Storage for a secure Power Supply from Wind and Sun

How much balancing and storage is necessary to establish a secure power supply meeting the demand of consumers using only renewable energies and what are the mayor influences?

This Topic was rarely researched during the past. Now, for the first time, it was systematically analysed, using European wind data since 1970 and solar radiation data since 1996.

The dissertation “***Speicherbedarf bei einer Stromversorgung mit Erneuerbaren Energien***“ (storage requirement with a power supply using renewable energies) was developed by the author at the Institute for Heat- and Fuel-Technology of the Technical University Braunschweig (Prof. Dr. Reinhard Leithner) in cooperation with the Institute for Physics of the University Oldenburg (Prof. Dr. Juergen Parisi) and the Institute for Energy Systems and Energy Economics of the Ruhr University Bochum (Prof. Dr. Hermann-Josef Wagner). Published as book by Springer Berlin Heidelberg New York 2010, it shows how to establish a secure power supply without fallback to fossil and nuclear power stations, only using wind and sun energy combined with storage plants.

The challenge

Power production and consumption must always be precisely aligned to each other. That’s a special challenge, facing a weather dependent energy production from wind and sun. The long time analysis and the proposed new types of storage plants prove the solvability of this challenge. They open holistic approaches for a regenerative power supply, meeting the demand.

Sun and wind are the major regenerative energy sources

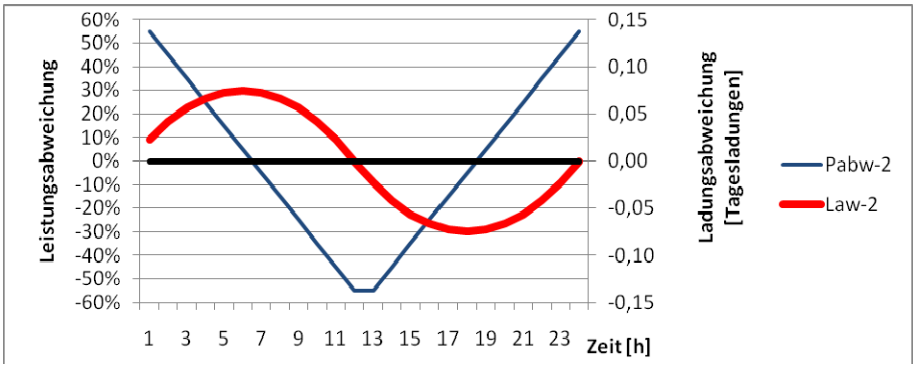
The irradiated sun overshoots the energy demand of humankind by the factor 8000. The energy of wind, fuelled by the sun, overshoots the demand by the factor 700. Other natural and sustainable available forms of energy, like hydro energy from rivers or chemically bound energy from growing plants are available in a clearly smaller scale. A power supply using renewable energies will therefore draw onto wind and sun energy in a huge scale.

New calculation methods

The capacity required for storage plants to balance between weather depending electricity production and the consumption of electricity can be determined for all European countries using available data of wind speed, solar irradiation and electricity demand. In the form of **load divergence** and **storage emptying curves** sustainable calculation methods were developed for this purpose. The good availability of data in Germany enables to compare the actual wind and solar power feeds with the calculated values. Thereby the applied calculation methods were validated.

