Invisible Gigantic Hydro Power Storage Plants in Lignite Open-Cast Mines
-
A Key Technology for Short-Term Storage to Implement the Energy Transition

Horst Schmidt-Böcking

Preamble

Energy is the most important base for mankind besides air and water.

Content of this talk

1. Why is the storage of electrical energy important and what storage methods can be used?
2. Hydro power storage systems
3. Hydro Power Storage Plants in Lignite Open-Cast Mines

In 2045, after a "successful" energy transition: Total energy demand in Germany approximately 1200 to 1500 billion kWh/year if almost exclusively electrical energy is used

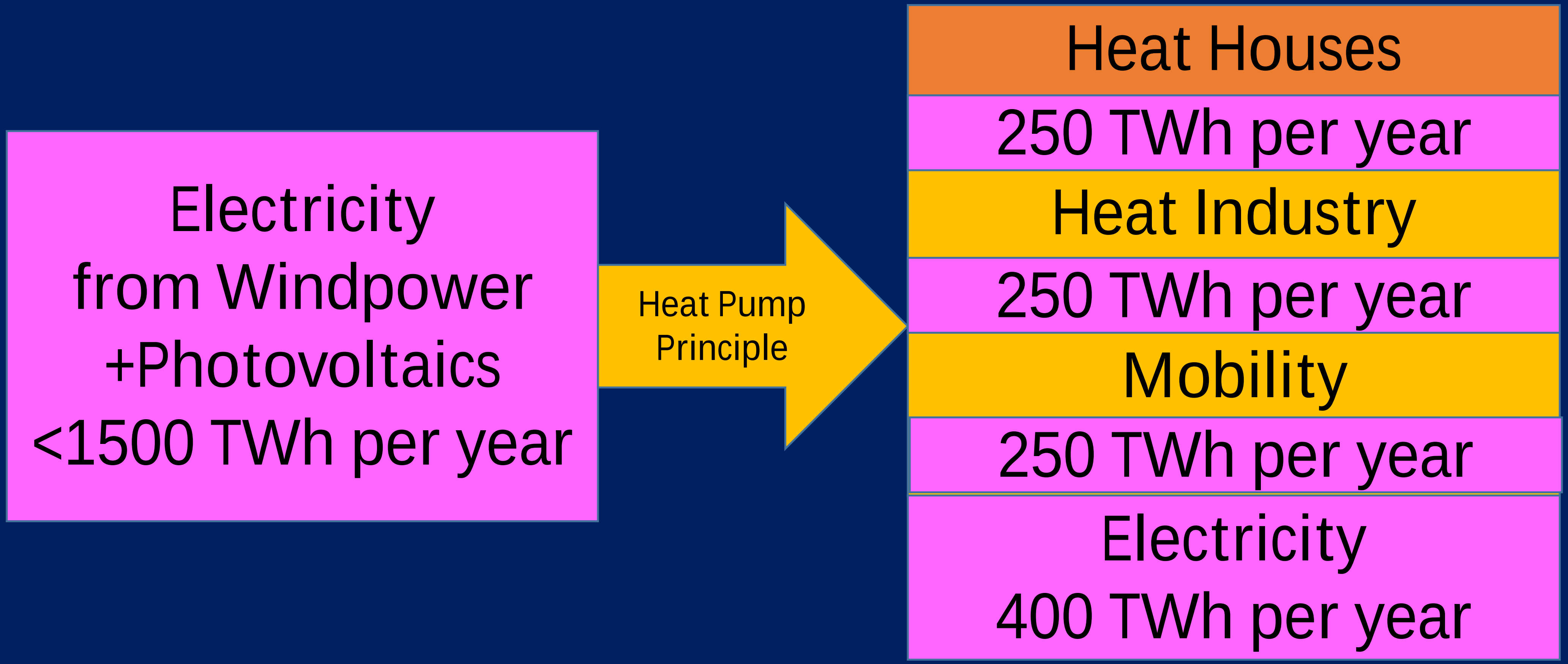
1. Why is the storage of electrical energy important and what storage methods can be used?

Total energy demand in Germany in 2021:
Approx. 4000 TWh/year,
if generated from fossil fuels (coal, oil, natural gas, etc.)

Heat Houses 1000 TWh per year
Heat Industry 1000 TWh per year
Mobility 1000 TWh per year
Electricity 1000 TWh per year

In 2045:

After a "successful" energy transition: The total energy demand in Germany is approximately 1200 to 1500 TWh/year, if almost exclusively electrical energy is used.



The goal is:

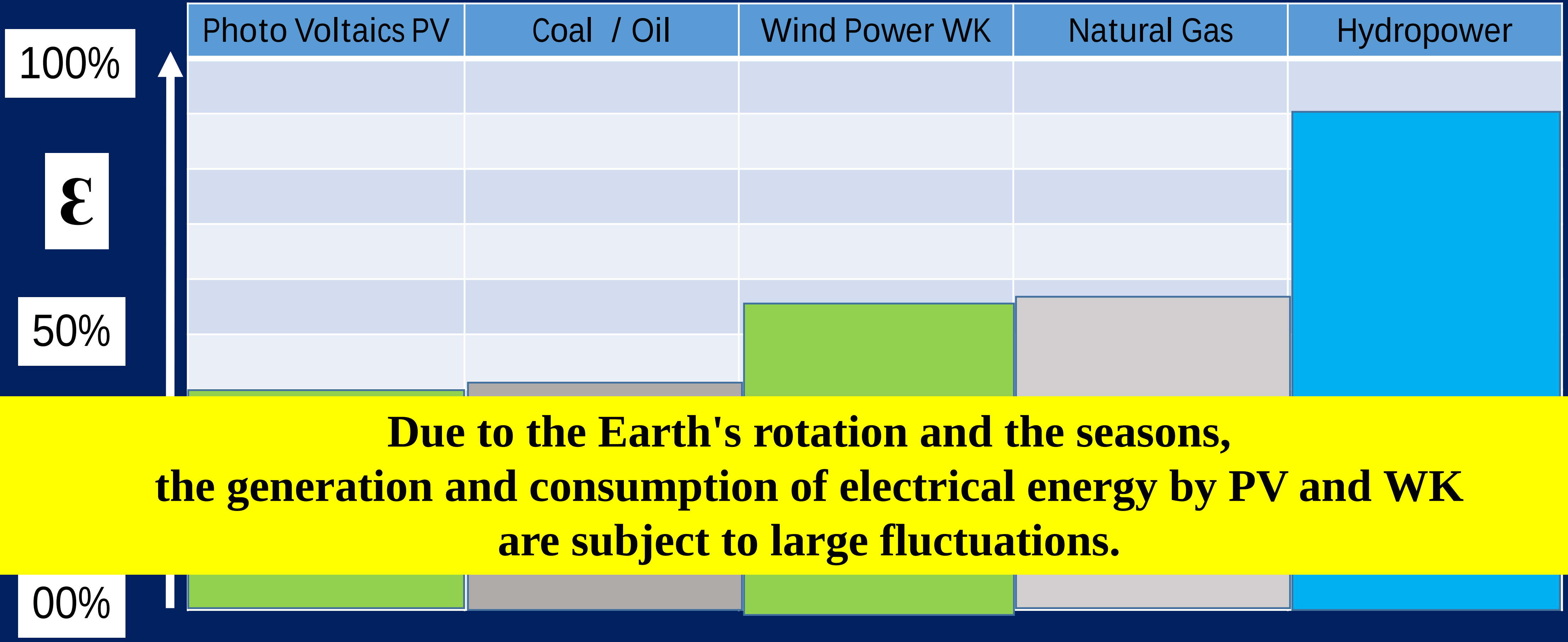
to generate approximately 80% of the required energy from wind power and photovoltaics, and approximately 20% from biomass etc..

The sun provides mankind with a virtually unlimited amount of environmentally friendly, renewable energy in the form of light.
Therefore, an energy crisis does not exist on Earth.

This solar energy is converted into electrical energy with high efficiency using modern technologies such as wind turbines and photovoltaics.

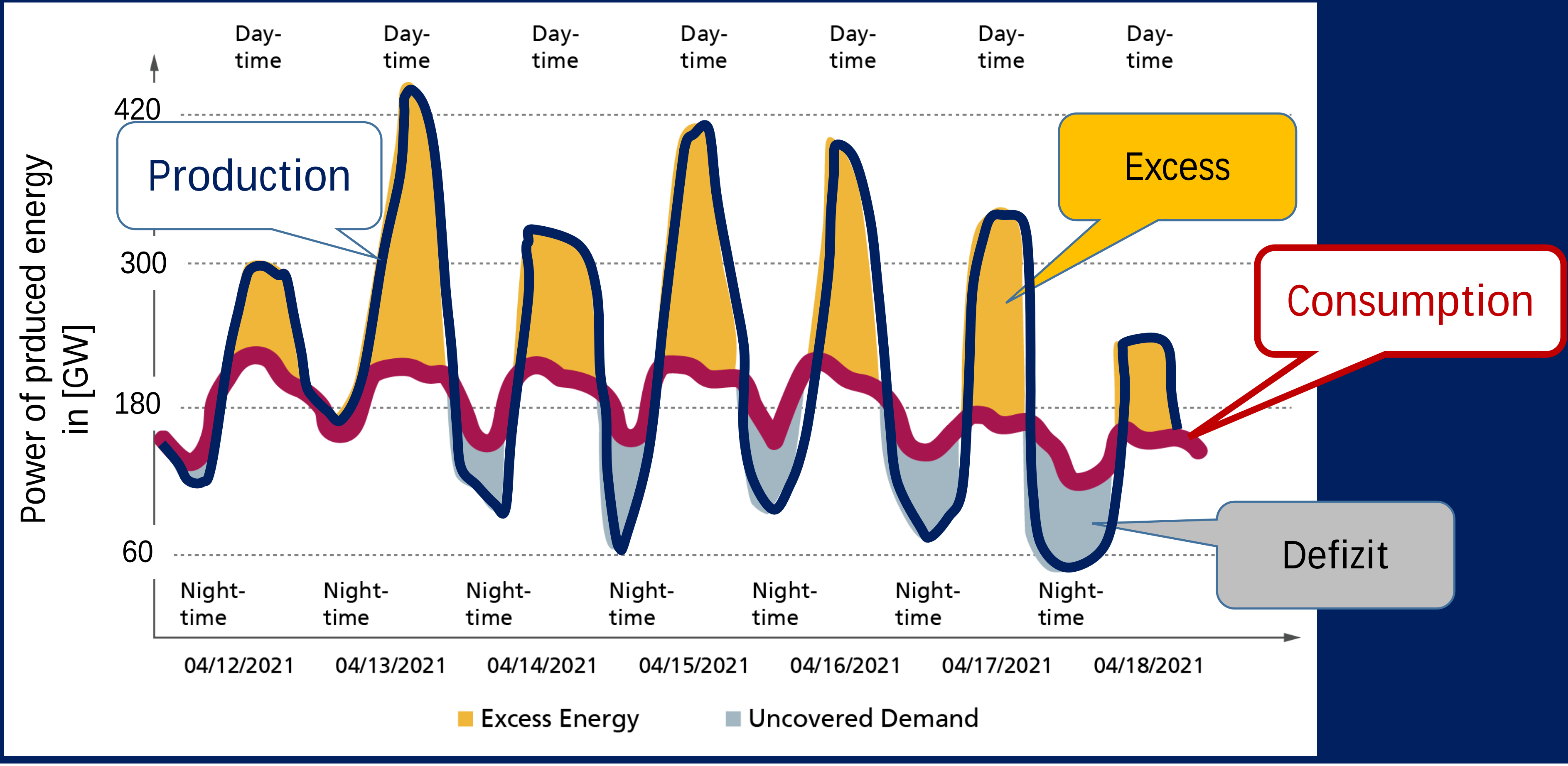
Covertion-Efficiency ε from Primary Energy E_0 to Electric Energy E_1

$$\varepsilon = E_1 / E_0$$



Due to the Earth's rotation and the seasons,
the generation and consumption of electrical energy by PV and WK
are subject to large fluctuations.

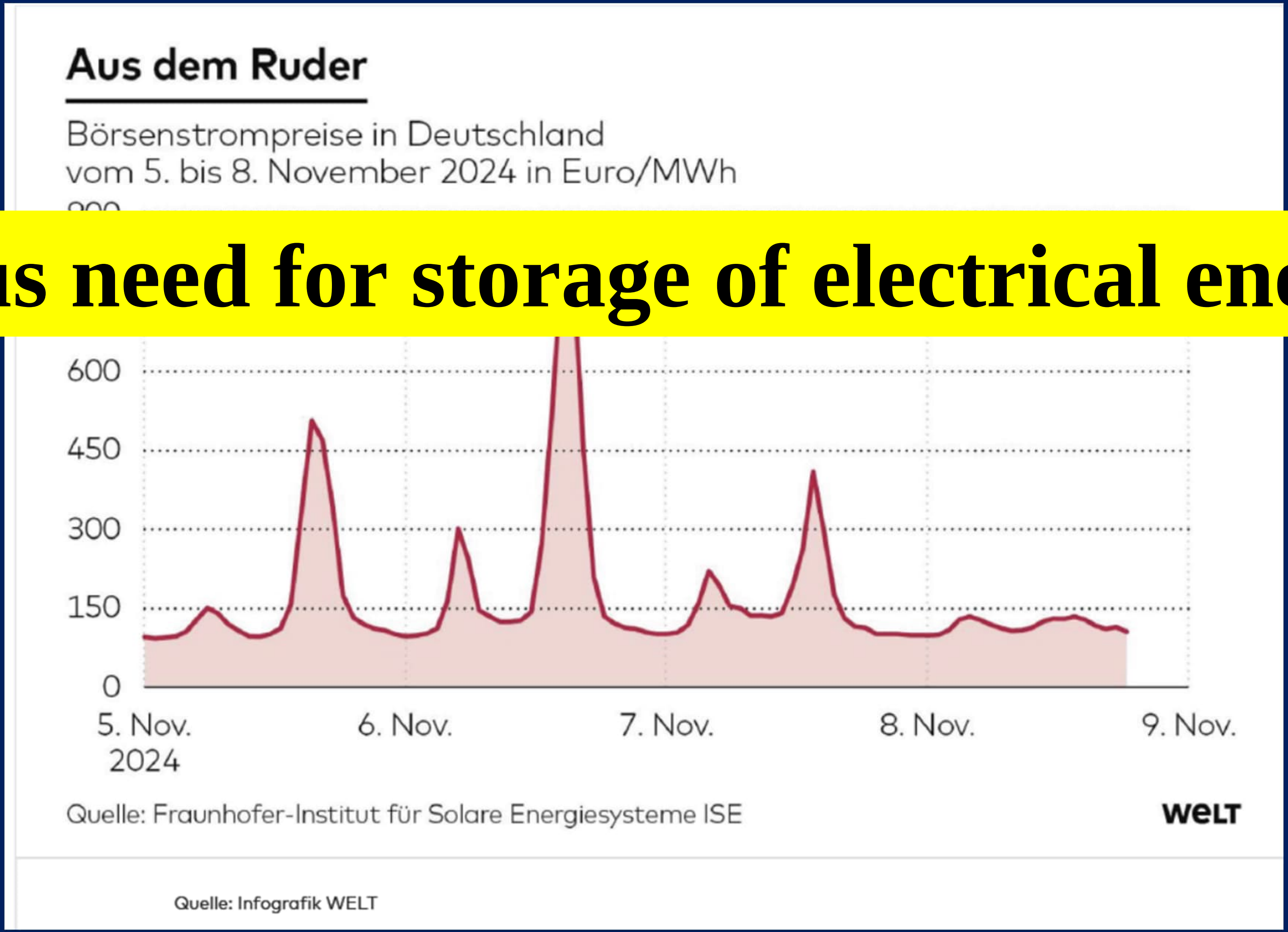
Which power fluctuations can be expected in 2045 using only PV and WK?



Excess energy during day time in this April week is about 10 TWh
Deficit (night) is about 3 TWh

Therefore, we need huge short-term storage devices which can store energy for hours to several days.

A further important aspect: How do these fluctuations affect electricity prices?



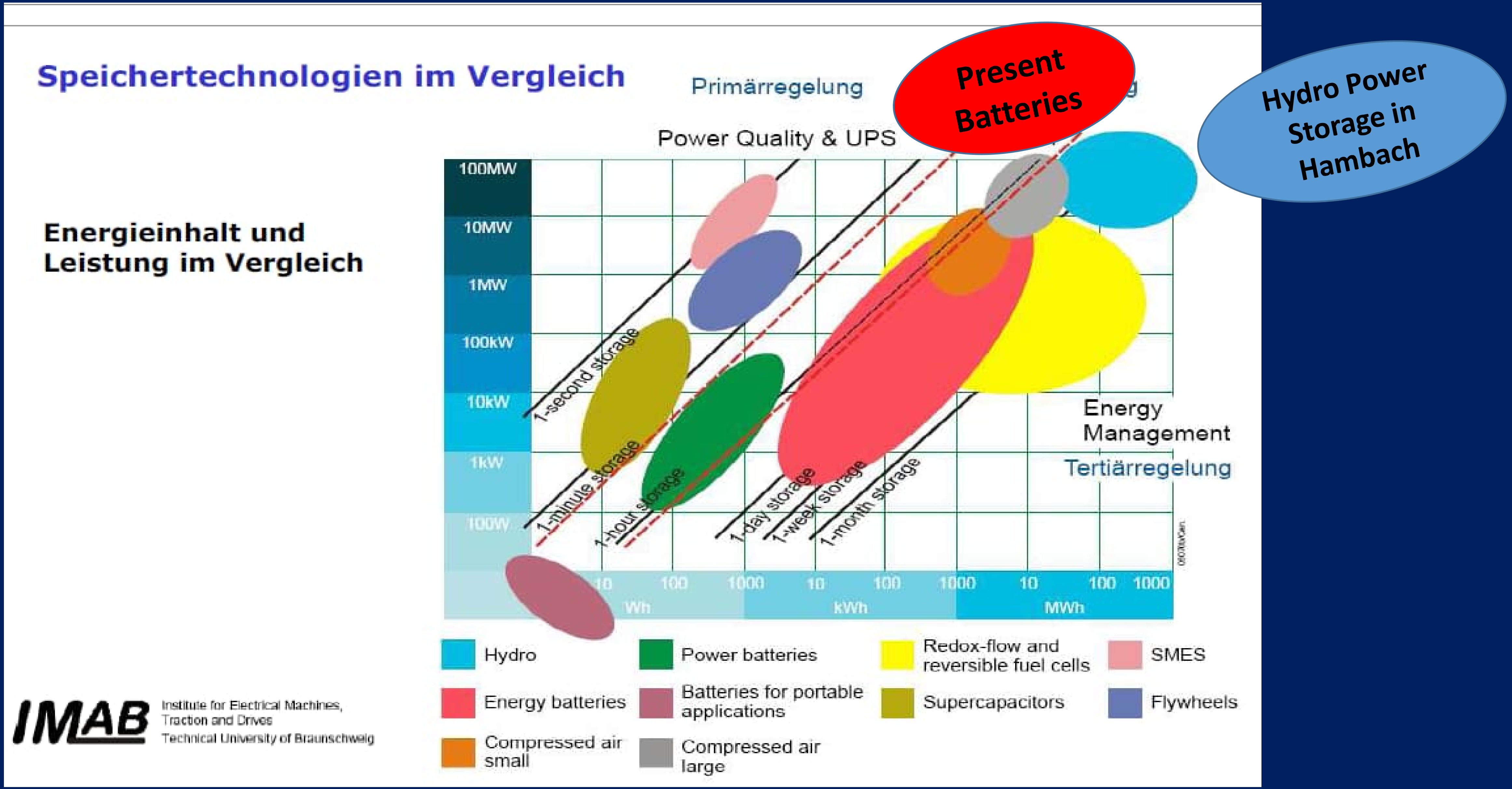
Thus need for storage of electrical energy.

These fluctuations are the tool used by energy suppliers to create power outages and thus make electricity very expensive!

Many different methods of storing electrical energy are currently being discussed, tested and used.

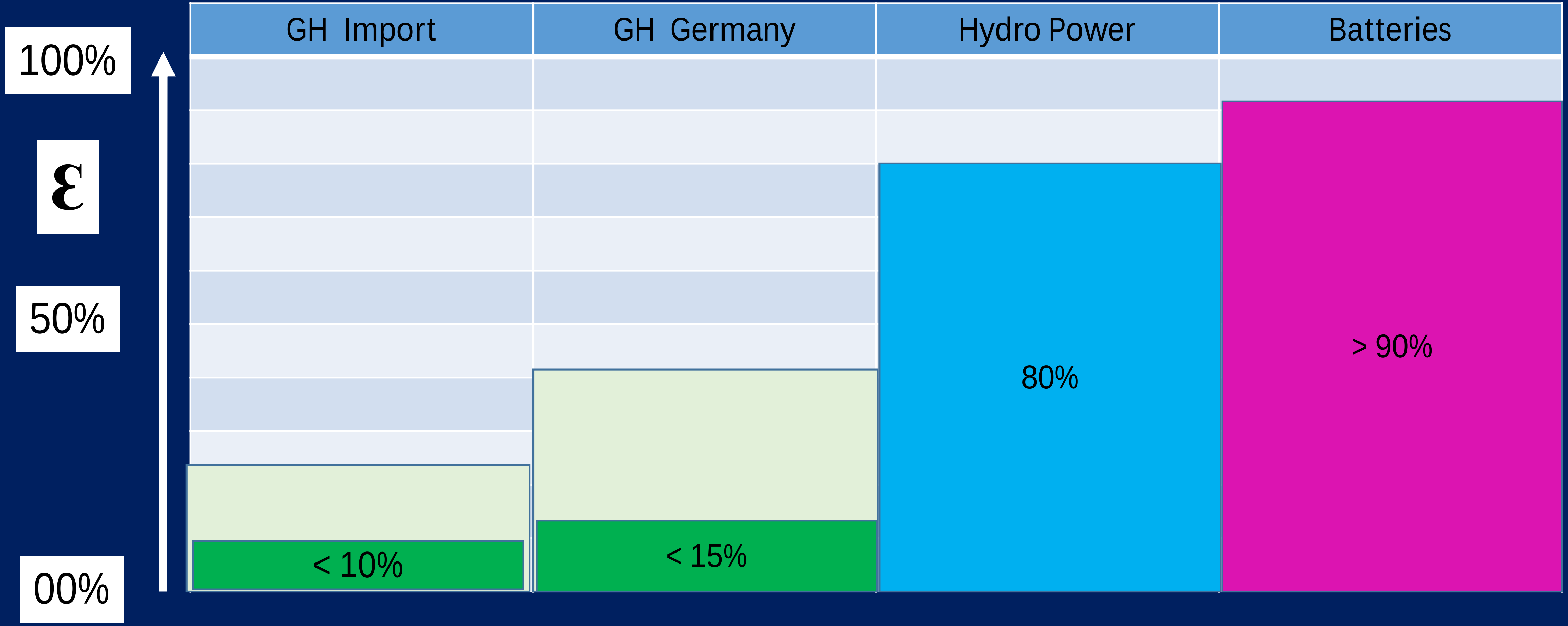
Like green hydrogen, batteries such as lithium-ion batteries and pumped water storage.

A survey of technologies storing electrical energy cheaply and on a large scale?

