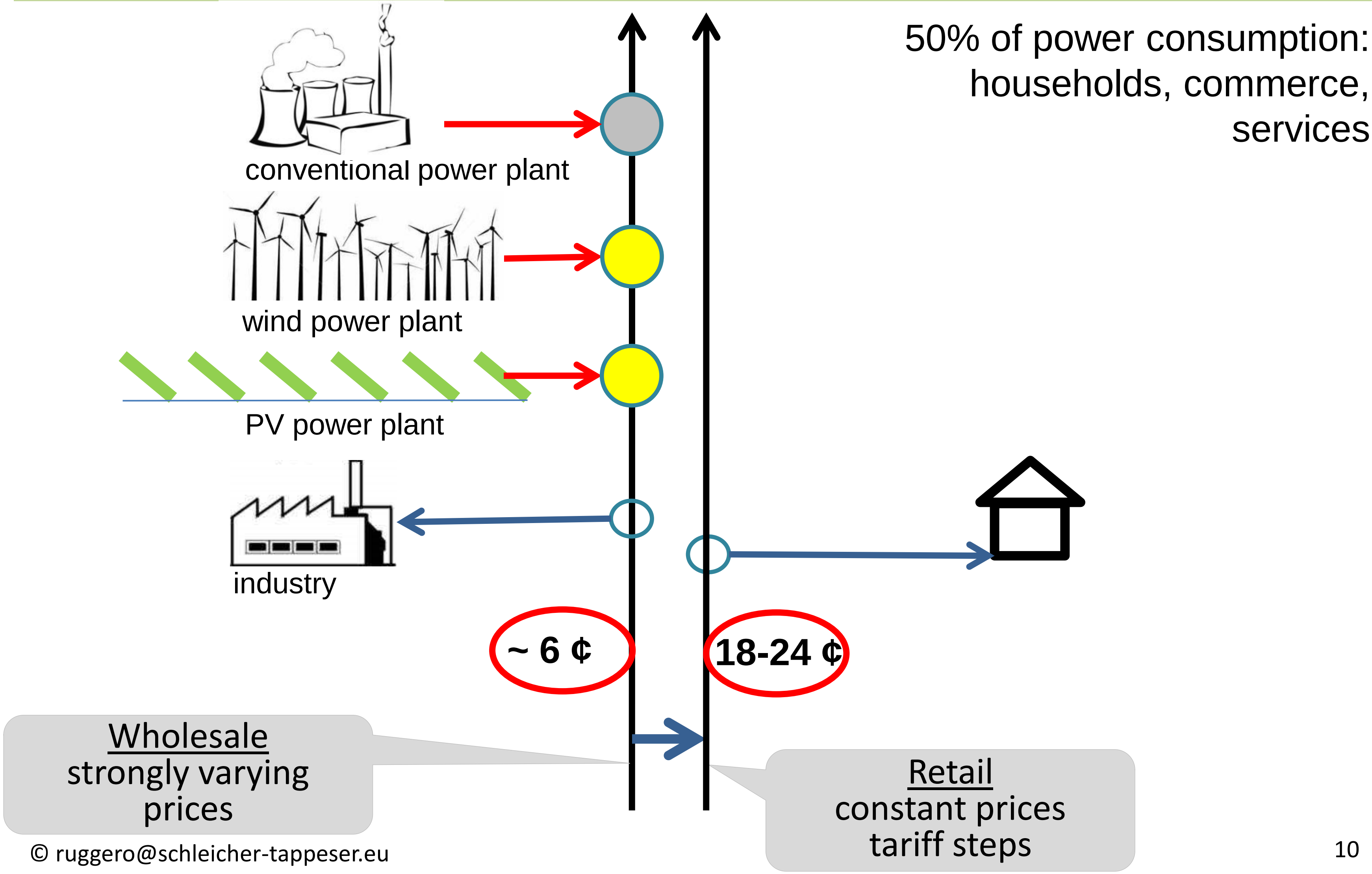

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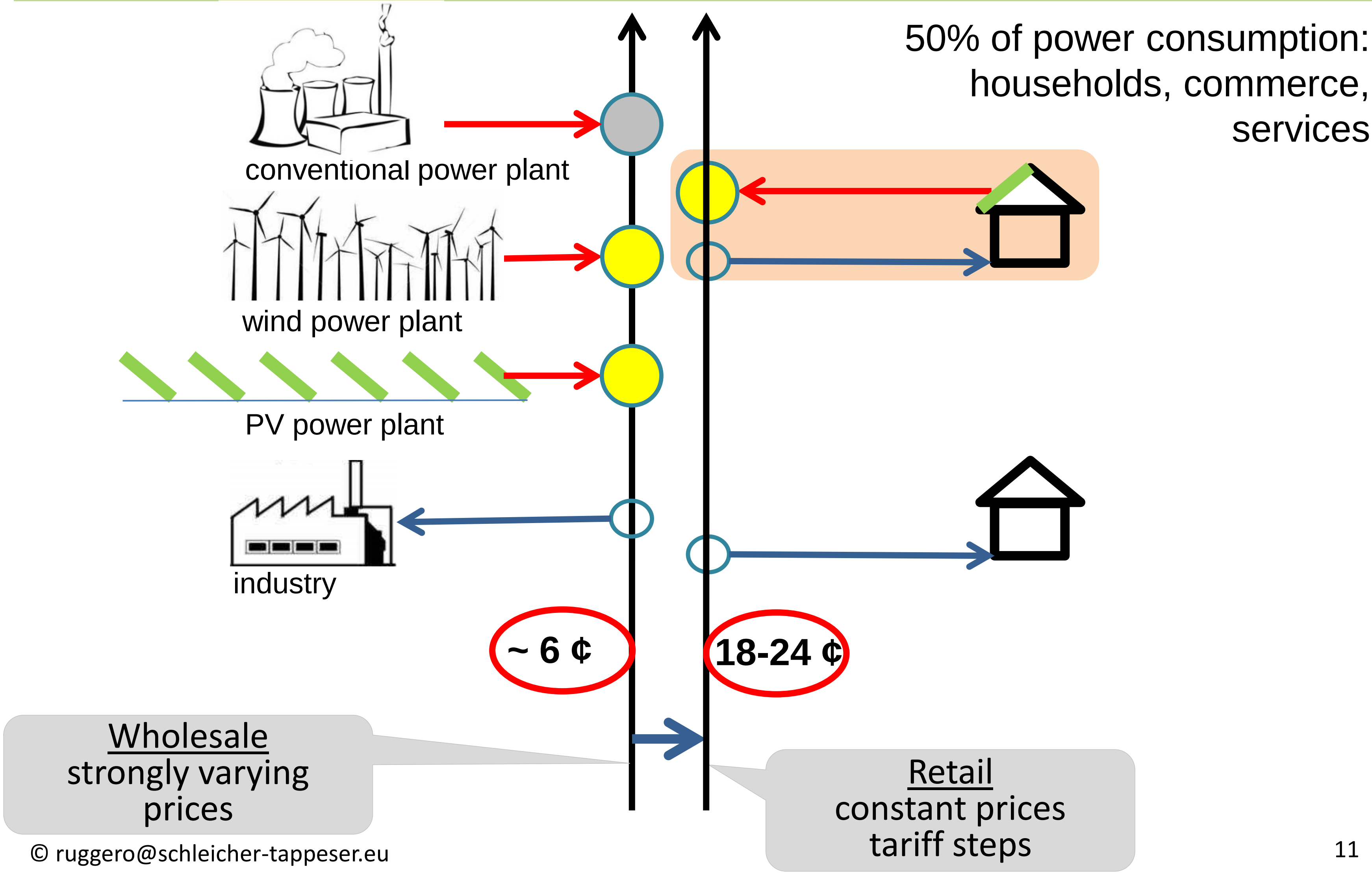

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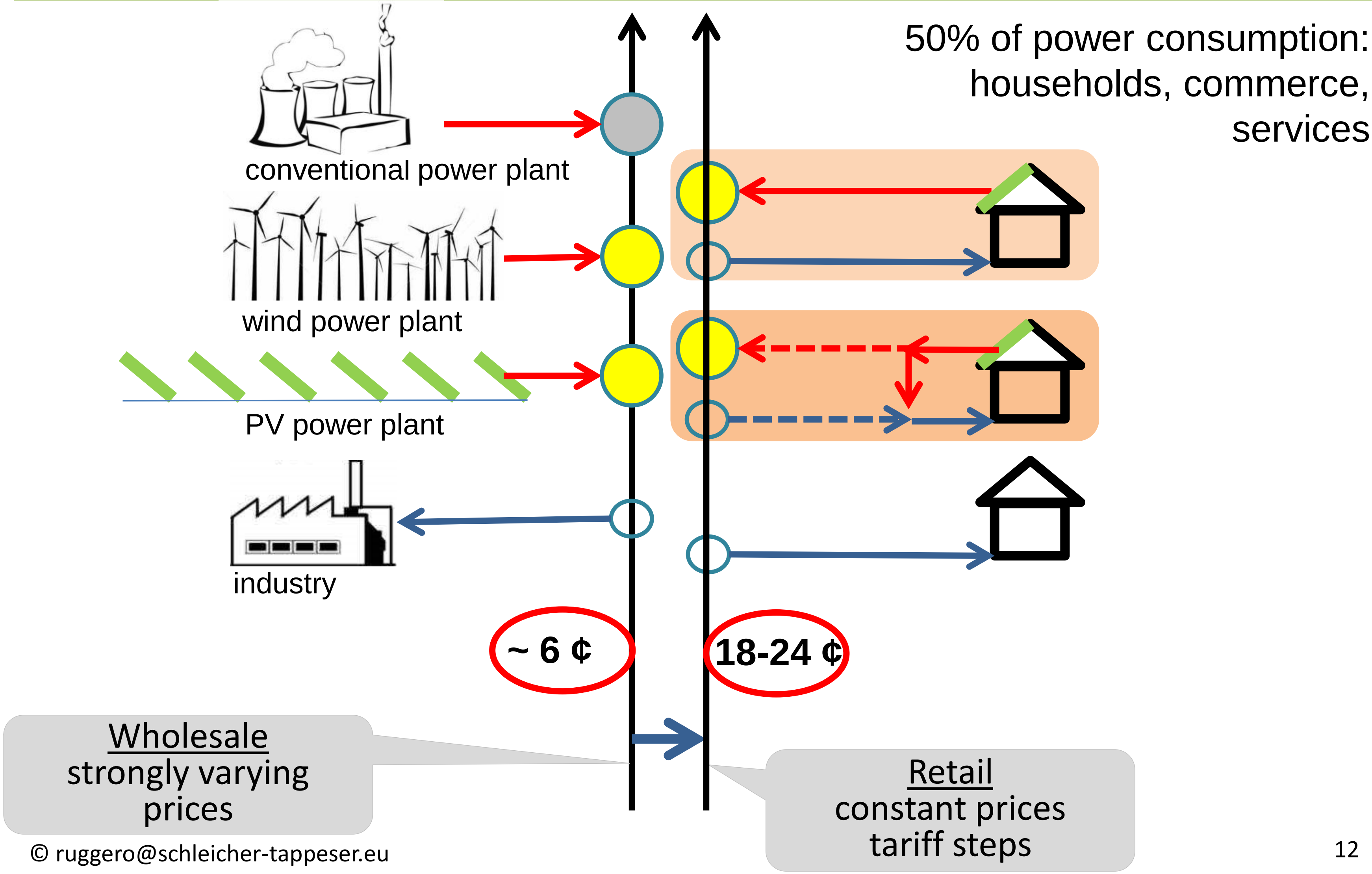

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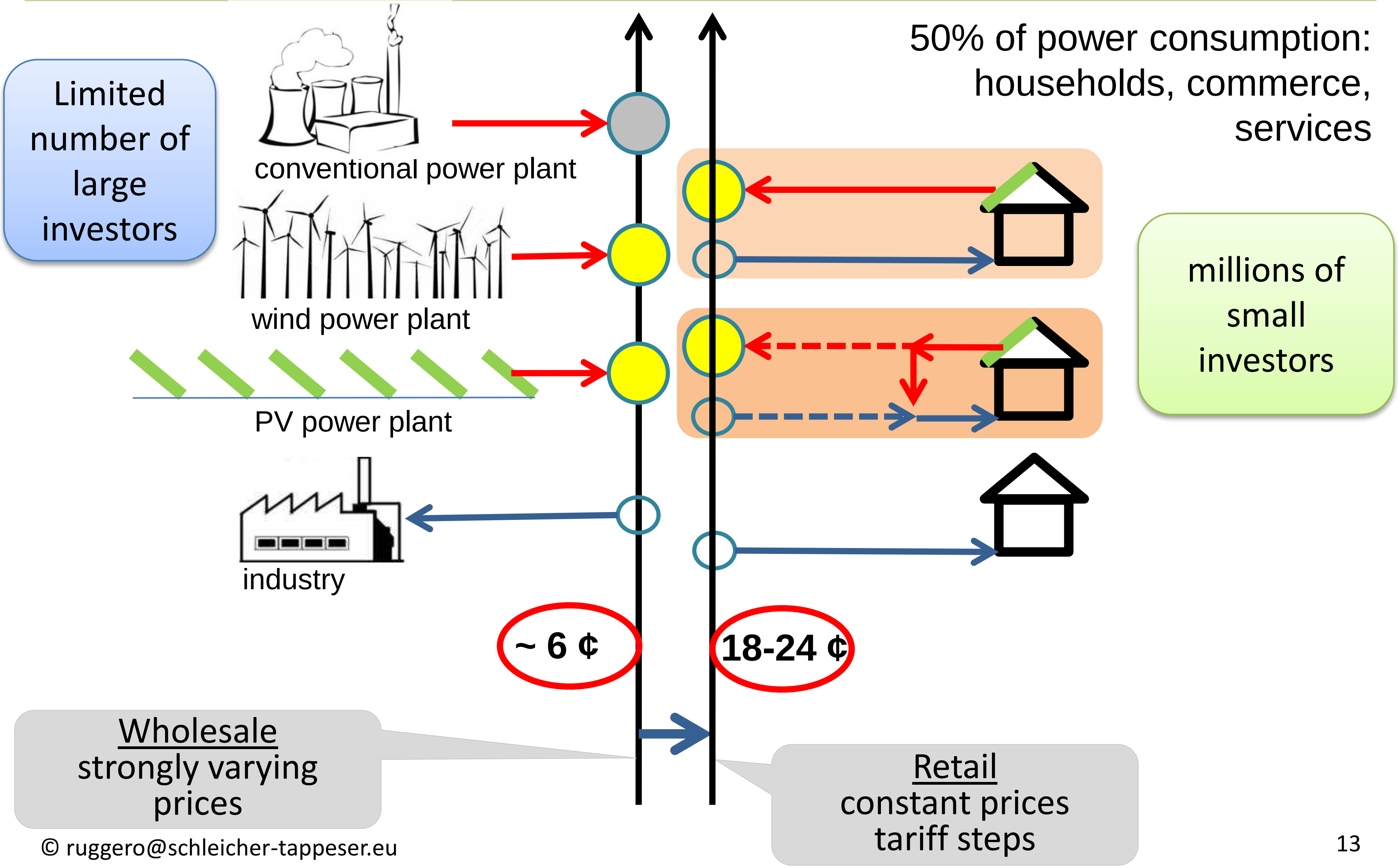

