



How to integrate large shares of variable renewables into electricity systems



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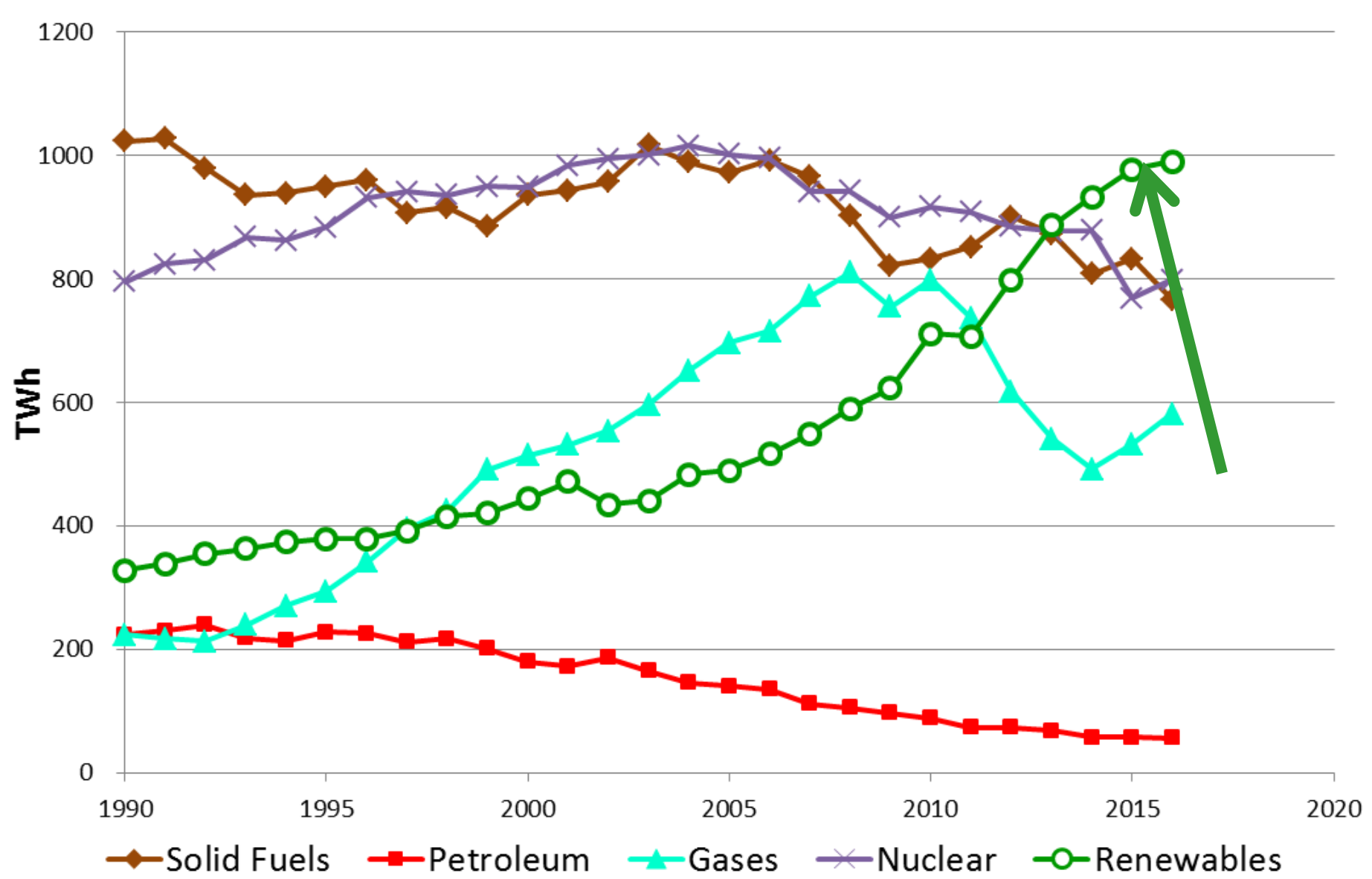
Salzburg, 29 August 2017

- 1. Introduction: Motivation**
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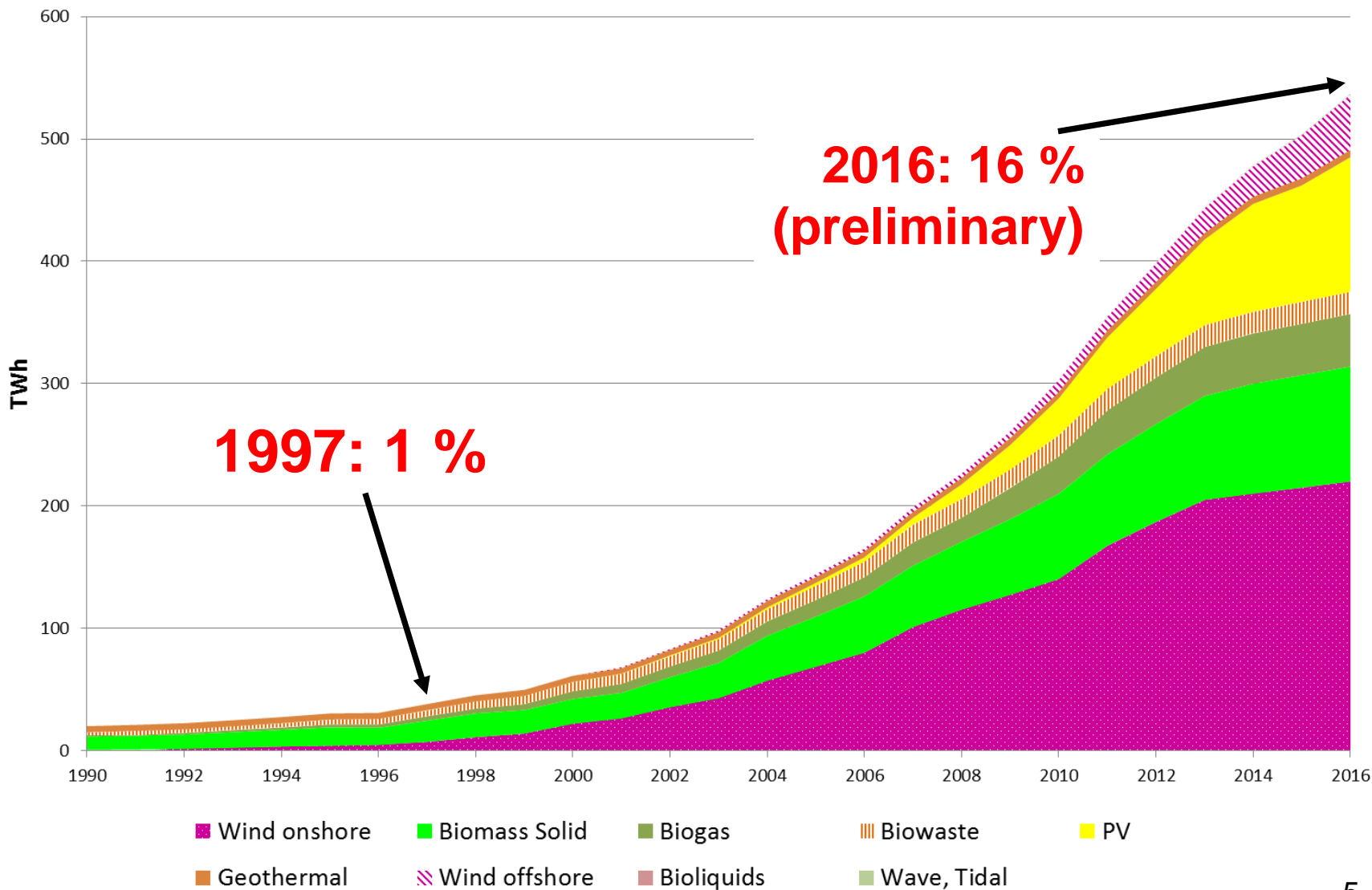
Motivation:

- * **Climate change → Paris agreements**
- * **Phasing out of fossile & nuclear**
- * **Targets for renewables**
- * **Competition & democracy**
- * **It is not possible to squeeze variable renewables into the system by violence**

Introduction: Electricity generation EU-28



EU-28: Electricity generation from „new“ RES



Source: EUROSTAT, own estimations

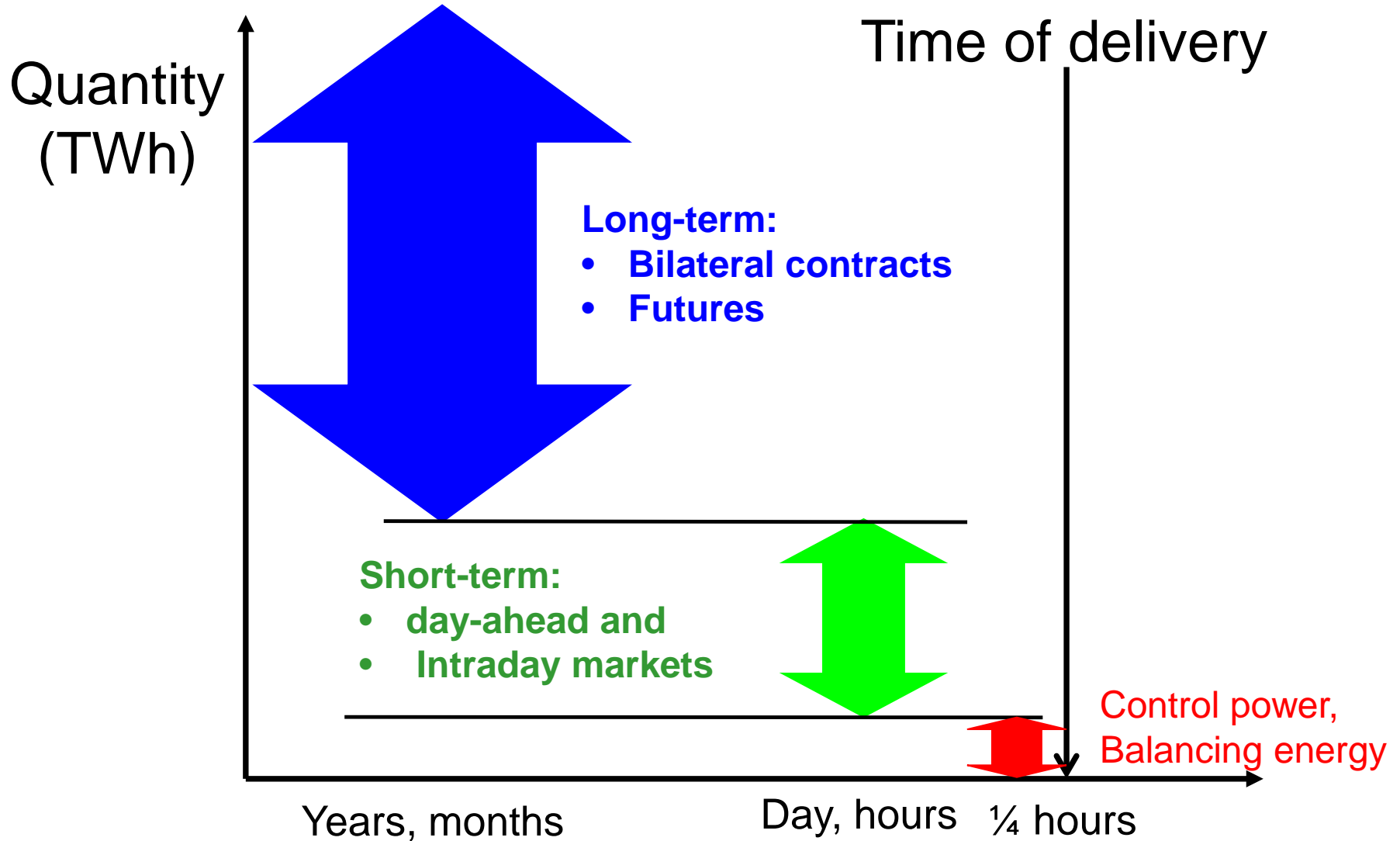
... to identify the major boundary conditions to integrate even larger amounts of variable renewables into the electricity system

Very important:

Our reflections apply in principle to every electricity system world-wide

.... are based on **electricity economic** point-of-view

- Identification of hourly residual load over a year for various scenarios with large quantities of variable renewables;
- Applying a fundamental model to calculate (static) hourly residual loads and electricity spot market prices;
- Integration of flexibility in a dynamic framework for price calculation;