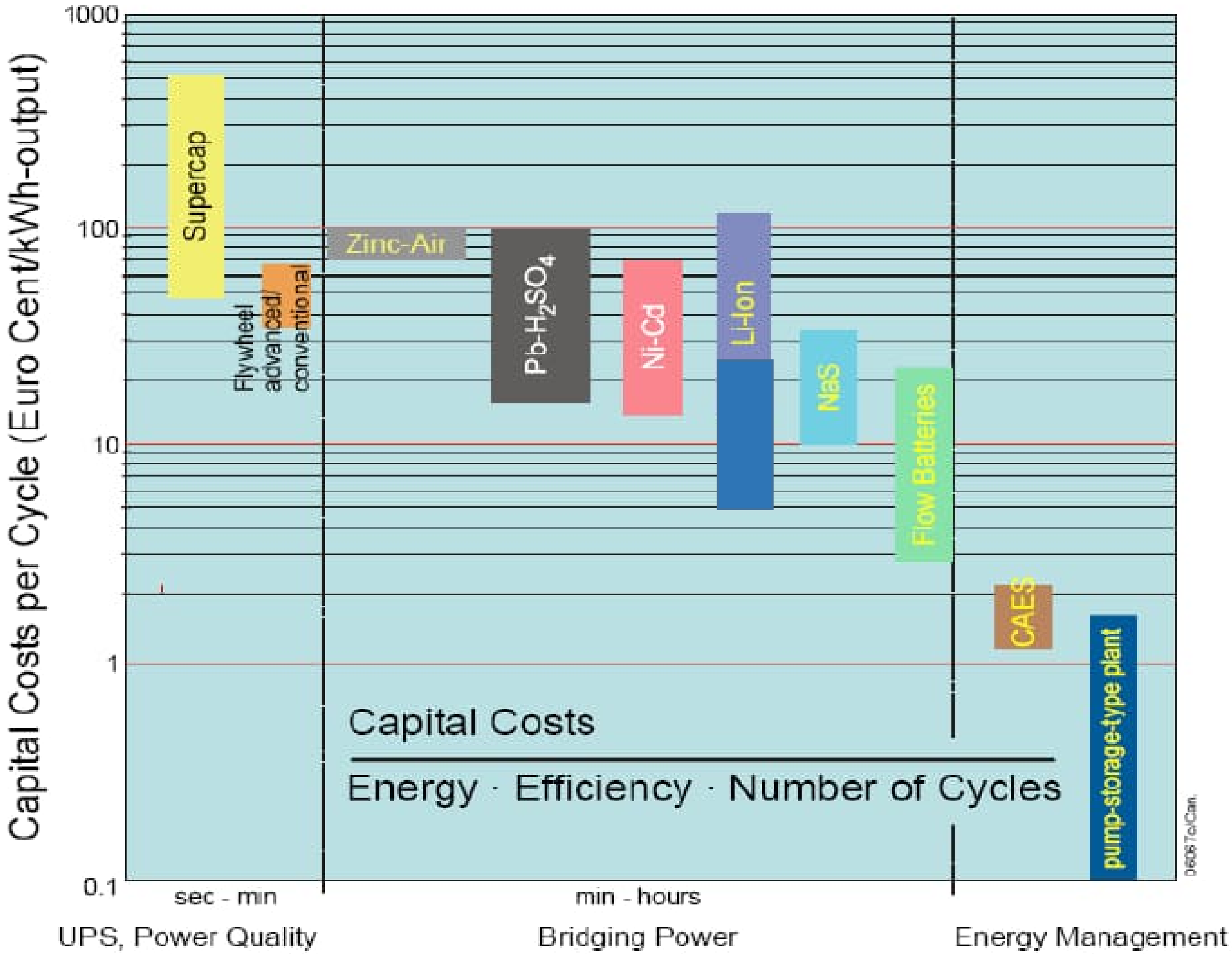


Energy storage efficiencies of electricity (losses)

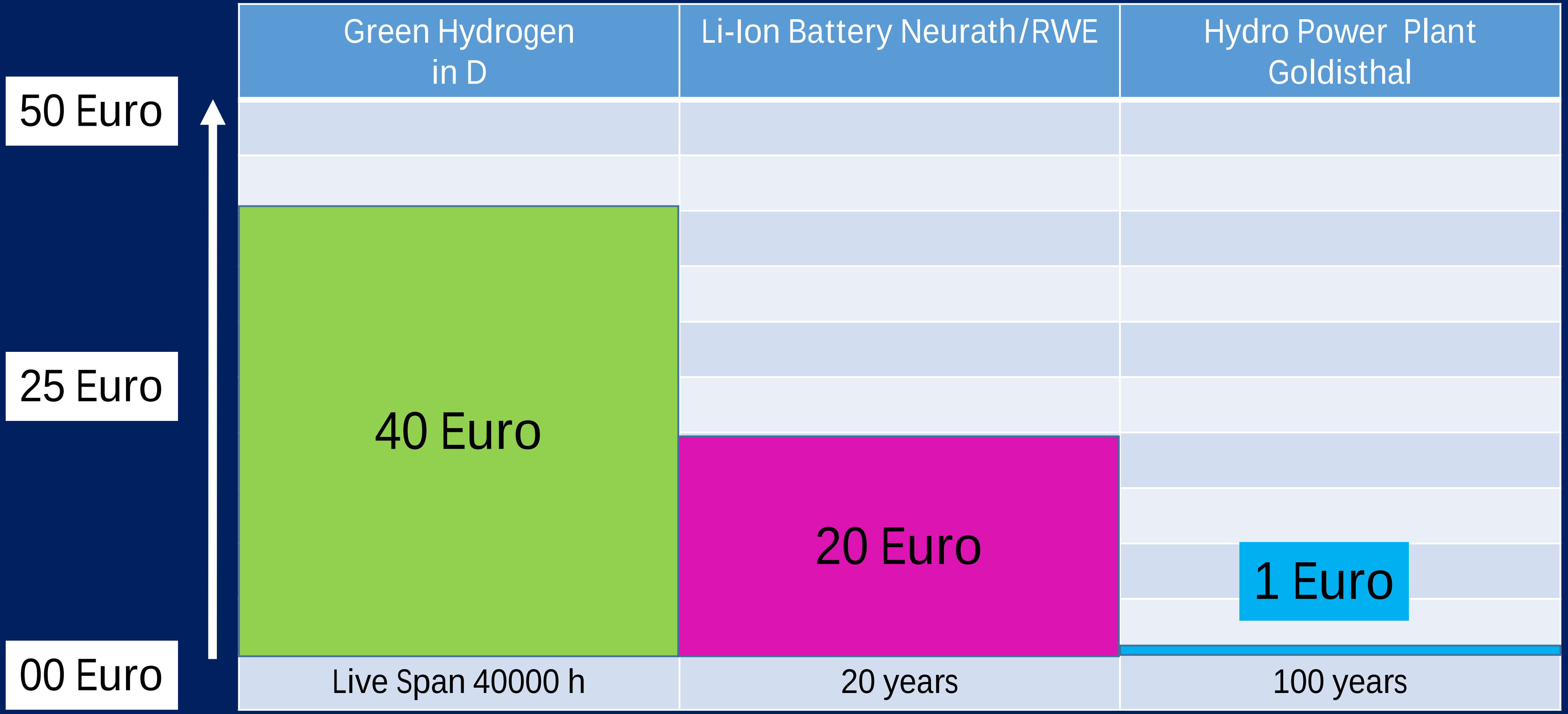
$\varepsilon = E_1 / E_0$



Energiespezifische Investitionskosten bei Berücksichtigung von Wirkungsgrad und Lebensdauer



Expenses per 1 kWh Energy Storage Capacity and per 1 year of Live Span



Requirements for short-term storage technologies:
High reconversion efficiency > 80%
Very high storage power > 100 GW
and huge Storage capacity > 1 TWh
Low storage costs (consumer) < 6 cents/kWh

Suitable short-term storage options are therefore only
hydro power storage and batteries (e.g., Li-ion, Na-ion, ...)

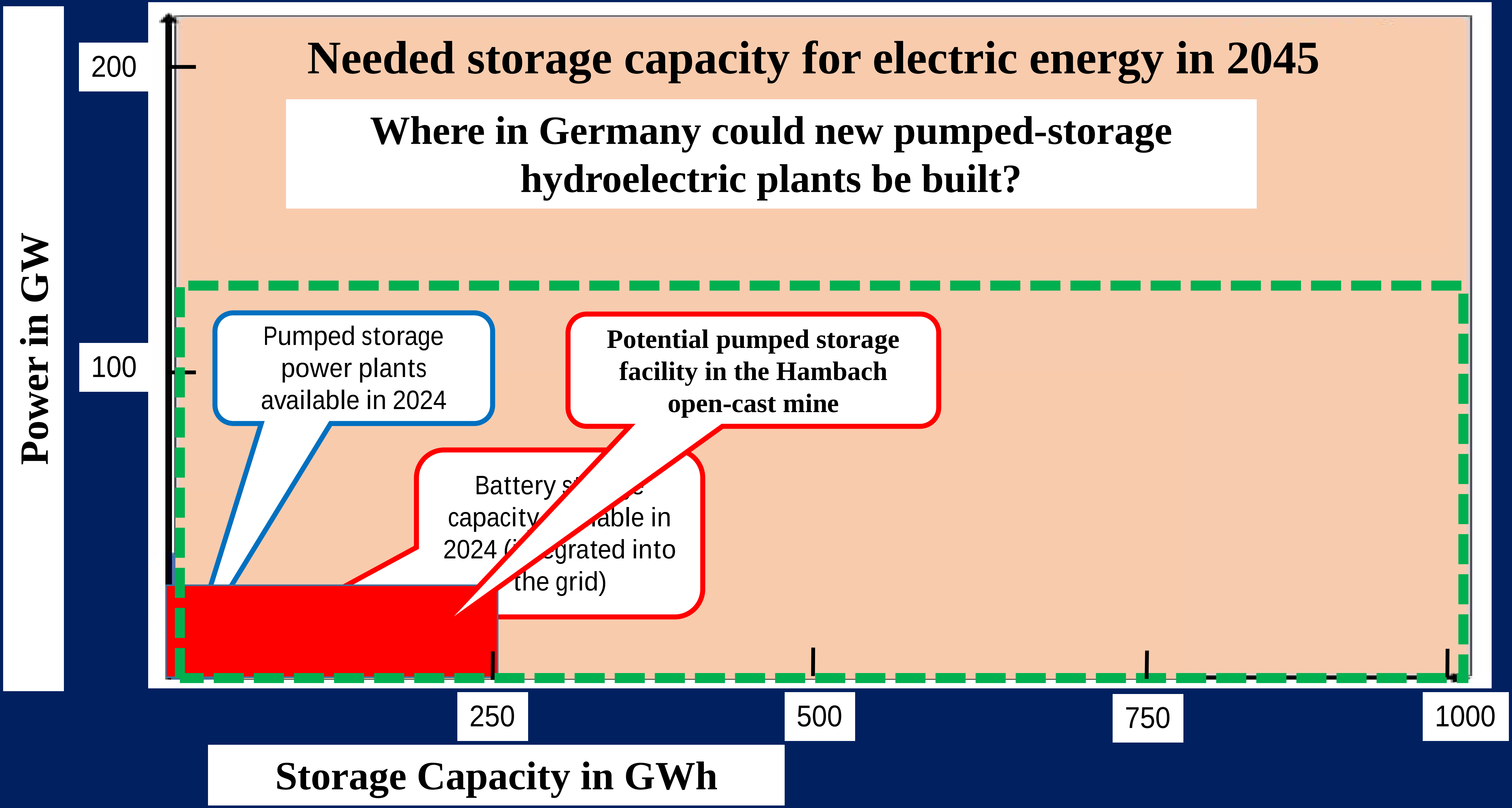
Green hydrogen technology is eventually suitable for reconversion to electricity
for long-term storage (winter lull)
as well as for use in the chemical and steel industries.

Technology and economic efficiency of batteries (e.g. Li-ion or Na-ion batteries)

Advantages:
Variable storage capacity 5 kWh to 500 MWh (mobility, home storage)
Very high variable power.
Mostly “small” private investment

Disadvantages:
Manufacturing requires rare raw materials (dependent on foreign imports), (not environmentally friendly),
Limited lifespan of 15-20 years only,
High demand due to mobility and household needs,
Can catch fire or explode
Low voltage (< 400 volts) => requires new electric transmission grid (very expensive).

High investment costs (example):
RWE is building a 235 MWh lithium-ion storage facility in Neurath
Cost: 140 million Euro => 600 Euro/kWh, plus:
approximately 5 times shorter lifespan than turbines in pumped storage power plants
=> 3000 Euro/kWh



Needed storage capacity for electric energy in 2045
Where in Germany could new pumped-storage hydroelectric plants be built?
Power in GW
200
100
Pumped storage power plants available in 2024
Potential pumped storage facility in the Hambach open-cast mine
Battery s
capacity
able in
2024 (i
egrated into
the grid)
250
500
750
1000
Storage Capacity in GWh

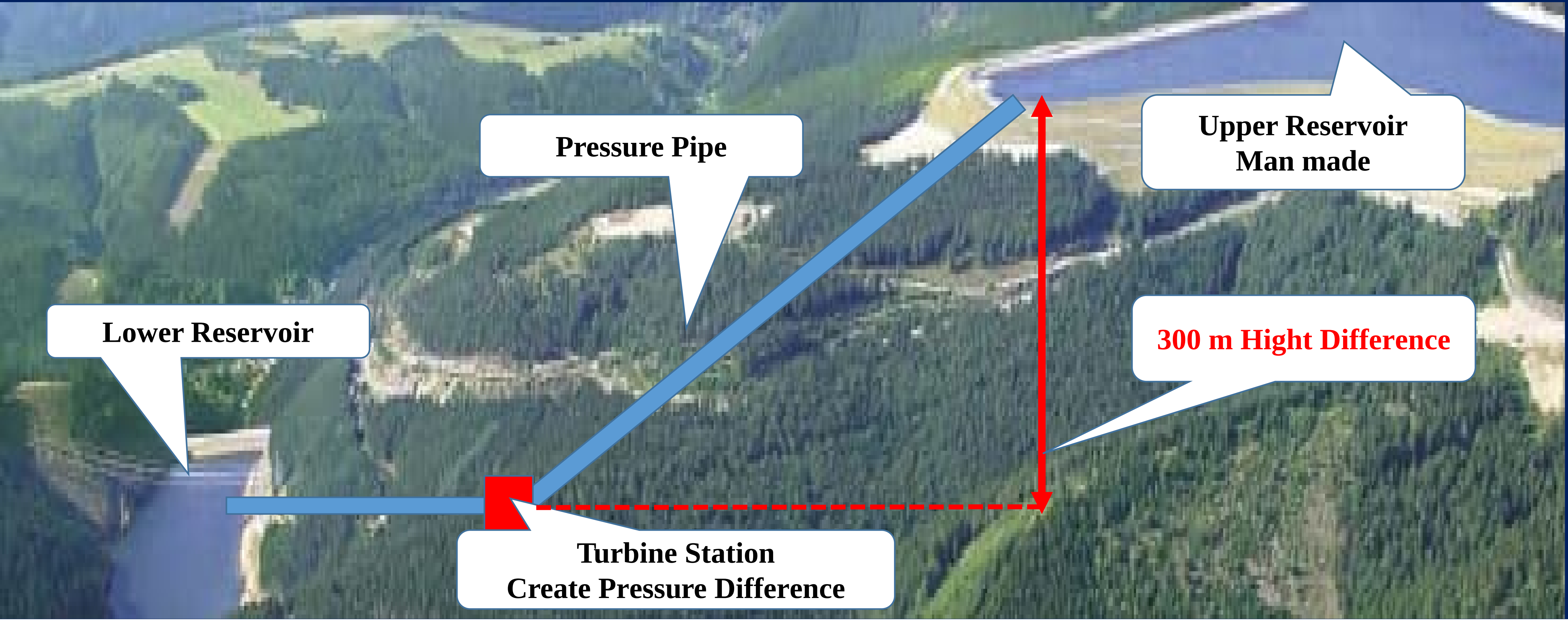
2. Hydro power storage systems

Pumped storage power plants have so far in Germany mainly been built in the low mountain ranges.

So far, all attempts to build new large pumped-storage power plants have failed. For example, in the Eifel and Black Forest regions.

Bavaria is building a new pumped-storage power plant on the Danube (2-3 GWh).

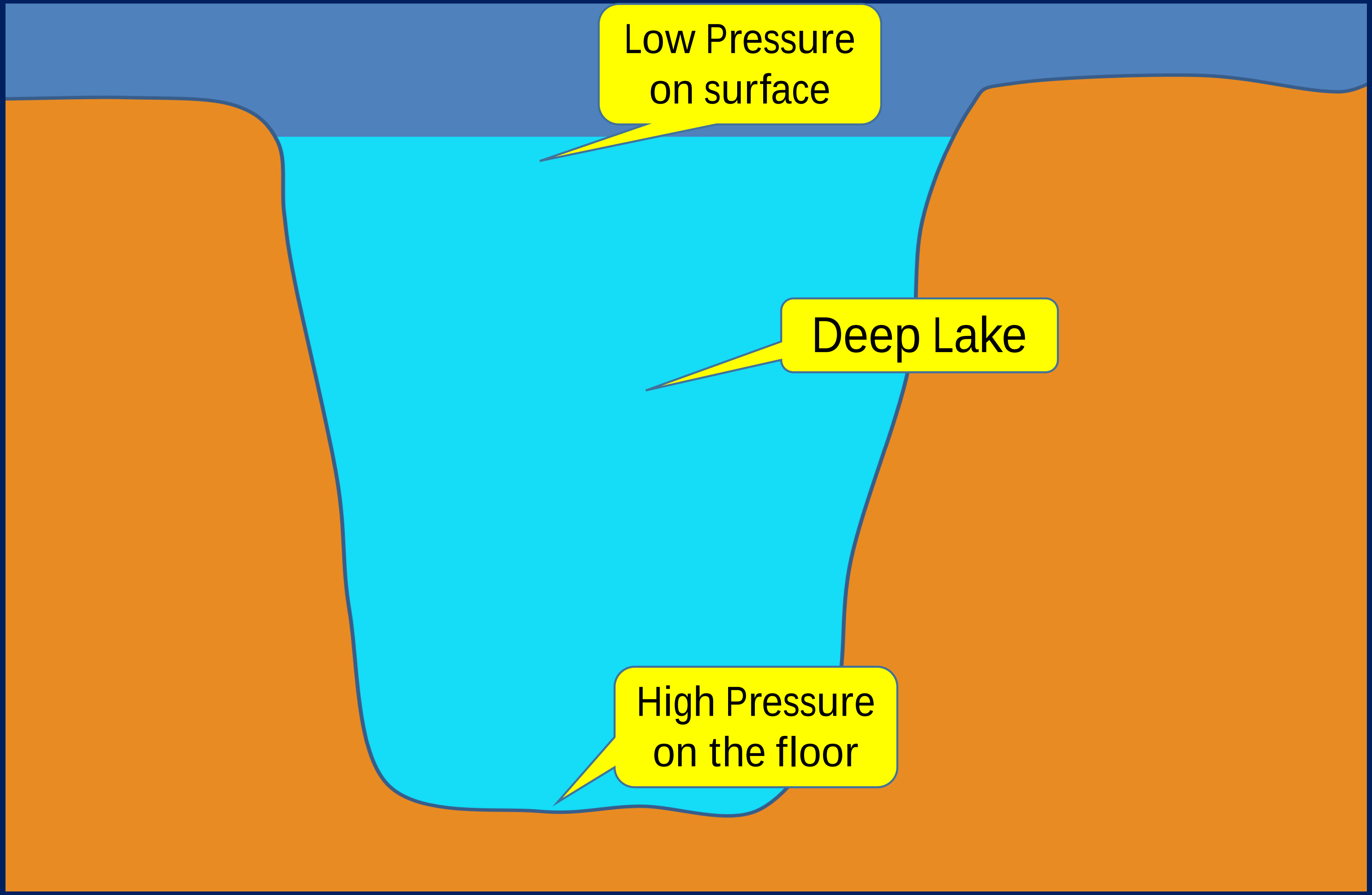
Example of a traditional pumped storage power plant: Goldisthal/Thuringia



PSKW Goldisthal / Thüringen

1060 MW Power and 8,5 GWh Storage Capacity (1 Nuclear Power Station 8,5 h)

New concept of a Hydro Power Storage on the floor of the ocean or of a deep lake



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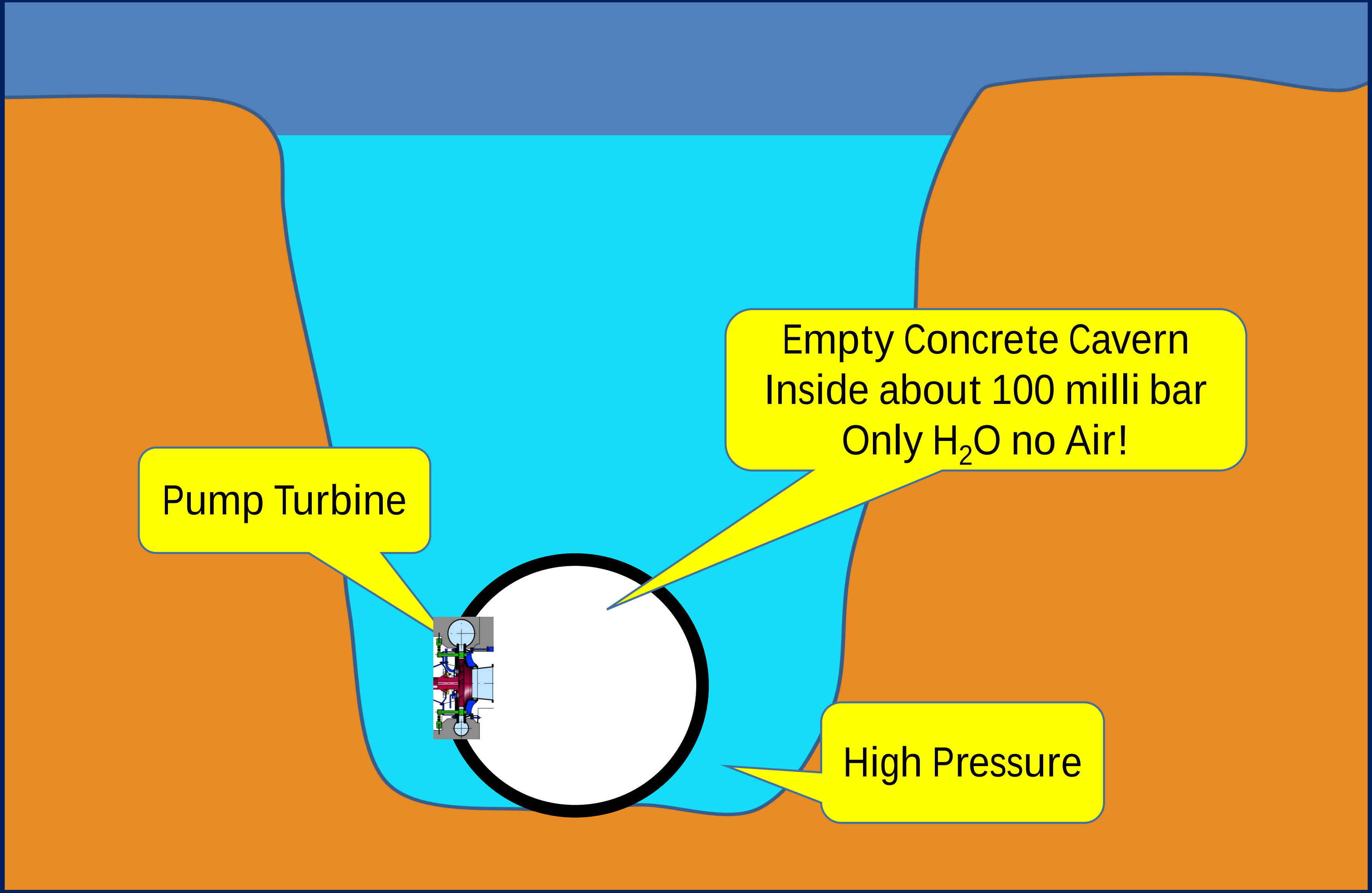
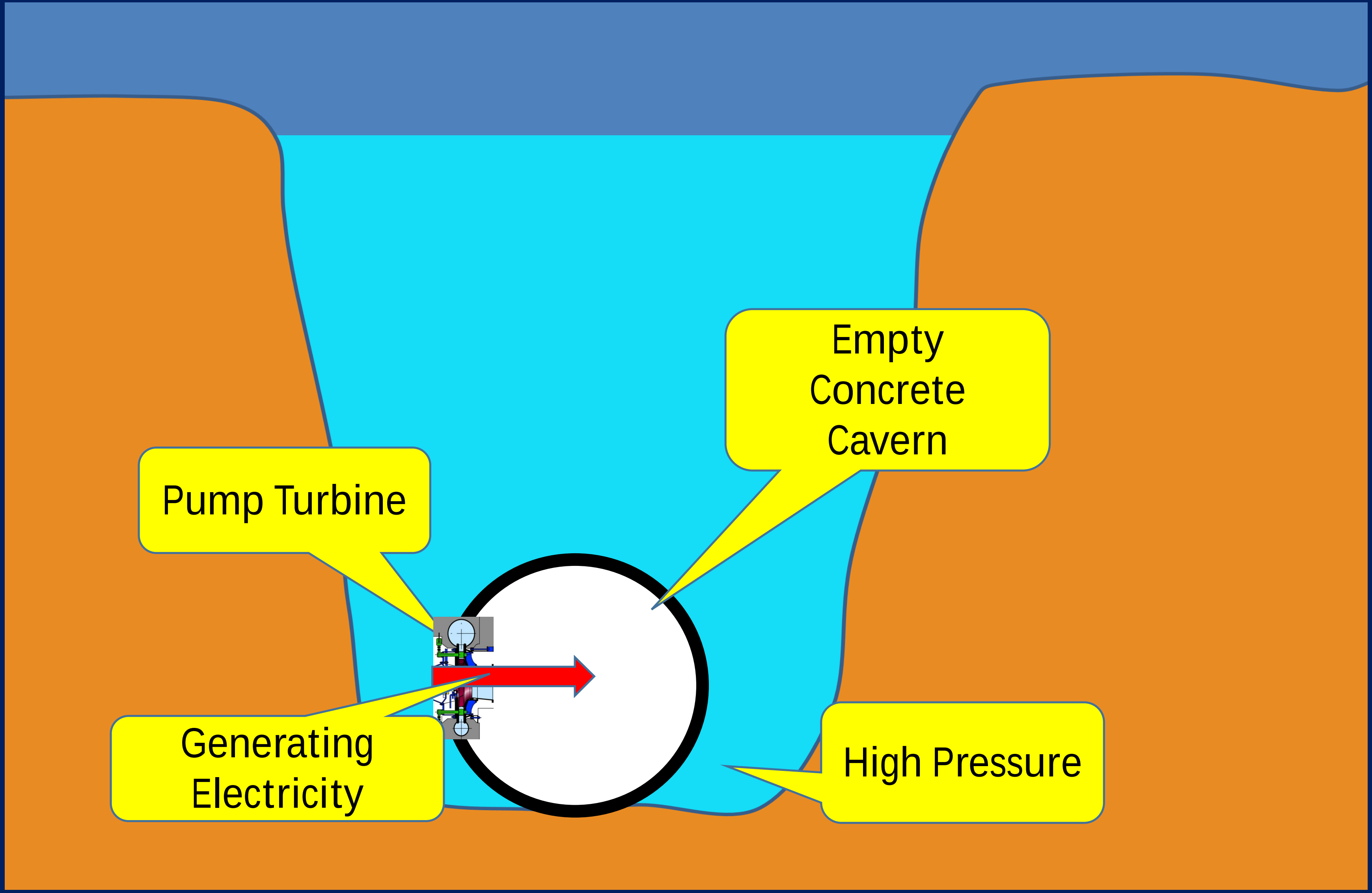
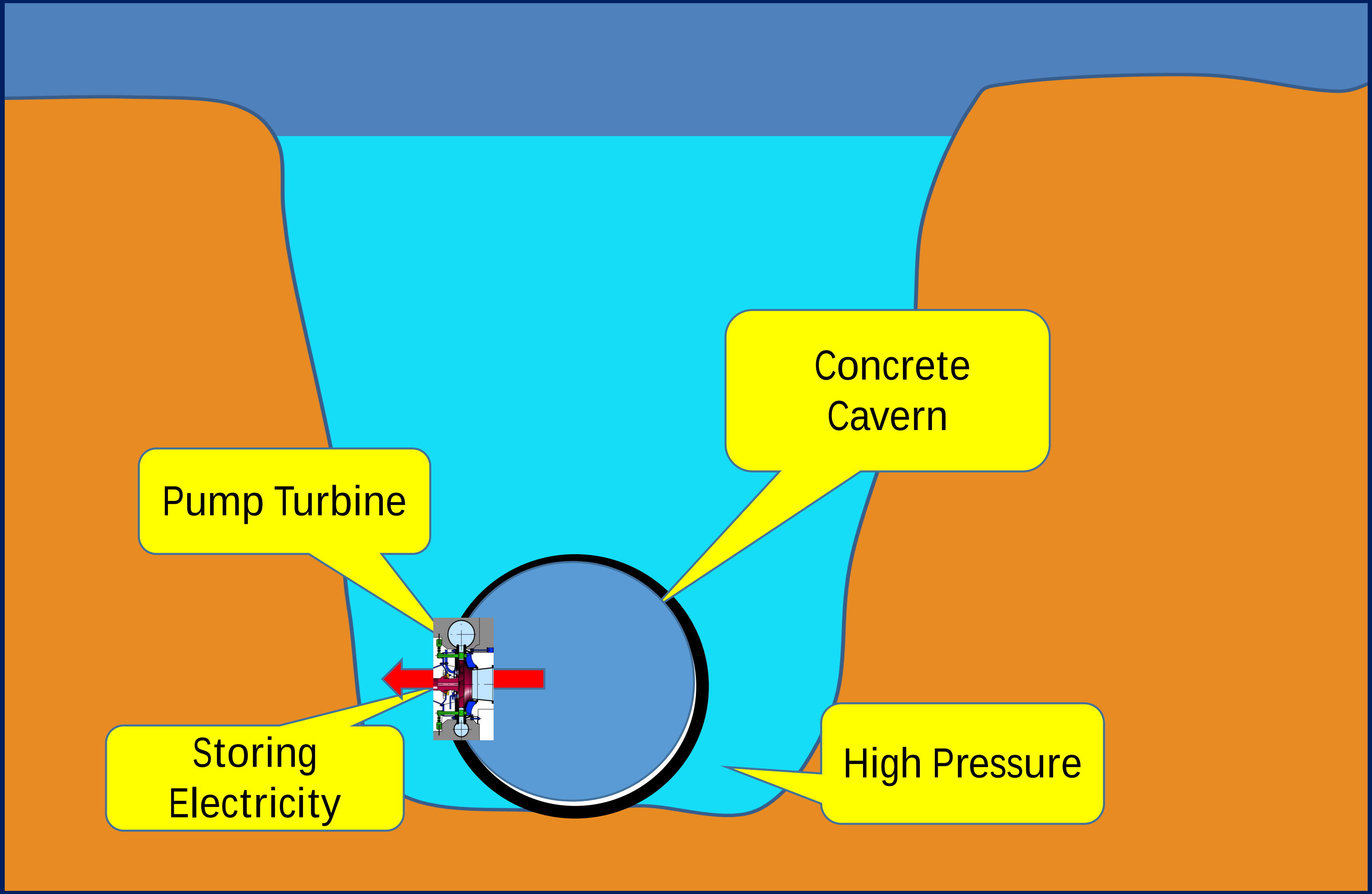