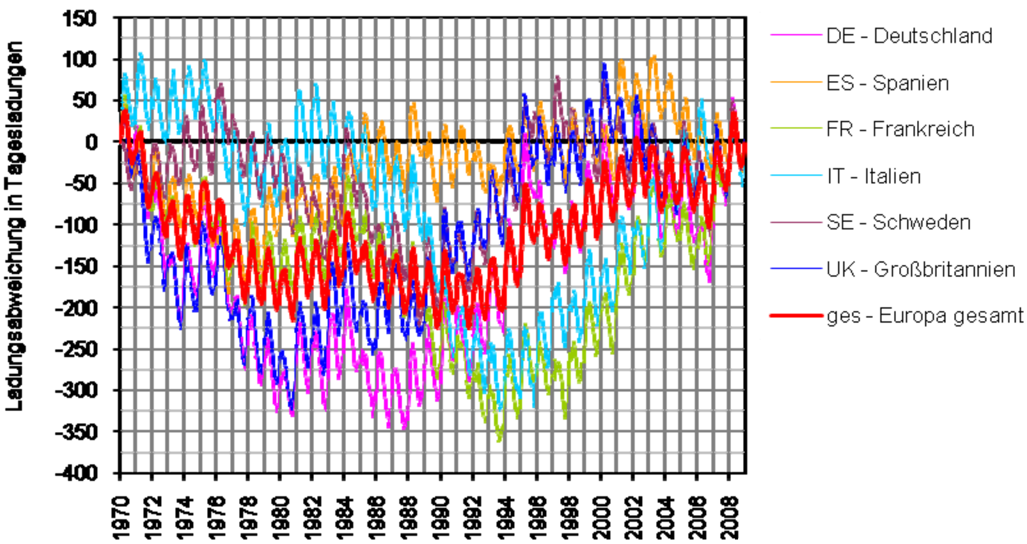
Load divergence - explanation

A daily load is the energy, which is turned over by a consumption area in a long time average during one day.



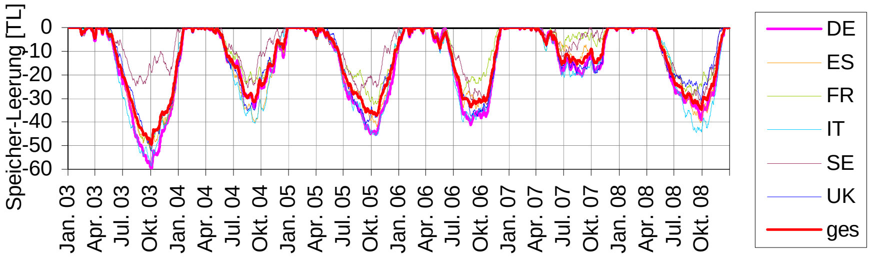
If a production power is diverging from its average value first upwards, then downwards and upwards again (see Pabw-2), then at permanently requested average power, a storage unit would first be charged, then discharged and finally charged again. The load (see Law-2, right ordinate) of the storage unit would first increase, then decrease and finally increase again. The load divergence shows clearly, how a storage unit would be stressed, to produce a steady power, serving the average power from a fluctuating power.

Load divergence of wind energy in Europe



Shown are the load divergences of wind power plants for selected countries and the consumption proportion rated sum of all countries of the European power grid. For all European countries a typical curve shape can be seen. In autumn and winter the load divergence increases – the storage units would be charged, in spring and summertime, the load divergence decreases – the storage units would be discharged. The global weather is in Europe responsible for stronger winds in the winter then in the summer. This continental effect could not be balanced by a powerful European network. Nevertheless it can be seen, that there are significant differences between the yearly winds in different European countries.

Storage empting curves



The figure shows storage emptying curves for the largest countries of Europe and consumption proportion rated for the entire continent (ges). With the assumptions, the scenario bases on, the usage of storage units for a secure power supply, meeting the demand, can be seen (discharge in daily loads [TL]). The exemplary shown curves are part of a wind power plant supply which power trait complies with the plant holdings in Germany in 2010. The necessary storage capacity can be quoted from those curves, based on a representative long time analysis, which would be necessary for an always stable power supply, meeting the demand.

Equal collaboration to the benefit of all cooperating countries

Each European country is able to produce enough energy from wind and sun to satisfy its own demand. Therefore all anticipating countries become equal partners of an energy network with mutual and peace spending advantage.
This concept differs fundamental from the conventional energy supply with mayor differences of interests between exporting and importing countries of energy sources.
It also is an alternative to “Dessertec” (solar electricity for Europe coming from the Sahara) or approaches to massively increase offshore wind energy plants in the North Sea with using the natural water sources of Scandinavia for pumped hydro power stations with the consequent interventions in the water eco systems there. For electricity importing countries are such suggestions unattractive, with uneven dependencies on renewable power supply from other countries.