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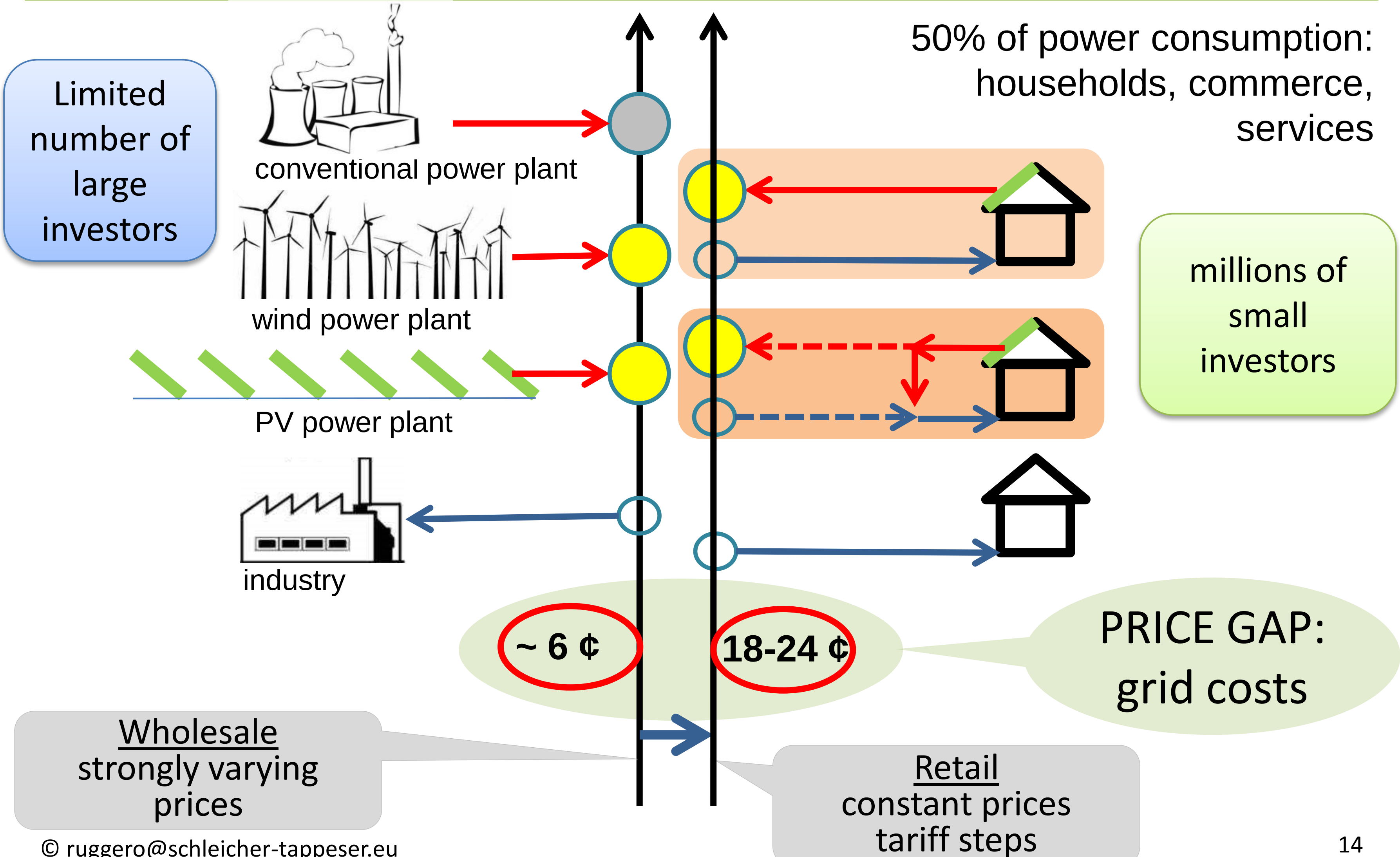
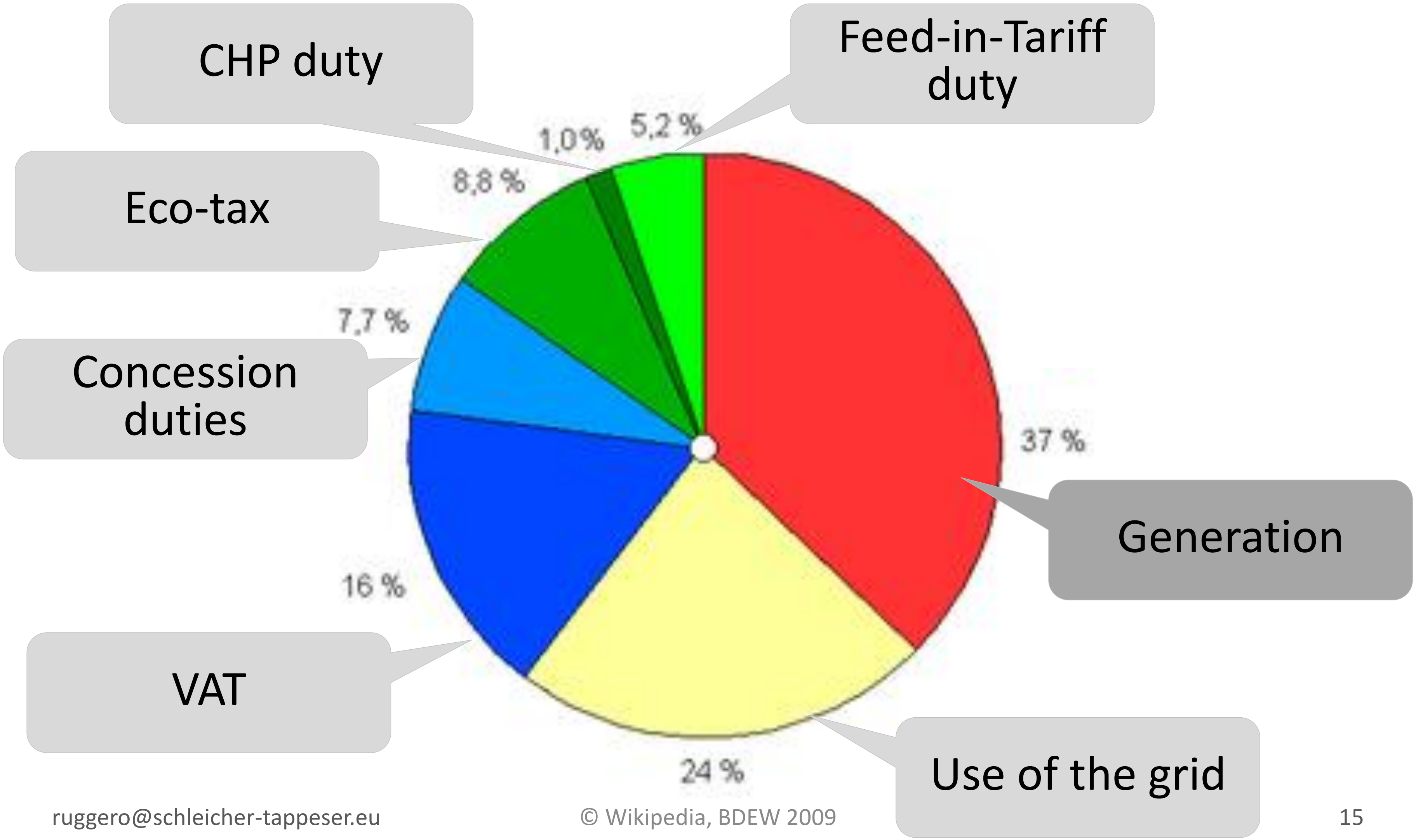
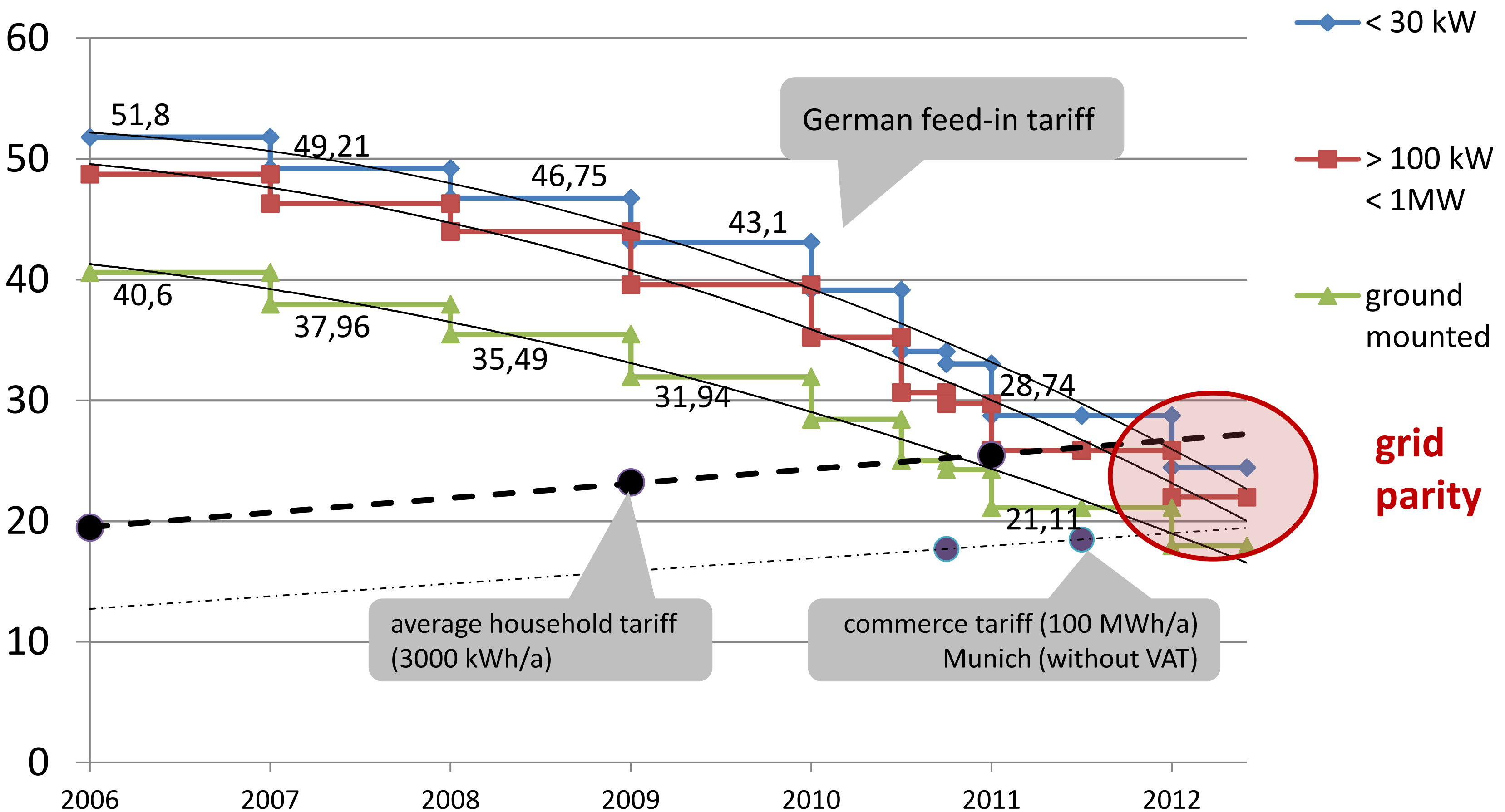


Composition of the retail price in Germany: the costs of the grid



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



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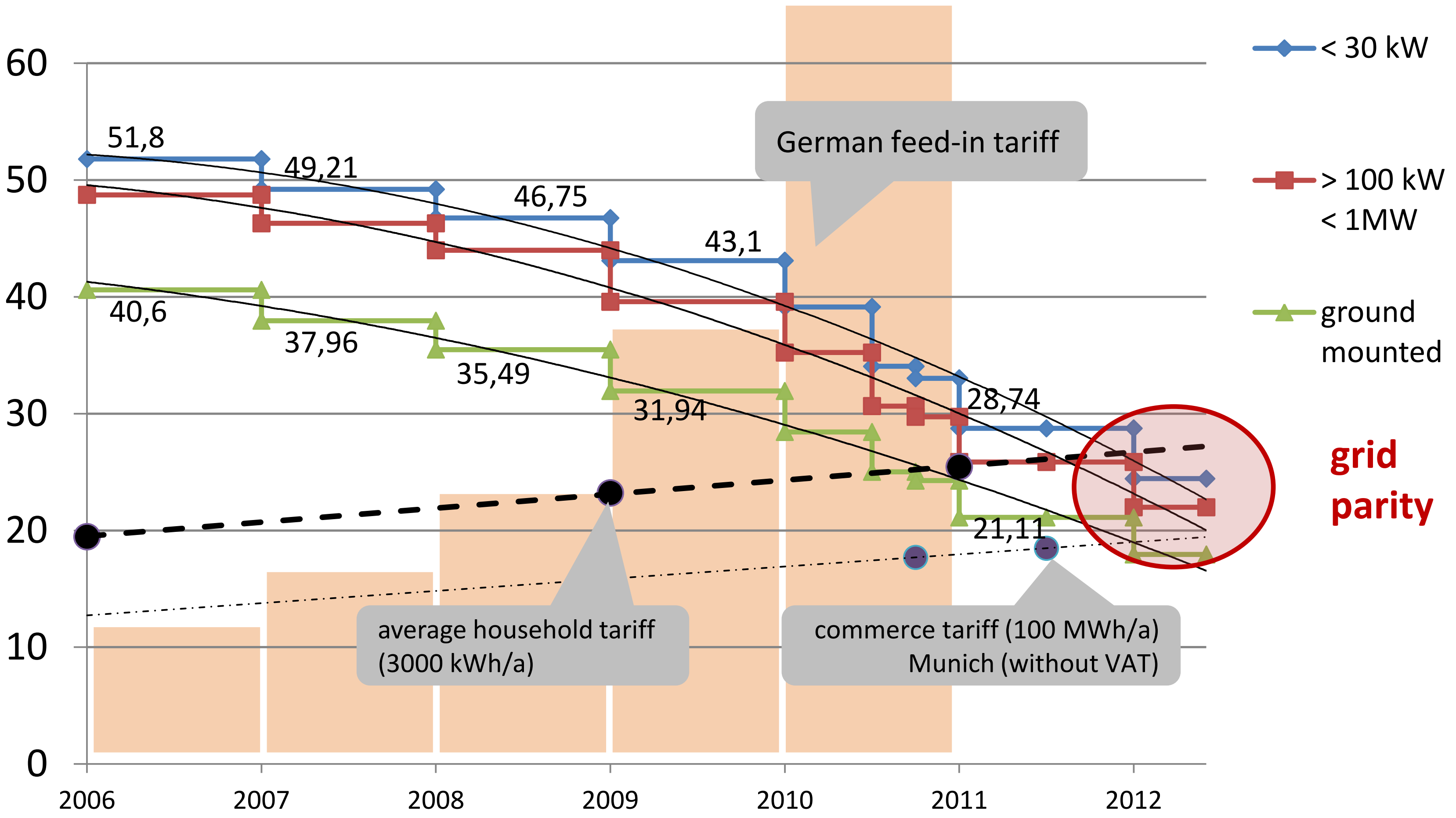


