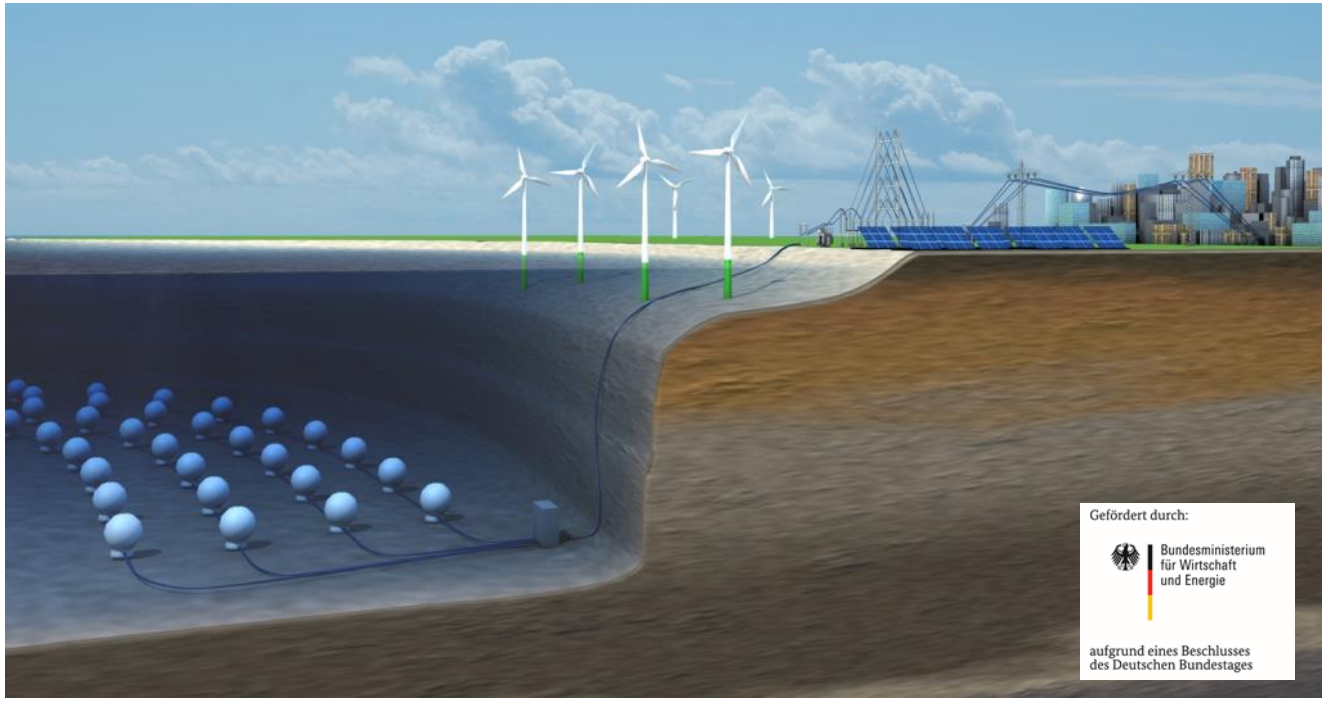
StEnSea: Stored Energy in the Sea

Bernhard Ernst

2022 Fall Technical Workshop, Minneapolis, Oct. 26th, 2022



