Institut für Elektrische Energietechnik

Prof. Dr.-Ing. habil. Ingo Stadler

Old markets, new markets and new market modells für Energy Storage

Ideas derived from technical requirements

Content

- Storage Need
  - How much?
  - When, where and for what?
  - Storage as a competitor to gird extensions?
- Storage Promotion, Storage Introduction
  - „Renewable Energy Sources Act“ for Energy Storage?
  - Discriminating of Storage Technologies
  - Is there a need for storages to compete at markets? And at which market?
  - Retrospect: Germany has immense storage capacities – but is denying it
  - Establishment of strategic electricity reserves

From: „Energieszenarien für ein Energiekonzept der Bundesregierung“

ewi gws prognos

Tabelle A 1-11: Bruttostromerzeugungskapazitäten nach Energieträgern 2008-2050, in GW (Szenarien I A bis IV A)

		Referenz				Szenario I A				Szenario II A				Szenario III A				Szenario IV A			
	2008[1)]	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050
Bruttoleistung, Absolutwerte in GW																					
Kernkraft 2)	20,4	6,7	0,0	0,0	0,0	12,1	4,0	0,0	0,0	20,4	12,1	0,0	0,0	20,4	20,4	8,0	0,0	20,4	20,4	15,6	2,6
Steinkohle	30,7	28,5	18,0	17,9	10,9	24,0	17,9	18,4	15,1	21,3	18,2	18,9	14,8	19,6	18,2	19,1	14,8	19,2	17,8	18,6	14,0
CCS	0,0	0,0	0,0	2,5	4,9	0,0	1,5	4,6	10,7	0,0	1,8	5,1	10,4	0,0	1,8	5,3	10,4	0,0	1,5	5,0	9,7
Braunkohle	22,4	21,4	11,8	7,9	7,9	21,4	11,8	6,2	0,7	21,2	11,7	6,6	0,7	21,0	11,4	6,3	0,7	21,0	11,4	6,2	0,6
CCS	0,0	0,0	0,0	1,0	7,0	0,0	0,0	0,4	0,6	0,0	0,0	0,5	0,6	0,0	0,0	0,4	0,6	0,0	0,0	0,3	0,5
Erdgas	25,7	24,4	45,7	44,5	41,5	22,4	36,7	25,7	20,1	16,3	26,5	27,4	22,0	16,0	18,6	21,8	22,5	16,6	19,1	16,7	22,1
Heizöl	6,7	0,7	0,4	0,1	0,0	0,7	0,4	0,1	0,0	0,7	0,4	0,1	0,0	0,7	0,4	0,1	0,0	0,7	0,4	0,1	0,0
Pumpspeicher 3)	7,5	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7	7,7
andere Brennstoffe 4)	3,2	3,5	3,8	4,1	4,4	3,5	3,8	4,1	4,4	3,5	3,8	4,1	4,4	3,5	3,8	4,1	4,4	3,5	3,8	4,1	4,4
Erneuerbare Energien	39,1	87,6	97,5	103,1	106,4	90,0	101,2	108,9	113,9	90,0	101,6	110,8	117,6	90,0	101,6	110,8	117,6	87,6	97,5	103,1	106,4
Lauf und Speicherwasser	5,2	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6	5,6
Wind onshore	23,9	33,3	33,7	35,2	36,4	33,3	33,7	35,2	36,4	33,3	33,7	35,2	36,4	33,3	33,7	35,2	36,4	33,3	33,7	35,2	36,4
Wind offshore	0,0	7,6	12,6	15,2	17	10,1	16,3	21,0	24,5	10,1	16,7	23,0	28,25	10,1	16,7	23,0	28,25	7,6	12,6	15,2	17,0
Biomasse	3,5	5,7	6,0	6,0	6,0	5,7	6,0	6,0	6,0	5,7	6,0	6,0	6,0	5,7	6,0	6,0	6,0	5,7	6,0	6,0	6,0
Photovoltaik	6,0	33,3	37,5	38,8	39,0	33,3	37,5	38,8	39,0	33,3	37,5	38,8	39,0	33,3	37,5	38,8	39,0	33,3	37,5	38,8	39,0
Geothermie	0,0	0,3	0,4	0,6	0,7	0,3	0,4	0,6	0,7	0,3	0,4	0,6	0,7	0,3	0,4	0,6	0,7	0,3	0,4	0,6	0,7
andere erneuerbare Brennstoffe 5)	1,2	1,6	1,6	1,6	1,7	1,6	1,6	1,6	1,7	1,6	1,6	1,6	1,7	1,6	1,6	1,6	1,7	1,6	1,6	1,6	1,7
Insgesamt	156,3	180,5	185,0	185,4	178,8	181,9	183,7	171,1	161,9	181,2	182,1	175,7	167,3	179,0	182,3	178,0	167,8	176,7	178,3	172,2	157,9
Bruttoleistung, Struktur in %																					
Kernkraft 2)	13,0	3,7	0,0	0,0	0,0	6,7	2,2	0,0	0,0	11,3	6,6	0,0	0,0	11,4	11,2	4,5	0,0	11,6	11,5	9,0	1,7
Steinkohle	19,7	15,8	9,7	9,6	6,1	13,2	9,8	10,7	9,3	11,7	10,0	10,8	8,9	10,9	10,0	10,7	8,8	10,9	10,0	10,8	8,9
CCS	0,0	0,0	0,0	1,3	2,7	0,0	0,8	2,7	6,6	0,0	1,0	2,9	6,2	0,0	1,0	3,0	6,2	0,0	0,8	2,9	6,2
Braunkohle	14,3	11,9	6,4	4,3	4,4	11,8	6,4	3,6	0,4	11,7	6,4	3,7	0,4	11,7	6,3	3,5	0,4	11,9	6,4	3,6	0,4
CCS	0,0	0,0	0,0	0,5	3,9	0,0	0,0	0,2	0,3	0,0	0,0	0,3	0,4	0,0	0,0	0,2	0,3	0,0	0,0	0,2	0,3

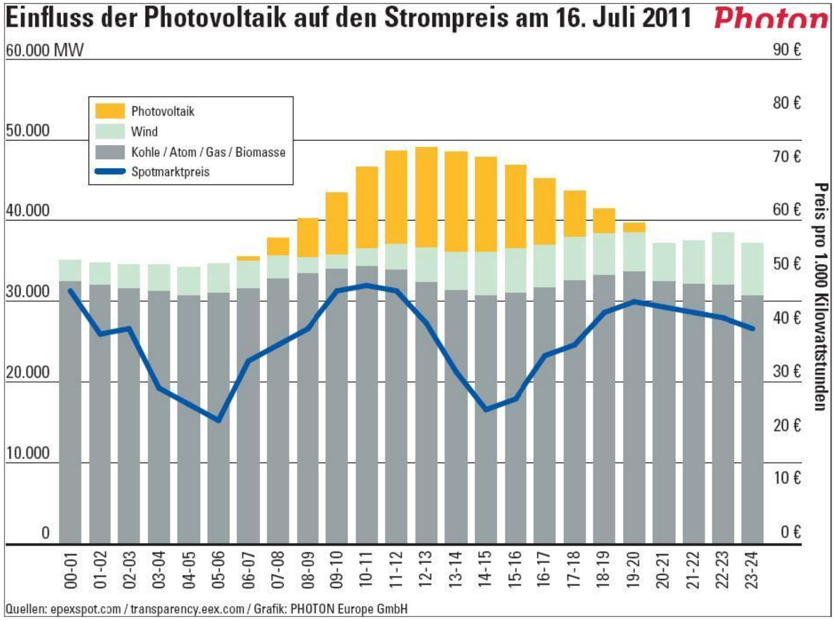
On behalf of governmental organisations:

- Based on only few reference days per year
- No consideration of grid bottlenecks
- No consideration of energy storage

<u>How much</u> storage we need currently cannot be answered!

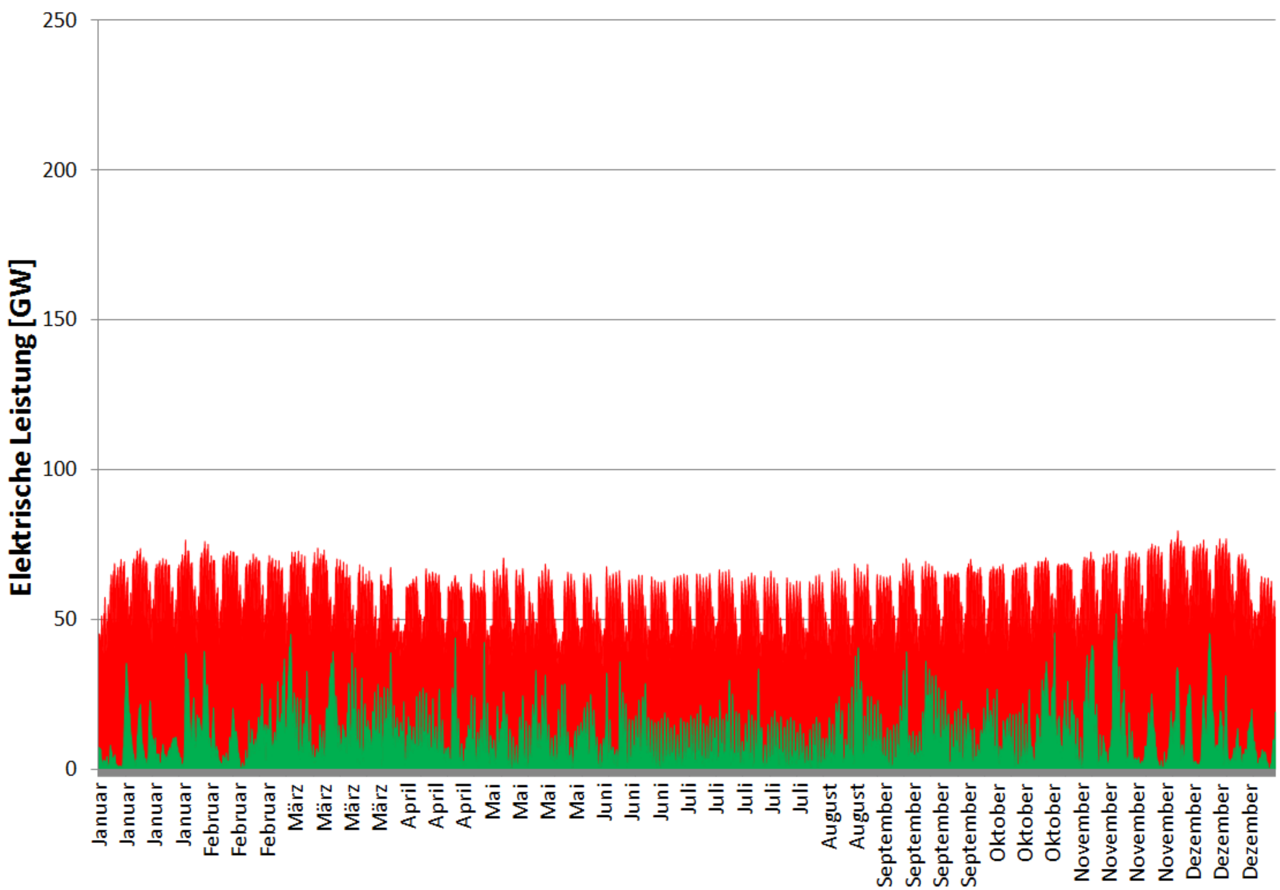
When do we need energy storage?