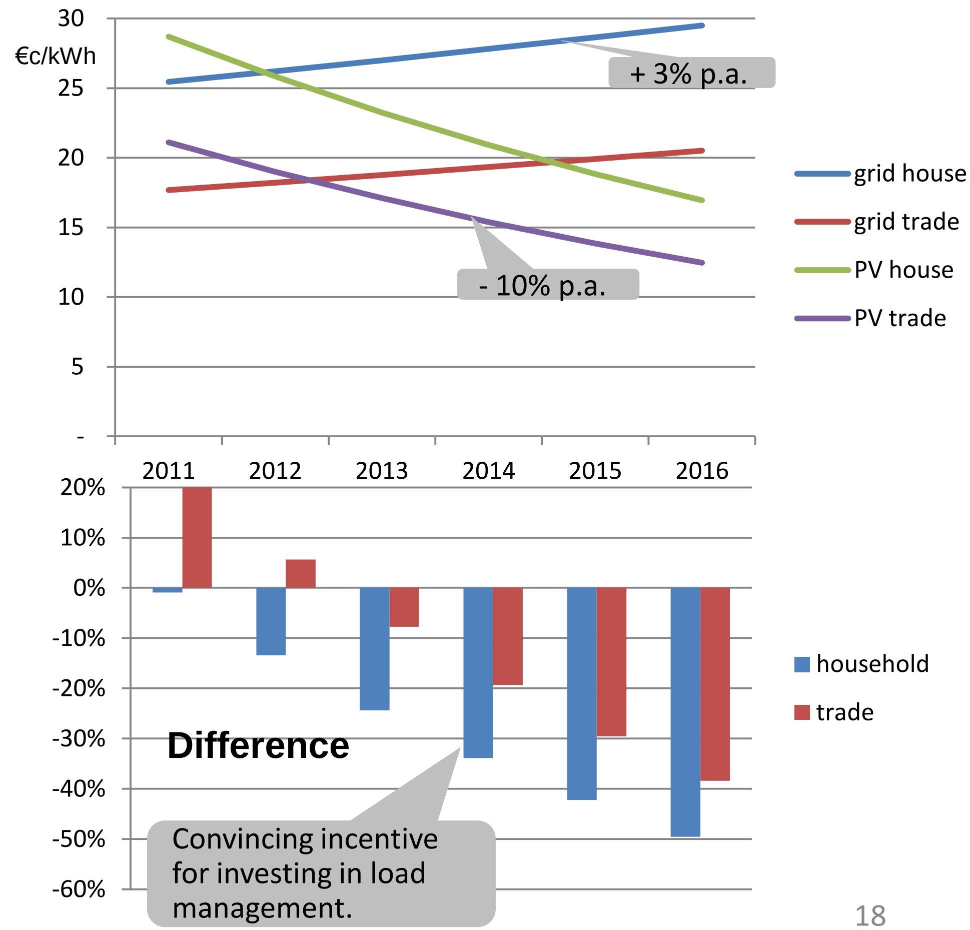
Scenario for the next five years

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

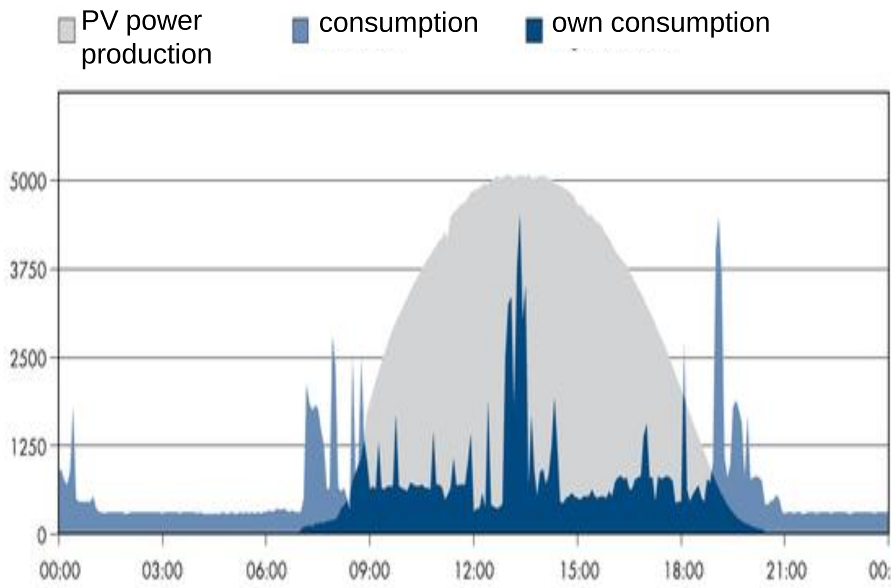
- Scenario assumptions
  - System price development: *-10% p.a*.
  - Power from the grid: + 3% p.a.
  - present FIT in Germany represent present PV power costs

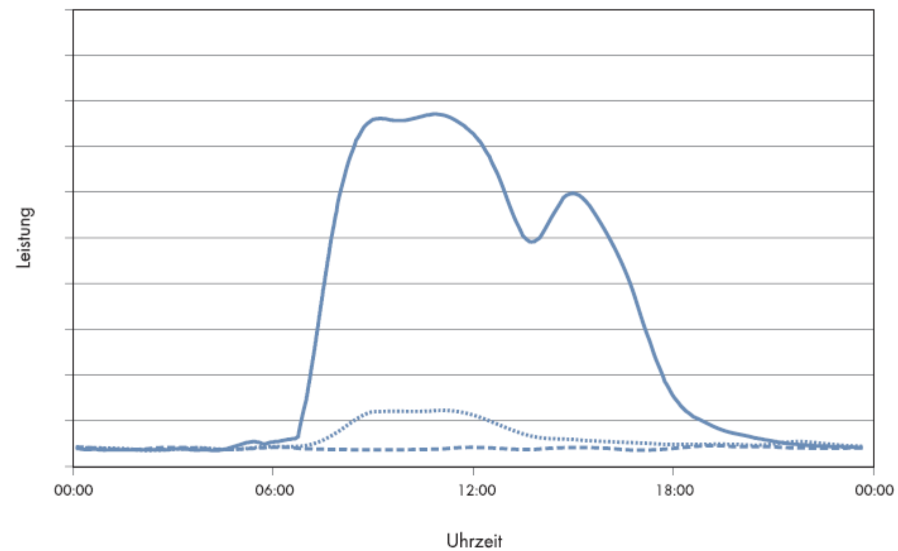
➢ In five years PV power from the roof could cost 40% less than power from the grid

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



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

The coming boom: captive power generation

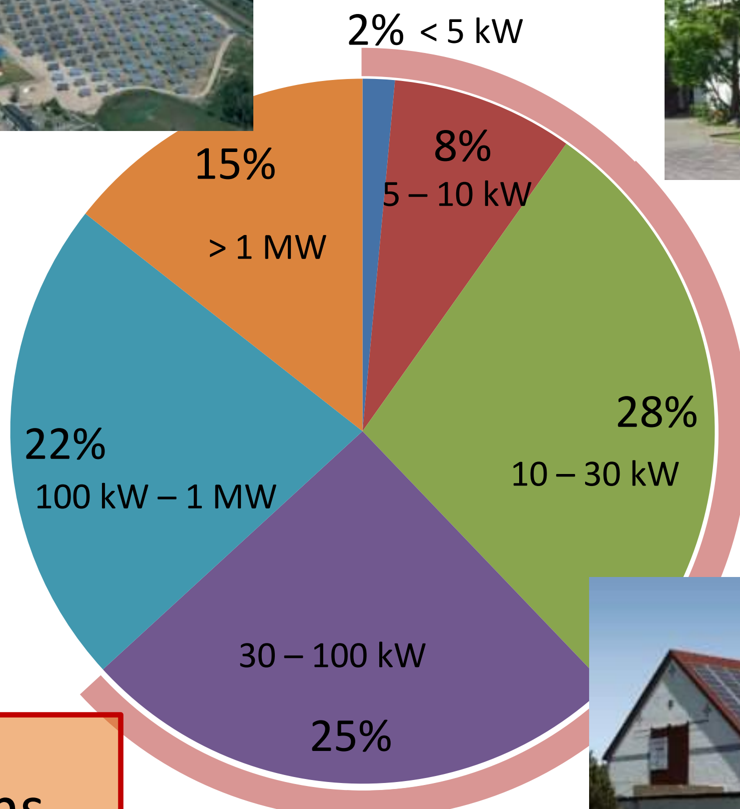
Attractive investments even without incentives:

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

> ➢ PV growth independent from incentives

> ➢ Boom in power management technologies

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

ruggero@schleicher-tappeser.eu

Across the world grid parity is advancing – key parameters

- Electricitry prices in the country considered — €/kWh

- Solar radiation
- Performance of the installation

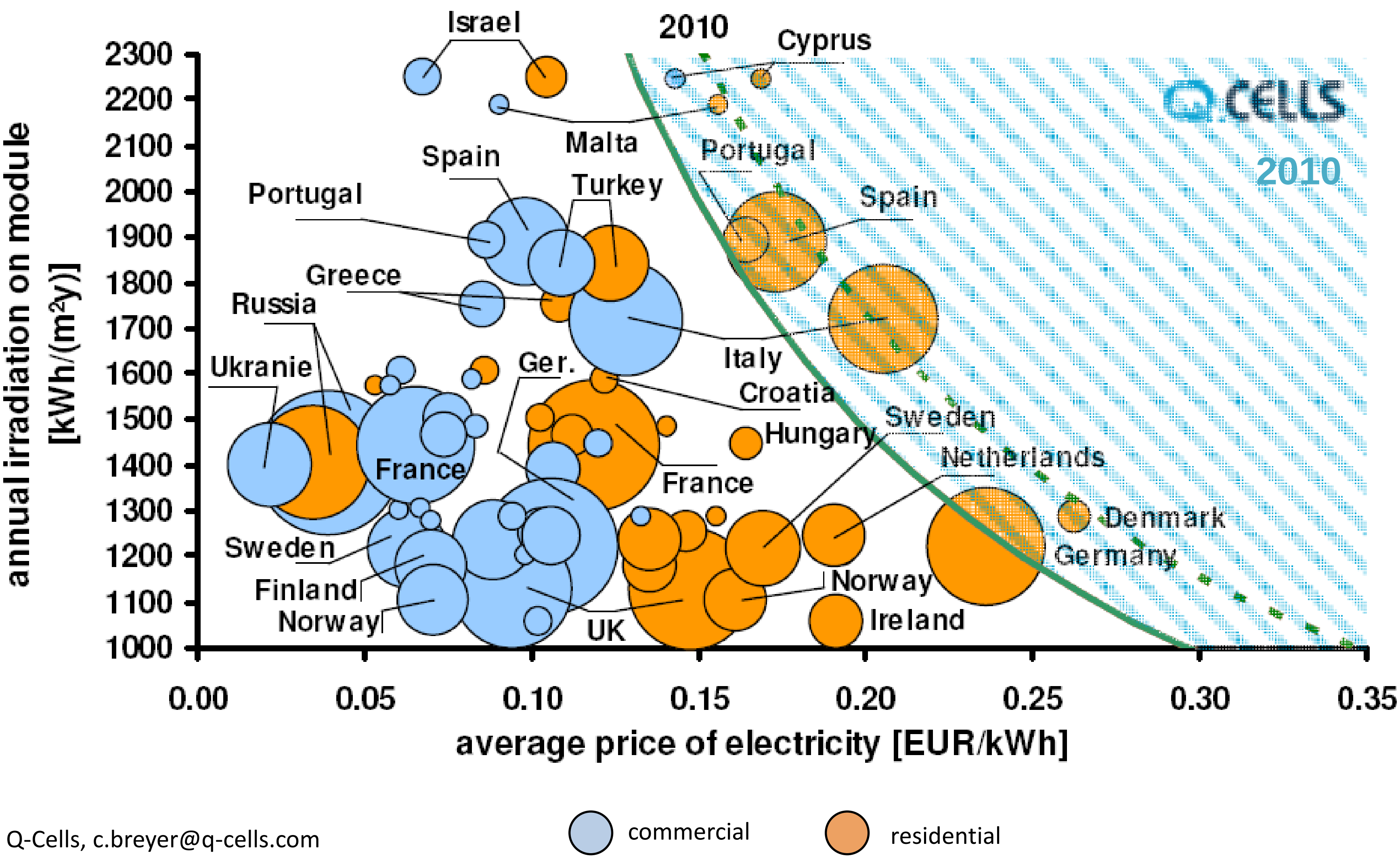
} kWh/kWp

- Investment costs PV
  - Project development, planning
  - Components
  - Installation
- Financing