Source Picture: Hochtief

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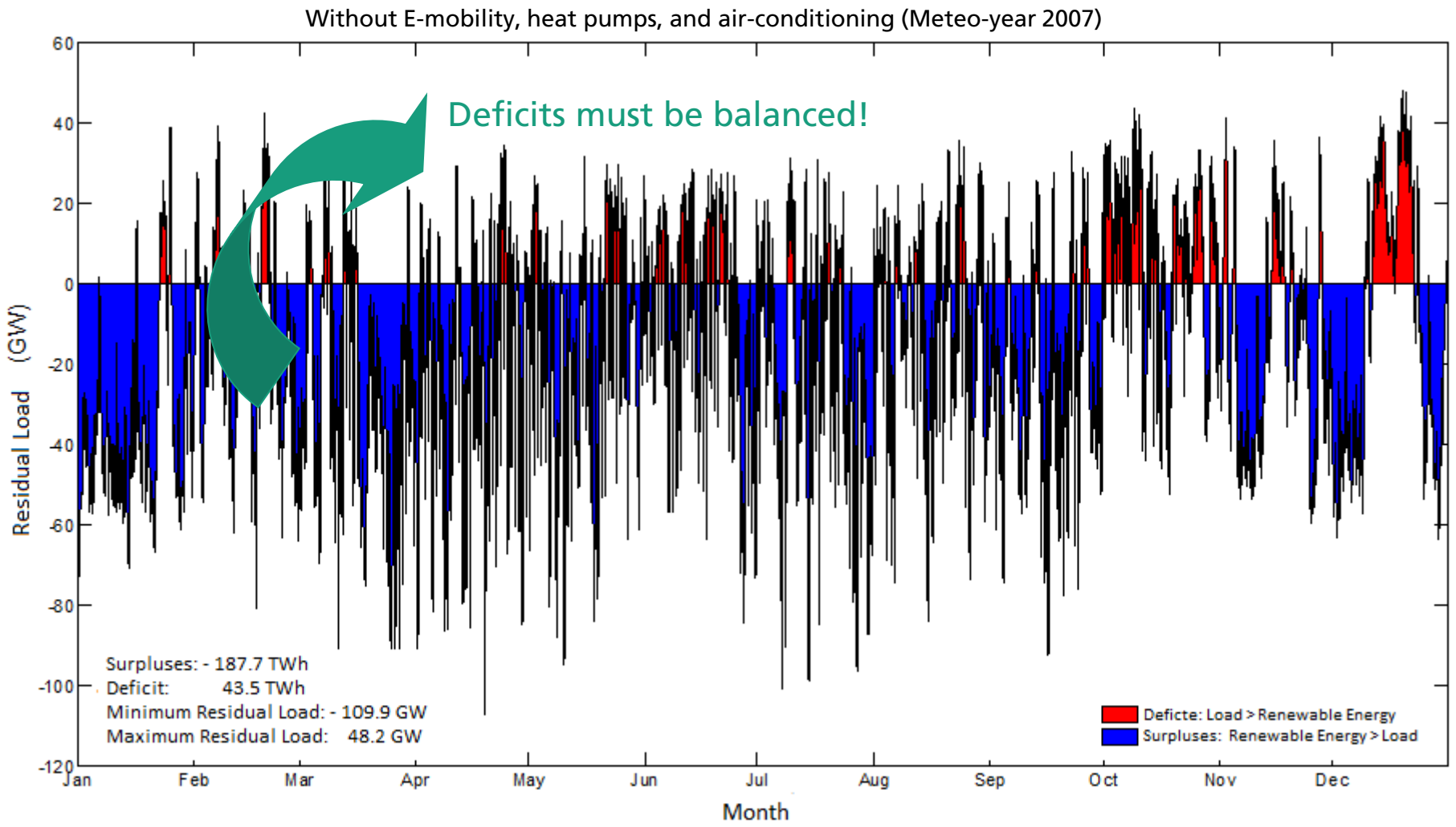
Scenario: 100% Renewable electricity in 2050



