Drivers for storage needs, current and future technologies and potentials

International seminar on large scale balancing from Norwegian hydropower

Sand, Norway - September 12/13th, 2012

EnBW AG , Holding, Head of Conv. Generation & Hydro Power, Dr. Bernd Calaminus

EnBW

Energie
braucht Impulse

Brief Portrait

EnBW Energie Baden-Württemberg AG

- Third-largest energy company in Germany
- Business segments: electricity generation and trading, electricity grid and sales, gas, energy and environmental services
- Annual revenue 2011: ~ € 18.8 billion
- Costumers: ~ 6 million
- Employees: ~ 20,000
- Headquarter in Karlsruhe

EnBW group		31/12/2011
Nuclear	MW	3,333
Conventional power stations	MW	6,986
Storage plants / PSP with nat. inflow PSP without nat. inflow	MW	1,299 545
Run of River Plants	MW	926
Other renewable energies	MW	313
Total	**MW**	**13,402**

To Start with a Fundamental, Robust Question:
Prerequisite (not only) for a Strongly Industrialised Economy

(NO In Situ Experiment!)

- Transport / distribution
- Domestic or import

- Resource dependency
- Mix of supplies
- Grid stability

- Efficient demand, but still at high level
- Squeeze-out of electricity- intensive industries does not help

Where do I reliably get the needed electric power from at any moment at competititve conditions?

- Wheather-driven?
- Limited elasticity of demand (DMS)

- Regional
- EU
- World markets

- **Reliable Power (quantity and quality) is needed, not only random yearly production (..TWh)**

Some German Electricity System Flashlights

Still a Strongly Industrialised Country, *Little Virtual Bear Sale*

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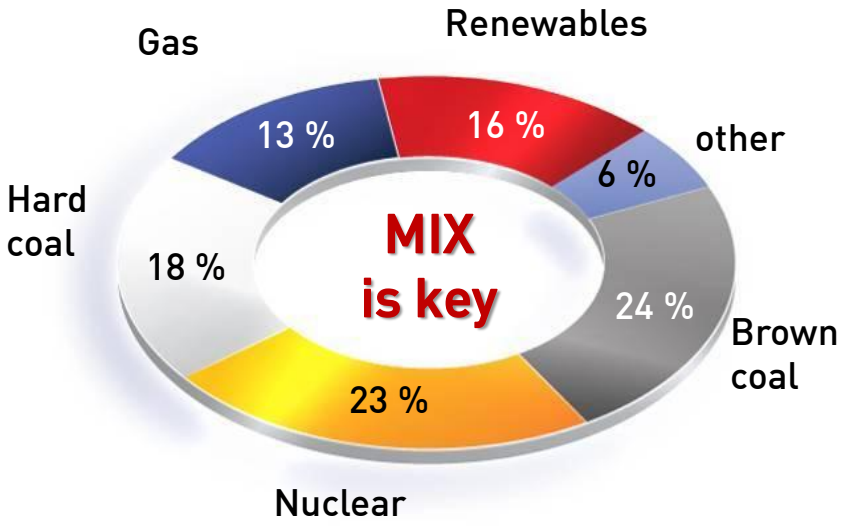
Generation (electr., gros, 2009)
(597.1 Mrd. kWh)

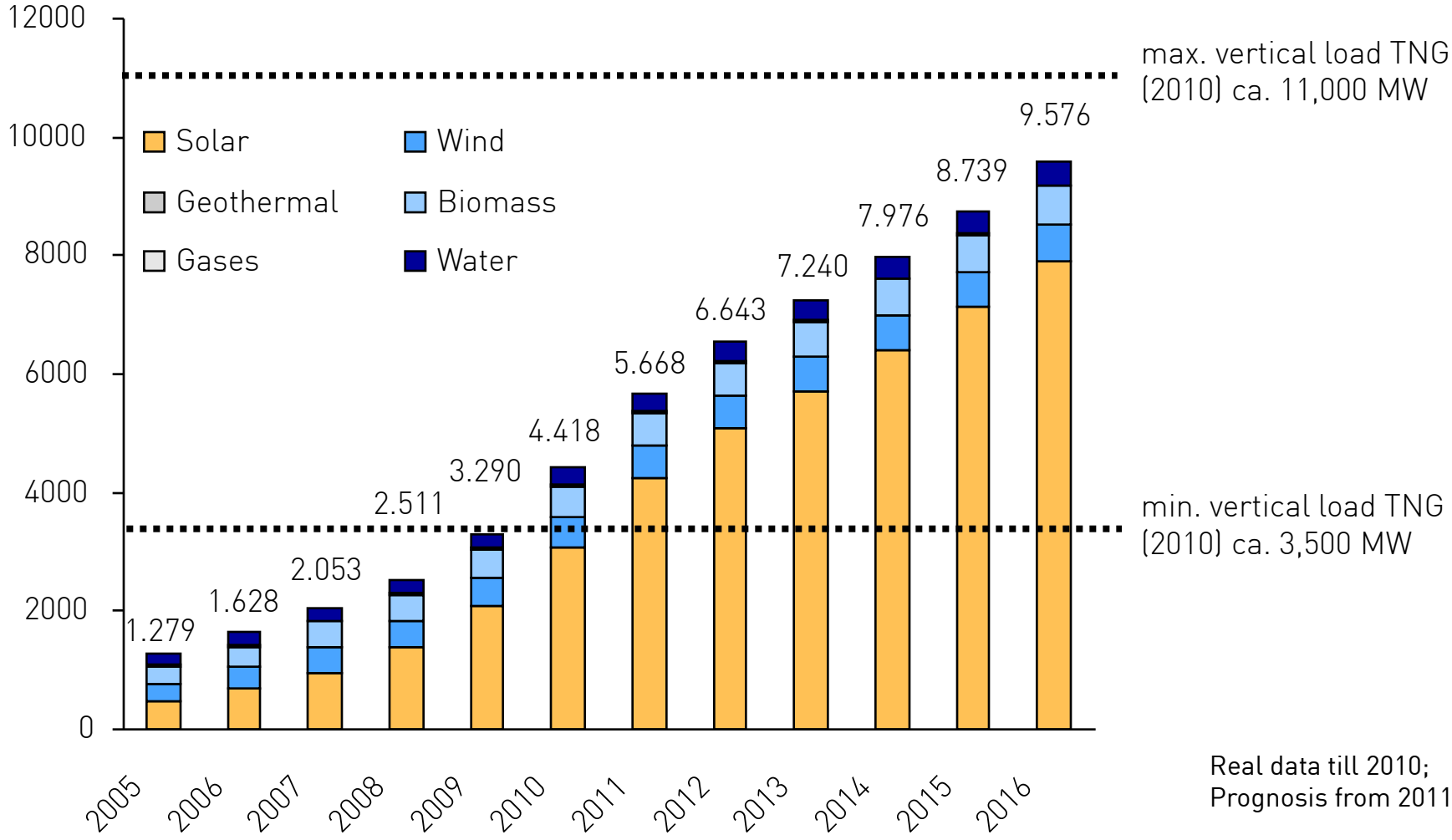


- Reliable, secure and competitive supply (16' average downtime/a)
- Net exporter
- Nuke phase out (last in 2034)

- Nuke phase out (last in 2022); 7+1 units shut down (mainly South)
- Reliable, secure and competitive supply as a SINE QUA NON!
- Net importer? Secured power ext.?
- RES boost: share of generation
  35% in 2020
  50% in 2030
  80% in 2050 (minimum)
- New „centralisation"? Wind in North, Solar in South...; grid is behind schedule!
- More regulation, less market?
- Future business models? „Capacity"
- Real cost, NIMBY („S21")...

Installed RES Power in EnBW TransNet BW

Balancing Zone between 2005 and 2016

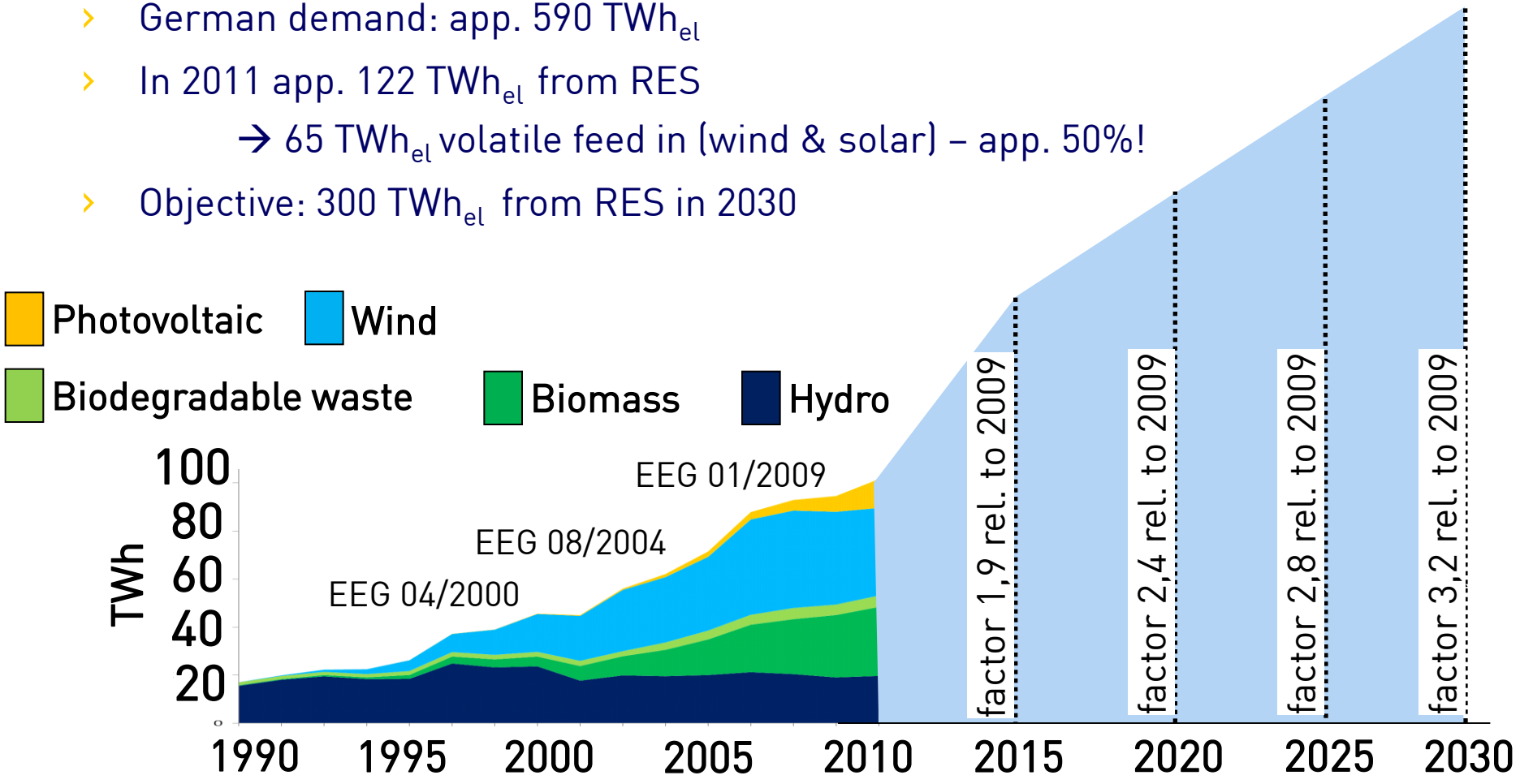


Real data till 2010;
Prognosis from 2011

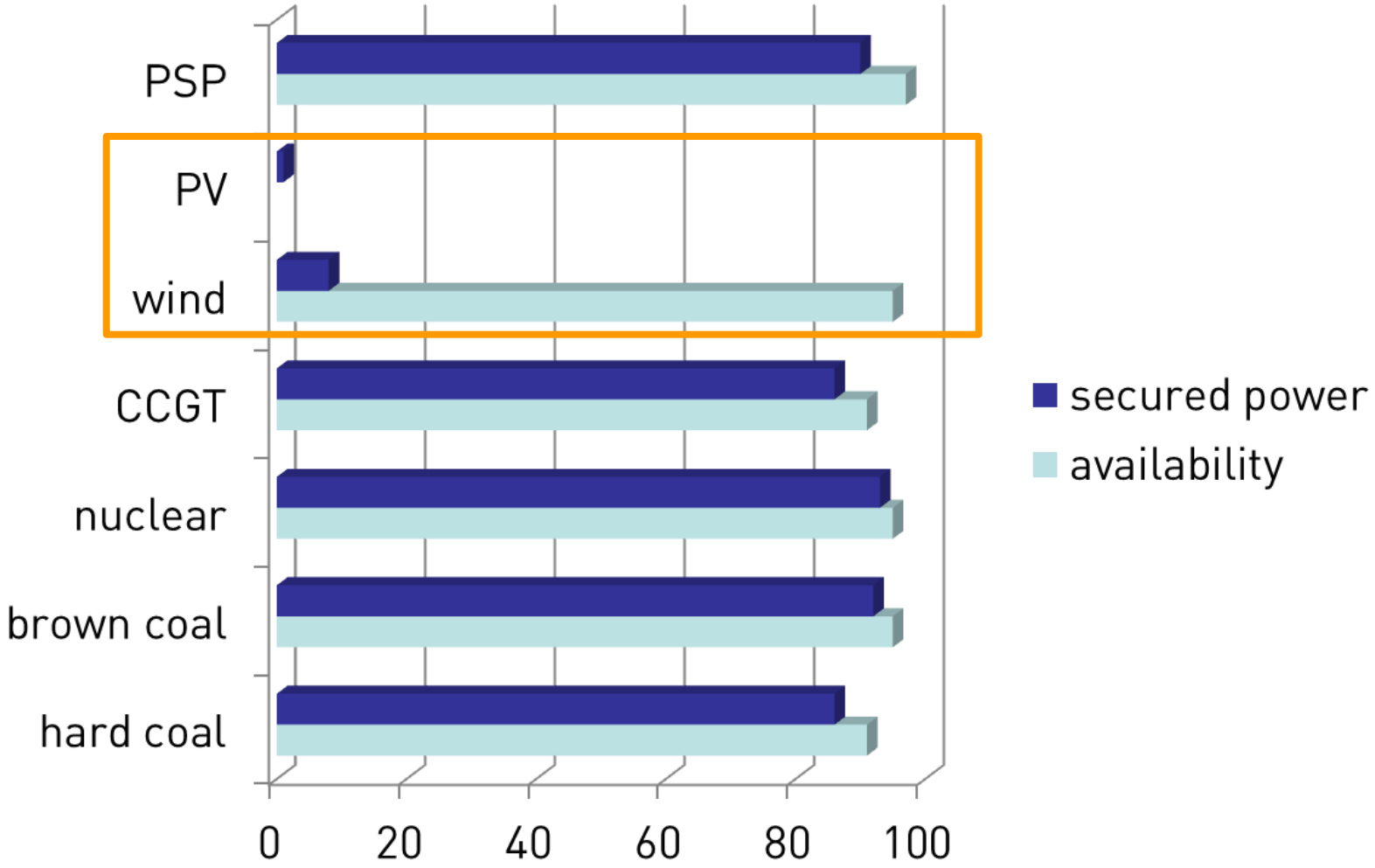
Source: EnBW TransNetBW

“Energiewende” in Germany with Ambitious Objectives

- German demand: app. 590 TWh_{el}
- In 2011 app. 122 TWh_{el} from RES
  → 65 TWh_{el} volatile feed in (wind & solar) – app. 50%!
- Objective: 300 TWh_{el} from RES in 2030