- Currently we get the impression that storage need even decreases
- Photovoltaics removes the business case for pumped hydro storages



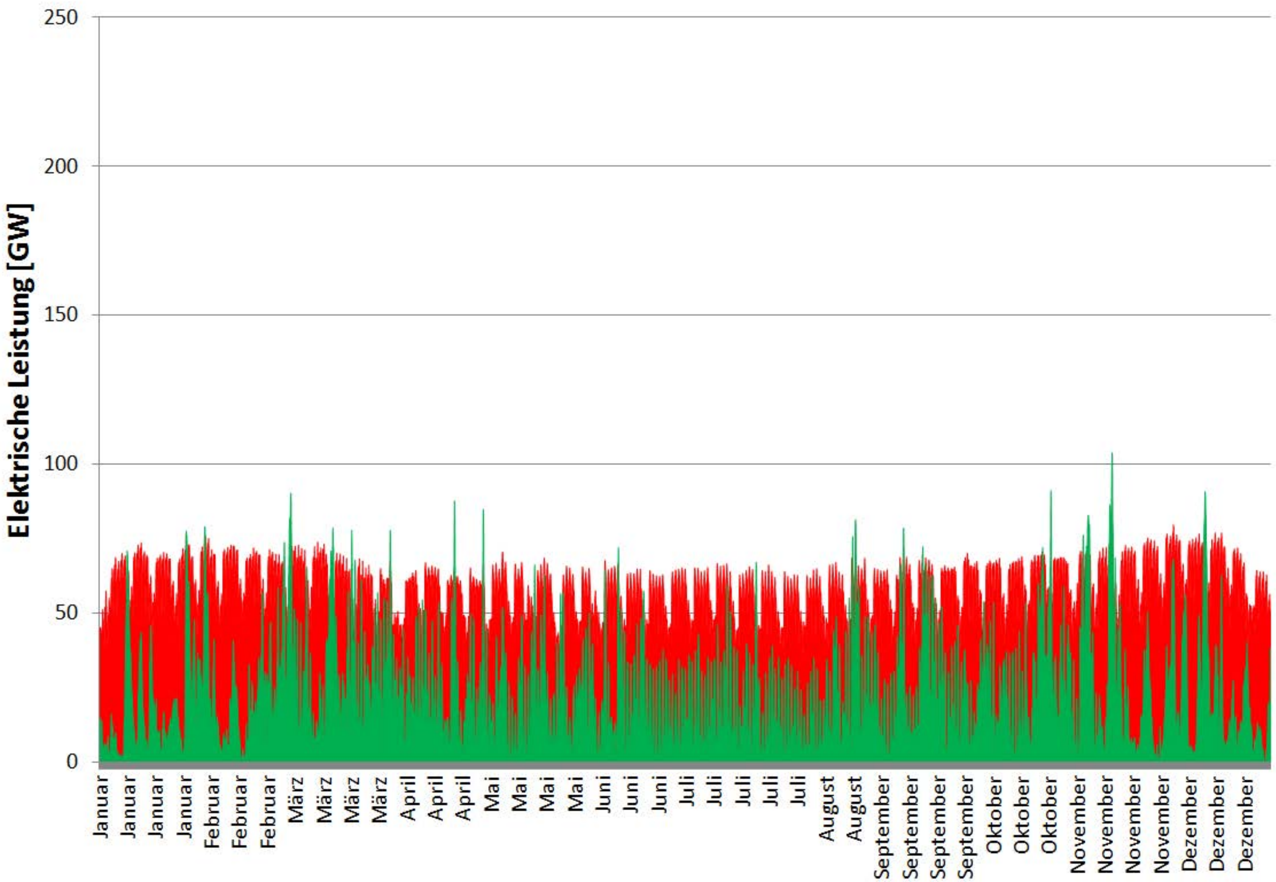
- This is more a temporary effect
- In future for sure energy storage need will drastically increase

Renewable Generation (20%) and Consumption 2010 Germany



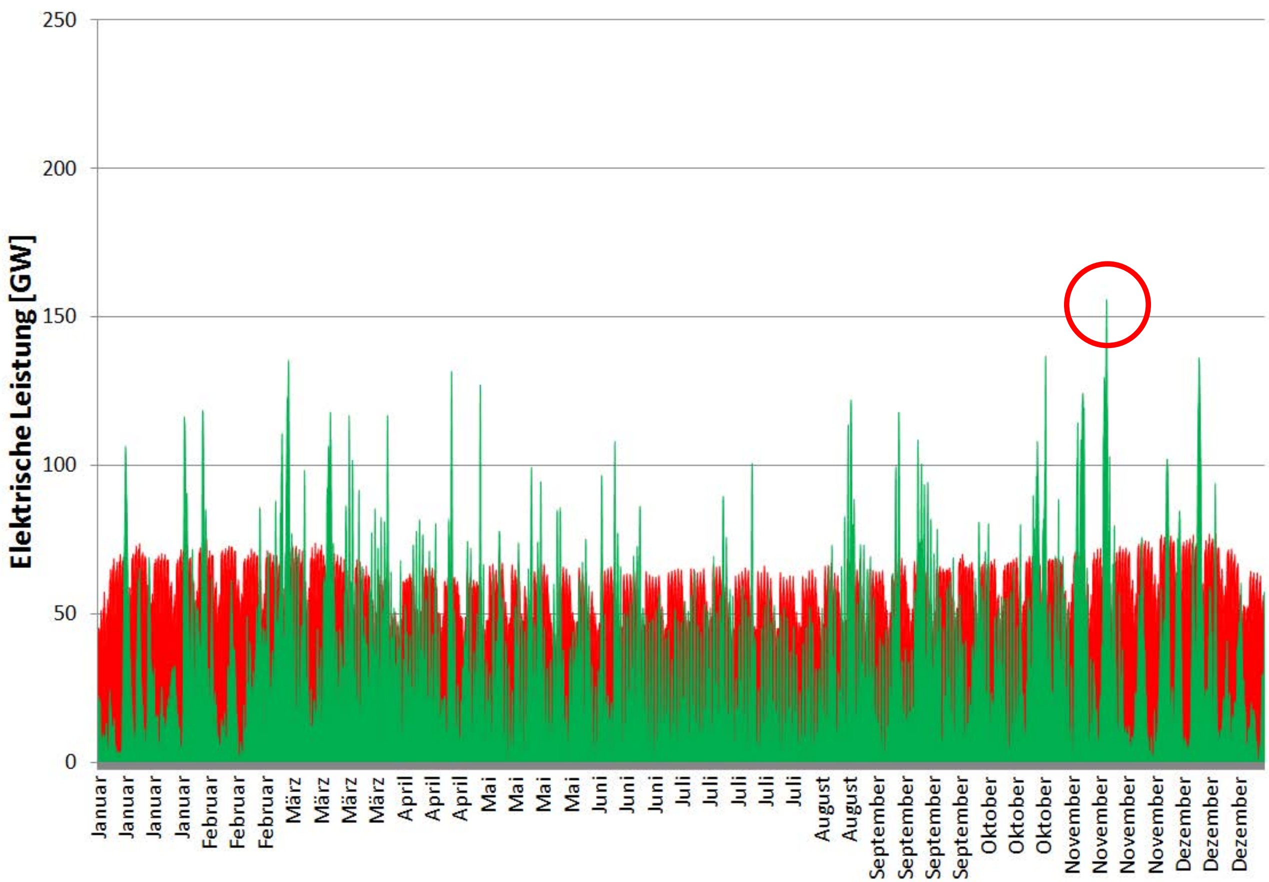
- Red:
  consumption 2010
- Green:
  wind + solar 2010

Renewable Generation (40%) and Consumption 2010 Germany



- Can storage be justified with 40% Wind and Solar?
- Hardly. At least not with ideally complementary conventional power stations
- So, not renewables but unflexible conventional power generation could become the reason for early energy storage

Renewable Generation (60%) and Consumption 2010 Germany



- With 60%?
- More reasonable
- Or will flexible gas power stations the cheaper alternative?

