The Economy of Electricity Storage

Applications and strategies for (large scale) power storage technologies

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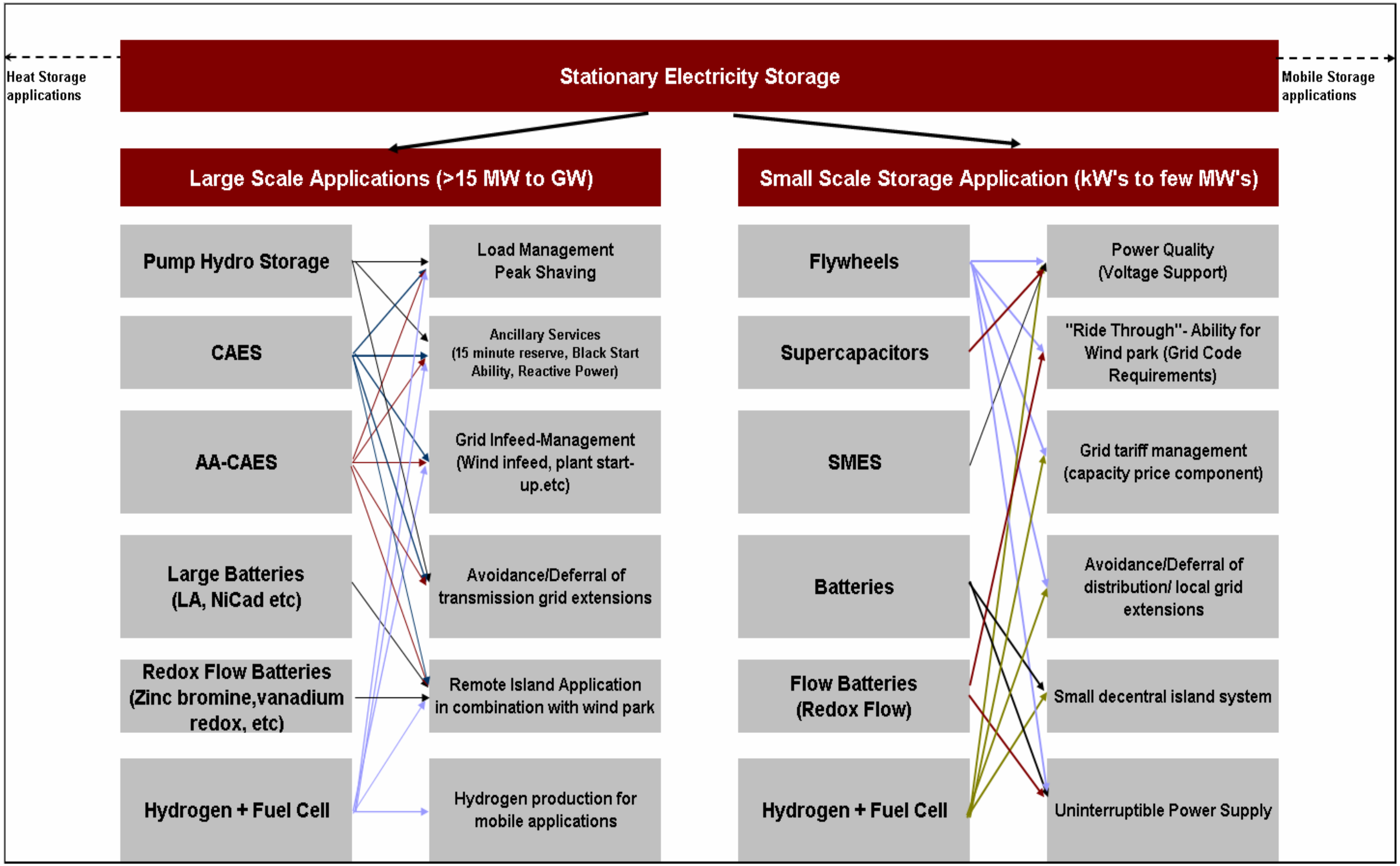
Agenda

- Overview storage technologies and applications
- Strategies for large scale power storage technologies
- Fundamental market features of target markets in central Europe
- Model based quantification of storage value for selected countries and technologies