„Installed Capacity“ is one Aspect ⇨ Contribution to Secured Power Supply at Any Moment is the Other

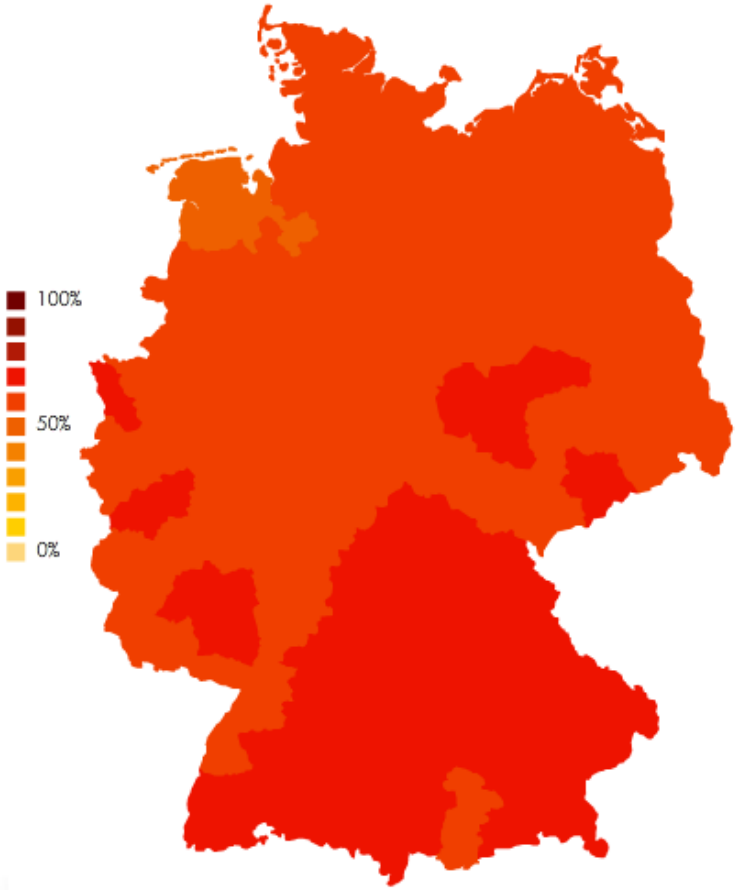


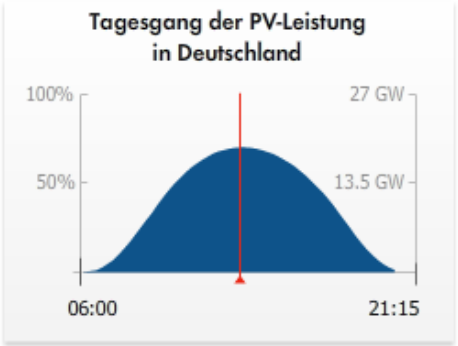
PV in Germany

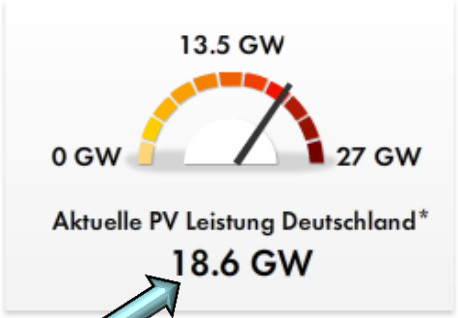
As of 08/2012: about 28 GW (+7,5 GW in 2011!) / ca. 1,000 Full-load hours / Invest based on „EEG“ feed-in tarifs / hardly dispatchable / high share in regions with comparatively weak grids

Relative Leistung vom 18.08.2012 - 13:15 Uhr

50 to 70 GW by 2020?!







*Hochgerechnete Leistung aller lt. Bundesnetzagentur am Stichtag 30.04.2012 installierten PV-Anlagen mit insgesamt 26.99 GW Nennleistung.

Was leistet PV in Deutschland?

Eine spannende Frage, die Ihnen hier anschaulich und tagesaktuell beantwortet wird. So können Sie hier zu jedem Zeitpunkt die Summe der aktuellen Leistung aller in Deutschland bis zum angegebenen Stichtag installierten PV-Anlagen einsehen.

Durch die zusätzliche Auflösung der Daten nach dem jeweiligen Postleitzahlengebiet haben Sie zudem erstmalig die Möglichkeit, auch einzelne Regionen zu betrachten. Hier wird die regionale relative Leistung sichtbar, also die aktuelle Abgabeleistung im Verhältnis zur installierten Nennleistung der PV-Anlagen in der jeweiligen Region.

Die animierten Grafiken machen deutlich, welchen Beitrag die PV zur Stromerzeugung in Deutschland bereits heute leistet und zeigt, dass Photovoltaikanlagen zu einer Reduzierung der teuren Spitzenleistung zur Mittagszeit beitragen.

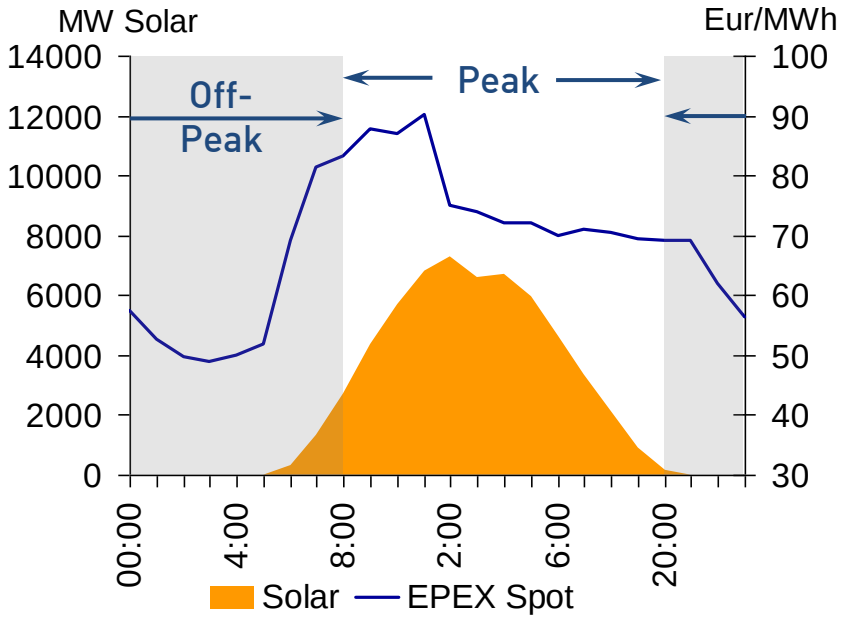
Modellansatz zur Datenberechnung

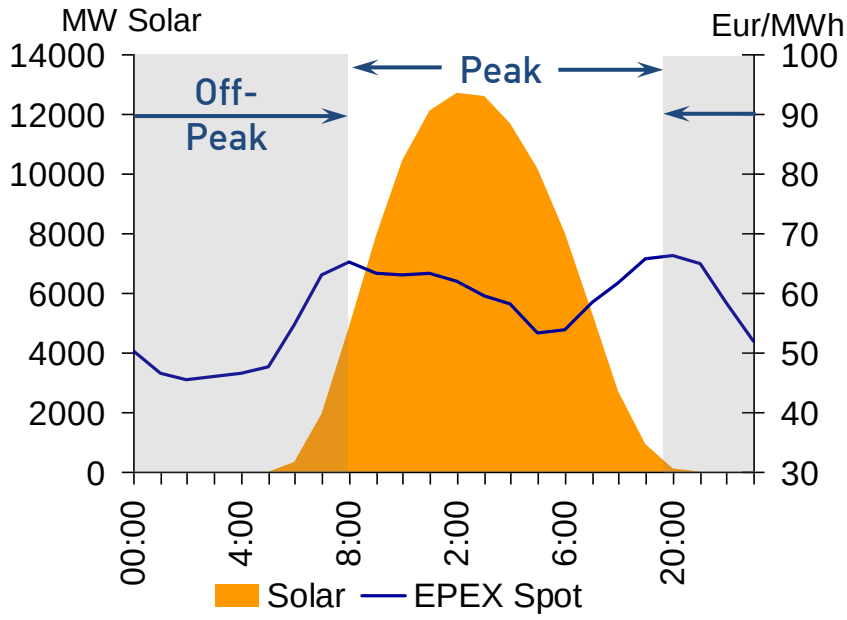
Zum Vergleich: Der Netto-Stromverbrauch in ganz Deutschland entspricht einer Durchschnittsleistung von rund 60GW (Quelle: AG Energiebilanzen)

SMA web site

Peak/Off-Peak Spread Damped by PV

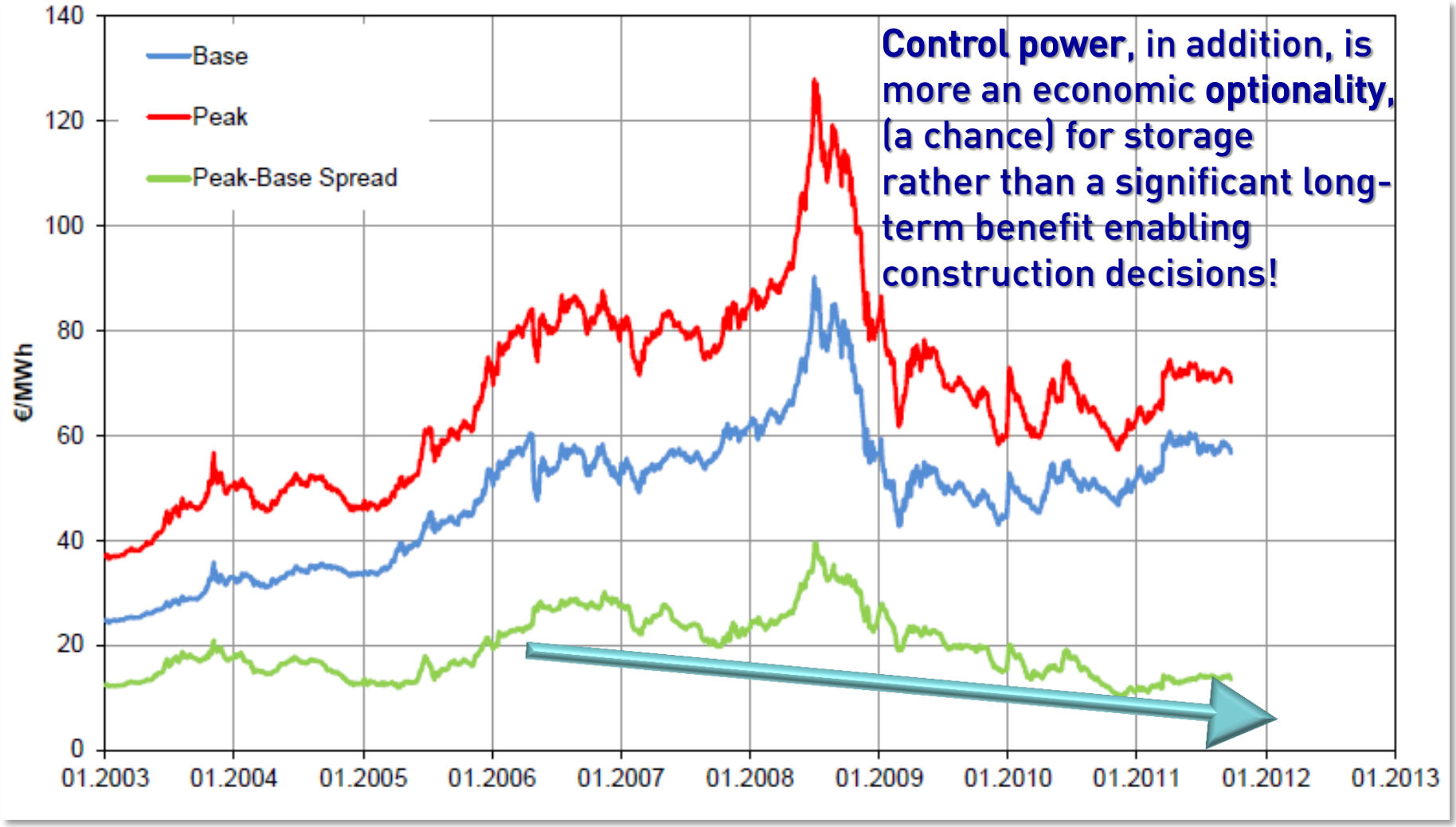
Peak Cut-off, Affecting Margins of Short-term Storage





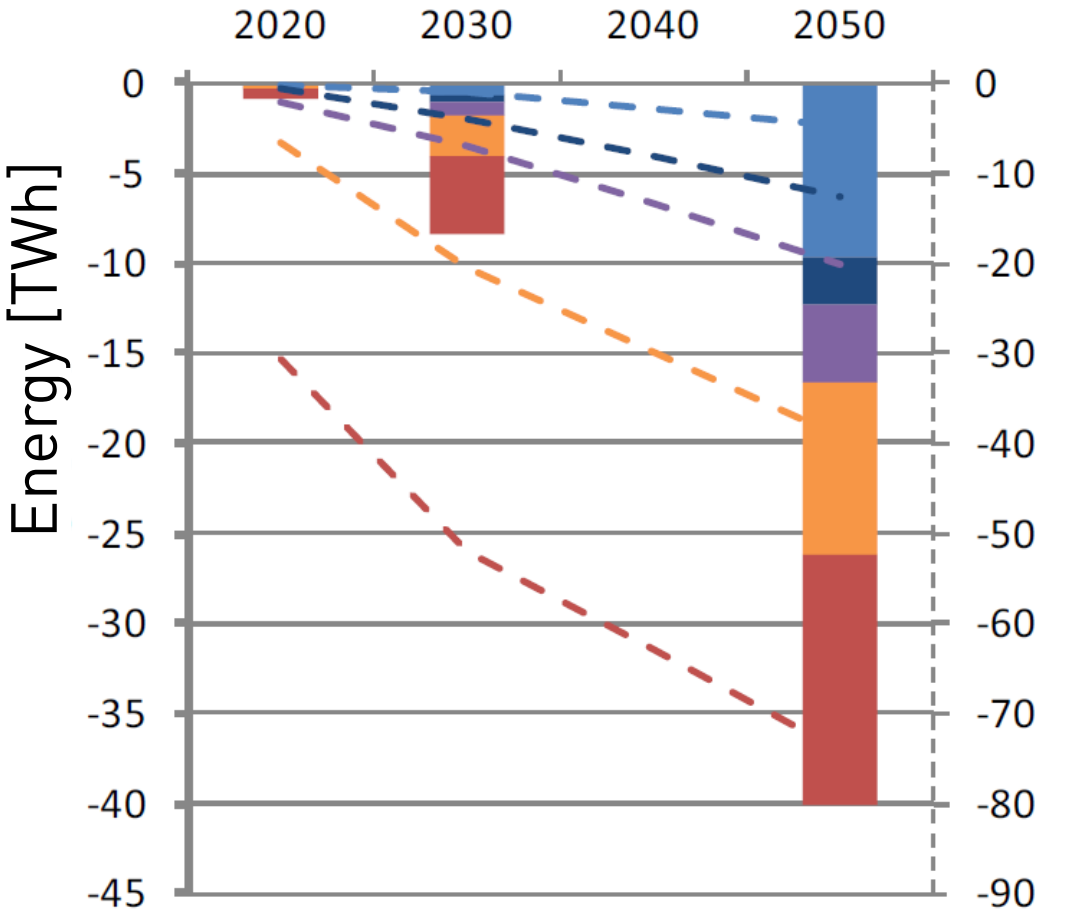
Price-Spreads as the Relevant Parameter for Storage

Futures Markets: Volatile and Decreasing Spreads



Source: EEX; Graph: Öko-Inst.

