The Dependence of Storage Demand on Generation Park, Grid Expansion and Storage Systems

Presentation on
12th November 2012
at session C3 of the
7th International Renewable Energy Storage Conference and Exhibition
IRES 2012
of
EUROSOLAR and the World Council for Renewable Energy (WCRE)
at
bcc Berlin Congress Center,
Alexanderstr. 11
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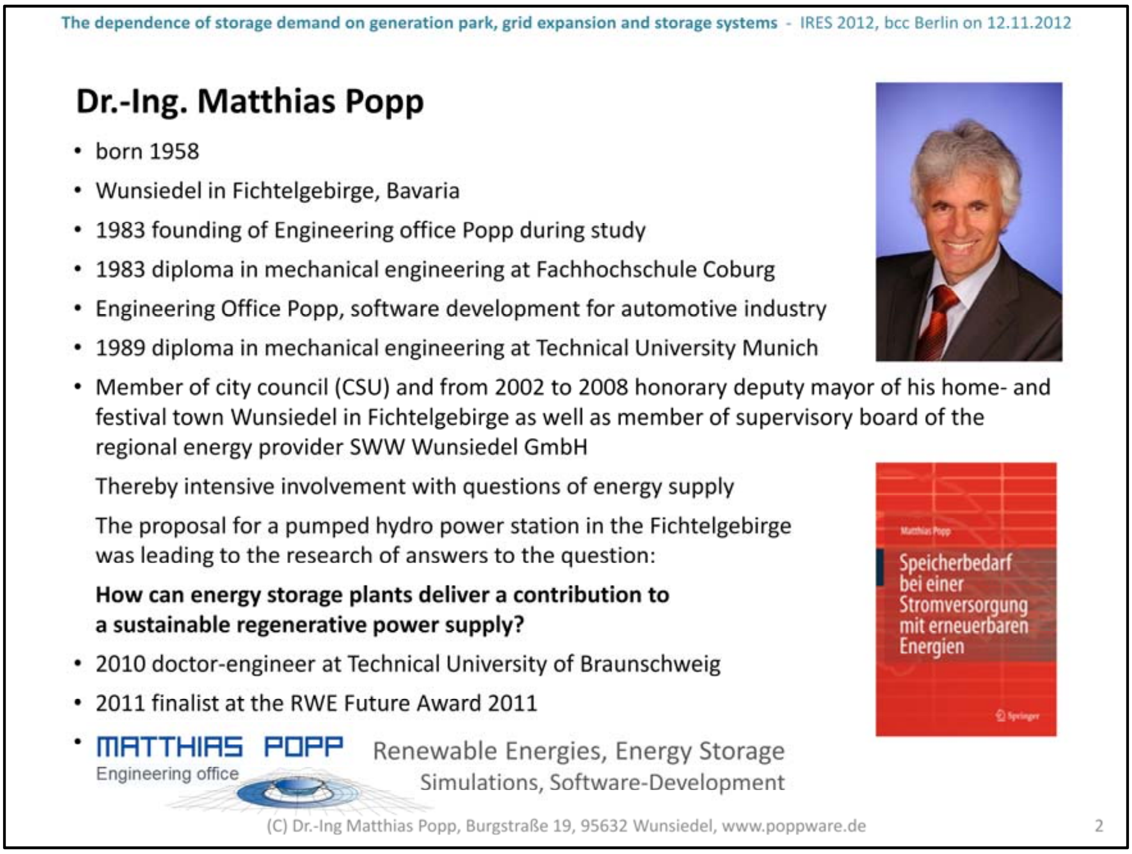
Dear Ladies and Gentlemen,

the presentation refers to researches of my doctoral thesis concerning the storage demand of Europe at a renewable power supply and additional volatility analysis for Germany and Switzerland, commissioned by gas and power supply companies, concerning the key problem for the success of the Energiewende.

What is necessary, to receive the power of wind and sun disposable on demand.

My presentation informs about the dependencies of storage demand for this mission.



In the later available conference documentation and on my homepage, you can get more information about my person and my office.

Lets come to the subject.

In 2008, induced by a public discussion concerning a pumped hydro power station in the Fichtelgebirge, I asked myself the question how much storage demand will be required, to realize a power supply with renewable energy. They shall take the main load in future, when fossil energy carriers will become more expansive and fewer available.

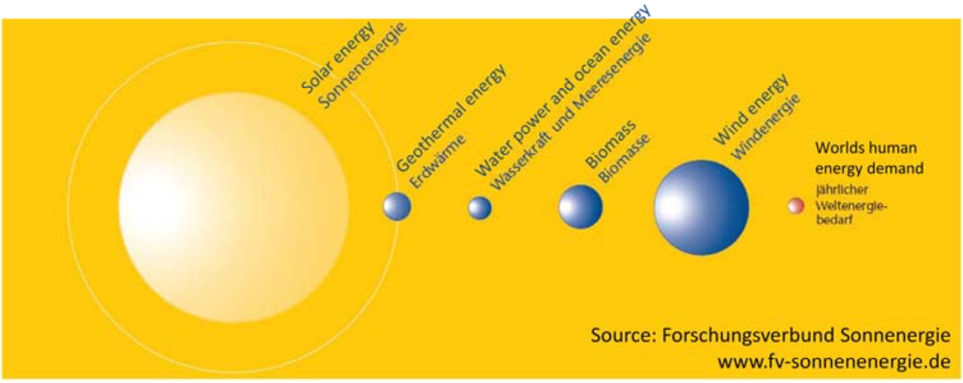
In 2008, I could find nor a literature, neither a research facility in Germany, which could give me an answer to this question.
Internet researches offered extensive available data material, to analyse this question.

My education and my long-time examination with analysis and computing of large data basis enabled me, to systematically research this question for Europe, based on energy weather data over nearly 40 years.

The subsequent developed doctoral thesis is published as book by Springer publishing company and reached the final of RWE Future Award 2011.

The dependence of storage demand on generation park, grid expansion and storage systems - IRES 2012, bcc Berlin on 12.11.2012

Is it possible to achieve a 100% renewable power supply?



- **The energy supply of the sun overshoots the demand of mankind by about 8000 times,**
- **The thereby powered movement of air, the wind, overshoots the demand by about 700 times.**

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The irradiated energy by the sun and the thereby driven winds exceed the worldwide energy demand of mankind by many dimensions.

These practically unlimited available energy sources will overtake the main load of a regenerative power supply in future.

Main attention has to be given to these two power sources, if the dense populated European countries shall be supplied in a sustainable renewable way.

Other sources, like biomass, hydro - or geothermic power will bring an additional contribution.

Power Supply According to Type of Energy System

availability of power	conventional systems (limited, getting shorter energy carriers)	regenerative systems (energy potentials, taken from self regenerating natural cycles)
as required	• gas-fired, • oil-fired, • stone coal-fired	• storage water (as far as capacity is available), • bio methane
largely constant	• nuclear, • brown coal-fired	• geothermic, • biomass, • mine – and landfill gas, • waste combustion
energy weather dependant	• heat-operated cogeneration (CHP, powered from fossil energy carriers)	• river, • solar, • wind, • heat-operated cogeneration (CHP, powered from regenerative energy carriers)

The short time availability of power from the generation stations is of main importance for the ability to supply on demand.

The task for the further development of the existing production system is to substitute conventional power plants by renewable ones.

If the thereby emerging power supply system doesn’t have the ability, to supply exactly on demand, additional systems are required to keep production and consumption in a precise balance.

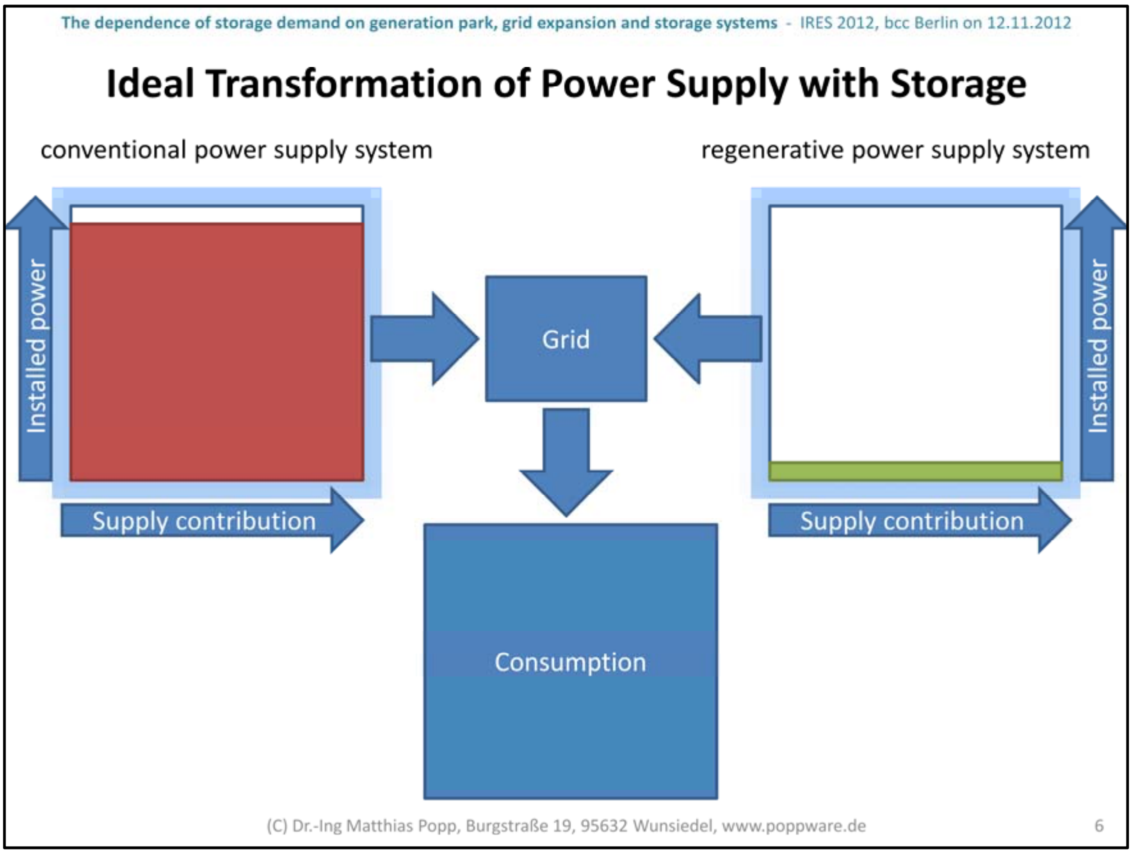
Balancing of Production and Consumption

Level	Technology	Alternatives	Effects
Demand side	**Demand side management**	• pay scale incentive • load movement • load throw-off	Time shift, abdication or disruption of consumption at production deficiencies
Production side	**Production side management**	• down regulation • shut down	Abdication of the usage of existing renewable power potentials like river -, wind -, sun -, biogas power, ..., at excessive supply
Power grid	**Powerful long distance transmission**	• HVDC (high-voltage direct current link) • HVAC (high-voltage alternating current link)	Utilization of large-scale statistic balancing effects to reduce regional requirements on the regional power supply systems
Additional	**Storage**	• pumped hydro • gas storage • battery storage • ...	Supply on demand by charging the storage with production surpluses and discharging at production deficits

The measurements, which are coupled to additional investments and operating expenses, enable at different approaches a partly or complete balance between weather dependent power production and occurring consumption.

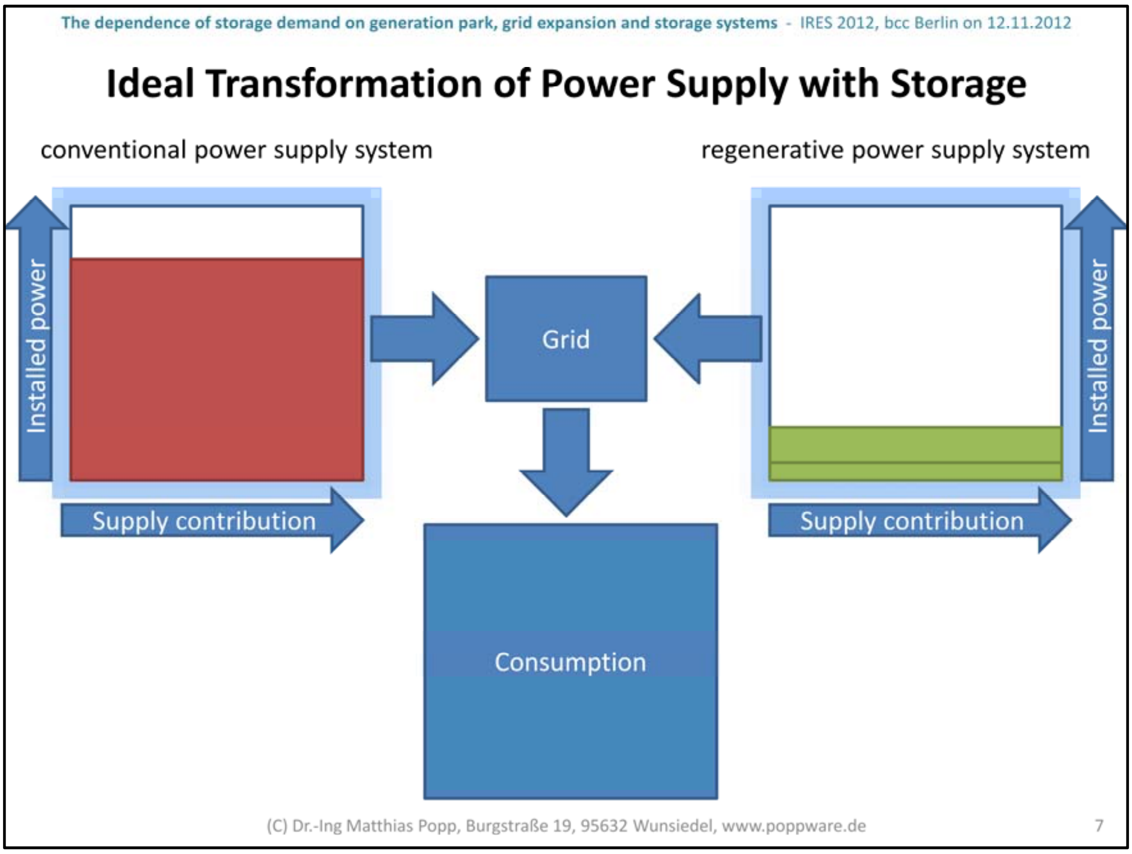
Demand side measurements can lead to a reduced quality of supply.

Suitable dimensioned storage systems enable a power supply on demand.