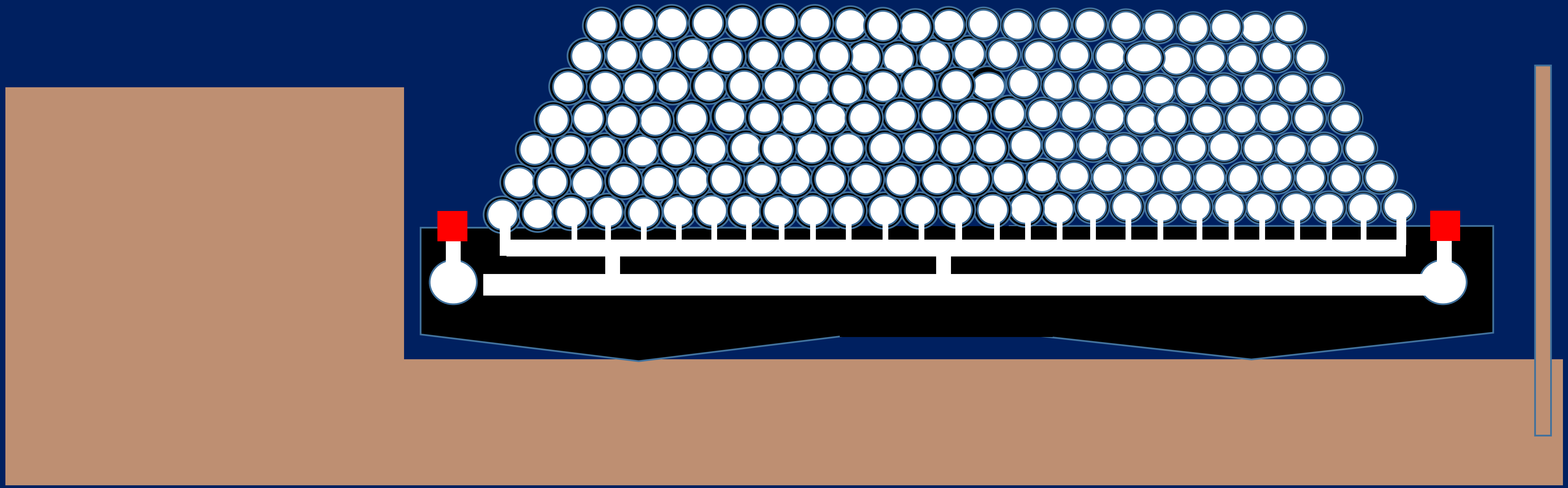
New concept of a Hydro Power Storage on the floor of the ocean or of a deep lake

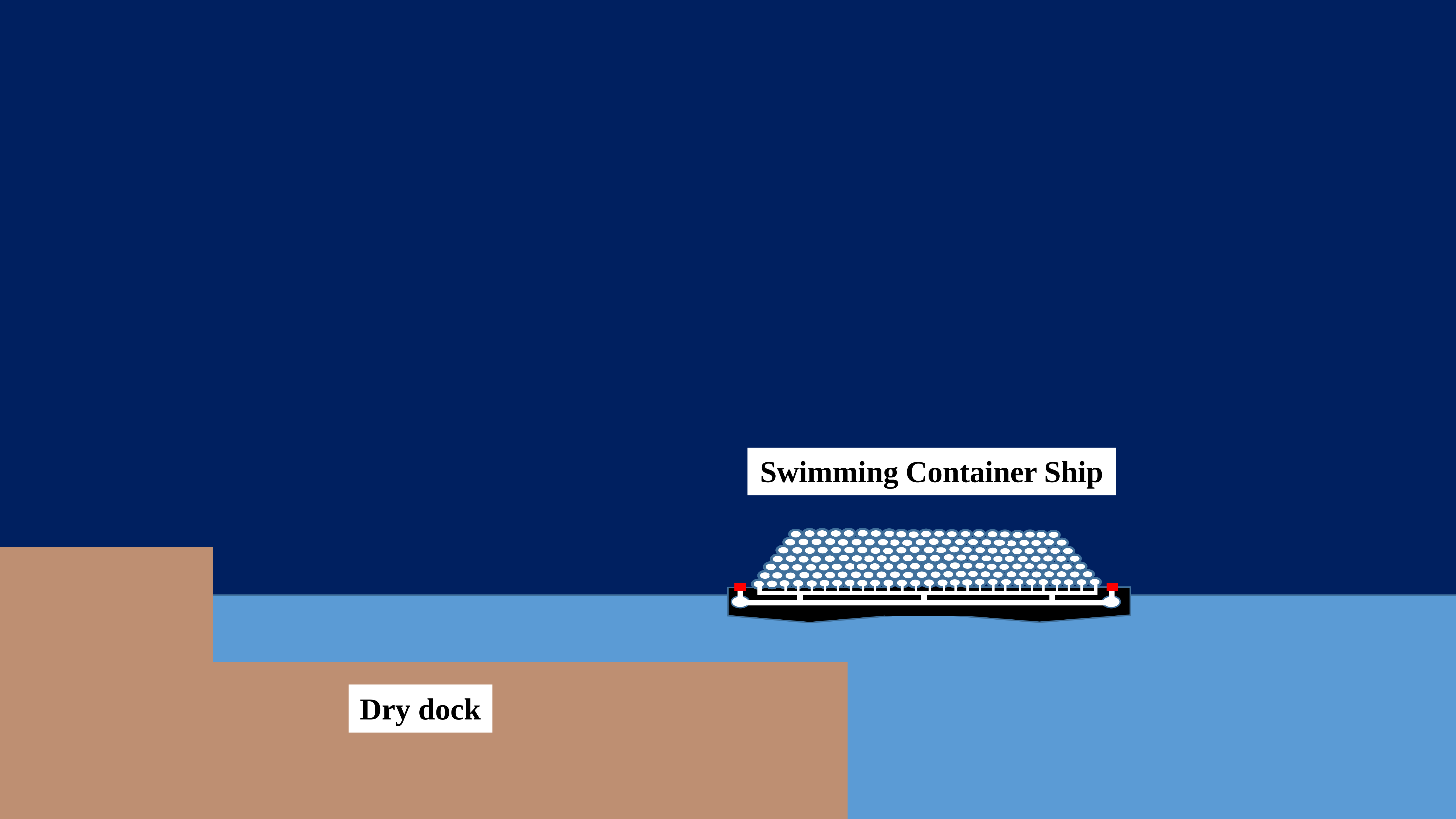


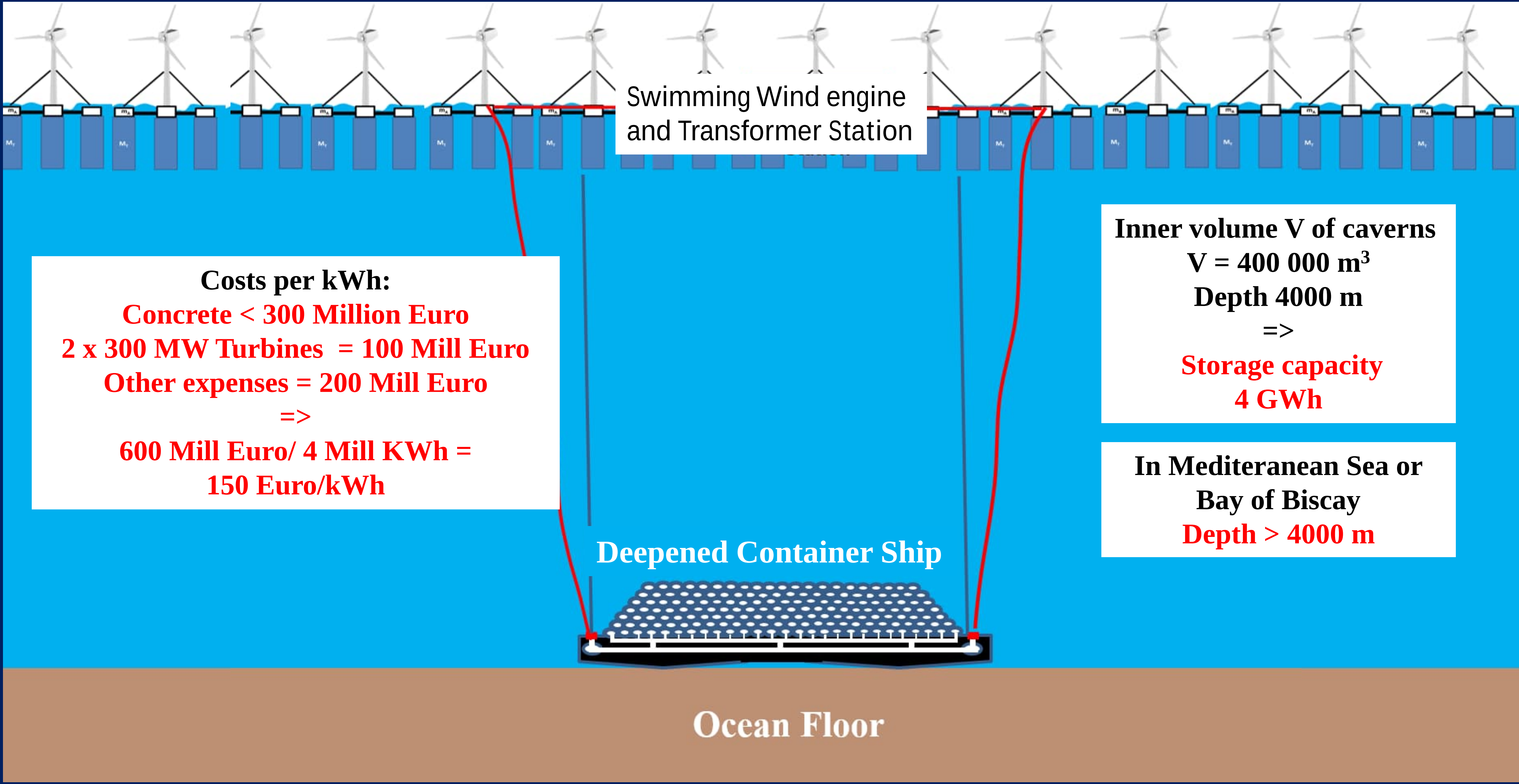
New concept of a Hydro Power Storage on the floor of the ocean or of a deep lake



Construction of Container Ship (Cavern system) in Dry Dock:
Red squares: two 200 MegaW Turbines




Swimming Container Ship
Dry dock


Swimming Wind engine
and Transformer Station
Costs per kWh:
Concrete < 300 Million Euro
2 x 300 MW Turbines = 100 Mill Euro
Other expenses = 200 Mill Euro
=>
600 Mill Euro/ 4 Mill KWh =
150 Euro/kWh
Inner volume V of caverns
V = 400 000 m³
Depth 4000 m
=>
Storage capacity
4 GWh
In Mediteranean Sea or
Bay of Biscay
Depth > 4000 m
Deepened Container Ship
Ocean Floor

STENSEA – Die bauliche Konzeption eines Tiefsee-Energiespeichers

STENSEA === STorage of ENergy in SEA

StEnSea - Stored Energy in the Sea (fraunhofer.de)

Forschungsprojekt Stensea - HOCHTIEF Engineering (hochtief-engineering.de) im Bodensee 2016 getestet.

Zeitschrift, :Bauingenieur, Organ des VDI für Bautechnik, Springer Verlag, Bd 88, Juli/August 2013

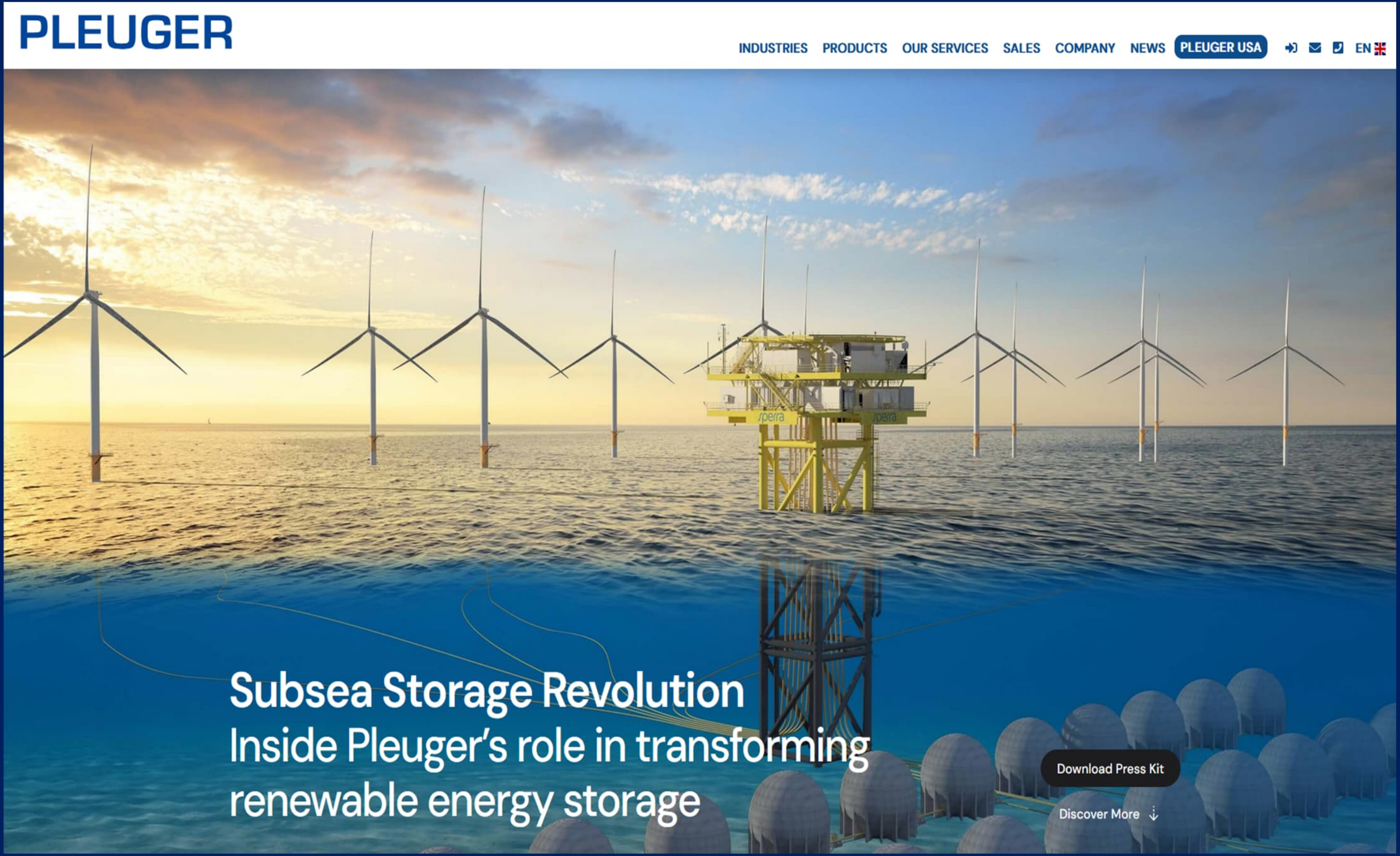
J. Bard IWES Fraunhofer Institut Kassel
M. Meyer Hoch&Tief Frankfurt/Essen
plus Uni-Stuttgart-Voith / Turbinen

Idee und Patente 2011 Horst Schmidt-Böcking und Gerhard Luther

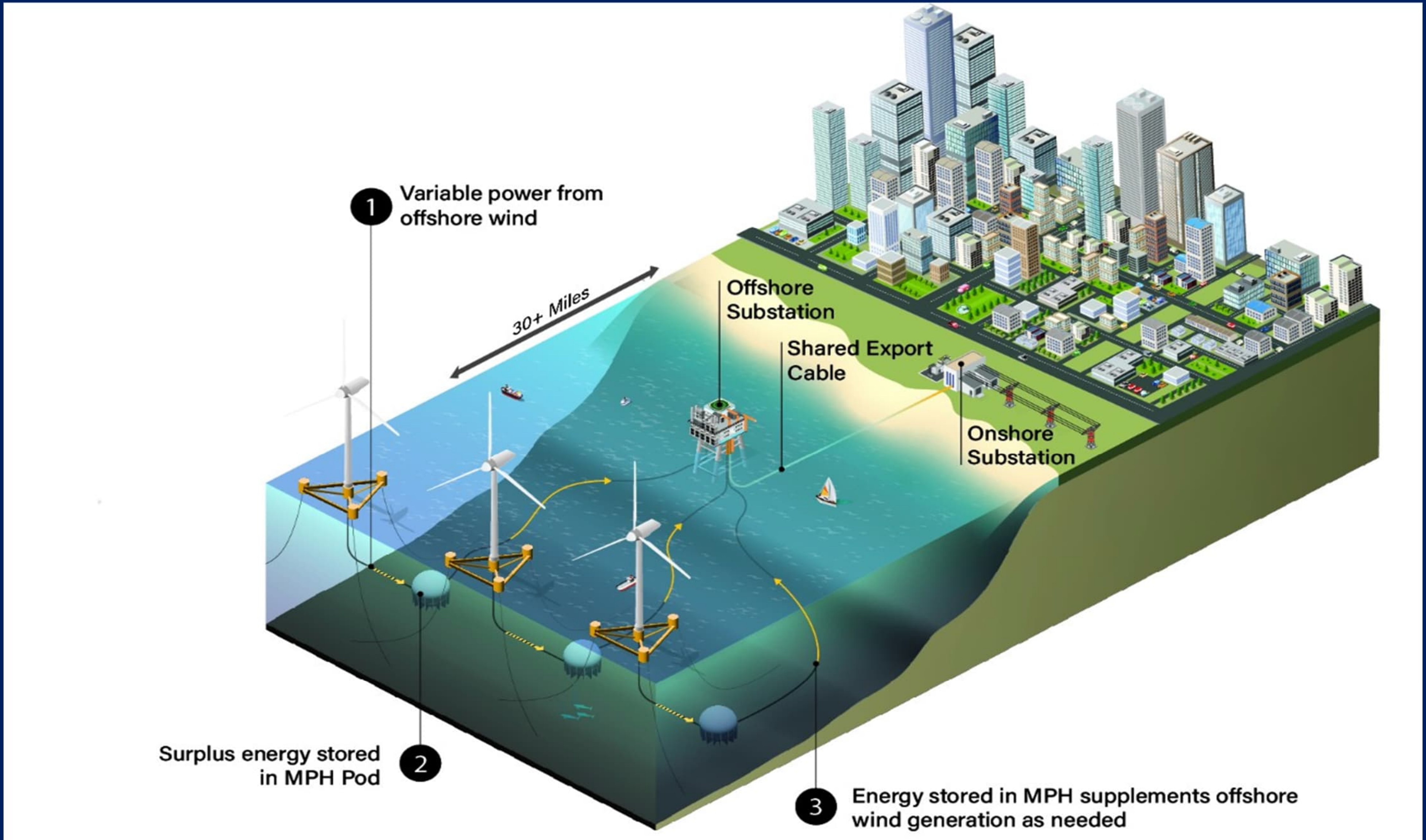
Test im Bodensee in 100 m Tiefe
Nov. 2016

GERMAN RENEWABLES
2017 AWARD
TECHNOLOGY | SYSTEMS | MARKET

Fraunhofer IEE and Partners planed a Spherical Energy Storage System on the Seabed off the California Coast   November 2024 (and in Norwegian trench)



Huge global potential

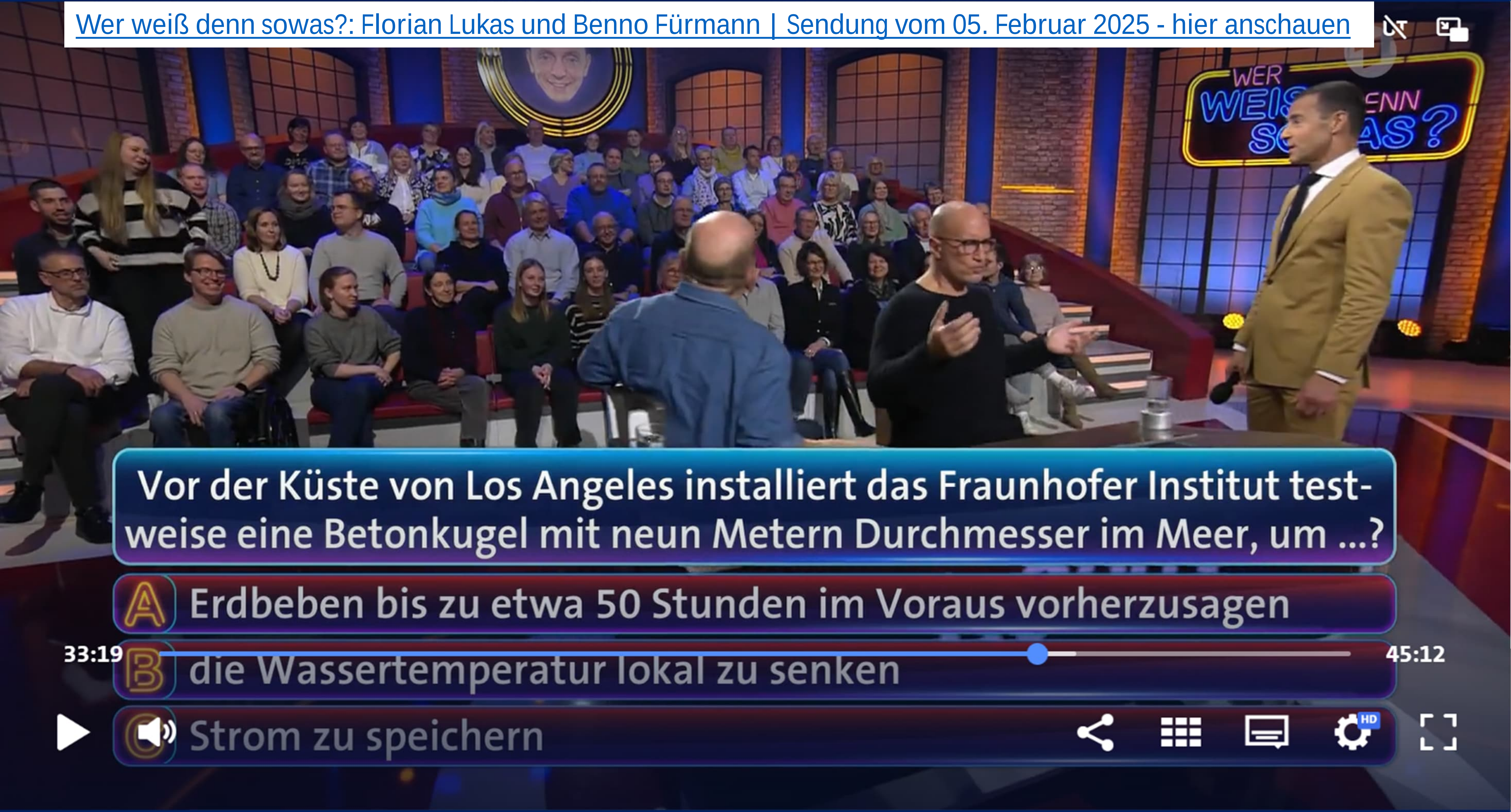


© sperra

Installation im tiefen Wasser zusammen mit schwimmenden Windkraftanlagen.