Expectation of

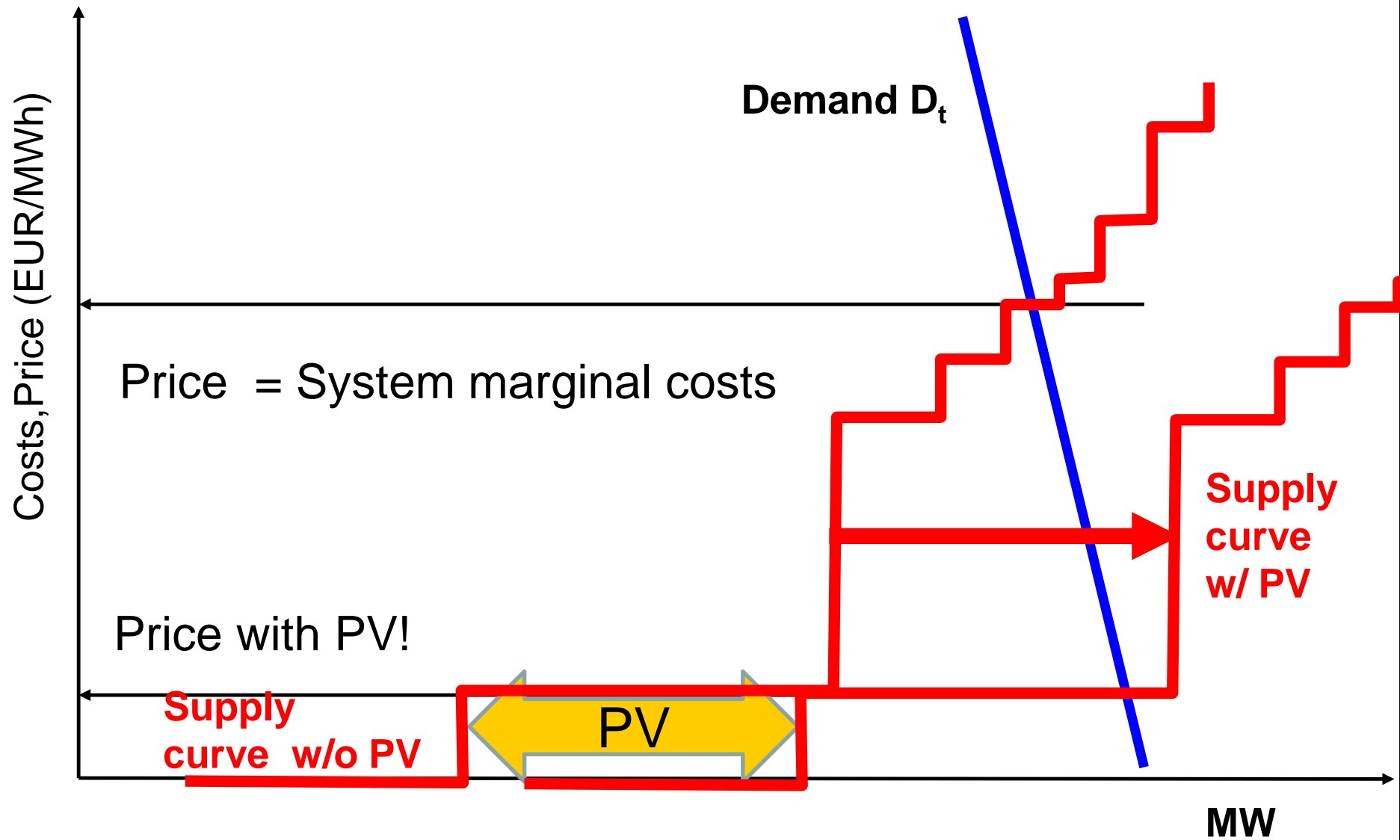
prices = Short-term marginal costs

(Short-term marginal costs = fuel costs)

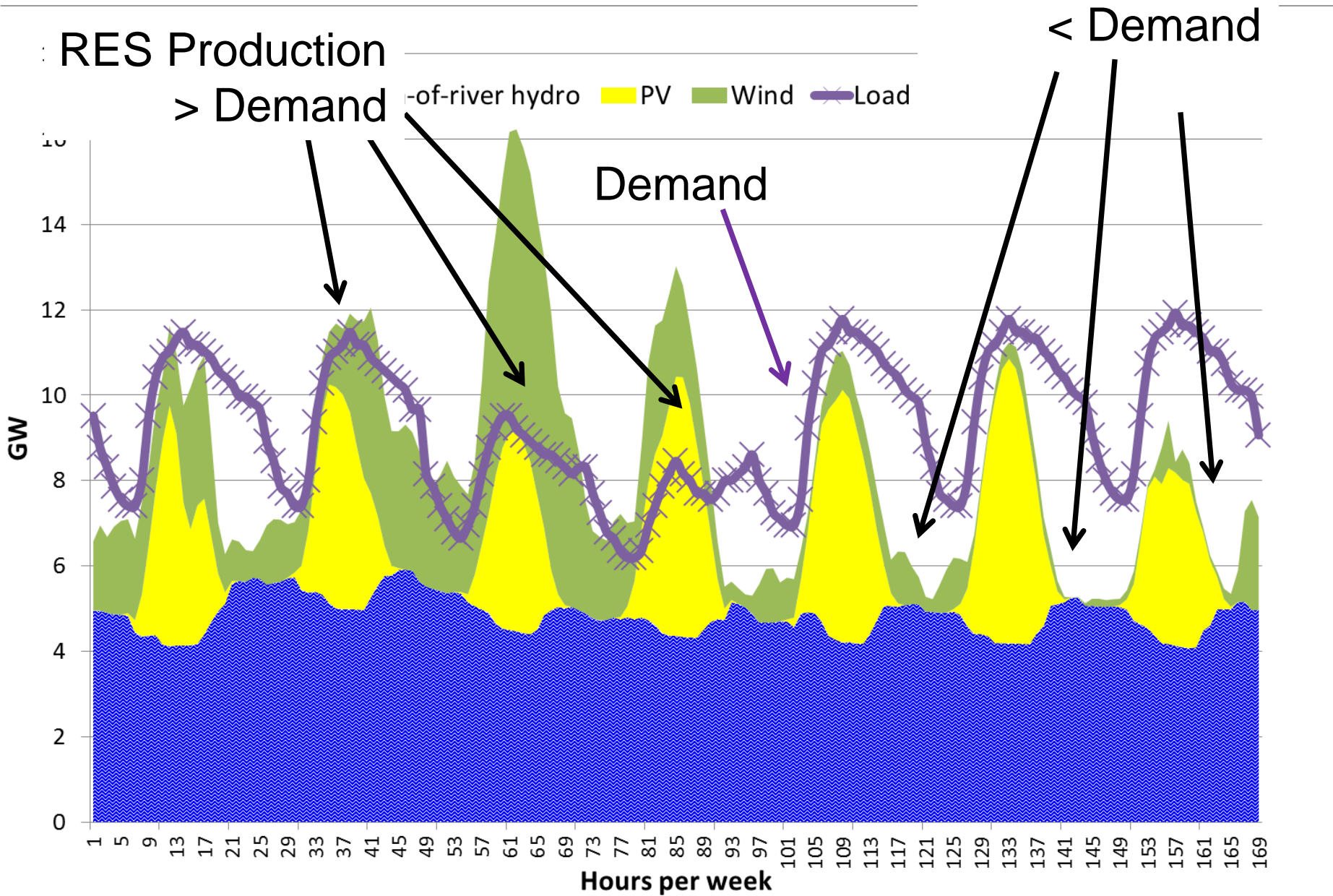
**due to huge depreciated excess
capacities at the beginning of
liberalisation!**

3 HOW VARIABLE RENEWABLES IMPACT THE ELECTRICITY SYSTEM AND PRICES IN ELECTRICITY MARKETS

Example: prices without and with PV

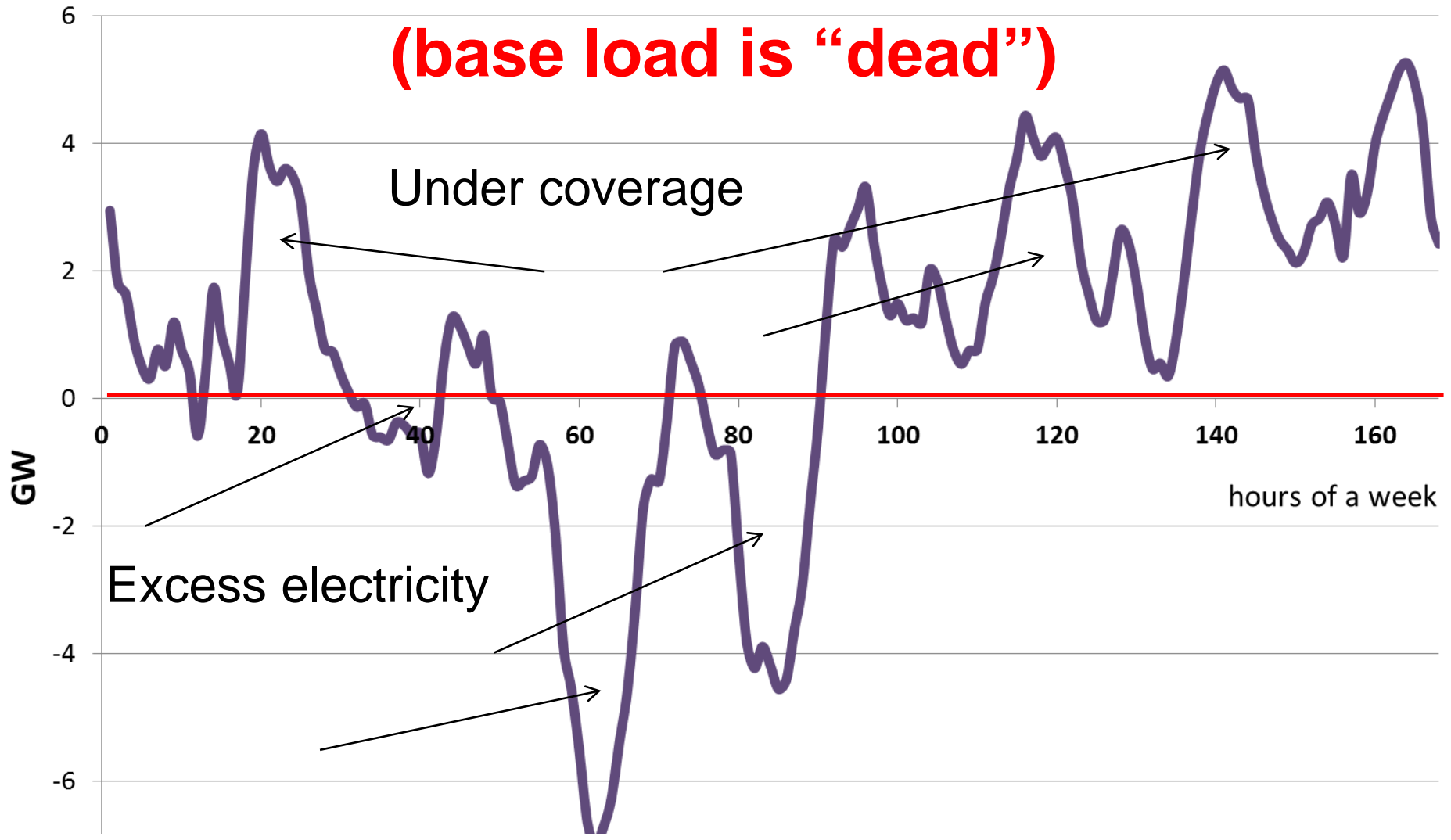


Supply and Demand



Key term of the future: Residual load

(base load is "dead")