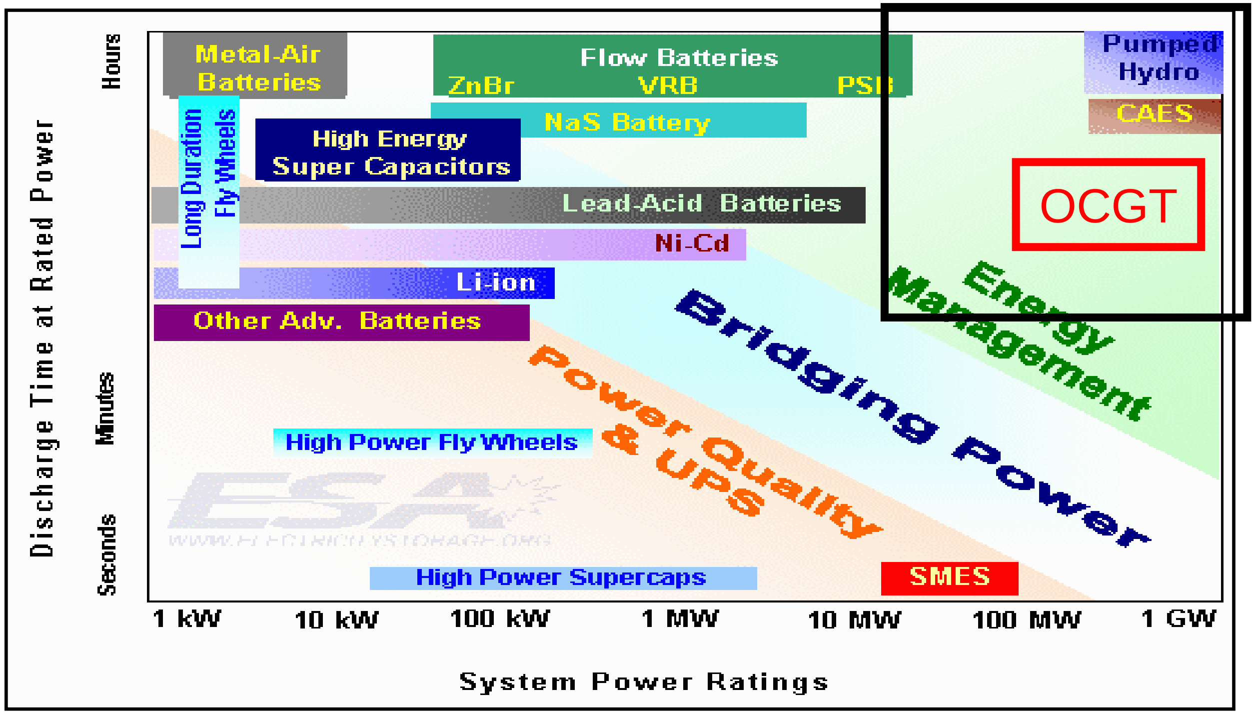
Clustering storage technologies and applications



Potential applications for stationary storage technologies

Benefit of an AA-CAES	On-Grid	Off-Grid
Inter-temporal arbitrage (peak shaver)	x	
Balancing of the system	x	
Grid loss avoidance	x	
Grid investment avoidance/deferral	x	
Reserve capacity emergency supply	x	x
Voltage/ Frequency Support	x	
Seasonal/day-night renewable energy storage	x	x
Uninteruptable Power Supply	x	x
Power Quality Management	x	

Source: ECN, EWI



Source: ESA

Various stationary storage applications exist:

- Production capacity from kW to GW,

- Storage duration from milli-seconds to weeks,

- Life Time/cycle demand from 10‘s to 1000‘s cycles,

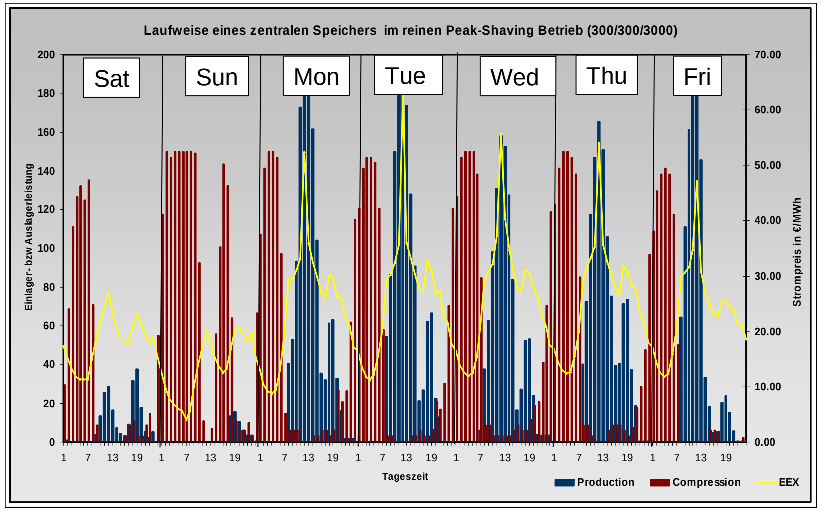
- Response time milli-seconds to minutes.

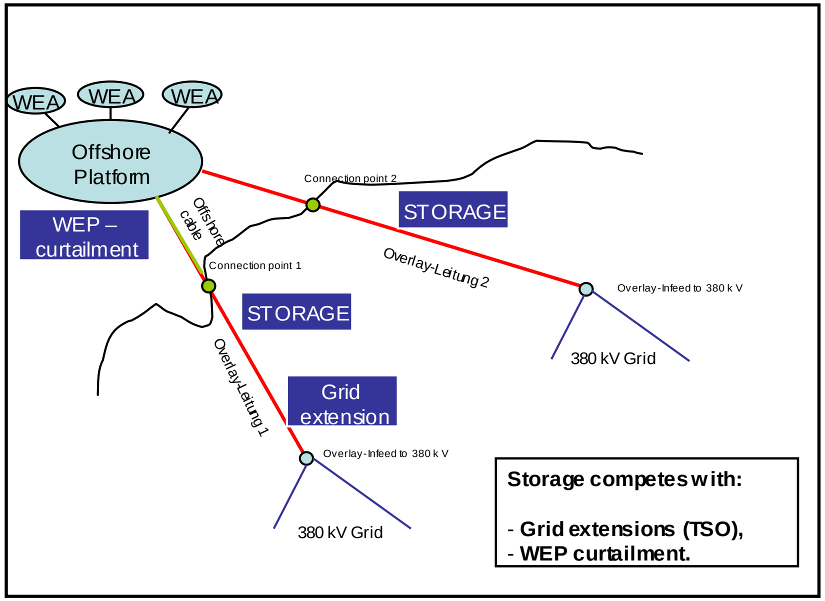
Part I:
Application Strategies and Target Markets

Strategies for a successful operation of large scale storage technologies in Central Europe

Potential application strategies for large scale electricity storages

- A storage unit can be applied as „**peak shaver“ and provider of ancillary services** (Central Application).
- A storage can be used in order **to manage grid infeed** by decoupling power generation from power supply to the grid (in combination with a wind park or an „inflexible“ thermal plant).
- A storage can be used in combination with a wind park **in grid autark areas** (power islands) to constitute the island`s („zero-emission“) power system.