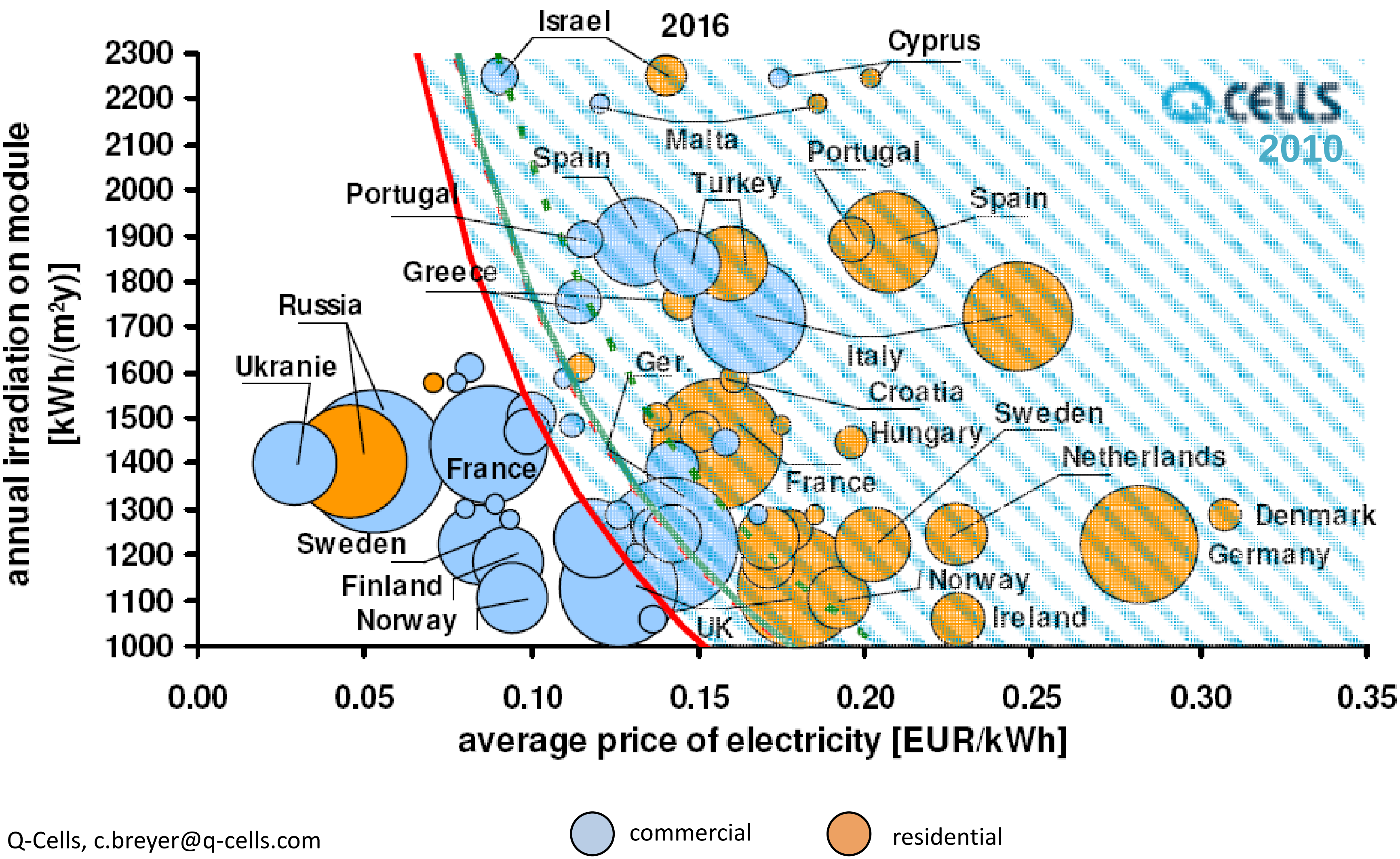
} €/kWp

} €/kWh

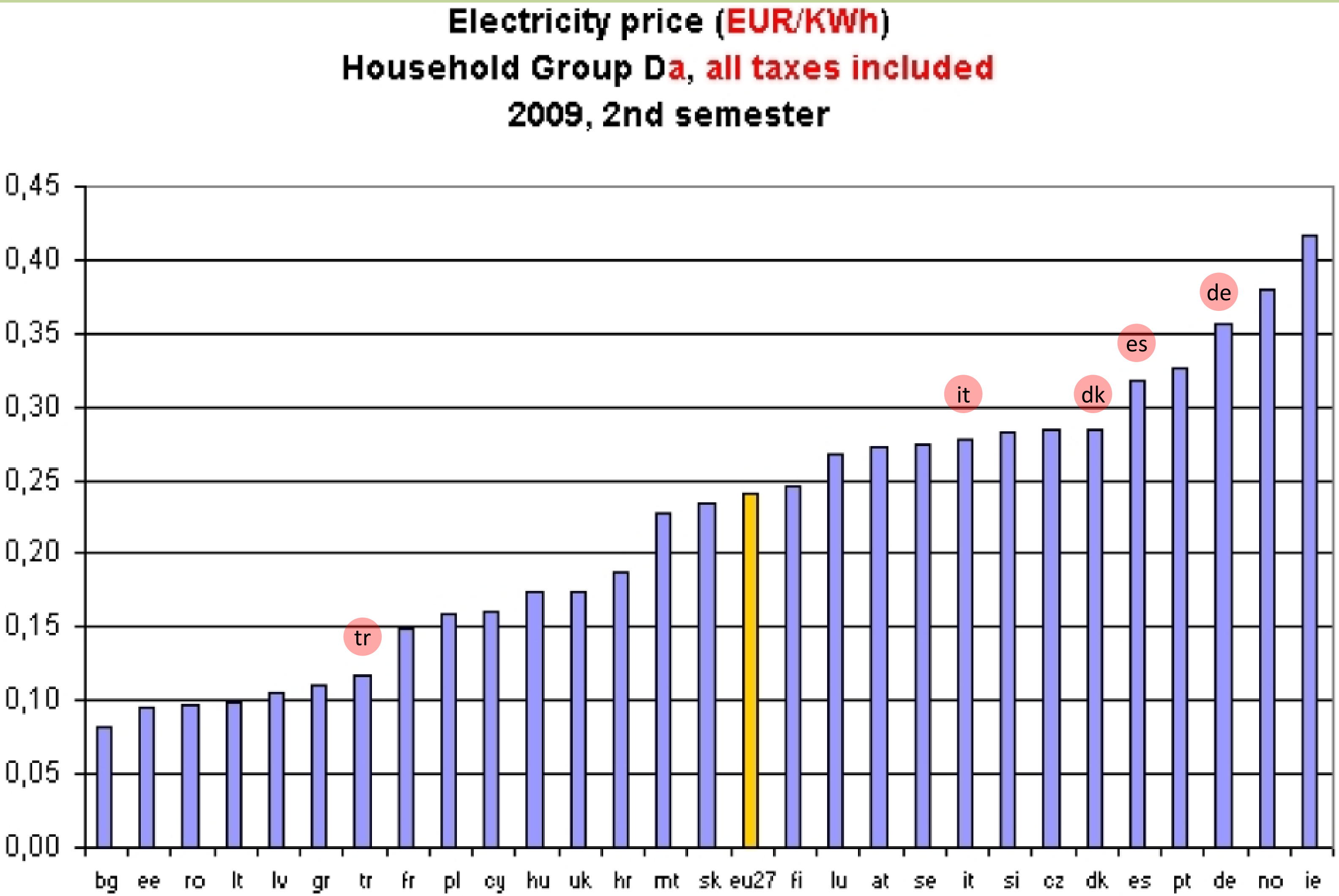
Grid parity in Europe 2010



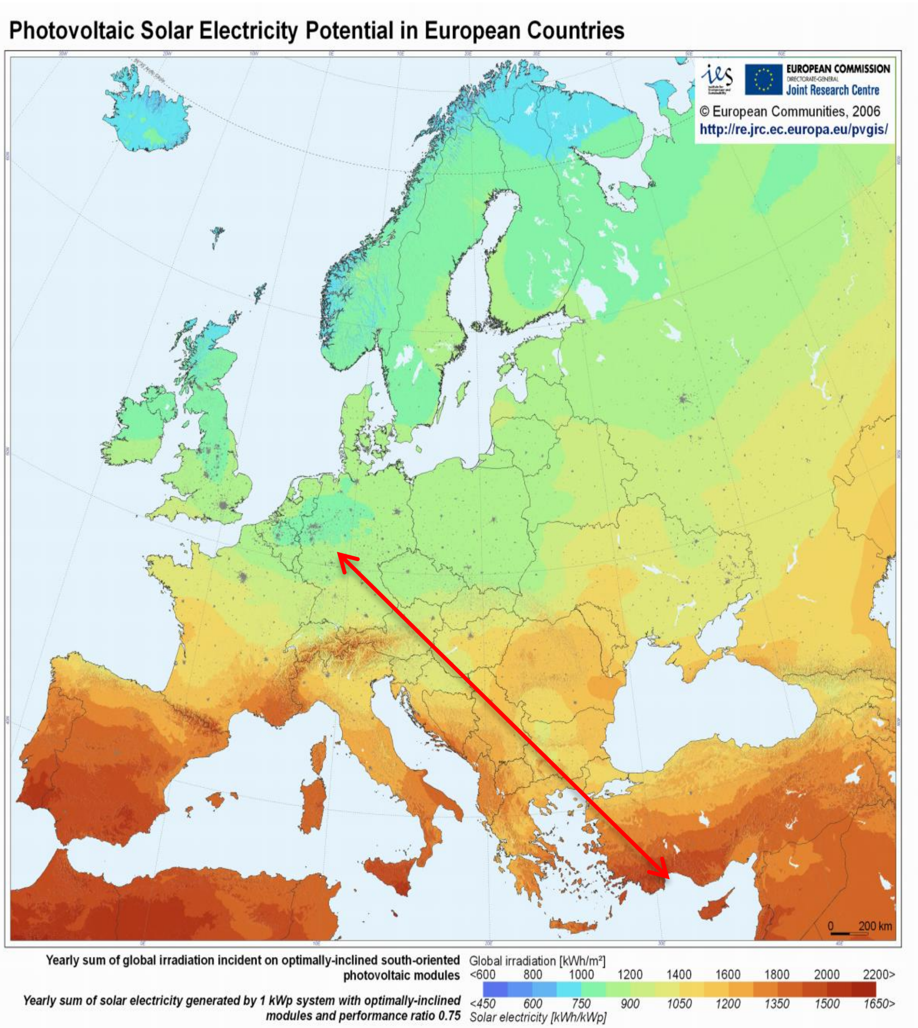
Grid parity in Europe 2016

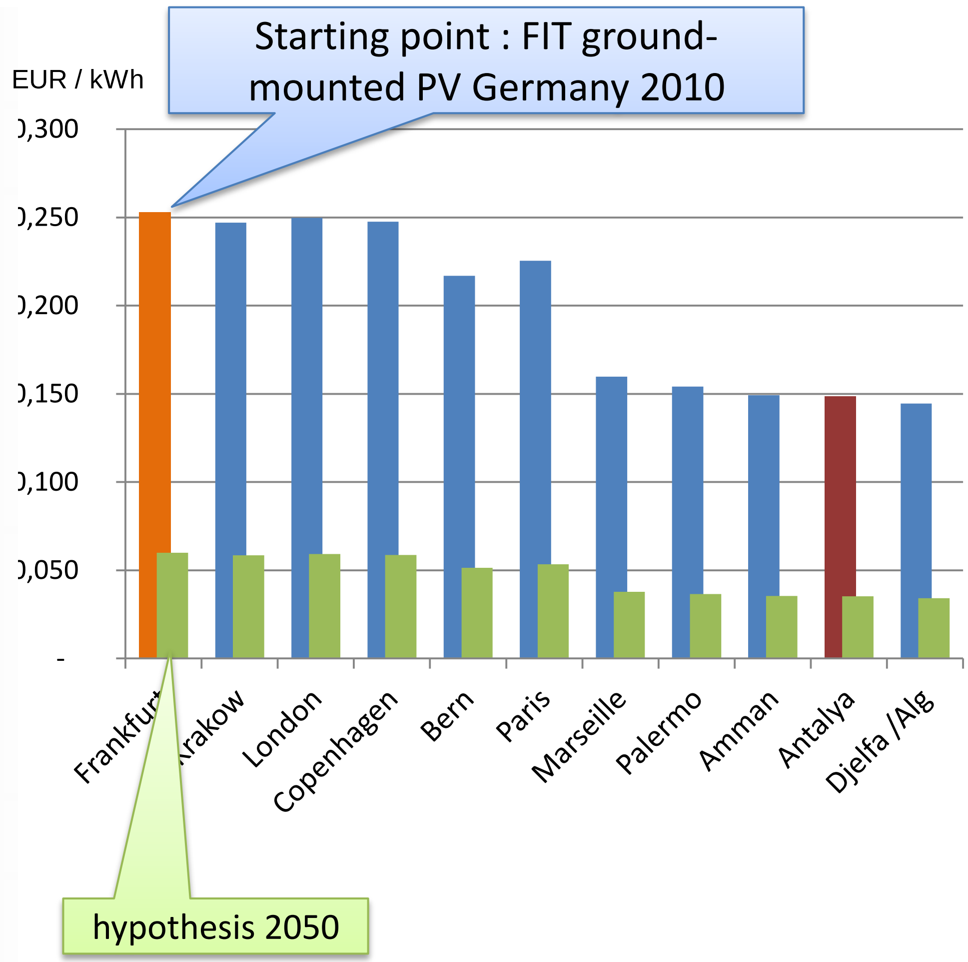


Differences in electricity tariffs are much more important…



… than the differences in solar radiation





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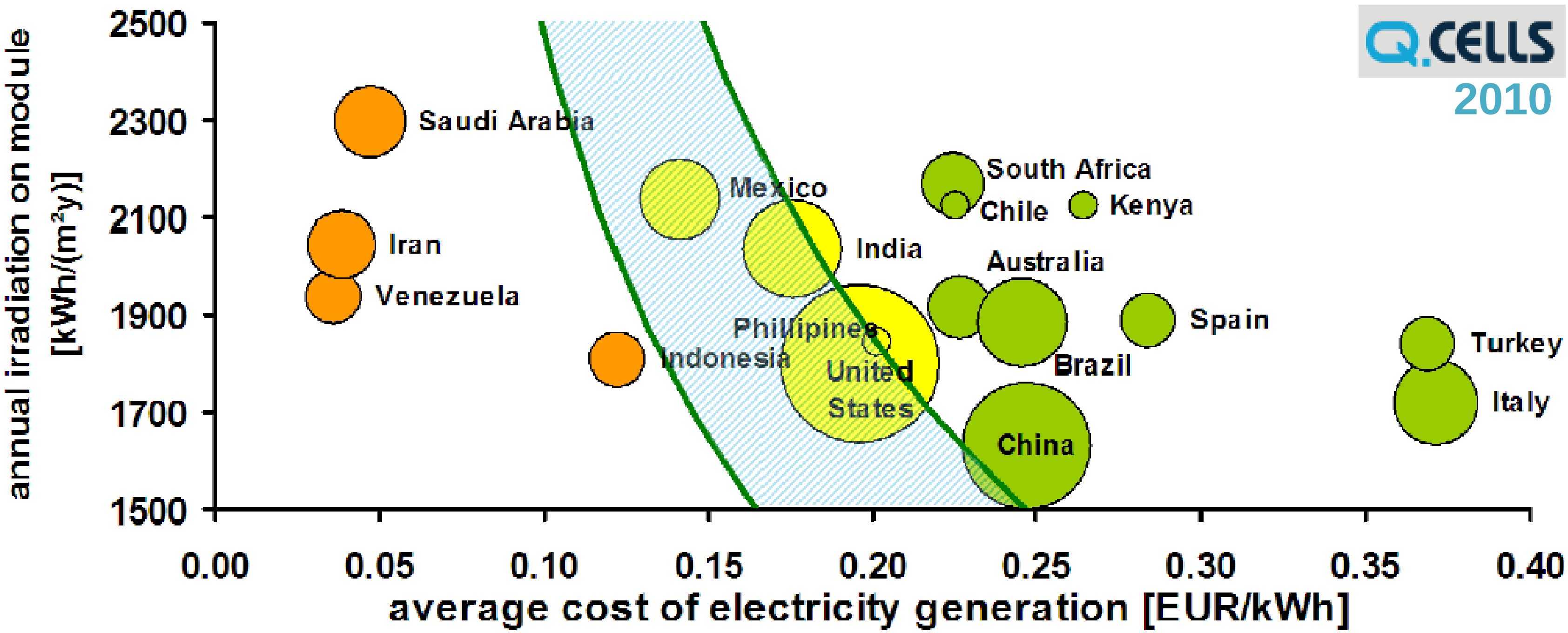
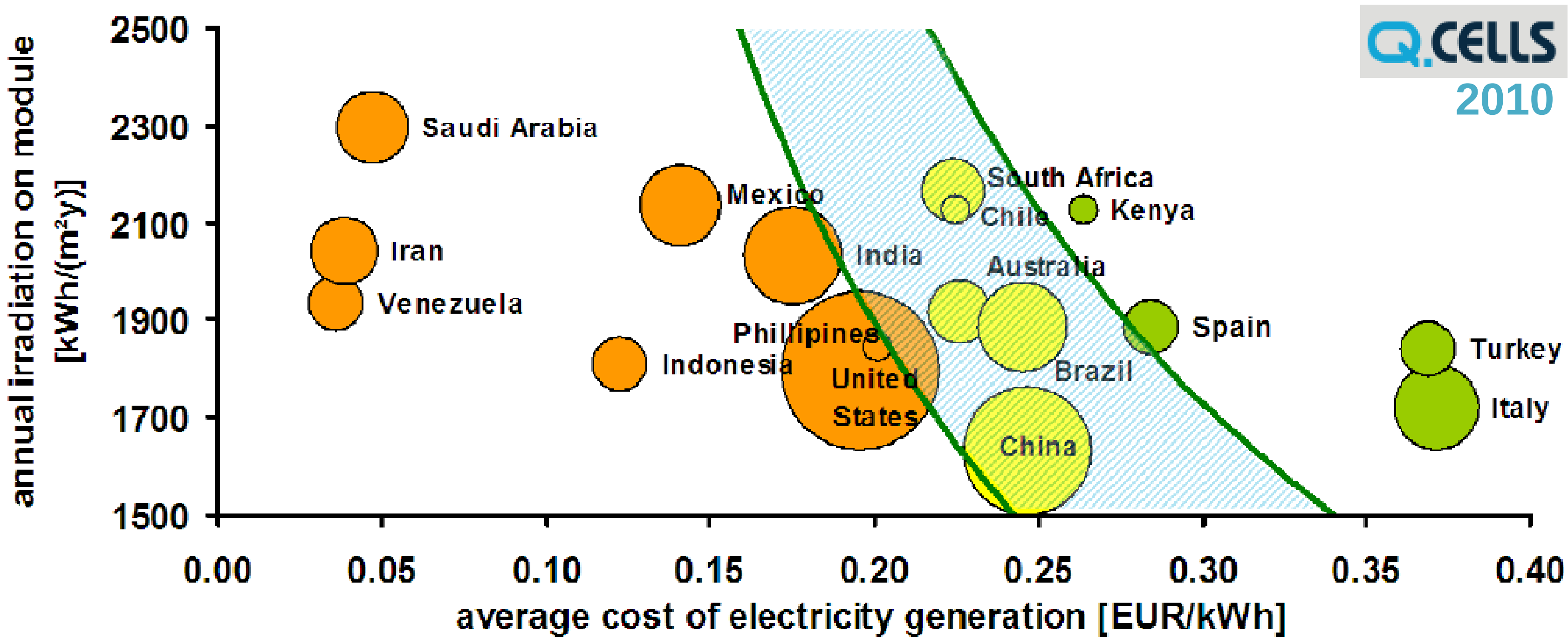
Data: http://sunbird.jrc.it/pvgis

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

TOWARDS A NEW CONTROL LOGIC OF THE ELECTRICITY SYSTEM

Operators try to increase the share of own consumption → deal with fluctuation locally

- 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)
- Storage of electricity
  - Batteries
  - Flywheels

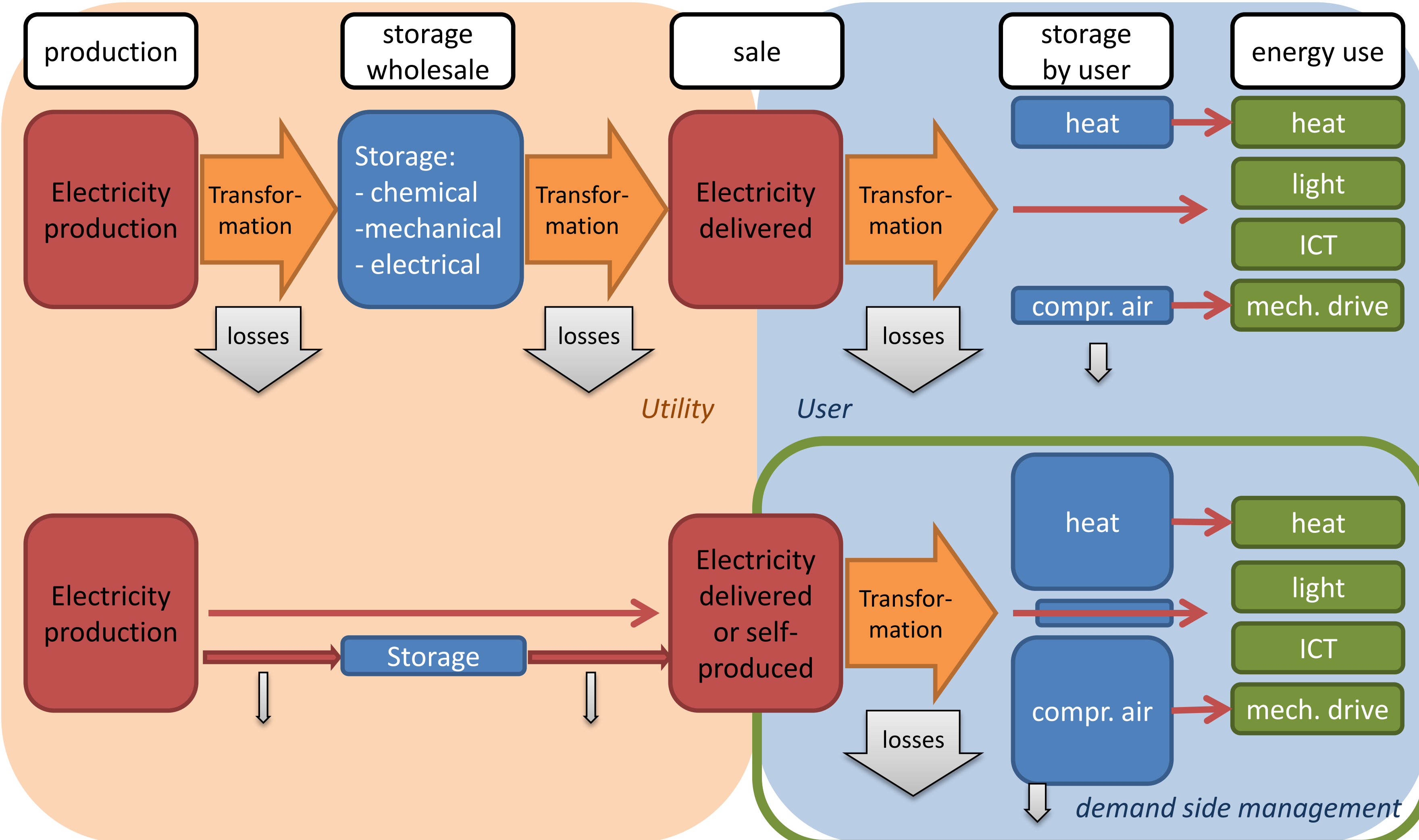
➢ Flexibility of the user system increases

Fluctuating power in the electricity system: Strategic choice of storage opportunities

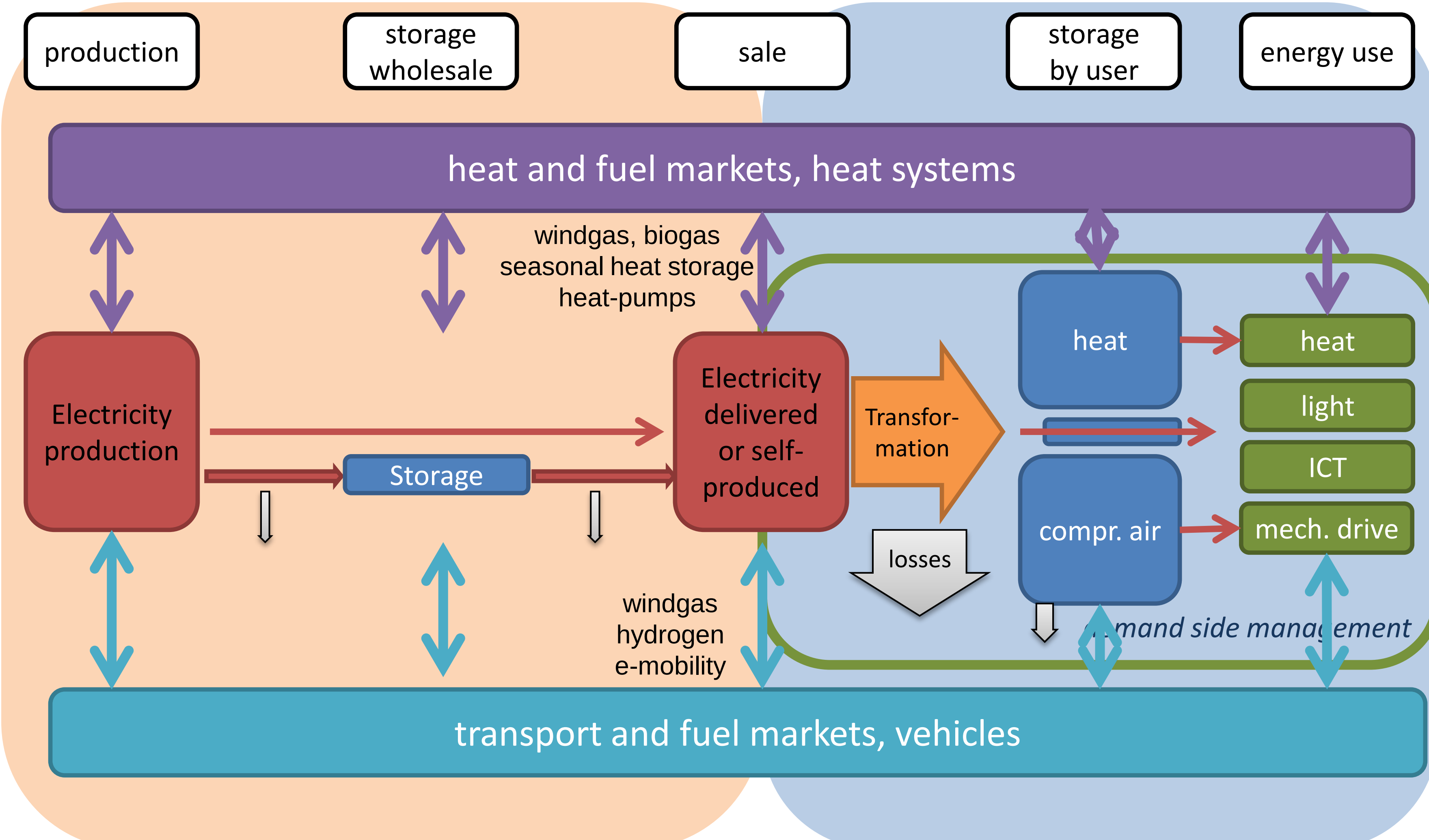
- Storage I – focus on electricity:
  electricity in, electricity out
  - condensers (storage in electric field)
  - batteries, hydrogen/ fuelcell, synthetic methane/cogeneration (chemical storage)
  - flywheels, compressed air (mechanical storage)
- Storage II – systemic approach to the usage chain:
  electricity in, other energy out:
  - heat storage for most heat applications (buildings, production…)
  - compressed air for mechanical applications (production processes)
  - chemical energy for heat applications and mechanical applications (synthetic fuels for heat and transport)