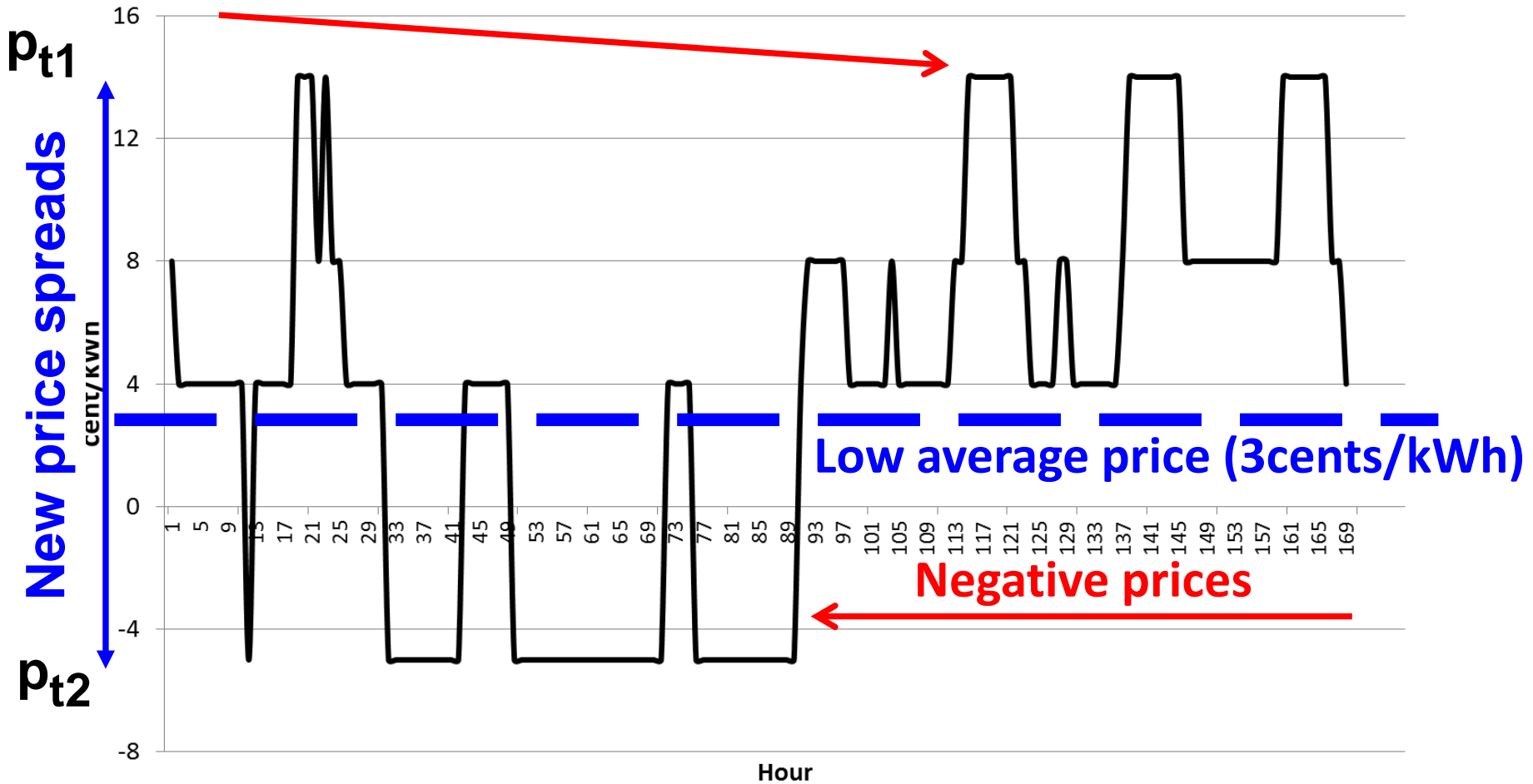


Residual load = Load – non-flexible generation

Deviation from STMC-pricing in spot markets

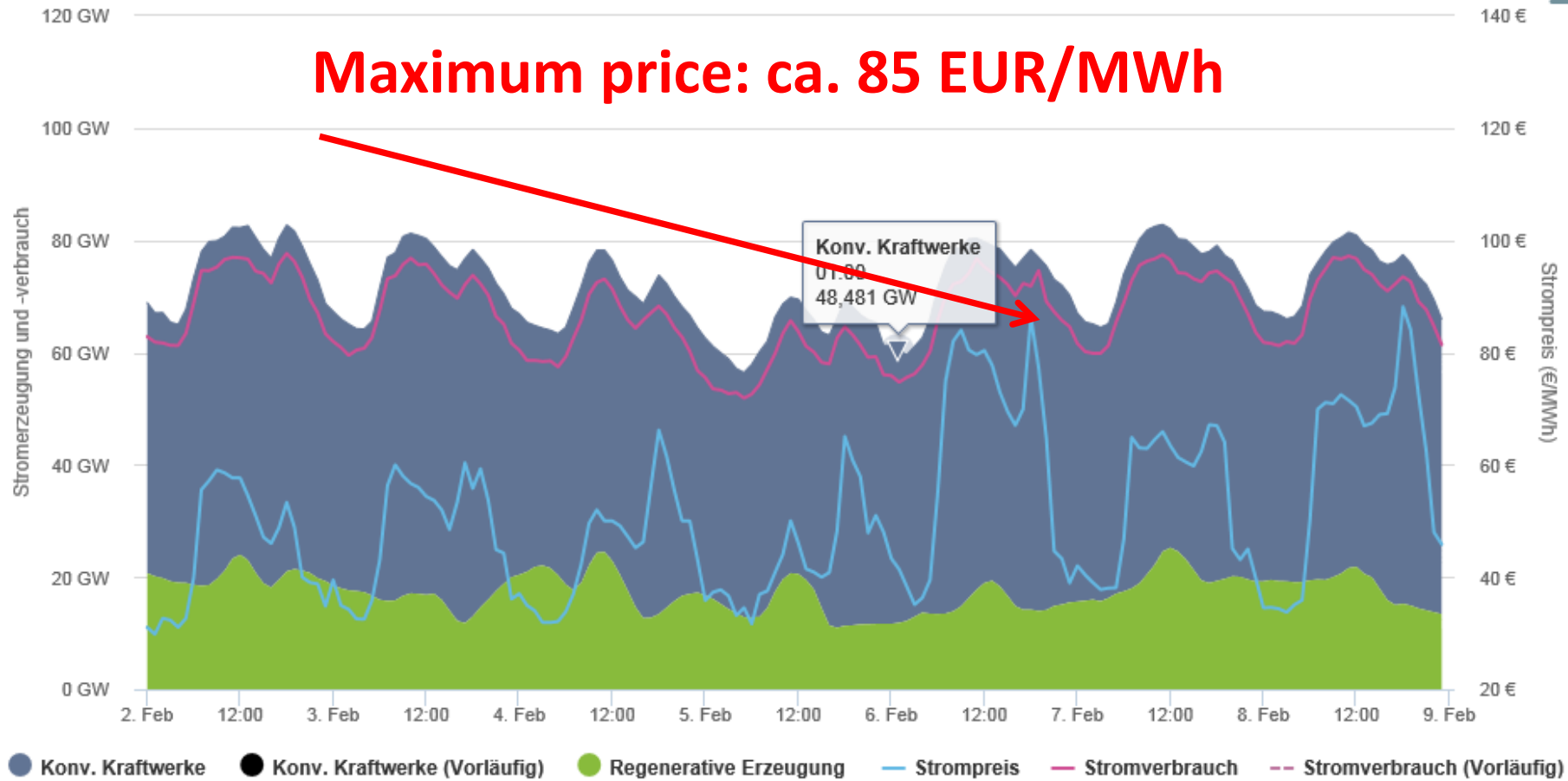
Scarcity prices

Electricity price spot market

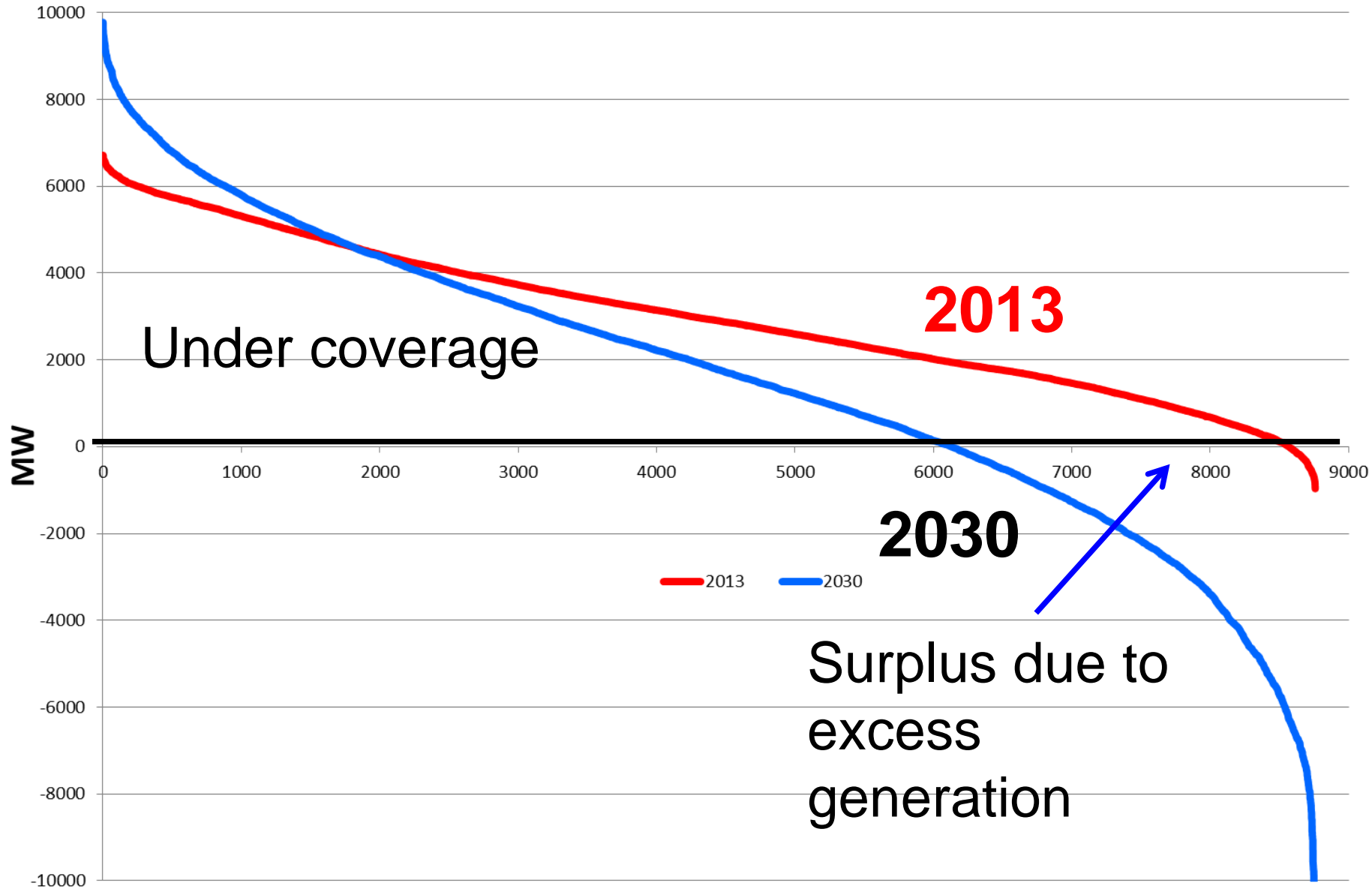


→ These price spreads provide incentives
for new flexible solutions!!!!

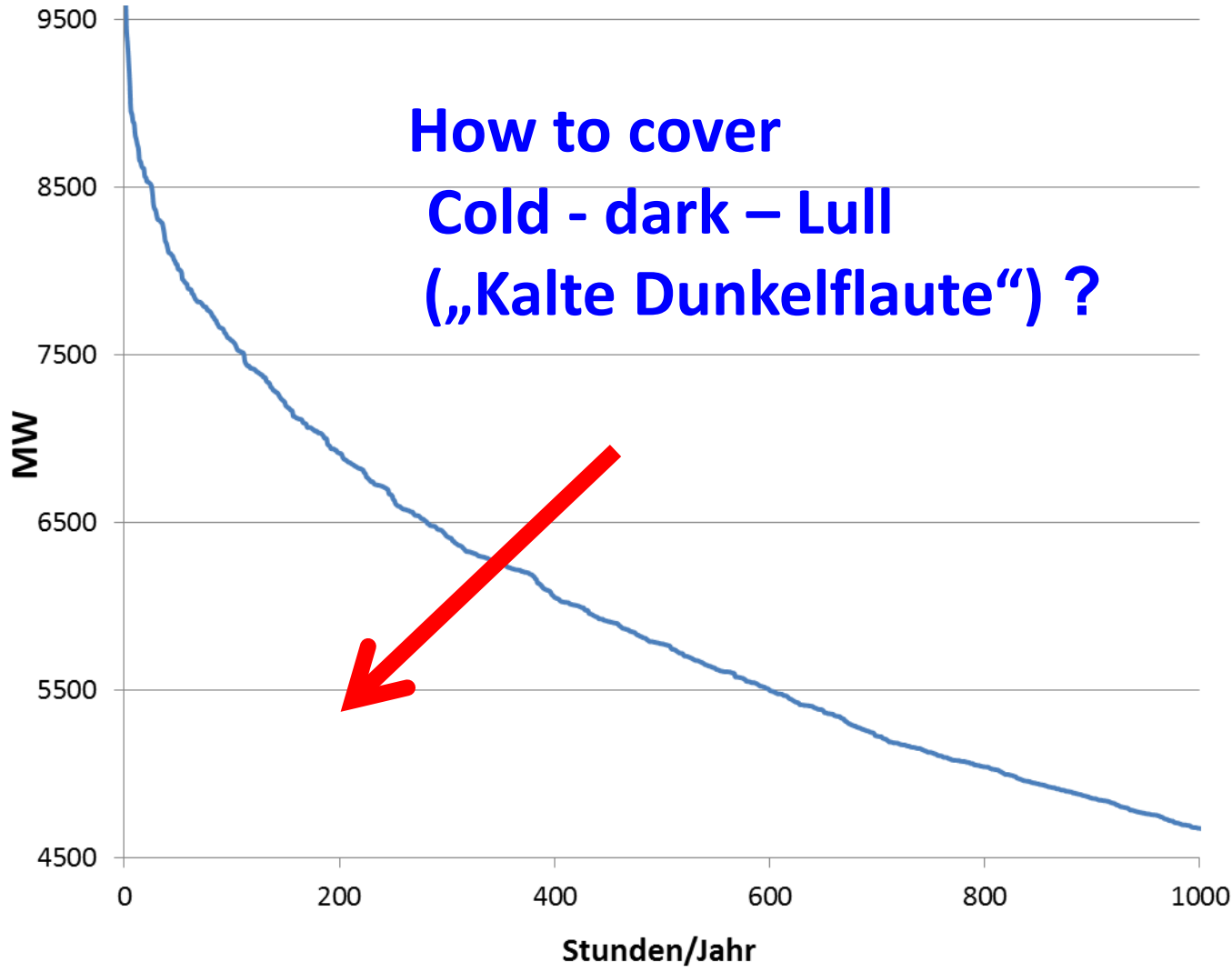
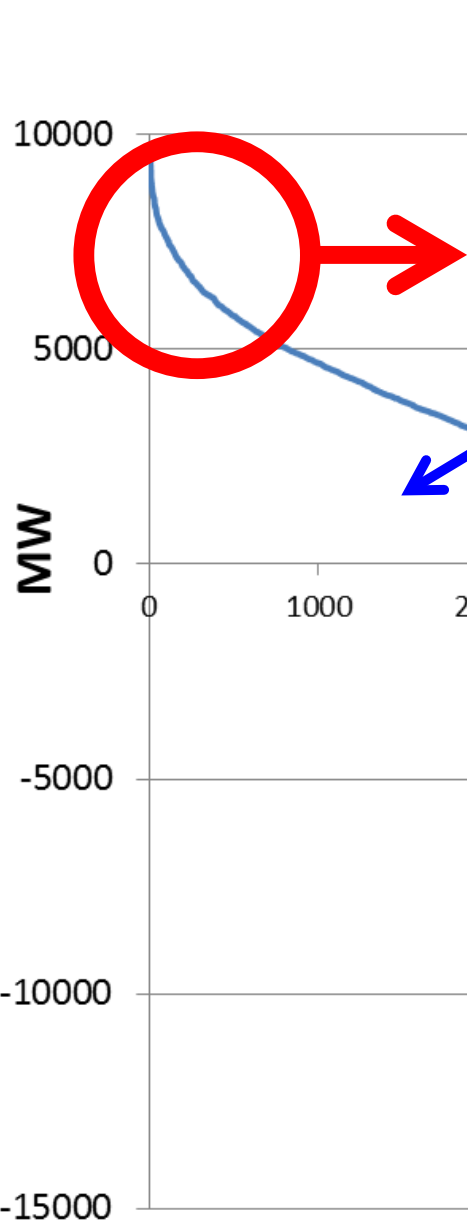
Remark: Cold - dark – Lull („Kalte Dunkelflaute“)



Classified residual load



Classified residual load



How to cover
Cold - dark - Lull
 („Kalte Dunkelflaute“) ?