Strategy I: Storage as „Central Application“

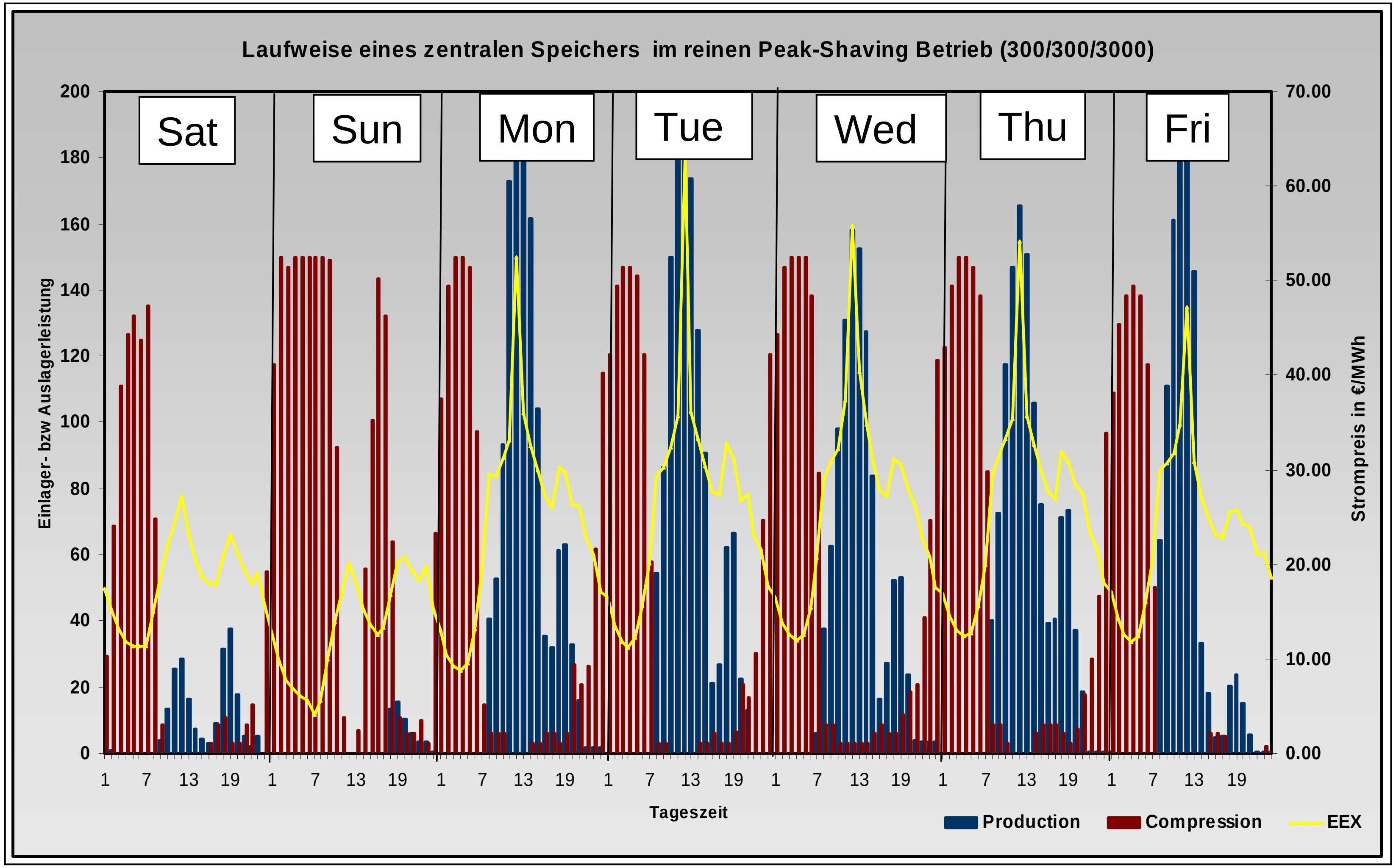
- Typical Storage Unit Size: 300 MW Turbine, 4-10h Storage Volume

- The storage is used in order to shift low price electricity production from baseload technologies to peak price hours,

- The unit is refinanced by price spreads between low system charge prices and high sale prices minus efficiency losses and other variable cycle costs,

- Other benefits:
  - Provider of tertiary reserve (minute reserve),
  - Other ancillary services (black start ability, reactive power)