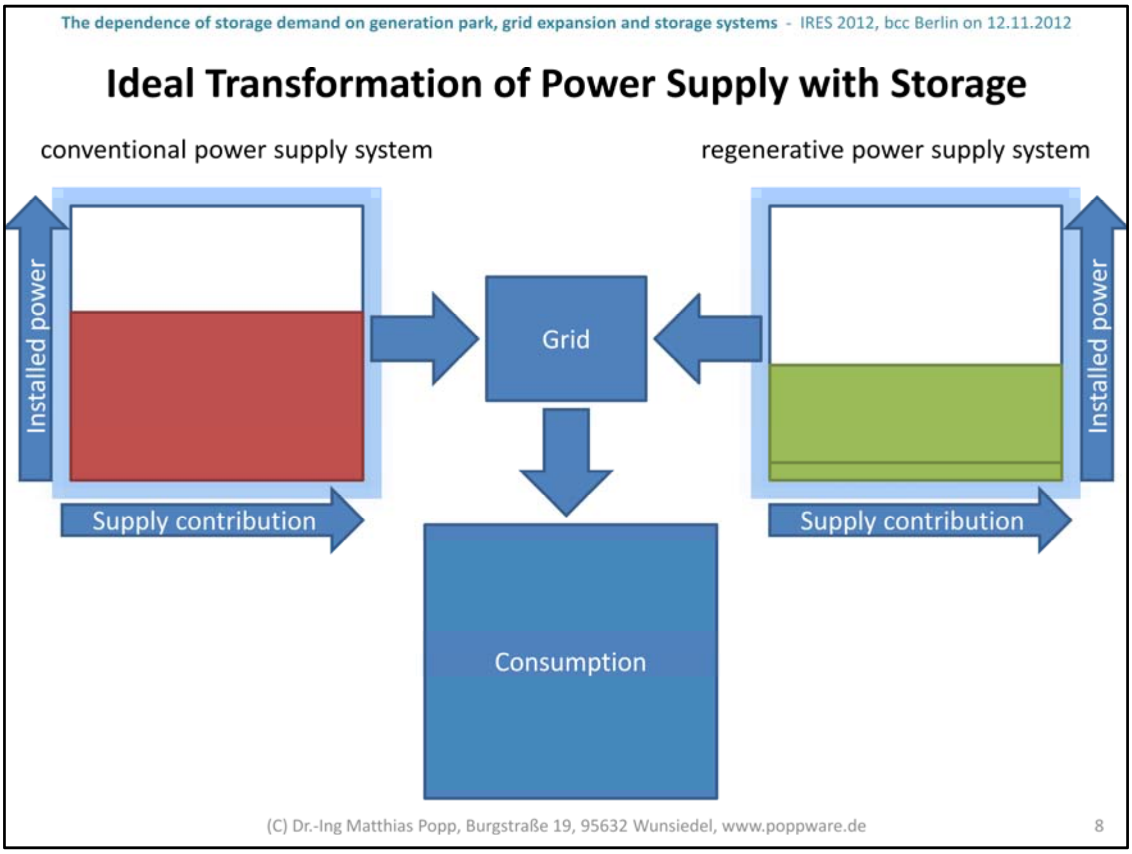


Historically, the conventional power supply system was designed, to cover the power consumption exactly in every moment.

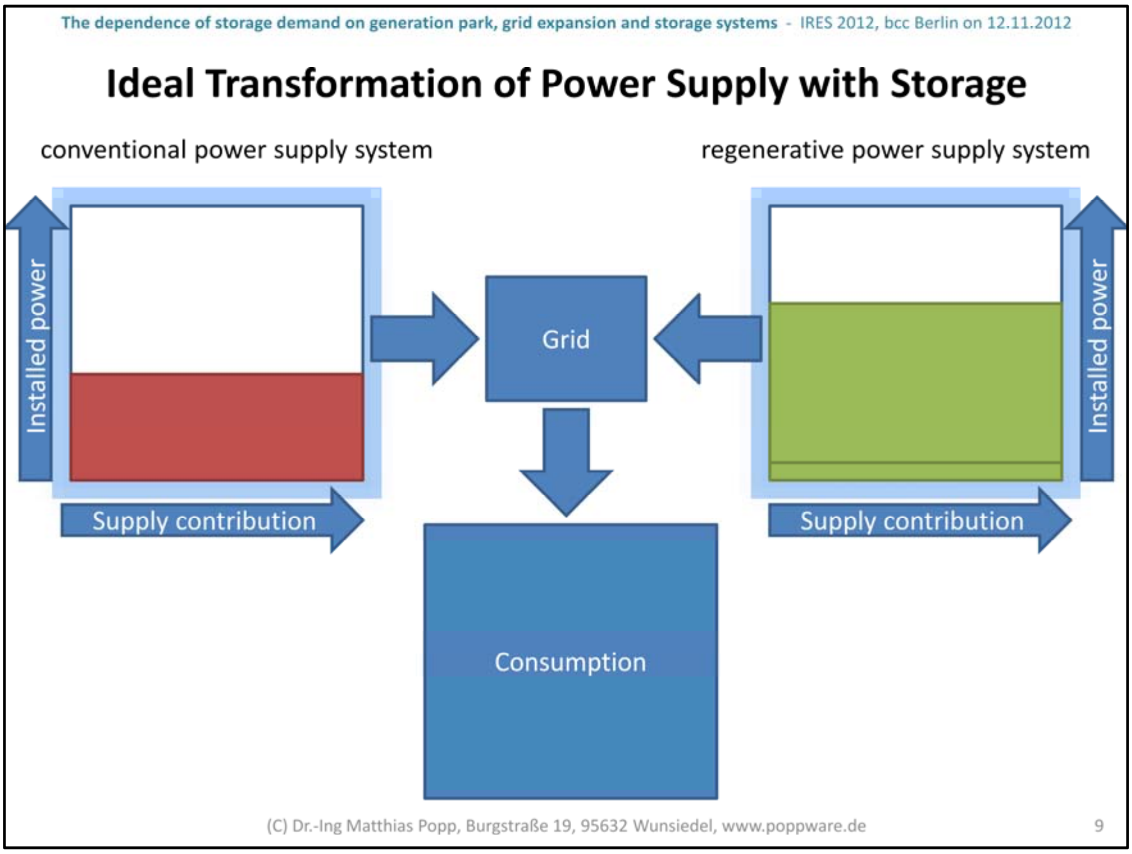
With hydro power, an independent renewable power source, meeting the demand, was available up from the beginning.



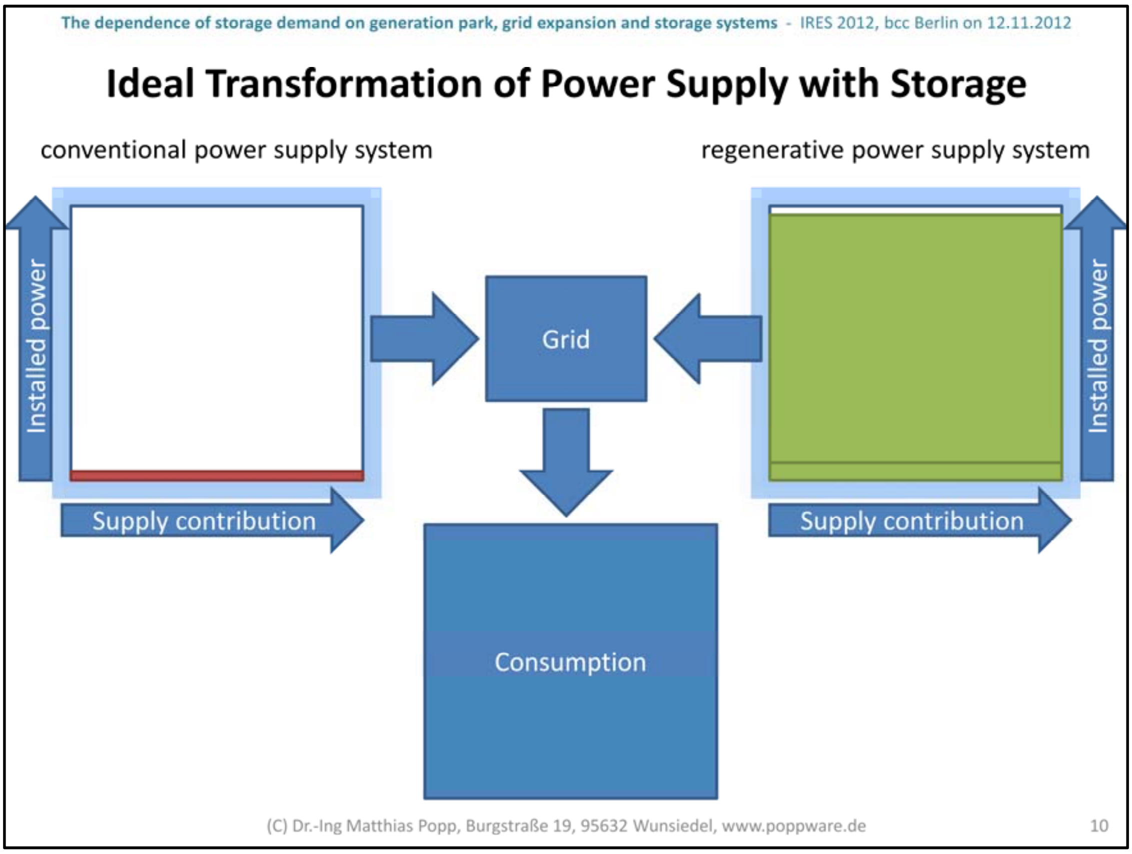
With an ideal transformation of the power supply system, the new added regenerative power systems, could substitute the same amount of production capacity of conventional systems.



Renewable energy systems, designed to meet the demand from the beginning, would enable to dispense conventional power systems.

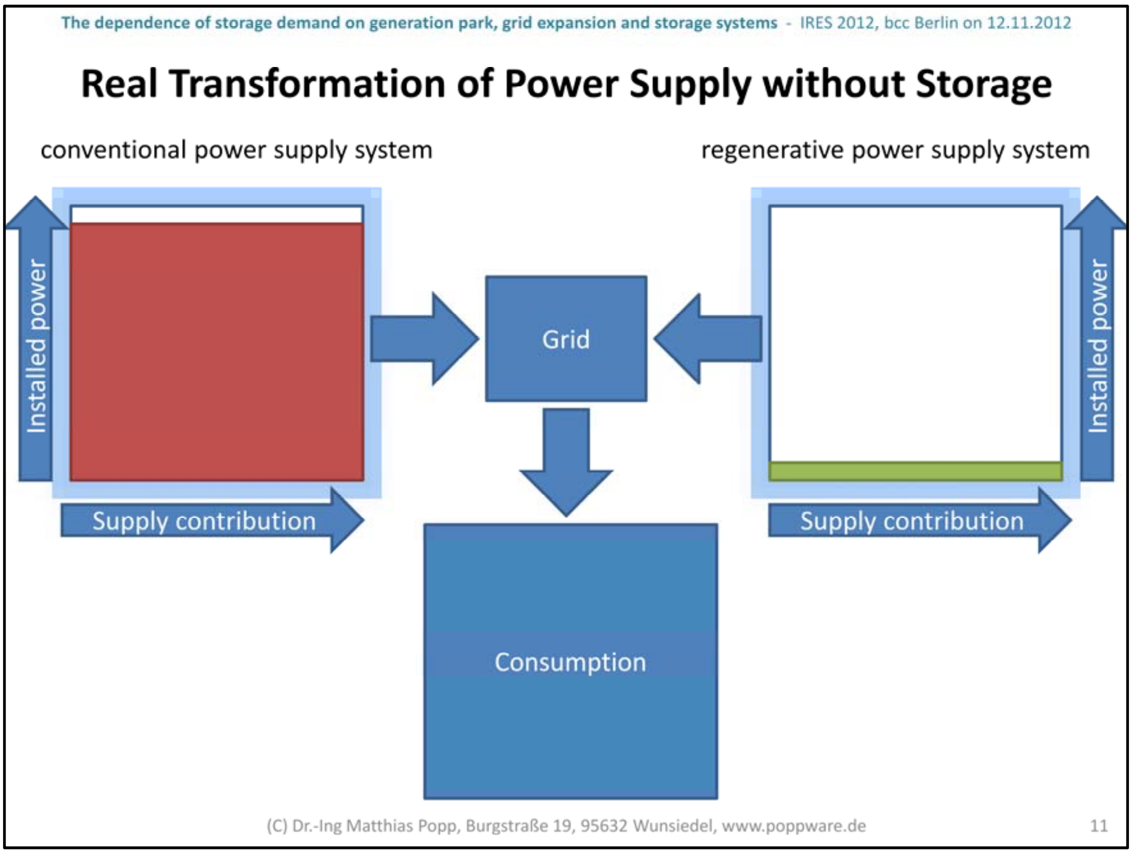


The capacity utilisation and thereby the cost-effectiveness of the residual conventional power stations would remain on the level, they were designed for.

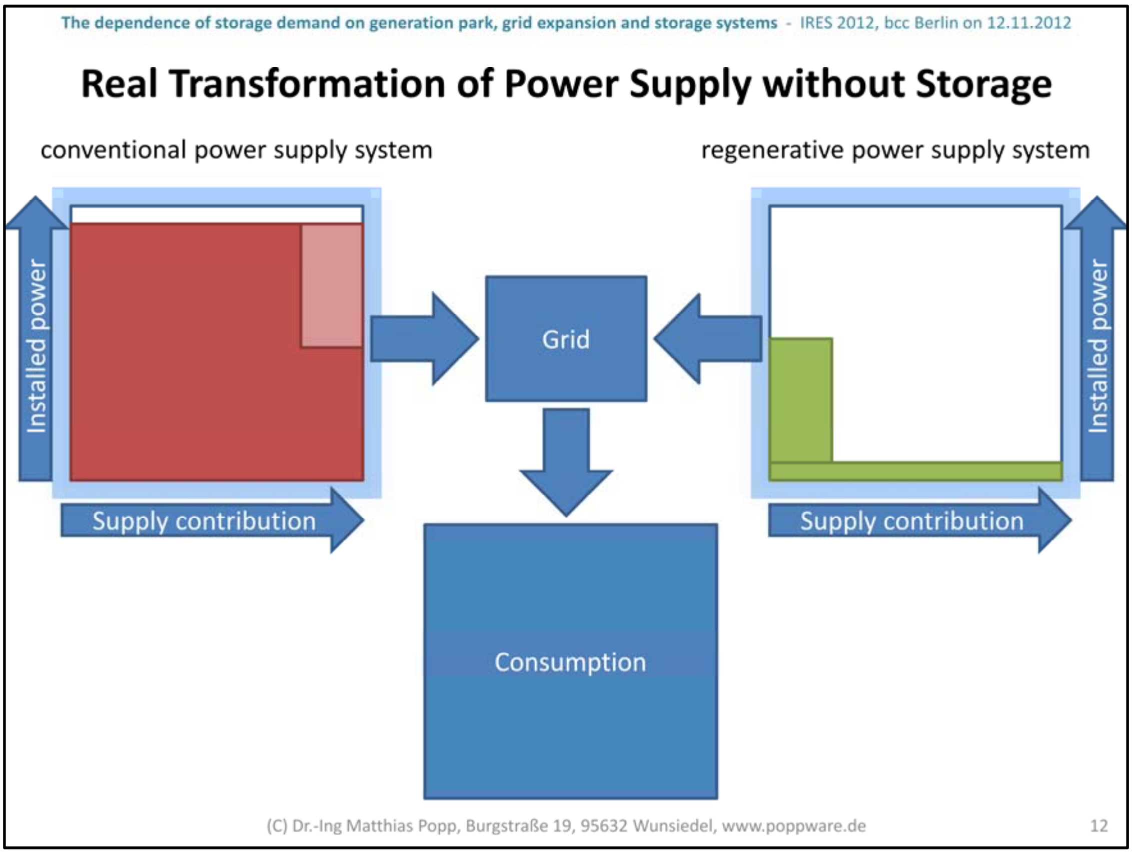


When finished, the regenerative power supply system would have displaced the conventional system.