- For sure not to store the last kilowatthour
- (criticism of dena II-grid study)

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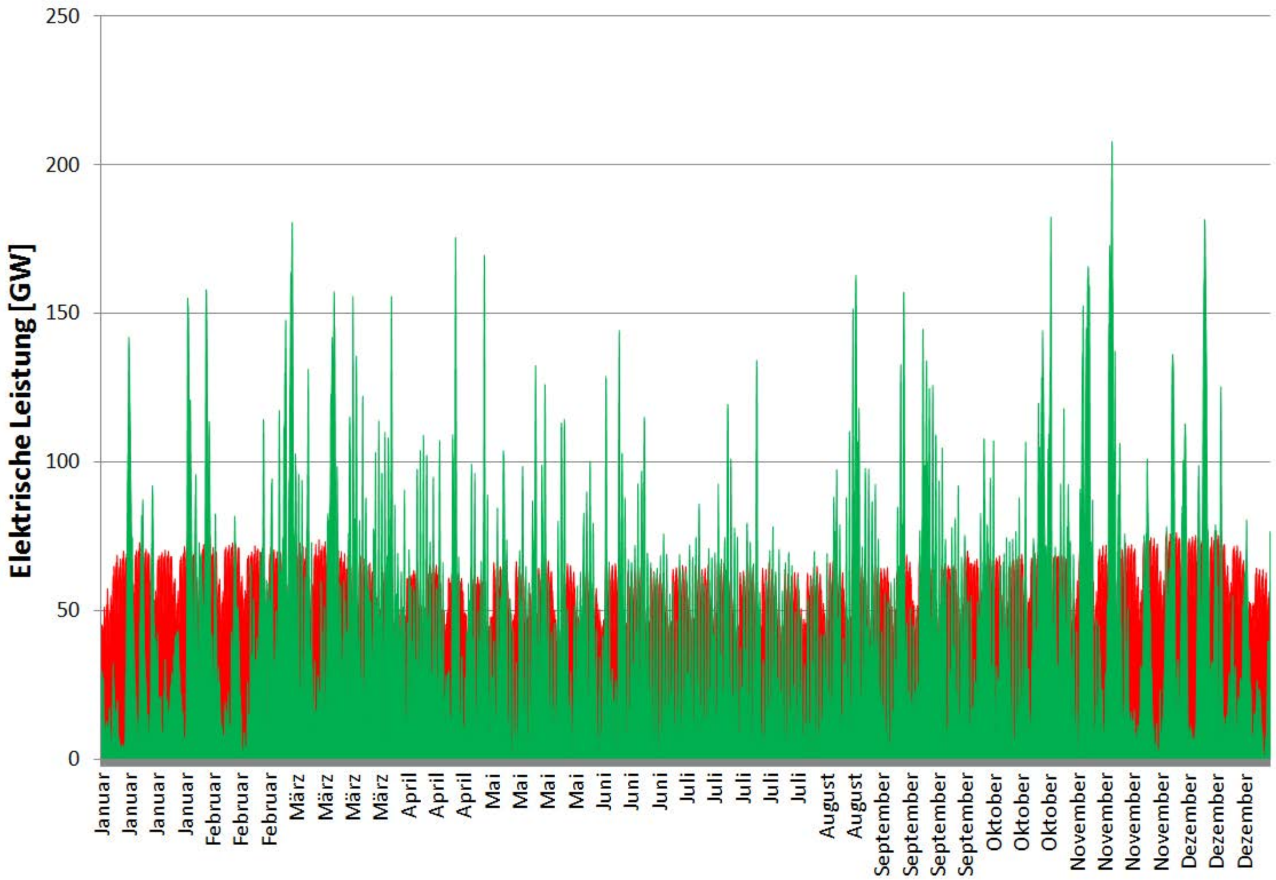
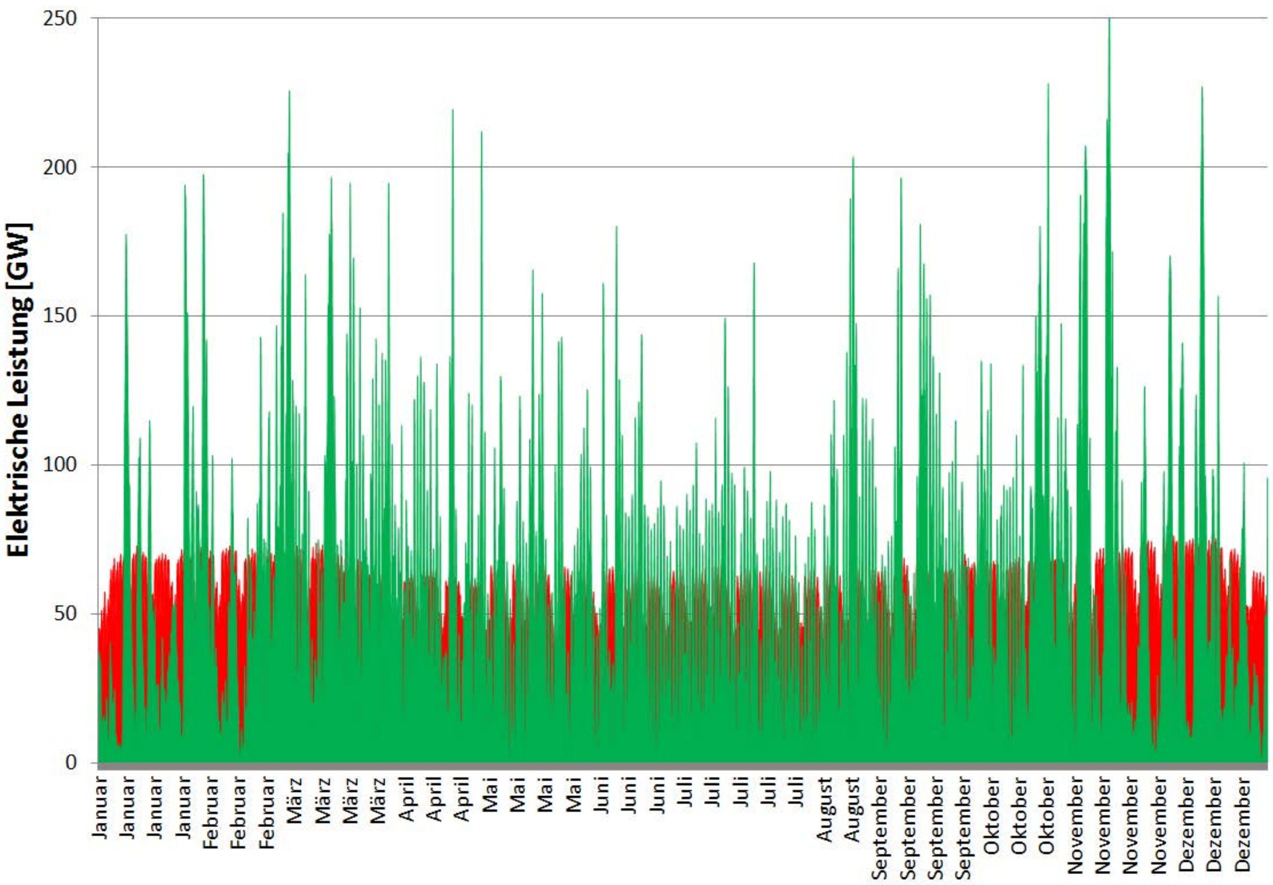
Renewable Generation (80%) and Consumption 2010 Germany