By a regulated capacity „market“ with STMC pricing?

or

By competition between supply-side and demand-side technologies and behaviour (incl. Storages, grid and other flexibility options) with correct scarcity pricing signals?

4 THE CORE PROBLEMS OF CAPACITY PAYMENTS

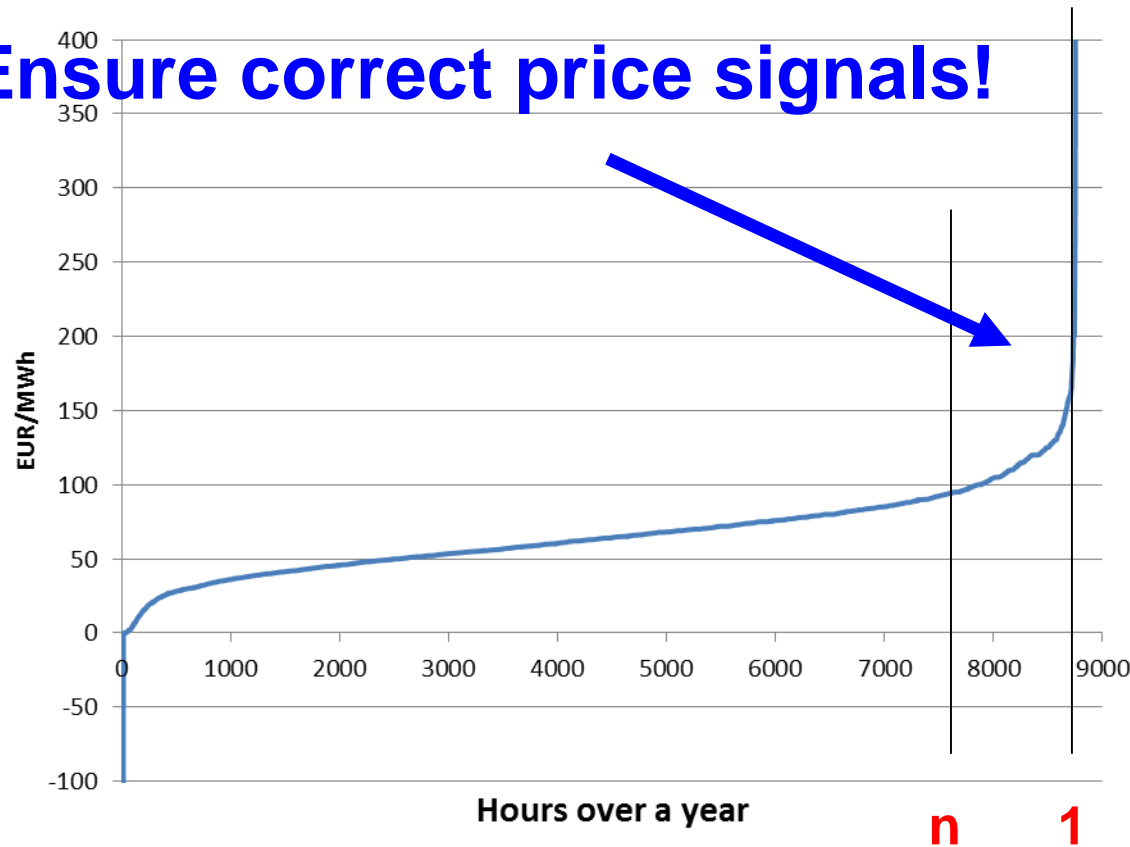
All regulatory capacity payments for power plants distort the EOM and lead to wrong price signals for all other options

Price peaks at times of scarce resource should revive the markets and lead to effective competition

We should strive to retain system resource adequacy by ensuring correct price signals and without capacity payments

Cost duration curve

Ensure correct price signals!



Generators stay in the market if:

$$\sum_{t=1}^n (p_{elet_t} \cdot q_{elet_t} - c_{ft}) > (c_{cy} + c_{O\&M_y})$$

Given a price pattern, showing **excess and scarcity prices** it would be attractive for a sufficient number of flexible power plant operators to stay in the market!



REVISED ENERGY-ONLY MARKET

FLEXIBLE GENERATION

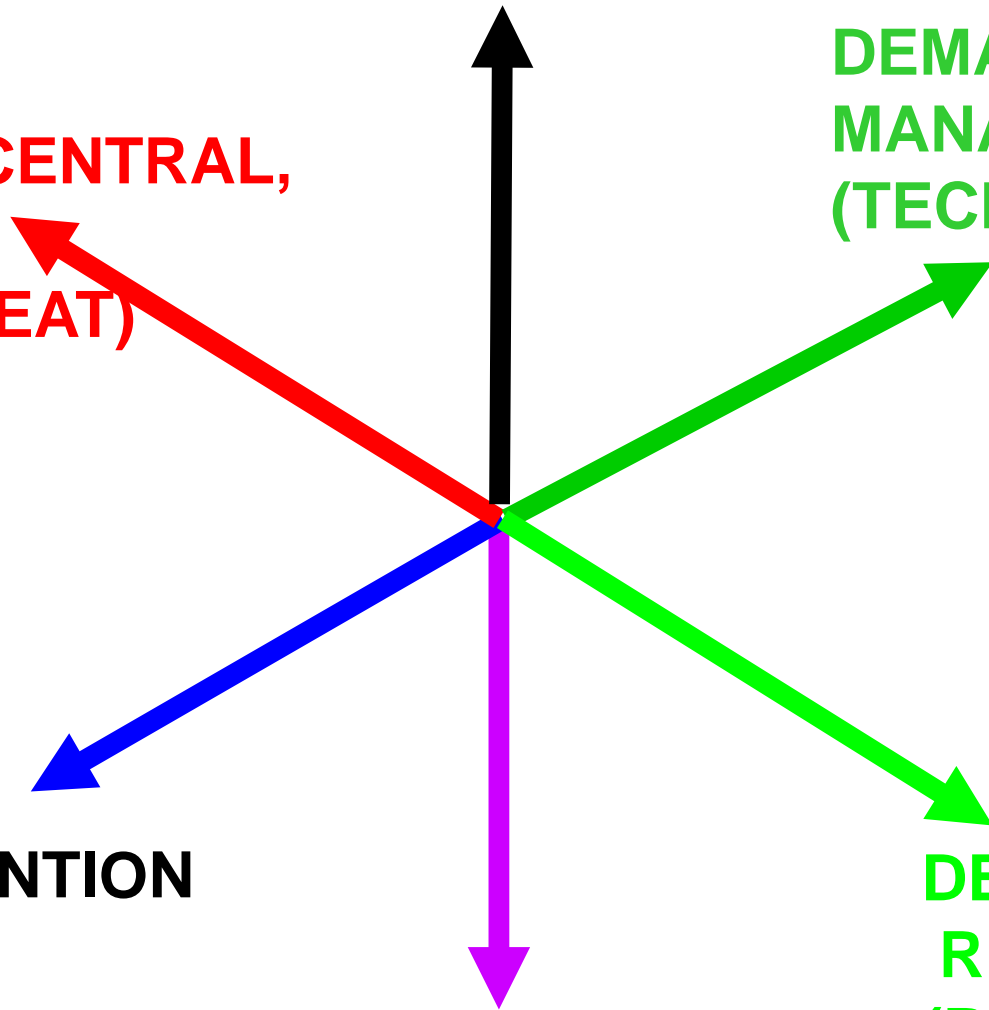
**STORAGES (CENTRAL,
DECENTRAL,
POWER-TO-HEAT)**