The regenerative System would be designed, to meet the demand of the users and to satisfy the supply needs at every moment.

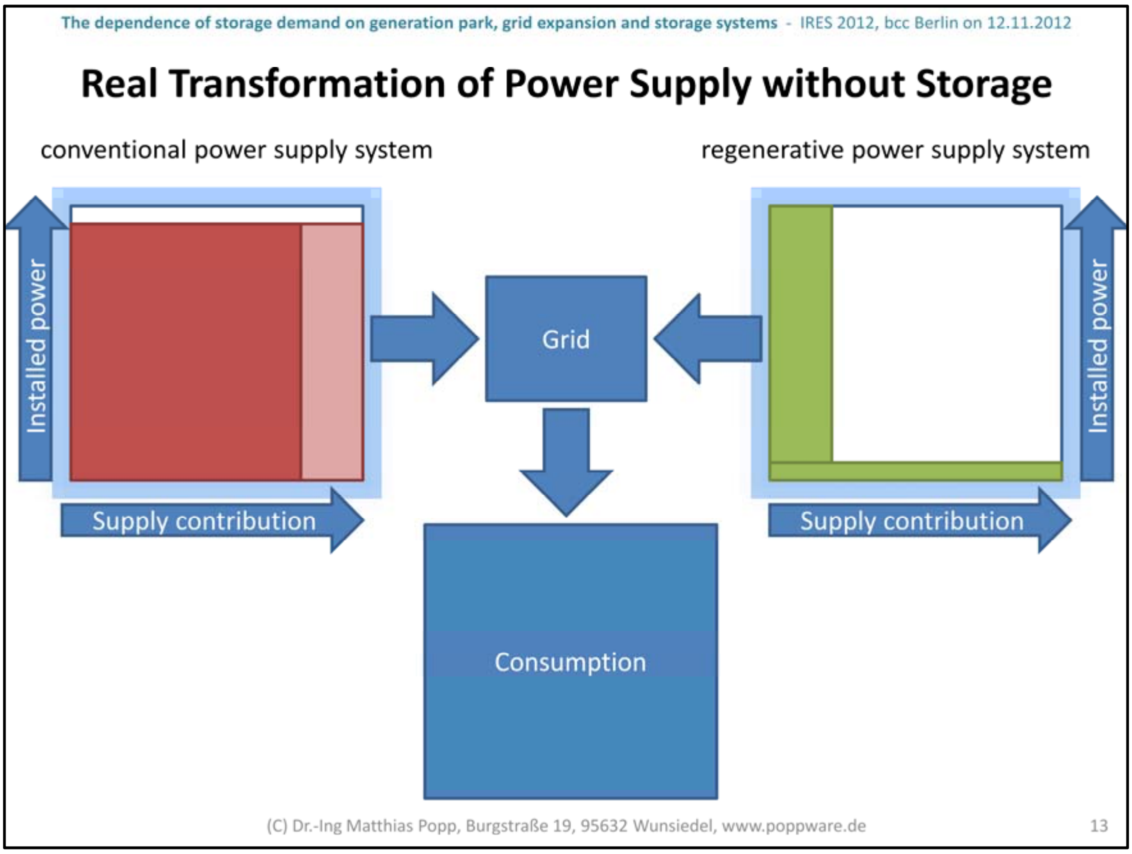


In reality, we had the same initial situation as shown in the ideal transformation.



With wind and solar, the addition of volatile power systems in Germany takes place without the addition of systems, which can balance the supplemental production power to meet the demand.

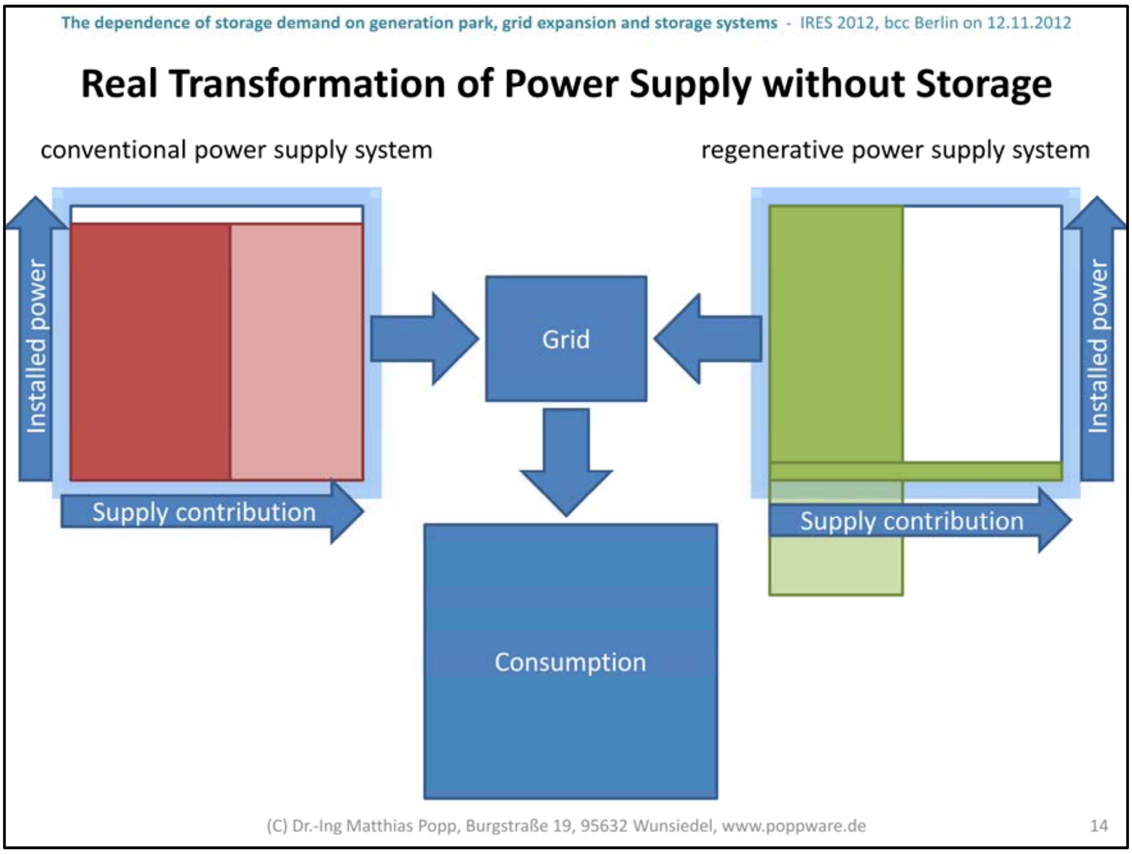
The addition of regenerative generating plants leads to a reduction of fuel consumption by the conventional power stations, but not to a replacement of these units.



Meanwhile, the installed power of regenerative systems reached the requested power.

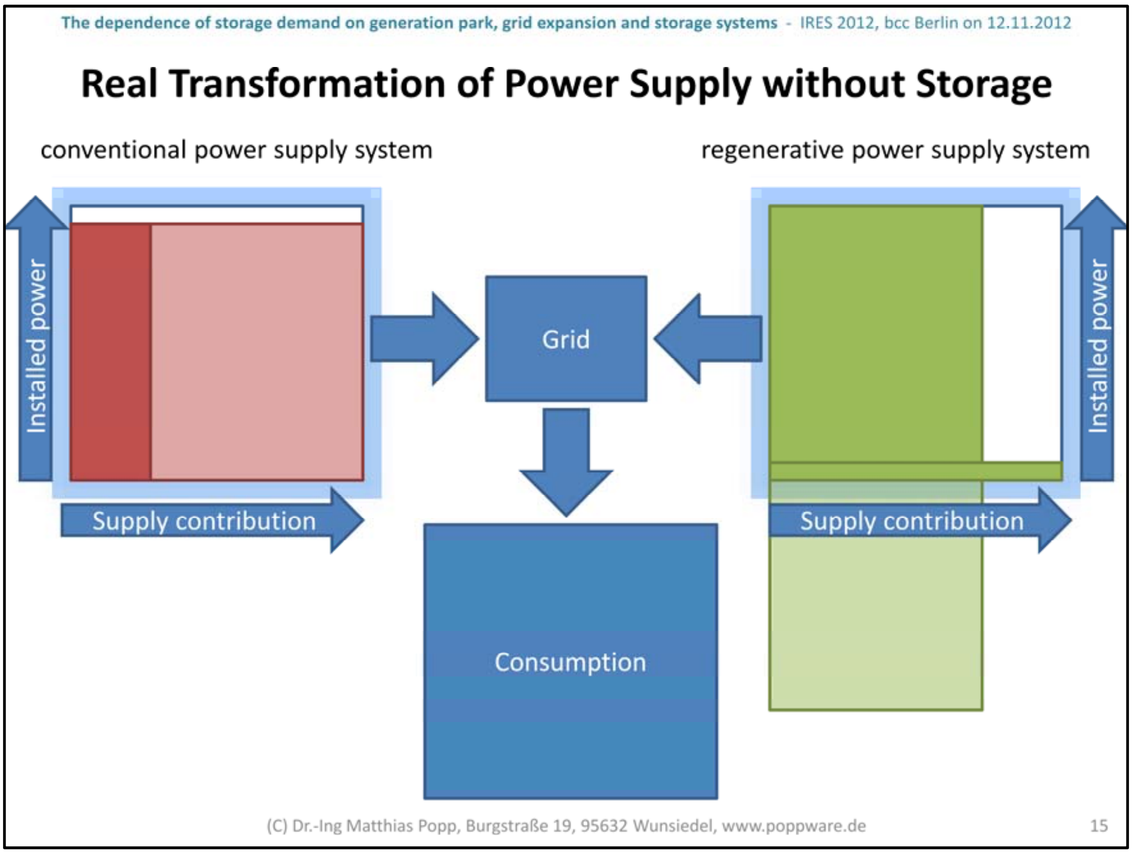
Up to now, the occurring regenerative production power can largely be used to cover the demand.

The conventional power system is increasing utilized below its capacity.

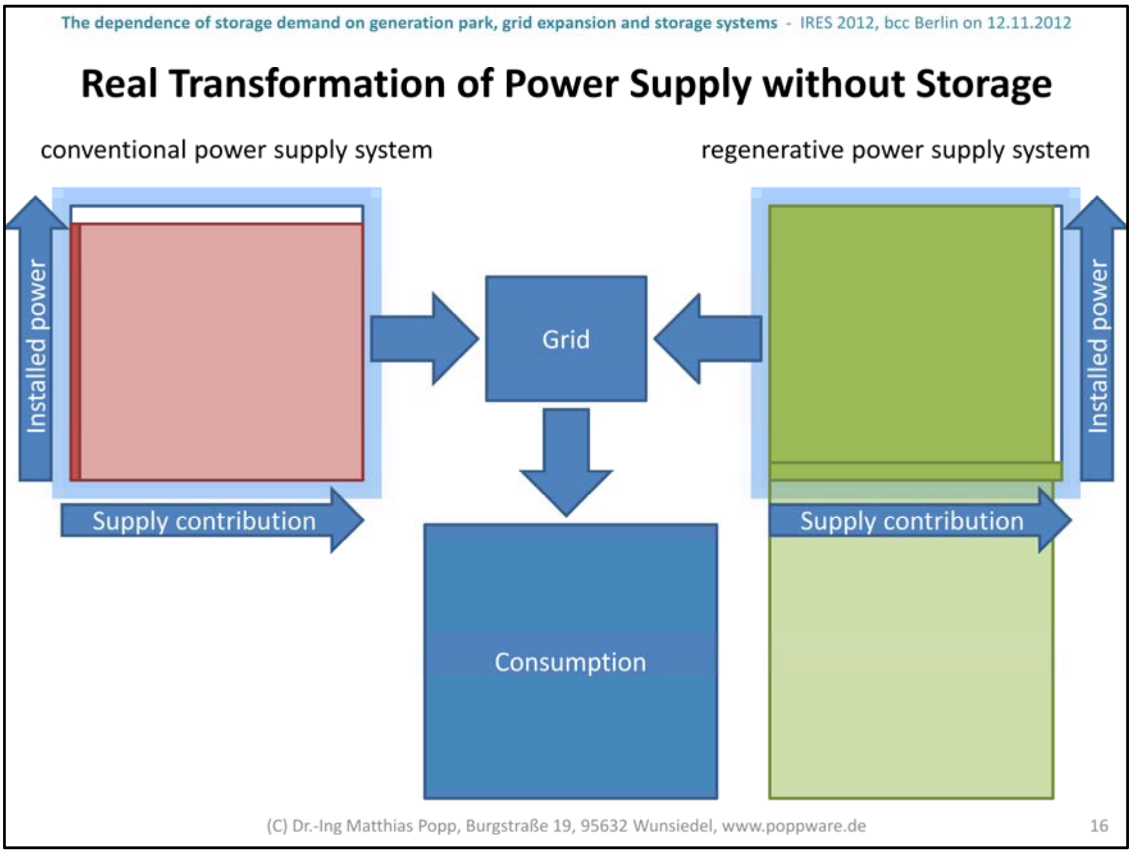


If the development of volatile production systems will be continued, without installing equipment to balance between volatile production and demand, only a fraction of the volatile available energy can be used for supply needs. The overshooting production must remain unused.

Nevertheless, the conventional power supply system must be kept in stand by mode with its complete production power for the ability to bridge weak wind phases.

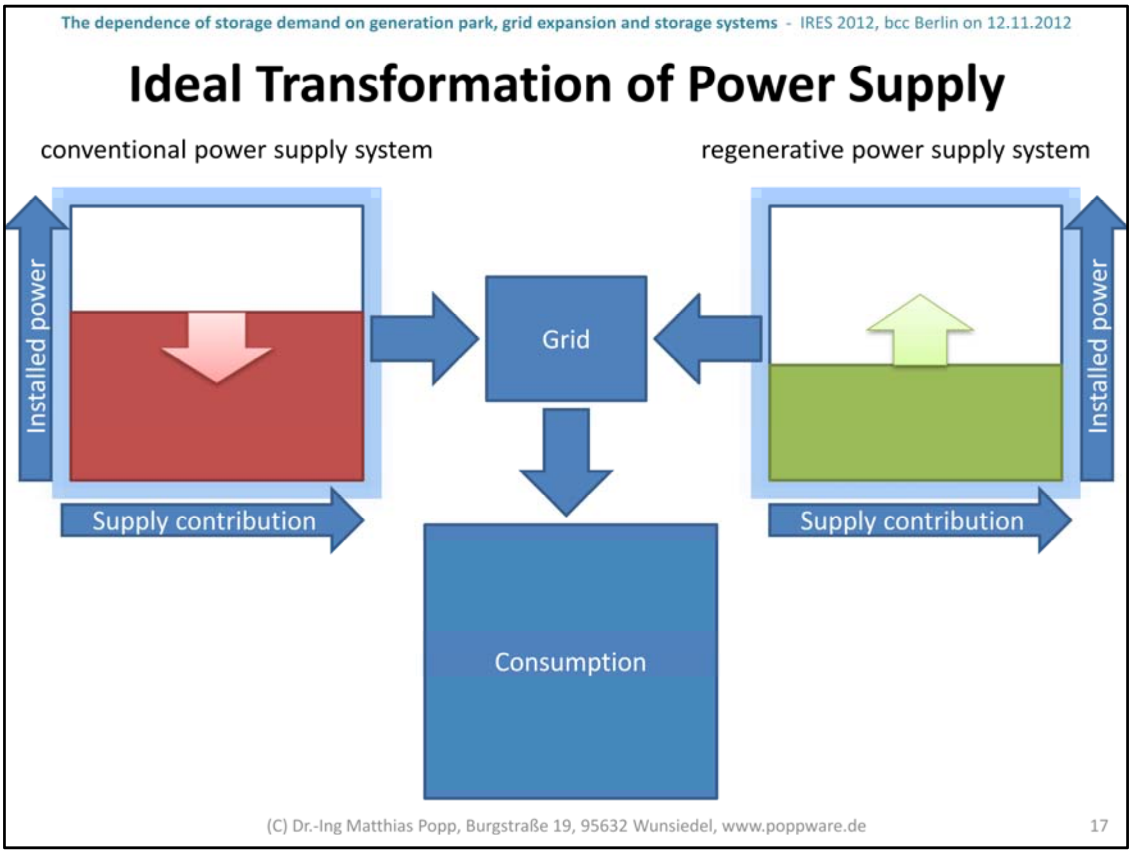


Keeping the existing power production capacity in stand by mode becomes highly questionable for this way of power supply transformation.