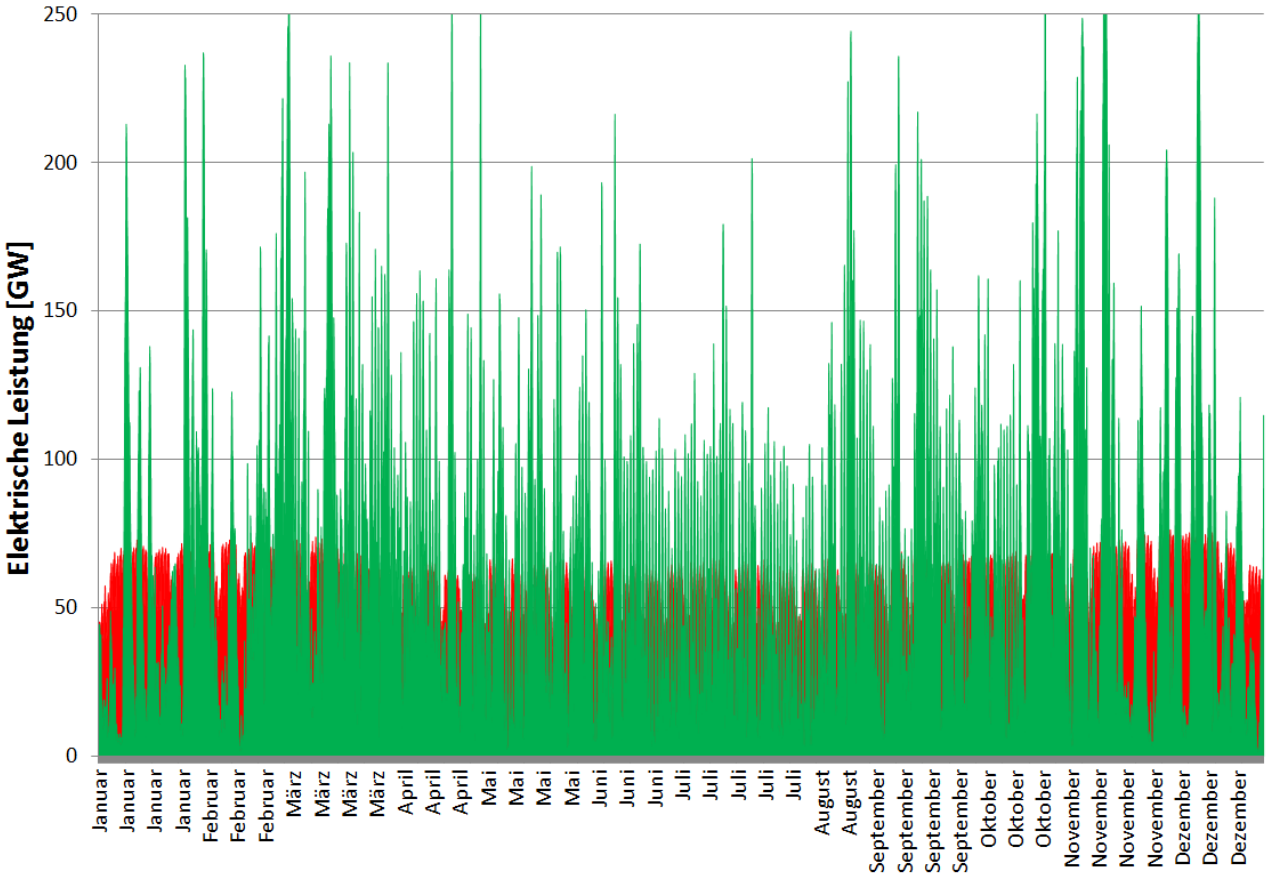


- With 80%?
- No doubt

Renewable Generation (100%) and Consumption 2010 Germany



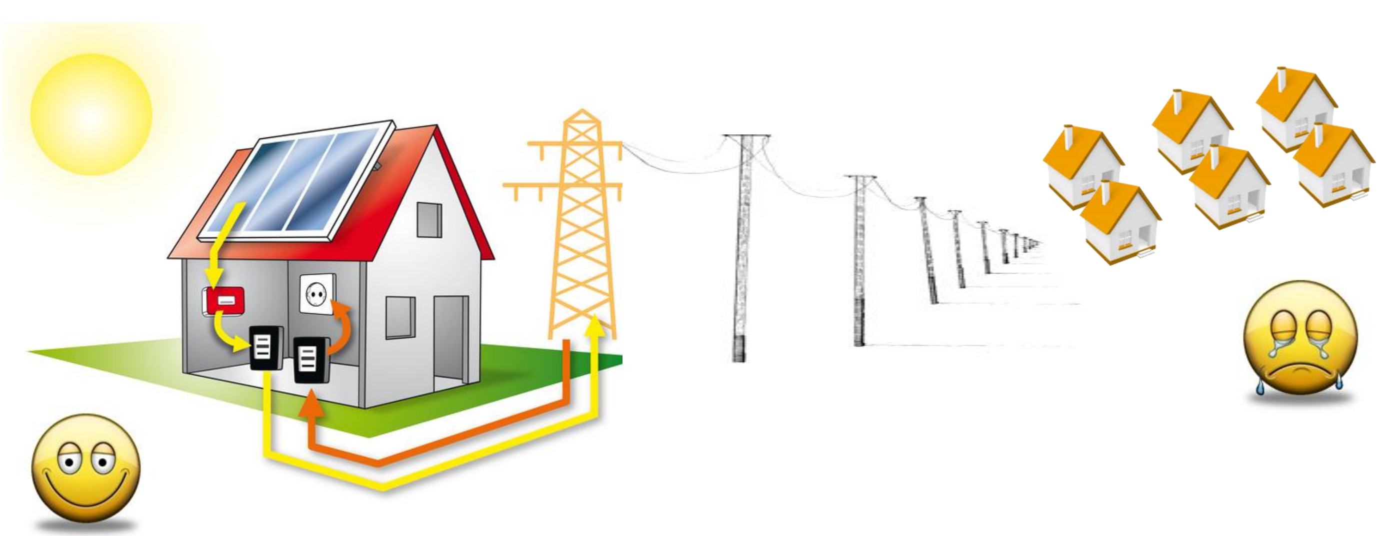
Renewable Generation (120%) and Consumption 2010 Germany



- Why 120%?
- For efficiency reasons pure renewable power systems always have over production
- The cheaper renewable technologies become the more advantagous over production becomes vs. Energy storage

Where and for What?: right and wrong balance areas

Self-consumption bonus, self-consumption malus, „market integration“



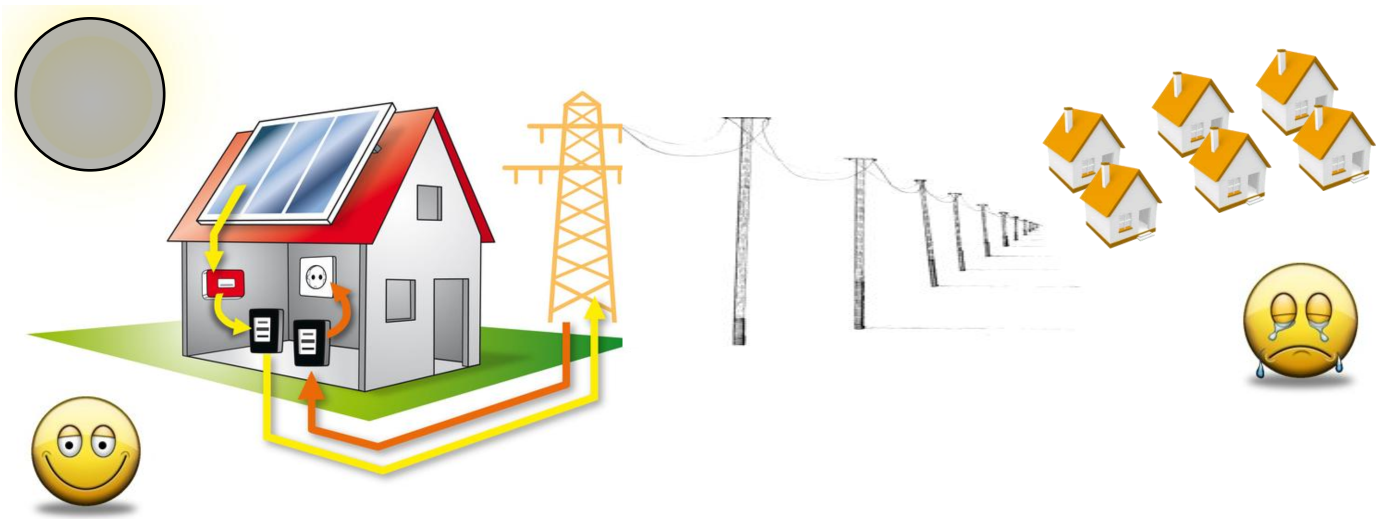
Windflaute

- Sun is shining
- PV system operators charge their storages
  - With all costs for storages
  - With all losses for storages

- Calm, no wind
- Society would require solar electricity
- … but that goes into the storages
- → old coal power stations are reactivated – and that without any requirement

Where and for What?: right and wrong balance areas

Self-consumption bonus, self-consumption malus, „market integration“



Kräftige Brise

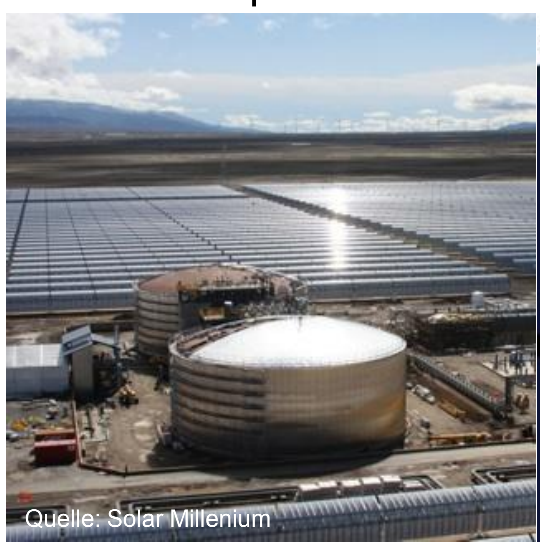
- It is getting night
- PV system operators start to discharge their storages
  - With all costs for storages
  - With all losses of storages

- Strong wind
- Everybody could be supplied by wind power
- … but PV operators electricity comes from their storages
- → Wind parkds will be shut down – and this without any requirement

… will not fulfill the aim of a 100% (80%)-supply by renewables!!!

Where and for What?: right and wrong balance areas

- … The single house is definitely the wrong balance area
- Similar arguments can be found for other small scaled balance areas
- Is then Europe (including North Africa) a suitable balance area?
    - Pre-requisite would be a European grid à la DESERTEC
    - Then one could use thermal energy storages in solar thermal power stations placed in North Africa
    - What is the value of energy storage in North Africa for Germany's security of poewr supply?
- Many arguments lead to Germany as an appropriate balance areas – which does not mean the absence of a European wide electricity exchange



Quelle: Solar Millenium

Quelle: Desertec

Energy Storage to overcome grid bottlenecks?

Are Grid Extension and

Energy Storage

competitors?

„Energy Storage avoids expensive grid extension“

WRONG

Energy Storage to overcome grid bottlenecks?

- Case Offshore-Wind power

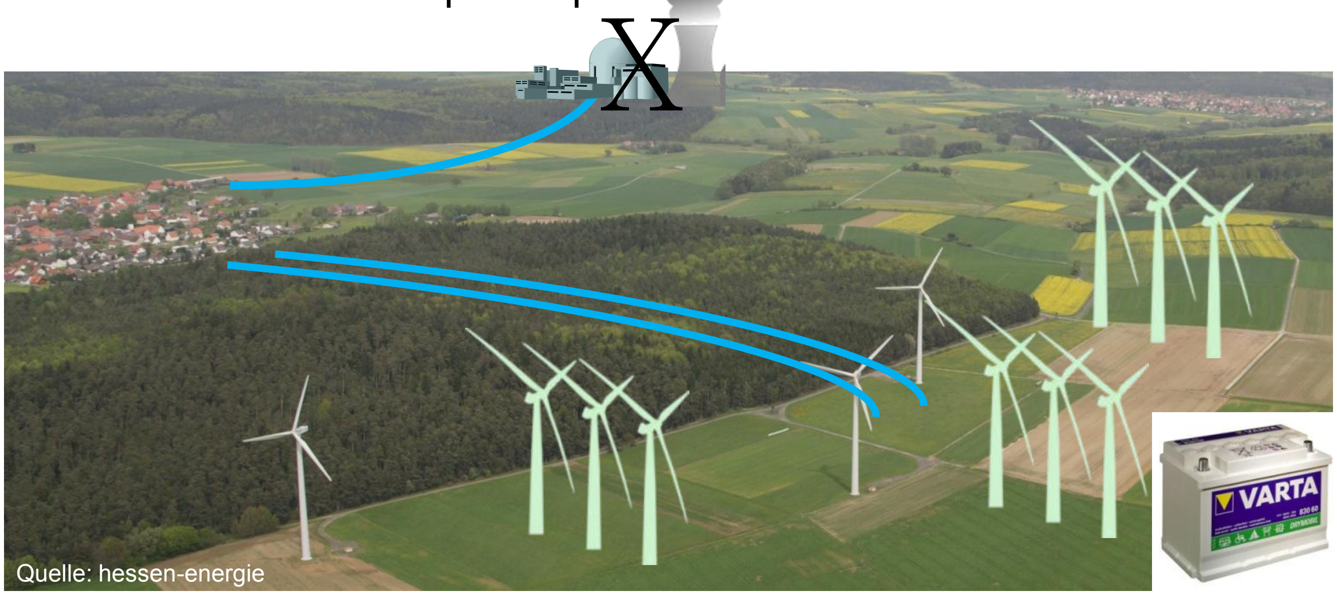
- Relatively easy:
- Where is no gird – there must be one – else electricity remains where it is
- Here, energy storage cannot help

Energy Storage to overcome grid bottlenecks?