Attempts to Quantify Time Patterns for Needs of Balancing Power



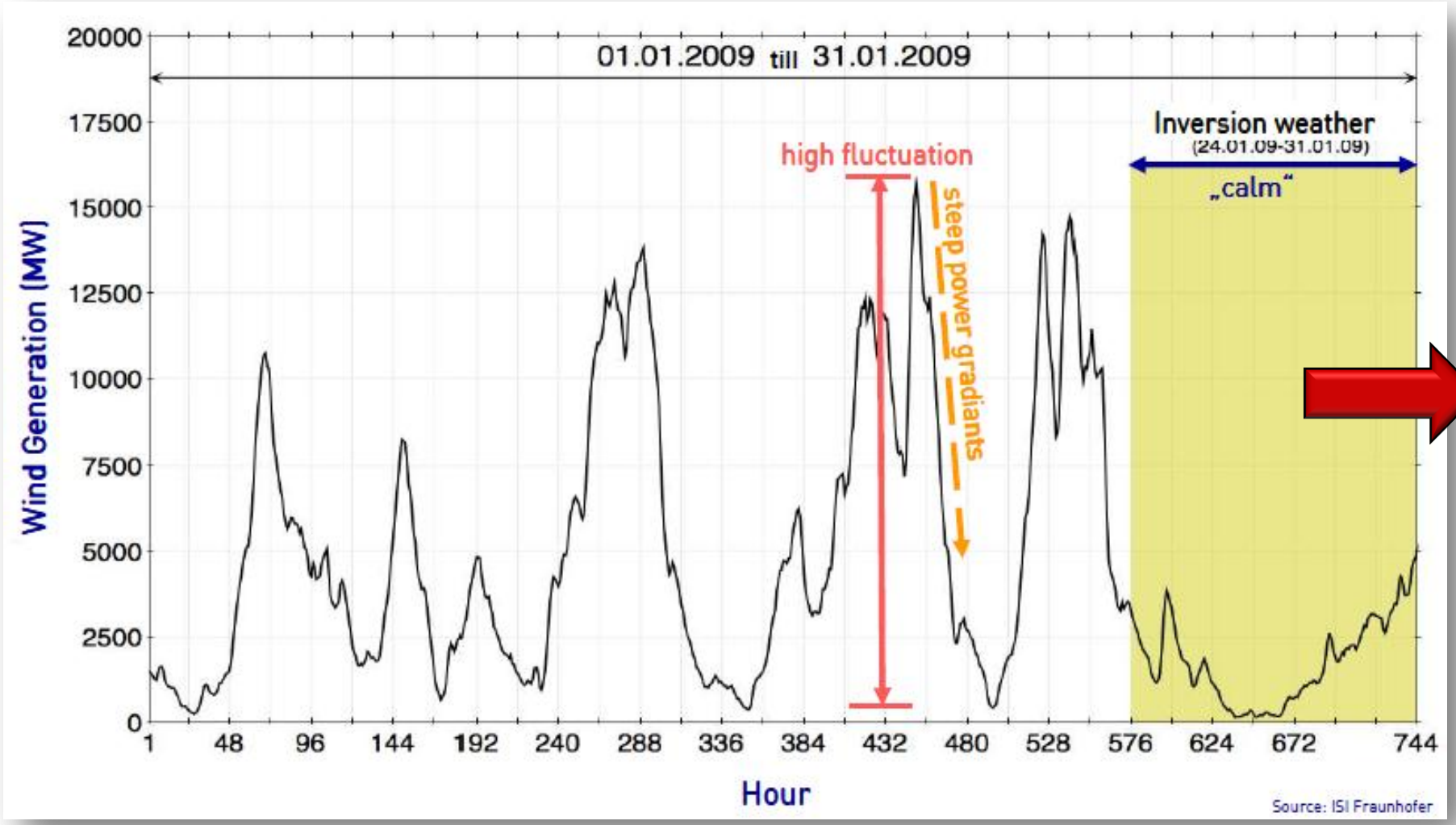
HOCHSCHULE REGENSBURG UNIVERSITY OF APPLIED SCIENCES

Fraunhofer IWES

source: Nitsch et al. 2010, Prof. Dr. M. Sterner
http://www.efzn.de/uploads/media/008_Prof._Michael_Sterner.pdf

notable excess of electricity starting from 50% RES feed-in is expected

Dynamic, Residual, Dispatchable Power & Energy Needed with Increasing RES



Multiple Day Storage: To Fill Calm-Periods by "Stored" RES, Need Exceeds Capacity by Orders of Magnitude

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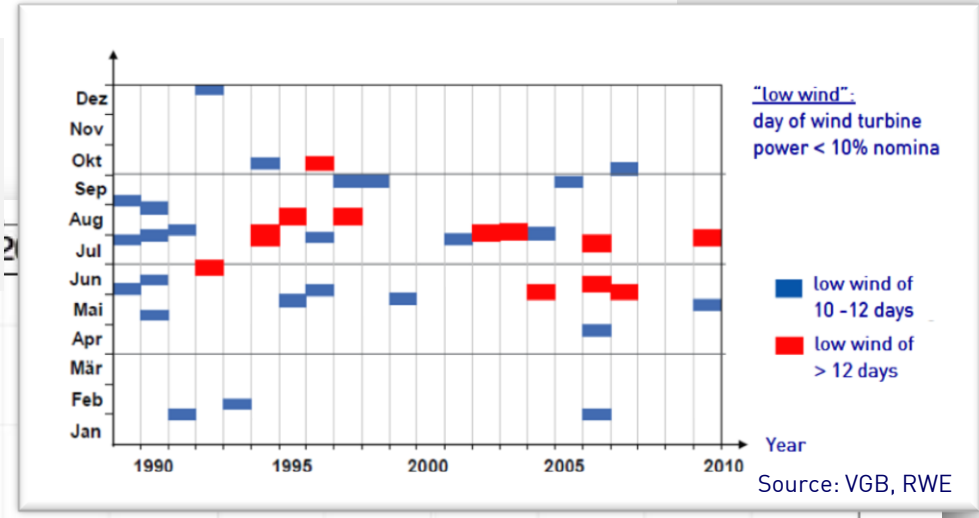
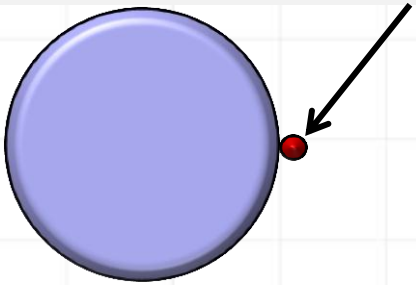
Rough estimate (order of magnitude):

600 [TWh/a] : 365 [d/a] = 1,64 [TWh/d]
1,64 [TWh/d] x 14 [d] = 23 [TWh]
23 [TWh] : 0,04 [TWh] = 575 = factor vs today. in D:

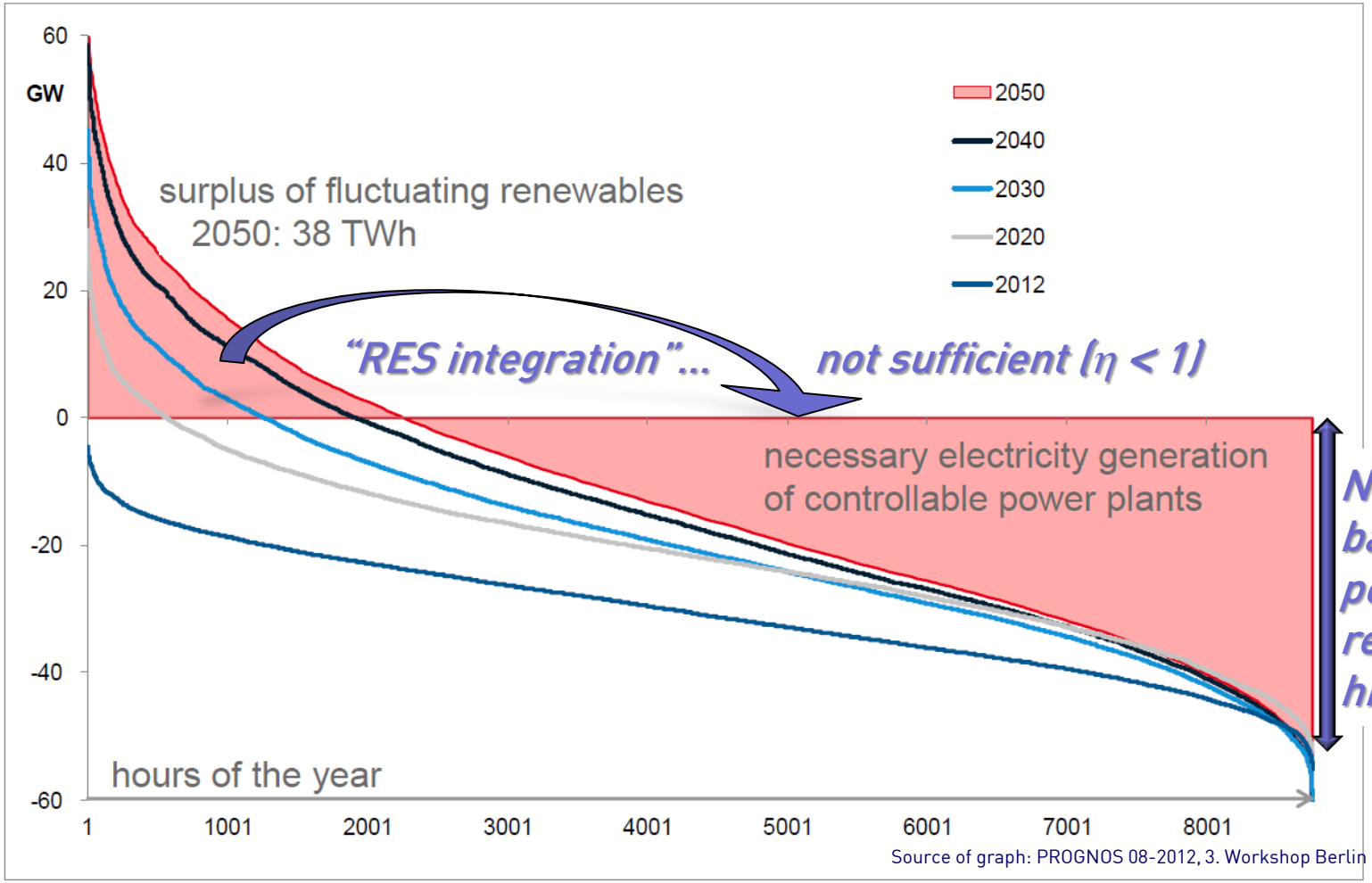




Dynamic Mismatch of RES Surplus and Demand

Sorted Hours over the Year

The total surplus of electricity in Germany will rise from 4 TWh in 2020 to 38 TWh in 2050



Source of graph: PROGNOS 08-2012, 3. Workshop Berlin

As Long as Backbone Exists and RES May be Redispatched, the Hard Need for Storage is Limited ("System Boundary")

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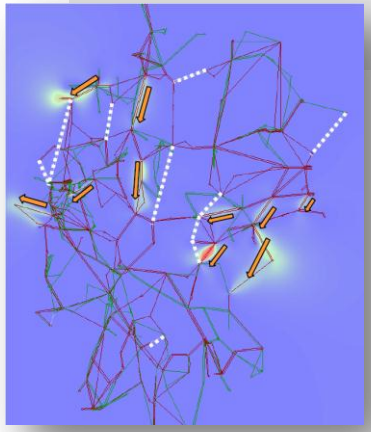


Dynamic, volatile RES supply

Balance out mismatch at any second: FLEXIBILITY

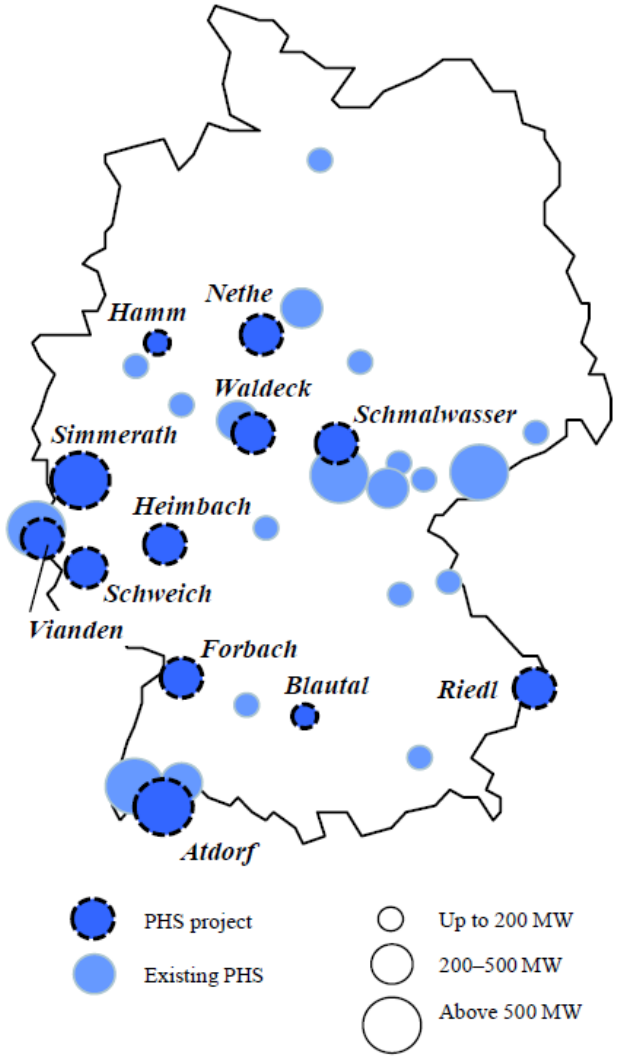
- Storage
- Dispatchable backbone mix
- Smart DMS P. to Heat
- Import / Export
- "redispatch" of RES ("last kWh")

(cover residual load, take-up excess power, control gradients, optimise economically within the system)

Variable load (daily, seasonal...)