120m
35m

[Wer weiß denn sowas?: Florian Lukas und Benno Fürmann | Sendung vom 05. Februar 2025 - hier anschauen]



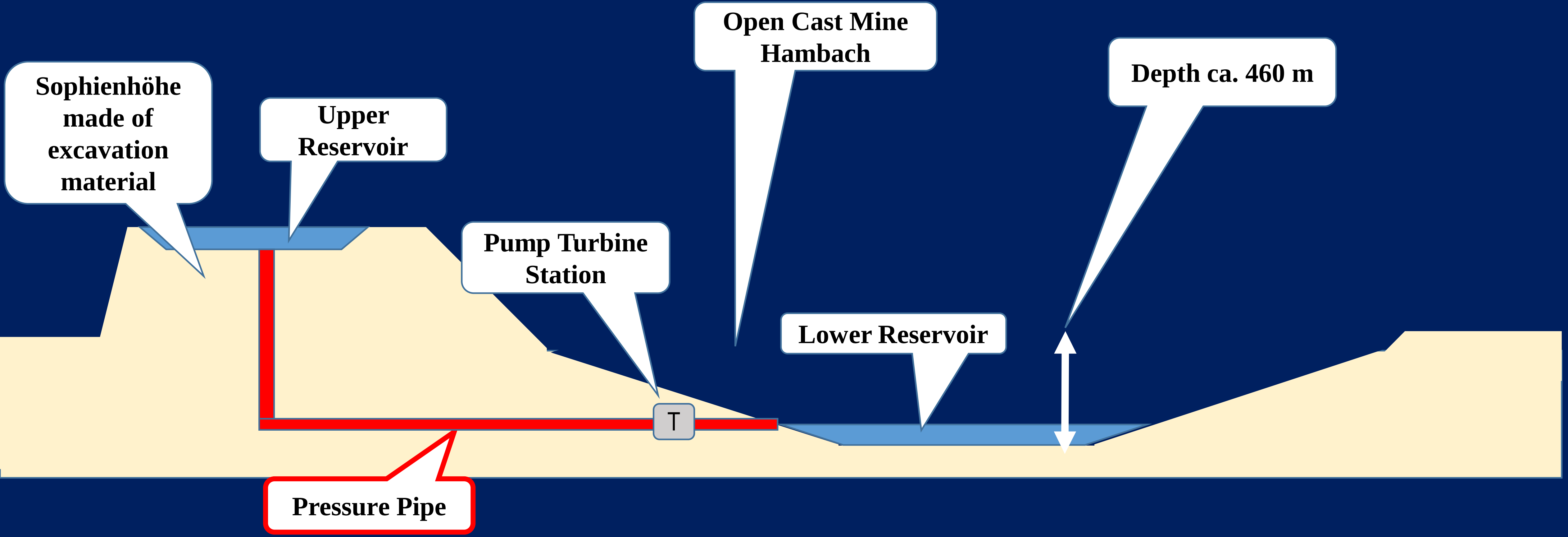
3. Hydro Power Storage Plants in Lignite Open-Cast Mines

Ministerium für Wirtschaft, Innovation,
Digitalisierung und Energie
des Landes Nordrhein-Westfalen

Concepts for the energetic re-use of open-cast mining pits

Final Sate of the U-PSKW in the recultivated Hambach open-cast mine

2019 Proposal MWIDE WI-E-0048



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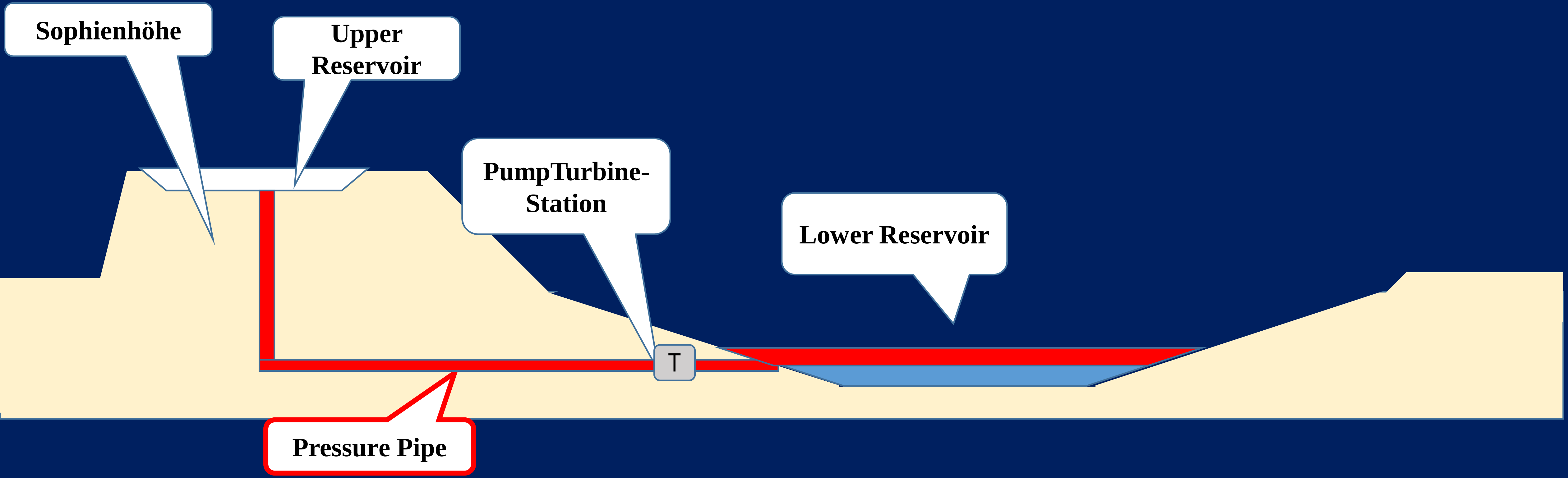
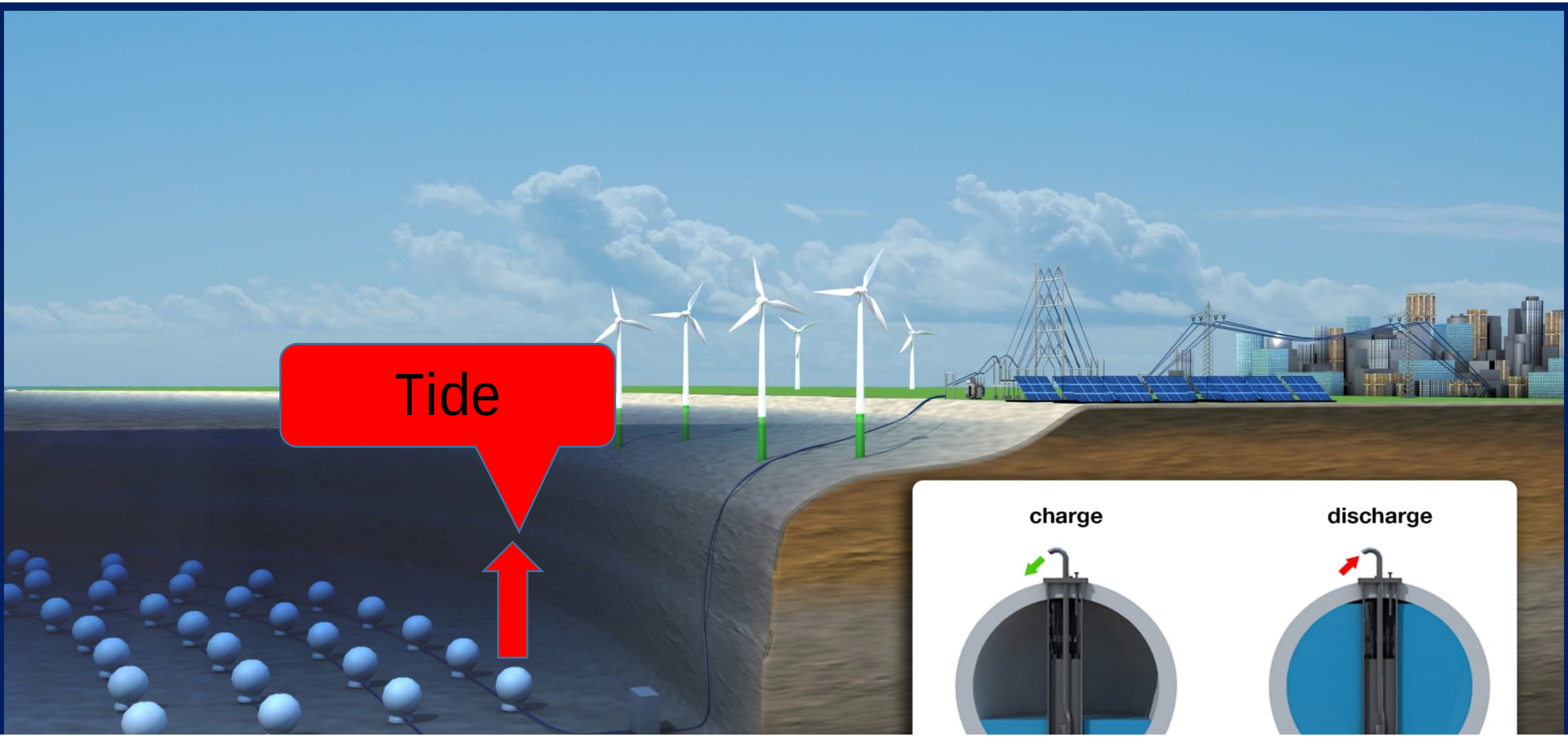


The expert's proposal would impede the flooding of the open-cast mine and thus the recreational area with its large lake for water sports and relaxation. Furthermore, the Sophienhöhe area would no longer be available as a recreational area. and Groundwater problem

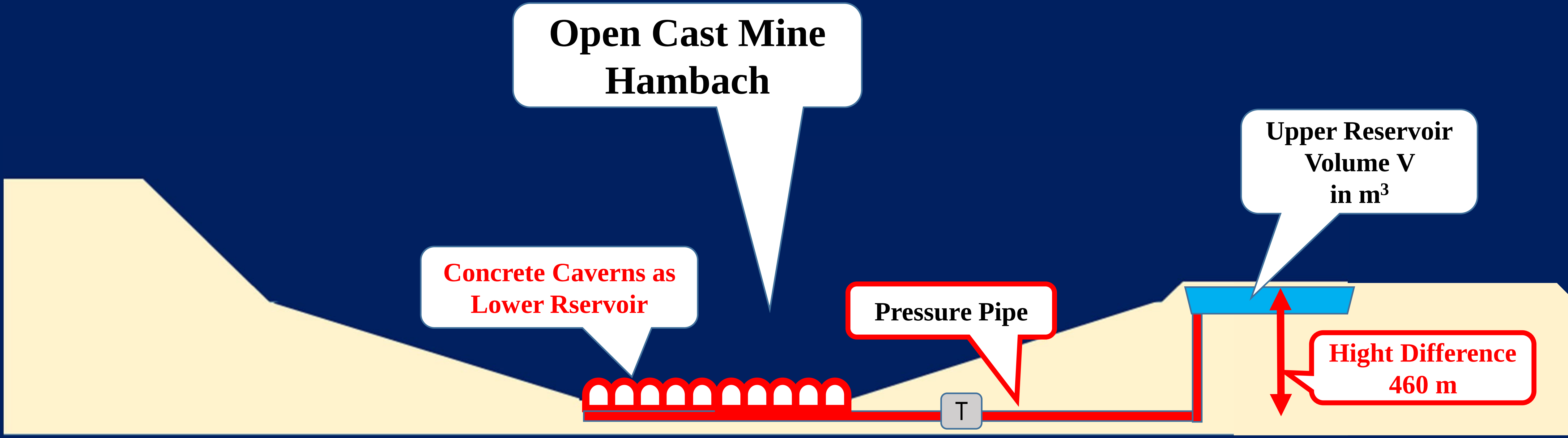
The "Outlook" section of the report (page 162) points to the construction of an underwater cavern pumped storage power plant (U-PSKW) as the better solution and calls for a further report on this.



This concept is uneconomical and has significant disadvantages:

1. Costs: 80 units, each with a storage capacity of 9000 kWh (total 1.72 GWh), cost €680 million. That's five times the cost per kWh compared to Goldisthal.
2. The concept requires a flooded open-pit mine, resulting in tidal fluctuations.
3. The spherical storage units are installed by floating them into place after partial flooding.

U-PSKW Concept with separated Upper Reservoir (z.B. Manheimer Bucht)
Cavern Principle

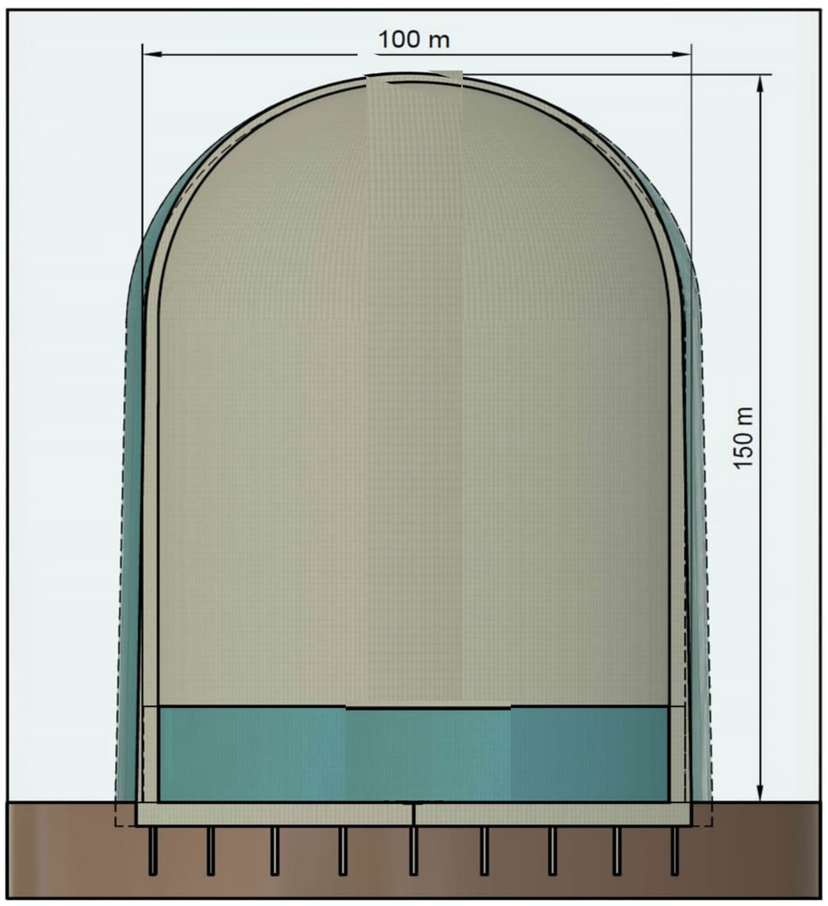


This submersible pumped-storage hydroelectric plant is completely separated from the open-cast mine lake, utilizing only the difference in elevation.

For $h \approx 400$ m and $V = 250$ Million m^3 => $S = 250$ [GWh]

This is sufficient to supply the entire state of North Rhine-Westphalia with electricity for approximately 16 hours.

Possible cavern structure => bell or tube shape, etc.
Many geometries are possible. Size is similar to nuclear power plant cooling towers.



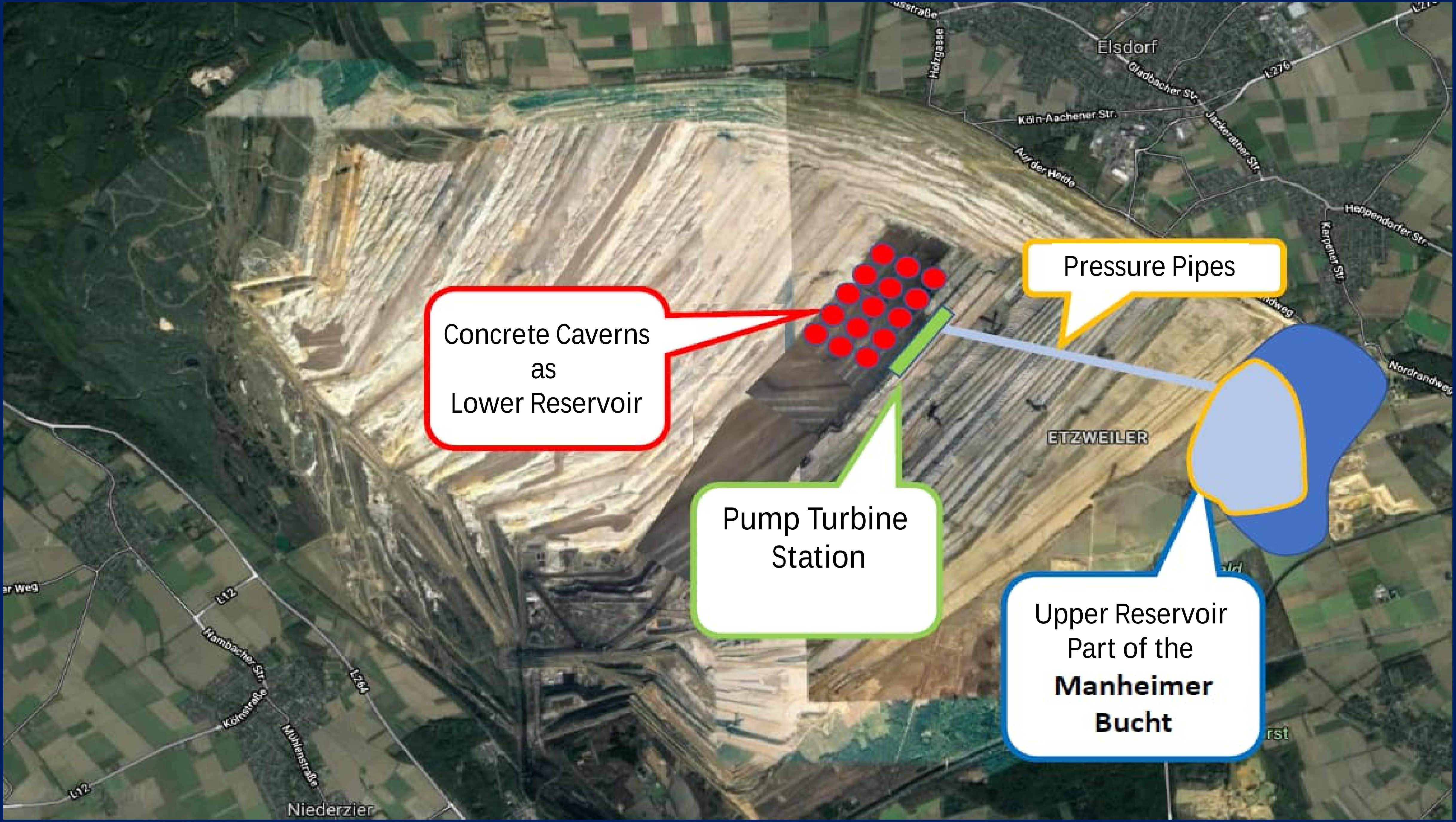
Prof. A. Garg und
Dr. T. Bender
Univ. of Applied Sciences-Mainz

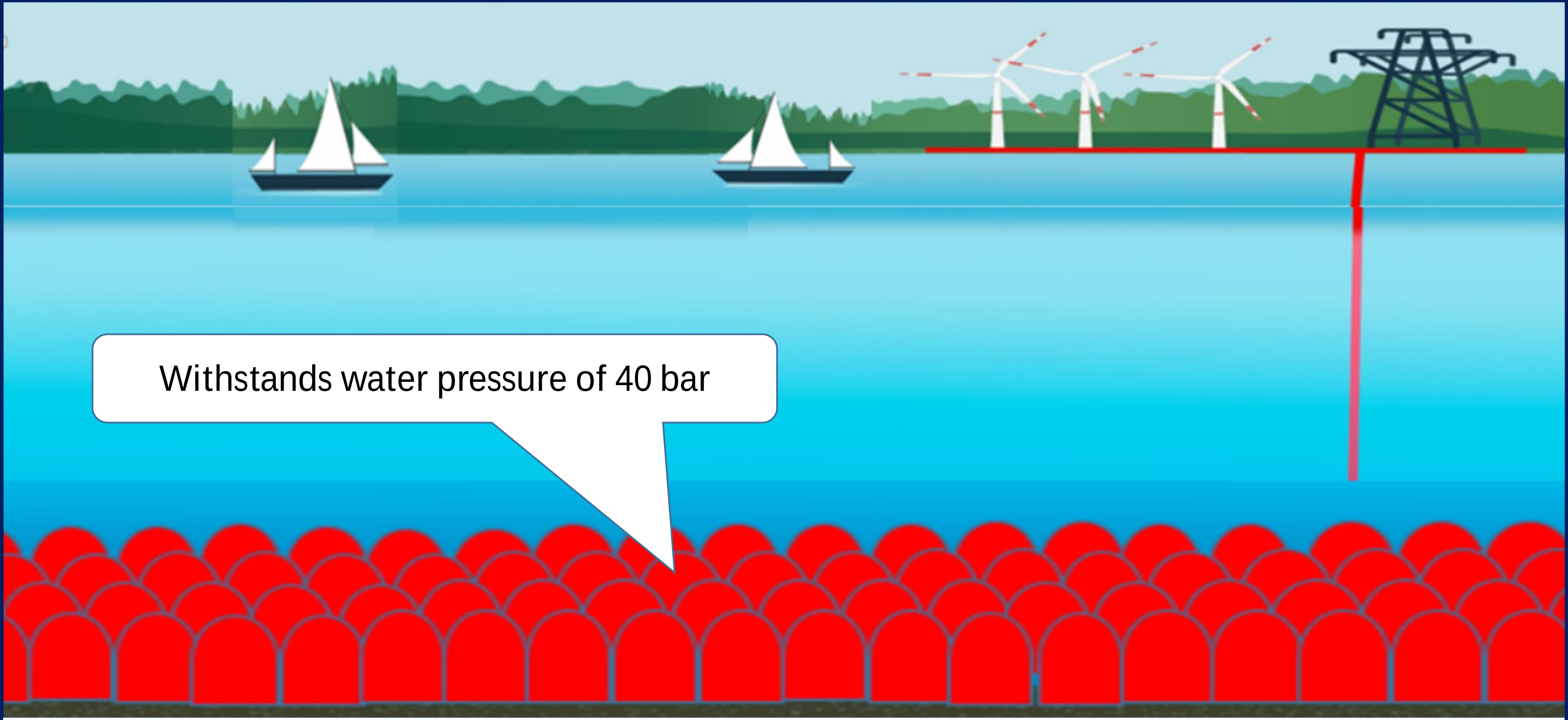
Possible cavern structure => bell or tube shape, etc.
Many geometries are possible.
Size is similar to nuclear power plant cooling towers.