**DEMAND-SIDE
MANAGEMENT
(TECHNICAL)**

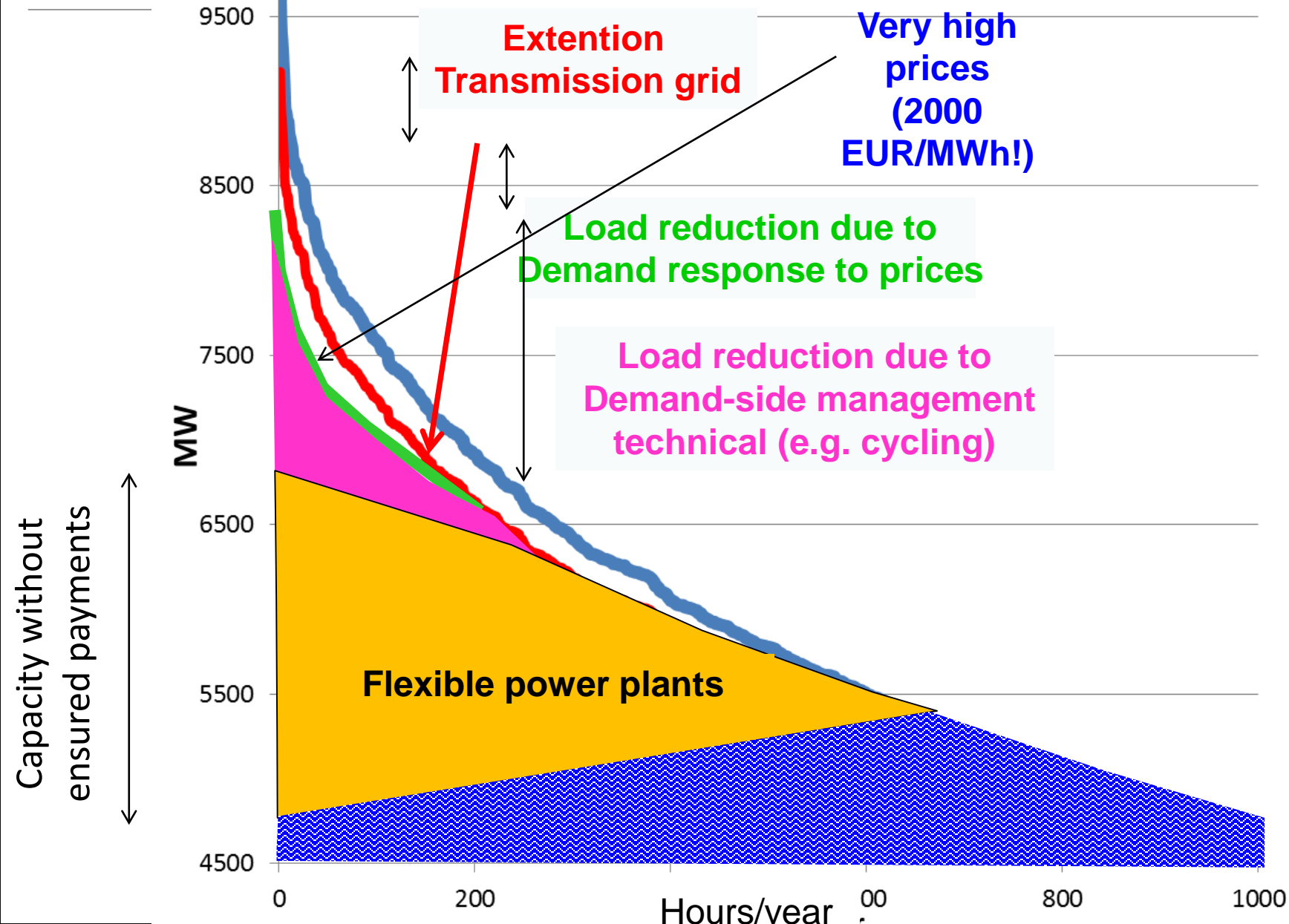
GRID EXTENTION

**DEMAND
RESPONSE
(PRICE SIGNALS)**

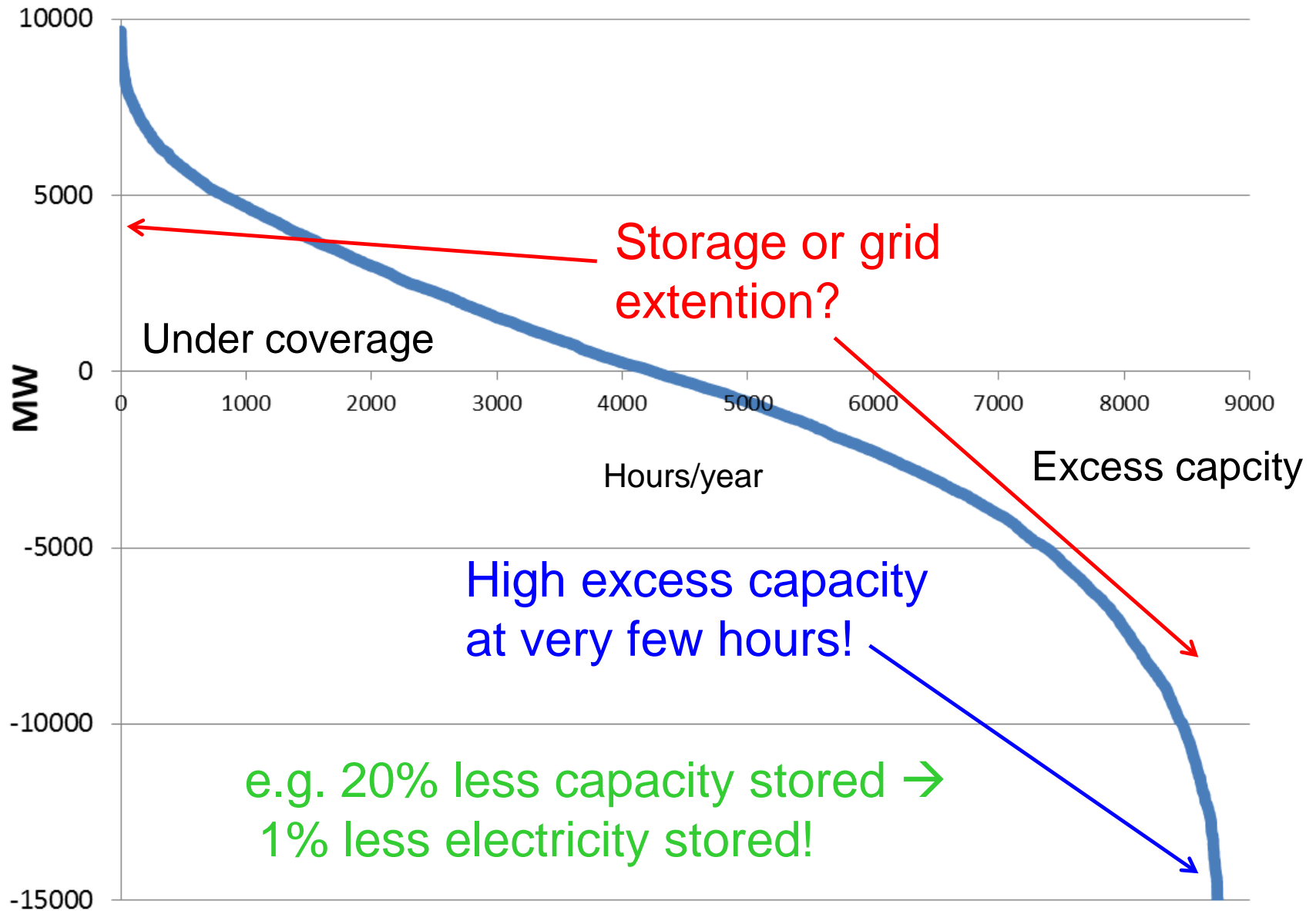
SMART GRIDS

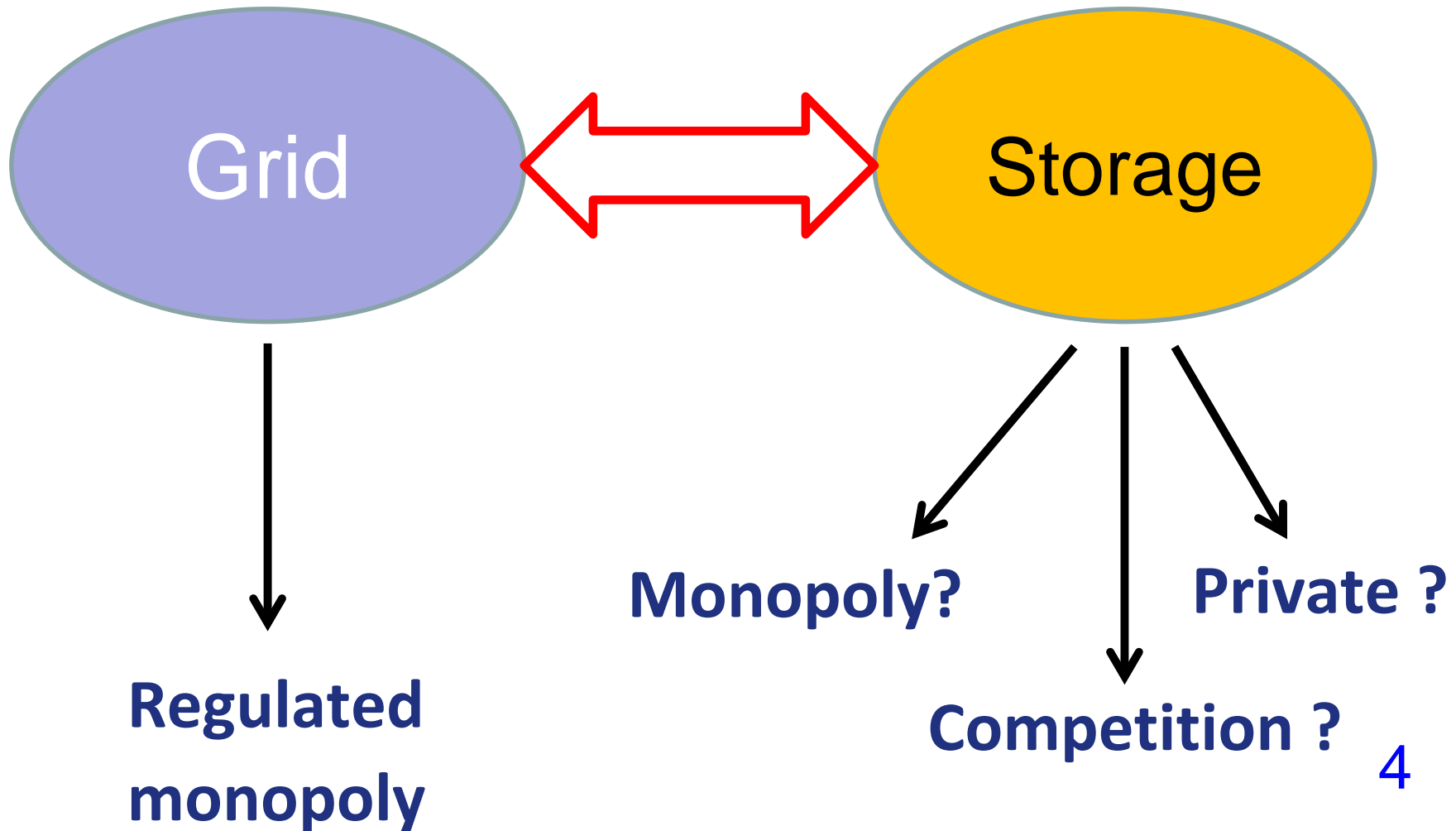


Flexible coverage of residual load



6. Storing every peak?





Specific question: How much storage do we need?

10000

Under coverage

4000 4500 5000 5500 6000 6500 7000 7500 8000 8500

-2500

-4500

-6500

-8500

-10500

-12500

-14500

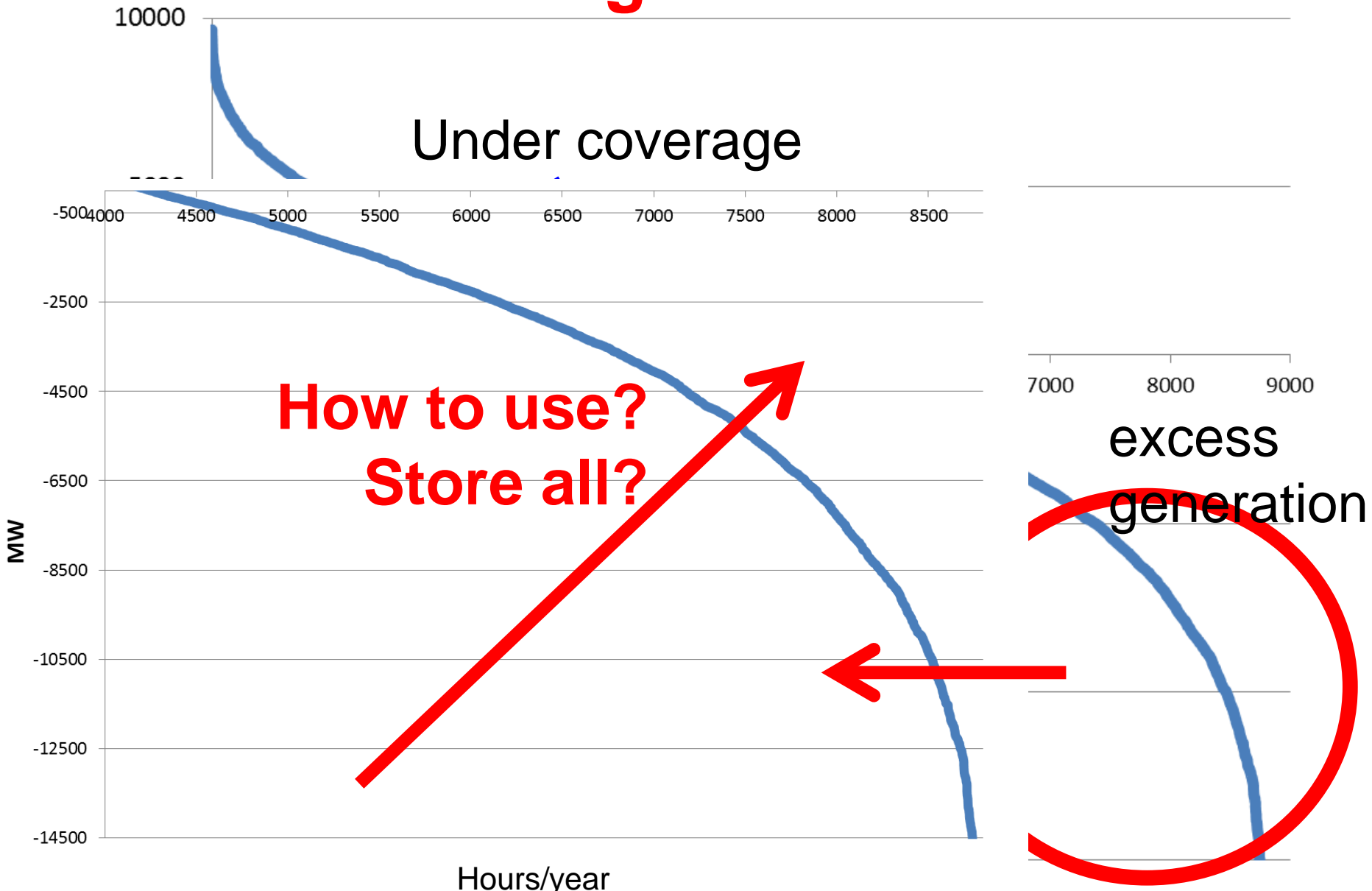
MW

How to use?
Store all?