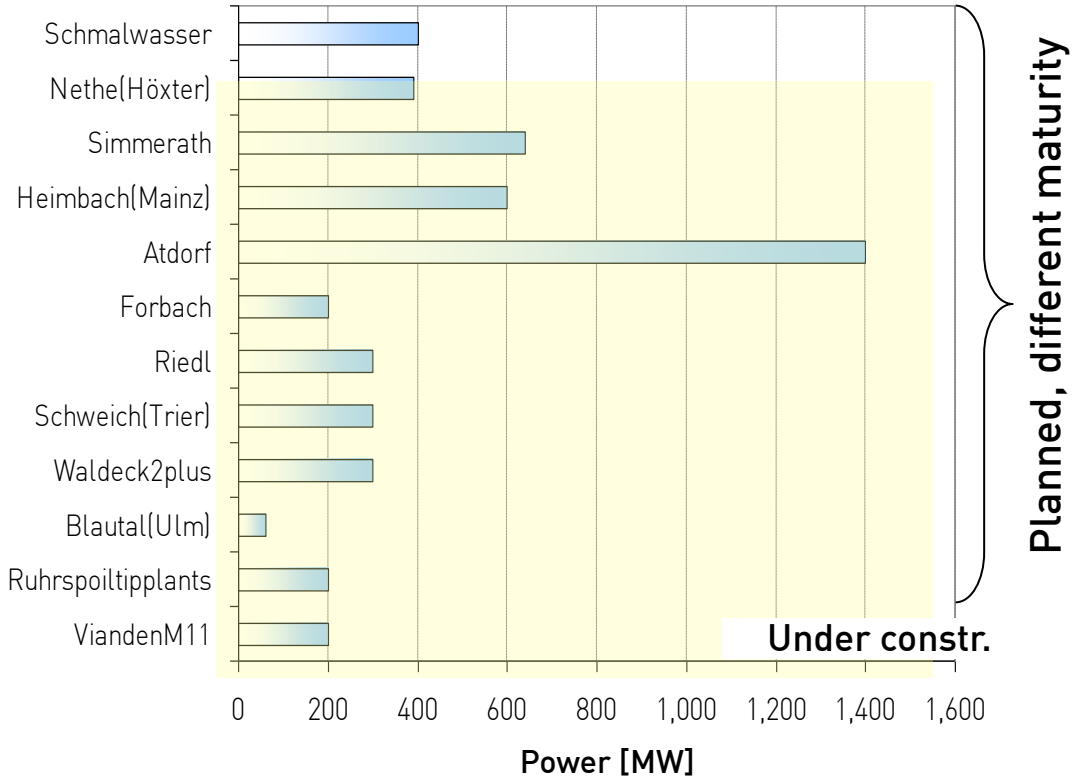
"Breathing System" can cope with RES still for a while: drivers for storage?

Potential PHP-Projects in Germany



- 1 project under construction ⇨ 0,2 GW
- tot.11 projects planned ⇨ 4,8 GW

Σ 5,0 GW



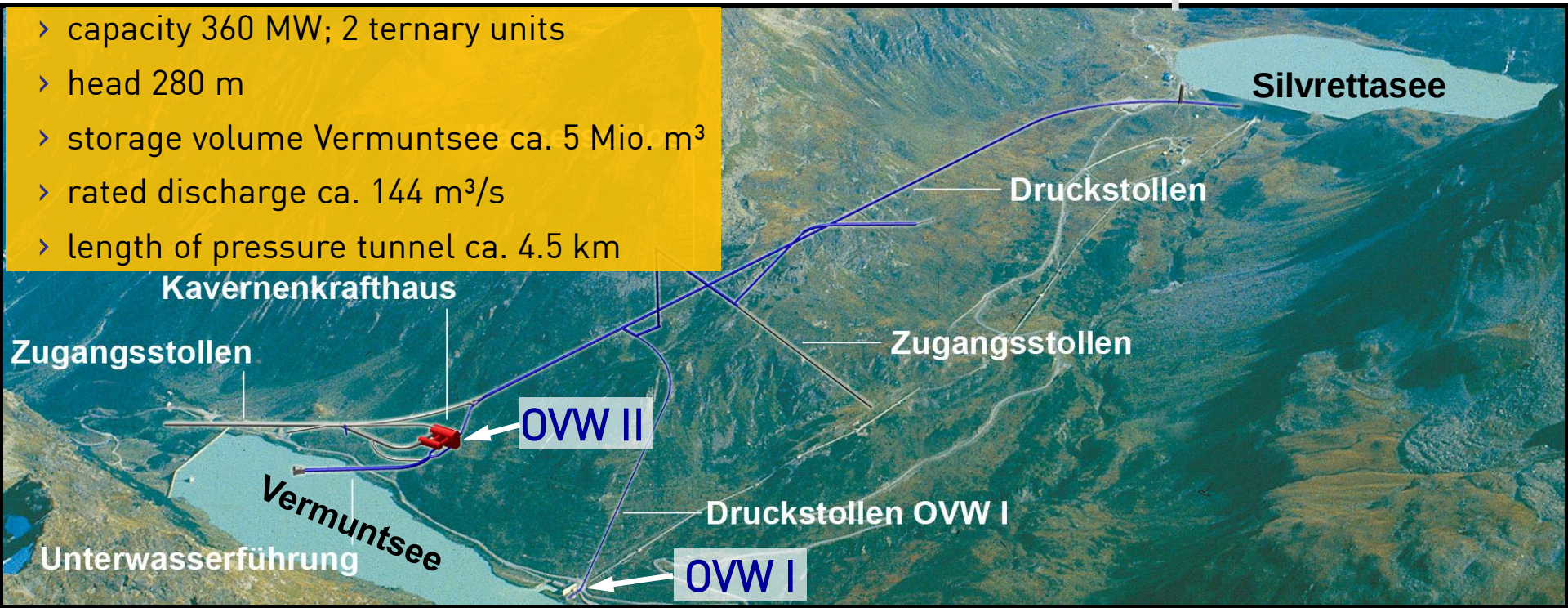
Source: EWL Working Paper No. 07/2011, PROSPECTS FOR PUMPED-HYDRO STORAGE IN GERMANY, Bjarne Steffen, Dez. 2011

PHP at EnBW

Obervermuntwerk II – Project Overview (Lead by VIW)

- pressure conduit (1943) has to be renewed
- opportunity for a new pump storage plant
- construction time app. 5 years
- start of construction planned in 2014 (decision taken)
- start of operation planned in 2018

- capacity 360 MW; 2 ternary units
- head 280 m
- storage volume Vermuntsee ca. 5 Mio. m³
- rated discharge ca. 144 m³/s
- length of pressure tunnel ca. 4.5 km

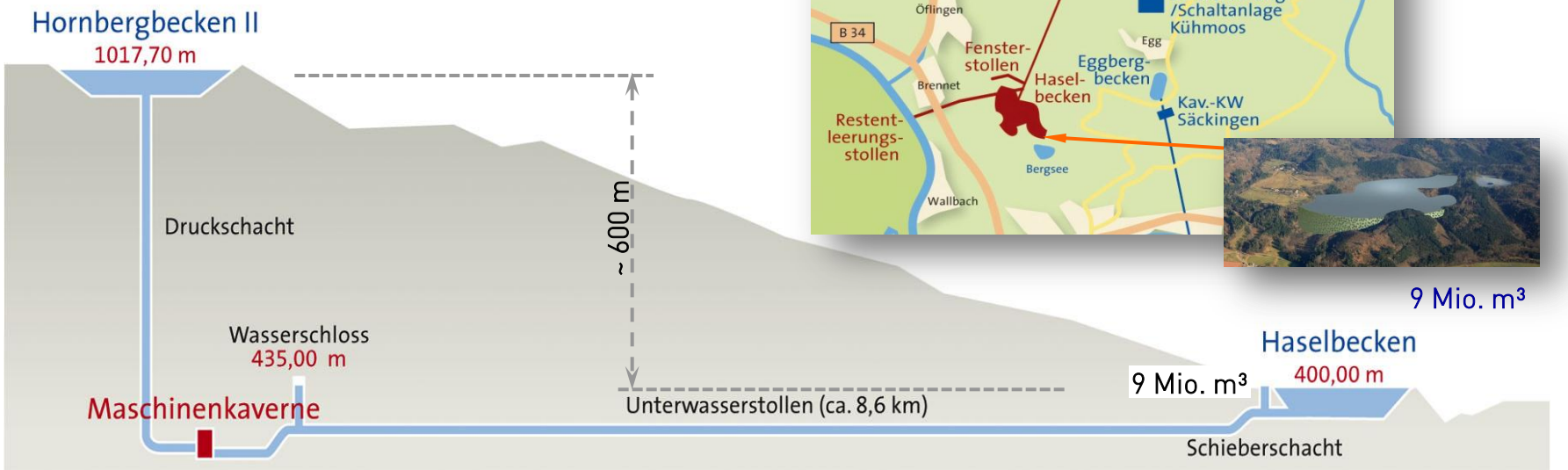


PHP at EnBW

Atdorf – Project Overview (together with RWE, Schluchseewerke)

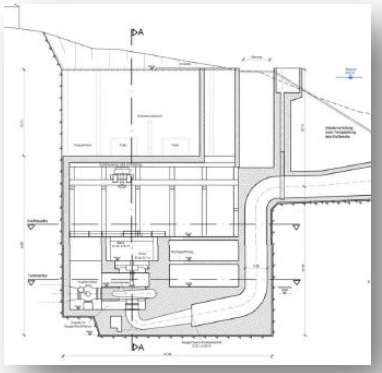
Project data:

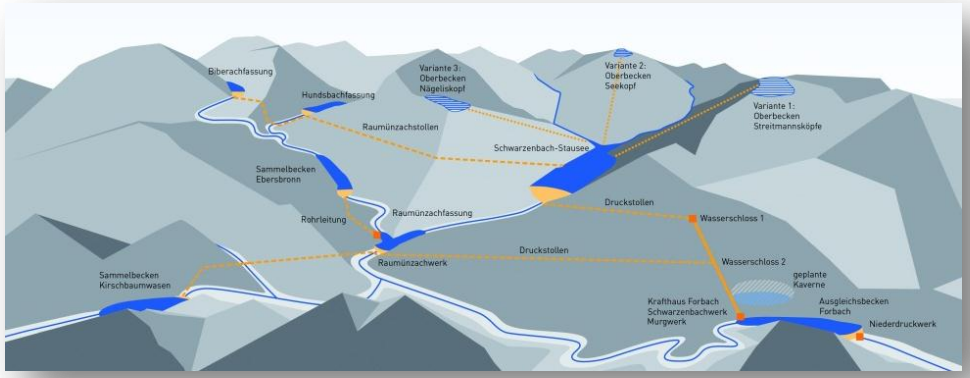
- 6 Units à 234 MW, in total 1,400 MW
- 9h/12h turbine-/pump-hours
- head 600 m
- rated discharge app. 280 m³/s
- expected permit in 2014, start of constr. planned in 2016 (open)



PHP at EnBW
Forbach – Project Repowering/Extension (1926)

- Power of 2 stages: 70 MW + 200 MW
- Start of construction foreseen in 2014, COD in 2019
- Upper stage shaft power house





neues Oberwasser Seekopf

1,8 hm³

Oberstufe neu 200 MW
1 Pumpturbine

320 m

Schwarzenbachstausee

9 hm³

Murg

Kirschbaumwasen

0,325 hm³

364 m

145 m

Unterstufe neu 70 MW
1 Pumpturbine

Murgwerk saniert ∑16 MW
3 Francisturbinen

bestehendes Unterwasser Forbach
+ Kavernenwasserspeicher
(0,204 + 0,371 = 0,575 hm³)

0,575 hm³

Niederdruckwerk
2 Rohrturbinen ∑ 2,5 MW

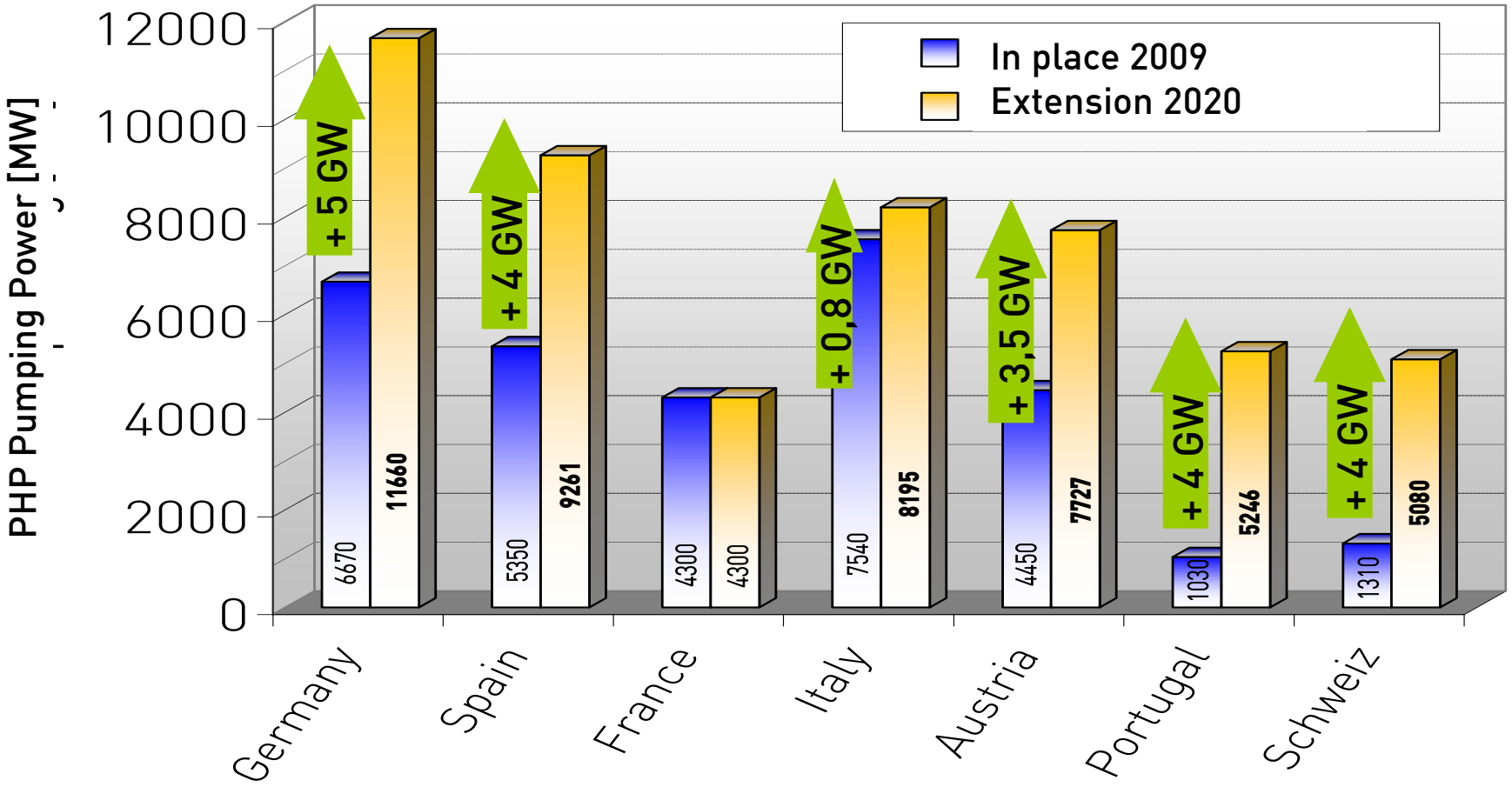
Murg

Energieableitung über die vorhandene
110 kV-Trasse durch das Murgtal

PHP Renaissance in Europe?