Source: IEE-calculation for UBA Energy goal 100% electricity from RE

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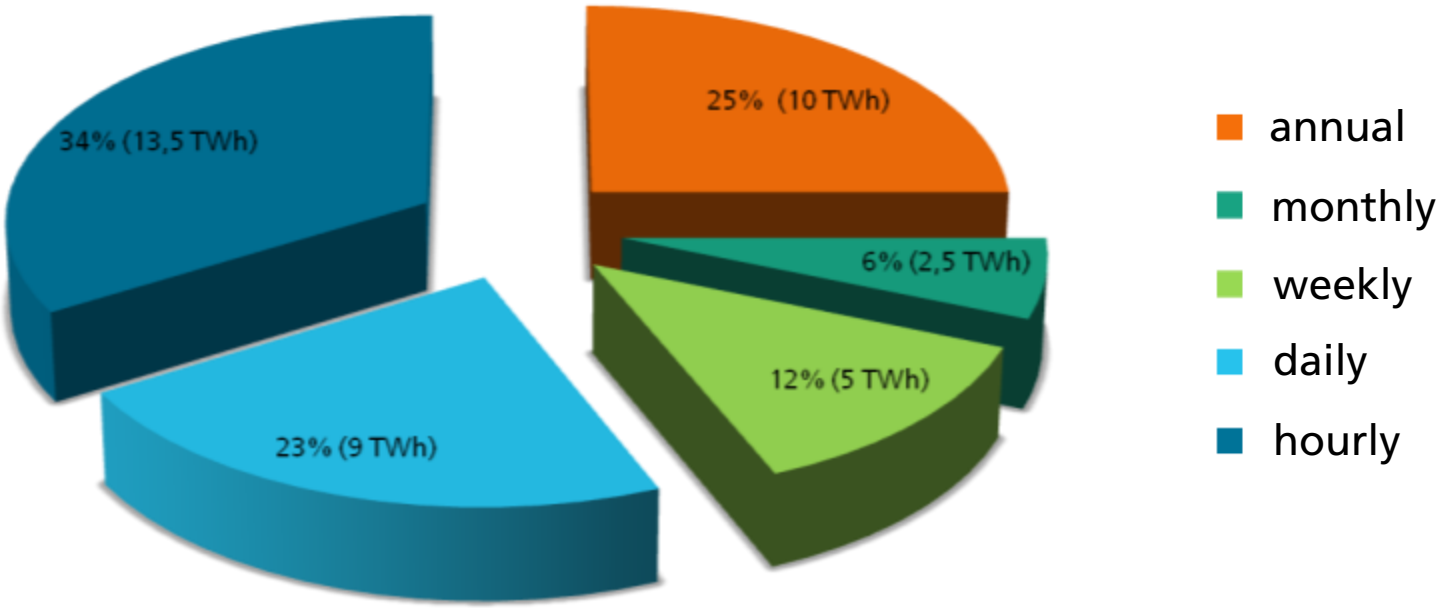
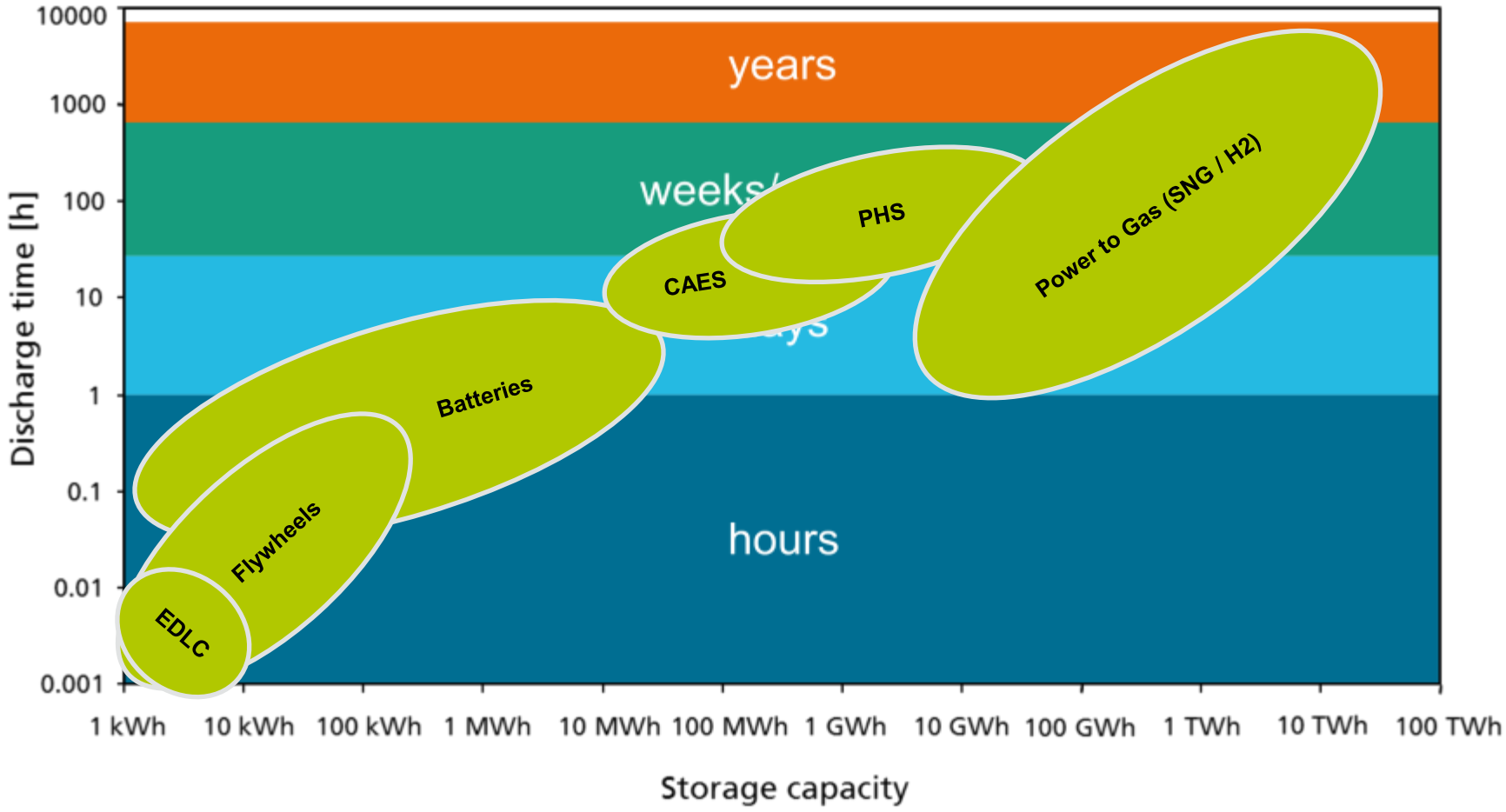
Balancing Needs | Example Scenario Germany 2050



→ Different Requirements for Storage!