Energy storage capacity per tower: 940 MWh

Final Sate of the U-PSKW in the recultivated Hambach open-cast mine

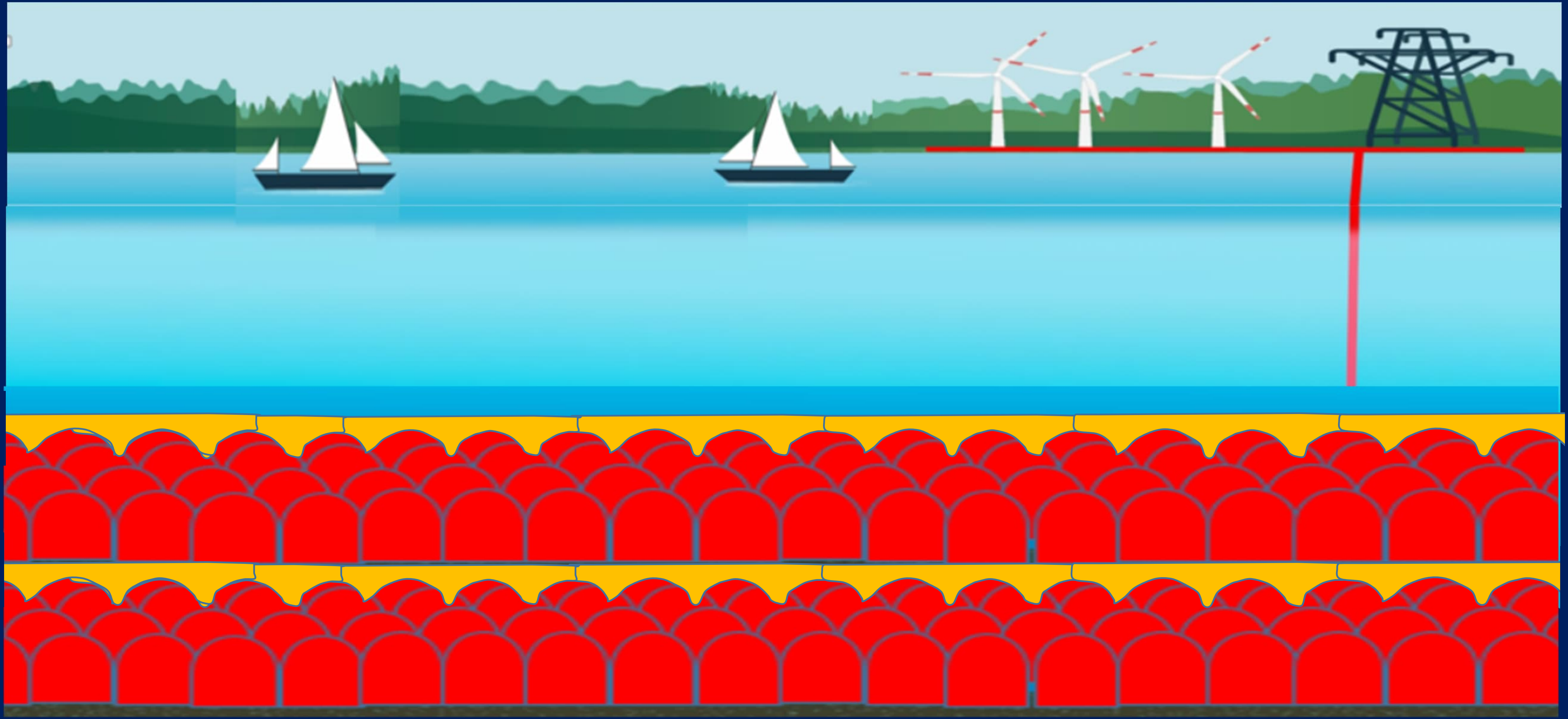
Installation of separated Upper Reservoir


Concrete Caverns
as
Lower Reservoir
Pressure Pipes
Pump Turbine
Station
Upper Reservoir
Part of the
Manheimer
Bucht
Elsdorf
ETZWEILER
Niederzier



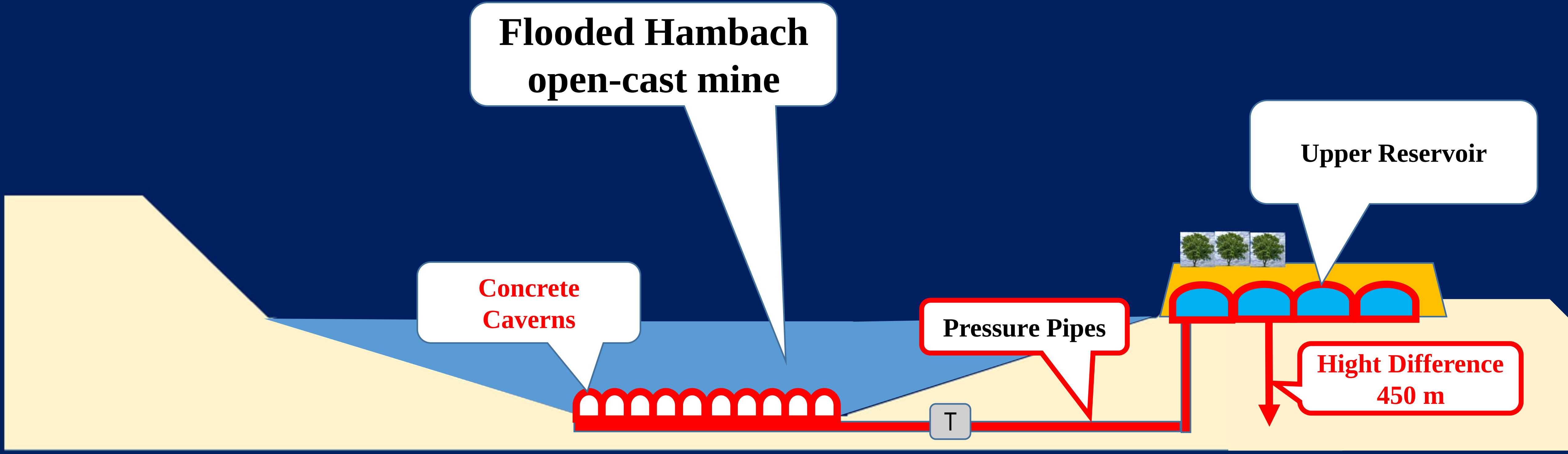
Vision:

A flooded lake as a recreational area with an invisible submersible nuclear power plant on the lake bed. Important: No tidal range in the open-pit mine lake.

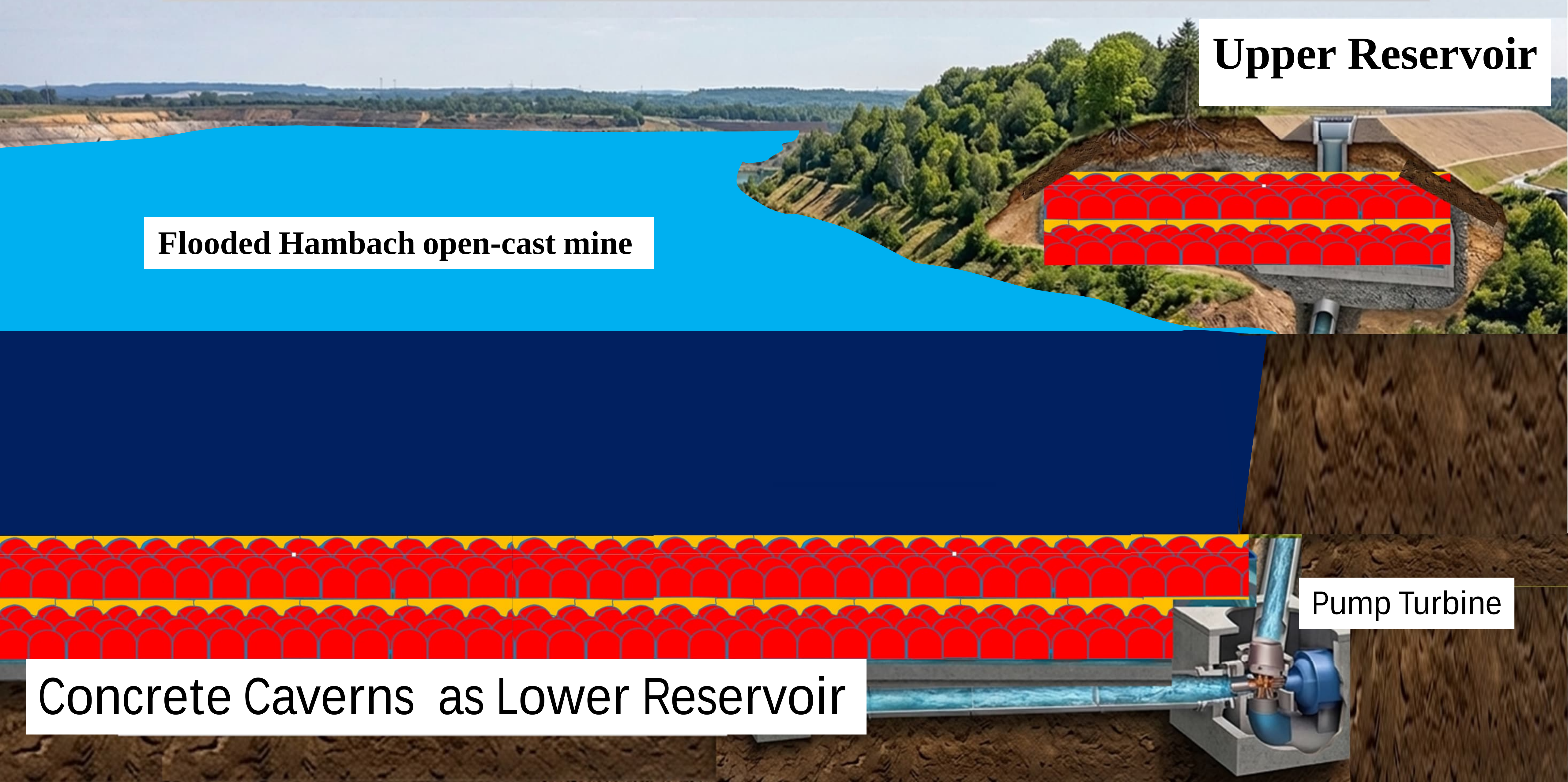


The caverns can be covered with mine filling material and even stacked on top of each other =>
Buoyancy and pressure reduction and concrete savings

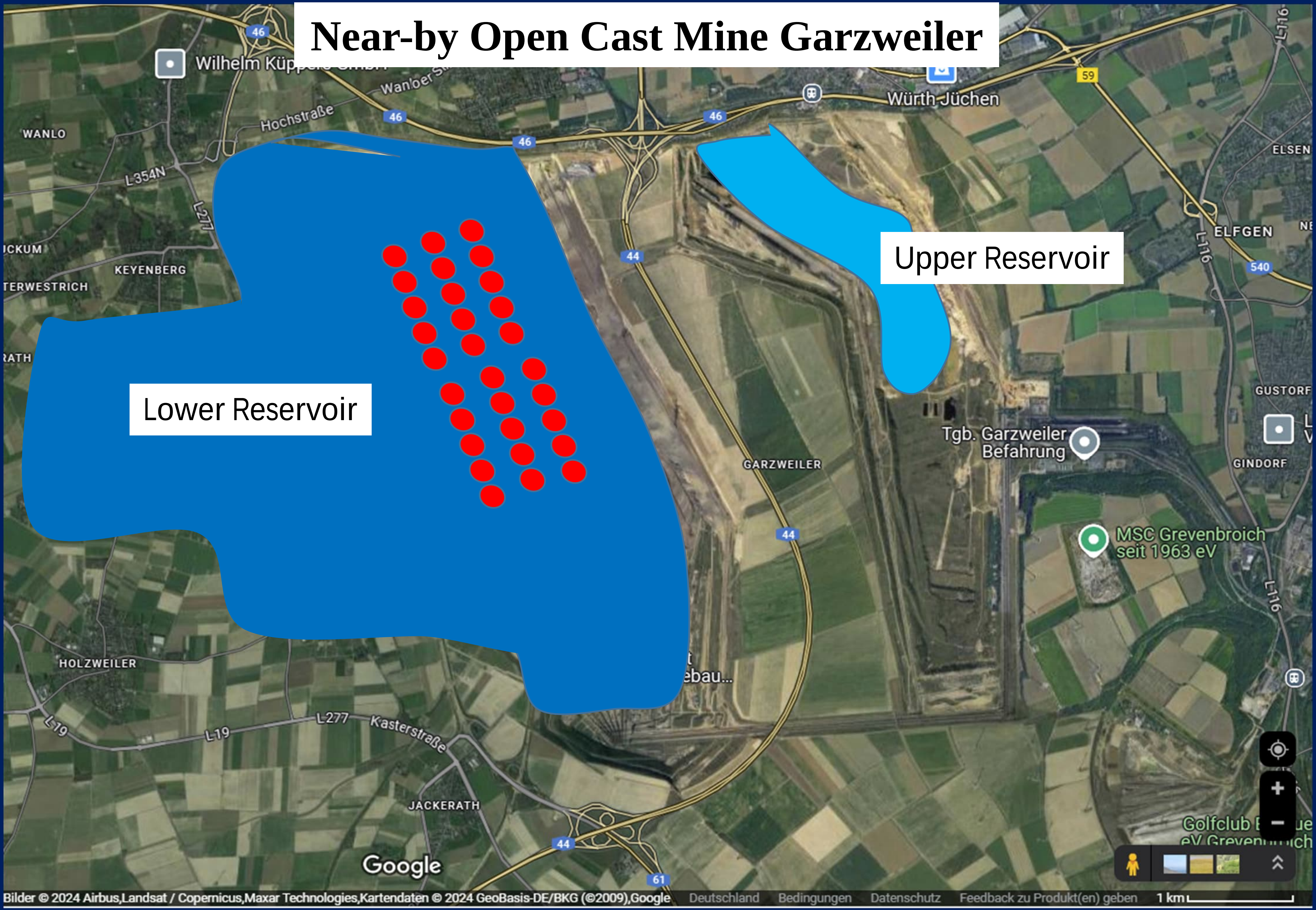
U-PSKW Concept with an Upper Reservoir made of concrete Caverns



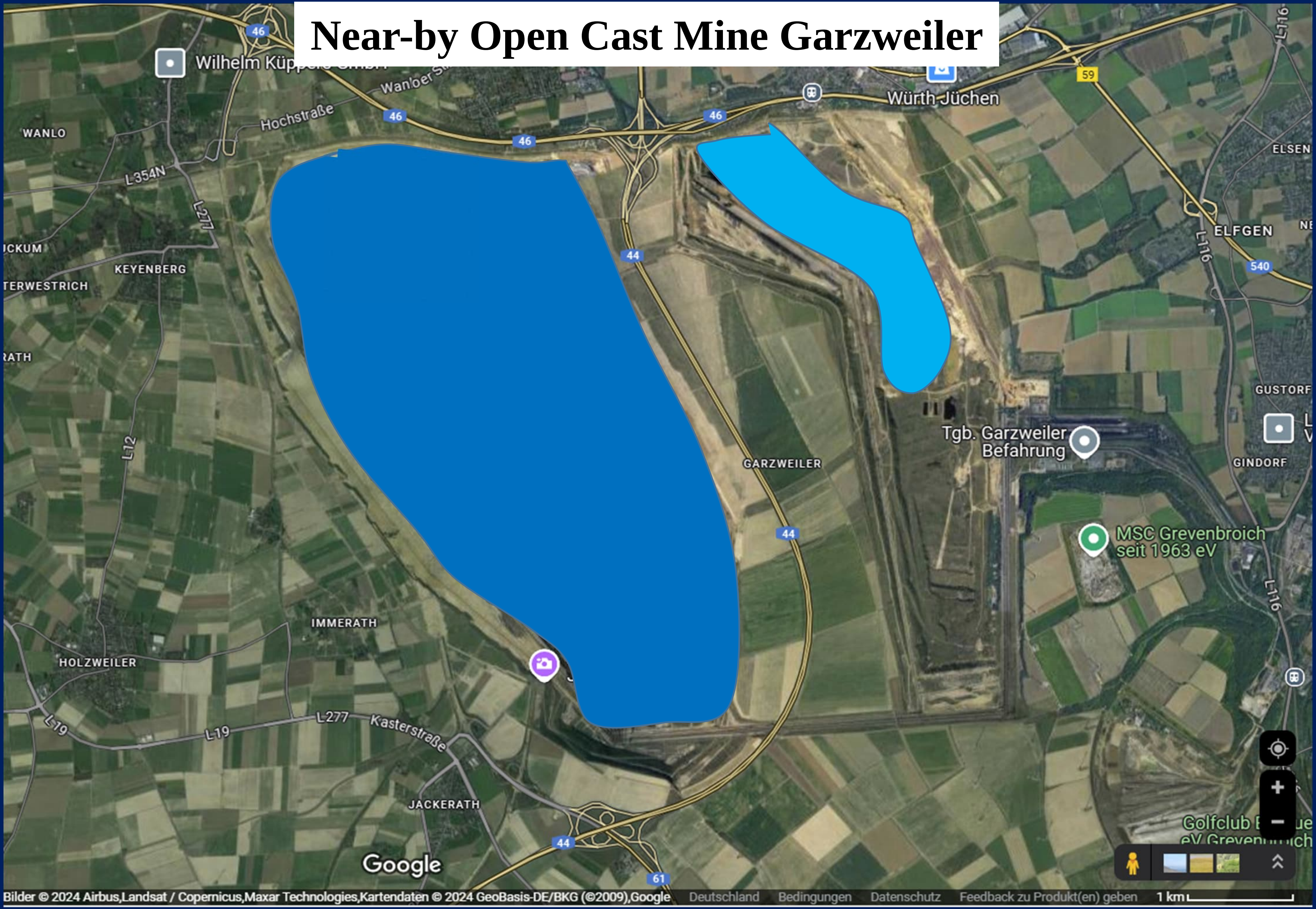
KI-painting: Invisible underwater cavern storage for electric energy



Near-by Open Cast Mine Garzweiler



Near-by Open Cast Mine Garzweiler



Potential storage capacity in GWh and storage power in GW

Case A:

The upper reservoir in Mannheim Bay can supply a maximum of approximately 240 million m³ of process water. At a depth of 400 m, this corresponds to approximately 215 GWh storage capacity.
Approximately 80 x 2.7 GWh units, each with a 300 MW pump turbine and 50 penstocks.
This would be 25 times larger than Goldisthal and
5.5 times the total number of pumped storage power plants in Germany.
6 times larger than the world's largest pumped storage power plant in the USA.

Storage Power in GW:

80 pump turbines each 300 MW => 24 GW,
But expandable to 50 GW with an additional cost of 4 billion euros

Potential storage capacity in GWh and storage power in GW

Case B:
Upper reservoir built as caverns and covered with excavation material of about 1000 million m³.
At a depth of 400 m, this corresponds to approximately 1 TWh storage capacity.
Approximately 400 x 2.7 GWh units, each with a 300 MW pump turbine and 200 penstocks.
This would be 115 times larger than Goldisthal and
5.5 times the total number of pumped storage power plants in Germany.
Enough energy to deliver the total energy for half a day in Germany.

Storage Power in GW:
400 pump turbines each 300 MW => 120 GW,
Needed to store in 8 hours about 1 TWh.

Final performance figures and costs must be determined by expert consultants.

Construction time and costs

Construction time, according to *Hoch & Tief* experts, is approximately 5-6 years.

Cost per kWh of storage capacity:
Goldisthal:
Commissioned in 2004   75 Euro/kWh

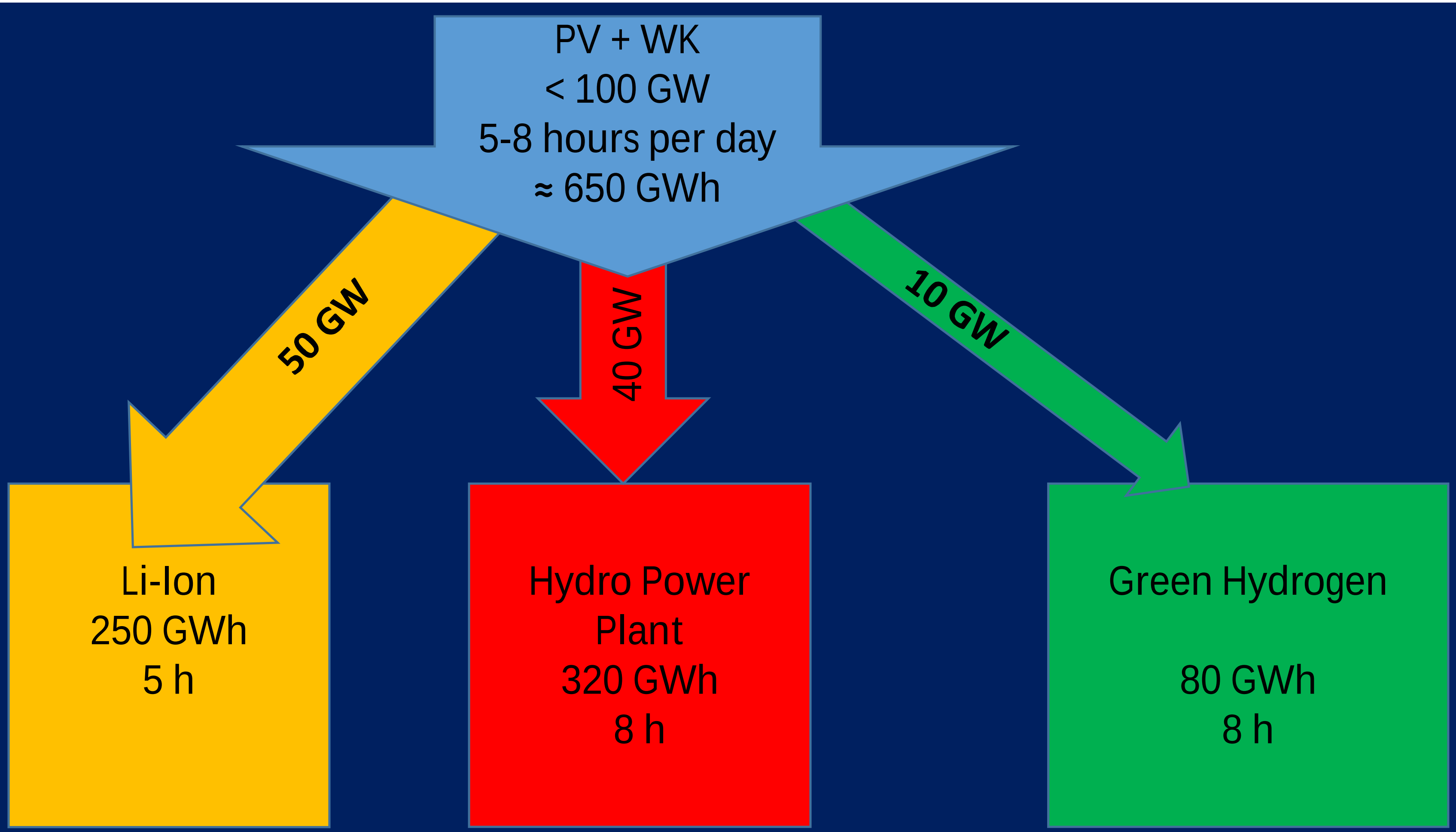
Hambach:
approx. 250–350 Euro/kWh
(possibly 150–250 Euro/kWh for large quantities)
Turbine component: approx. 20 Euro/kWhTotal:

Battery comparison:
RWE is building a 235 MWh lithium-ion storage facility in Neurath for 140 Euro million Euro.
⇒ 600 Euro/kWh, plus:
⇒ approximately 5 times shorter lifespan than pumped storage power plants => 3000 Euro/kWh.
⇒ Even if prices fall by a factor of 5, it's still more factor 2 more expensive
than underground pumped storage power plants.

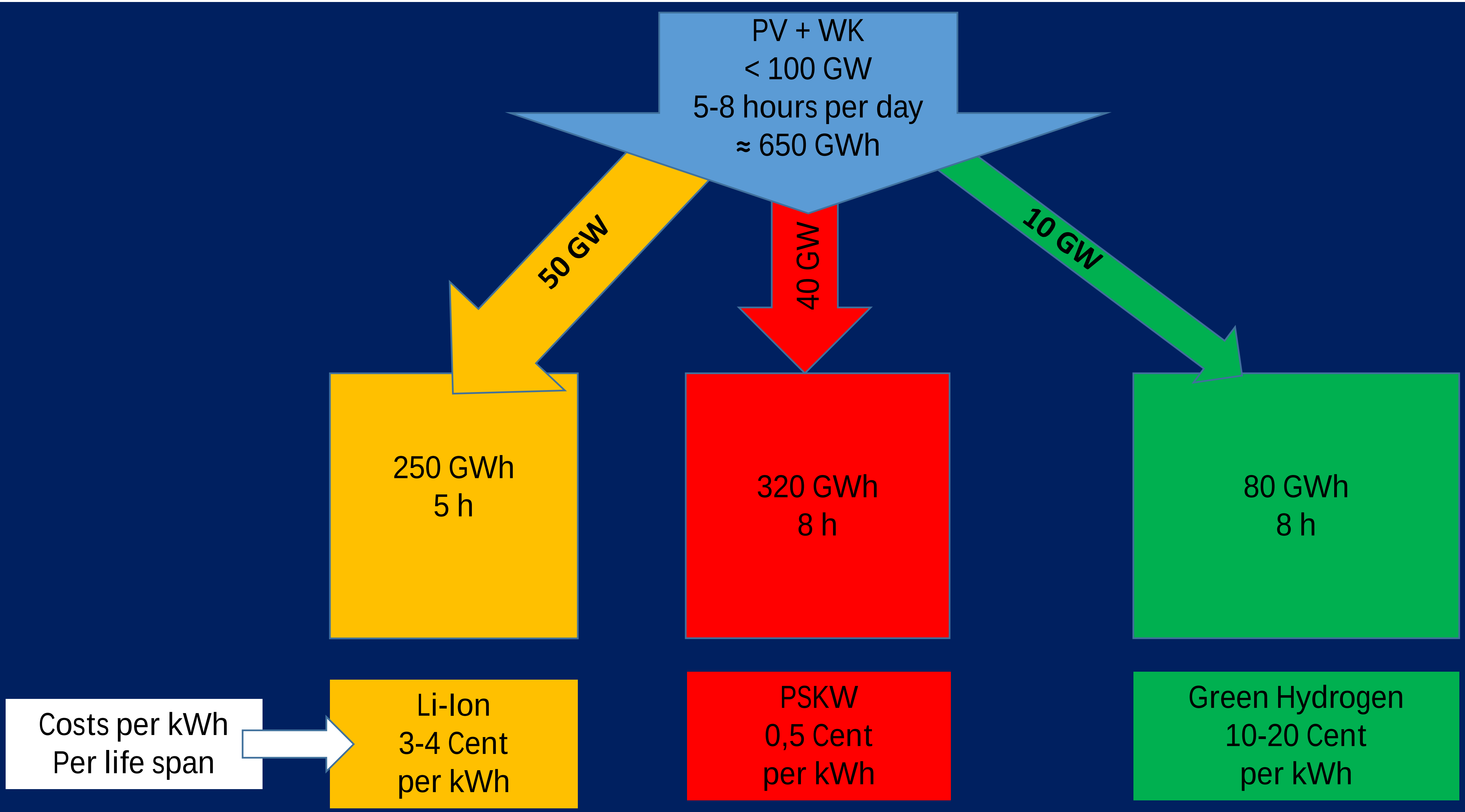
1. PSKW technology proven over 100 years	**=> completely mature!**
2. Low losses in the energy circuit	**=> 20% and no discharge or heat losses**
3. Very short start-up time	**=> cabout 1 Minute.**
4. Environmental amenity	**=> perfect.**
5. Primary resources	**=> no foreign dependence**
6. Low investment costs per kWh	**=> 150 Euro/kWh.**
7. Lifespan of turbines	**=> about 80 -100 yreas**
8. Lifespan of concrete caverns	**=> 1000 years and longer**
9. Huge storage capacity and power	**=> 1 TWh and > 40 GW.**
10. Reliable and affordable electricity supply	**=> Base load capable, suitable for KI expansion**

11. Enables a virtually self-sufficient energy supply for Germany at the lowest possible cost

Networking of green hydrogen, batteries and hydro power achieves significant efficiency improvements and cost savings.



Networking of green hydrogen, batteries and hydro power achieves significant efficiency improvements and cost savings.