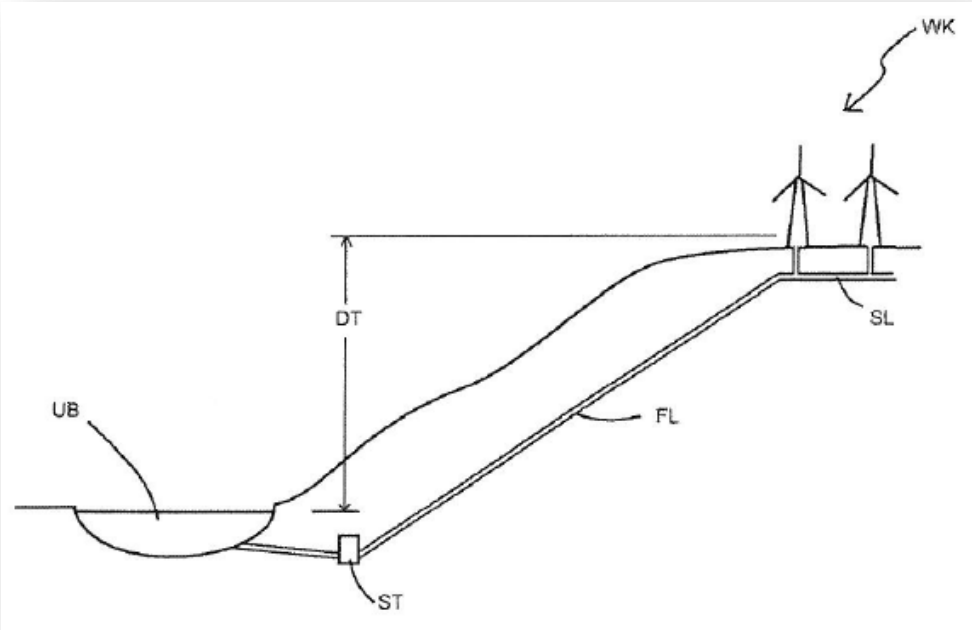
Mind the Gaps between Potentials – Announcements – Reals Projects!

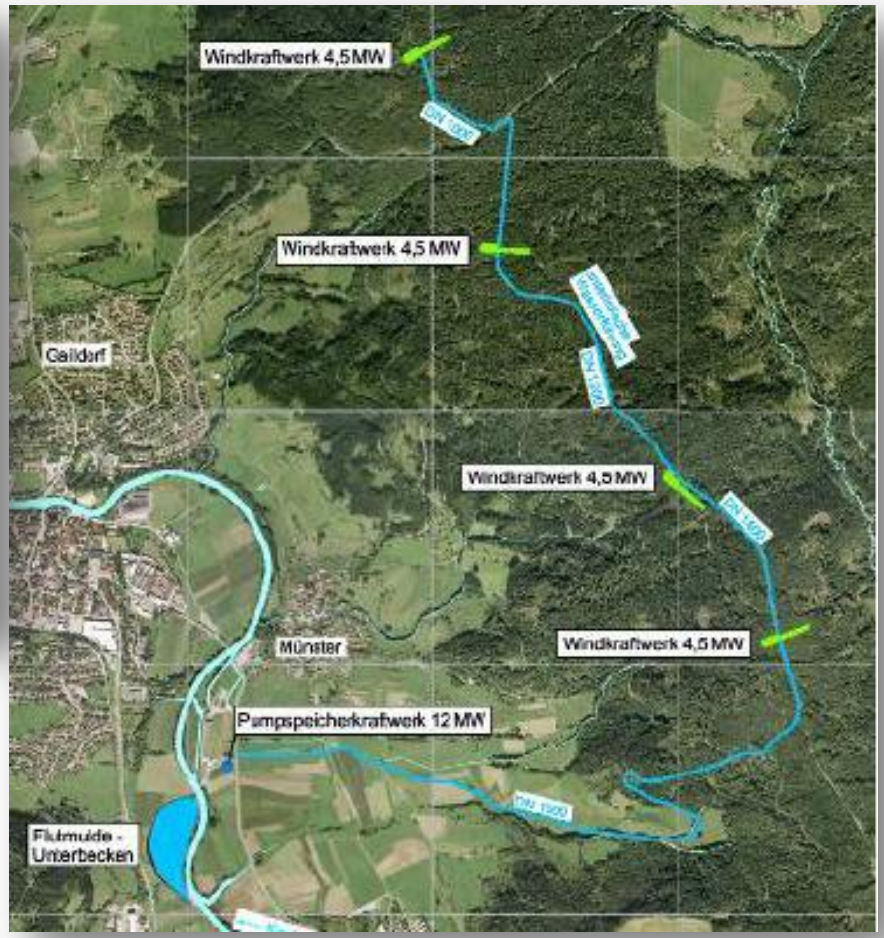
- Additionally around 21 GW in D, E, F, I, A, P, CH till 2020
- Some 10 GW announced in other Europ. Countries (e.g. Ukraine: +1,4 GW)



New Concepts: “Naturstromspeicher” (by VOITH et al.)

Upper Storage Basin in Lower Windtower-Section



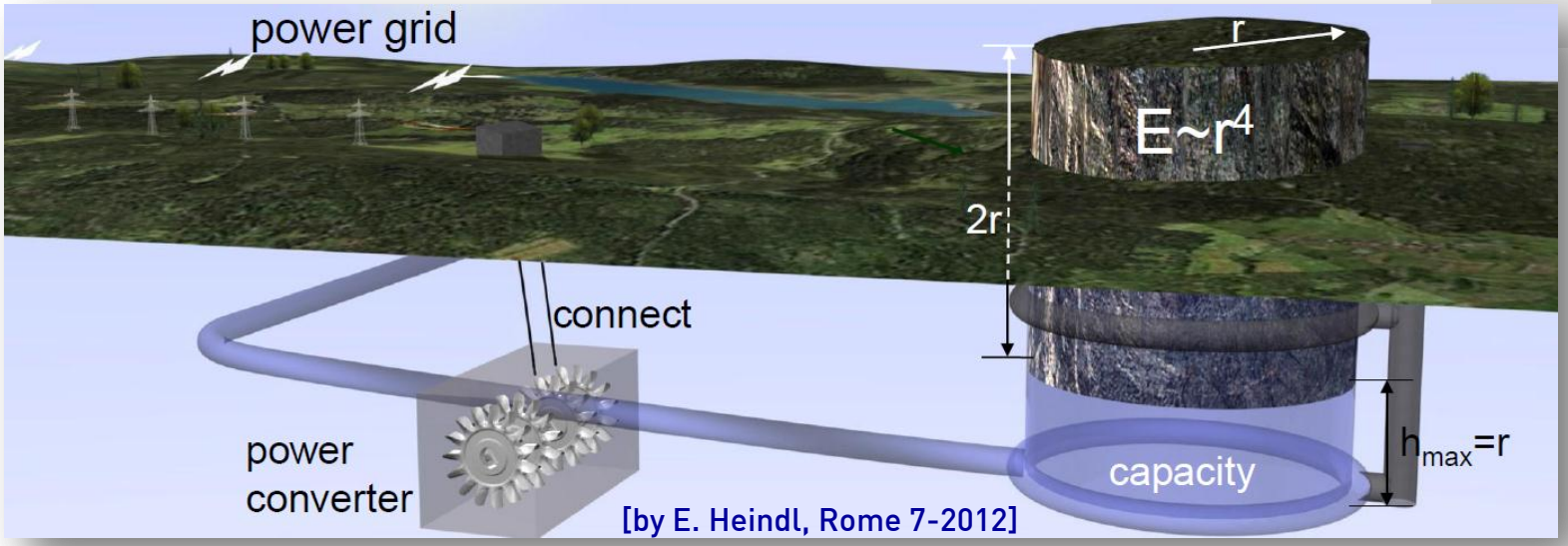


Pilot concept for Gaildorf

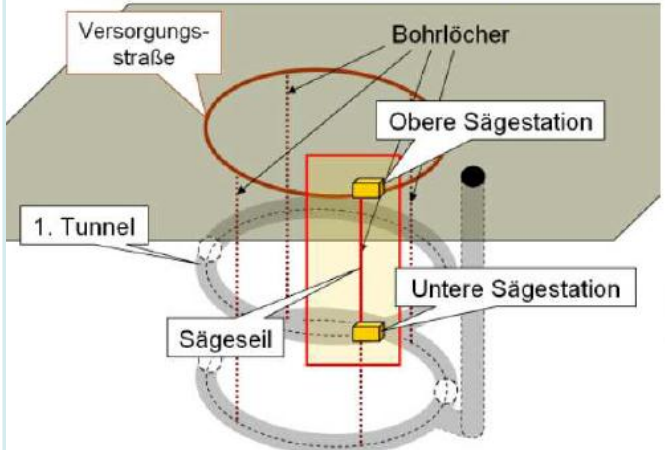
- Wind: 4 x 4,5 MW
- PSP: upper basin in 4 towers, each 40,000 m³
- PSP: lower basin at Kocher river
- PSP: 12 MW
- Head: max. 230 m
- Capacity: 70 MWh

„Granite Piston“ – Concept for Large Hydro Storage

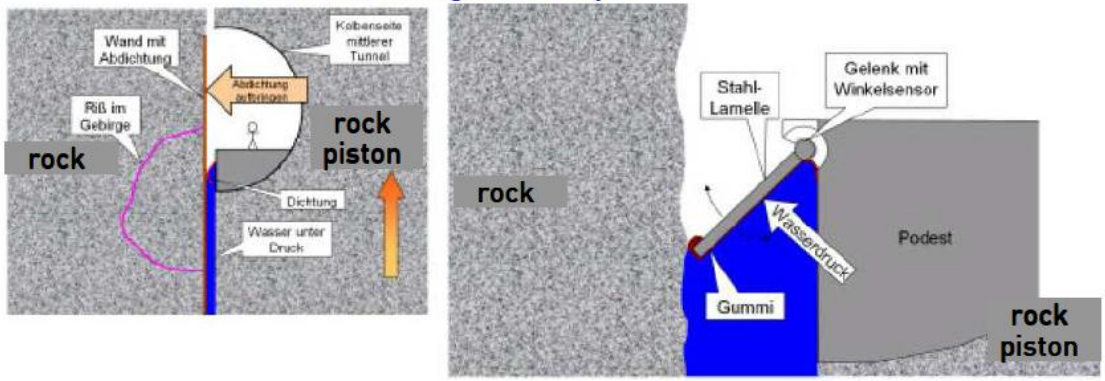
[r = 500 m: ≅ 400.000.000 m³ Water; Granite: x 2 ⇨ ca. 2,2 Bill. t; ≅ 1,6 TWh]



sawing concept for piston



wall sealing concept



water for
hydraulic lifting

Source: eduard-heindl.de

Power-to-Gas – Chain (1/3)

Differentiate: Exergy Efficiency / Power & Heat / Apps. for Mobility, Industrial Ressource etc.

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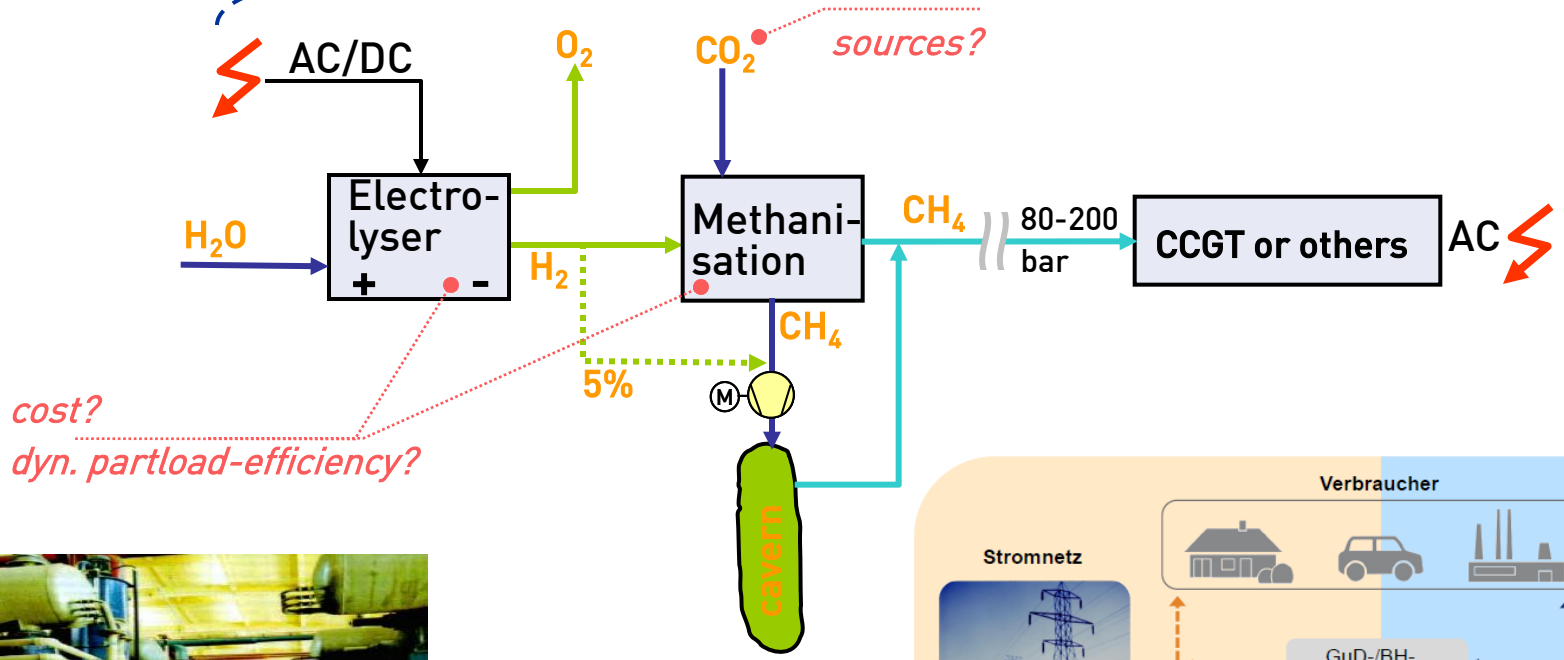
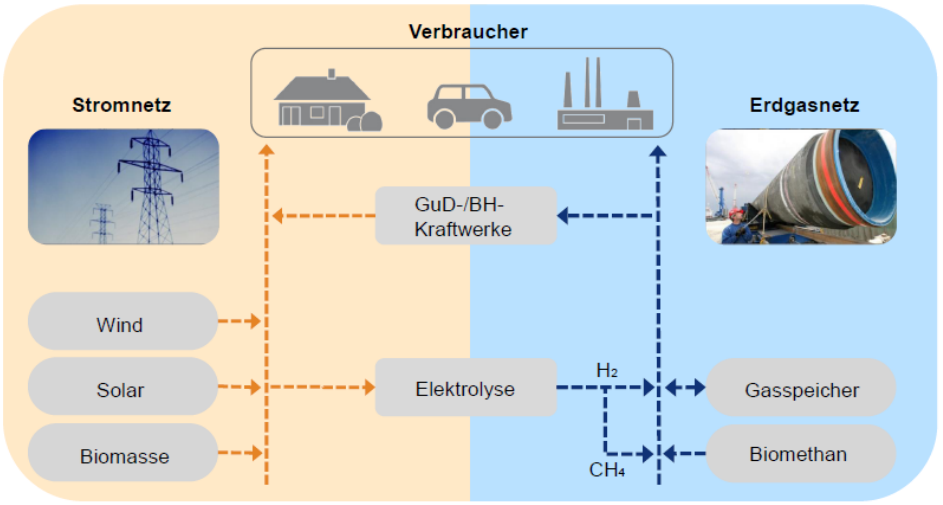
η = 25 – 30% over complete cycle „elect. to elect.“