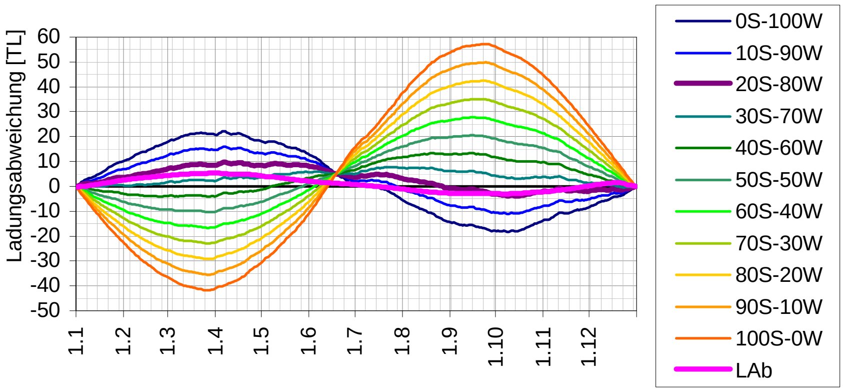
Minimizing the balancing and storage requirements

If every country produces its own average demand plus a certain production reserve from wind and sun power stations, then the needed storage capacity for balancing the demand would fluctuate between a few day loads and some month loads of the average consumption. This huge difference is caused by several different influences.

A continental distribution and cross-linking of volatile electricity production enables considerable balancing effects between temporary overproduction and deficiencies because high- and low-pressure areas which are moving across the continent are causing different weather conditions in different regions. Strong winds occur in Europe mainly during winter time. An optimized combination of power production using wind- and solar energy on the other hand reduces the need to balance dramatically in comparison to a mono structure using only wind- or only solar power stations.

Considerable influence on the need to balance between production and consumption also has the capacity factor of wind power stations. It tells the amount of average power output compared to the rated power. German wind power stations in the year 2010 have an average capacity factor of 20%. This value proves unfortunate to the intended increase of wind power to the total power supply. The power transferred by the power grid as well as the balancing and storage needs could be drastically reduced by using wind power stations with a degree of utilisation of 50% for example.

Combination of wind and sun



This graphic shows the variation of solar and wind energy allotments which alter the load divergence in daily loads [TL] of the recoverable electricity compared to the load divergence of the electricity demand in Germany (LAb). The example shows how the load divergence of the renewable electricity production can be drawn near to the curve of demand and how the storage demand can be minimized. According to the underlying assumptions, this would be at a power production with a ratio of 80% wind and 20% solar energy the case. The available wind energy is based on a degree of utilization of 50% and the available solar energy was scheduled power proportional to the global irradiation. Basis is a time average between 1996 and 2008 for an area of wind energy harvest in Hessen (a federal state of Germany) and the urban centre of Frankfurt am Main for the solar energy harvest.
Explanation to the legend:
%S-%W (example: 20S-80W): load divergence at a production structure with the contribution of solar energy (20%) and wind energy (80%) for the combined curve in %. Solar and wind contribution together always makes 100%. Lab: load divergence of the average demand.

A further strong lever to reduce the balancing demand is the power production reserve. This is the installed production power which enables to produce more regenerative energy than the demanded long time average. This production reserve is necessary to balance transmission and storage losses and to bridge years with little wind or high electricity demand. The more production reserve there is the less storage is necessary and the faster those storage devices will be charged again.
Also with the conventional power production system it is not enough to have power stations which just meet the average demand. A sustainable electricity production needs to be able to serve the highest possible peak of demand.

A skilled tuning of all parameters allows a secure power supply what will meet the demand with a storage capacity of only a few days. The storage capacity needed would be much more than available in the year 2010.

New pumped-storage hydroelectricity plants with high capacity and independent of mountains

Ringwallspeicher as a new type of pumped-storage power plants are introduced. They could be built in all countries also in non-mountain regions without serious intervention in existing water ecosystems and could be equipped with the required large capacities.