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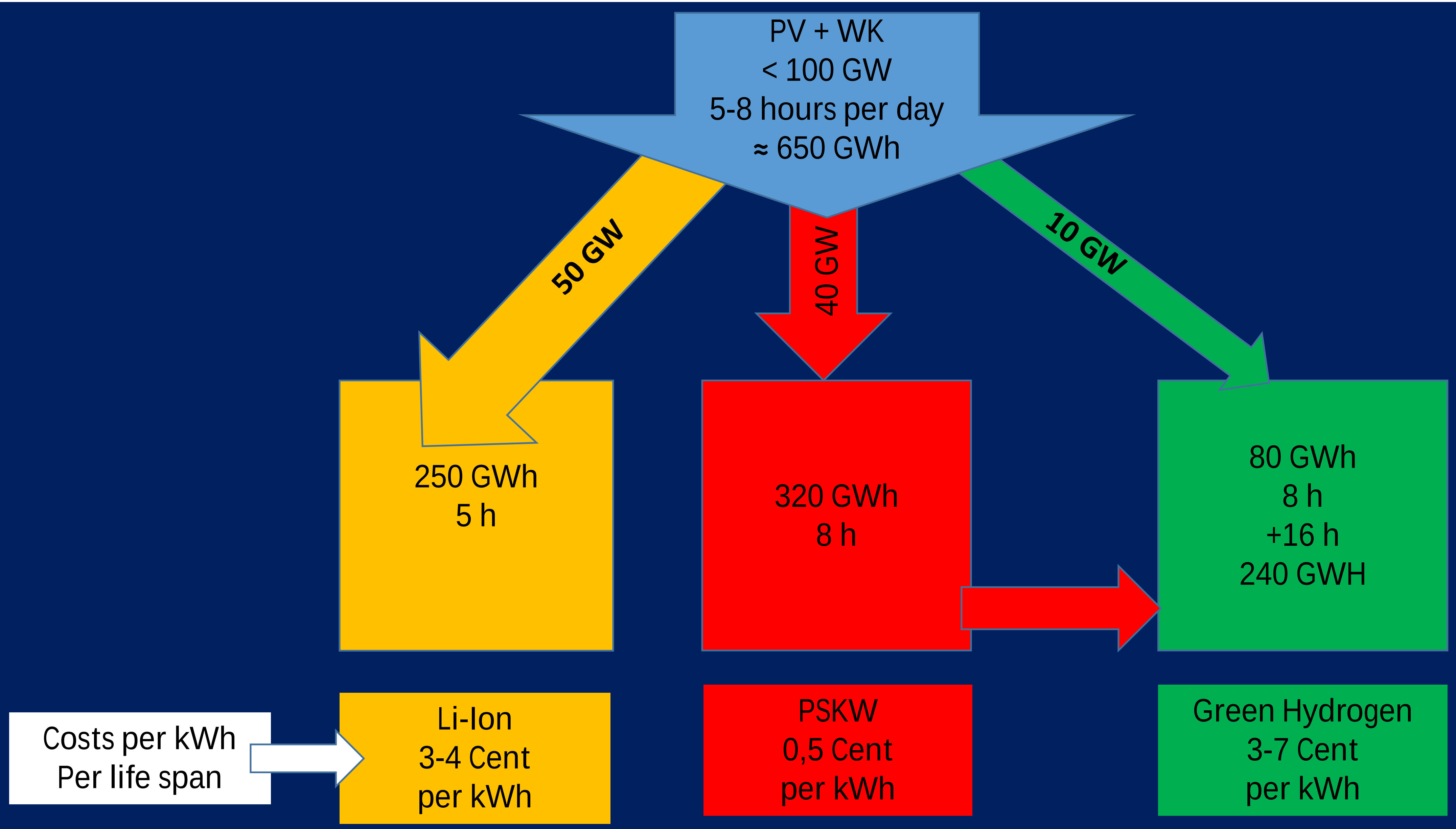
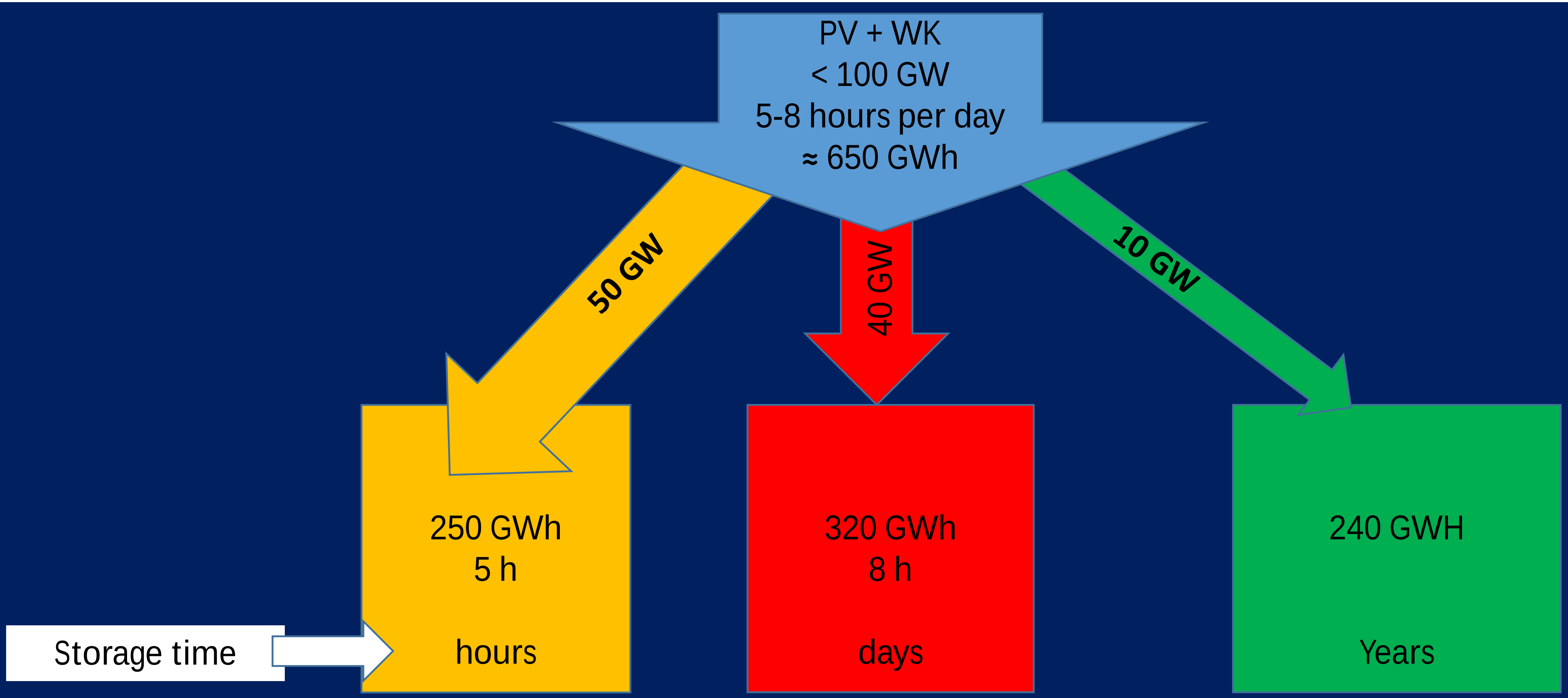


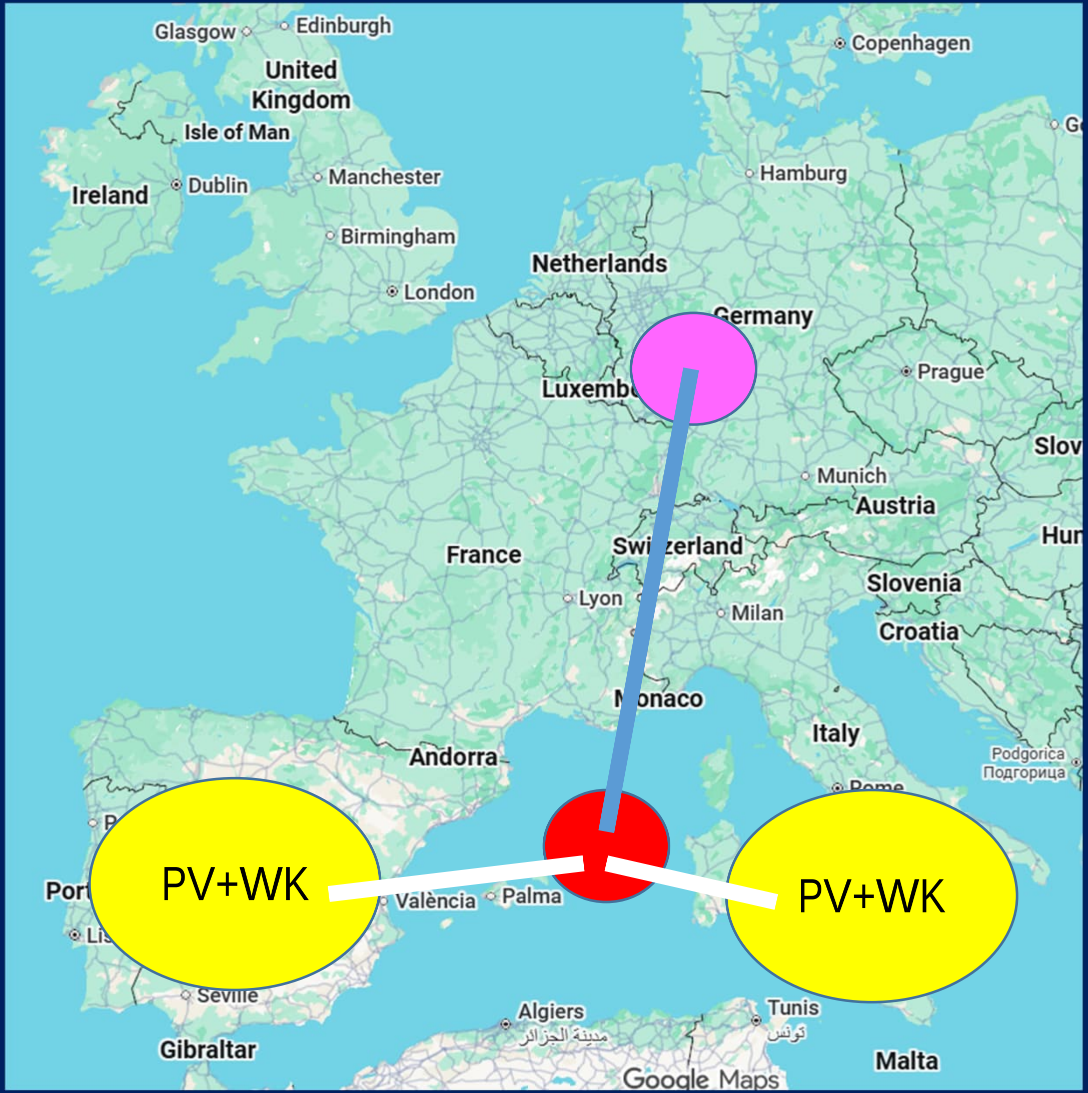
Networking of green hydrogen, batteries and hydro power achieves significant efficiency improvements and cost savings.

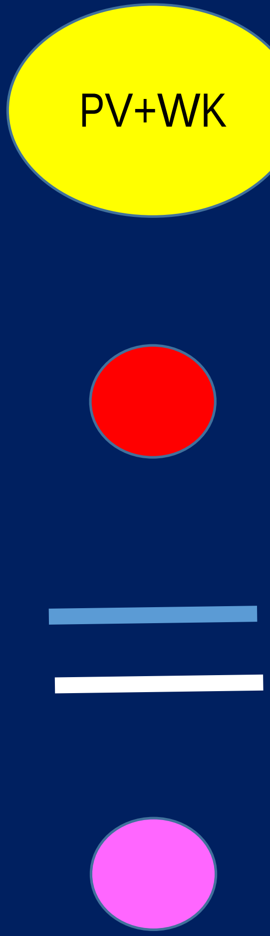


Thanks for Listening

Networking green hydrogen and batteries brings significant efficiency improvements and cost savings.

The solution to Western Europe's energy problems





Power generation AC

Electricity storage 1 10 TWh

Power line 40 GW DC

Electricity storage 2 1 TWh

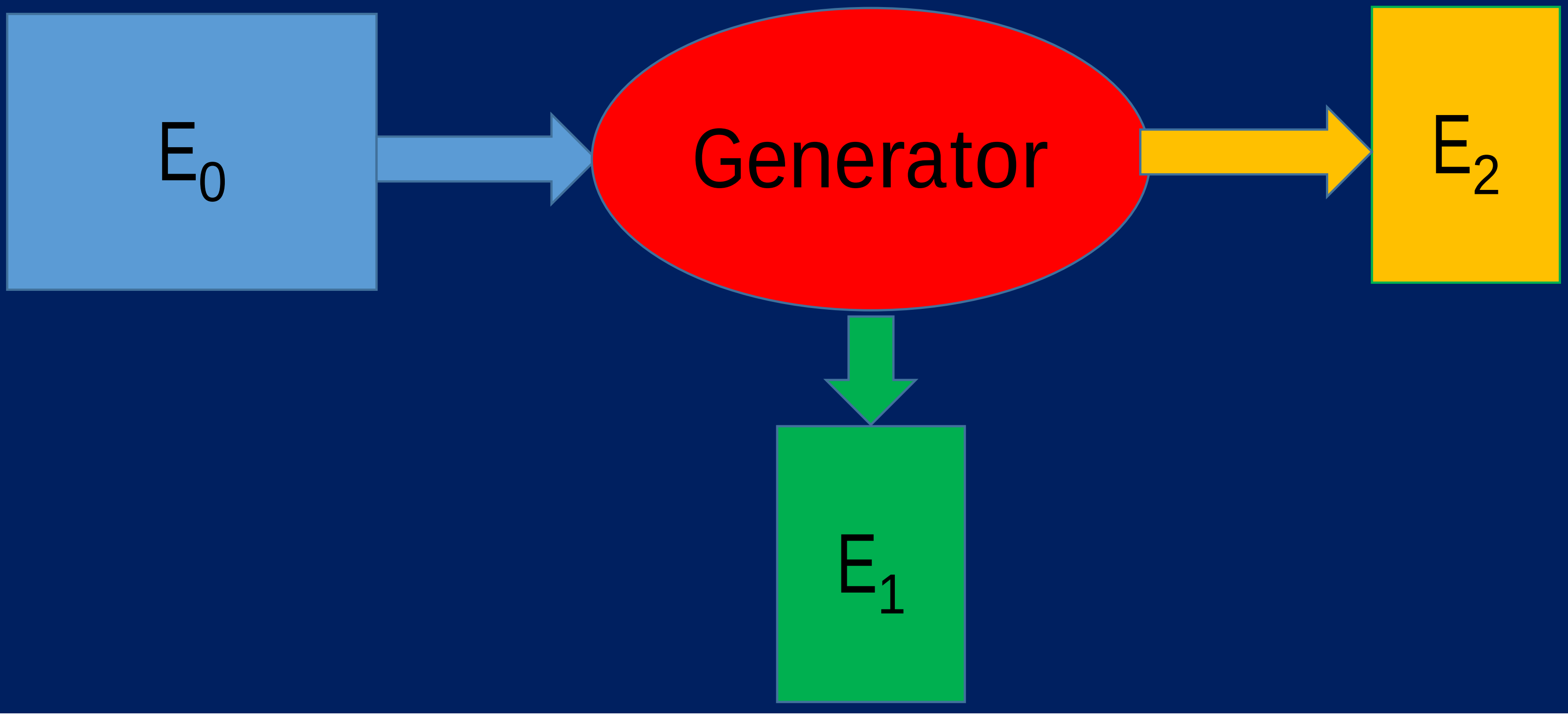
The solution to Western Europe's energy problems

Electricity storage in the mediterranean Sea 1000 caverns
with each 400 thousand m^3 volume in 4000 m depth => 4 TWh
Costs: 1000 x 600 Million Euro = 600 Billion Euro

Power line 40 GW DC Energy transport per day: 24 h x 40 GW = 0,96 TWh

Electricity tempory storage 2 Hambach 1 TWh

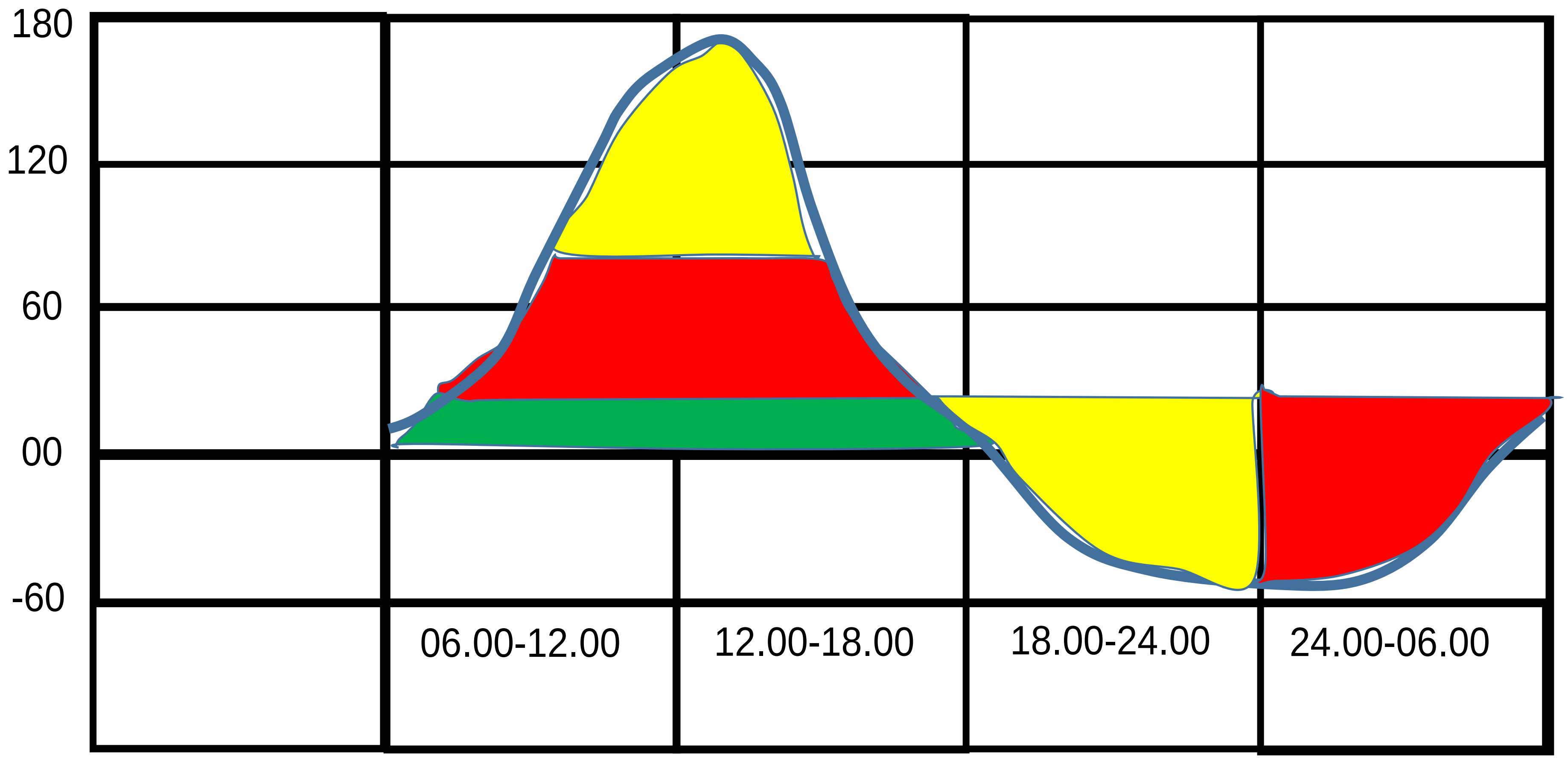
Use of Energy means: converting Energy from State E_0 into State E_1
Energy Flow Diagram from Primary Energy E_0 to Electric Energy E_1



Energy Conservation:

$$E_0 \equiv E_1 + E_2$$

Efficiency $\mathcal{E} = E_1 / E_0$



180
120
60
00
-60
06.00-12.00
12.00-18.00
18.00-24.00
24.00-06.00

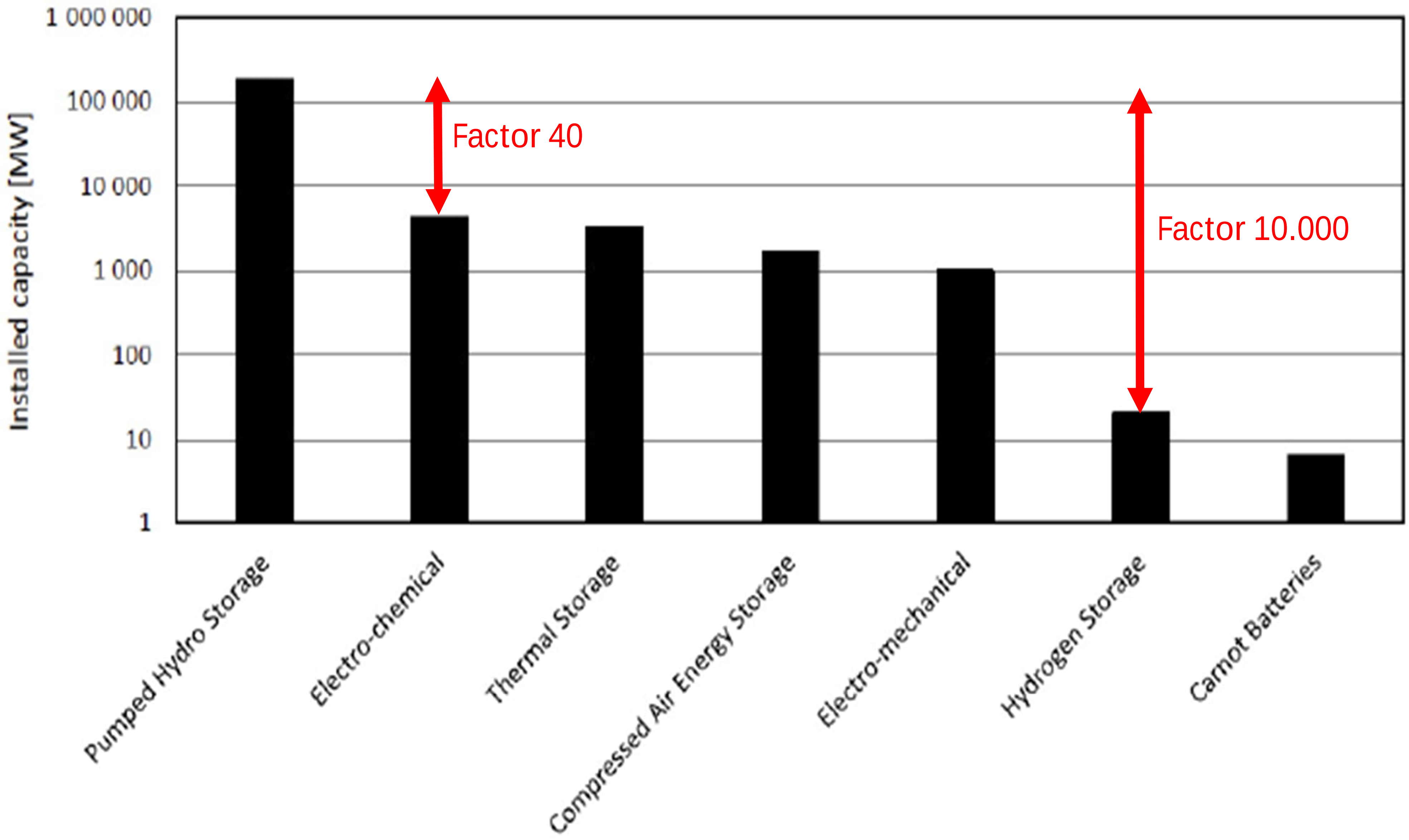
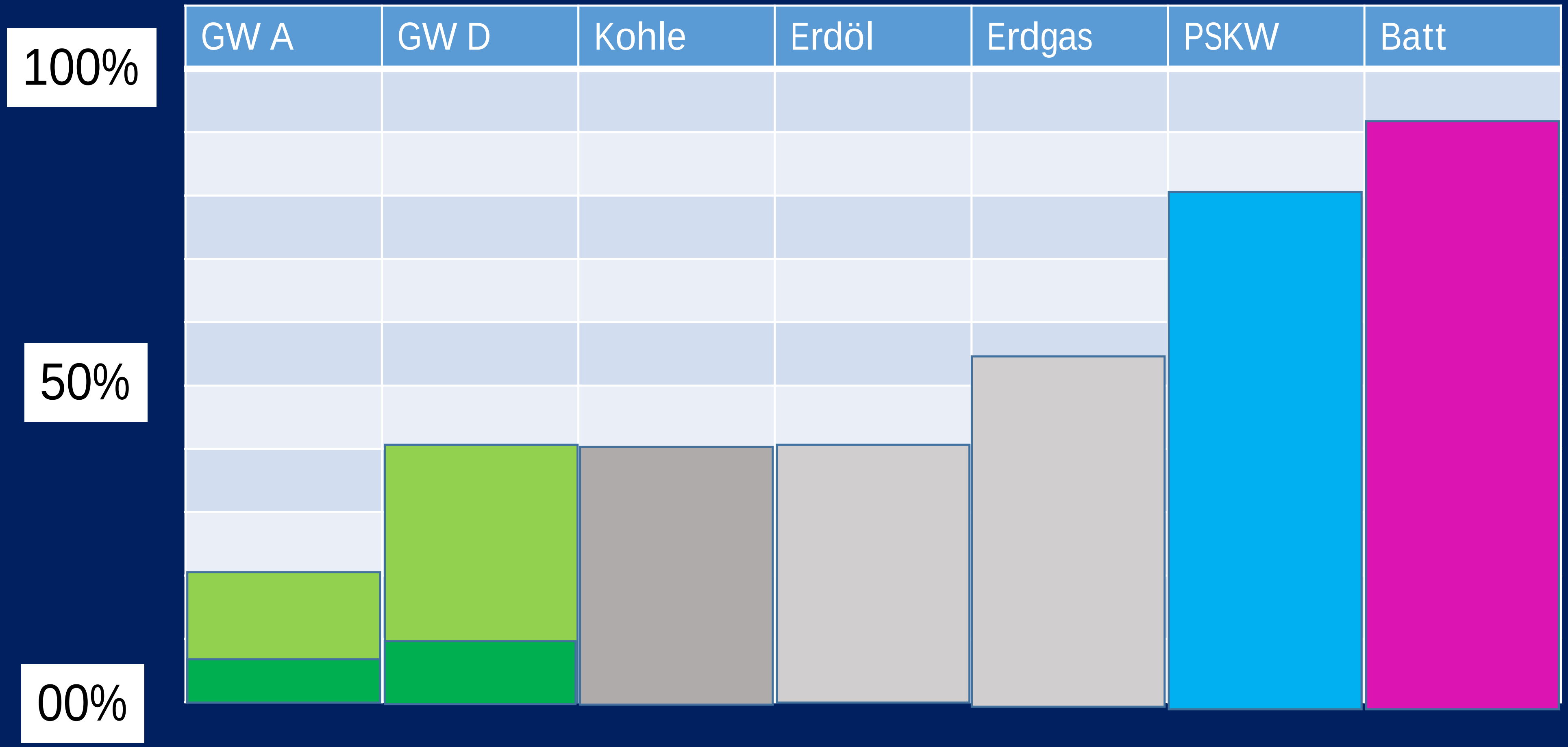