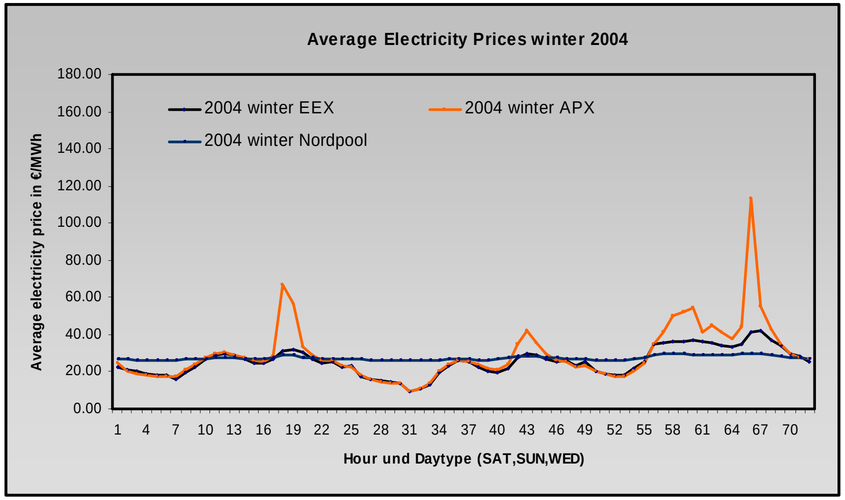
Operation of a central storage in Germany

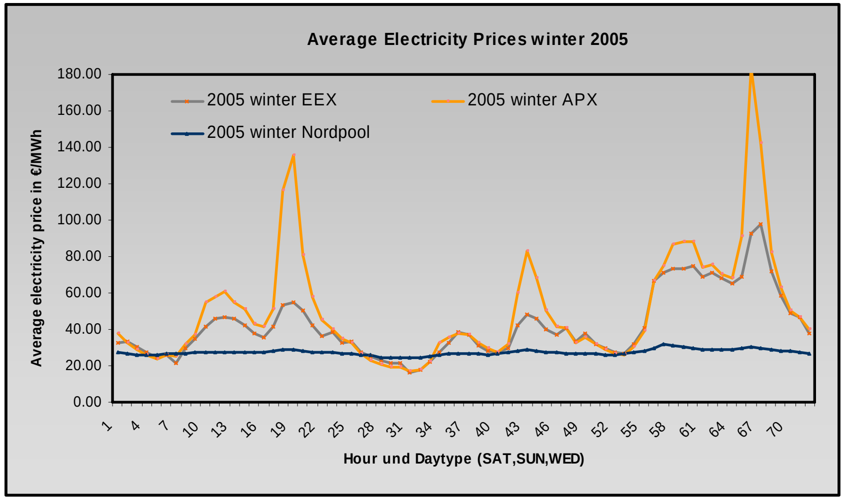


The operation profile is determined by the price curve and the turbine/storage/compressor ratio.

Seasonal storage is not an economic option for Germany (OCGT competition, few cycles).

Spot Market Prices in Central Europe: Example





- The Spot Market price curves in central Europe vary significantly as a consequence of different market fundamentals. The development over time (2004 => 2005) is also country specific.

- Storages need price spreads, not necessarily high prices.

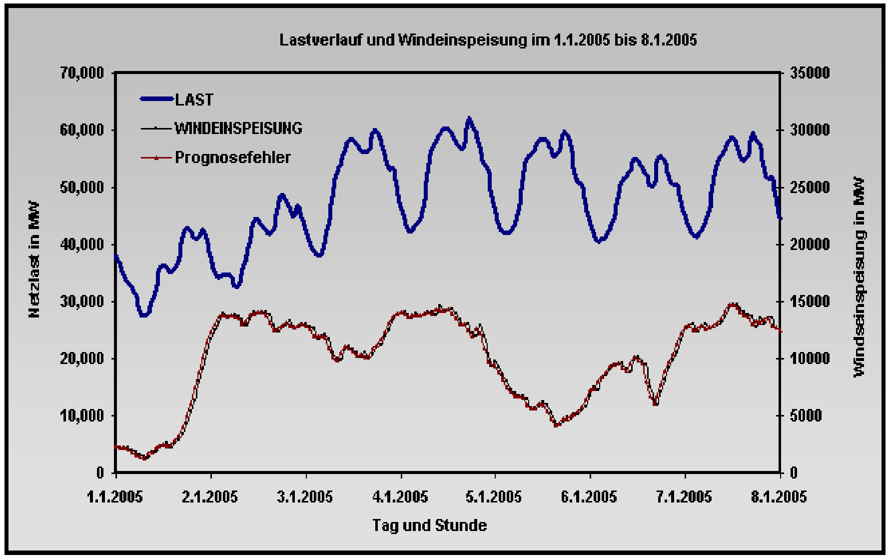
- The more frequent price spreads occur the larger can be the turbine/storage ratio.

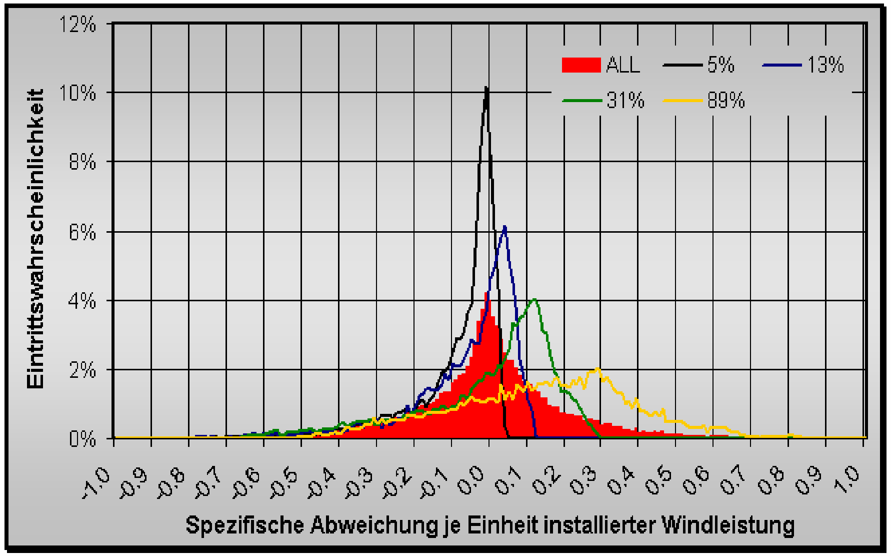
- Each country needs its optimum plant design which „suits“ the price curve.