- Case Onshore-Wind power (decentralized)

- Not that easy:
- Does not need grid as close to power consumers?
- But: in a restricted area wind power peaks occur at the same time

- Electricity will be needed here or elsewhere



Quelle: hessen-energie

- Grid is not anymore strong enough
- Add a big battery

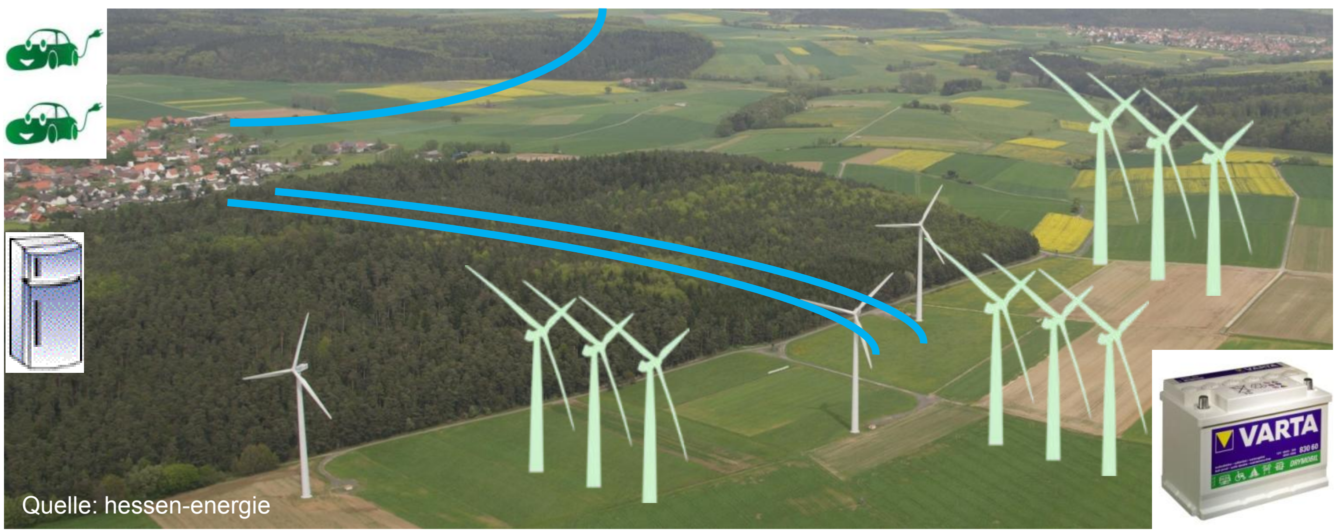
- As a consequence, also decentralized wind power application requires grid extension

Energy Storage to overcome grid bottlenecks?

- Case Onshore-Wind power (decentralized)

- Not that easy:
- Does not need grid as close to power consumers?
- But: in a restricted area wind power peaks occur at the same time

- … but electric cars and demand side manage-ment



- Not a battery

- As a consequence, also decentralized wind power application requires grid extension

Energy Storage to overcome grid bottlenecks?

- Photovoltaics is the only technlogy that does not need to create grid bottlenecks
- PhD thesises of Scheffler (TU Chemnitz), work of Kerber (TU München) and own investigations in Cologne grid:
  - In urban grids and
  - In industrial areas
  - Almost no limitations for grid integration is existing for the installation of PV power plants

Berlin: Where are the 28 GW PV?

Hamburg: Where are the 28 GW PV?

München: Where are the 28 GW PV?

Köln: Where are the 28 GW PV?

Residential areas …

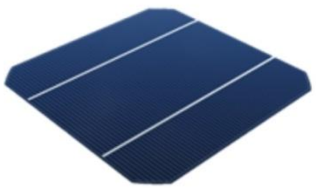
- … and here grid restrictions are evident

… farms

- … and here grid restrictions are evident

Energy Storage to overcome grid bottlenecks?

- What is the best way for PV?



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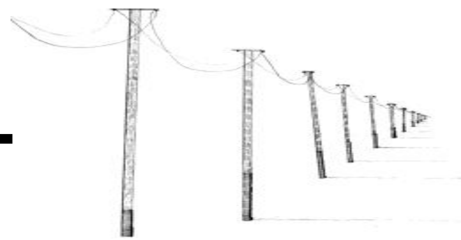

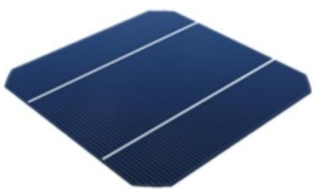

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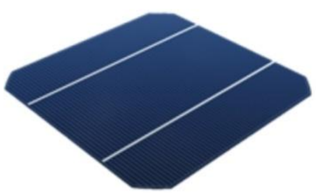

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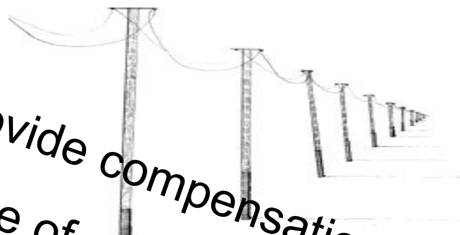
Energy Planning

- 100 % allowence for PV electricity
- But no compensation for switchin-off during grid bottleneckts
- 50GW or even 70GW can be integrated without any grid extension

Energy Storage to overcome grid bottlenecks?

Are Grid Extension and Energy Storage competitors?

NO!



Grids provide compensation in case place of generation and consumption are not in accordance

Energy Storage provides Compensation in case time of generation and consumption are not in accordance.

Renewable Energies and Storage …

- … require different market introduction methods

Renewable Energies	Energy Storage
The more the better	Storage increase system losses; only as much as needed
The faster the better	So far we can do it without, …
Independent where, every kWh*	Place plays a role depending on the storage task
Independent wich kind of technology*	Depending on storage task power, capacity, storage duration, losses are significant

*) at leiast during the introductionary phase. Is not any more true when renewable energies play a major role in energy supply

Discrimination of single storage technologies

… when they absorb energy exclusively generated by renewables, and reconvert it into **electric** energy

No electricity tax is only valid for **pumped hydro storage**, why?

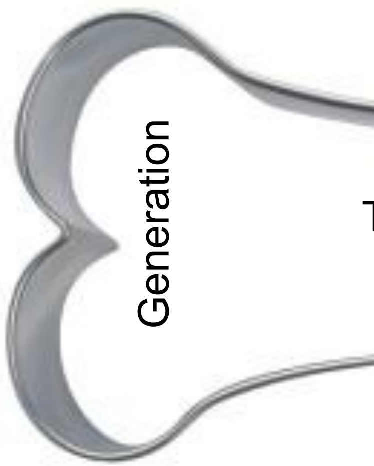
No grid charges for ***Electricity*** storages

Our Electricity Supply System – it‘s a Bone

Coal Production → Coal Storage → Coal Transport → Coal Dump

Pumped Hydro

Natural Gas Production → Desulfurization, CO_2-Separation → Gas Distribution → Gas Storage

