Ringwallspeicher

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Ladies and Gentlemen,
let me introduce myself and give you some information about my office.

Dr.-Ing. Matthias Popp

- born 1958
- Wunsiedel in Fichtelgebirge, Bavaria
- 1983 founding of Engineering office Popp during study
- 1983 diploma in mechanical engineering at Fachhochschule Coburg
- Engineering Office Popp, software development for automotive industry
- 1989 diploma in mechanical engineering at Technical University Munich
- Member of city council (CSU) and from 2002 to 2008 honorary deputy mayor of his home- and festival town Wunsiedel in Fichtelgebirge as well as member of supervisory board of the regional energy provider SWW Wunsiedel GmbH

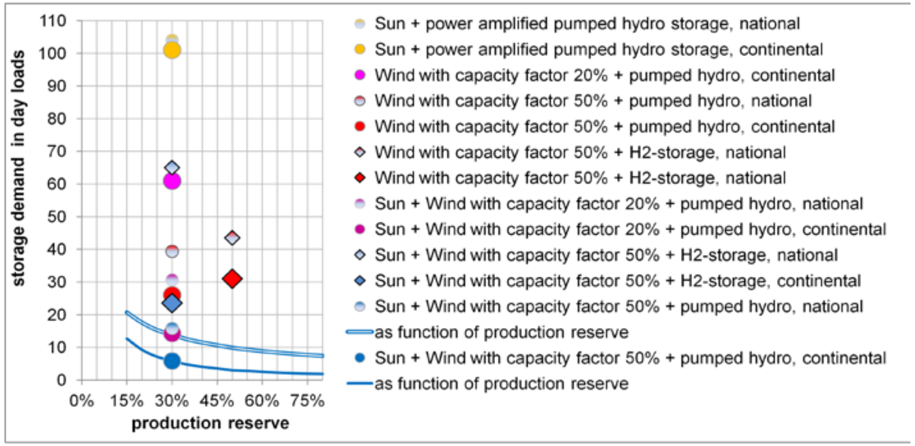
  Thereby intensive involvement with questions of energy supply

  The proposal for a pumped hydro power station in the Fichtelgebirge was leading to the research of answers to the question:

  How can energy storage plants deliver a contribution to a sustainable regenerative power supply?
- 2010 doctor-engineer at Technical University of Braunschweig
- 2011 finalist at the RWE Future Award 2011
- MATTHIAS POPP Engineering office — Renewable Energies, Energy Storage Simulations, Software-Development

Last year I made a doctorate with the title:
„Storage demand for a power supply with renewable energies".
This doctoral thesis is published as book by Springer in German language.

How large has to be the „battery“?



Assumptions: pumped hydro storage efficiency 80%, H2-storage efficiency 40%, no self discharging, continental power transmission efficiency 95%

A wide range of analysed results are shown in this diagram.

Every entry in this figure shows a solution for a regenerative electric power supply system, that meets the demand.

The required storage capacity varies form more than 100 day loads in pure solar power scenarios, downwards to some day loads in scenarios with an optimized mix of wind and sun and highly efficient storage systems.

The better the tuning between wind and sun and the cooperation of countries across borders and the higher the chosen production reserve and the higher the storage efficiency, the lower the required storage capacity will be and vice versa.

For example, at 30% production reserve, a storage capacity minimizing combination of sun and wind with a high capacity factor would require about 14 day loads of storage capacity in a national solo run and about 6 day loads in a European cooperation.

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More detailed:

A range of analysed results are shown in this diagram.

Pure solar energy would require the largest storage systems. A powerful continental transmission grid could barely reduce it.

Wind energy with capacity factor 20% would work in combination with normal pumped hydro systems only in a powerful cooperation across countries with a storage demand of about 60 days.

Wind energy with capacity factor 50% would require about 26 day loads with clearly less storage capacity and would also allow a secure power supply in a national solo run with about 40 day loads.