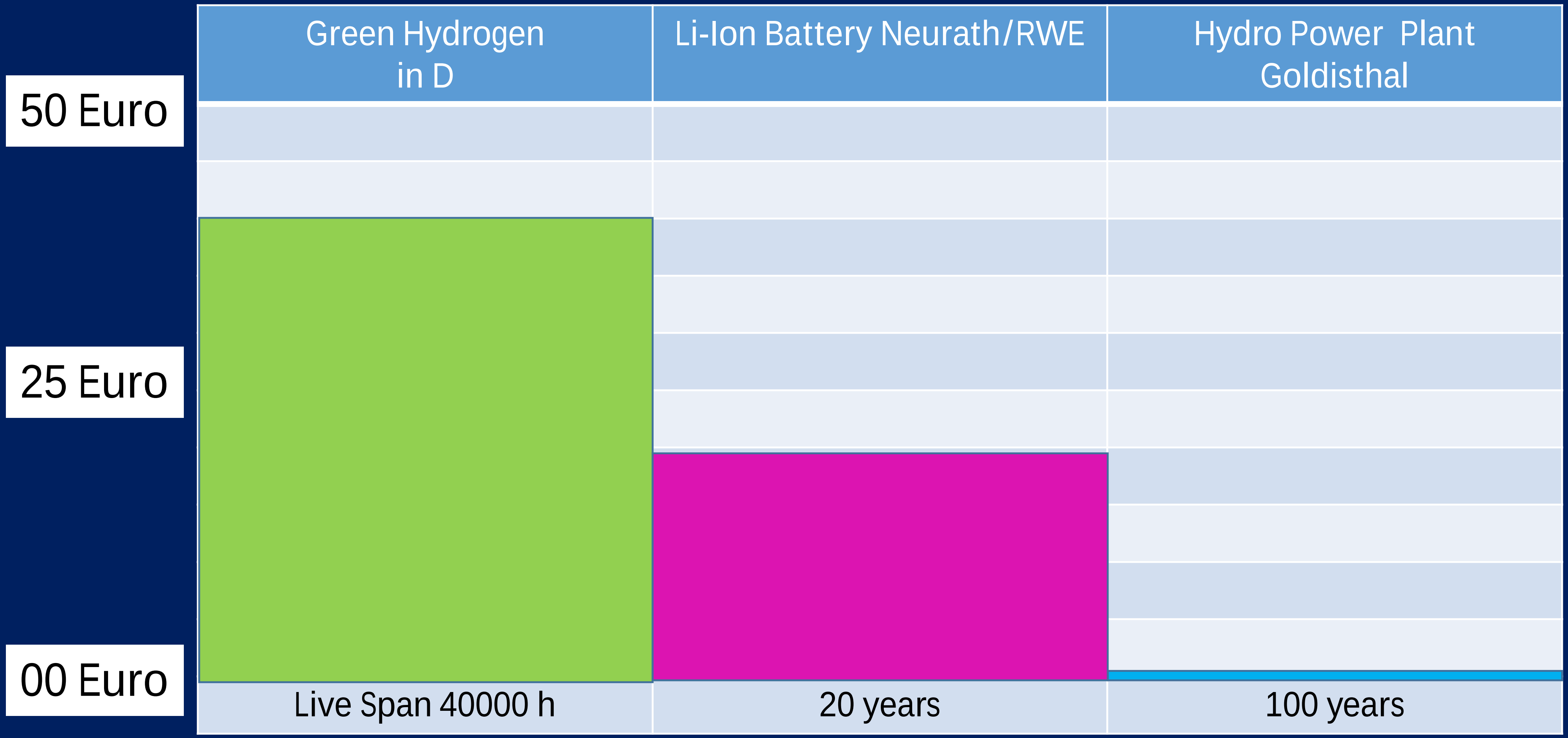
Figure 1. Overview of global installed grid scale electricity storage systems power rating in 2020.

Energiespeicher-Effizienzen von Elektrizität (Verluste)

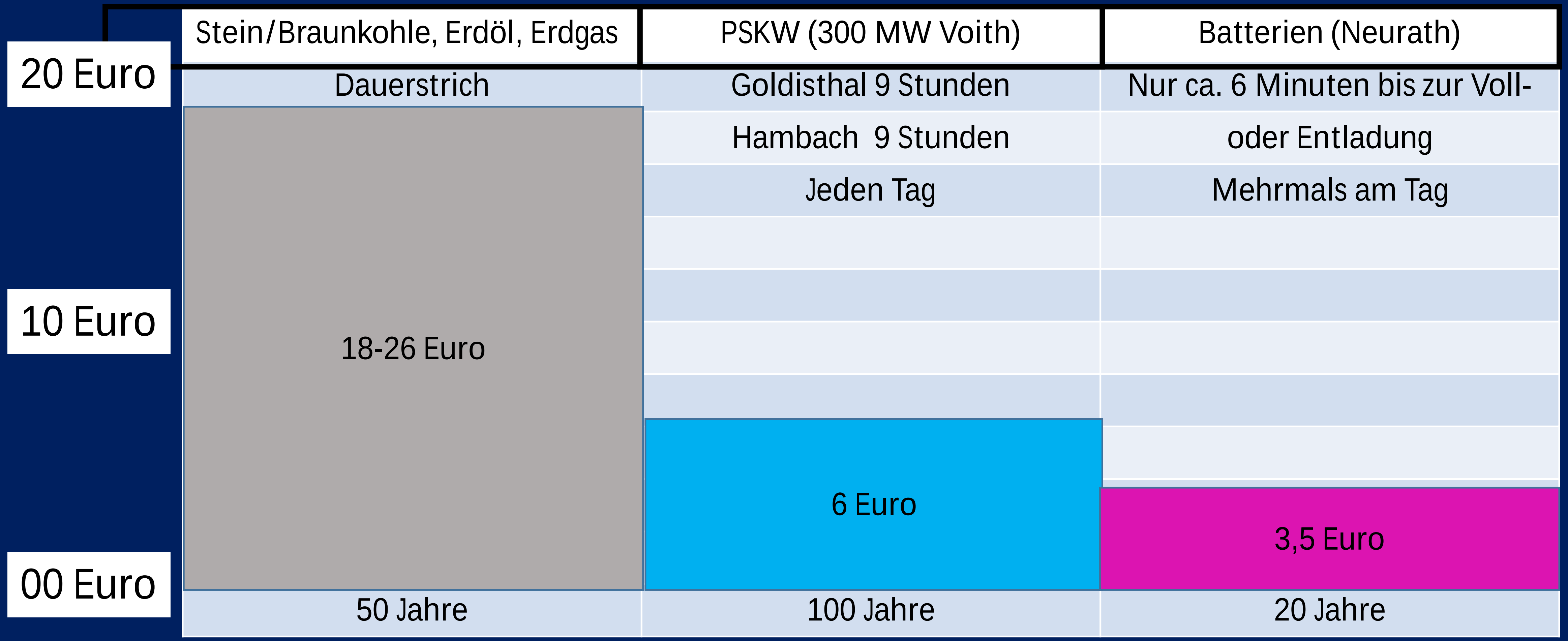
$\varepsilon = E_1 / E_0$



Expenses per 1 kWh Energy Storage Capacity and per 1 year of Live Span



Kosten in Euro pro 1 kW Energieleistung und 1 Jahr Lebensdauer



Technologie des „Grünen Wasserstoffs“
a. in Deutschland

Elektrische Energie aus WK und PV	→	Wasserstoff durch Elektrolyse	→	Transport Speicherung	→	Rückverstromung in Gaskraftwerken	Wenig Leistung
100 %		80 %		75 %		30 %	=> 70 % Verlust

In der Realität noch höhere Verluste, da Elektrolyseanlagen EA nur am Tag bei Überschüssen Wasserstoff erzeugen. EA werden abends abgeschaltet, bzw. runter gefahren, müssen morgens wieder auf Temperatur gebracht.
Hätten ohne Vorspeicher pro Jahr in Deutschland nur ca. 1500 Betriebsstunden!

D.h.: von 100 % EE-Strom gelangen nur << 30 % als Strom zum Verbraucher!

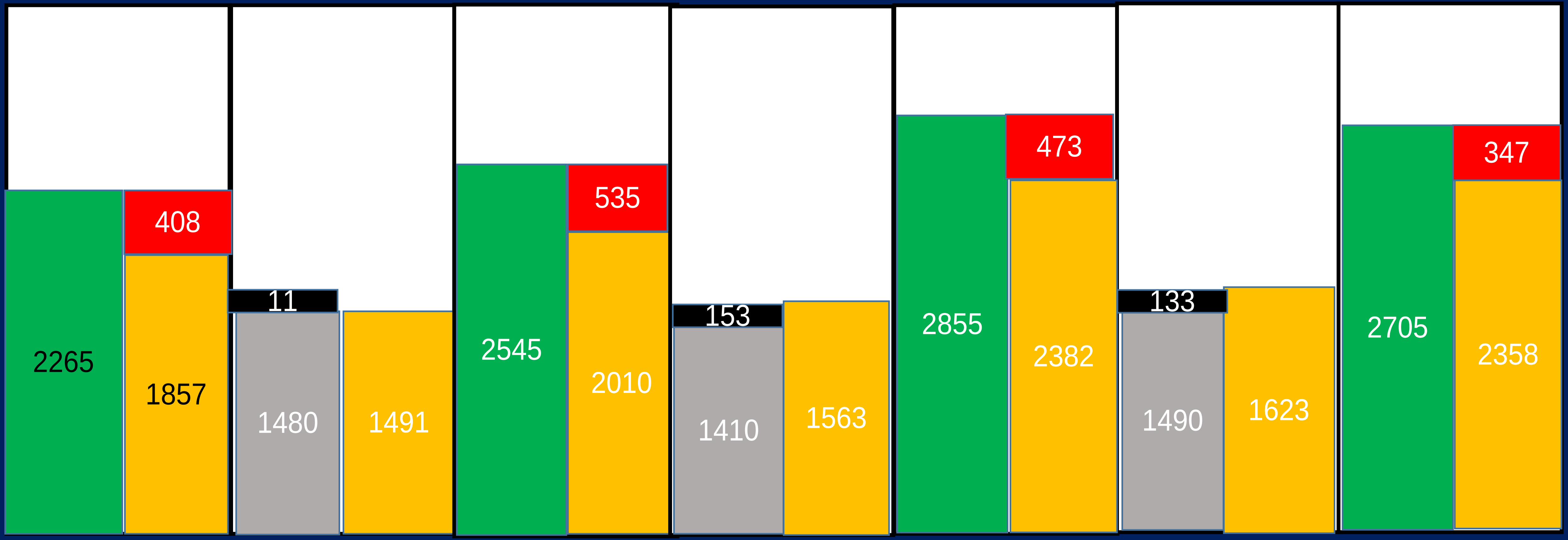
Technologie des „Grünen Wasserstoffs“
b. in Afrika, Amerika etc.

Elektrische Energie aus WK und PV	→	Wasserstoff durch Elektrolyse	→	Verflüssigung Chemie	→	Transport Speicherung	→	Rückverstromung in Gaskraftwerken
100 %		80 %		53 %		48 %		=> 80 -90 % Verlust

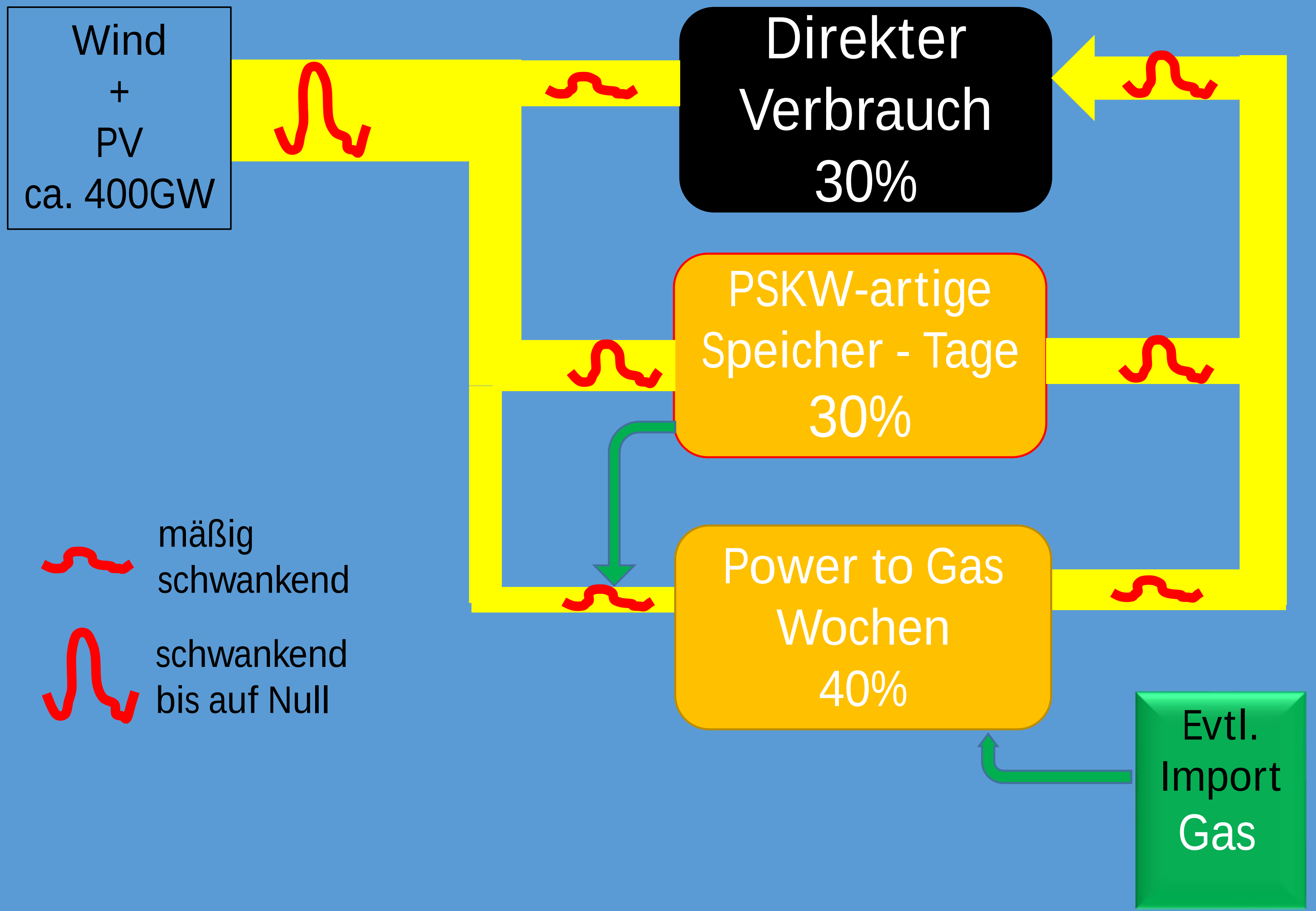
D.h.: von 100 % WK oder PV-Strom gelangen nur bei Rückverstromung < 20 % zum Verbraucher!

Die Investitionskosten der Gesamttechnologiekette sind extrem hoch: Teure Elektrolyseanlage, teure Leitungen, teure Gaskraftwerke etc.

PSKW bisher in den Mittelgebirgen errichtet.



Potential der Stromleistungs-Flüsse:
100% des Strombedarfs werden aus Wind und PV gedeckt (Max 130GW)



Pumpspeicherkraftwerke

Prinzip Einsatz von Strom → Wasser wird von einem tief gelegenen Wasserbecken in ein möglichst hoch gelegenes Wasserbecken gepumpt, aus dem dann im Bedarfsfall über Turbinen und Generatoren wieder Strom erzeugt werden kann.

Stand Bekanntestes und mit Abstand am häufigsten eingesetztes Verfahren
Pumpspeicher-Kraftwerke sind technisch ausgereift. Der sog. Umwälzwirkungsgrad beträgt bei ihnen etwa 75 ... 80 Prozent

Technische Vorteile:

- Beliebig lange Vorhaltezeit, da *kein Speicherverlust*
- Schnelle Ein- und Umschaltzeiten (45 ... 72 s)
- Augenblicksreserve

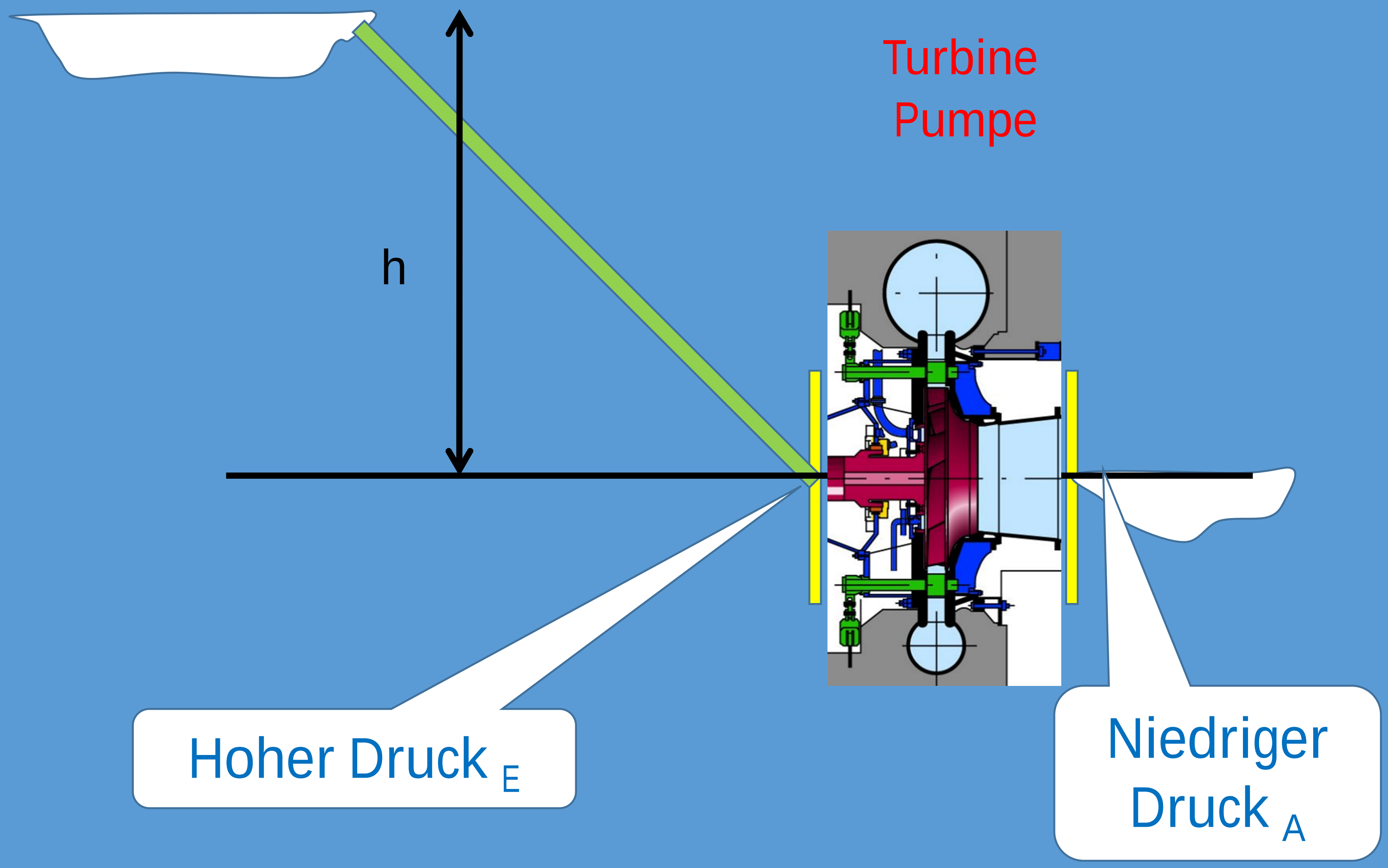
Zukünftige Entwicklung

- In **Deutschland** kaum noch freie Geländekapazitäten, nur Modernisierung ⇒ Ausbaumöglichkeiten weitgehend erschöpft!
- Weltweit weiterer Neubau, wo *Kapital und Gelände* gegeben

Probleme

- *Ökologische Probleme* beim Neubau durch Stauwehr und neu angelegte Becken
- *Akzeptanzprobleme* in der Bevölkerung