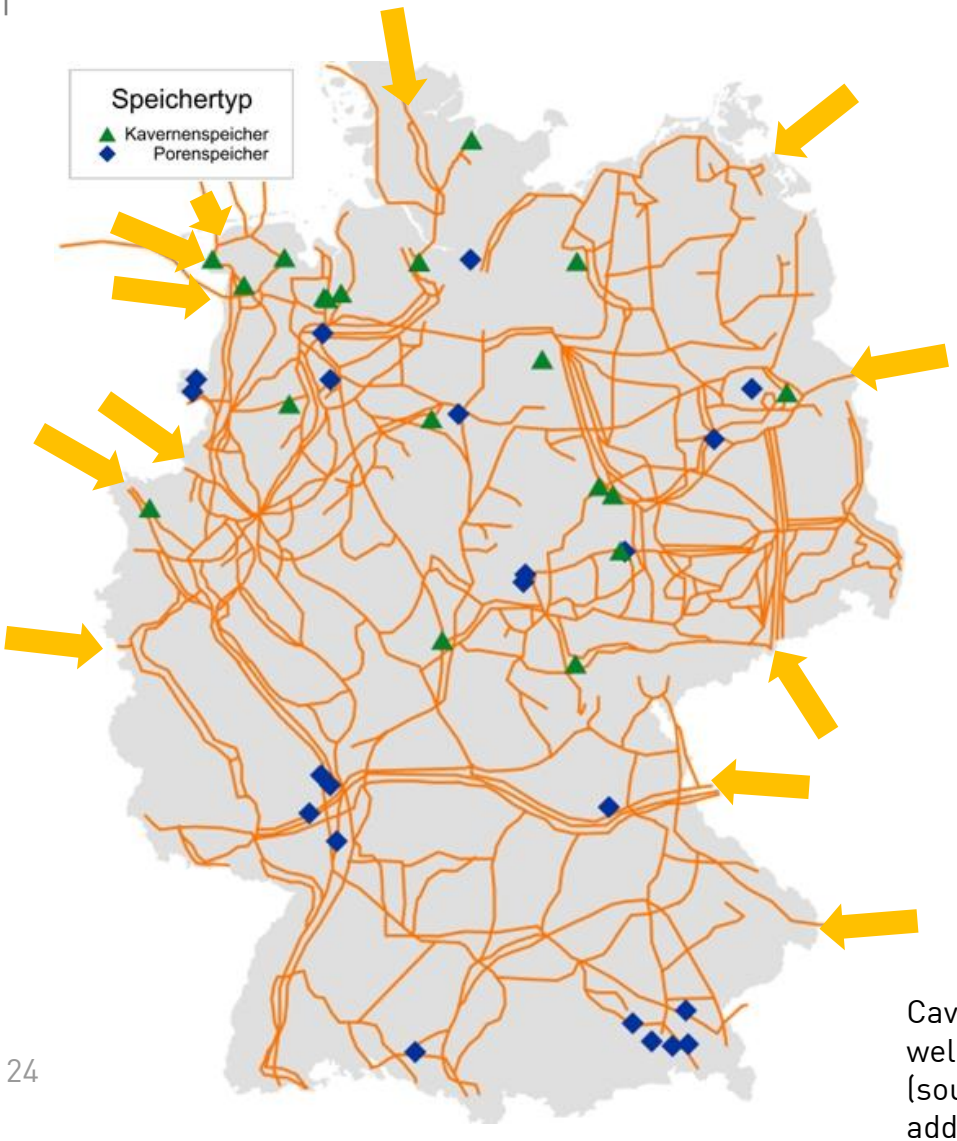
H_2-Production: 33,000 Nm³/h



Quellen: vgl. Sterner (2010), Specht et. al. (2010)

Gas System in Germany with High Performance (2/3)

However: Cold Period in Europe in 02/2012 Revealed Transport Bottle-necks



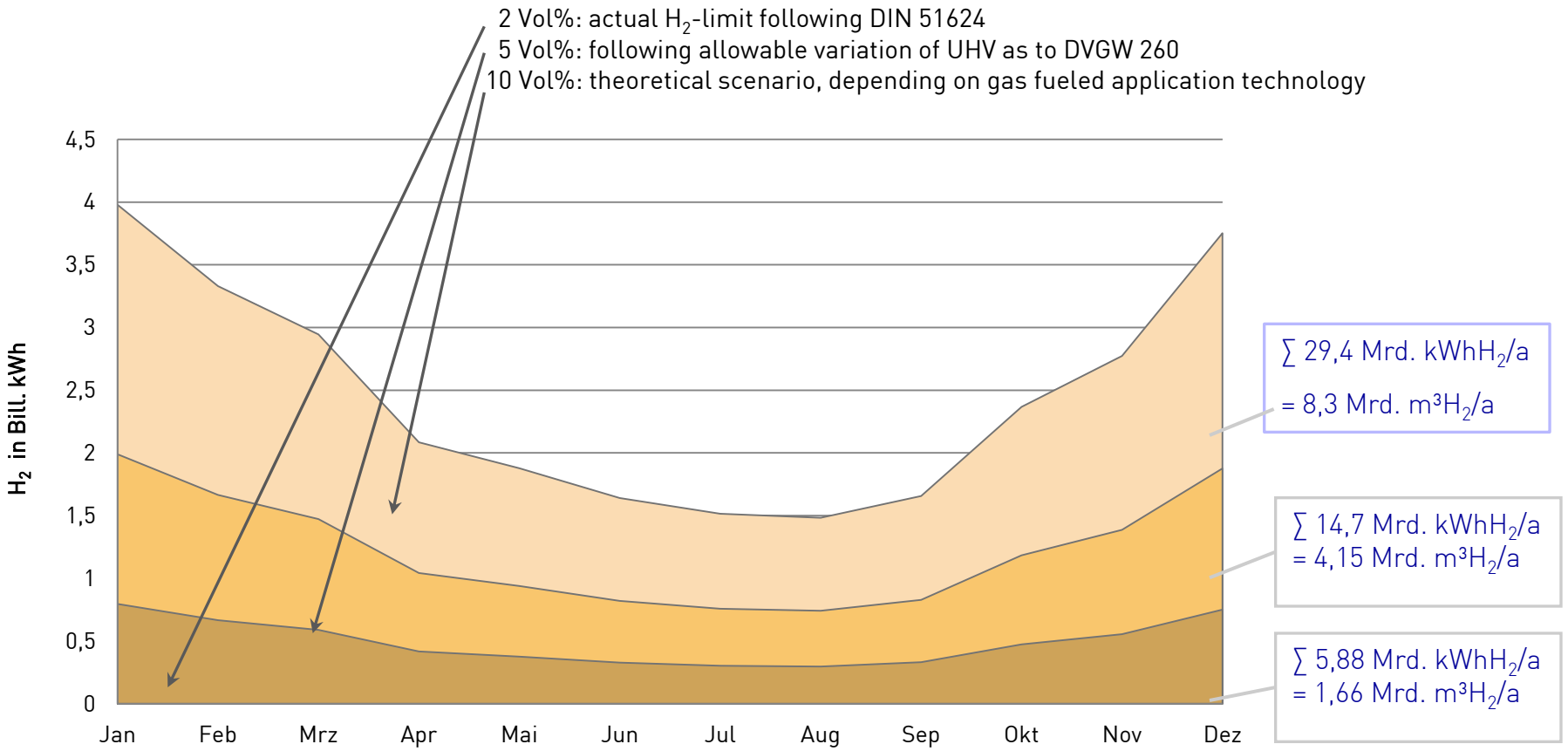
- Length of pipeline grid: 436.000 km (2009)
- Number of major gas storage plants: 47
- Storage volume:
  ca. 21 Bill. Nm^3 working gas,
  equivalent of about 220 TWh_{th}
- Gas needs: 976 TWh_{th} (2010)

⇨ Infrastructure is available in D
⇨ ...and asks for further use

Caverns and pore storage as well as pipeline grid in 2010 (source: DBI GUT GmbH); additional feed-in points

Gas Demand (and Flow) is Seasonal (3/3)

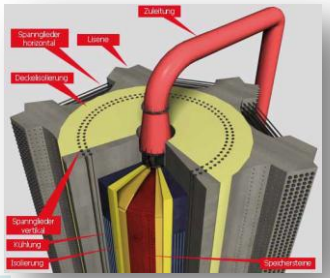
Injection Potential for H_2 Varies over Time



- Hydrogen injection depends on gas flow (respectively gas demand; time & location)
- Potential is actually limited at 2 Vol% due to gas vehicle reservoirs (tightness of tanks)

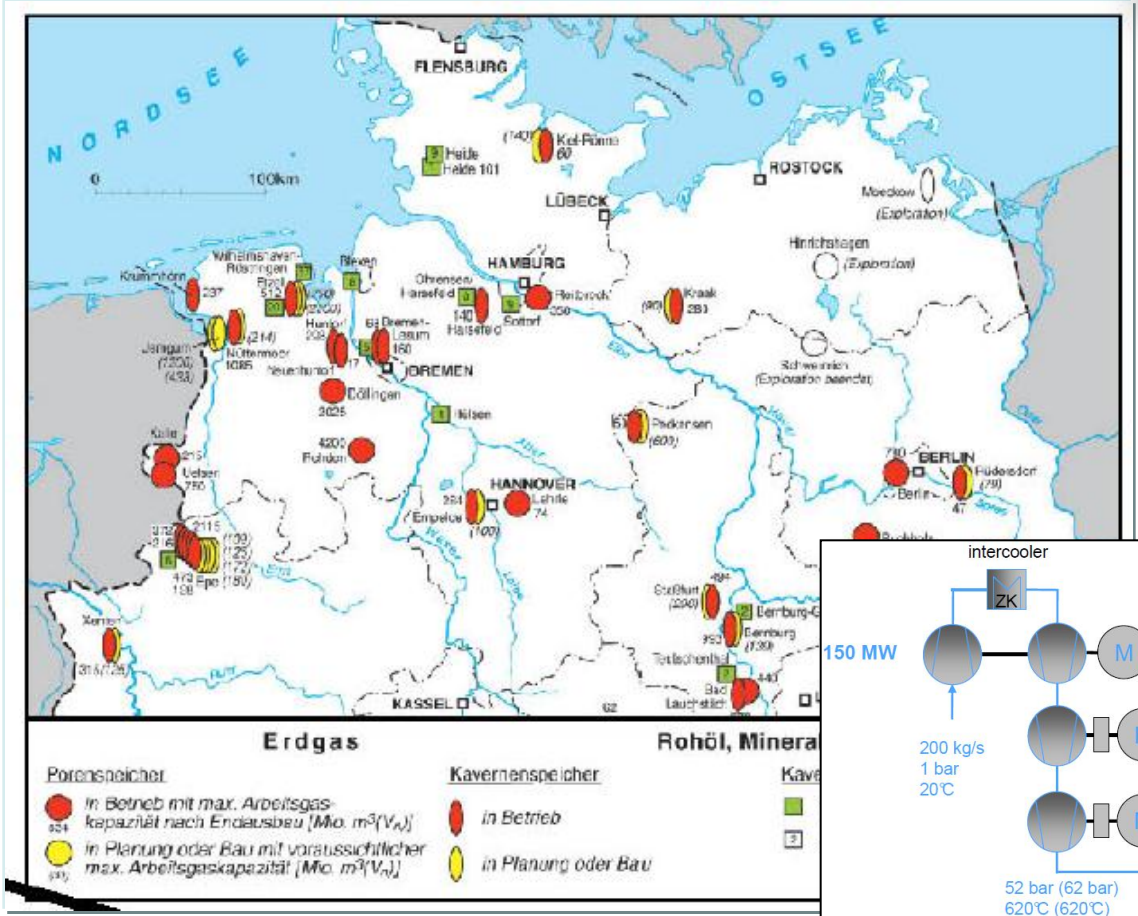
Adiabatic Compressed Air Energy Storage

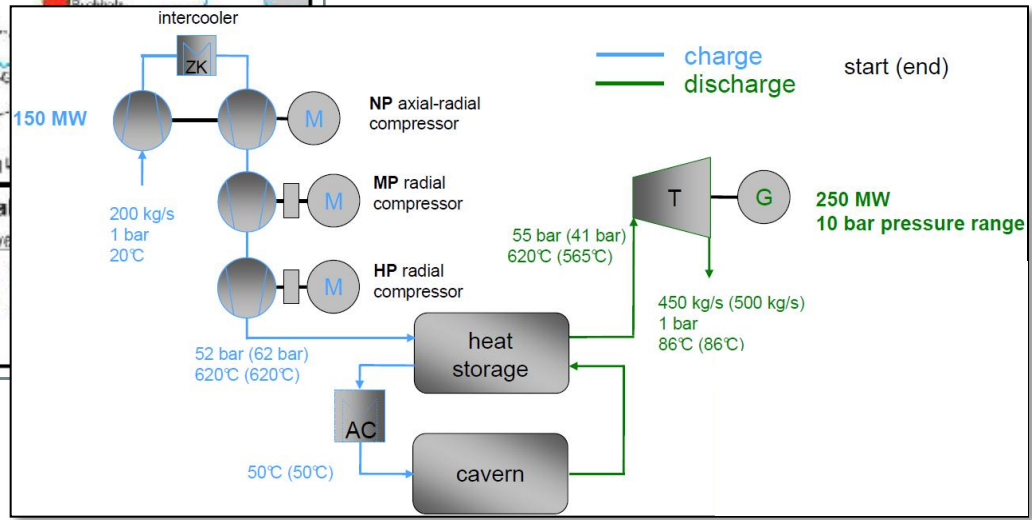
AA-CAES with Considerable Potential, but also Need for Development Progress



Source: DLR, ADELE-Project

- Salt dome formations are available in „windy“ areas in northern Germany
- If roughly 10% of potential gas caverns were used for AA-CAES, this would represent about 21 GWh of capacity (1,200 GWh as hydrogen)
- CAES comparable to today‘s PHP capacity in D