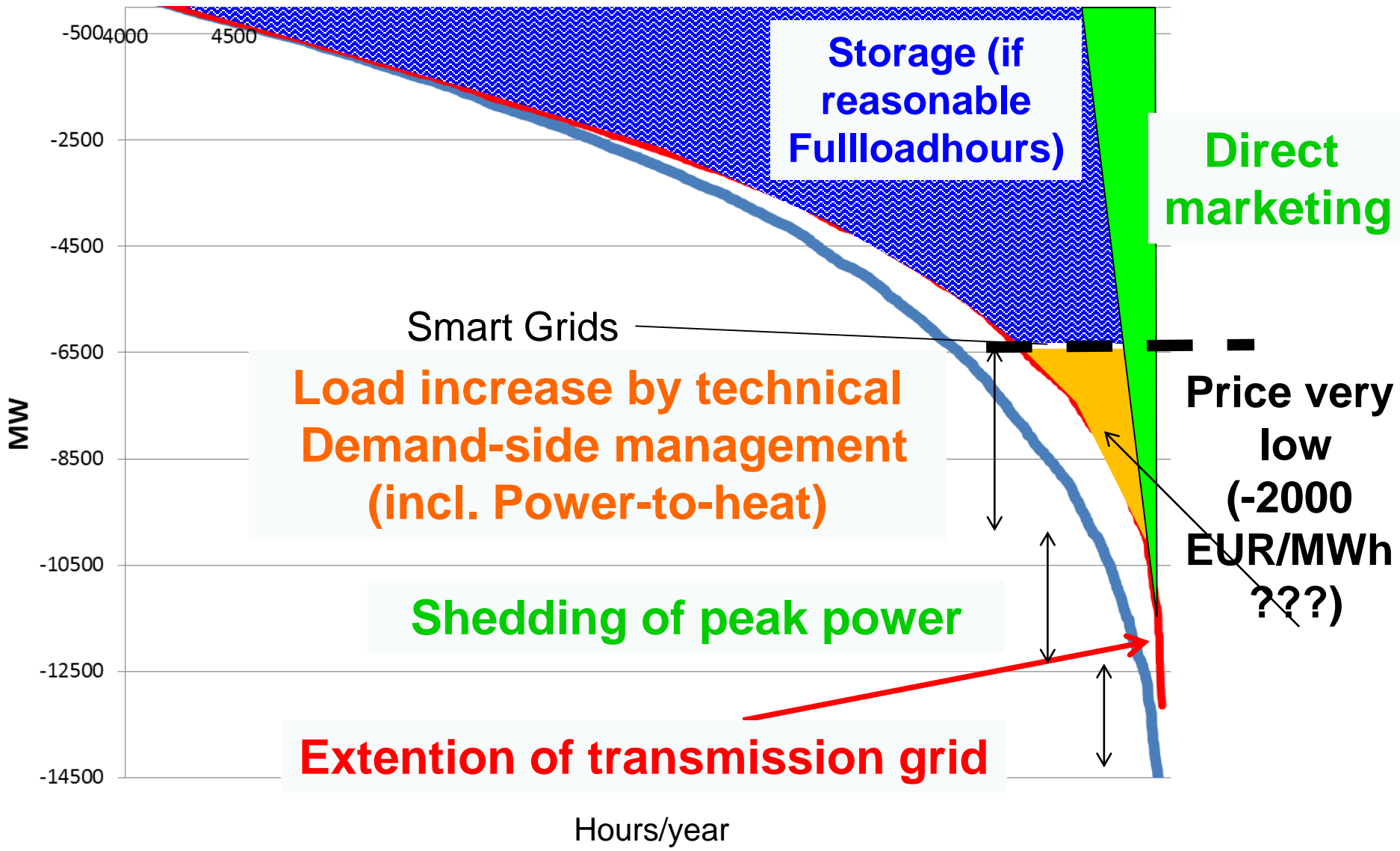
7000 8000 9000

excess
generation

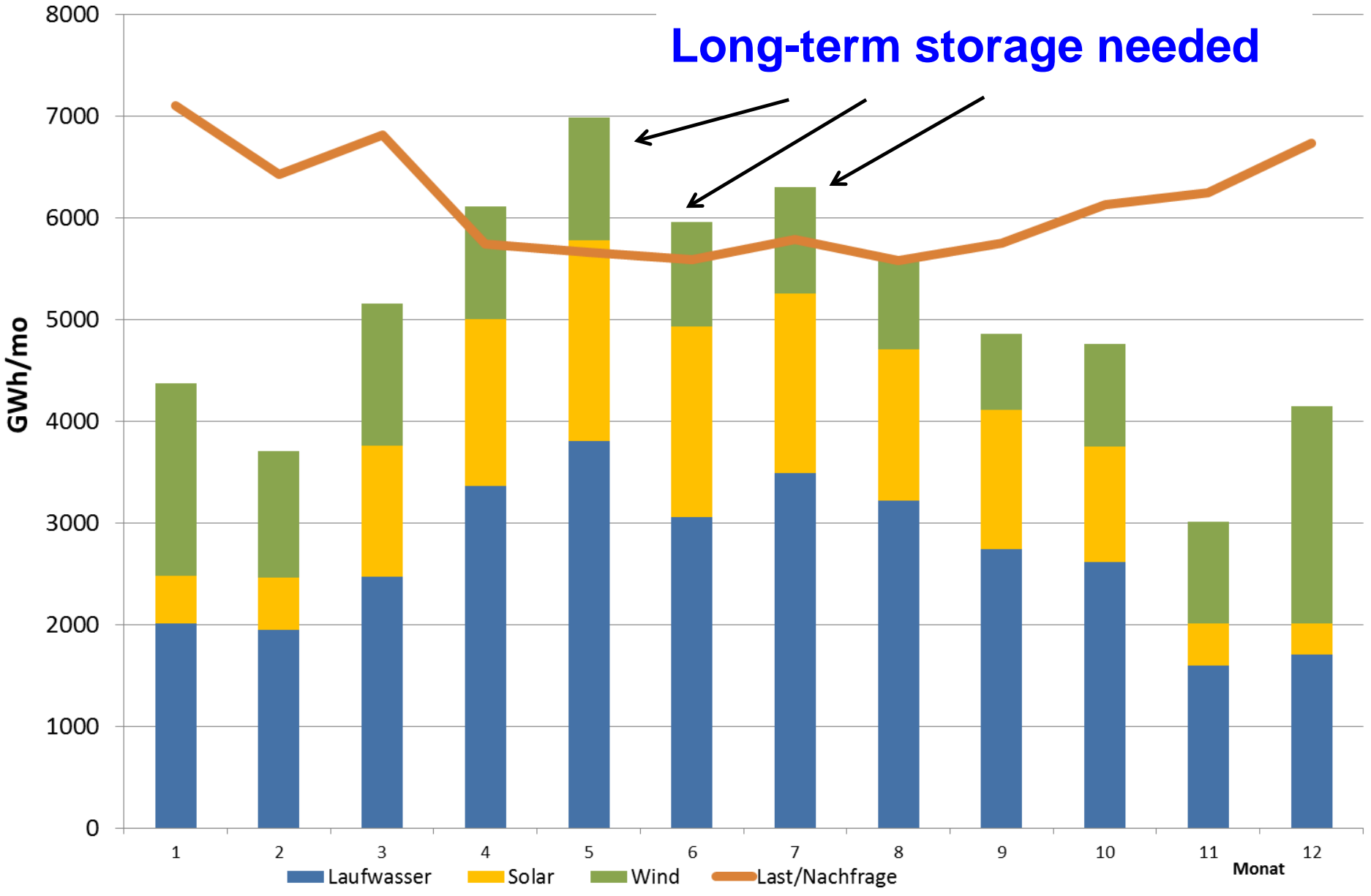
Hours/year



Flexible use of excess electricity



Demand for long-term storage



Sector coupling / Sector integration

- * In times of surplus generation: How to **use excess electricity** in meaningful way?