➢ Less losses with systemic approach

Less losses with systemic approach



Less losses with systemic approach: stronger coupling with heat and transport



Potential for load management
(using different kinds of storage)

Shares in power consumption 2008 (Germany)

	Heat	Cold	Mech. Energy	ICT	Light	Sum
Industry	7,9%	1,9%	30,6%	1,8%	2,1%	44,4%
Trade & services	3,5%	2,1%	5,7%	3,9%	10,6%	25,9%
Housholds	13,7%	5,3%	0,6%	4,6%	2,3%	26,6%
Transport	0,2%	0,0%	2,7%	0,2%	0,2%	3,1%
TOTAL	25,3%	9,4%	39,6%	10,5%	15,2%	100,0%

Options: heat storage, compressed air storage, shifting operation

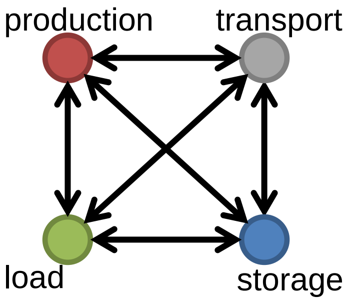
Overall: <u>high potential for innovation</u> – <u>process owner decides</u>

A new innovation wave: power management technologies

- Until now missing incentives for load management, smart homes, buildings ... → neglected opportunities
  - ICT technologies exist, no large-scale diffusion, missing standards, large companies awaiting 12-digit turnovers
  - New storage technologies emerging
  - Coupling with heat market not developed, heat storage options neglected
  - No priority in the design of production processes, process owners not motivated
  - ➢ Huge neglected development potential
- In three years cheap local PV gives strong incentives → innovation wave

Captive power production can facilitate the system change …

- 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

<table>
<tr>
<td>Traditional
Large power plants fossil and nuclear
Transformation</td>
<td>

- Production follows demand: base / middle / peak load
- Load management only with large consumers
- Central control