Ref.: Data from BMU Leitstudie 2011

Capacities and discharge times of different storage technologies



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Pumped Hydro Storage (PHS)

Operating principle:

- potential energy

Application:

- Short to medium term storage (h-d)
- Peak load, Grid Services

Properties:

- Low energy costs
- Geographical dependency
- High capacity and efficiency (up to 88%)
- High construction costs and long construction time

Status & Trend:

- R&D: Use of “natural” height differences

Source picture bottom right: bmwi-energiewende.de; Source picture top right: http://www.energystorageexchange.org/ and Google Maps

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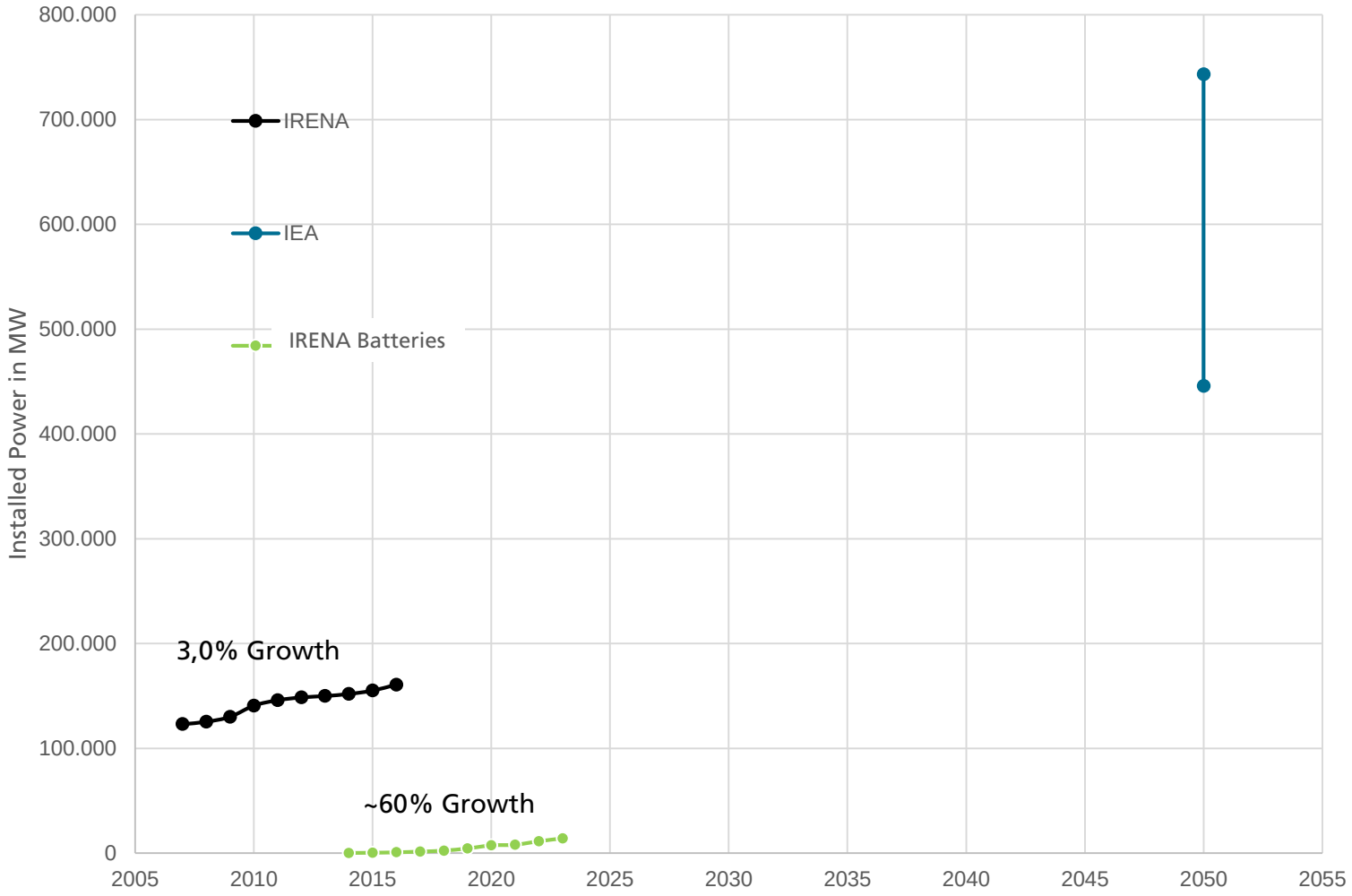
Pumped Hydro (PHS): Global Trend