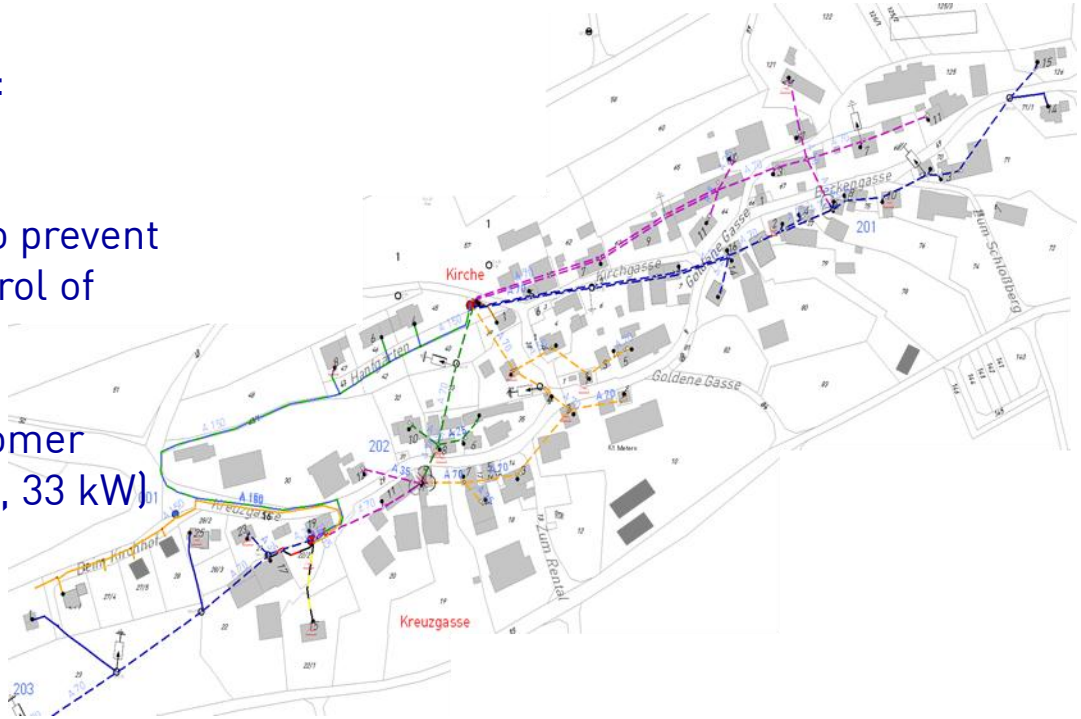




Distributed Accumulators for Various Purposes

EnBW Examplary Pilot Projects / „Volksspeicher“ Are under Discussion

- „Netlab 2“ - Zwiefalten/Sonderbuch:
  - 1.2MW local town grid
  - high PV feed-in
  - ⇨ find intelligent methods to prevent overload through active control of
    - producers
    - consumers
    - controlable local transfomer
    - storage (Evonik, 16 kWh, 33 kW)



- Varta Microbattery & EnBW ODR in Neuler-Schwenningen:
  - Lithium-Ion-battery system (63kWh/27kW)
  - ⇨ Integration of PV in the distribution grid of ODR
  - ⇨ Grid stability (prevent from grid extension)
  - ⇨ Smart Grid control

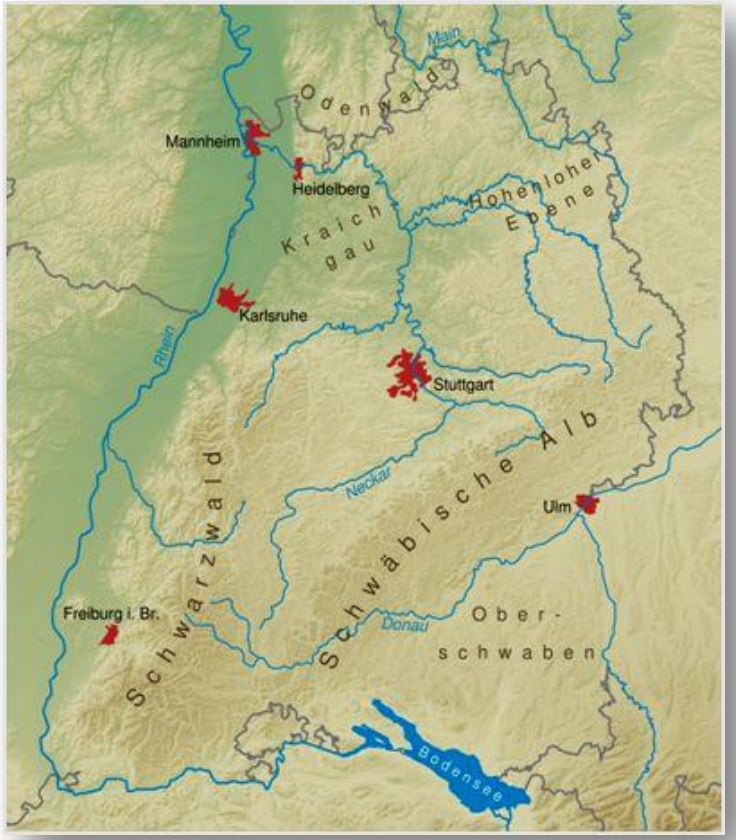
Study on PHP-Potential in Baden-Württemberg

Procedure Applied by EnBW with HPI

- Criteria for the selection process
- Determination of potential-surfaces ⇨ sites
- Determination of power [GW]
- Determination of working capacity [GWh; „Tank-size“]
- Ranking of sites following techno-economical criteria
- Validation of invest estimates for samples

GIS-based process, data:

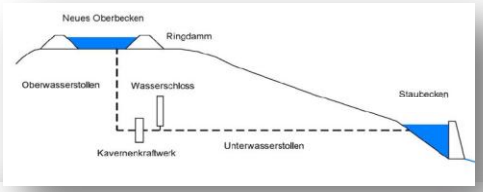
- „DGM 50“ (DGM 5)
- Topografical maps (TK 25, TK 100)
- Digital landscape-model „DLM 50“
- Grid (high and highest tension)
- „FFH“-areas and „Natura 2000“
- Nature preservation areas
- Water protection areas (zone 2 and 3)
- Geological survey maps
- Administrative areas (Regional planning, communities...)



Surface of the „Land“ 35,794 km²

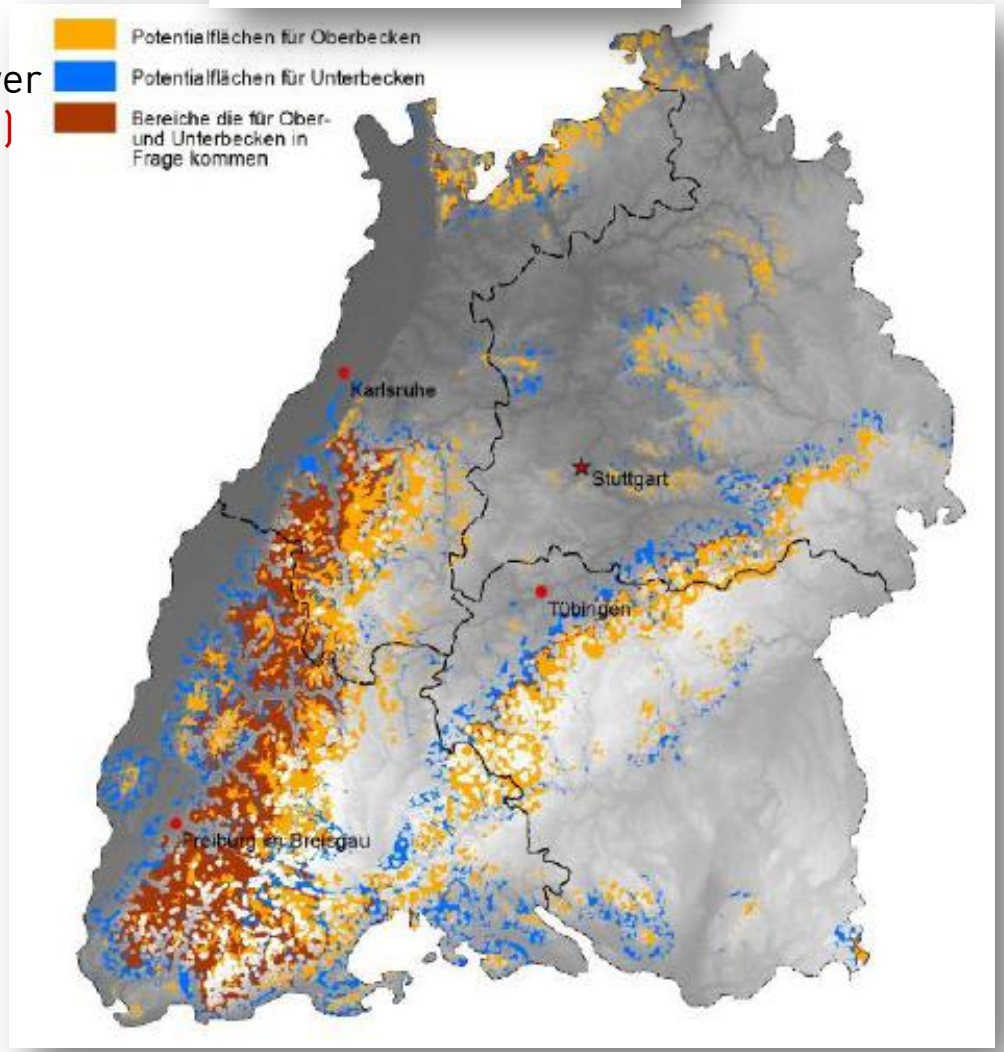
Topographically Suitable Areas for PHP in Baden-W.

Criteria and Graphical Results



Topography minus main infrastructure:

Potential upper basin areas (yellow), lower basin areas (blue), respectively both (red)

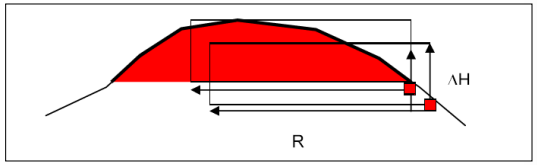


Main criteria:

- min. 40.000 "MWm" (200m / 200MW)
- capacity (energy) 8 pump-hours
- max. 5 km distance UB to LB

Flatness criteria for analysis of relief:

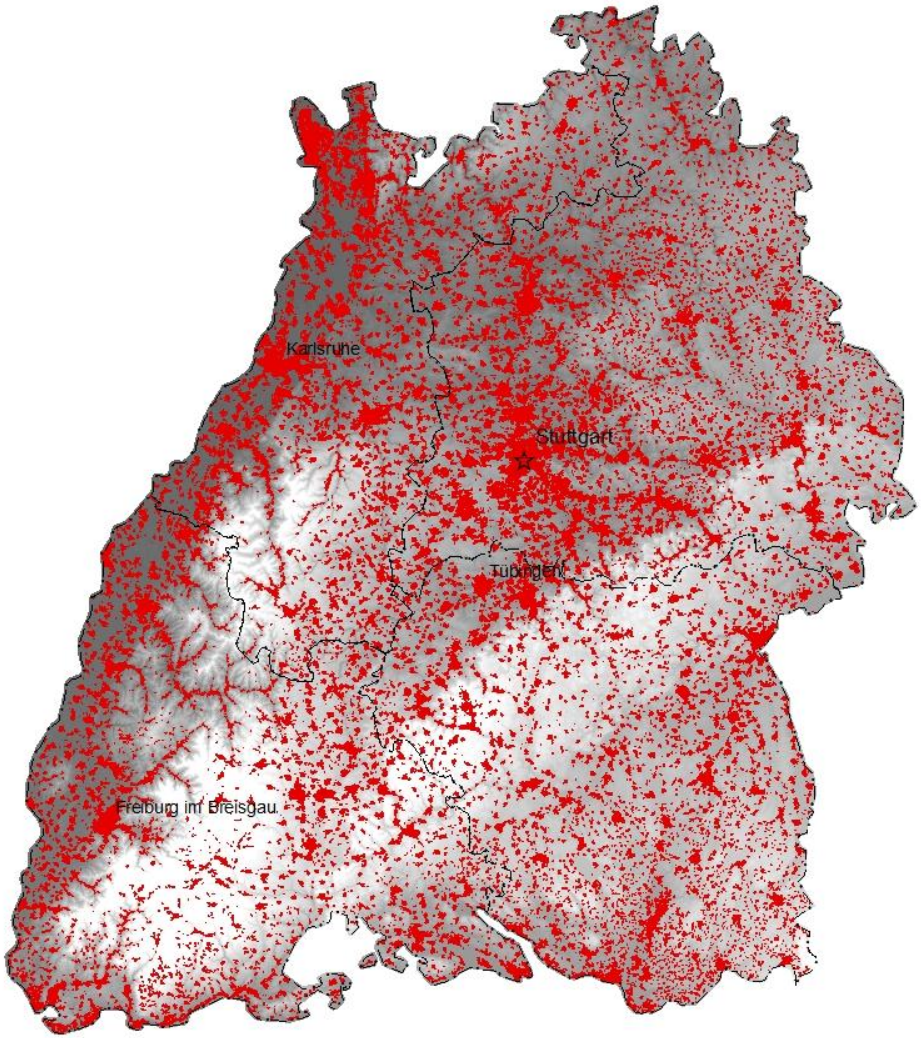
- summit
- slope
- valley



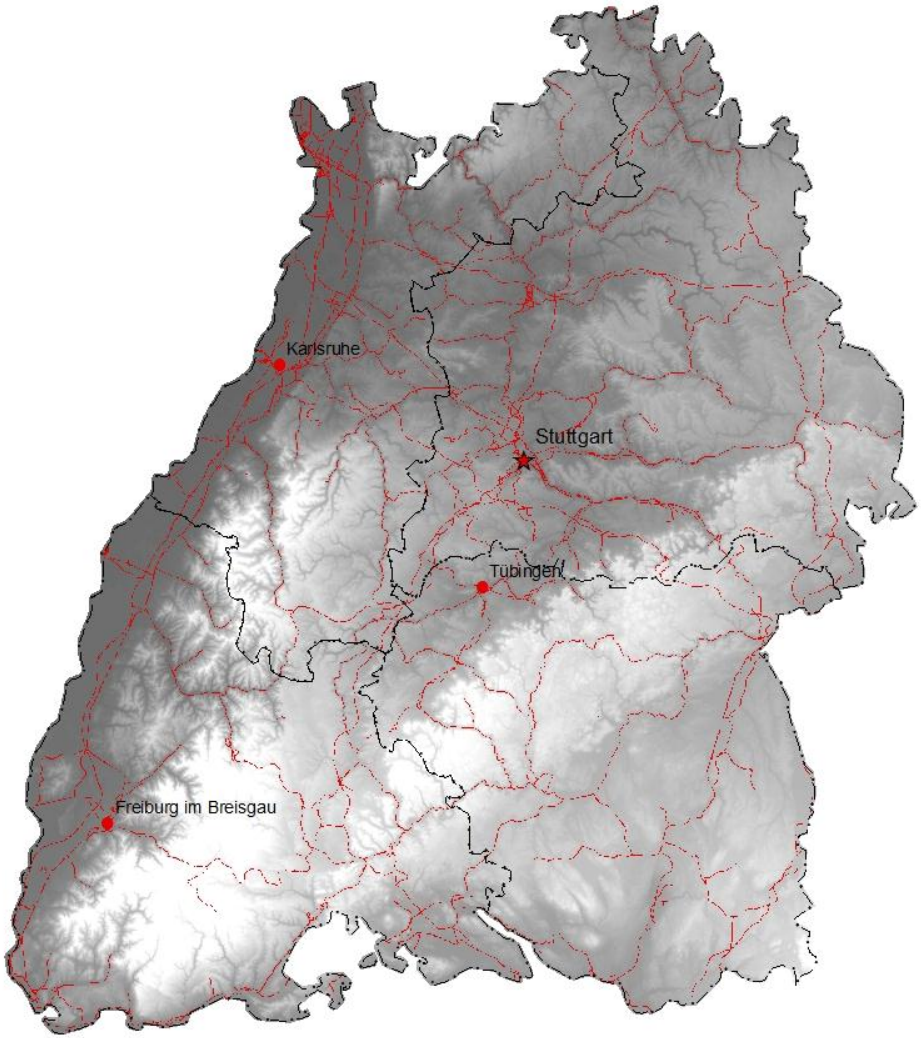
3 Cost-categories A, B, C:

- < 1.200 €/kW
- 1.200 – 1.600 €/kW
- > 1.600 €/kW

Example for Surface Exclusion:
„Inhabited Areas“



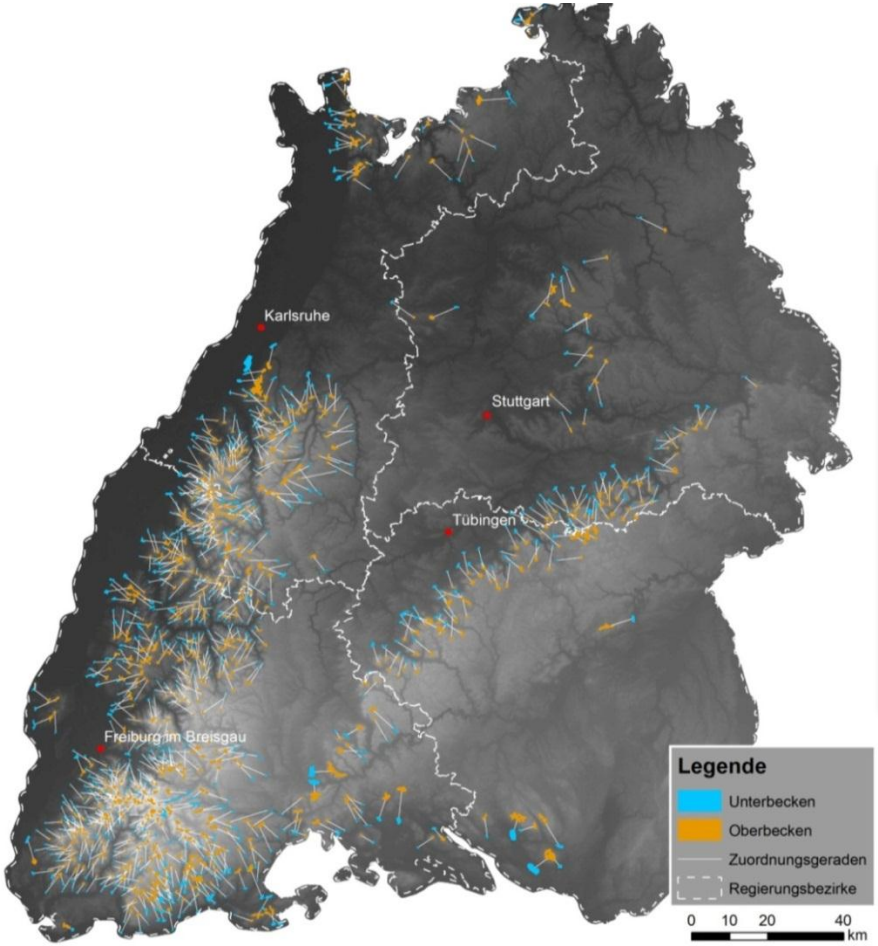
Example for Surface Exclusion:
„Main Infrastructure“ (Highways, Railways…)



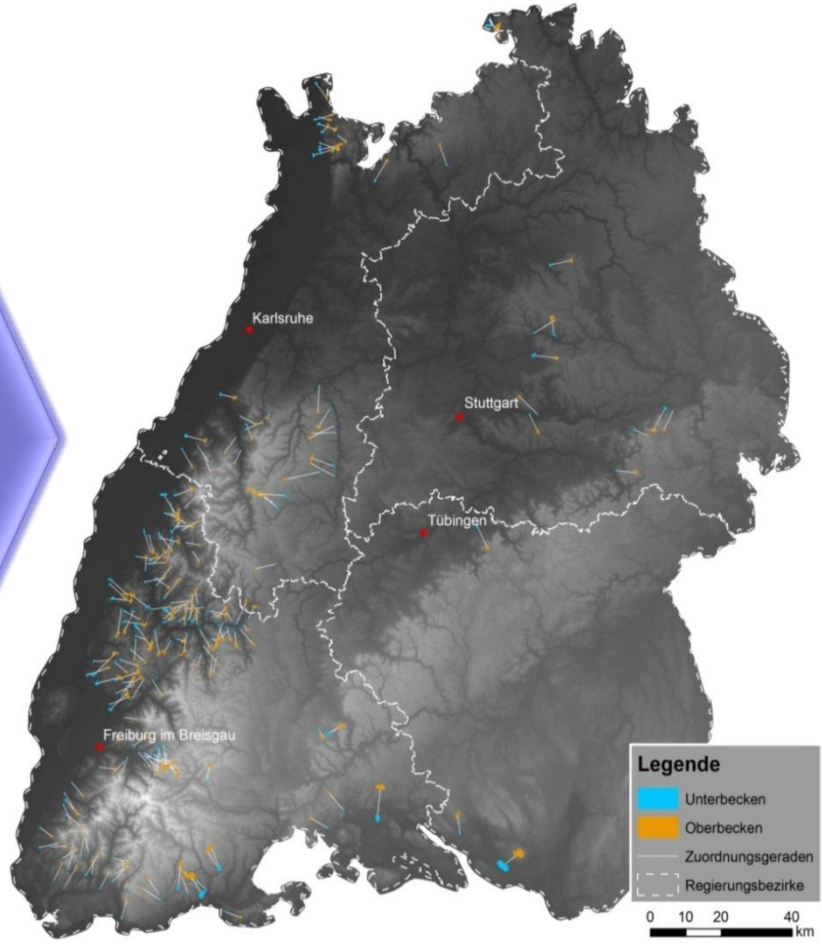
Results of GIS-Based Research for Locations after Plausible Filtration

Technically Reasonable Sites (845), 201 of which Show *Low* Conflict Level

- **845 Sites** between 71 MW and 15.234 MW (medium 678 MW) / power Σ **573 GW** / working capacity Σ **4.584 GWh**



- **201 low conflict sites** between 84 MW and 10.828 MW (medium 580 MW) / power Σ **116 GW** / working capacity Σ **928 GWh**



“Green Batteries in the Heart of Europe”?

Switzerland and Austria Express their PHP ambitions

CH: hydro tot. 13.3 GW (incl. 1.7 GW PHP); 2020: + 6 GW Turb. + 4 GW Pump

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK

bmwfi
Bundesministerium für Wirtschaft, Familie und Jugend

Bundesministerium für Wirtschaft und Technologie

Erklärung von Deutschland, Österreich und der Schweiz zu gemeinsamen Initiativen für den Ausbau von Pumpspeicherkraftwerken

Europa hat sich langfristig ambitionierte Ziele für eine nachhaltige und sichere Energieversorgung gestellt. Die Treibhausgasemissionen sollen bis zum Jahr 2020 gegenüber dem Niveau des Jahres 1990 um 20 Prozent verringert werden, der Anteil der erneuerbaren Energien am Gesamtenergieverbrauch soll auf 20 Prozent steigen und die Energieeffizienz soll maßgeblich erhöht werden.

Deutschland, Österreich und die Schweiz sind sich dahingehend einig, dass die verstärkte Nutzung der erneuerbaren Energien für die zukünftige Stromversorgung nicht ohne einen entsprechenden Ausbau von Leitungs- und Speicherkapazitäten zu realisieren ist. Ausreichende Speicherkapazitäten sind eine Grundvoraussetzung für den weiteren verstärkten Zubau von Anlagen auf Basis von erneuerbaren Energien und somit für die Erreichung der oben genannten energie- und klimapolitischen Ziele.

Deutschland, Österreich und die Schweiz sind weiterhin der Auffassung, dass aus gegenwärtiger Sicht Pumpspeicherkraftwerke die einzige großtechnisch verfügbare Speichertechnologie darstellen. Pumpspeicherkraftwerke eignen sich besonders gut zum Ausgleich der volatilen Einspeisung von Wind- und Solaranlagen. Durch ihre schnelle Verfügbarkeit sind sie in der Lage, sowohl zur Deckung kurzfristigen Strombedarfs beizutragen, als auch Stromüberschüsse zu speichern.

Gemeinsames Ziel von Deutschland, Österreich und der Schweiz ist es, die Nutzung dieser Technologie in den drei Ländern weiter auszubauen und neue Potenziale zu erschließen. Weitere Schwerpunkte für gemeinschaftliche Vorhaben sind der koordinierte bedarfsgerechte Ausbau der dafür notwendigen Übertragungsnetze sowie die Koordinierung der Forschungs- und Entwicklungsaktivitäten für die Entwicklung von neuen alternativen Speichertechnologien.

Dementsprechend soll die Zusammenarbeit – speziell zu den genannten Themen – auf trilateraler Ebene weiter vertieft, sollen die bestehenden Kontakte ausgebaut und gemeinsame Schritte auf politischer Ebene im europäischen Rahmen vorbereitet werden.

Unterzeichnet in drei Original-Exemplaren in deutscher Sprache.

Für das Bundesministerium für Wirtschaft und Technologie
der Bundesrepublik Deutschland

Berlin, 16. April 2012

Dr. Philipp Rösler

Für das Bundesministerium für Wirtschaft, Familie und Jugend
der Republik Österreich

Wien, 20. April 2012

Dr. Reinhold Mitterlehner

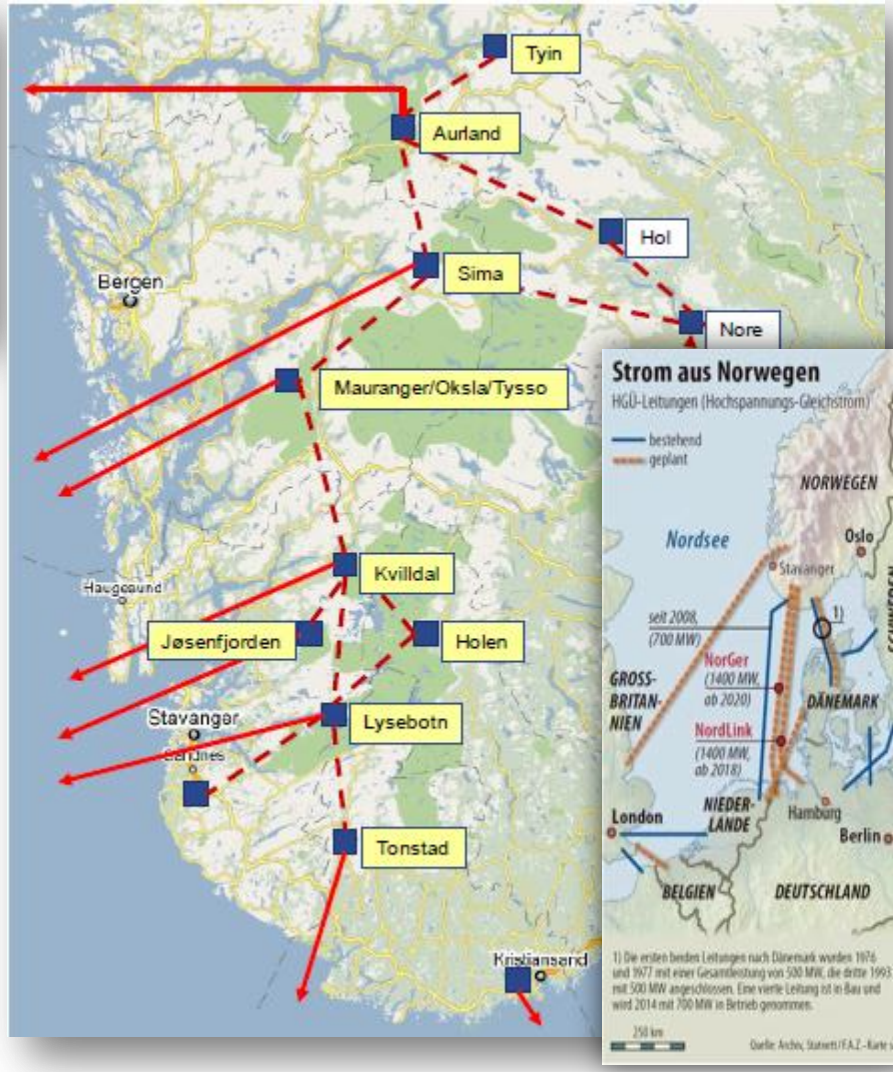
Für das Eidgenössische Departement
für Umwelt, Verkehr, Energie und Kommunikation

Bern, 1. Mai 2012

Doris Leuthard

Norwegian Dam-/PHP Power as Part of an EU-Solution?

Parts of German Politicians/Academics Are in Favour for the Blue Battery [GB, NL, DK, D...? Acceptance for Grids, Plants? Market Coupling? Tbd...!]



- Very recent report (12/2011) issued by CEDREN/SINTEF
- Hydro potentials for EU markets to balance out fluctuating wind power
- **Main scenario**: #12 new hydro power plants using existing reservoirs (**within** working level permits)
- **11.2 GW** in parallel to existing plants
- #5 of which as **PHP with 5.2 GW**, remaining 6 GW as dams (turbining only)

NOR_LINK & NOR_GER confirmed?

Some Conclusions and Messages

Need for system „flexibility“ increases with share of RES

- „Flexibility“ means: +/- balancing, short and freqent start-up, fast ramping, broad amplitude range, black-start capability (POWER-storage; volatility of prices)
- Storage of „electricity“ is – if already in place - the „friend“ of RES (PHP = 1st choice: efficient, large, fast, affordable)
- Intraday storage (conv. PHP) fits well with PV-patterns – but peak damping leads to spread decrease, hampering arbitrage

Market and other framework conditions

- Actual conditíons do not favour longterm investments in storage plants (regulatory drivers, e.g. for balancing power, adapted to actual situation?)
- To have the chance of getting realised, specific invest of efficient storage should not exceed arround 1,000€/kW
- System-perspective is key for longterm decisions! (Grid extension is prerequisite ⇨ spatial balancing!)
- Residual “backbone” of dispatchable, secured power will remain essential for long period (but: redispatch by TSO, strategic reserve, part-load, little full-load op. hours per year ⇨ “Drivers” to continue operation?)
- National (or even sub-national) autarkie ambitions lead to sub-optimal solutions (win-win for all partners is needed); EU-market-coupling and market-integration of RES would be helpful
- Euphoria arround storage does not automatically translate through acceptance „IMBY“
- No „silver bullet“, but the need for intelligent MIX of measures / technology contributions