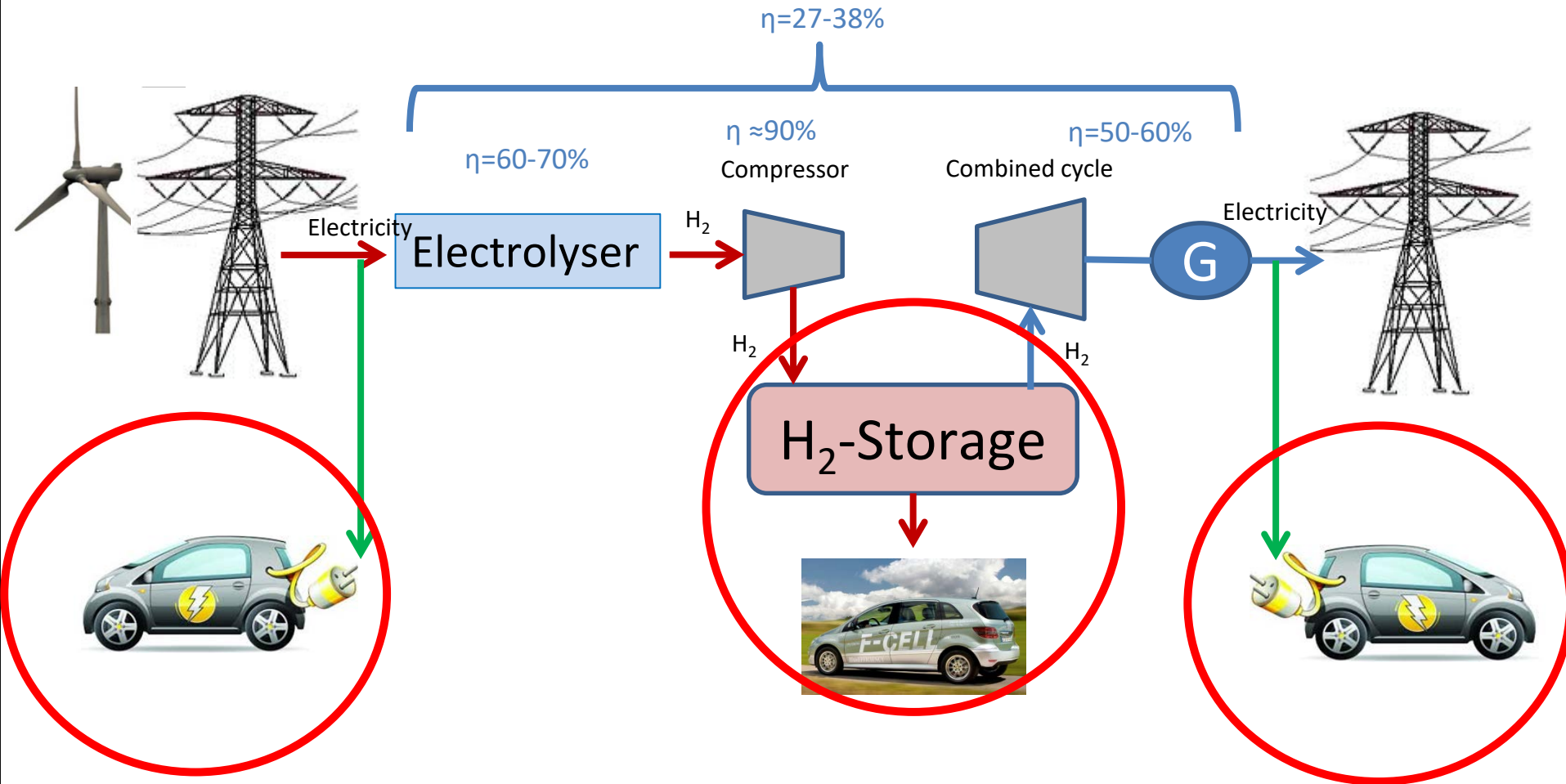
Heating/Cooling

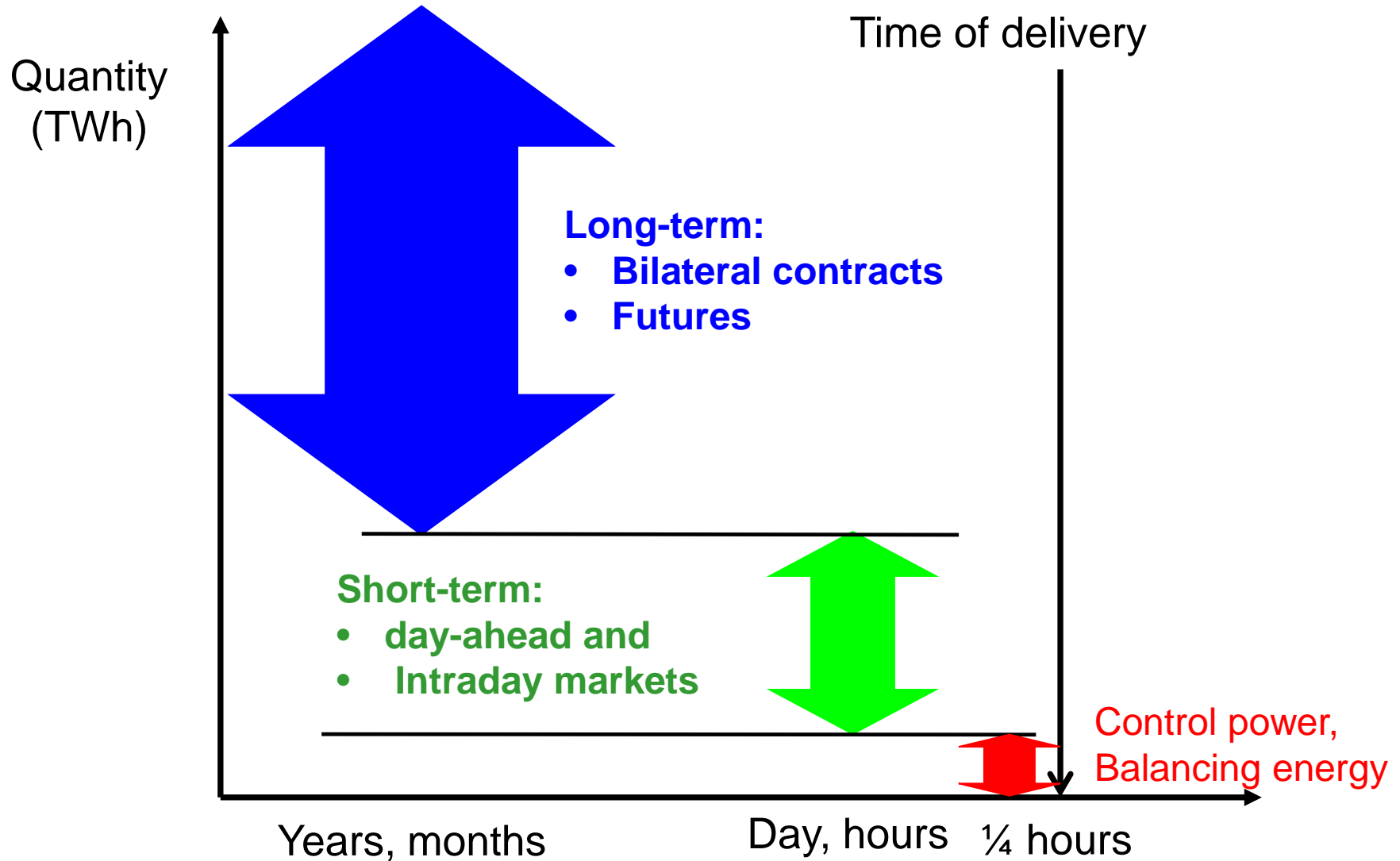


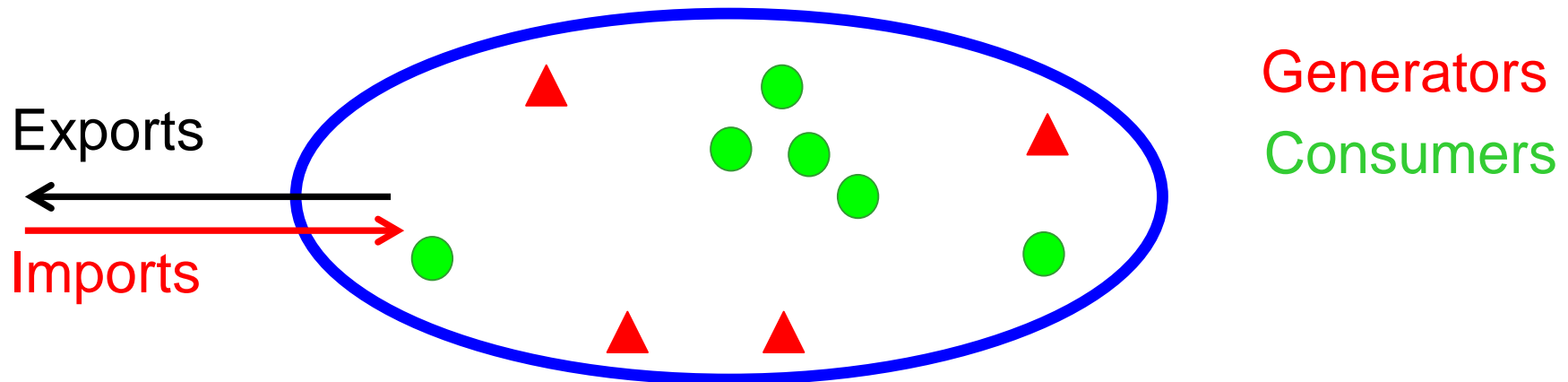
Transport

- * Vague simplified suggestions, no convincing long-term solutions
- * **Central** (Ptx approaches, e.g. H2) vs **decentral** (end user level, E.g. Evs, heat pumps for heating) applications
- * How to **fit use with time of surplus**, e.g. of PV for heating ?

Sector coupling hydrogen: Storage and fuel in transport?







Balancing group: entity in a control area of an electricity system; it has to ensure that at every moment demand and supply is balanced

E.g. municipal utility of Vienna, Dresden, Helsinki

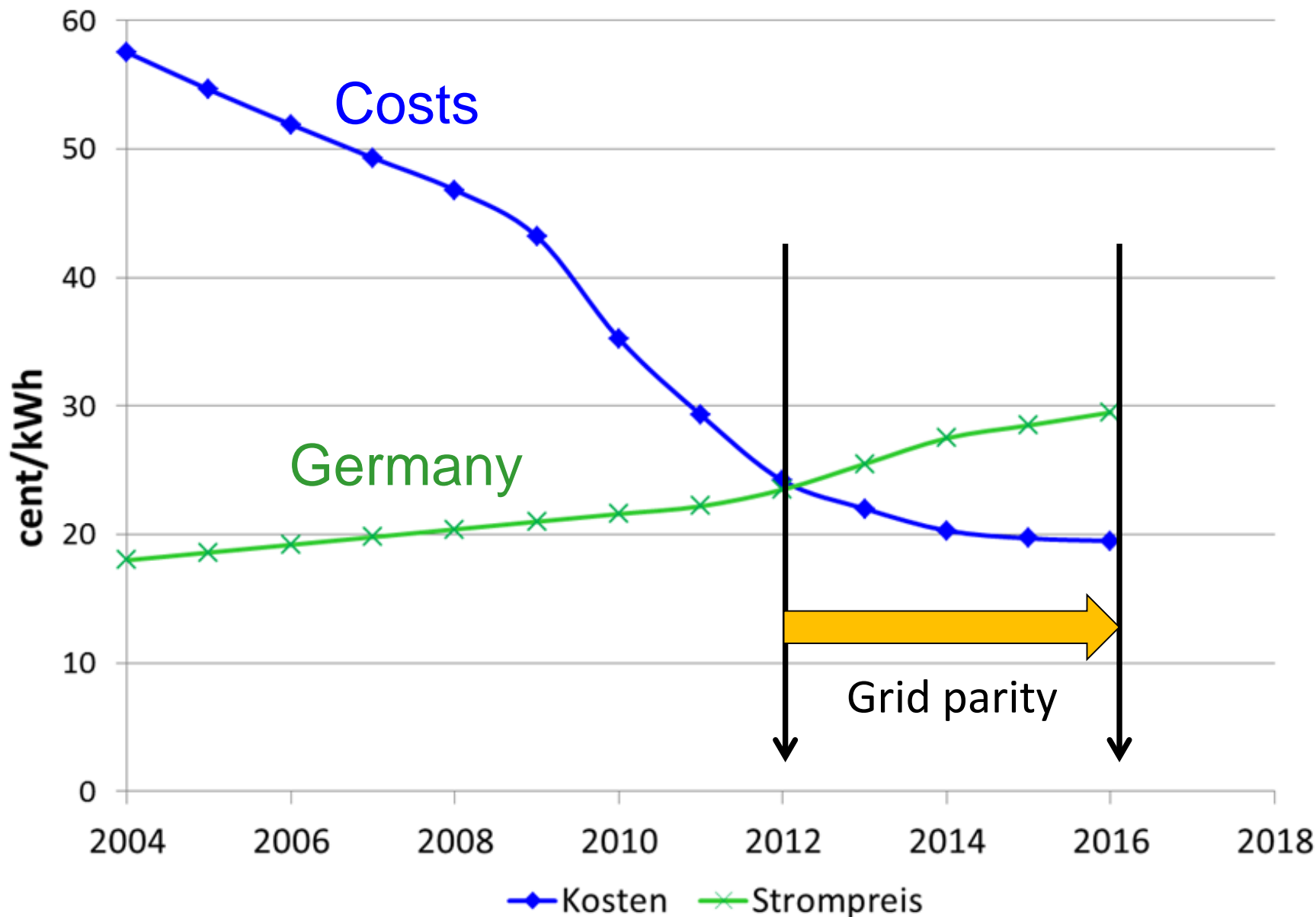
**To meet this target: own generation , storage, flexibility,
Trading in long-term, day-ahead and intraday market**

Every difference → high costs!

8. IS THE TIME FOR SUBSIDIZING RENEWABLES OVER ?

As long there is no price on CO₂

Grid parity: PV-costs and household electricity prices

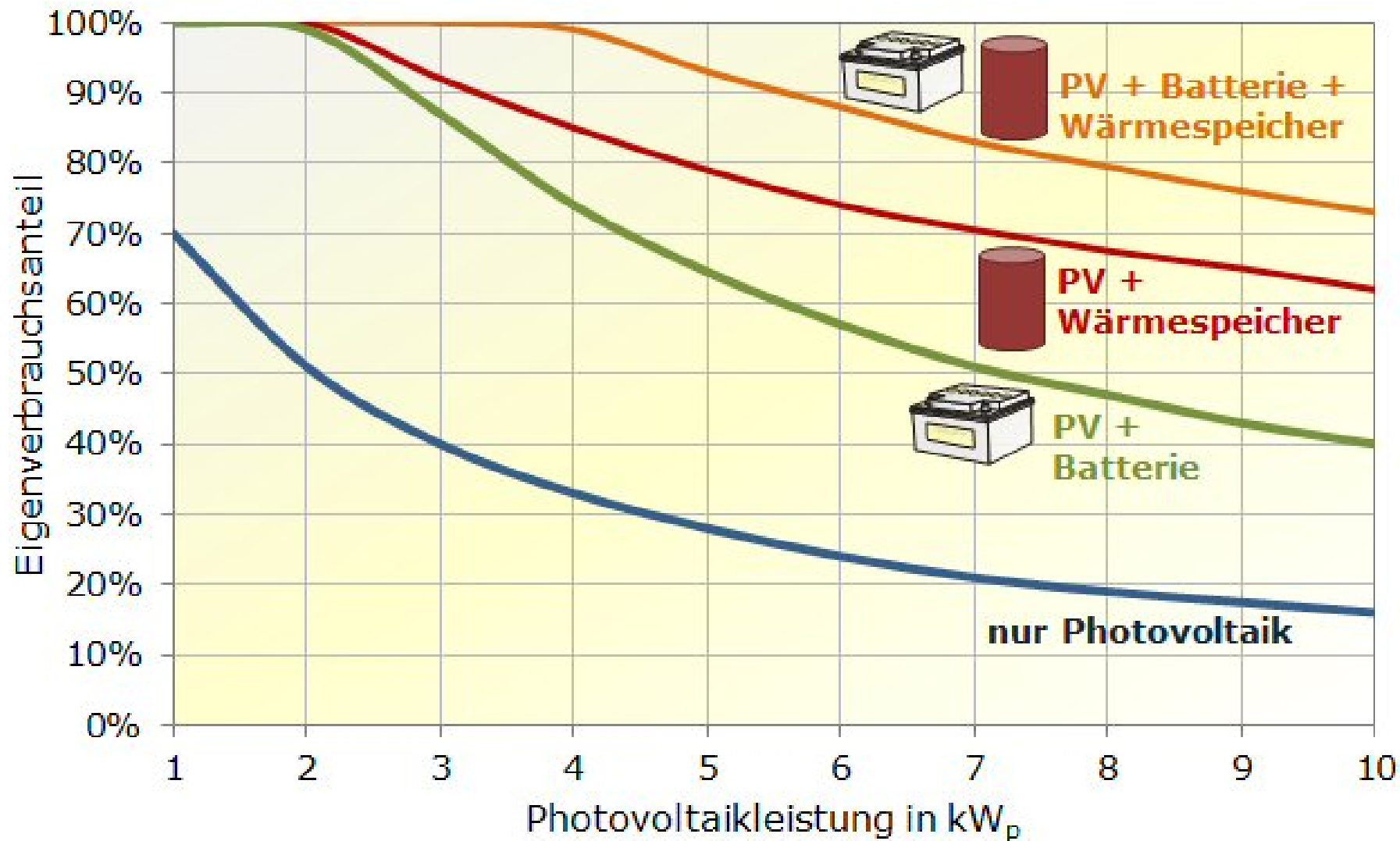


$$\begin{array}{c}
 \text{Savings/revenues} \qquad \qquad \qquad \text{Costs} \\
 \hline
 \text{E}_{\text{Own}} * \text{P}_{\text{HH}} + \text{E}_{\text{Feed-in}} * \text{P}_{\text{feed-in}} > \text{Annuity}
 \end{array}$$

Grid parity term

Subsidy still necessary?