At the end, two power supply systems would have to be financed, with a total production capacity, much higher then needed.

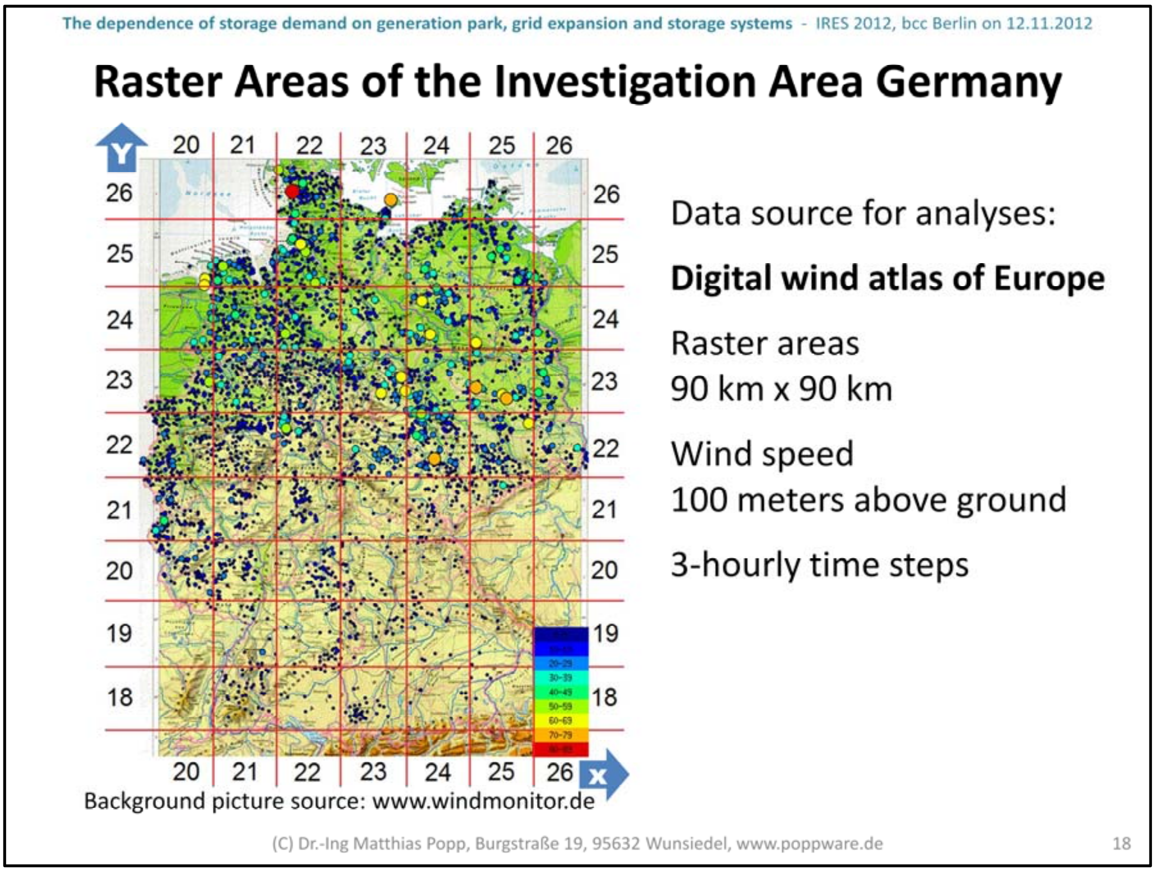
The use of storage systems, which enable a power supply on demand based on volatile renewable energy, offer a solution, away from this unfortunate development.



An ideal transformation of the power supply system will take place, if the possibility of balancing power on demand is realized in coordination with the construction of new volatile renewable power plants.

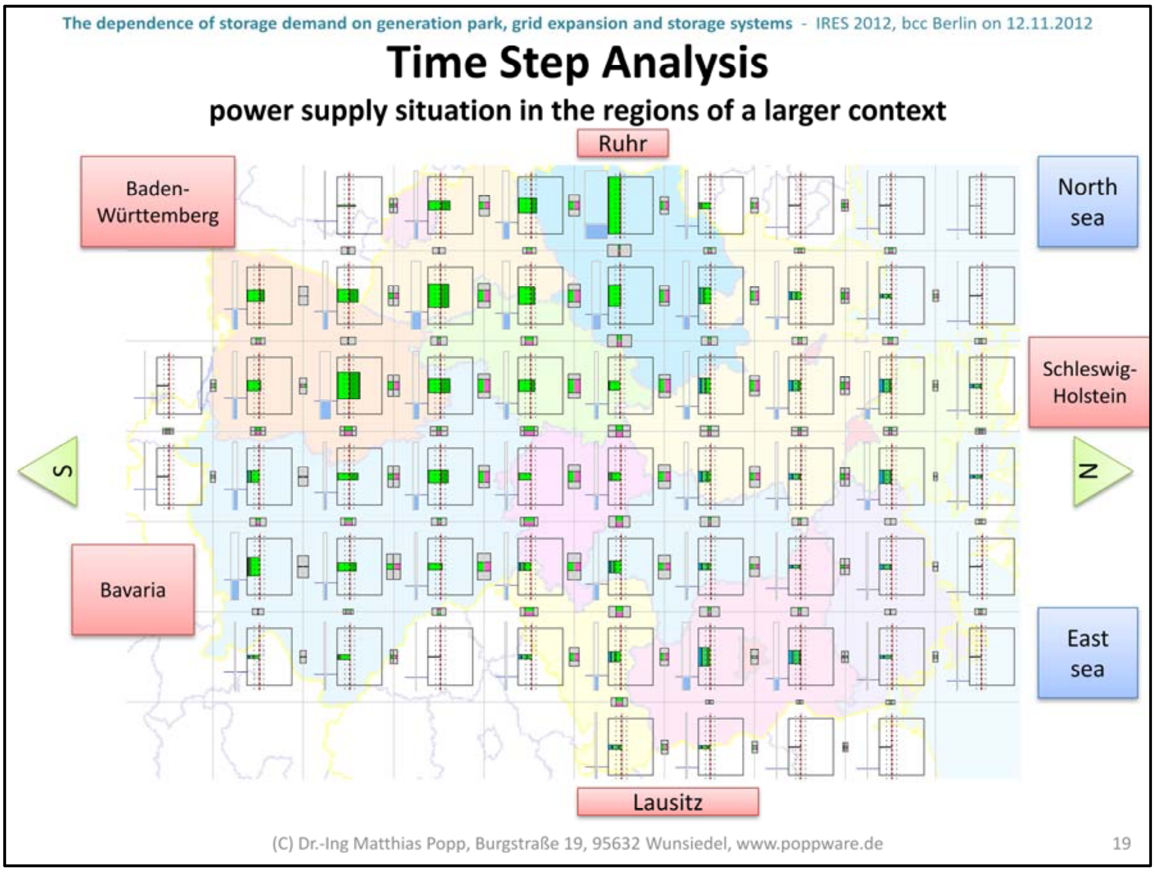
In this case, the added renewable power supply capacity will have the ability, to replace conventional systems, instead of only reducing their capacity utilisation.

Now let’s investigate the required properties of the storage devices.

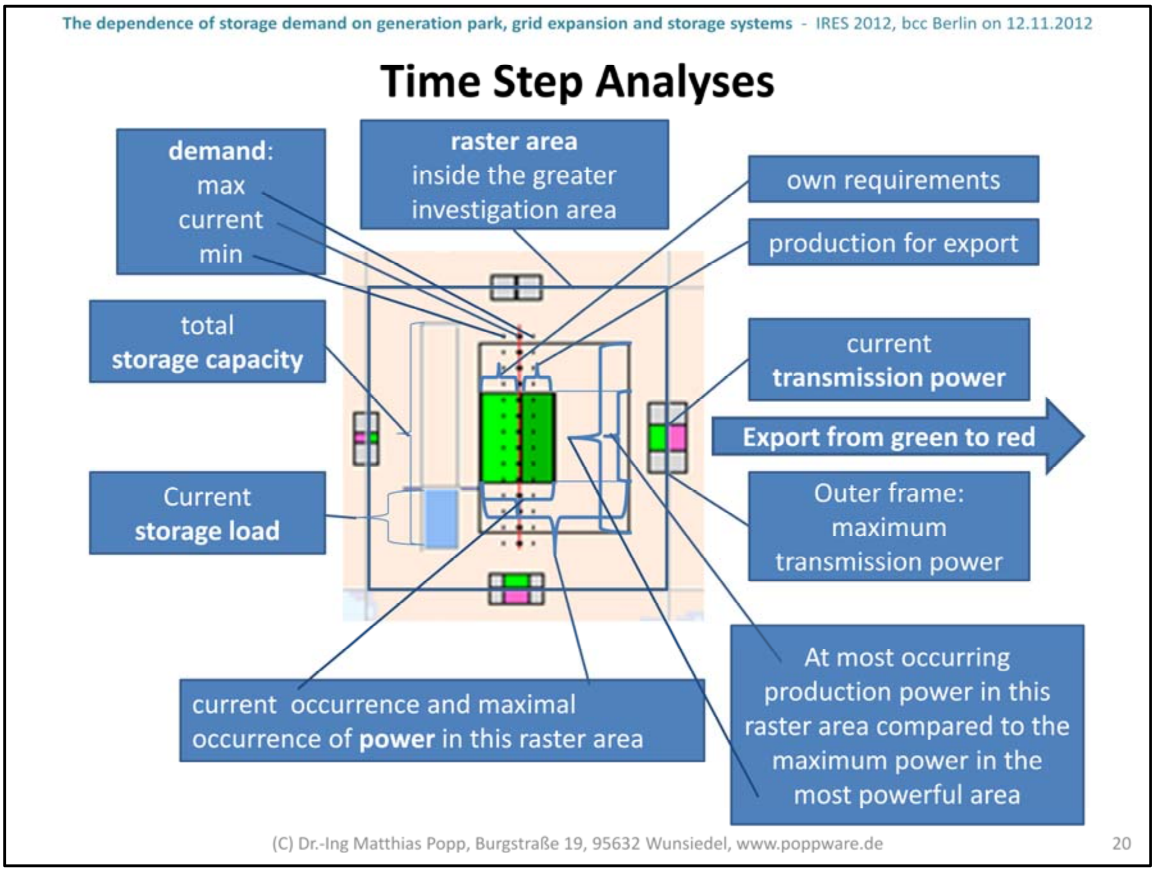


Germany is the investigation area of the following analyses.
It is divided into raster areas of the used digital European wind atlas.

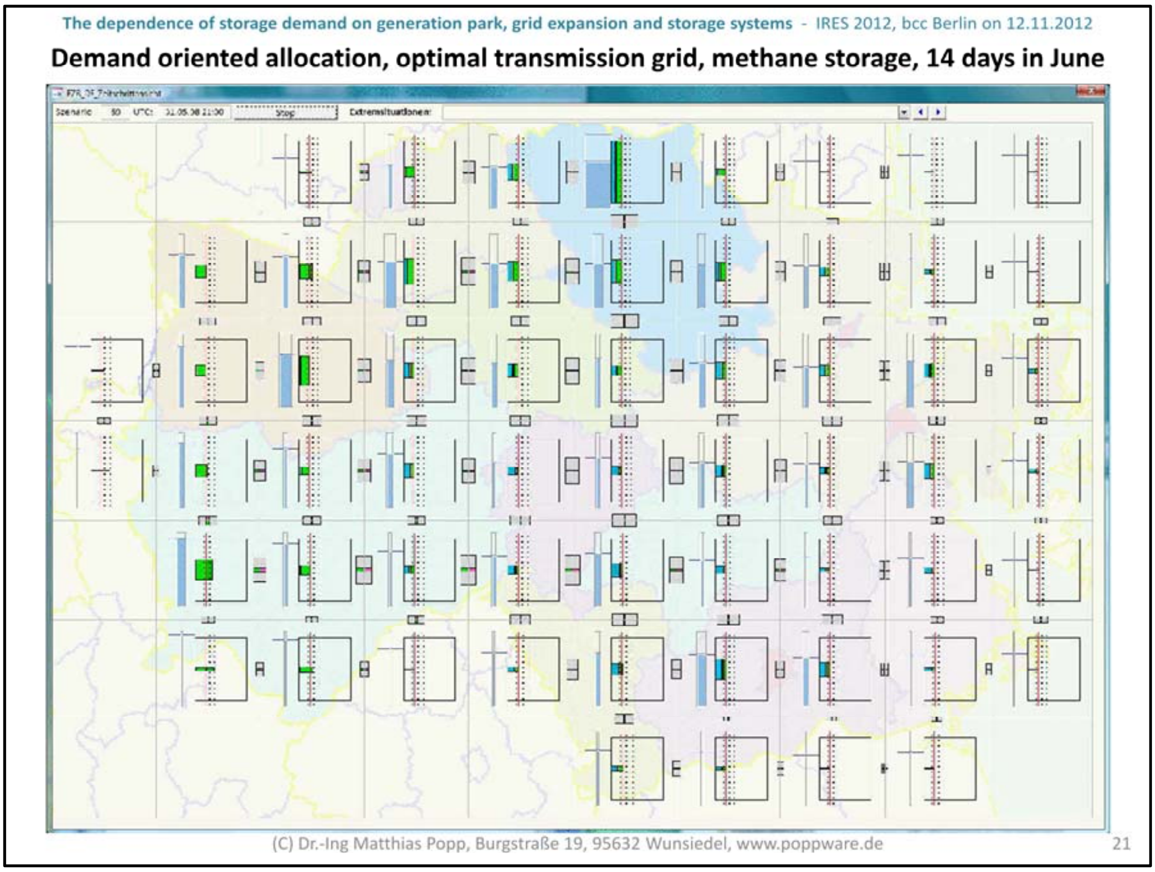
The production and consumption situation as well as the transmission and storage demand of the subareas can therewith be investigated and presented in its overall context.