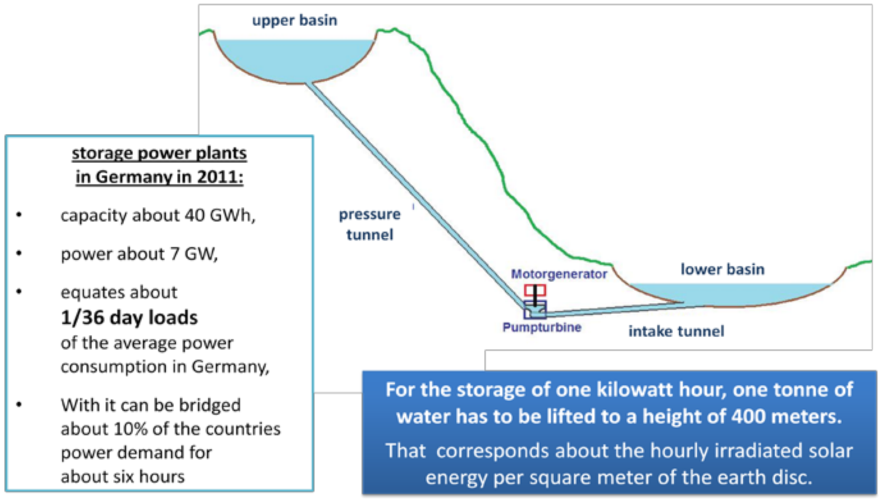
A storage capacity minimizing combination of sun and wind with capacity factor 20% would need about 30 day loads in a national solo run and about 14 day loads in a European cooperation.

A storage capacity minimizing combination of sun and wind with a high capacity factor of 50% would require about 14 day loads of storage capacity in a national solo run and about 6 day loads in a European cooperation.

Storage systems with a lower 40% efficiency would require, with 50% production reserve, about 43 day loads in a national solo run and 31 day loads in a European cooperation, when using wind energy with capacity factor 50%.

With an optimized production, a power supply, meeting the demand can still function in a national solo run with about 65 day loads at this low degree of 40% storage efficiency.

Pumped Hydro Storage



The available pumped hydro storage capacity of Germany correlates to about the 36-th part of a day load of the average power demand.
To store one kilowatt hour of energy, which comes for a price of about 20 Cent for a private household, a tonne of water has to be lifted to a height of 400 meters in a pumped hydro storage system.
For a regenerative power supply of Germany, based on wind and sun and without fallback to fossil or nuclear energy carriers, that would mean, ...

Required Storage Capacity

Storage demand in an isolated national initiative of Germany:
in an optimized production structure with electric power, alone from wind and sun, with 30% production reserve

capacity about 20 TWh, power about 90 GW
corresponds to about **14 day loads** of the average consumption,
requires about **500 times the existing storage capacity**

Storage demand of Germany in an European cooperation:
in an optimized production structure with electric power, alone from wind and sun, with 30% production reserve

capacity about 9 TWh, power about 90 GW
corresponds to about **6 day loads** of the average consumption,
requires about **200 times the existing storage capacity,**
efficient upgrading of the European power grid and a complete upgrade of wind- and solar energy in all countries of Europe

... , that in a national solo run, the actually available storage capacity would be required about 500 times as large.