Ringwallspeicher-Hybridkraftwerk (Ringwall-storage-hybrid power plant)

The exemplary shown plant would have a diameter of 11.4 kilometres (7.08 miles) and a height of 215 meters (705 feet). The maximum water gauge deviation in the upper basin is 50 meters (164 feet) and in the lower basin 20 meters (65 feet), the average height deviation between the two water surfaces would be 200 meters (656 feet). The upper basin and the south ridge are covered by solar energy plants. In combination with approximately 2000 wind energy plants (hub altitude for example 160 meters (525 feet), rotor diameter 120 meters (394feet)) this device could replace the power production of two nuclear power stations and deliver secure electricity which meets the demand.
By using the excavation of the outer water-ring for the lower basin the ring wall for the upper basin can be build. Using electricity over production, water is pumped into the upper basin, which will flow through a turbine back down if there is an electricity deficiency. The dimensioning of this device: doubling the geometric dimension of diameter, height and gauge deviation in the upper and lower basin leads to an increase of the storable energy capacity by the factor 16. Therefore a Ringwallspeicher enables maximum storage capacities.

A secure power supply, only using wind, solar and storage power plants in Europe is therefore a real option.

Comparing to other approaches

At this concept all techniques are known and knowledge of many decades exists.

Concerning the amount of balancing and storage requirements, this analysis is probably the only and first one ever which analyzed this demand on the basis of long-time wind and solar energy data on a national and European wide level.

<u>Dessertec</u>
Electricity for Europe coming from the Sahara Dessert would lead to a dependence on electricity from the same cultural area we are already depending on to import oil and gas.

<u>Building Scandinavian lakes into pumped storage power plants</u>
Considerations to convert Scandinavian lakes into pumped storage power plants would massively intervene with the existing naturally grown water ecosystems instead of building Ringwallspeicher, which hardly interfere with considerable ecosystems. Electrical transmission losses on the way there and back also have to be taken into consideration.

<u>Other storage technologies</u>
The application of storage devices with high efficiency reduces the demand of production plants. Using alternative storage technologies with a lower efficiency (such as hydrogen or methane systems) a lot more wind and solar plants would have to be installed in order to balance the losses.

<u>Biomass energy</u>
The suggested system would be environmental friendly because it disclaims on the growth of biomass and the involved enormous land requirements. Now (2010) Germany would be able to return half of its land used to grow mono cultures (approx. 6500 square kilometres (2510 square miles)) which are used to produce electricity back to the nature, if the suggested system was used. Those areas could become spacious cross linked areas of unspoiled nature in the middle of the highly industrialised country. The demand for land of large Ringwallspeicher including the land of wind power plants and the necessary land to install them would be a lot less than the land currently (2010) used to grow biomass for electricity production.
Whereas the enormous demand of land to produce electricity from biomass is only a fraction of our energy production, the suggested system using Ringwallspeicher-hybrid power stations could sustainably supply the whole country with electricity only using a sixth up to a half (depending on the design) of the land currently used for biomass.

<u>Brown coal</u>
The land required for a single Ringwallspeicher is not more than the area used by large brown coal surface mining.
If the system using Ringwallspeicher-hybrid power stations was already established and someone would suggest to start mining brown-coal for the next 40 years in order to produce electricity where an area of 85 square kilometres (33 square miles) would be digged over up to 400 meters (1312 feet) deep, everyone would call it utopistic and declare this person crazy.
However, such brown-coal surface mining areas are real and people might find the earth movements for such a Ringwallspeicher, which are less than the ones for brown-coal mining, futuristic at first sight.
If we succeed in building one of those systems, then it will be accepted in the same way as the coal industry during the last 200 years.

Summary

Disclaiming

- *on land used for growing biomass*
- *in favour of Ringwallspeicher-hybrid power stations*

Opens free spaces for

- spacious cross linked areas of unspoiled nature.

Prof. Dr. Carsten Ahrens of the Jade University Oldenburg characterized the Ringwallspeicher at the Ingeniera 2010 in Buenos Aires as “technical building and tourism paradise”.
A clever configuration of Ringwallspeicher brings additional recreational value into the region. They will probably prove to become touristic magnets.
The implementation of the suggested concepts for a sustainable, meeting the demand and secure renewable power supply is more of a society decision-making than a technical or economical challenge.

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Matthias Popp: Speicherbedarf bei einer Stromversorgung mit erneuerbaren Energien, Springer-Verlag Berlin Heidelberg 2010, ISBN: 978-3-642-01926-5