This map shows Germany rotated by 90 degrees to the right, divided into the raster areas, with symbols on it, to represent the power supply status of each area.



The symbols in the raster areas show the demand, the situation of power production, the use of storage system and the power transmission with the neighbour areas.



The following animation shows the countrywide dynamic of power supply for an exemplary period of 14 days during summer.

It presents a situation, arising under usual weather conditions in the German electricity grid, with an optimized regenerative production and a high share of volatile power.

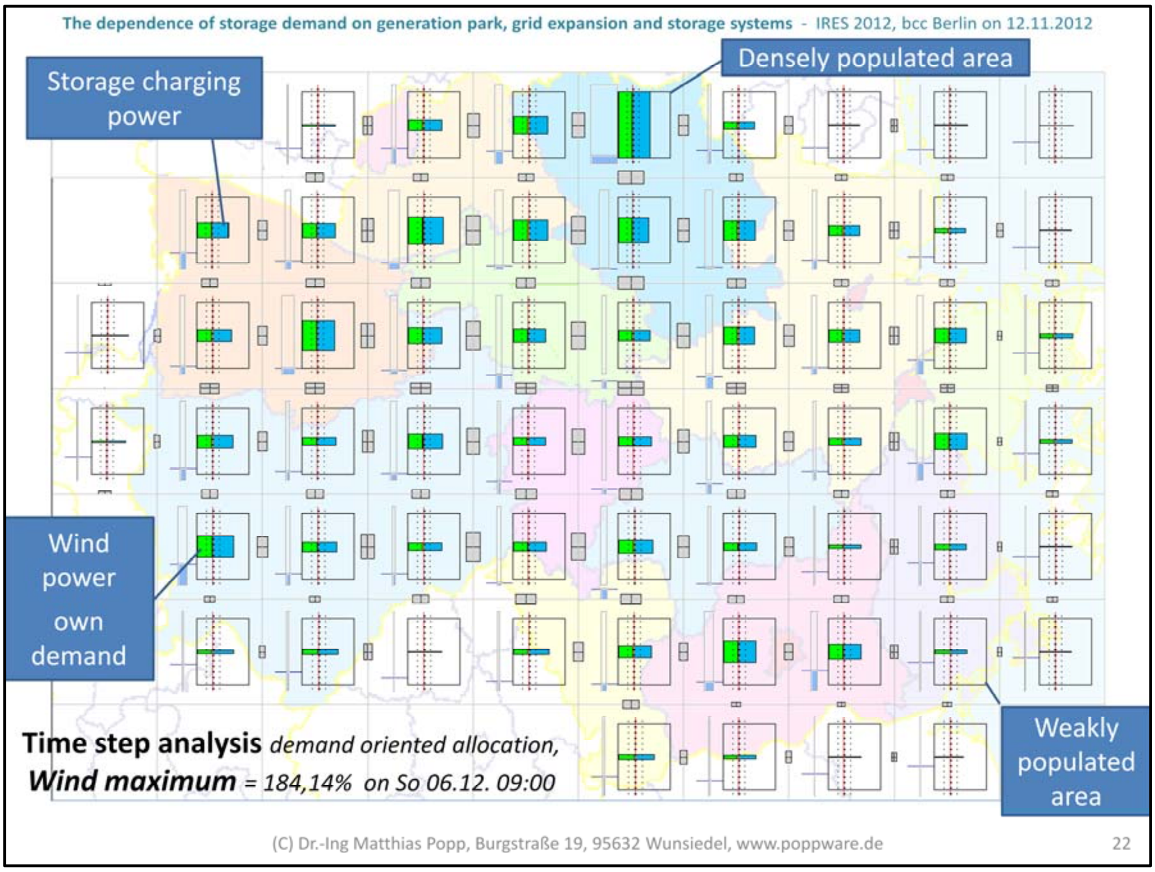
The following assumptions belong to the shown scenario:

Optimized design of wind and solar power stations, to minimize the storage demand, with the ability to produce 120% of the in average consumed energy.

Additional 10% renewable base power.

Demand oriented allocation of the power production systems over the country, combined with storage capacity to bridge 20 days, based on methane with 38% degree of efficiency.

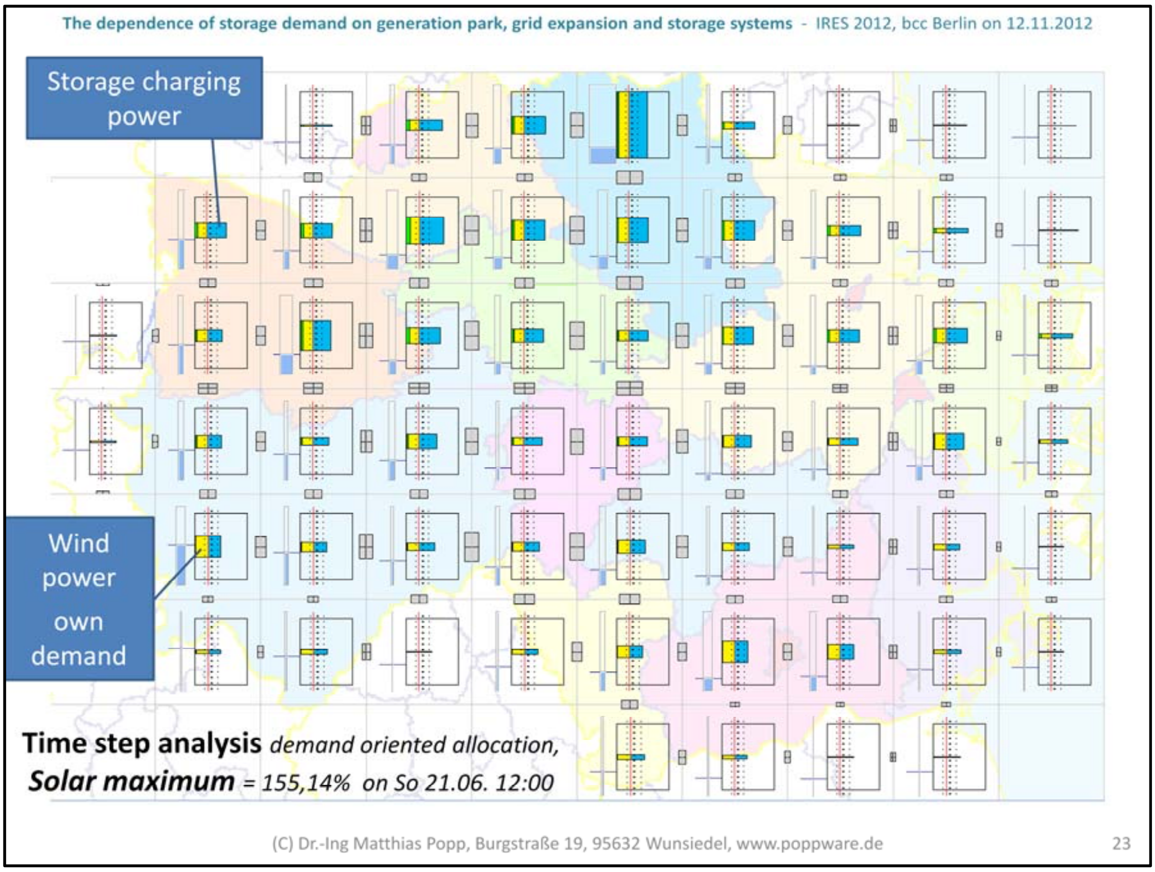
Transmission conditions, to balance up to 50% of overruns and deficits between the included regions.



Now, some special situations are presented, which naturally occurred in the analysed period.

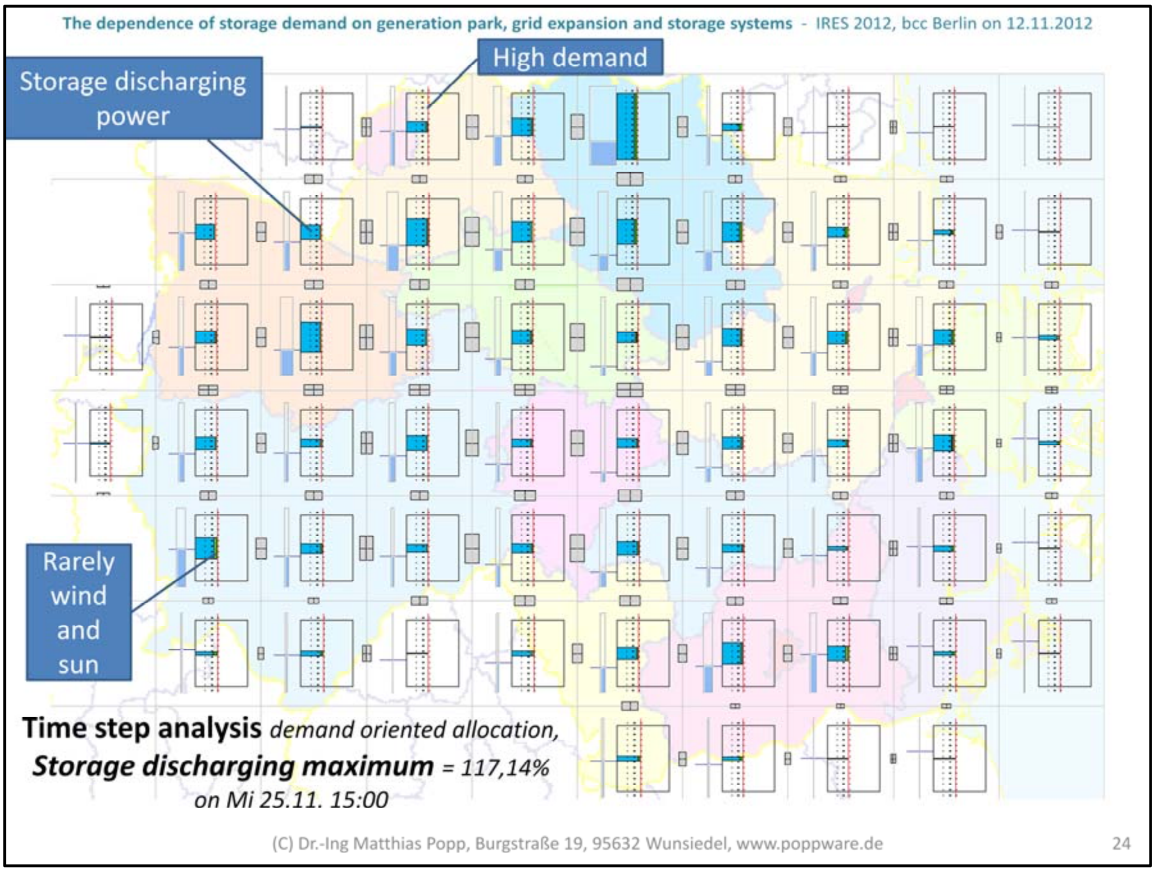
The first situation shows the maximum of wind power in December.

No power transmission takes place.



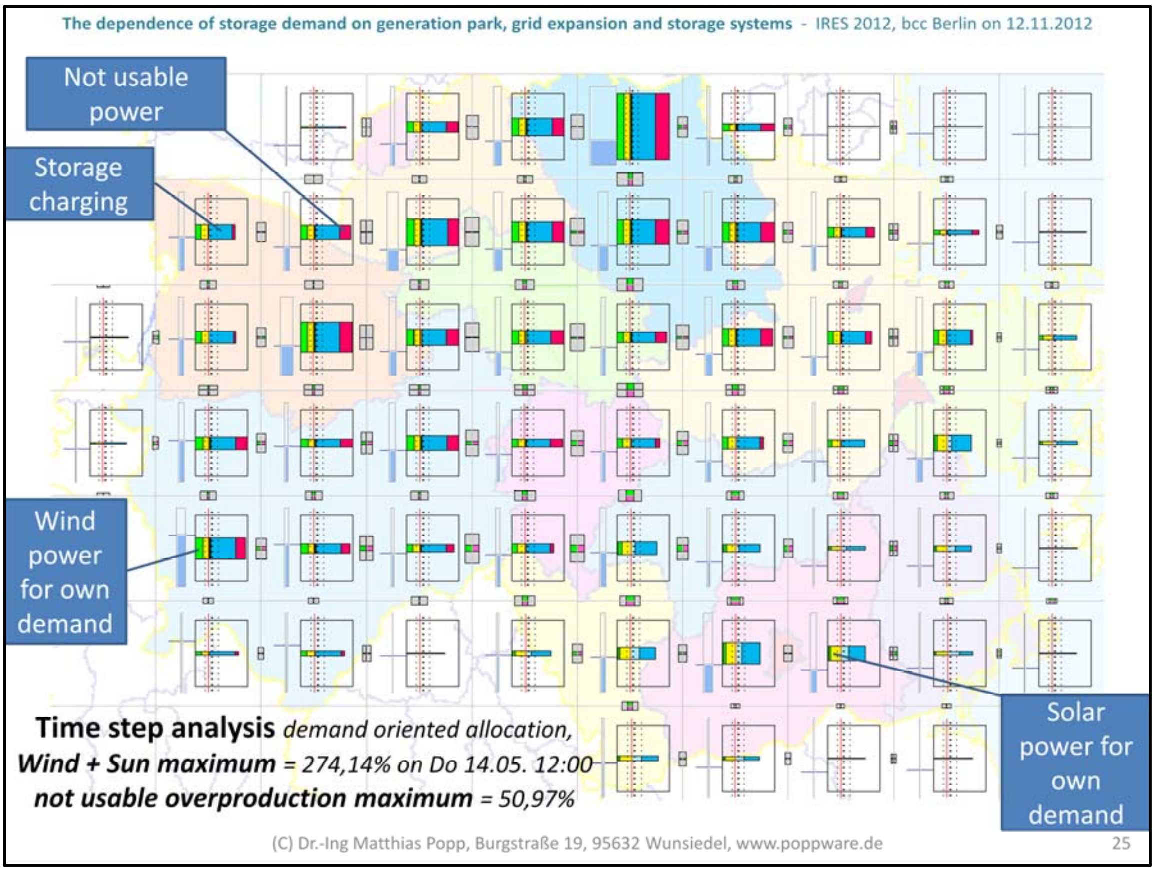
This slide shows solar maximum power in summer all over the country.

No power transmission takes place.



Shown is here the maximum of storage discharge with high consumption all over the country and rarely wind and sun in November.