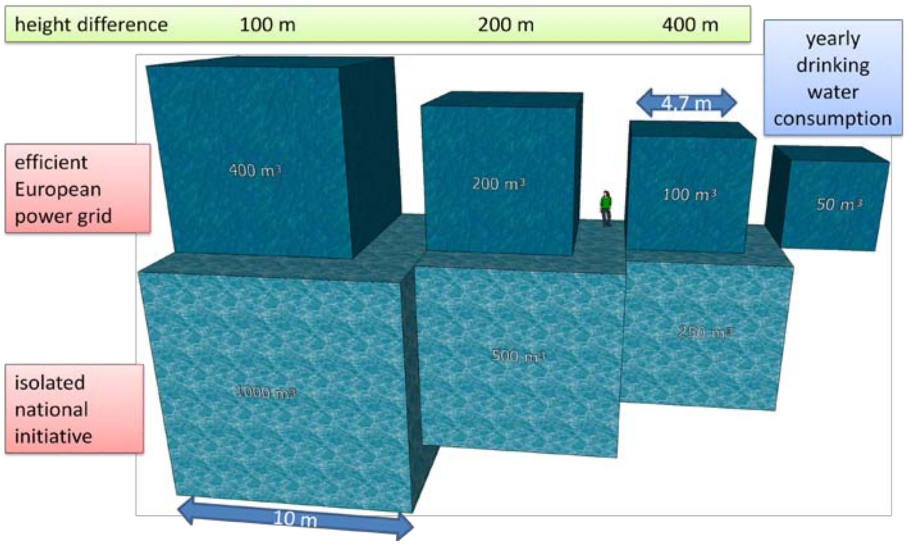
In an optimized European cooperation, which unfortunately can‘t be expected today, the required storage capacity would still reach about 200 times of the existing capacity.

Water Demand for Energy Storage

- About **80 million inhabitants require** in Germany, inclusive the total economy, an average electric power supply of about **60 GW**.
- In average, that makes **per person** about **750 Watt** of electric power consumption.
- For a secure and every time meeting the demand, 100% regenerative power supply, a **minimum storage capacity between 6 and 14 day loads** would be required, depending on the production structure and cross country cooperation.
- That makes an average **storage capacity between 100 and 250 kWh per person**.
- If **water storage systems** with a **height difference of 400 meters** would be available, that would require an **exchange volume between 100 und 250 cubic meters**.
  That would be a cube of water with an edge length between 4.7 and 6.3 meters.
- At a **height difference of 200 meters**, the required amount of water would double to **200 to 500 cubic meters** or cubes with an edge lengths between 5.9 and 8 meters.
- At a **height difference of 100 meters**, the required volume of water would fourfold to **400 to 1000 cubic meters**. The edge length would be between 7.4 and 10 meters.
- In Comparison to these volumes, the average **consumption of drinking water** in Germany is **about 50 cubic meters**.

The thereby required water volumes of pumped hydro systems per person of the German population are shown on the following sheet in a true scale.

Water Demand for Energy Storage per Person



The required storage capacity per person would be between 100 and 250 kilowatt hours, depending on the reachable cross country balancing effects.

Depending on the reachable average height differences of the water surfaces of the pumped hydro storage systems, the necessary exchange volume per person would be between 100 m³ and 1000 m³.