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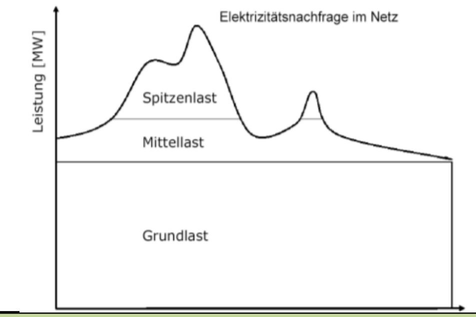
<td>
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<tr>
<td>Supply 100% REN
Integrated optimisation of the whole system</td>
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- Fluctuating production with wind and sun dominates
- Load management, storage
- Complexity requires optimisation on several levels

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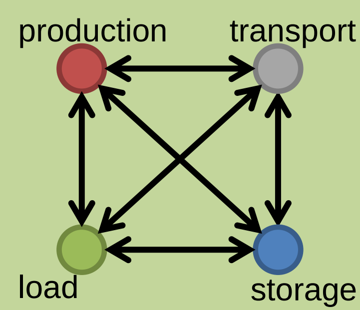
<td>
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<tr>
<td>Contribution
Captive power production
Optimisation on the consumption level</td>
<td>

- Optimisation subsystem
- Partial buffering of fluctuations at the local level
- Facilitation of optimisation at higher levels

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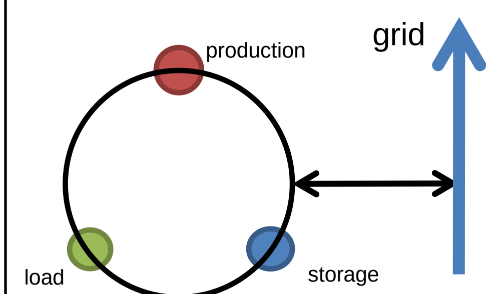
<td>
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Captive power production challenges present market & control structures

- Grid increasingly reduced to buffer function → rising costs per kWh → need to use consumer flexibility for own optimisation
- Present tariffs favour new peak grid loads (in and out)
- FiT level looses control over PV growth
- FiT remains essential for installations with low own consumption

➢ Need for time-dependent and power-limiting tariffs guiding the input/output optimisation of private systems

❖ Every distribution grid has its own optimisation requirements: grid pattern, generation and consumption structures differ

→ → Under present rules, optimised private systems may rapidly produce new heavy burdens to the public grid infrastructure

Three Scenarios

1. Business and Regulators seize the opportunity
   - rapid transformation of the electricity system requires strong efforts, steady monitoring and mutual learning
   - rapid transition towards renewables
   - low costs for electricity consumers
2. Regulators fail to act in time, business acts
   - Rapid growth of distributed captive power production with PV
   - Heavy problems in grids, mistaken investments
   - Sudden policy changes, market disruptions, costly adaptation
3. Adequate business models missing
   - Slow development of captive power generation
   - Heavy investments in centralised renewable power
   - Later breakthrough of captive power pushed by non-European companies
   - Oversized and costly public system – who pays?

Location matters – The centralistic approach is getting unsustainable

- Traditionally national monopolistic utilities planned central generation and corresponding grids for a given demand → coherent systems
- Liberalisation has brought diverging developments:
  - competition for use of conventional generation plants at national level
  - regulated monopolistic planning for construction and use of grids
  - slow unbundling of grid planning and power plant siting
- Feed-in-tariffs:
  - renewable power use: regulated priority for fluctuating sources
  - free choice of location for investors

➢ The real grid is not a copper plate – geography matters!
  - Plant siting not coherent with existing grid
  - Fluctuating renewables permanently change flow patterns
  - ❖ PV prosumers change demand patterns – but could mitigate fluctuations

➢ Need to consider existing grid structure → location-dependent prices

➢ Need for stronger coupling with European partners

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

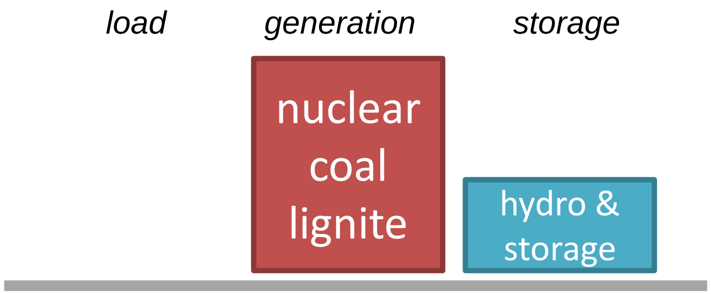
load *generation* *storage*

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

load *generation* *storage*

nuclear
coal
lignite

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



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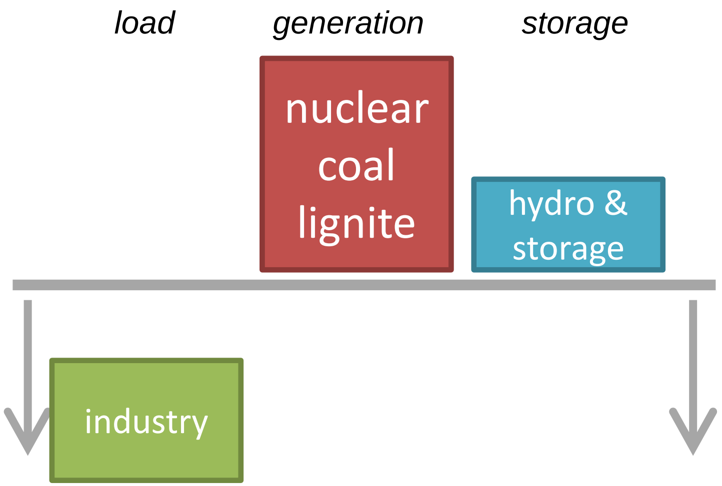

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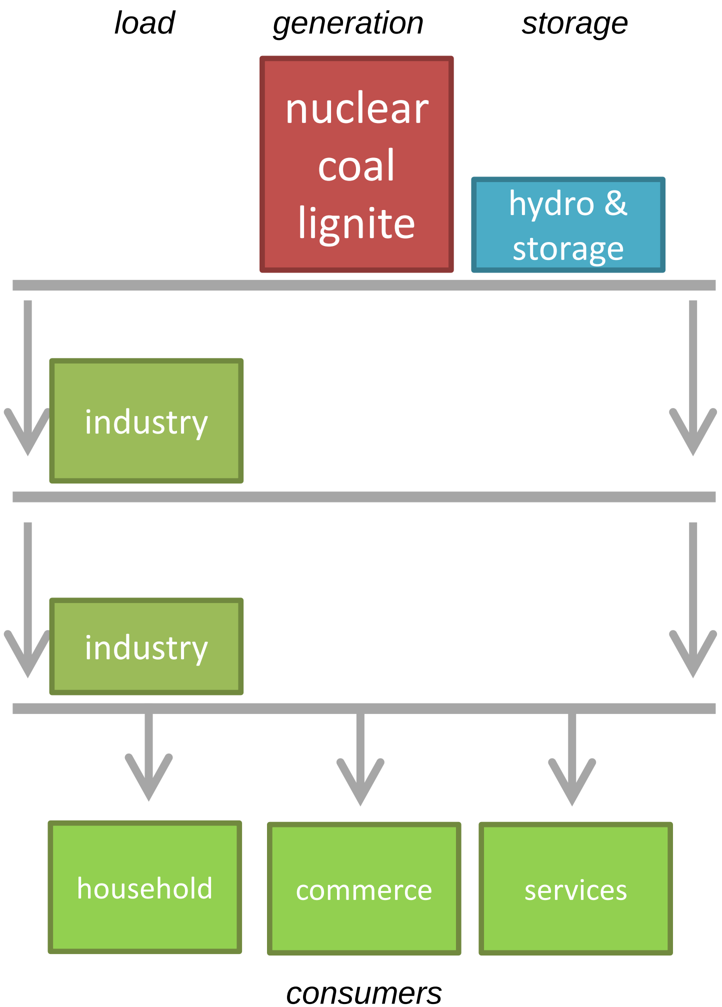

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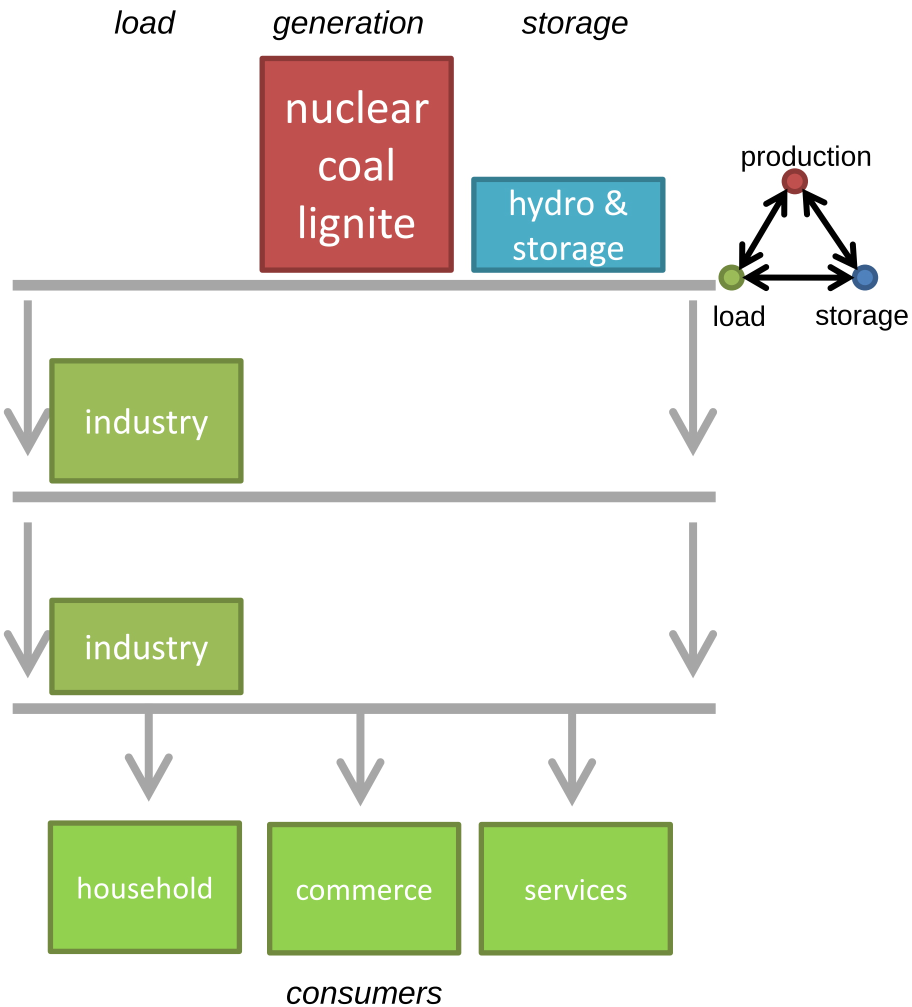
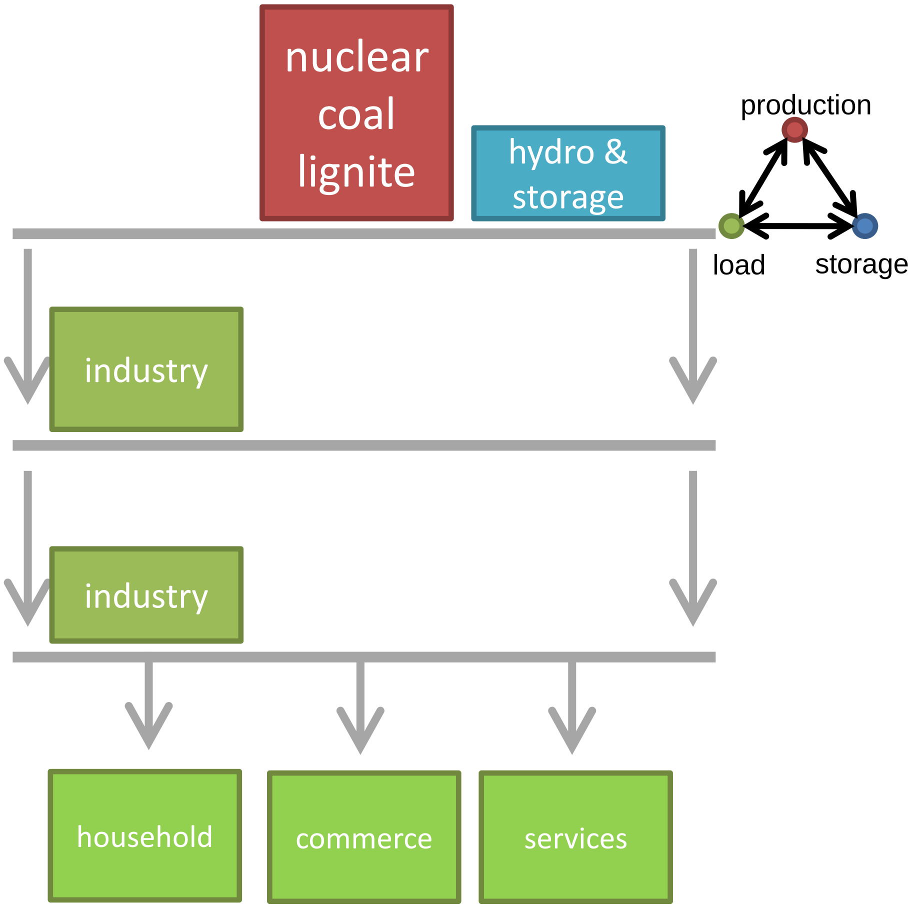