Large scale storage and wind energie

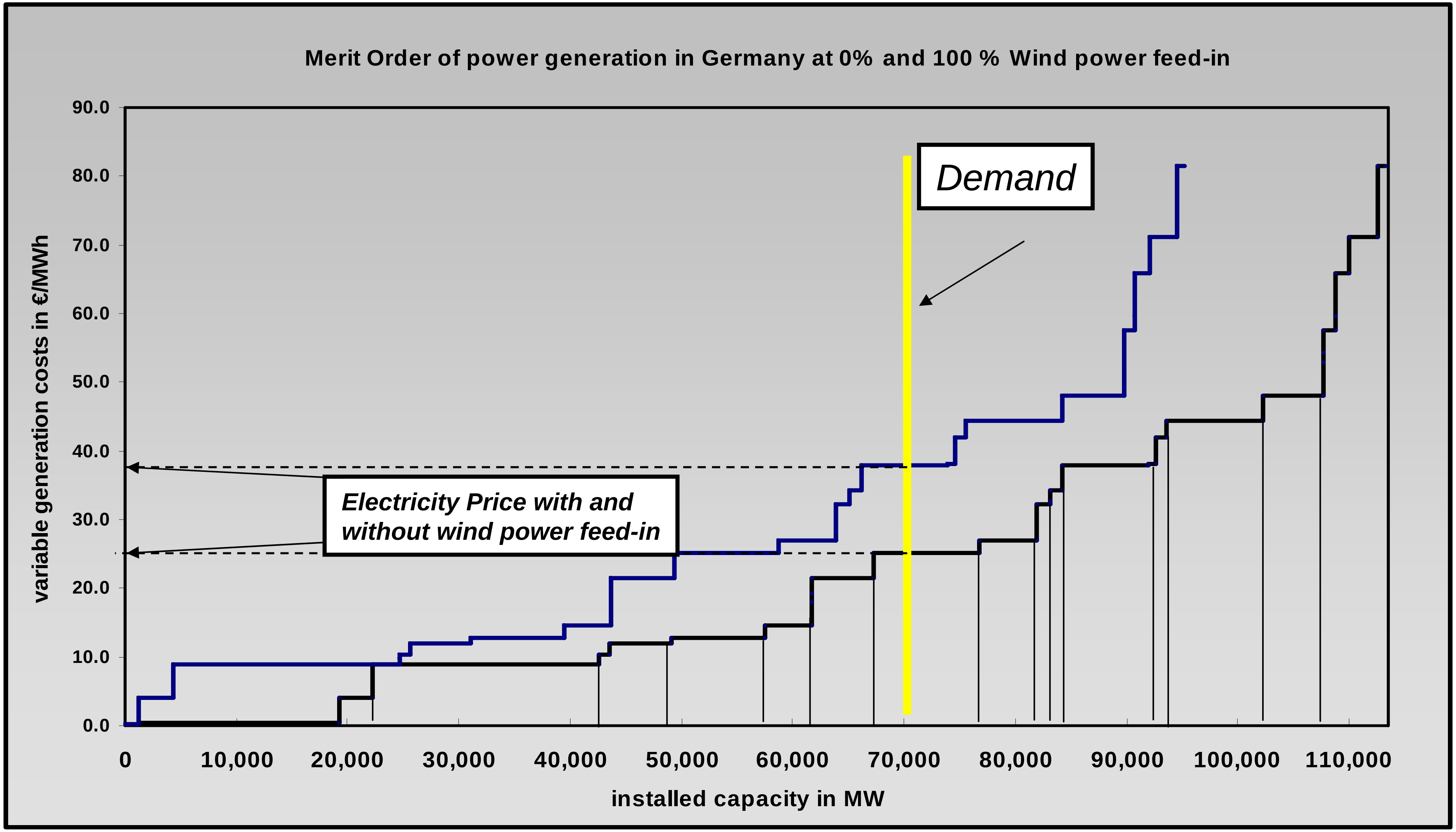
- Not the whole wind power fluctuation has to be balanced by storages in central application but the additional demand in balancing power due to wind forecast errors needs to be balanced out.

- Regulating and reserve power demand is derived from overall system forecast eror consisting of:
  - Unforeseen power plant outages,
  - Load forecast error and
  - Wind infeed forecast error.





Electricity wholesale price effects of wind power feed-in



The wind infeed variations induce power price volatility => value of storage is increased.

Strategy II: Managing production and grid feed-in (1/2)

- Typical unit size: ~100 MW, Storage volume depends on location,

- Storage decouples power production from power infeed to the (transmission) grid,
  - WEP: high Balancing Costs (Difference of spot market value minus balancing price (SBP/SSP) in a specific ¼- Stunde) can be avoided for wind park operators (In Spain WEP operators have to face balancing costs depending on the chosen promotion system, in UK they are obliged to pay for their program deviations),

  - Cost intense start-up procedures in thermal power plants can be avoided:
    - attrition costs and fuel spendings can be avoided,
    - High-efficiency (but inflexible) plant design possible.