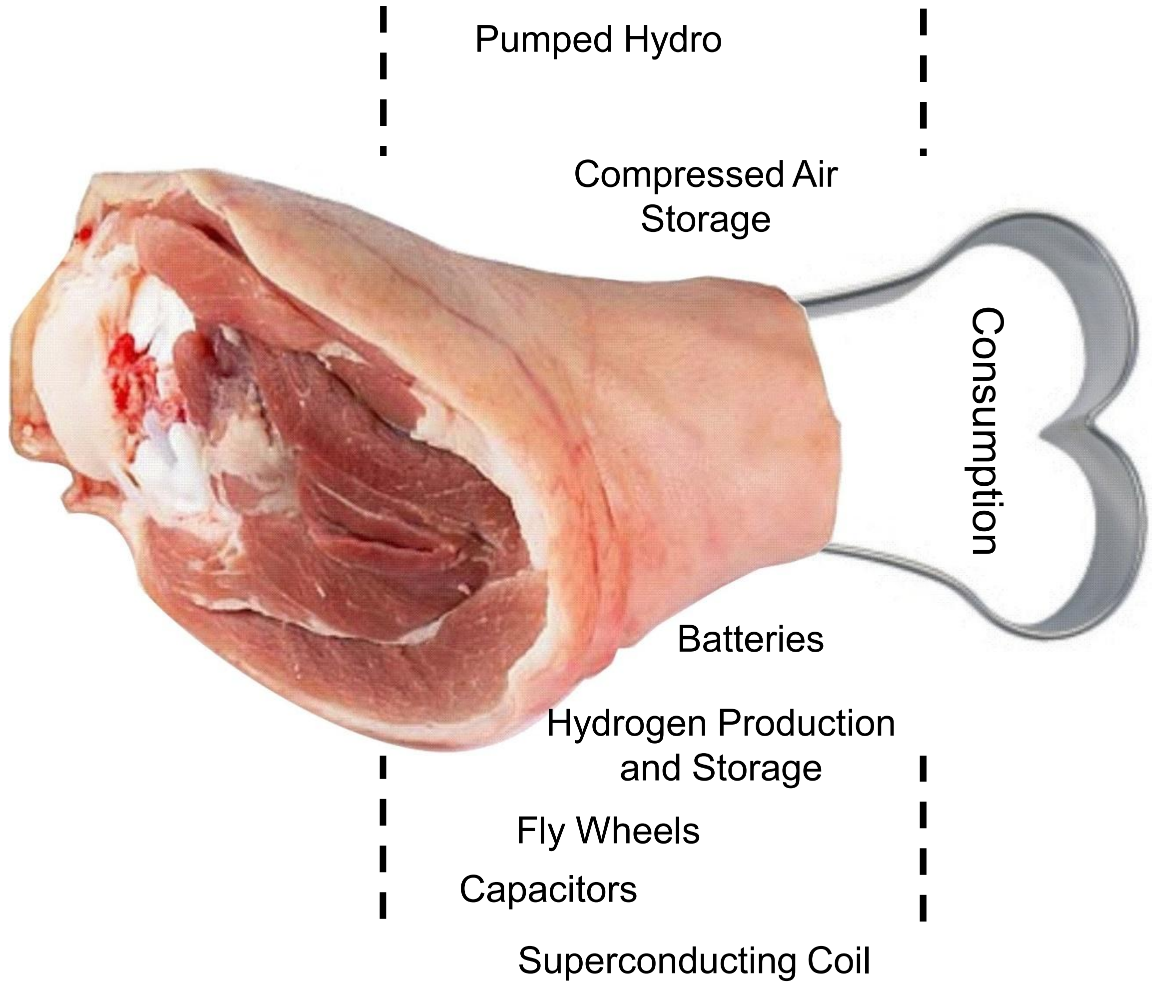


Quelle: stunksitzung.de

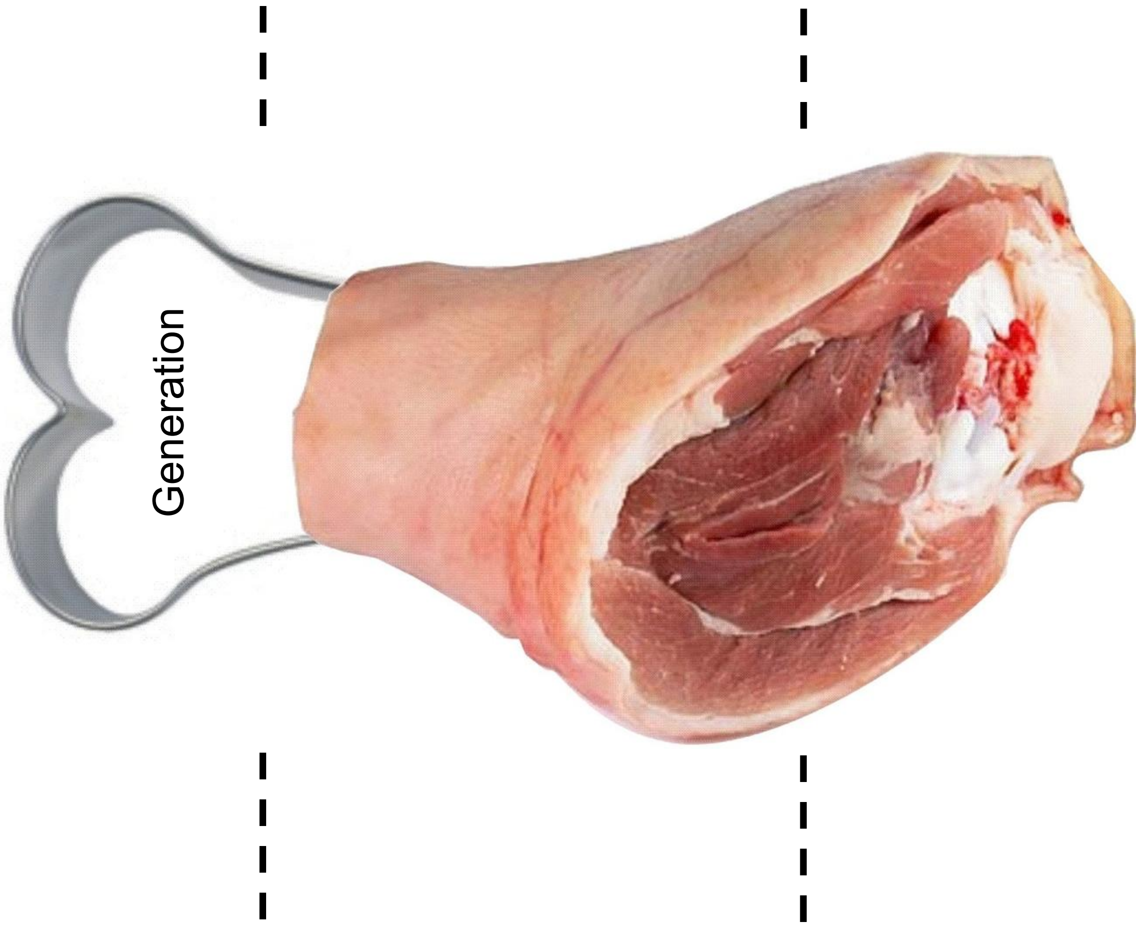
Oil Production → Oil Pipelines, Oil Tanker → Refinery → Oil Tank

Uranium ore → Uran-235 → Enrichment → Storage → Fuel Element Production → Fuel Element Storage

The Energy Bone - Today



The Energy Bone - Tomorrow



Unser Stromversorgungssystem – ein Knochen

Coal Production → Coal Storage

Pumped Hydro

Compressed Air Storage

on

Cold Applications

Heat Applications

Storage Heating

Circulation Pumps

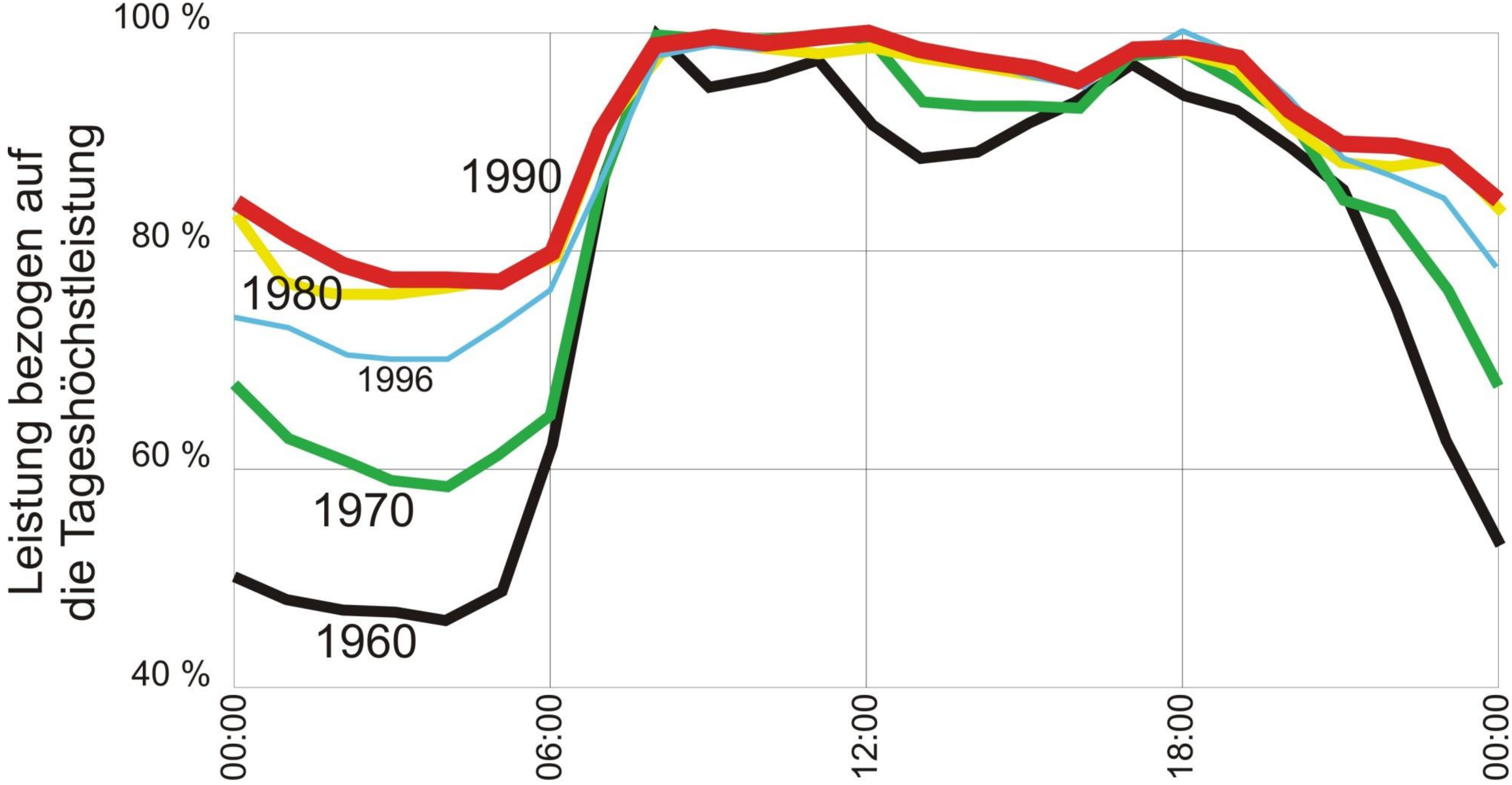
HVAC - systems

Compressed Air in Industry

CHP with Heat Storage

Heat Pumps with Heat Storage

Energy Storage – not a new topic



Energy Storage in Germany

Removal of tabus for the largest already existing storage capacity

5,5 GW
33 GWh

Introduction of storage heating has been an early smart grid

40 GW / 320 GWh

- A child with fantastic capacities must not be discriminated because of its ugly parents (coal and nuclear)
- This child can provide high value for the planned energy change

Is there a need for Energy Storage to compete in marketes?

More self-confidence of storage community

2 x 3 is 4
Widdewiddewitt and three is nine !!
Energy industry makes the markets
Widdewidde like it needs them …

Derivative markets

PV, Wind, …

Intraday market

~~Primary conrol market~~

(Storage Market)

~~Minute market~~

~~Secondary control market~~

Spot market

(Capacity markets)

Capacity Markets

The suitable market design for storage?

- recently often demanded from conventional power generation industry for gas and coal fired power stations
- Example of capacity markets, Brazil:
  - Energy Planning Authority EPE plans national energy supply (completely missing in Germany)
  - Regulatory body ANEEL launches calls for (storage) power stations
  - Cheapest/best offer gets permission to build power station / storage

- is a mechanisms that funds ability to provide power and energy – and not only kilowatthours
- Energy storage in future will guarantee security of supply. There is no need (and no sense) for storages to compete on a pure energy related market (similar to control markets)
- possible procedure:
  - A regulator determines necessary storage capacity (according to power, capacity, time frame and local distribution requirements)
  - A call for storage need is announced
  - The price for different storage tasks is determined in competition amongst different solutions and suppliers (technology open, no limitation for electricity-to-electricity storages, chances for biogas storages, demand side management and thermal energy storages)

For capacity markets, against spot markets

- is volatility at spot markets high enougt, storages could establish also in this kind of market
- waiting long enough price differences will become large enough
- this will lead to unnecessary high electricity prices as the price will be the same for all power providers (and not only for storage units) – so-called windfall profits will be generated

- Capacity markets also for conventional power stations?
- Why not? In the next decades there is a need for fast reacting conventional power stations!
- but only when those power stations are suitable to support energy change, meaning:
  - switching-on and switching-off in a reasonable time frame (and not only with better controllability)
  - „Power-to-Gas ready" – even when operated in the next ten years with conventional natural gas

Long-Term Storage

Technologies:

- Hydrogen
- Renewable Methane

Characterized through:

- Unique for long-term storage
- Awful efficiencies

Consequences:

- Absolute necessity for Germany‘s security of supply
  - Balance of time-related balance for production surpluses and production deficites
  - (in case of an intercontinental transmission grid required for all kinds of grid failures)
- Long-term storage must not compete on any kind of market
- …