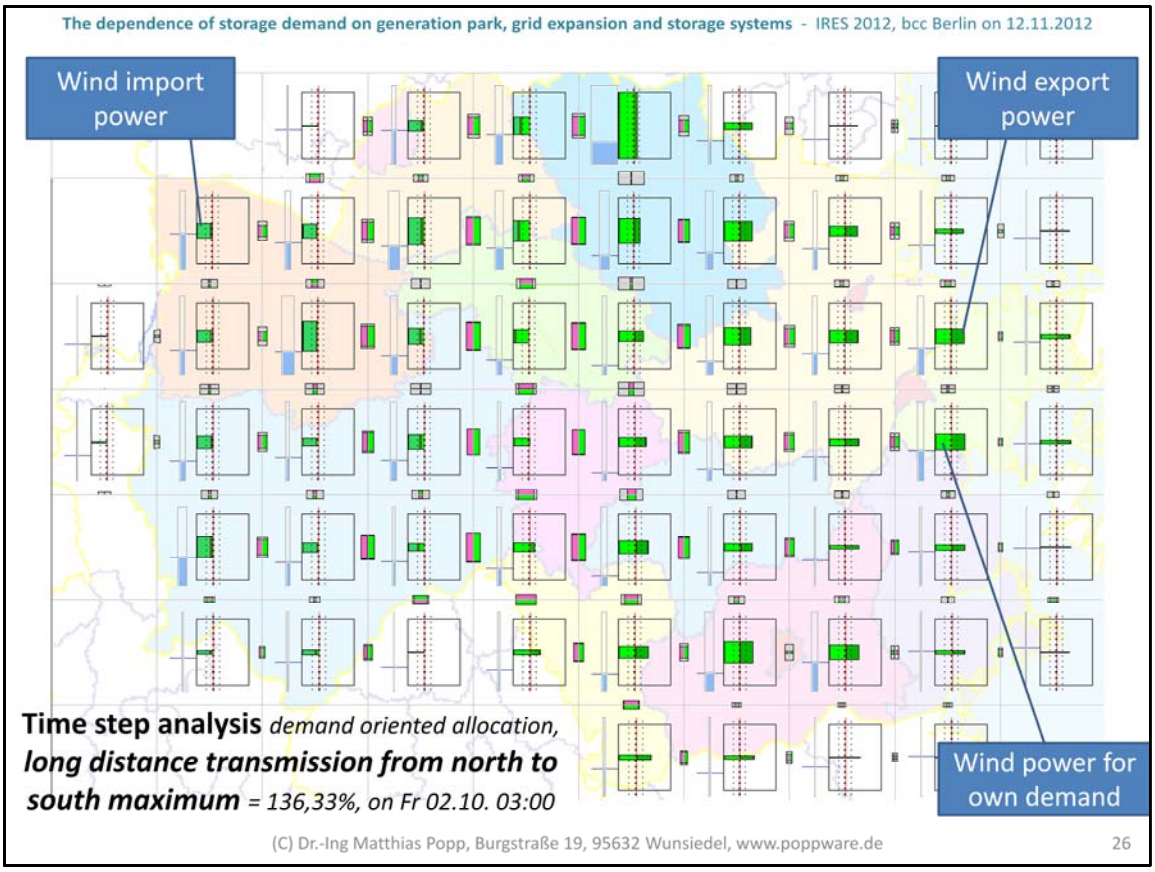
Again, no power transmission takes place.



This situation in Mai shows maximum power production, wind and sun combined.

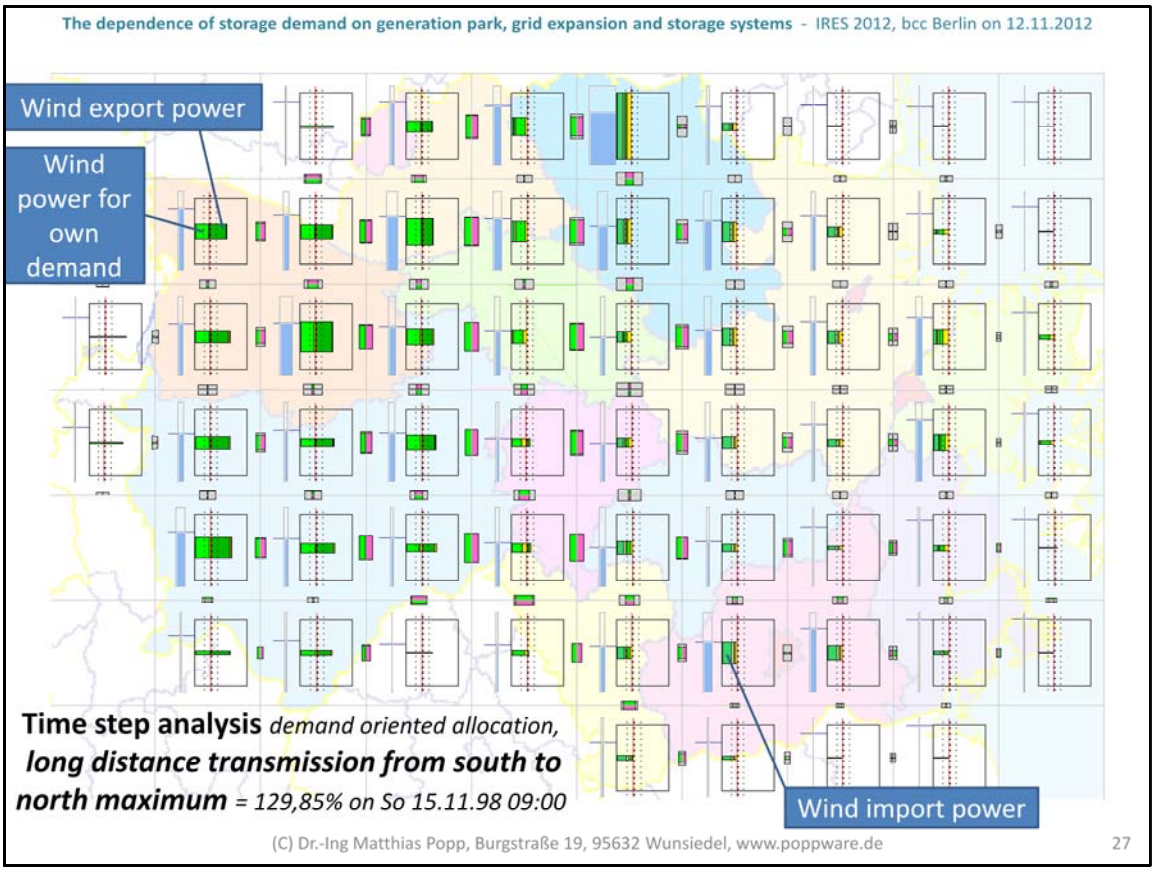
The Charging power for the storage systems is not sufficient to absorb the complete overproduction.

Production side management has to reduce the power generation.



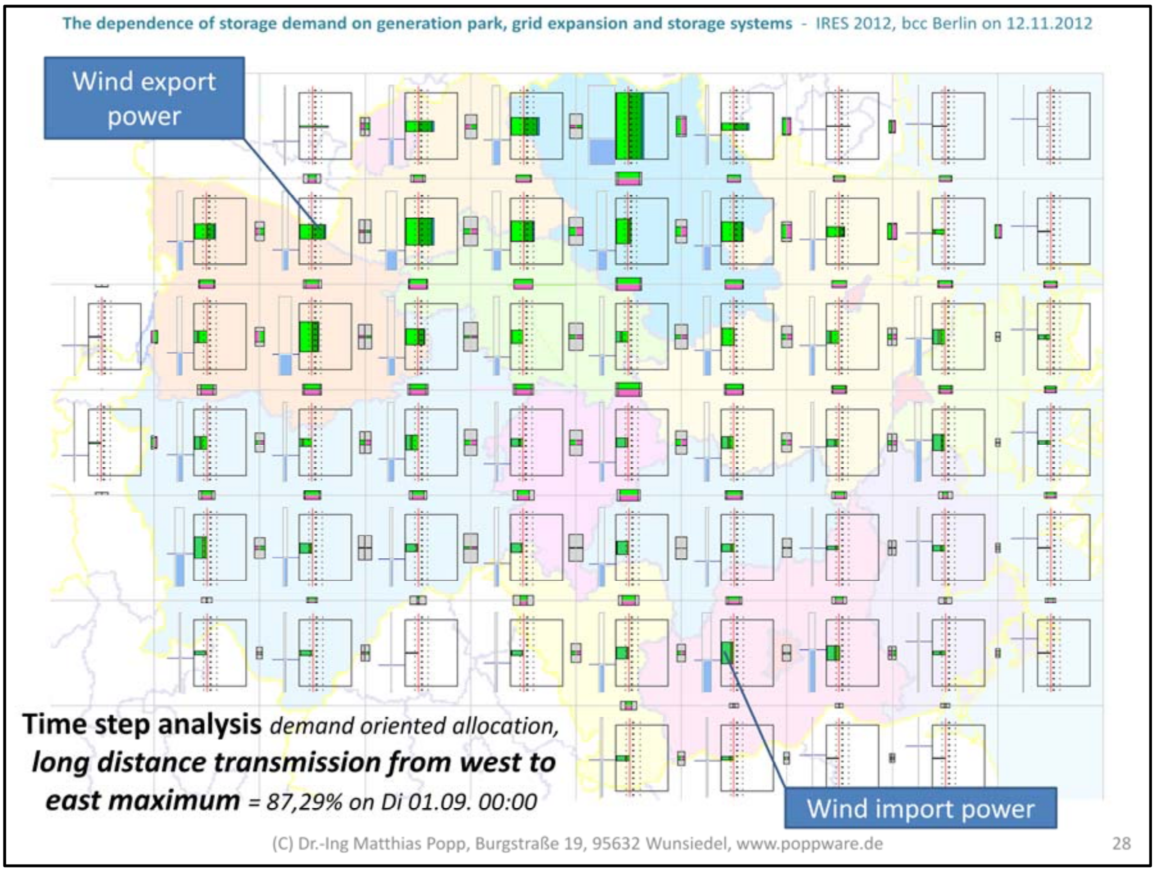
This slide shows a situation in October with wind surpluses in the north and deficits in the south.

Maximum transmission from north to south takes place.

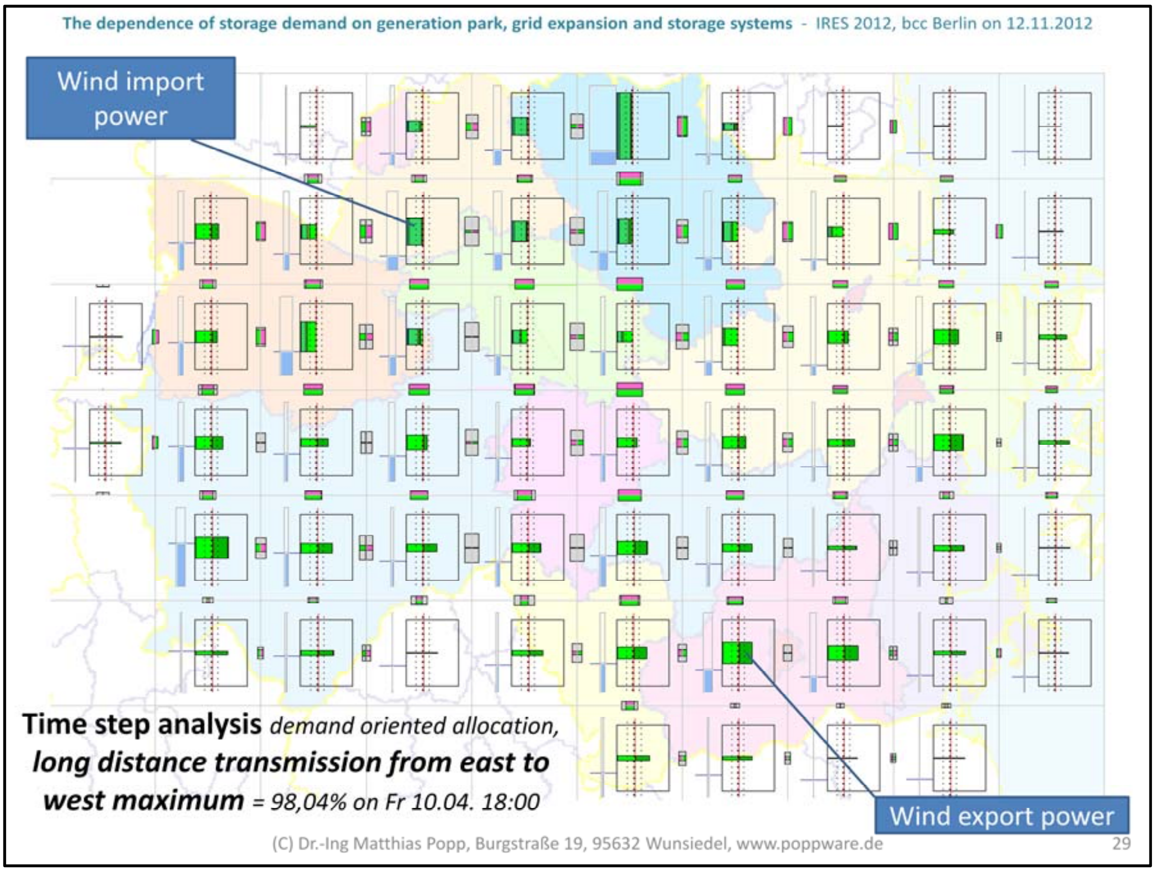


This November situation shows the opposite with Wind overproduction in the south and deficits in the north.

Maximum power transmission from south to north takes place.



This next slide of September shows the maximum power transmission situation from west to east.

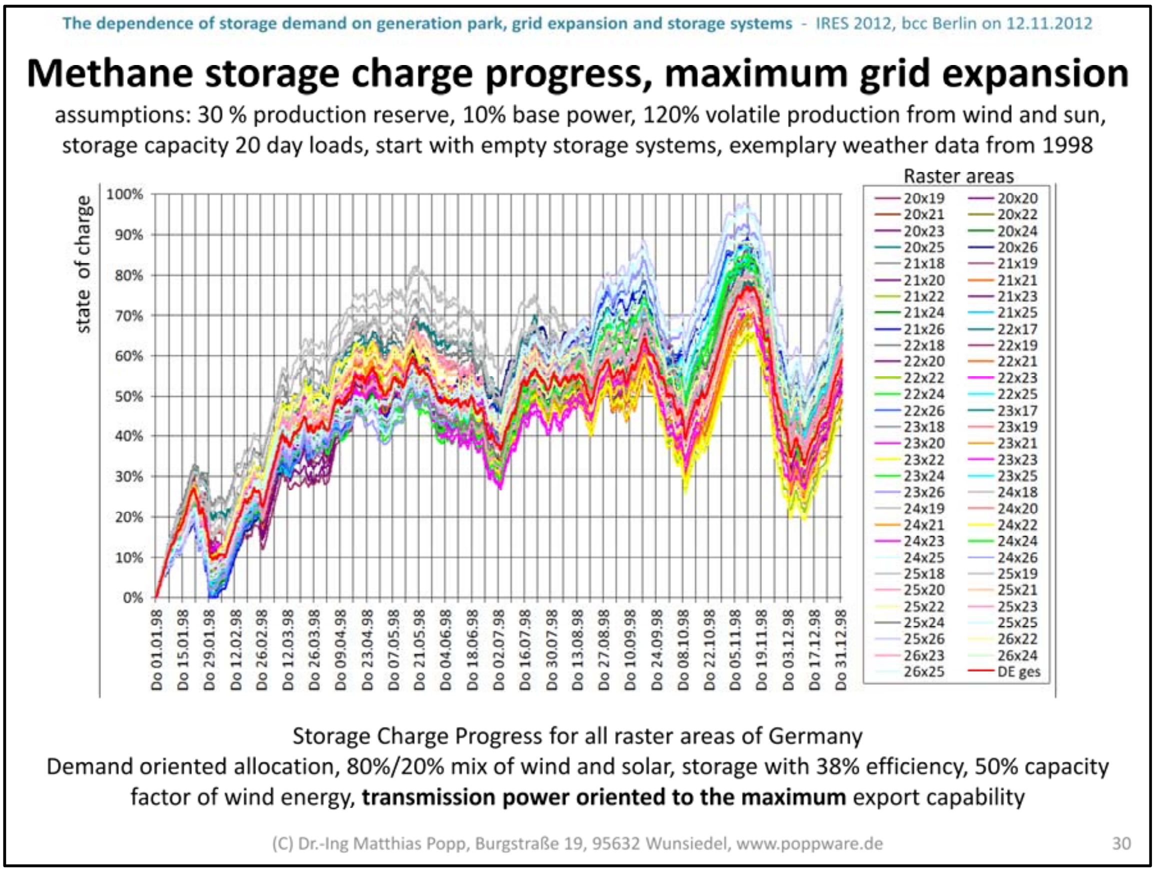


The last slide from April of this examples shows the situation with maximum power transmission from east to west.