Strategy II: Managing production and grid feed-in (2/2)

- Potential benefits of storage when used in combination with a wind park:

  - Peak-Price Sales are possible (with actual feed-in tariffs for wind power and electricity wholesale prices in most times not relevant);

  - WEP curtailment due to grid restrictions can be avoided (concentration of power generation in coastal areas => transport to centres of consumption makes grid extensions necessary)
    - Permission process can delay grid extensions.
      - storage could serve as (expensive) „bridging technology“.

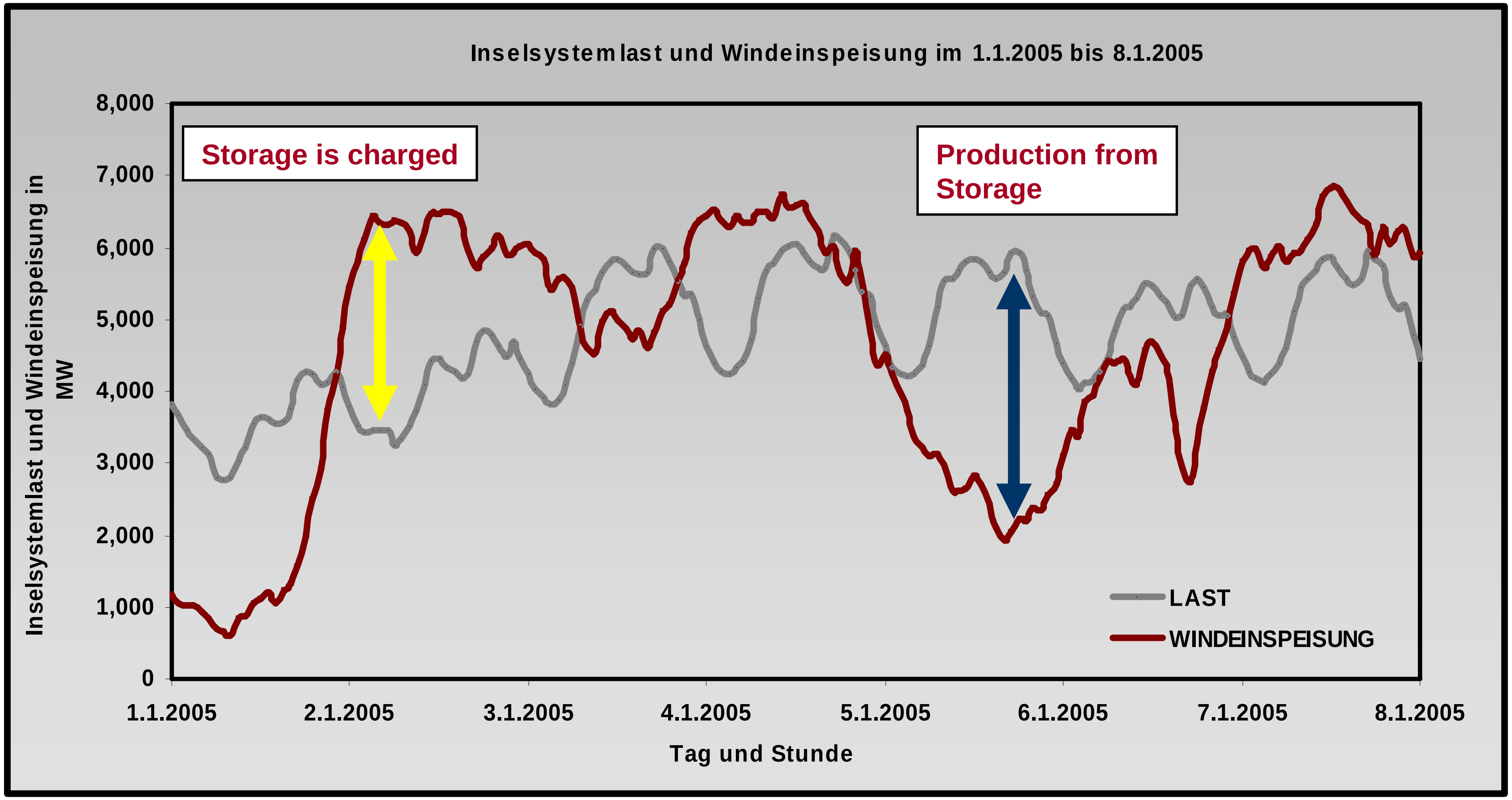
  - Potential savings in sea-side grid connection costs for offshore WEP relatively small since a (redundant) cable based connection to the transmission would still be necessary and large scale offshore-storage technology (CAES) is expensive and risky.

  ⇨ **In general, the CENTRAL application of large scale storages is economically meaningful, as both scale effects for the storage itself and also balancing effects within the system occur!! (exeption: grid constraints)**

Market Application III: Remote Area (Island) Solution

- Storage is used together with a wind power park (non-dispatchable, renewable energy sources) to provide power supply to an island;
- Storage has to adapt wind power generation to the load profile and provide ancillary services;
- the wind power park can be used to full capacity due to the uncoupling of production and demand;
- savings on grid connection costs or substitute for other more expensive dispatchable power supply systems on the island (gas turbine or wind/diesel system).
- Storages like AA-CAES or pumped hydro together with a wind park could form a „zero-emission“ and fuel independant power supply system for an isolated system.