Share of own consumption



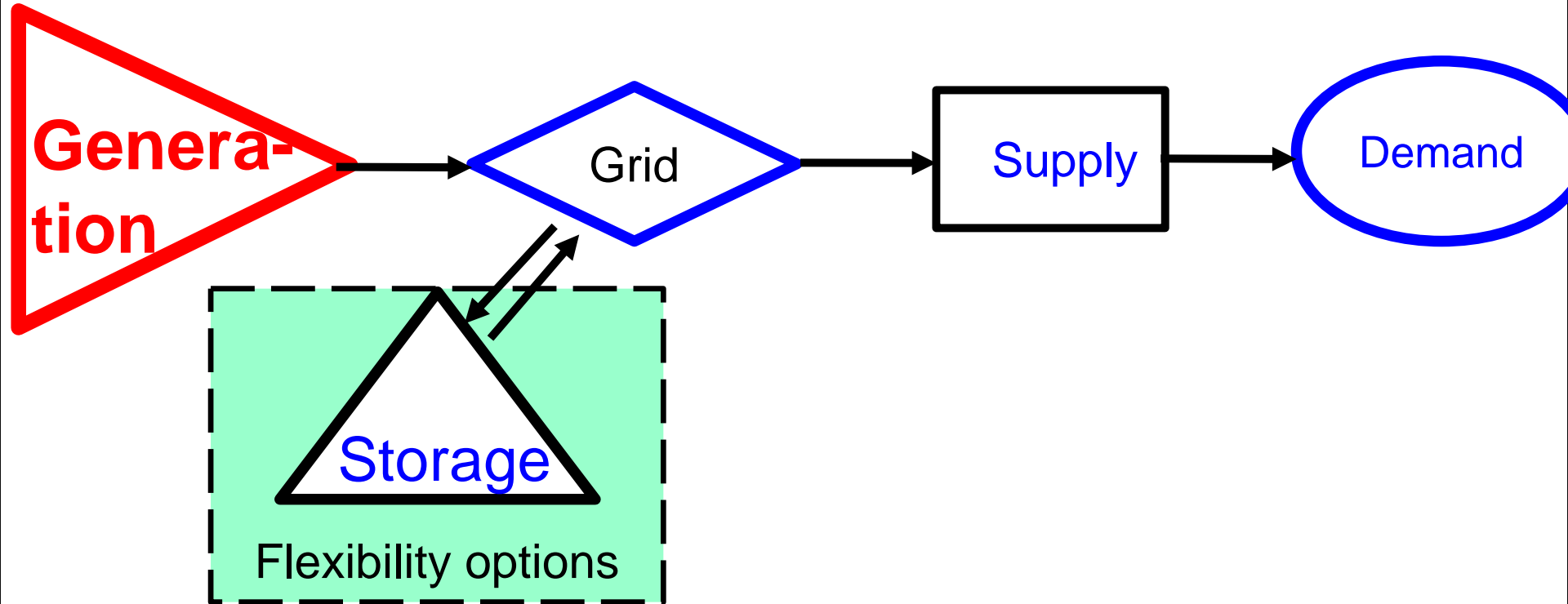
Tender for wind farms to be constructed between 2021 and 2025:

Project	MW	ct/kWh
EnBW He Dreiht GmbH	900	0.0
DONG Energy Borkum Riffgrund West II GmbH	240	0.0
Dong Energy Northern Energy OWP West GmbH	240	0.0
Dong Energy Gode Wind 03 GmbH	110	6.0*
Weighted average	1,490	0.44

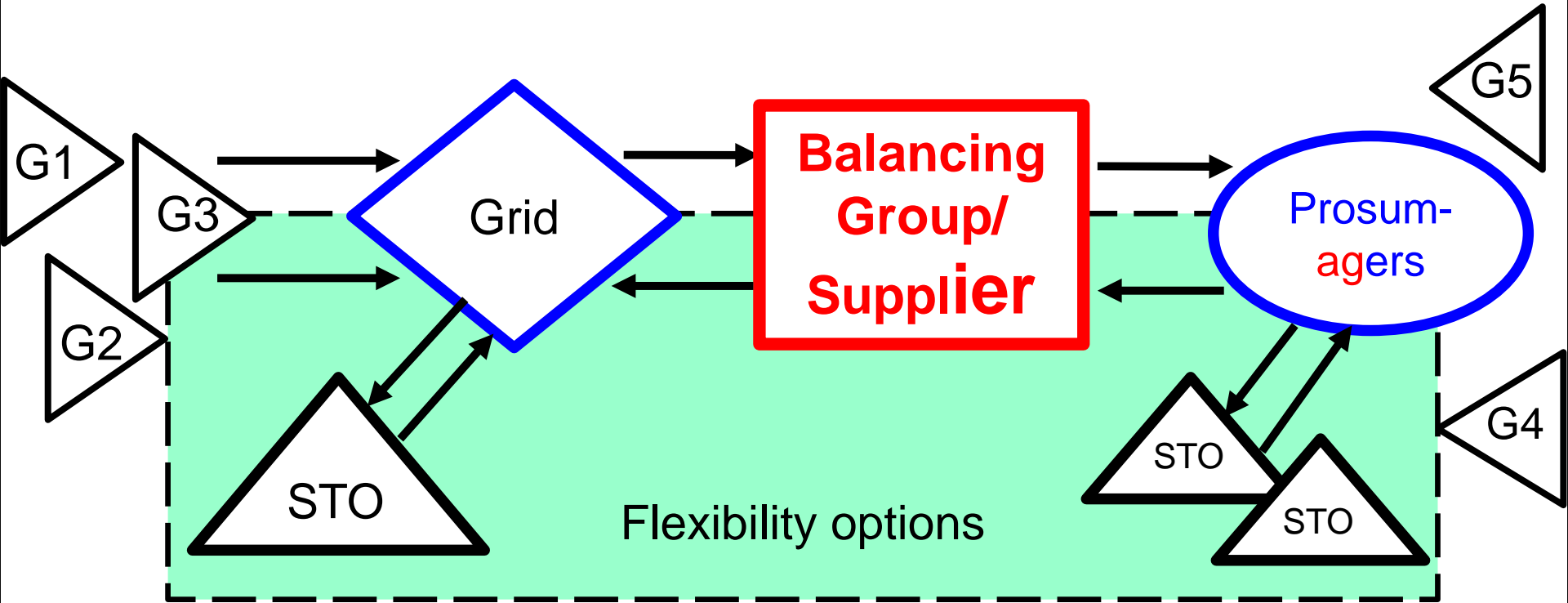
Source: Innogy

Bets on:

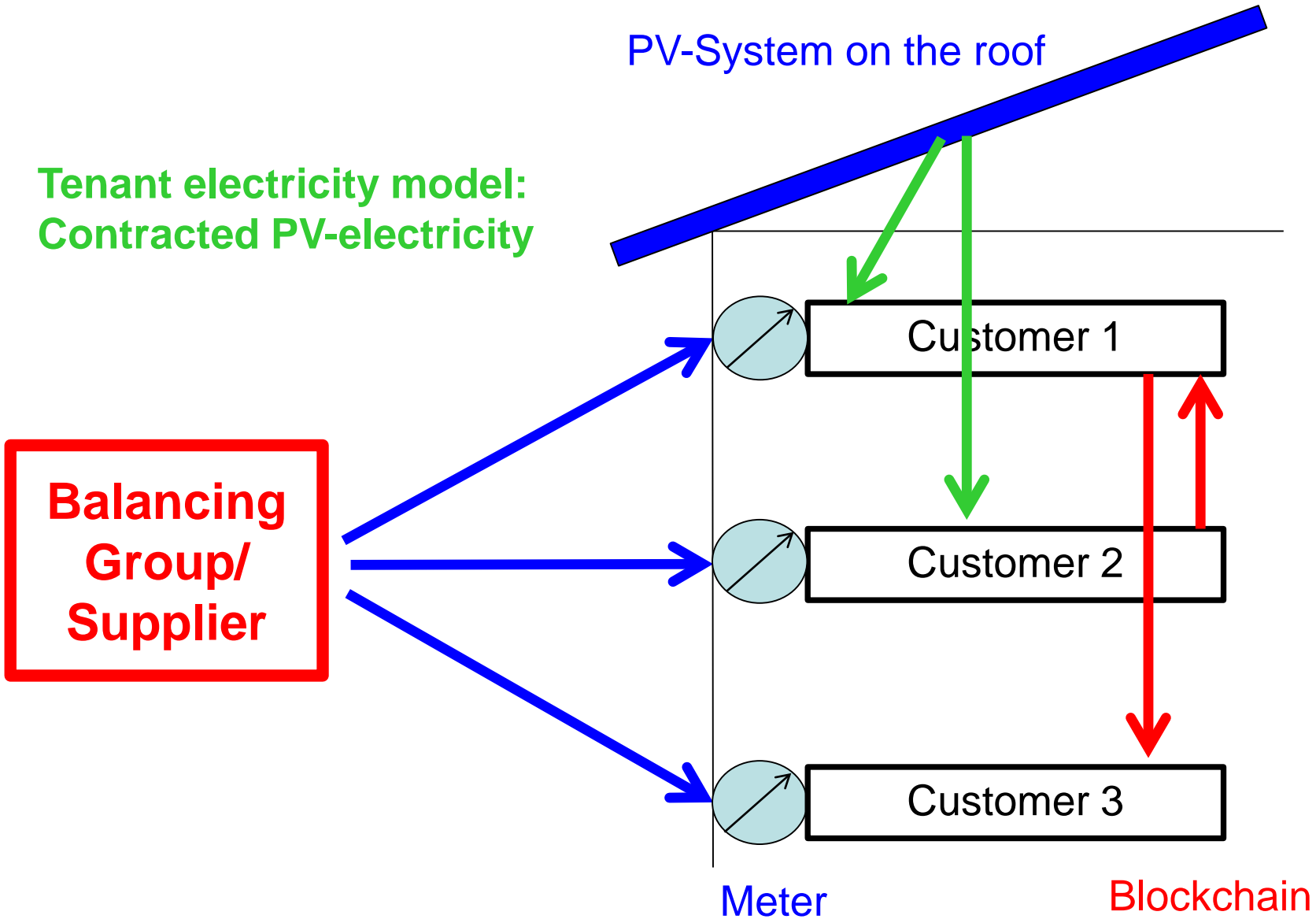
- Increasing electricity prices
- Decreasing technology costs
- Sector coupling works



New Thinking: Making the electricity system more democratic



Tenant electricity model and Blockchain



Tenant electricity model:
Contracted PV-electricity

PV-System on the roof

**Balancing
Group/
Supplier**

Customer 1

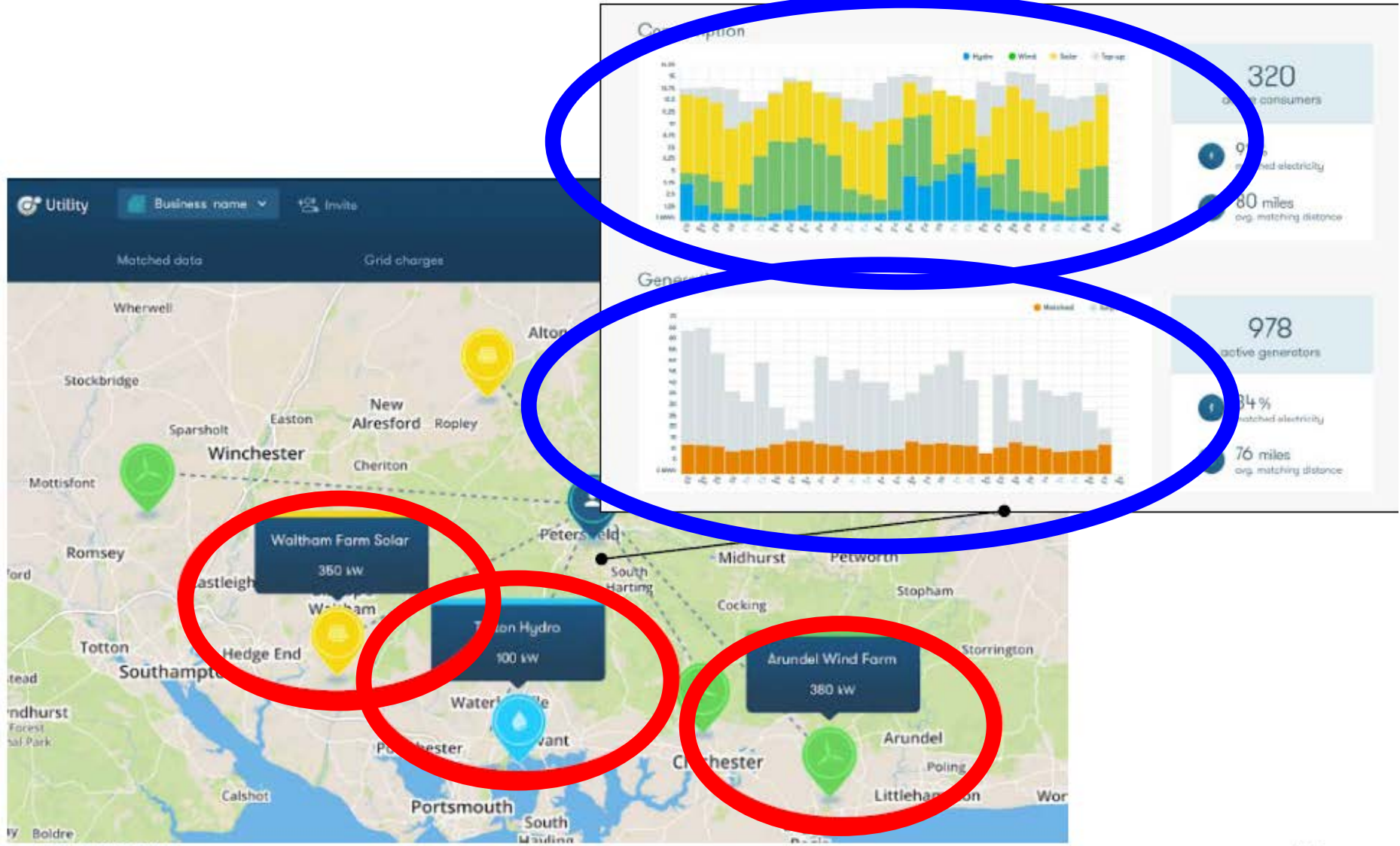
Customer 2

Customer 3

Meter

Blockchain

Peer-to-peer



12/04/2017

Source: piclo.co.uk

- Sustainable electric. system → integration of a broad **technology** portfolio & **demand-side options**
- **Larger** market areas favourable
- Very important: **correct price signals** (incl. CO₂)
- most urgent: exhaust **full creativity** for **flexibility** of all market participants incl. **decentralised PV systems**
- Capacity payments: **Any CP** will distort the system towards more conv. and less RES capacity
- **New key player: Balancing group (Supplier)**, no more the generator
- **Phasing out of Subsidies!**