We saw situations where power transmission did help to balance surpluses and deficits across the country.

On the other hand we saw situations where power transmission can't help to support the supply needs.

To analyse the part, power transmission can play for storage needs, storage load curves are introduced.



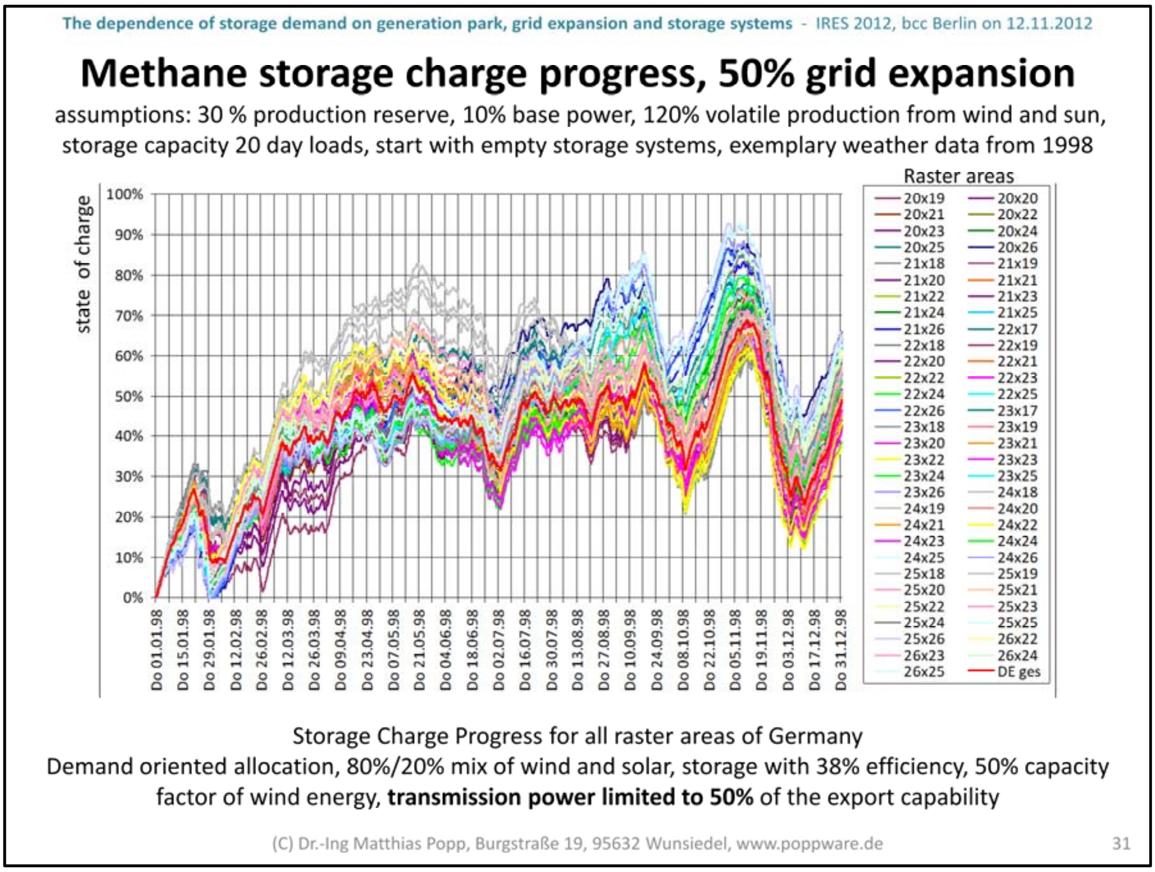
This chart shows charging and discharging of an assumed methane storage system with 38% efficiency in every region of Germany for one year.

Assumed are empty storage systems at the beginning of the investigation period and a capacity of 20 day loads of average consumption for every raster area.

It’s not necessary to follow every single curve, but recognize the simultaneity of charging and discharging in every region, caused from the power of wind and sun.

An important result of this analysis, with real weather data is, that the volatility of power in all regions of Germany is quite similar.

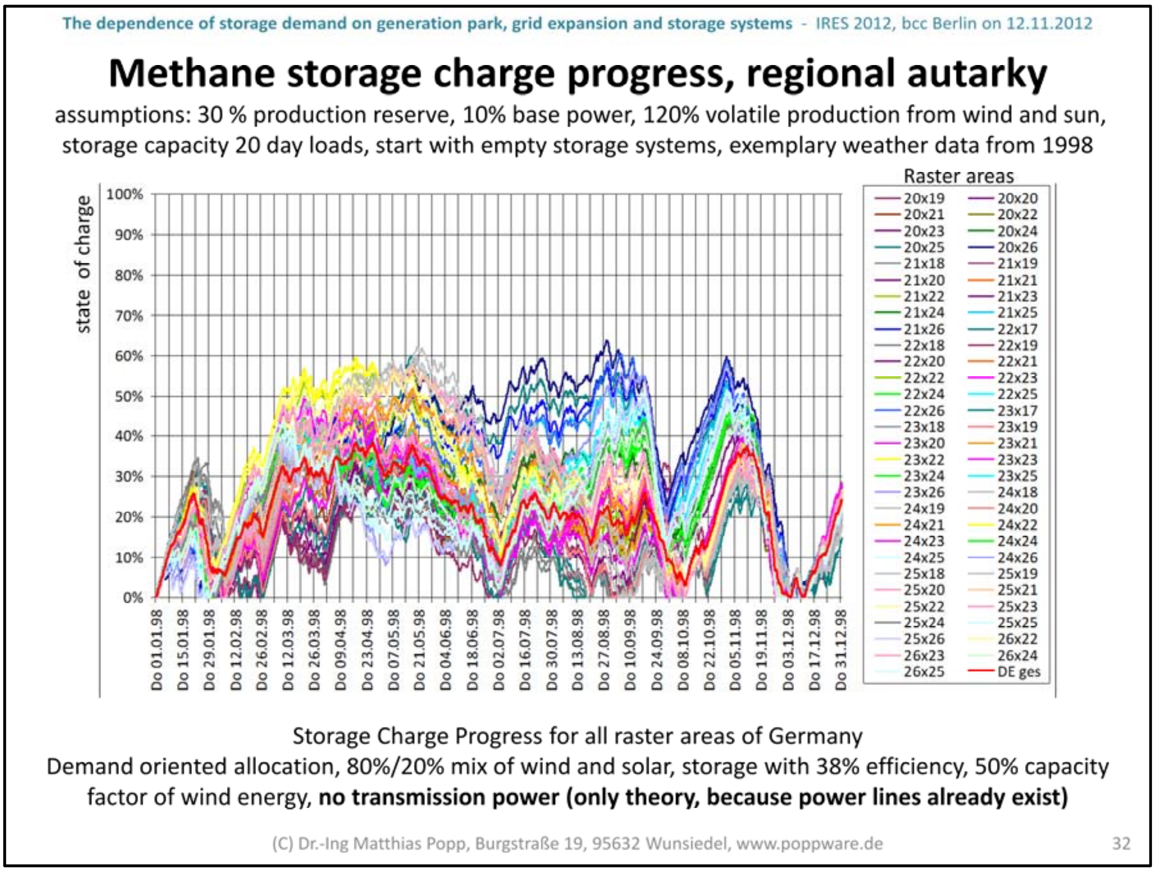
In the next slide, look what happens, if the grid could only transmit half of the power.



The storage charge would rarely change.

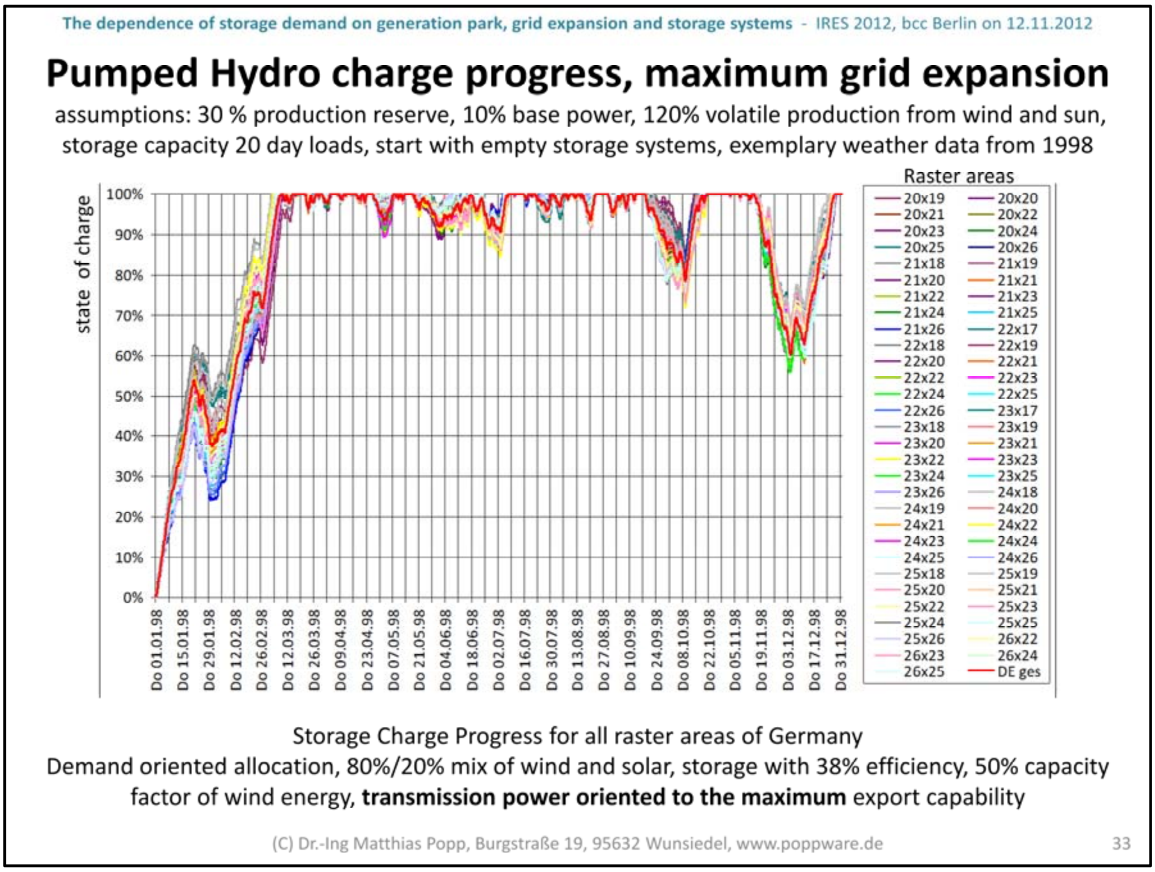
At the end of the exemplary shown year, the storage load is about 10% lower.

Now look, what happens, if no transmission capacity at all would be installed.



The storage systems would nearly have been able, to provide a secure power supply all over the year.

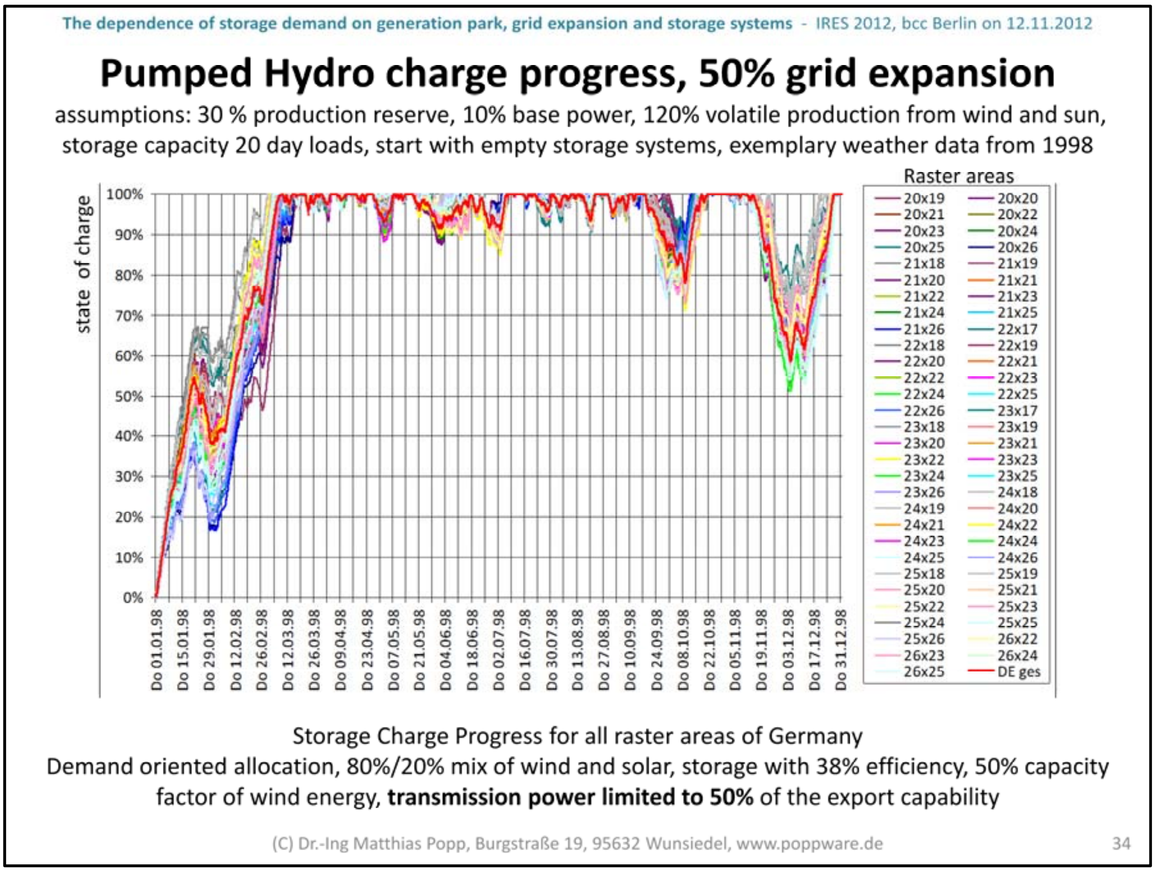
With a slightly larger production reserve, even this design of energy system would lead to a functioning power supply.



If the same production structure as before would be balanced with a 76% efficient pumped hydro storage system, the devices would charge much faster because of clearly lower efficiency losses.