Remote Island Application (not suitable for Germany)



- **Storage adapts Wind power feed in to system demand and provides all necessary ancillary services (frequency and voltage support)**
  - **-Trade - Off: „saved“ surplus generation from wind park vs. fuel costs of alternative peak load device (Diesel/Gas))**
  - **=> WEP Park Design !!**
  - **- <u>Compared to OCGT (350 €/kW vs. min. 800 €/kW):</u>**
    - **- economical feasibility questionable**
    - **- might be useful for special purposes: fuel independancy, „zero emission“ power system**

Part II:
The Central Application:
How does a perfect target market look like?

Fundamental features of potential target markets in Europe

Analysis of the Potential of a CAES plant in different countries

- **System Features which influence the potential benefits of a CAES plant:**

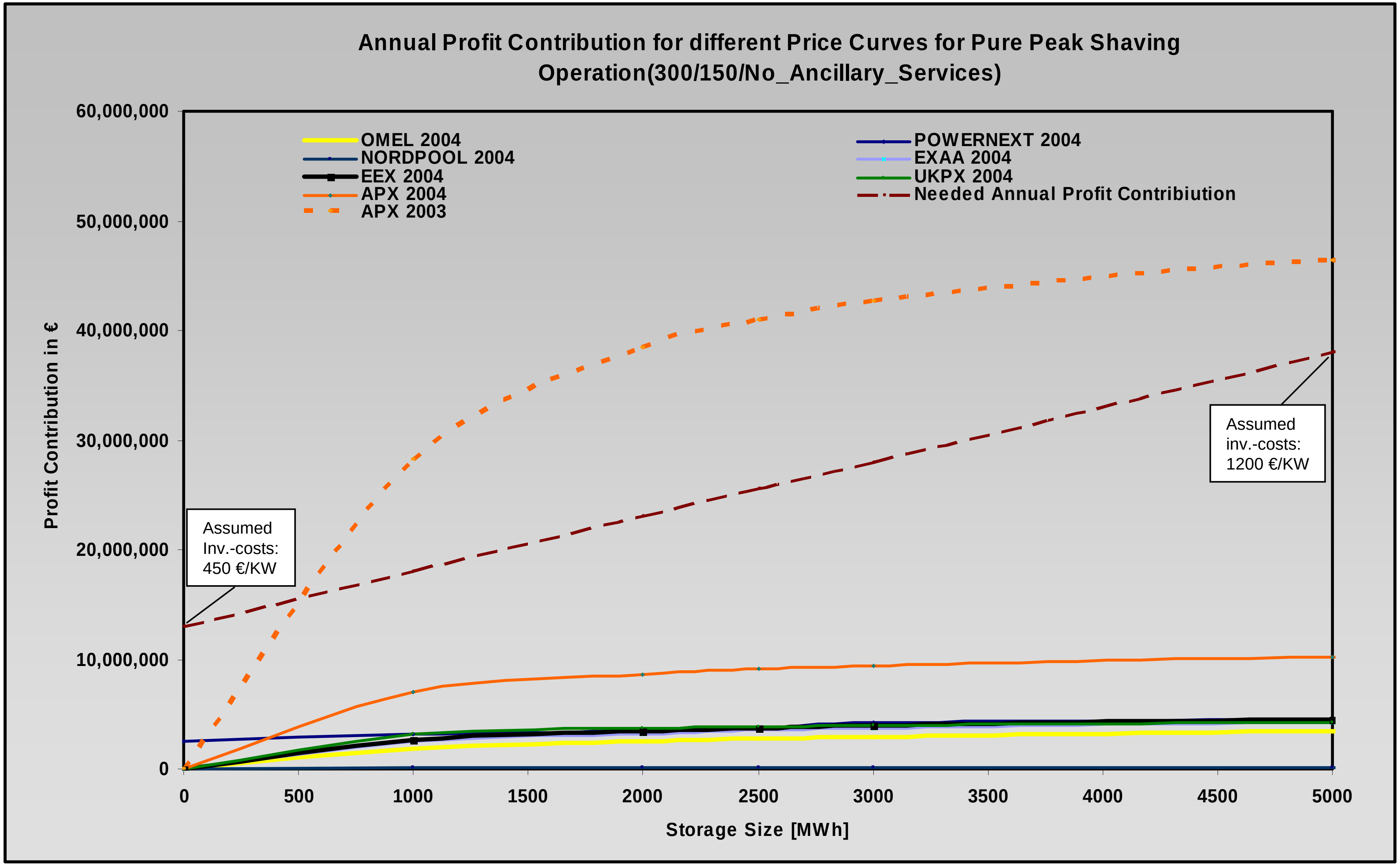
  - Available Base-Load Technology
  - Available Peak-Load Technology — **=> determines price spread between peak and off-peak**
  - Percentage of must-run (CHP) — **=> higher CHP-share lowers off-peak prices**
  - Percentage of non-dispatchable RES volatility — **=> higher RES-share increases price**
  - Available Storage Technologies — **=> storage plants reduce the price spread**
  - Available Import/Export capacities which could reduce price spreads — **=> imports/exports reduce the price spread**
  - Load Structure — **=> determines peak load technology**

  - Historical Price Volatility — **=> gives impression of frequency and size of price spreads**