Land Requirement for Energy Storage

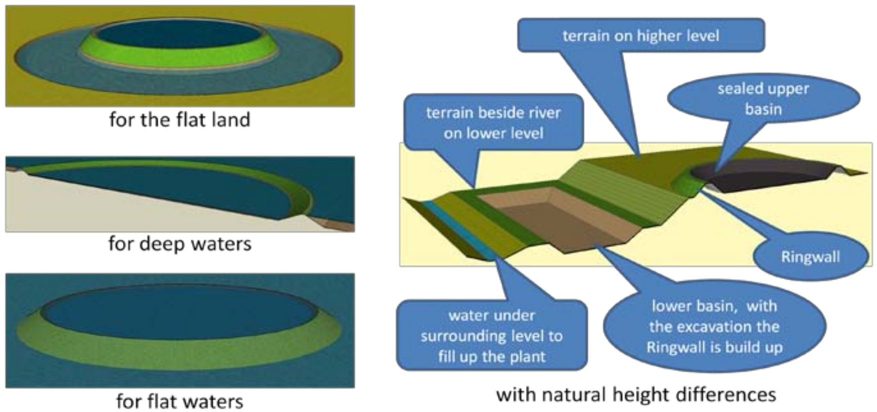
- The exchange volume of a pumped hydro storage plant must fit into the upper basin when charged and into the lower basin when discharged. The storage volume has to be provided two times.
- On a given land area, the larger the water gauge deviation between the charged and the discharged position is, the more volume can be stored.
- **100 - 250 cubic meters water volume requires at a gauge deviation**
  - of **1 meter** a water surface of **100 - 250 square meters**,
  - of 5 **meter** a water surface of **20 - 50 square meters**,
  - of 20 **meter** a water surface of **5 - 25 square meters**,
  - of 50 **meter** a water surface of **2 - 5 square meters**.
- In an optimistic case of cross county cooperation and 400 m average height difference and 50 meters gauge deviation, in the upper and lower basins of pumped hydro systems, the required water surface per person would be 4 m² (2 m x 2 m), to cover a storage capacity of 100 kWh. Together, that would be 320 km² or less than one per mill (0.09 %) of the countries area of Germany.
- In a less optimistic case of a national solo run and storage systems with a height difference of 100 m and a gauge deviation of 20 m, the required water surface area would be 100 m² (10 m x 10 m) per person at a capacity demand of 250 kWh. That would cover a land space of about **8000 km²** or nearly 2.3% of the country.

If pumped hydro systems shall be established in a more land saving way, than it depends on a gauge deviation as large as possible in the upper and in the lower basin, besides a maximum height difference between the two basins.

Taking all these thoughts in account, leads to the proposal of the Ringwallspeicher.

Ringwallspeicher

as geotechnical option to create large storage capacities



doubling geometric dimensions 16-folds the storage capacity

With a Ringwallspeicher, large storage capacities with a high degree of efficiency can be built also in areas, where classic pumped hydro systems wouldn‘t be considered, because large height differences can be established and natural existing height differences can be increased.

Also the water gauge deviations offer a wide scope in designing.

Bucket-wheels would excavate the lower basin to build the dam for the upper basin, which will be sealed on the inside.

The plant would be operated like a pumped hydro storage system.

The geometry of these storage plants would lead to a rapid growth of capacity with increasing dimensions.

The chief editor of the magazine „Bild der Wissenschaft“ liked this suggestion, ...

Ringwallspeicher Hybrid Power Plant

Alternative to two nuclear power stations with 2 GW average and 3.2 GW maximum power

„Ringwallspeicher as technical building and tourism paradise“
citation of Prof. Dr. Carsten Ahrens from the Jade Hochschule in Oldenburg,
he introduced the Ringwallspeicher at the 19th October 2010 on the Ingeniera 2010 in Buenos Aires.

..., therefore he ordered this illustration of a Ringwallspeicher from a graphic designer.
This is a very big and idealized model, which would probably not be built in this way. It shows principles and possibilities of the concept.
The illustrated plant would have an outer diameter of 11.4 kilometres (7.08 miles), a wall diameter of about 6 kilometres 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 difference between the two water surfaces would be 200 meters (656 feet).
The storage capacity would be about 700 GWh.
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 not demanded electricity, water is pumped into the upper basin, which will flow through turbines back down if there is an electricity deficiency.
Of course, this would also work with a larger number of Ringwallspeichers, which would have smaller dimensions, decentralized distributed over the country.
Especially, the lower basin should be usable for water sports activities, because the system is designed for long time balancing and therefore, the whole capacity will only rarely be used.
Mostly, the upper basin would be well filled and the lower basin would be on a low level.