Prinzip eines Wasserpumpspeicherwerkes

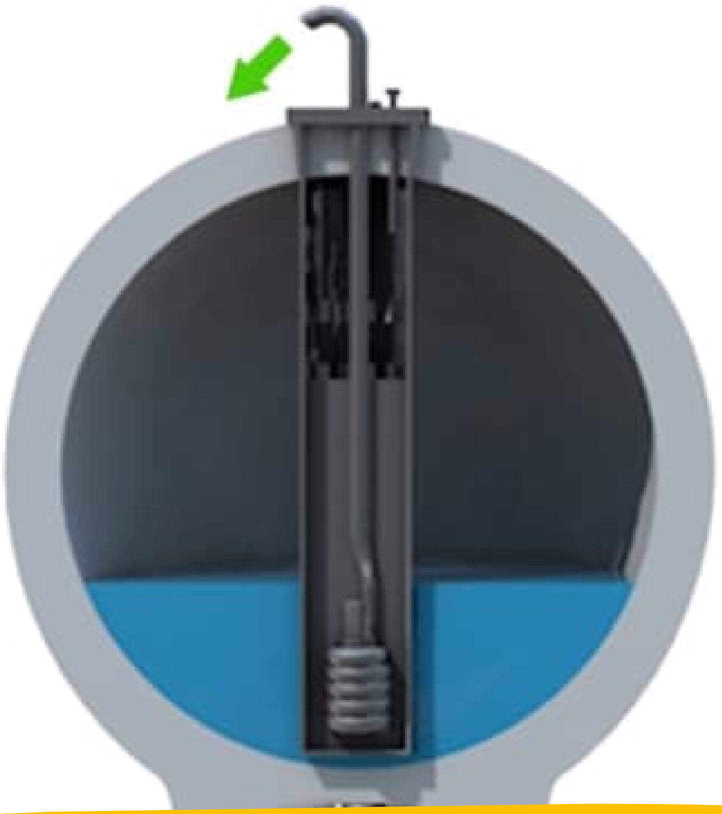



Wasserpumpspeicherwerk Goldisthal/Thüringen
1Giga W Leistung

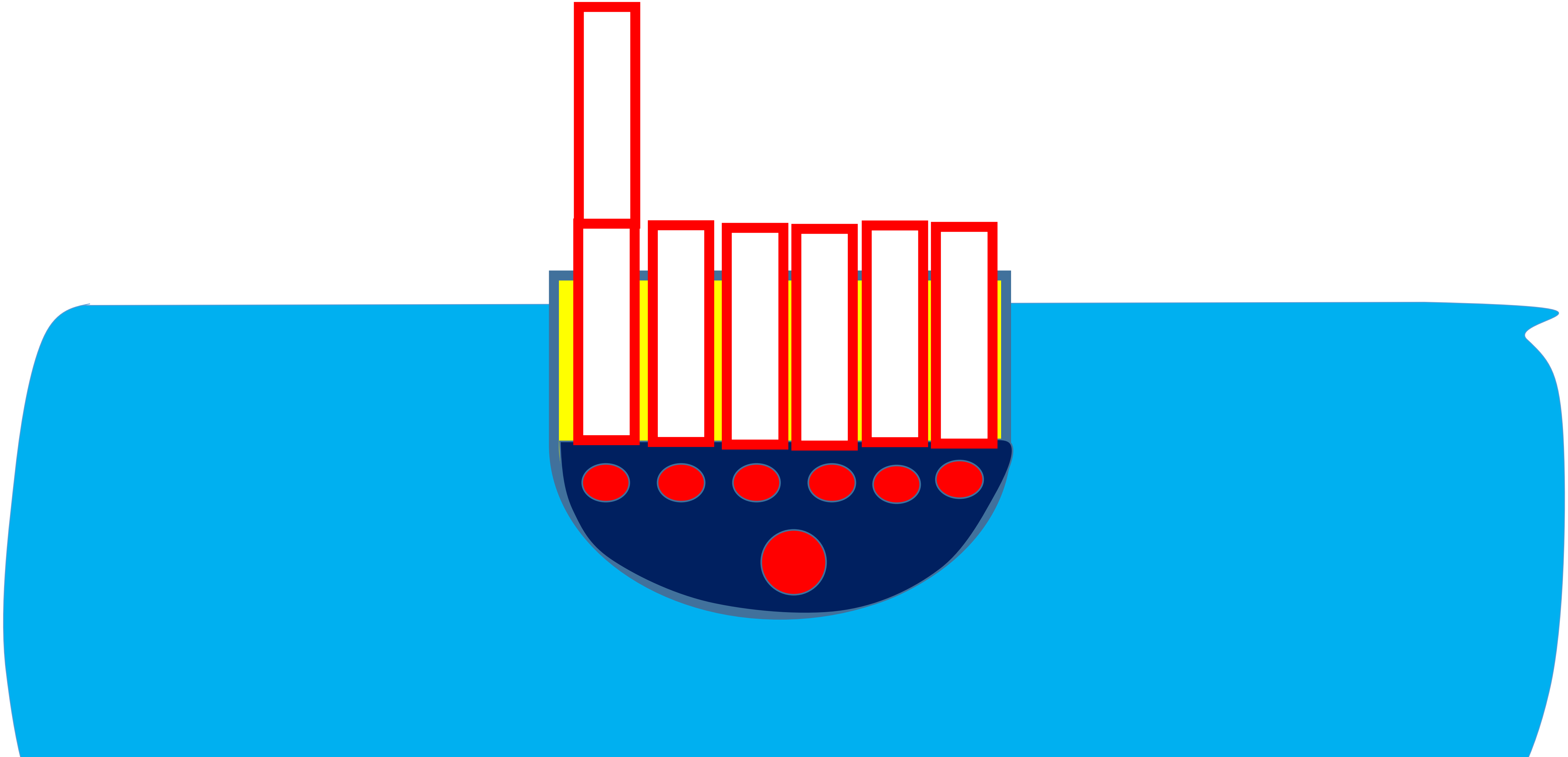
Probleme

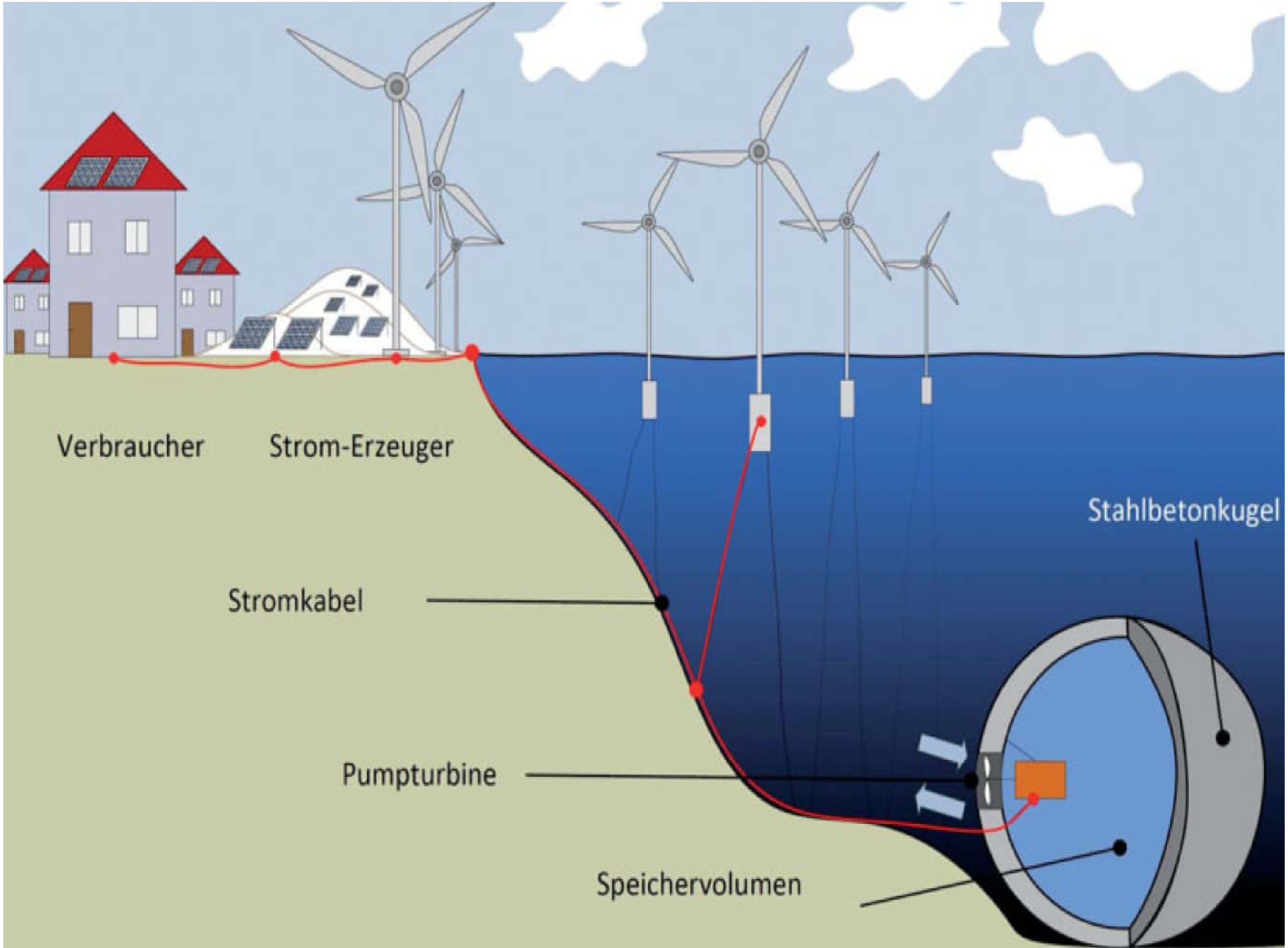
-Turbinen/Pumpenmontage bei Kugel

-Herstellung auf See?



Container bestehen z.B. aus großen Standard-Rohren, die miteinander vergossen werden. Rohre haben Verbindung mit Turbine/Pumpe




Verbraucher
Strom-Erzeuger
Stahlbetonkugel
Stromkabel
Pumpturbine
Speichervolumen

Meerestiefe/m	250	500	1000	2000	4000	10000
Druck/bar	25	50	100	200	400	1000
Speicherdichte/kWh/m^3	0,7	1,4	2,8	5,6	11,1	27,8

TAB. 2 | SPEICHERINHALT VON BETONKUGELN IN 4000 M MEERESTIEFE

Innendurchmesser/m	1	2	5	10	20	50	100
Volumen/m^3	0,524	4,189	65,450	524	4.189	65.450	523.599
Kugelschalendicke[1]/m	0,098	0,197	0,492	0,984	1,968	4,920	9,841
Speicherenergie/MWh	0,006	0,047	0,727	5,82	46,54	727	5818

[1] Die angegebene Dicke der Kugelschale ist zur Kompensation des Auftriebs erforderlich (Betondichte: ρ_{Beton} = 2400 kg/ m^3).

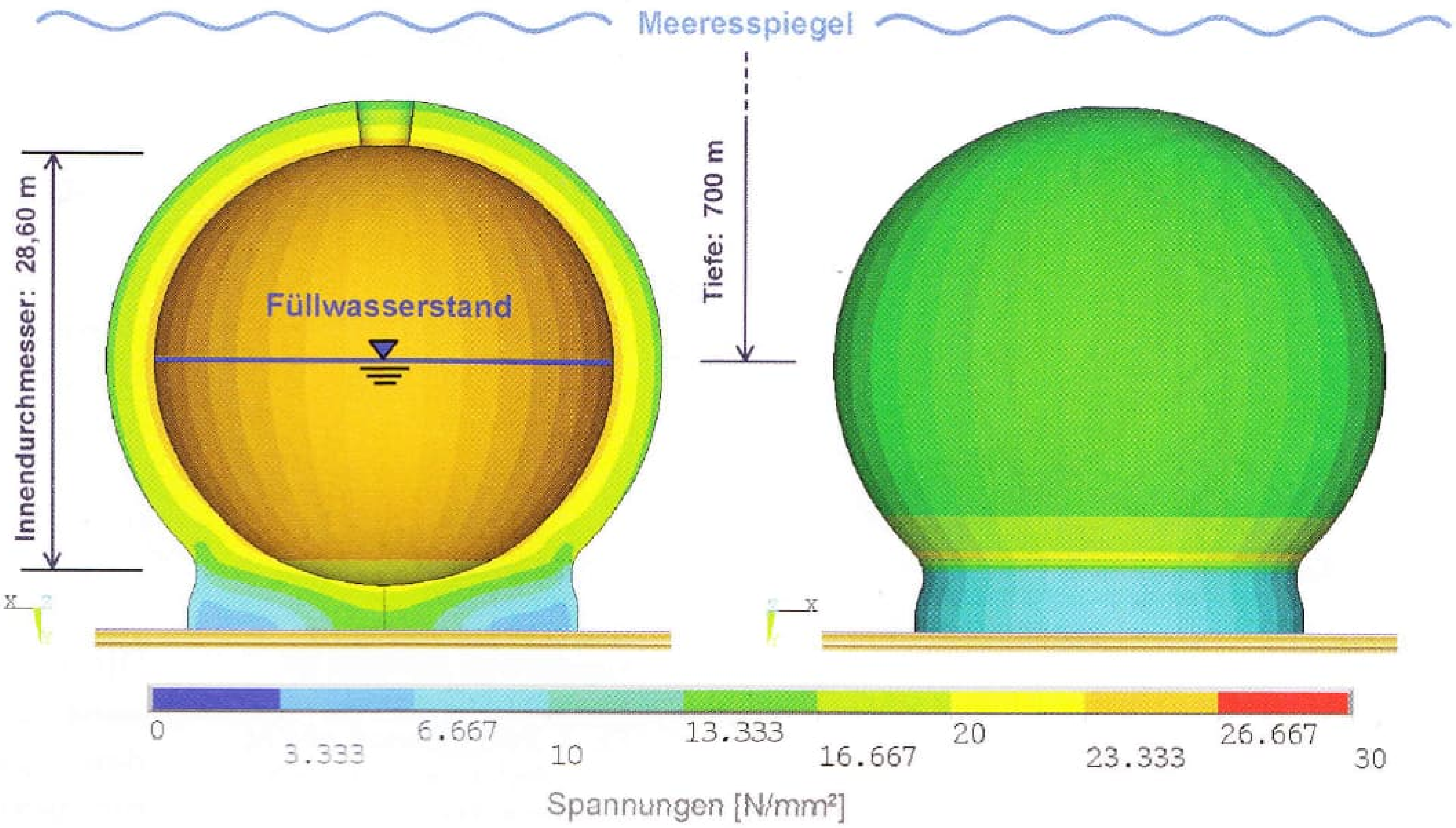
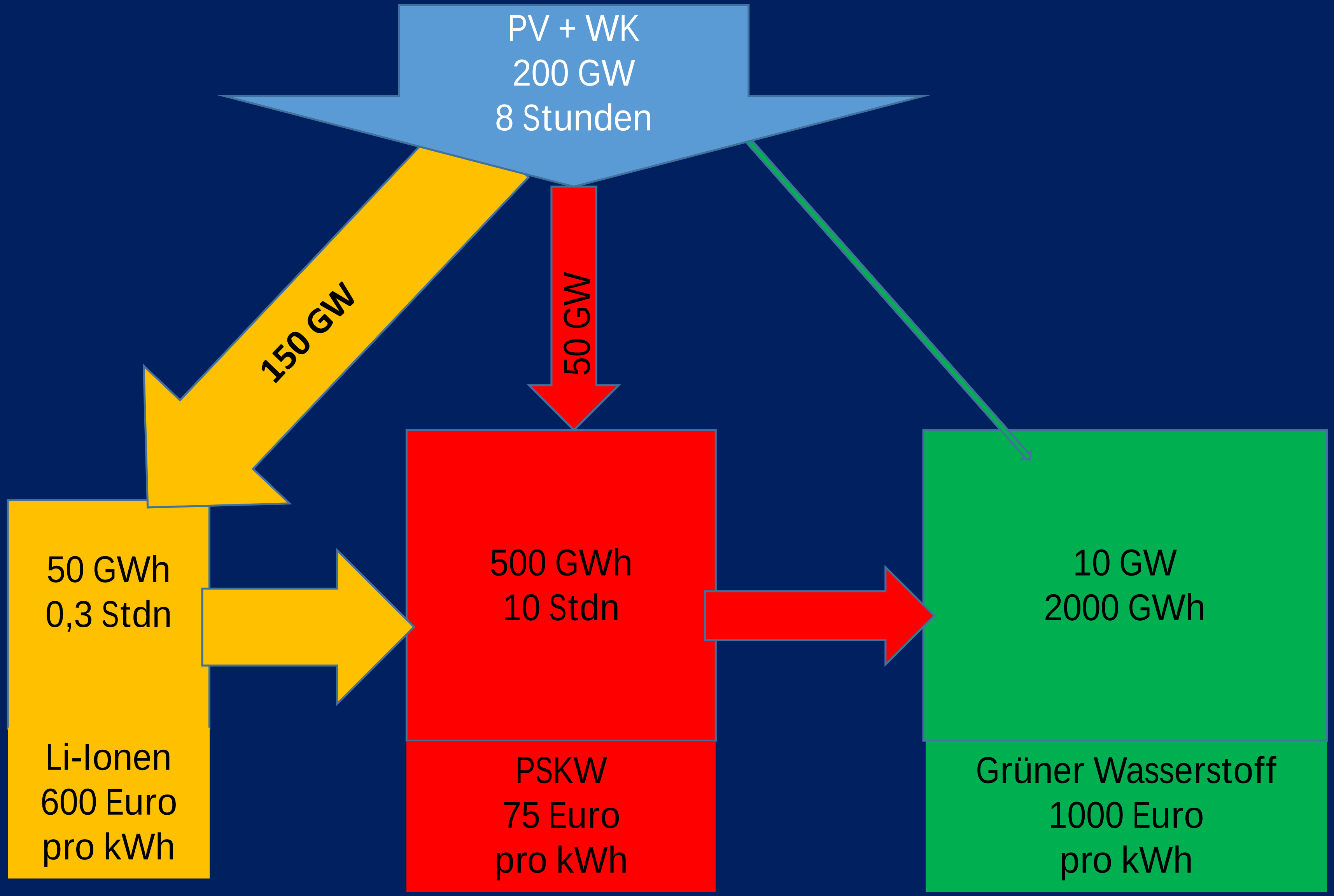
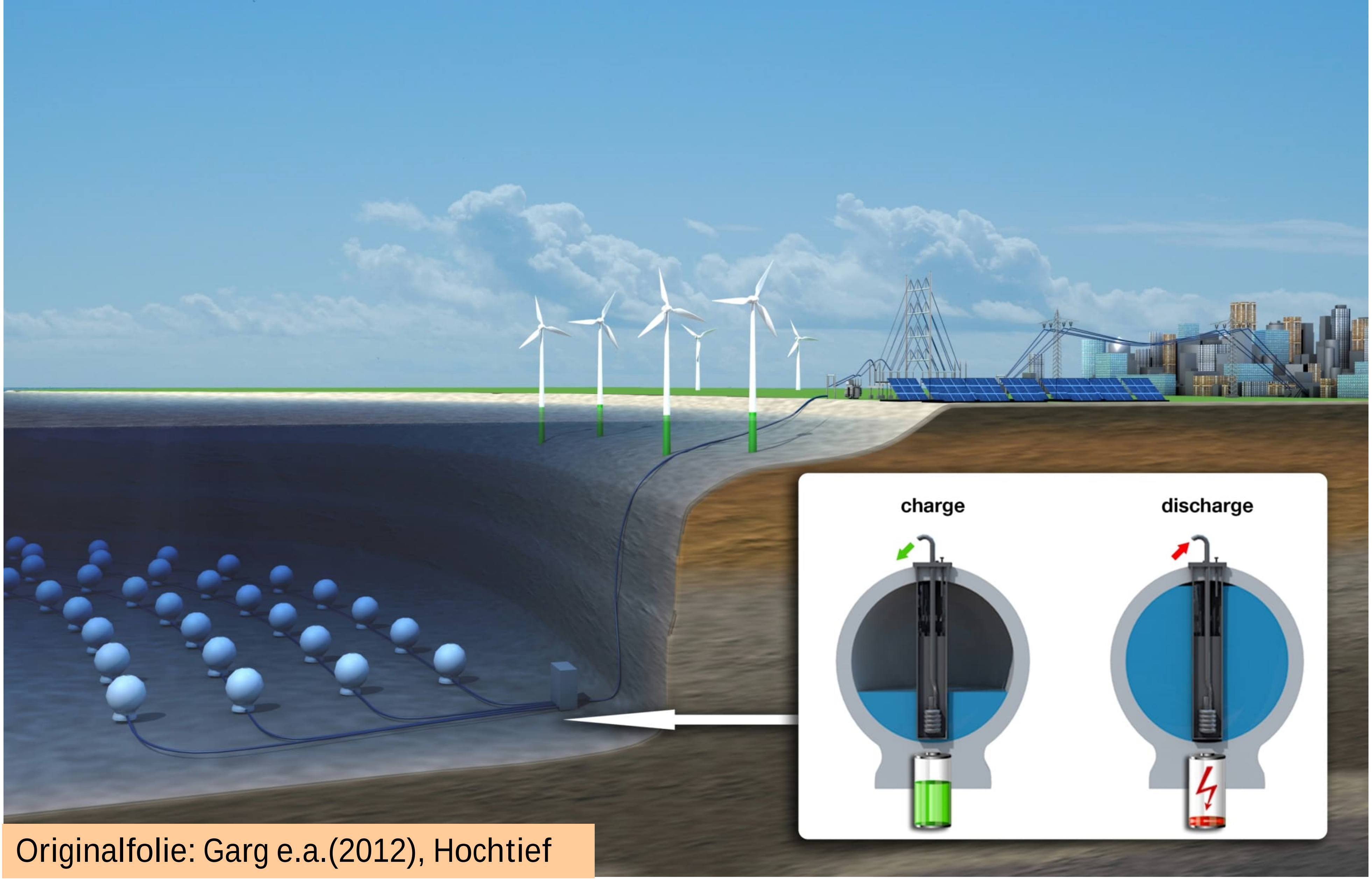


Bild 5. Spannungen in der Betonstruktur des Speicherkörpers
Fig. 5. Stresses in the concrete structure of the storage device


PV + WK
200 GW
8 Stunden
150 GW
50 GW
50 GWh
0,3 Stdn
Li-Ionen
600 Euro
pro kWh
500 GWh
10 Stdn
PSKW
75 Euro
pro kWh
10 GW
2000 GWh
Grüner Wasserstoff
1000 Euro
pro kWh

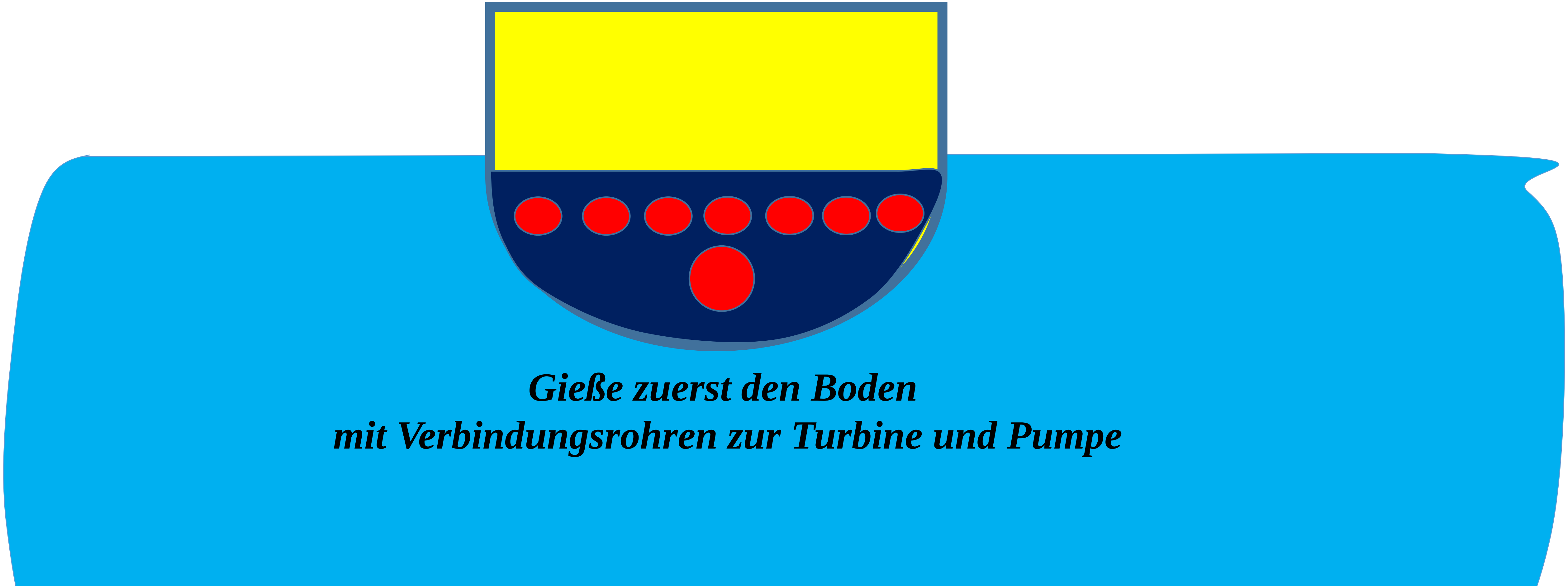
Projekt STENSEA 2012: Artist View



Quelle: Hochtief -A.Garg e.a.: Presentation C2 auf IRES 7 (2012): STENSEA (Stored Energy in Sea) -The Feasibility of an Underwater Pumped Hydro Storage System

Herstellung im Dock oder Hafen =>
wird so hergestellt, dass es immer gerade noch schwimmt

Zum Versenken wird es zum Bestimmungsort geschleppt
und mit etwas Ballast (Wasser?) gefüllt und dann auf den Meeresboden versenkt.



Gieße zuerst den Boden
mit Verbindungsrohren zur Turbine und Pumpe

Welche Vorteile bringt ein U-PSKW im Tagebau Hambach für das RR?

Unterirdisches Kavernen-PSKW und Erholungsfunktion am TB Hambach vereinbar

Beim Bau von PSKW verbleiben rund 95% der Wertschöpfung in Deutschland!

PSKW wären DAS KONJUNKTUR-Programm für heimische Bauwirtschaft + Maschinenbau (>20 Mrd.)

RR + NRW würde auf dem Energiesektor der zentrale Umschlagplatz für erneuerbare Energie (inklusiv H_2) werden und für viele Generationen bleiben.

dauerhafte Steuereinnahmen für Kommunen

Ehemalige Tagebaue sind die Ökokraftwerke und Energiespeicher der Zukunft

Der Tagebau Hambach heute *(Foto: Markus Clemens)*

...und ab 2030 *(©SPILETT New Technologies GmbH 2020)*

„Das Konzept ließe sich auf nahezu alle deutschen Tagebaue übertragen", meinen die Verfasser, und würde z.B. in Garzweiler, Hambach und Inden ein regeneratives Energiegewinnungspotenzial von bis zu 10 GW/p ermöglichen. Gleichzeitig eignet sich der Tagebau als gigantischer Energiespeicher. Zu diesem Thema, insbesondere zum Thema Pumpspeicherkraftwerk, der sogenannten „Wasserbatterie", wurden bereits intensive Gespräche mit dessen Erfinder, Prof. Schmidt-Böcking von der Goethe-Universität Frankfurt geführt und in konkrete Pläne übersetzt. **+Dr. Gerhard Luther, Uni Saarbrücken**

Dass es sich hier um ein realisierbares und zukunftsweisendes Konzept handelt, beweisen die Kooperationsangebote zahlreicher namhafter Firmen und Hochschulen (RWTH Aachen, Thyssen-Krupp, Salzgitter, Mannesmann, Shell, Toyota, Metropolitan Cities u.v.m.), die an der gemeinsamen Entwicklung der **SpeicherStadtKerpen** sehr interessiert sind.

Abbildung 2: Das System SpeicherStadtKerpen

Kostenabschätzung

Die Speicherkosten setzt das Fraunhofer IEE mit rund 4,6 Cent pro Kilowattstunde (ca. 1 Cent in 4000 m Tiefe) an, die Investitionskosten mit 1.354 Euro pro Kilowatt Leistung (Voith 150 Euro/kW) und 158 Euro pro Kilowattstunde Kapazität.

Diese Rechnung basiert auf einem Speicherpark mit sechs Kugeln, einer Gesamtleistung von 30 Megawatt und einer Kapazität von 120 Megawattstunden sowie 520 Speicherzyklen pro Jahr.

Größe einer Einheit: Volumen ca. 14000 m^3
Energiespeicherkapazität ca. 21 MWh
Turbinenleistung ca. 6 MW
Turbinenkosten ca. 8 Millionen Euro => 1.354 Euro pro Kilowatt

Im Vergleich:
Ein U-PSKW in 4000 m Tiefe und 500.000 m^3 Volumen
Speicherkapazität von 5000 MWh = 5 GWh
Turbinenleistung 600 MW
Turbinenkosten 100 Millionen Euro => 160 Euro pro Kilowatt
Betonkosten ca. 250 Millionen Euro

=> 70 Euro pro kWh

Invisible Gigantic Hydro Power Storage Plants in Lignite Open-Cast Mines-
A Key Technology for Short-Term Storage to Implement the Energy Transition

Horst Schmidt-Böcking

Preamble

Besides air and water, energy is the most important base for mankind.

Abstract:

The sun provides Earth, and thus mankind, with a virtually unlimited amount of environmentally friendly, renewable energy in the form of light. Therefore, an energy crisis does not exist on Earth. Most of this solar energy is stored as heat in the atmosphere and the oceans. However, to utilize this energy source in the atmosphere, we humans must learn to convert this energy into electricity using modern technologies, primarily wind turbines WK and photovoltaics PV, and then store it.

Many different methods of storing electrical energy (green hydrogen, batteries such as lithium-ion batteries, or hydro power plants etc.) are currently being discussed and tested. Energy storage by hydro power plants has been proven for a long time. It can not only store enormous amounts of energy, but it is also very economical and has an approximately 80% recovery efficiency for electricity. A proposal to erect huge hydro power plants is the idea of invisible pumped-storage hydroelectric power plants in open-cast lignite mines or in the deep sea.