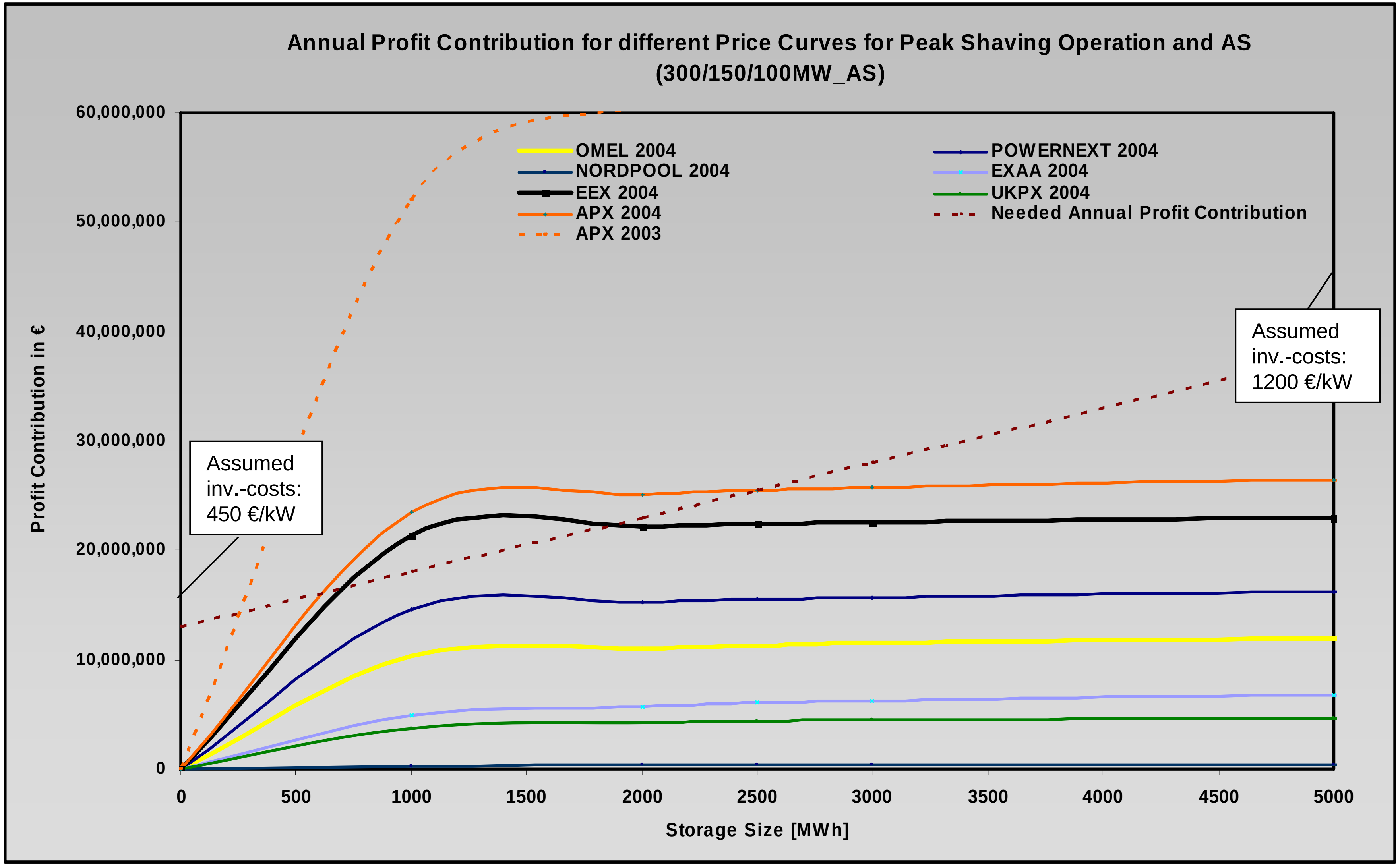
Overview: Potential target markets for large scale storage technologies - central application

Ratings from +++ to ---	Baseload Techn.	Peakload Techn.	CHP Must-run	RES Non-dispatchable	Storage	Interconnector	Load Structure/ Volatility
Germany	+++	+	++	+++	-	--	0
France	+++	-	---	--	-	-	0
Italy	---	-	+	0	---	-	0
Spain	++	++	+	++	--	--	0
Netherlands	--	++	+++	+	+++	++	+++
Belgium	++	++	0	--	-	0	++
Sweden	+++	++	+	--	-	---	--
Norway	--	--	--	--	---	+	--
Denmark	--	-	+++	+++	++	---	--
UK	++	++	-	0	-	+	0
Alpine	++	--	++	-	---	--	0

Potential Benefits from pure peak shaving operation from an AA-CAES plant in 2005



Potential Benefits from peak shaving operation and regulating power sales from an AA-CAES plant in 2005



Summary and Conclusions

- The central application (peak shaving, ancillary services) is the most promising application strategy for large scale storage systems, storages for grid infeed management purposes and remote island systems may be economically feasible, but only under certain conditions (grid restrictions).
- Storages need high price spreads, not high prices!
- The marginal benefit of storage volume decreases in a system!
- Since there are no capacity payments in Germany (besides for some ancillary services): No cycling - no money!
- In Germany storages are run in daily-/weekly cycles, large seasonal storages are economically infeasible (see above).
- The Dutch power market would be most promising for large scale storages in Central Europe. Other interesting markets such as Germany, Denmark or Spain exist.
- Growing WEP constribution increases value of storage technologies due to higher power price volatility and increased demand for regulating and reserve power.

Thank you very much for your attention!

For questions/comments please contact:

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