Strategic Electricity Reserves

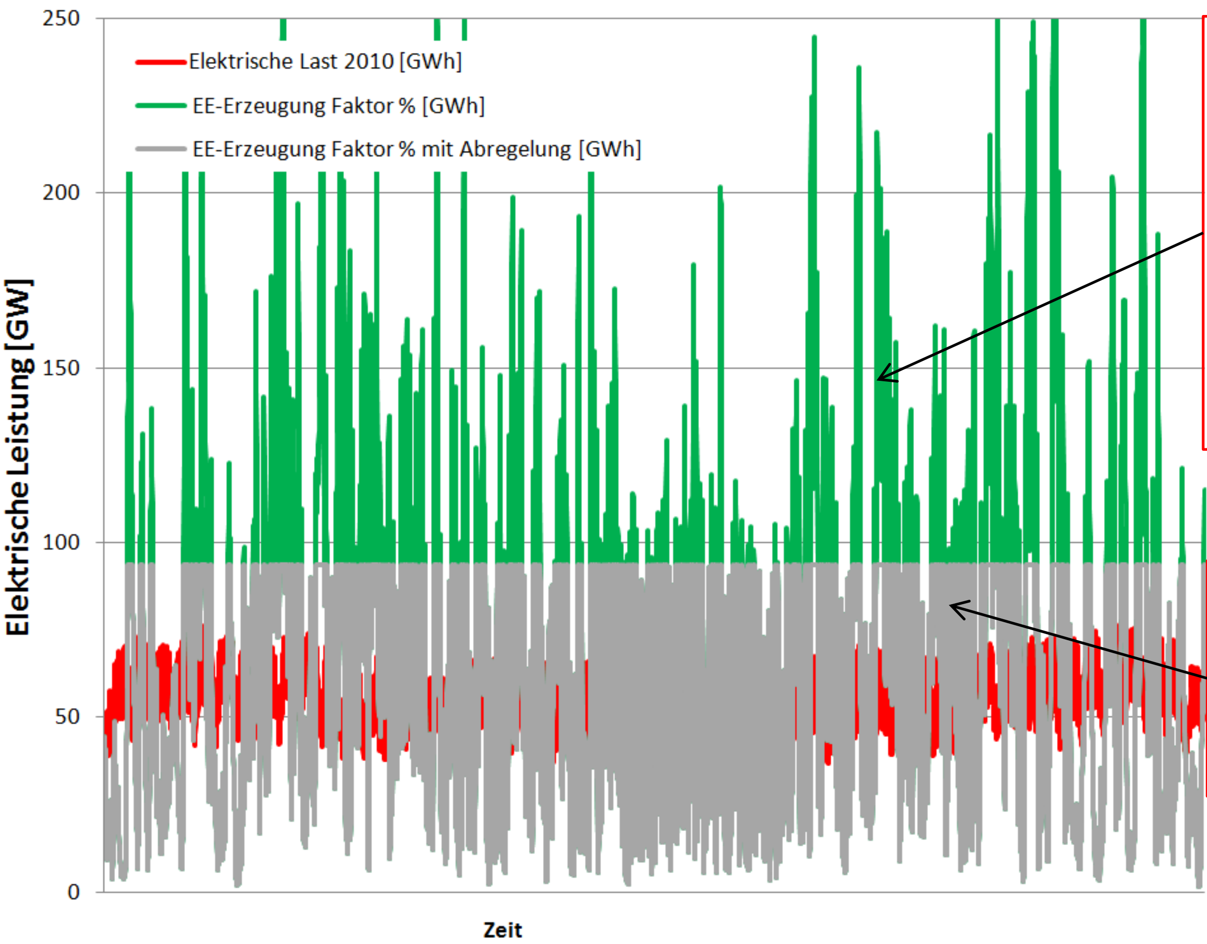
For oil based products in Germany the „Erdölbevorratungsverband (Association for oil stockage)“ exists since 1978 as a reaction to the oil crises in 1973

- Law for Oil reserves: ErdölBevG
- „Erdölbevorratungsverband“ has to keep reserves of oil and oil products equivalent to the amount of imports of 90 days
- Members of „Erdölbevorratungsverband“ is automatically who imports, produces lets others produce Otto fuels, Diesel fuel, […] in an amount of at least 25 tons per year.

For electricity we need to have the „Elektrizitätsbevorratungsverband (Association for electricity stockage)“

- Law for electricity reserves: StromBevG
- the Association for electricity stockage permanantly has to store electricity in from of hydrogen or synthetically produced methane, respectively, in an amount equivalent to electricity production of 90 (?) days.
- members of the „Association for electricity stockage“ is automatically who produces or imports electricity out of primary resources that cannot be stored in an amount equivalent to 90 days consumption in case the amount of electricity generated or imported exceeds 1 (?) GWh per year.

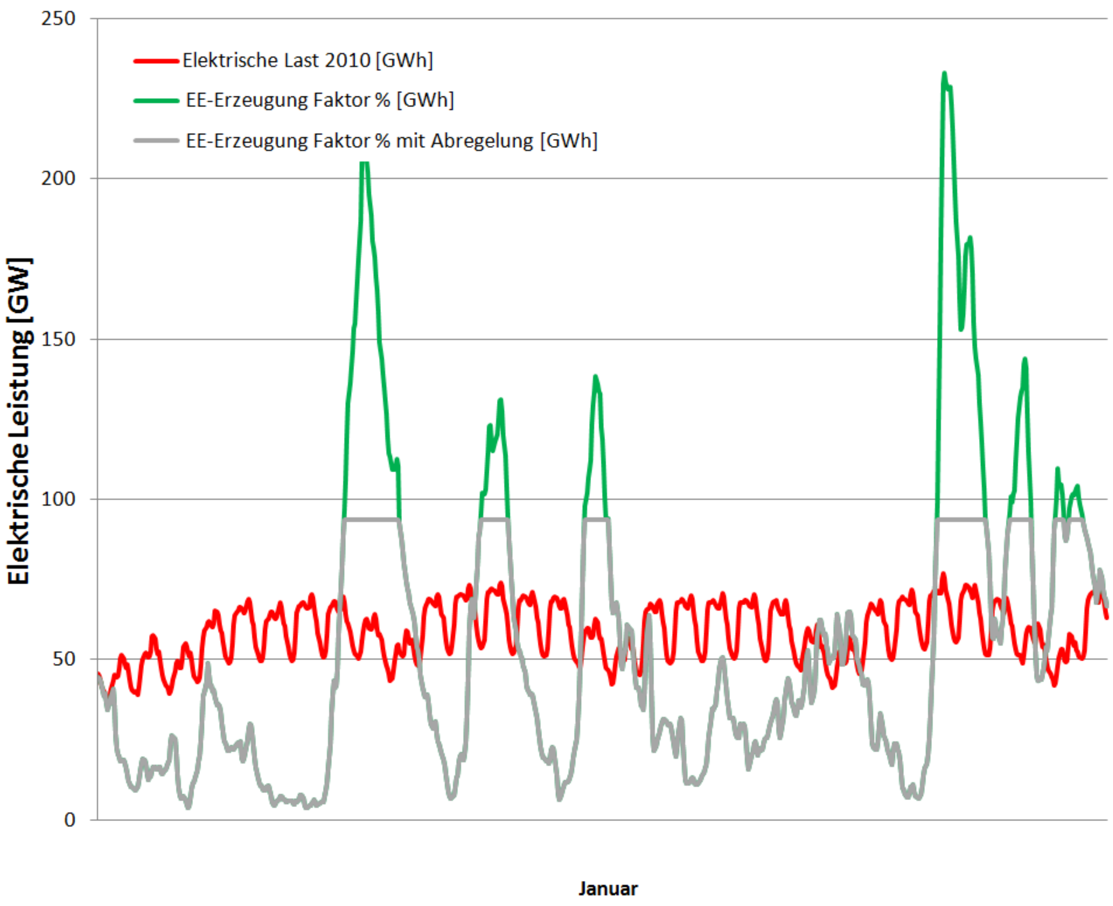
Renewable Generation (120%)



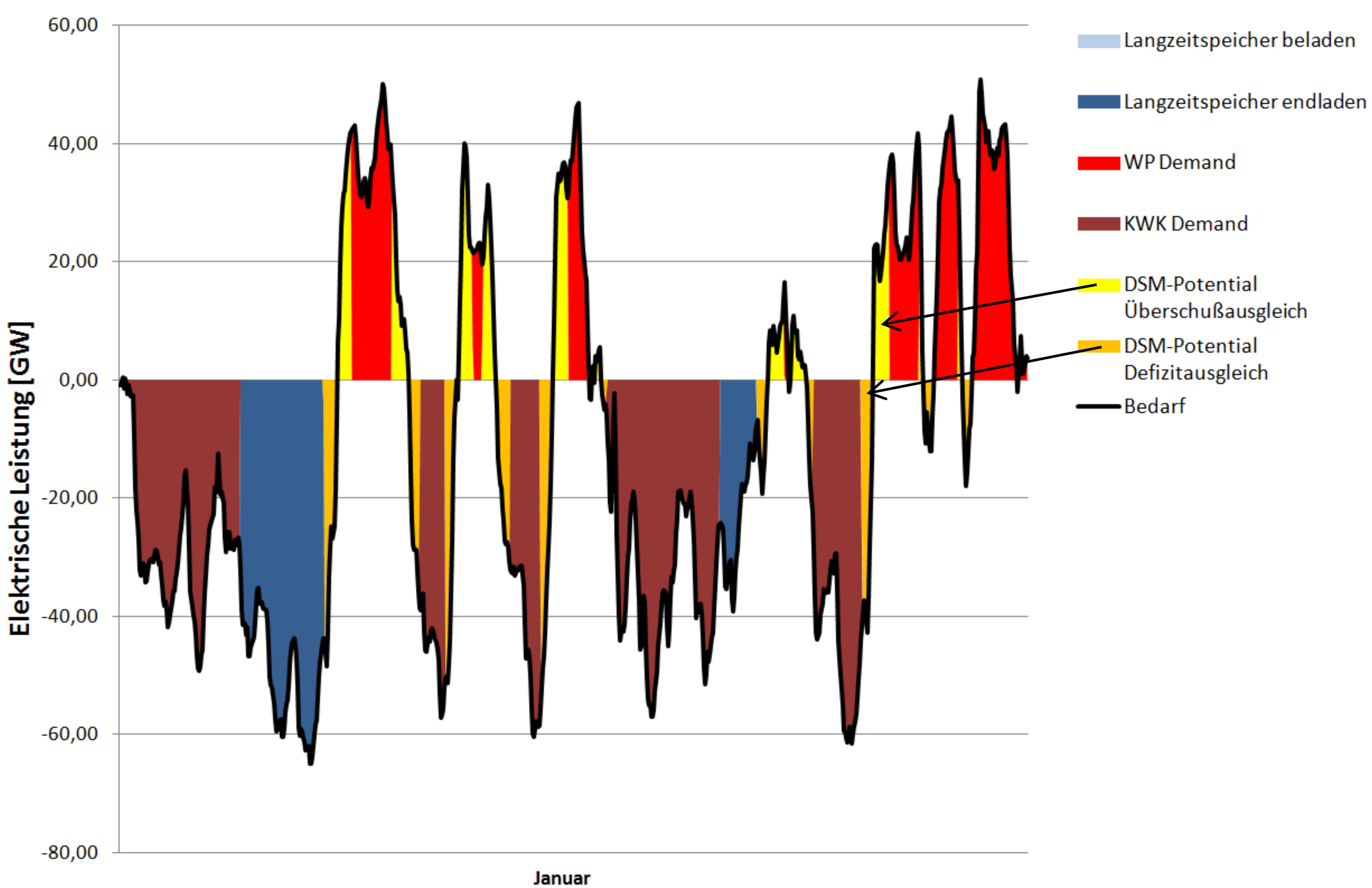
- Down-control
- Strategic electricity reserve
- non-electric consumption
  - Traffic
  - Heat (Cold)