Example Edersee

Center of a lovely holiday region, built by Kaiser Wilhelm about 100 years ago

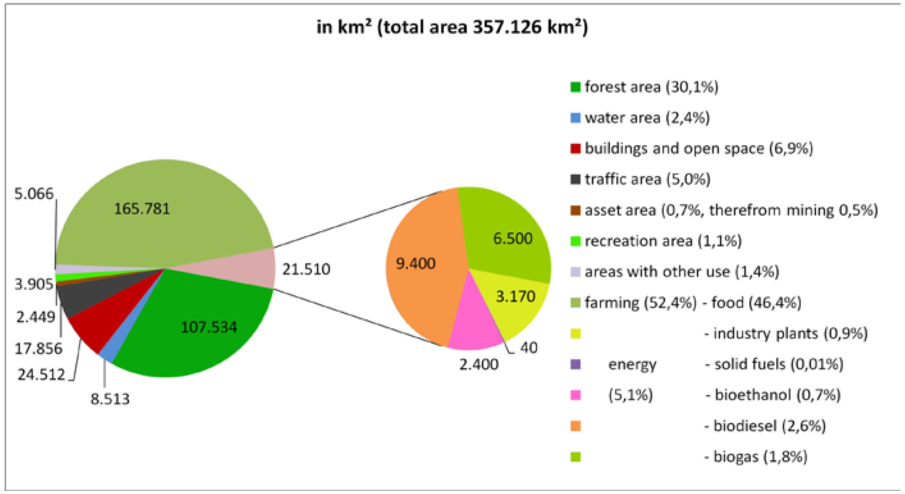
Such kinds of waters exist.
The largest dam lake of Germany is the Edersee.
In one season, during summer, the water level sometimes sinks down to 30 meters.

In heavy rain periods, the water surface rises up again.

When I made these photos in 2008, the lowering was about 20 meters.
On this day, the water surface was lowered again for more than one meter.

Also with these gauge movements, a lot of leisure and water sports activity take place.

Land Use in Germany



The idealized shown Ringwallspeicher would totally cover a land area of about 100 km², together with all wind and sun power plants.

30 of these hybrid power stations would have an average production power of 60 GW.

The required total land area would be about 3000 km².

They would have the ability to assure the complete electric power supply of Germany, meeting the demand, alone from wind and sun.

That would be less than 1 % of the countries area and less than half of the area of 6500 km², which is already used today, to cultivate biomass for electric power production with biogas plants.

Comparison Ringwallspeicher / Biomass

About half of the land area, used today for the production of biogas would be enough,

to guarantee the electric power supply for the total county with Ringwallspeicher hybrid power stations in a regenerative, sustainable and secure way.

Biogas power plants delivered about 3 % of Germanys electric power demand in the year 2010.

With Ringwallspeicher hybrid power plants, about 50 times more electricity can be produced on a given land area, than with biomass producing.
Given an area of 100 km², a Ringwallspeicher hybrid system could produce an average power of about 2000 MW, a biomass electricity production could produce about 40 MW.

The Chance

The abdication
- **of energetic used agricultural areas**
- **for the benefit of Ringwallspeicher hybrid power stations**

reopens free space for
- **large-scale cross-linked natural landscapes.**

Swimming islands
- **make it possible to secure water quality and to**
- **ecological enhance the originating water surfaces.**

Rethinking this way of land use could create free spaces for areas close to nature.

Comparison Ringwallspeicher / Brown Coal

Landscape impacts of larger degree, than needed for Ringwallspeicher are reality in Germany.

Brown coal mining areas are the only structures, where much more earth is moved, than needed for the construction of large Ringwallspeicher systems.

The competence of the operators of daylight mining areas about the movement of large earth masses, could be of interest for a cost-effective construction of these storage devices.

Storage systems will be needed, when fossil raw materials run low or become more expansive and renewable energies shall overtake the electrical power supply.

Comparison Ringwallspeicher / Brown Coal

Brown coal daylight mine Hambach

- example link: http://de.wikipedia.org/wiki/Tagebau_Hambach
- dimension: about 85 km²
- depth: up to 400 m
- operating time: about 45 more years
- electrical power: about 4 GW
- the elevated dump “Sophienhöhe” overtops the landscape about 200 meters
- the baring volume will reach more than 10 km³

These moved earth masses alone relate to the required earth volume of
seven Ringwallspeicher hybrid power stations with

- 215 m wall height,
- 14 GW average and
- 22.4 GW maximum power.