From top-down command to multi-level co-ordination

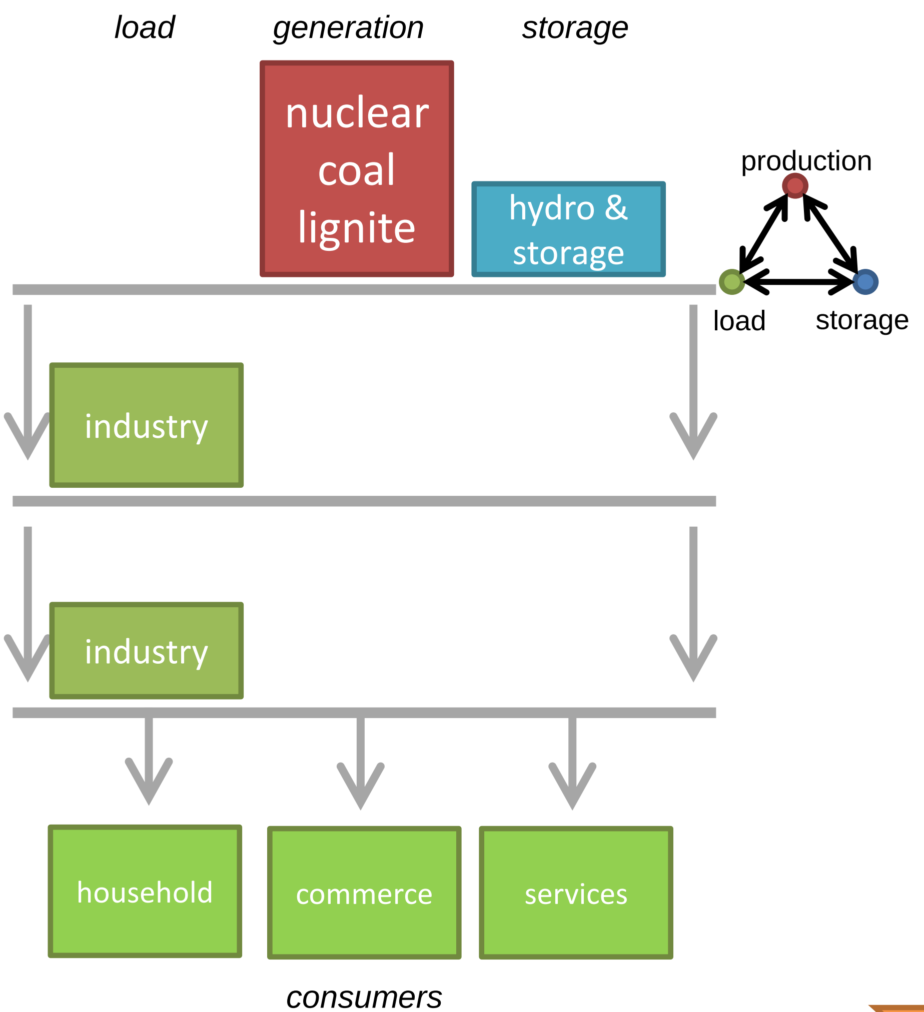
load *generation* *storage*

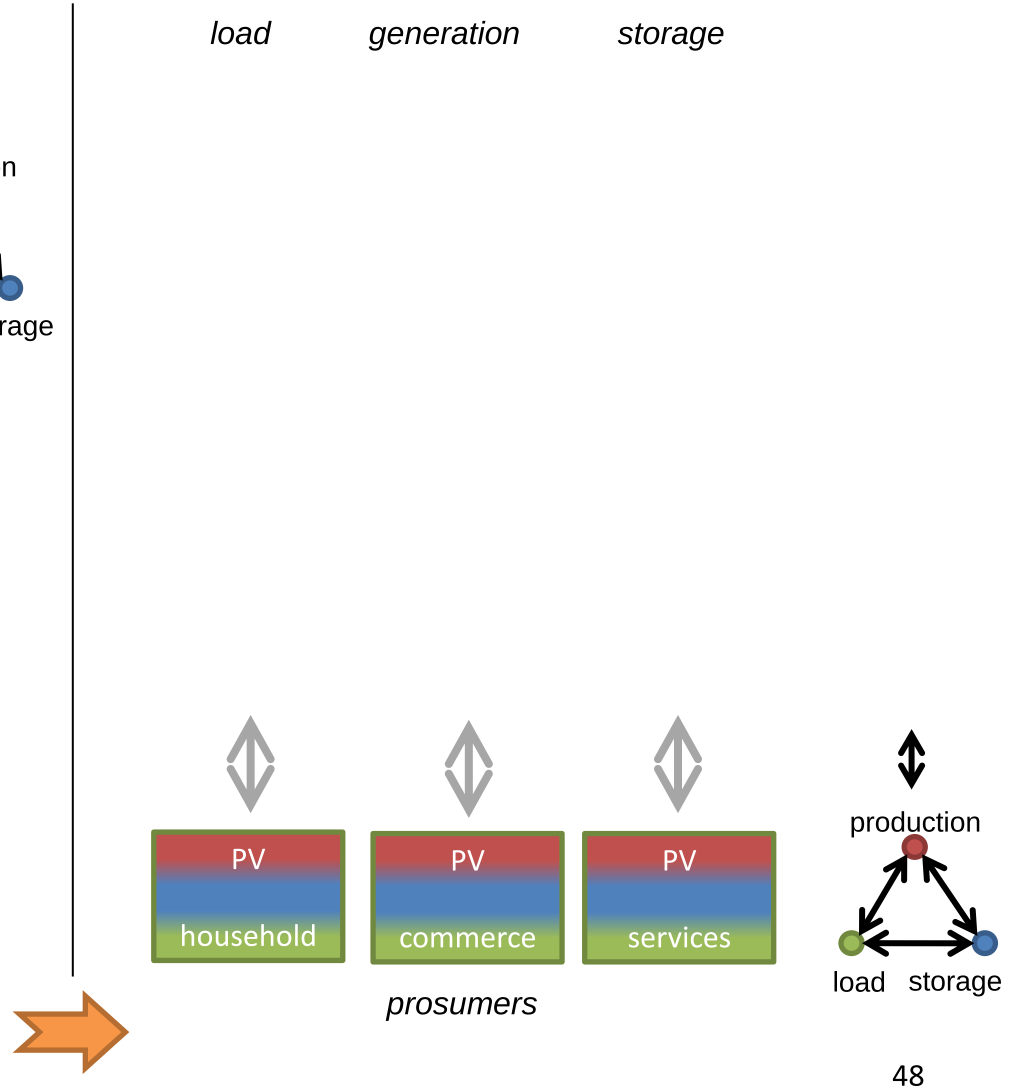


consumers

load *generation* *storage*

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





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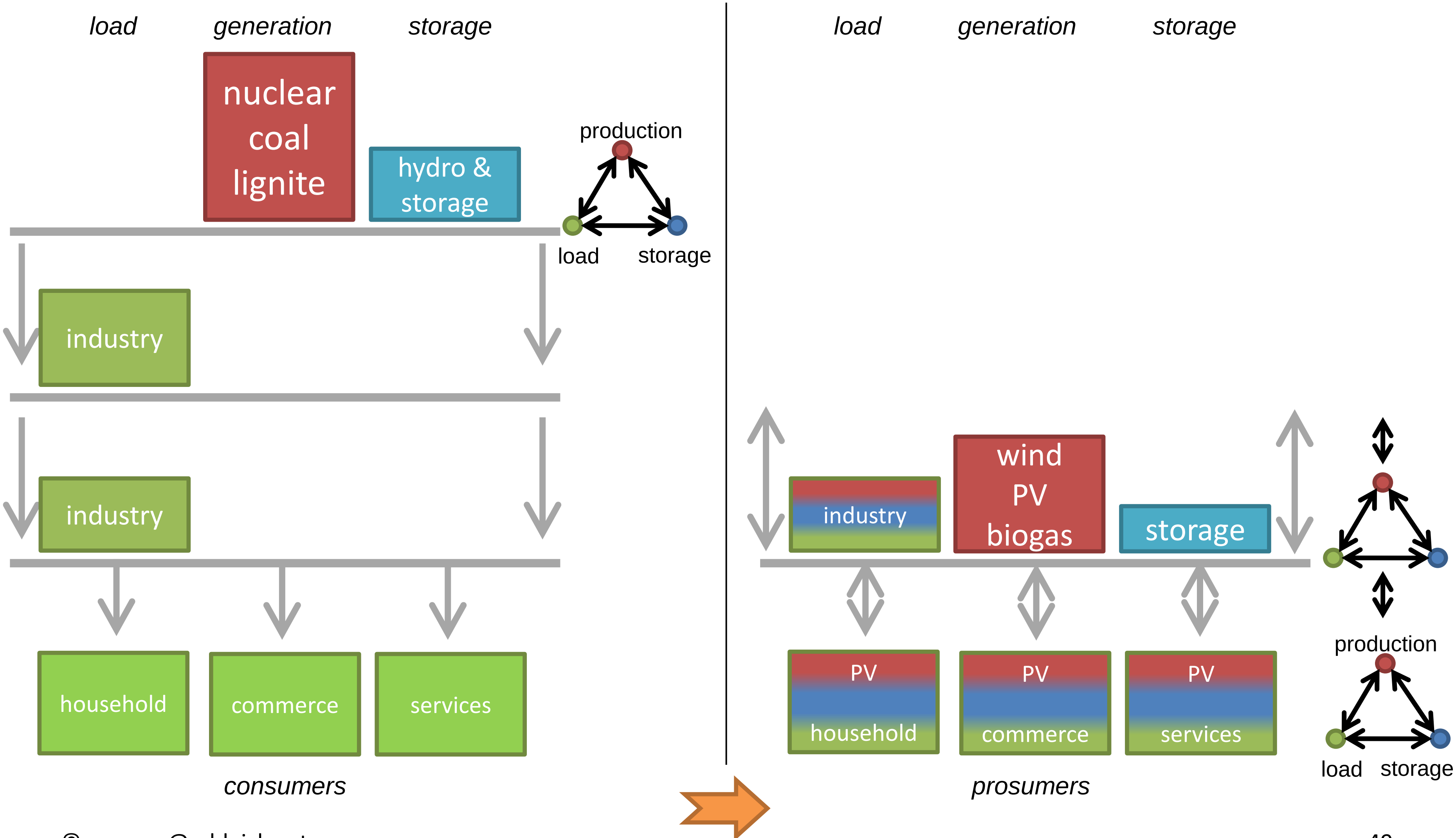

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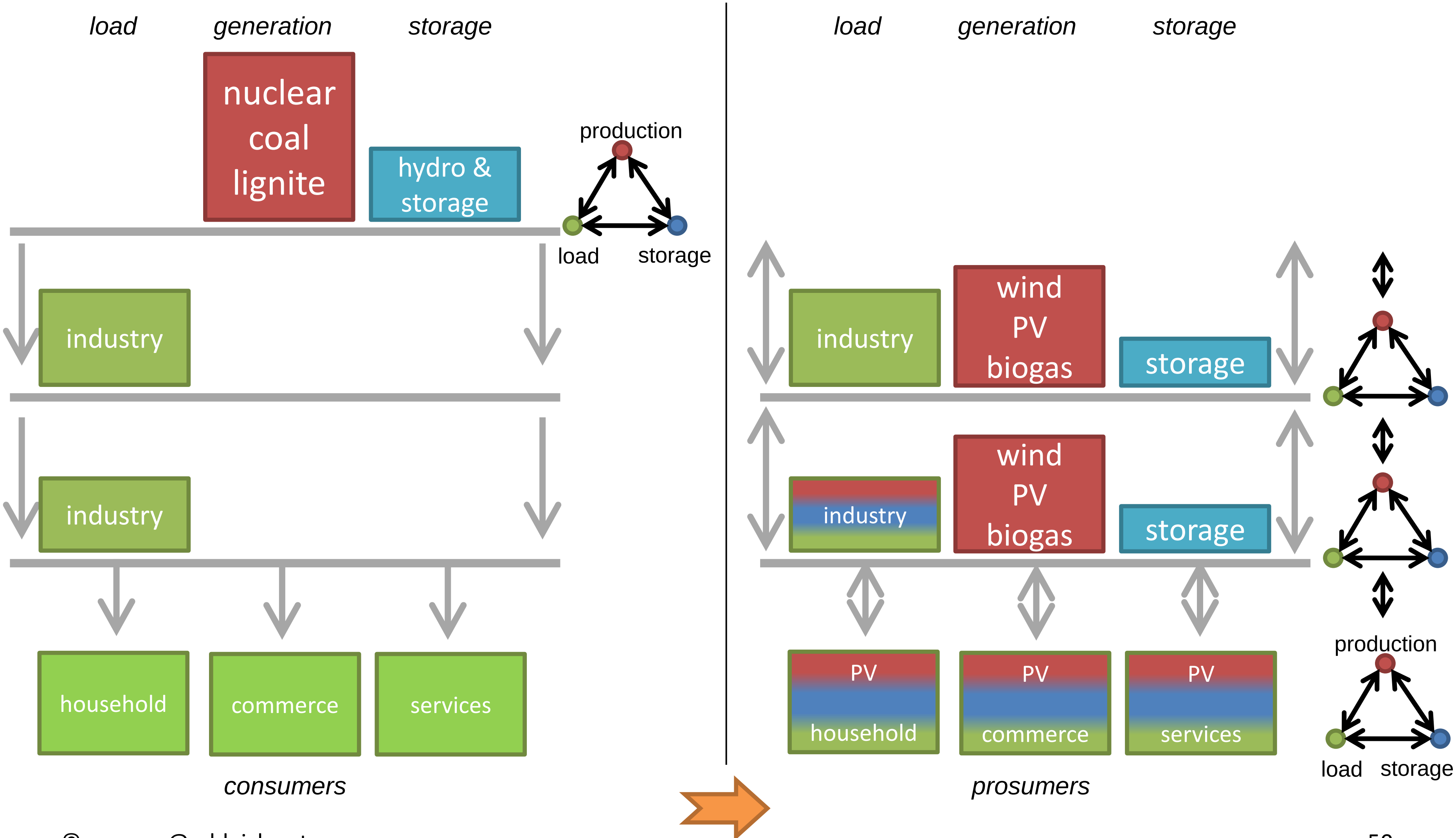