- Any kind of Storage
- Without discrimination

Renewable Generation (120%)

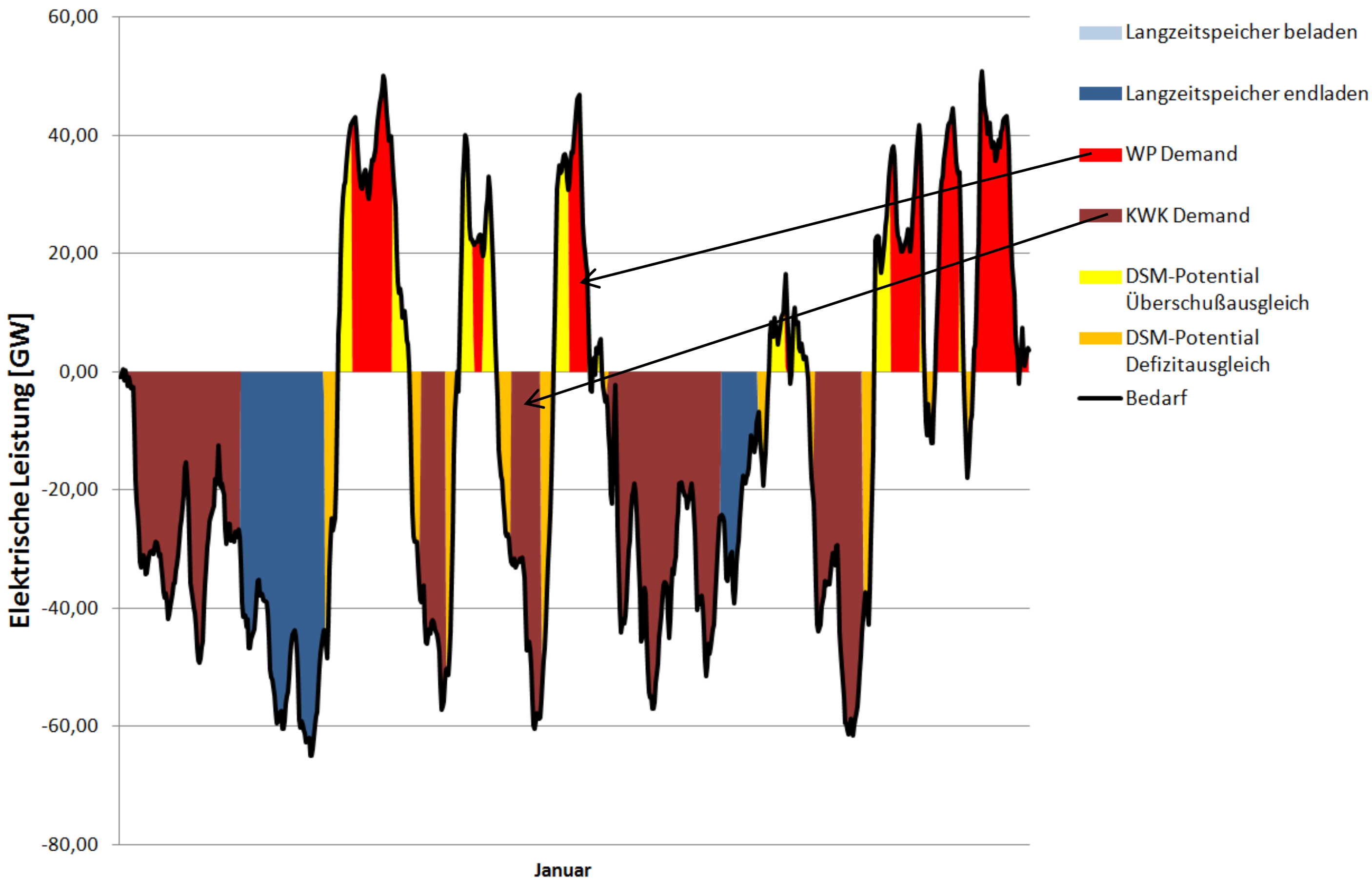


Renewable Generation (120%), Short-term < 1 Tag



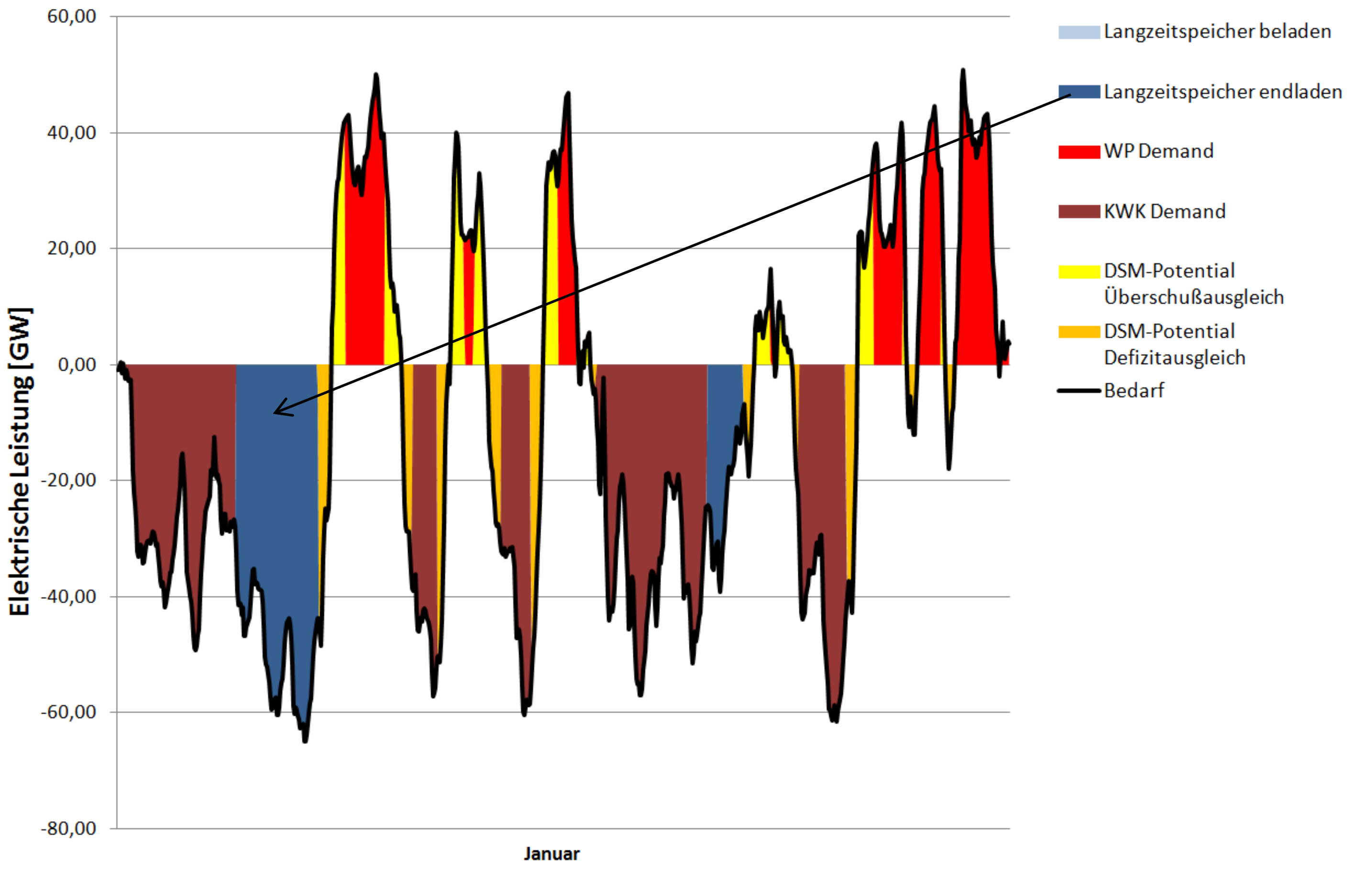
- Storage heating
- Pumped hydro
- Compressed air
- E-Mobility
- Batteries
- …

Renewable Generation (120%), short-term < 3 Tage



- Compressed air
- batteries
- Storage heating

Renewable Generation (120%), Long-term > 5 Tage



- hydrogen
- Synthetic Methane

Conclusion

- Storage Need
  - We will have tremendous storage need in future – in all time frames
  - Grids cannot replace storage – and storage not grids
  - Storage must guarantee system stability and not optimization of own consumption – at least when it is done with public money
  - Energy planning is superior to arbitrary introduction of storages

Conclusion

- Storage promotion, Storage introduction
  - Storages are/will be relevant for system stability and must not compete at existing markets
  - Capacity markets are ideal for the introduction of storage (existing capacity will be honoured and not the most frequent charging and discharging of storages)
  - Future energy supply is not an electricity supply – electricity, heat and transport are one system: no discrimination of not electricity-to-electricity storage types
  - Long-term storage is of immense importance for security of supply – Development of a strategic electricity reserve

Thank you
for your attention