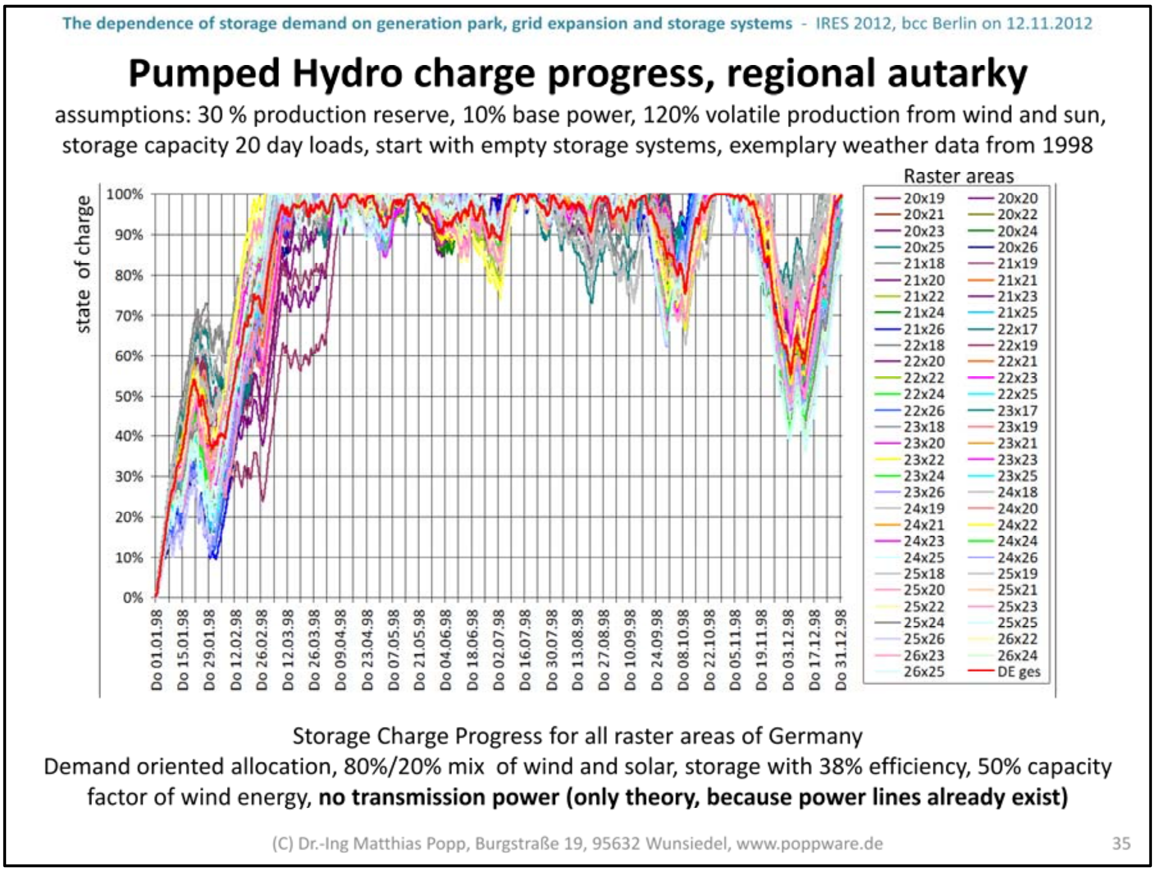
Storage discharge to bridge weak wind phases would accrue, however, in a similar dimension.

Less production power will become necessary, to achieve a secure supply system with the ability to recharge storage systems after calm phases.

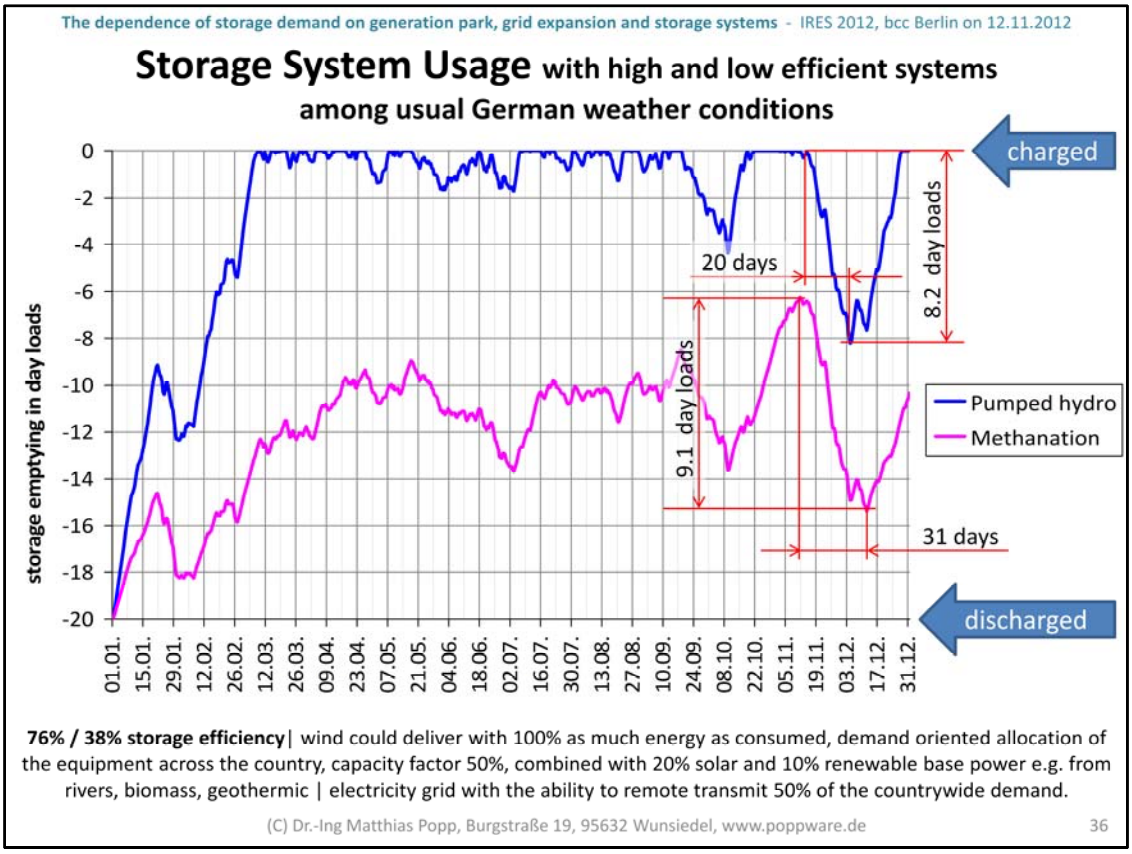


A power grid, that could transmit only 50% of the regional demand, would hardly change the quality of supply.

Storage demand, to bridge the longest calm wind phases would increase only marginally.



Even if theoretical no transmission power at all would be available, the storage demand to bridge calm wind phases would overtop the storage demand with best transmission conditions by only about 20%.



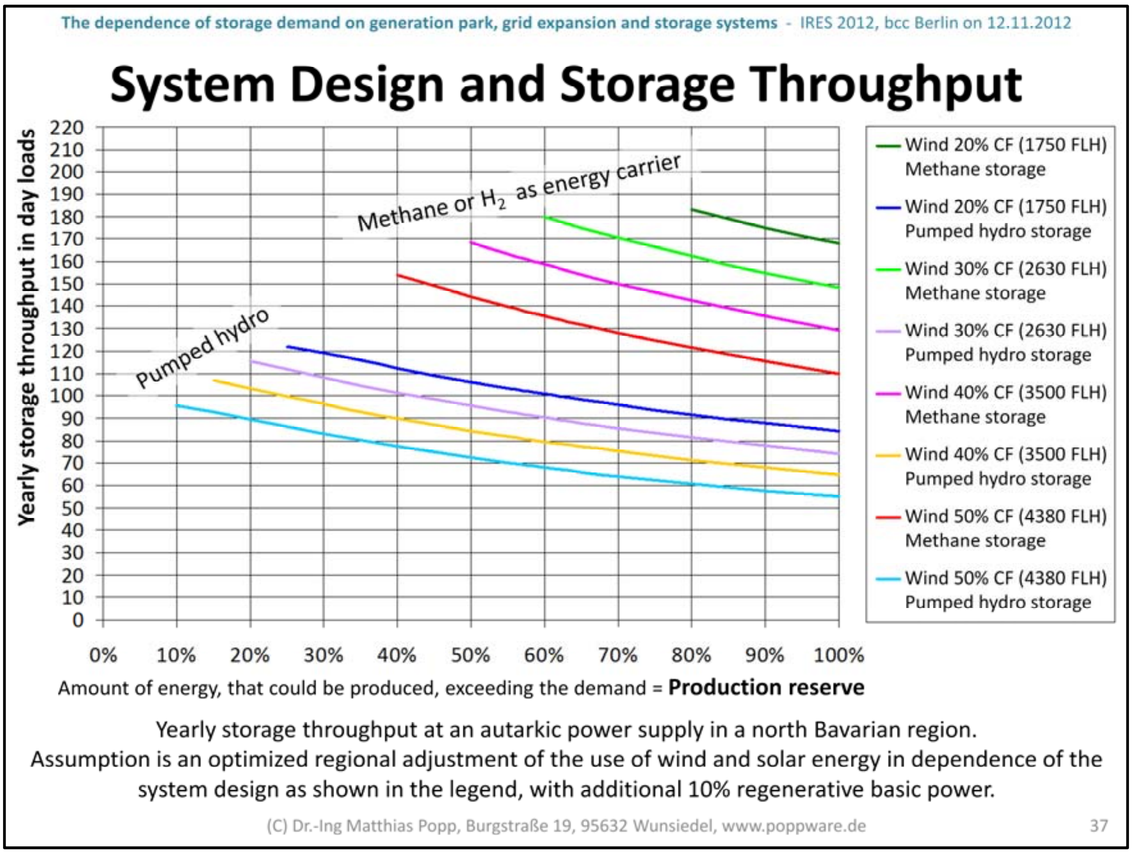
Longer weak wind phases will define the future challenge for storage systems and no longer the balancing between day and night.

During long lasting and country wide affecting meteorological conditions, neither a powerful electricity grid, nor a demand side management for short time load shift can fulfil the task.

If not a powerful conventional, on demand available production park shall be established and kept in standby state, storage systems, designed with the necessary capacity reserves, will be required to meet this challenge.

As soon as these systems will be available, neither network expansion, nor demand side management solutions, nor short time storage systems are required.

Short time storage and the task of demand side management can than be fulfilled by the long time storage systems.



The storage throughput is the annual average energy needed, to charge again after all emptying phases.

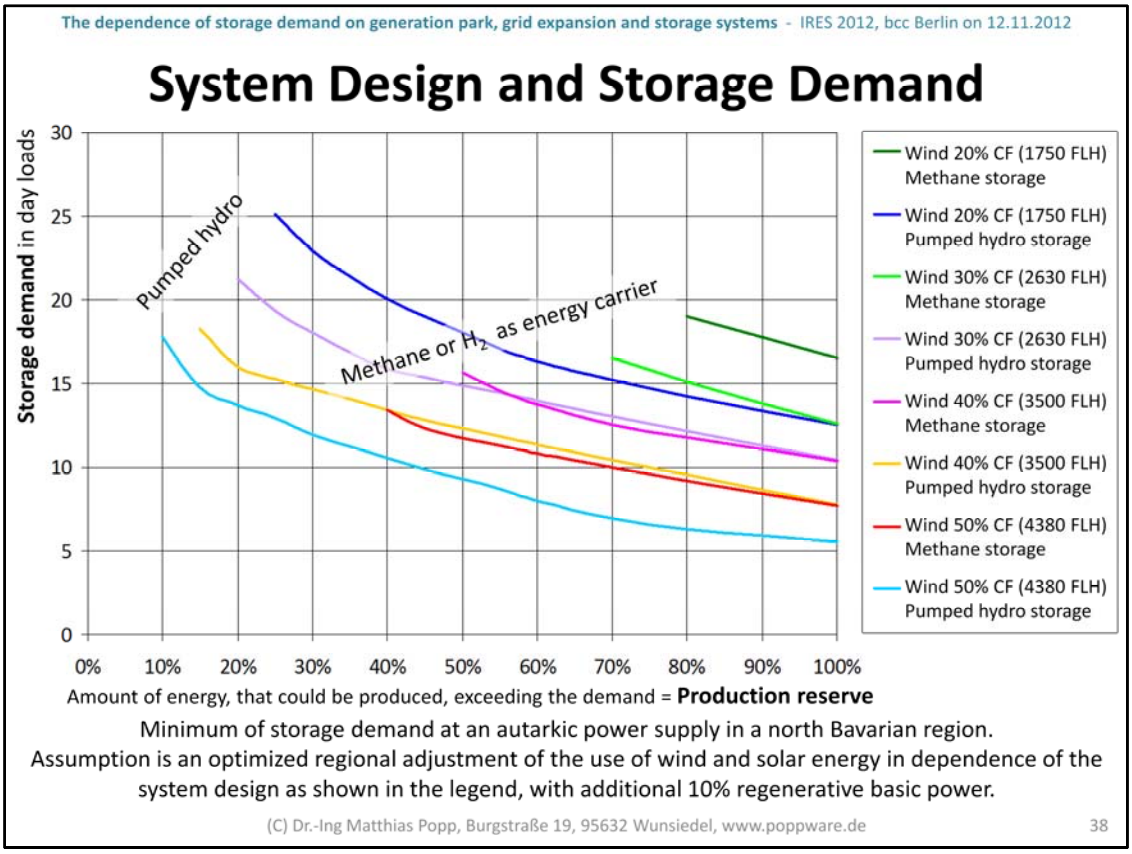
Large energy losses, taking place during a storage process, don’t accrue with high efficient storage systems.

Using low efficient storage systems, an energy equivalent of about half of the annual consumption is required to charge them.

High efficient storage systems reduce this value to about a quarter of the annual consumption.

They require less storage throughput and less production reserve, to achieve a stable power supply.

It will be an economical question, which storage solution, in an holistic approach, will open the more attractive development corridors.



The design of the production system, as well as the storage efficiency, has significant influence on the necessary storage capacity.

The storage capacity is determined by the largest discharge occurrence over a long period.

The characteristic lines show the minimum of necessary production power and the largest amount of expected storage discharge.

The obvious advantage of high efficient storage systems is, that less wind and solar power systems are needed, to achieve a secure power supply.

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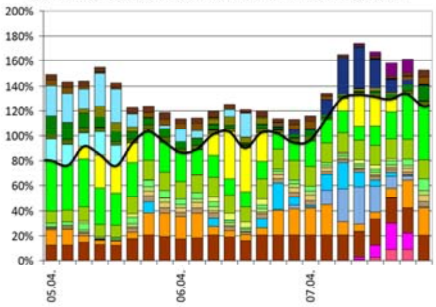
Thank you for your Interest

With a well-considered, holistic strategy, stakeholders in the energy market can bring themselves in an opportune position, when in future, regenerative power shall not only complement, but replace conventional power.

Order a Volatility Analysis for your company or organisation at

for a strategic advantageous transformation of the energy system



to determine a favourable development strategy for the renewable transformation of the energy system of your country, region or supply area.

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In the near future, important changes in energy economics will take place.

I hope, my presentation will motivate you and contribute to a holistic strategy, for an economic advantageous transformation of the energy system.