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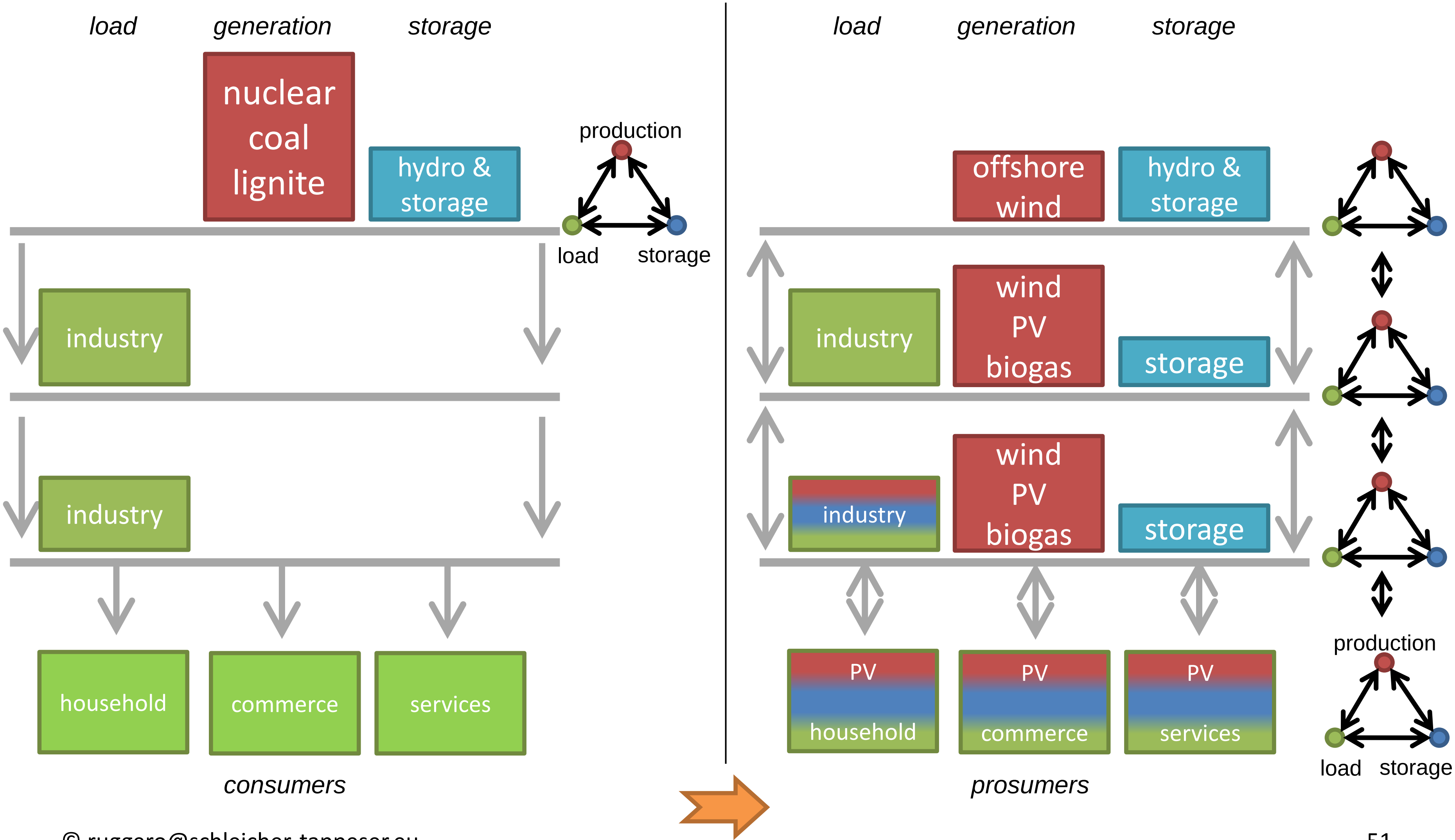

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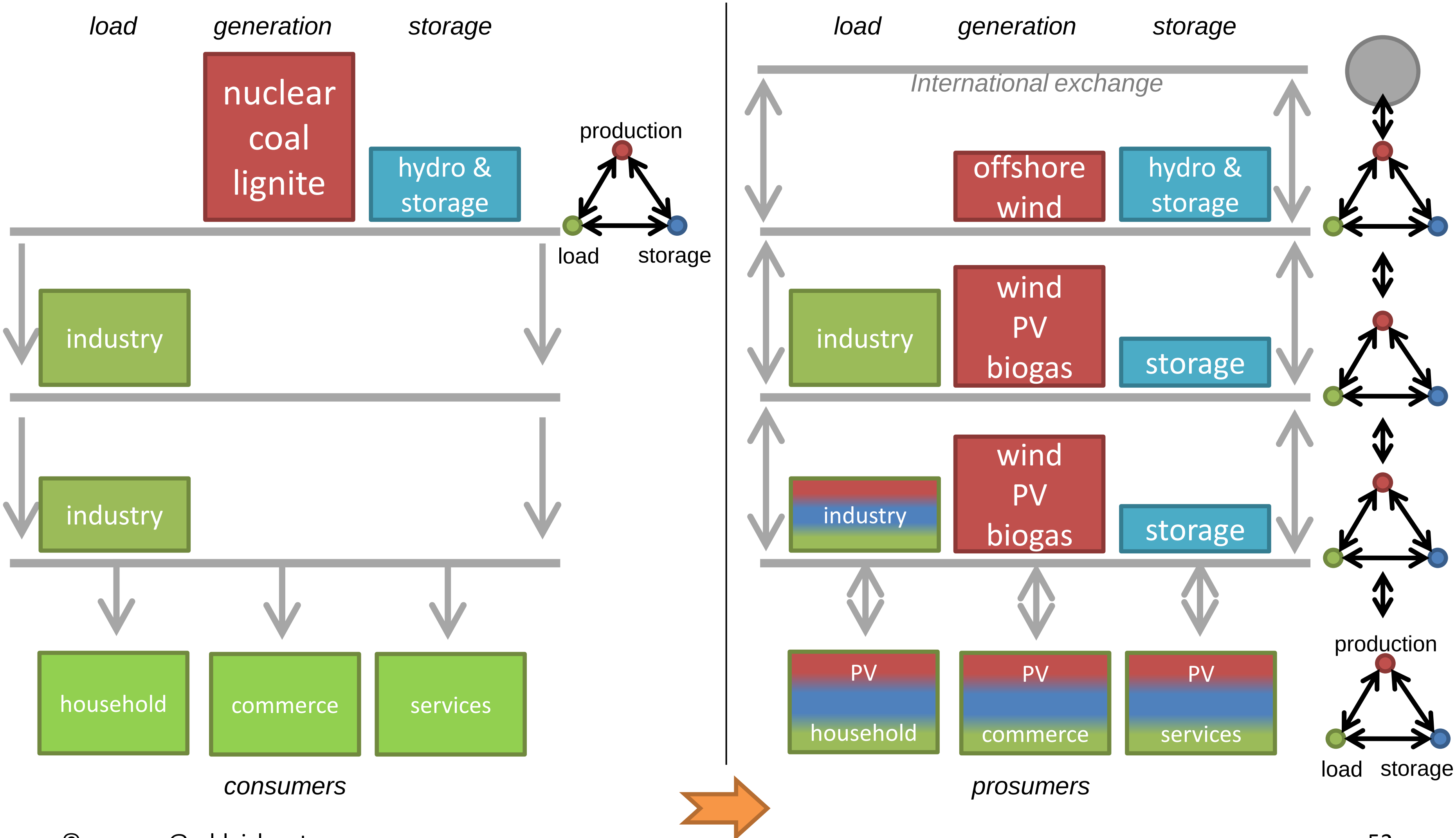

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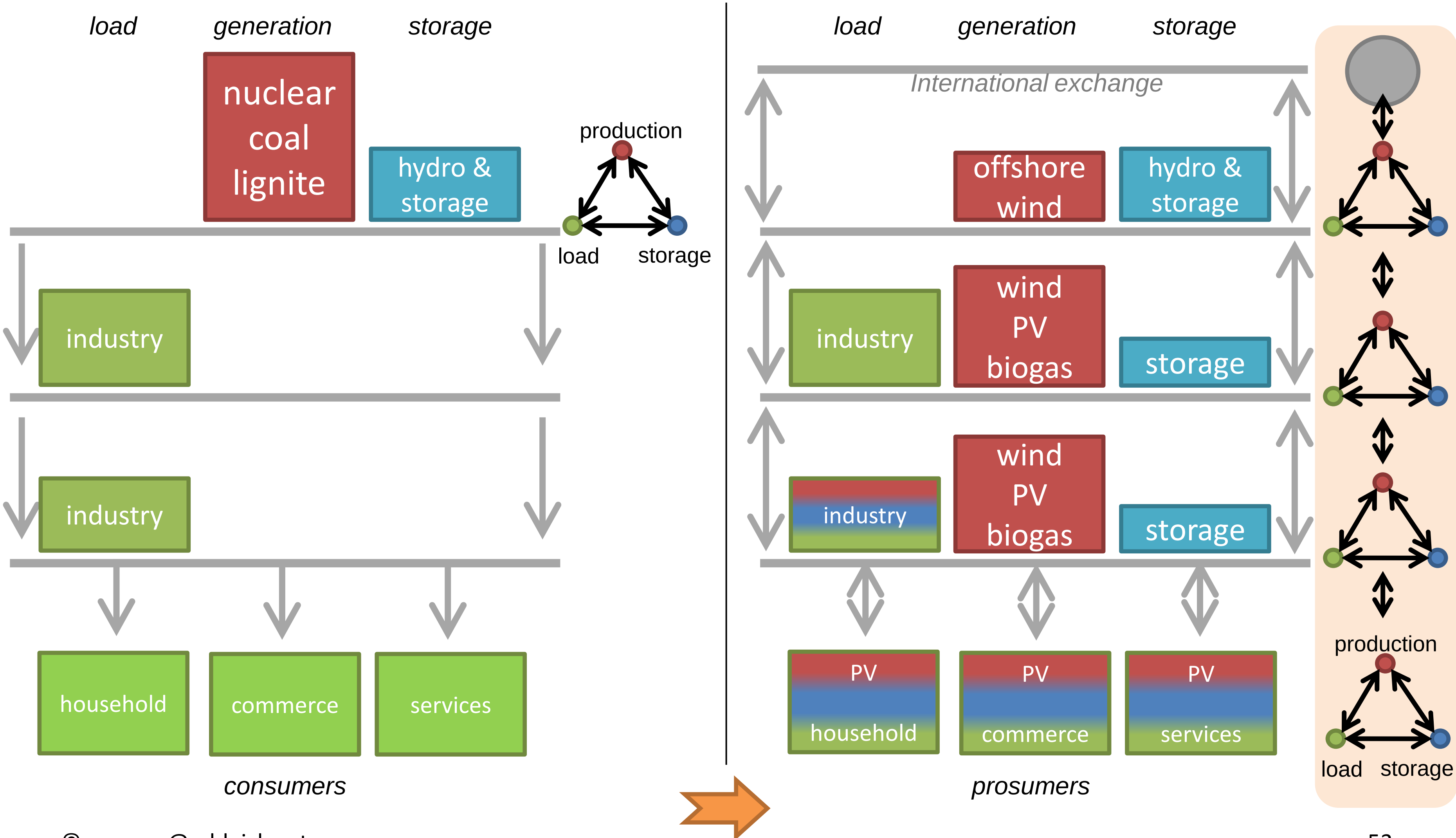

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Approaches for matching production and consumption of electricity

	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

MANAGING A TURBULENT TRANSFORMATION

Complexity increases …
… predictability decreases

- Optimising the combination of generation/ demand side management/ storage /geographical compensation is a complex task with no final solution
- Innovation and cost reduction in distributed sustainable energy technologies have different speeds and are much more rapid than in conventional technologies
- Nevertheless many investments have long liftimes
- The speeds depend on global market developments

➢ Conventional planning of the future energy mix or of the technology mix for dealing with fluctuations makes no sense

Turbulent transformation – What are lasting key orientations ?

The Semiconductor Revolution reaches the energy business

Semiconductors

- Short innovation cycles, steep learning curves
- microtechnology: scalable from very small to very large applications
- competitive mass production of small standardised modular elements
- large scope for reduction of materials: miniaturisation, thinner layers …
- large scope for cost reduction (several technological paths)

Photovoltaics

- direct conversion of light into electricity, no moving parts, no fuel, negligible maintenance and variable costs, no exhausts
- Scalable from very small to very large applications

ICT, power control, power electronics

- smart grids, smart homes, smart buildings… cheap distributed intelligence
- solid state transformers, power electronics boost efficiency and flexibility of power flow control as well as grid stability

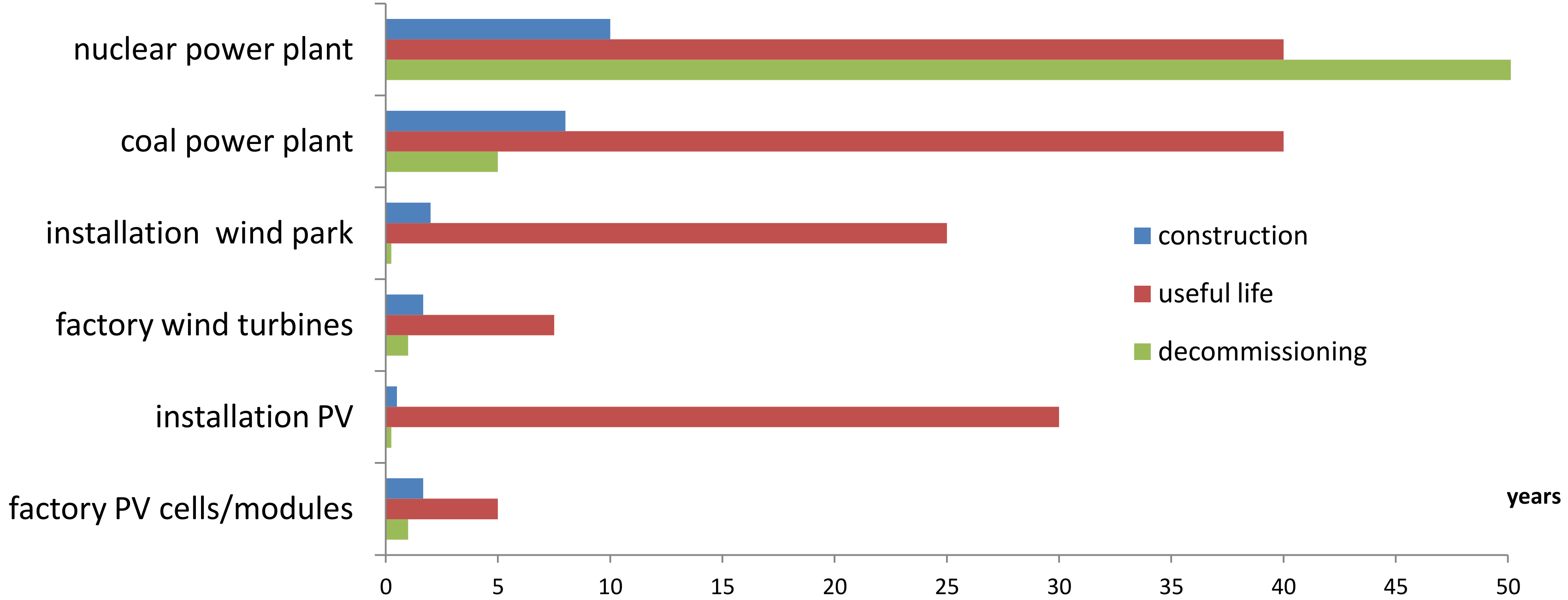
Unfamiliar to energy business: 4 to 10 times shorter innovation cycles

→ 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



Towards multi-level governance

- Accept the challenge of captive power production and organise the electricity system according to the principle of subsidiarity – establishing responsible system coordination at several levels
- Ensure far-reaching transparency concerning infrastructures constituting natural monopolies
- Use market mechanisms for complex optimisation tasks at each level
- Strive for steady development and reliable frame conditions, consider different life-times of investments
- Develop strategic visions

Business models for storage

- The transformation of electricity markets will be a driver for a coming boom for storage of all kinds of energy at all levels
- Business strategies for storage technologies must be embedded in systemic considerations of electricity / energy systems
- Comprehensive business models for the energy management of buildings and factories will be decisive for developing markets
- Flexibility is key in a turbulent transformation process: modularity, standardisation, scalability will be important for commercial success

THANK YOU

www.schleicher-tappeser.eu

ruggero@schleicher-tappeser.eu