The largest German daylight mine Hambach will reach a dimension, comparable to the water surface of the illustrated Ringwallspeicher.

The ground water level is deepened down to about 500 meters on a large scale.

The created hybrid power systems could provide much more electrical power, than this daylight mine.

Comparison Ringwallspeicher / daylight mine

Circular **Ringwallspeicher systems**
are an ideal concept, which will hardly be realized in this way.

In praxis, the dimensions of the plant and the run of the waterline will orientate on the possibilities and conditions of the landscape.

In opposite to **daylight mining projects**, populated areas and sensible zones can be recessed and integrated in the sustainable renewable energy system.

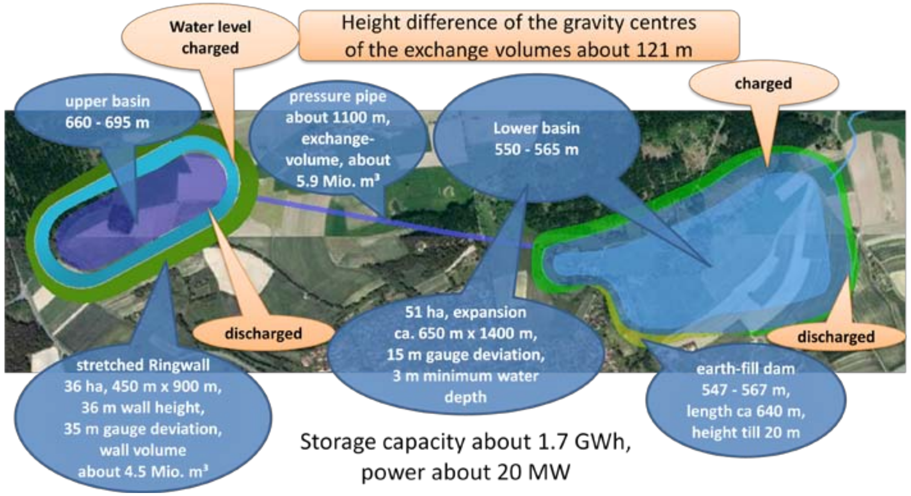
Ringwallspeicher will most likely not adopt this idealized, circular form, as shown in the illustration.

Sensible areas and urban areas can be recessed and integrated attractively in the created new landscape.

By using natural height differences, they can also be constructed in a smaller scale by a comparable economy.

Small Ringwallspeicher using natural Height Differences

to solve volatility problems of a supply area with about 15 000 inhabitants using a 100 % regenerative electric power supply



An example how such a storage system can be embedded in a hilly landscape for a small power supply area is shown here.

Flooding protection, recreational lake and sustainable supply with renewable energy could be combined.

Conclusion

A secure, robust and meeting the demand,
100% regenerative power supply requires today:

• one wind power station for about 1300 people,

• about 20 m² solar module area per person,

• about 40 m² water area per person
for power storage plants with high efficiency,
decentralized, distributed well over the country.

That requires in Germany about 1% of the countries area.

Compared to this, a 100% electrical power supply with biomass would require about 2200 m² per person or nearly half of the countries area.

Today, a secure and 100% regenerative power supply which meets the demand is a real option for the future.
There are a lot of different possibilities, to realize it.
It is less of a technical or financial challenge, than much more the question of winning acceptance in the society.
Also the establishment of appropriate public law and economical framework should be created to actuate the required investments.

Thank you for your Interest

If renewable energy production shall not stay a great dream and an expansive escapade of the German energy policy
-
than all regions, wanting a renewable, meeting the demand, power supply
-
should welcome the required production, storage and transmission systems.

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Simulations, Software-Development

You are welcome to contact me
to find out a suitable energy mix
for your preferred storage solutions and
for a holistic approach to lay out your
energy system.

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