Sources: IRENA (Black and green curve), IEA (Blue curve)

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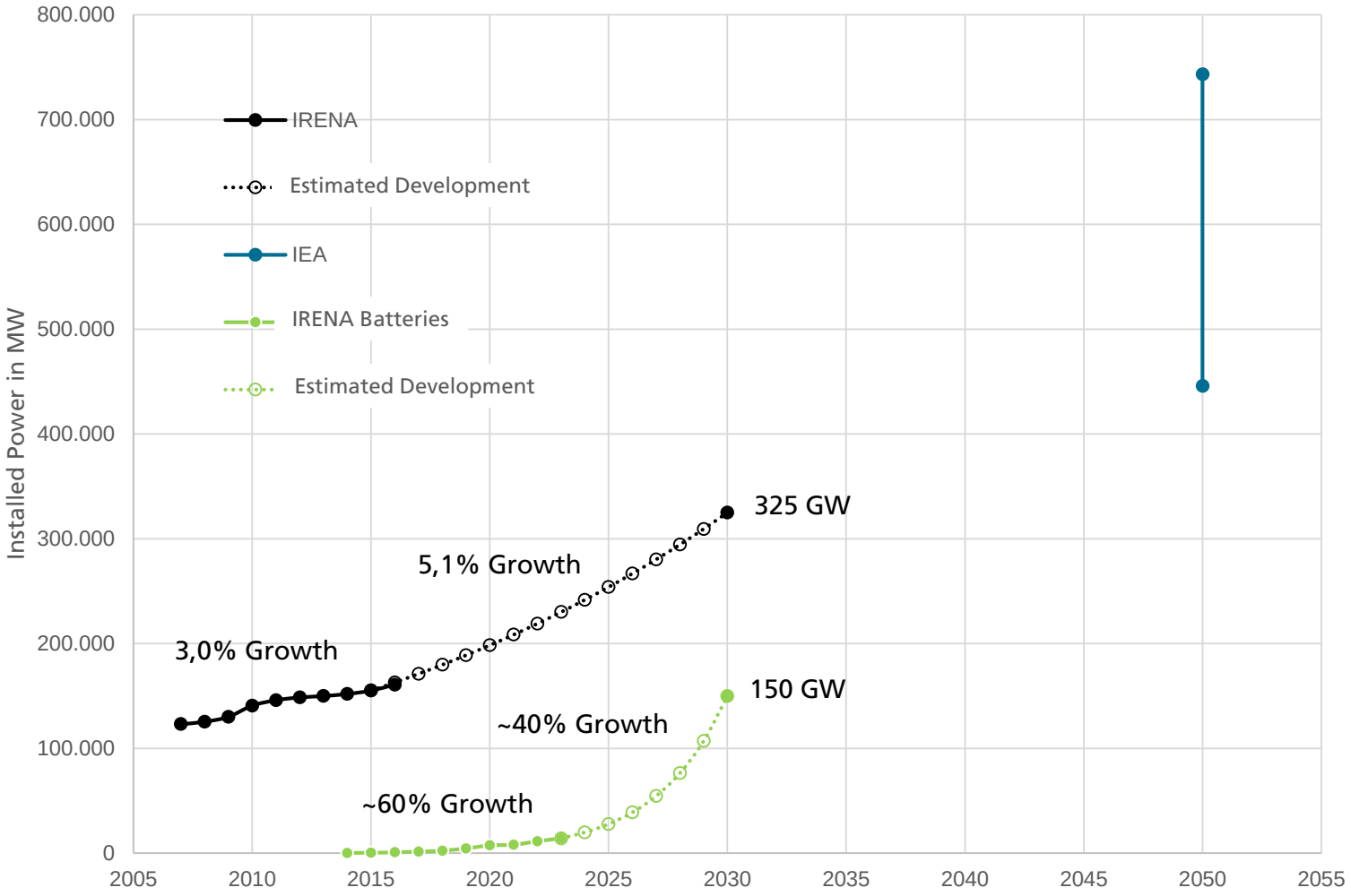
Pumped Hydro (PHS): Global Trend



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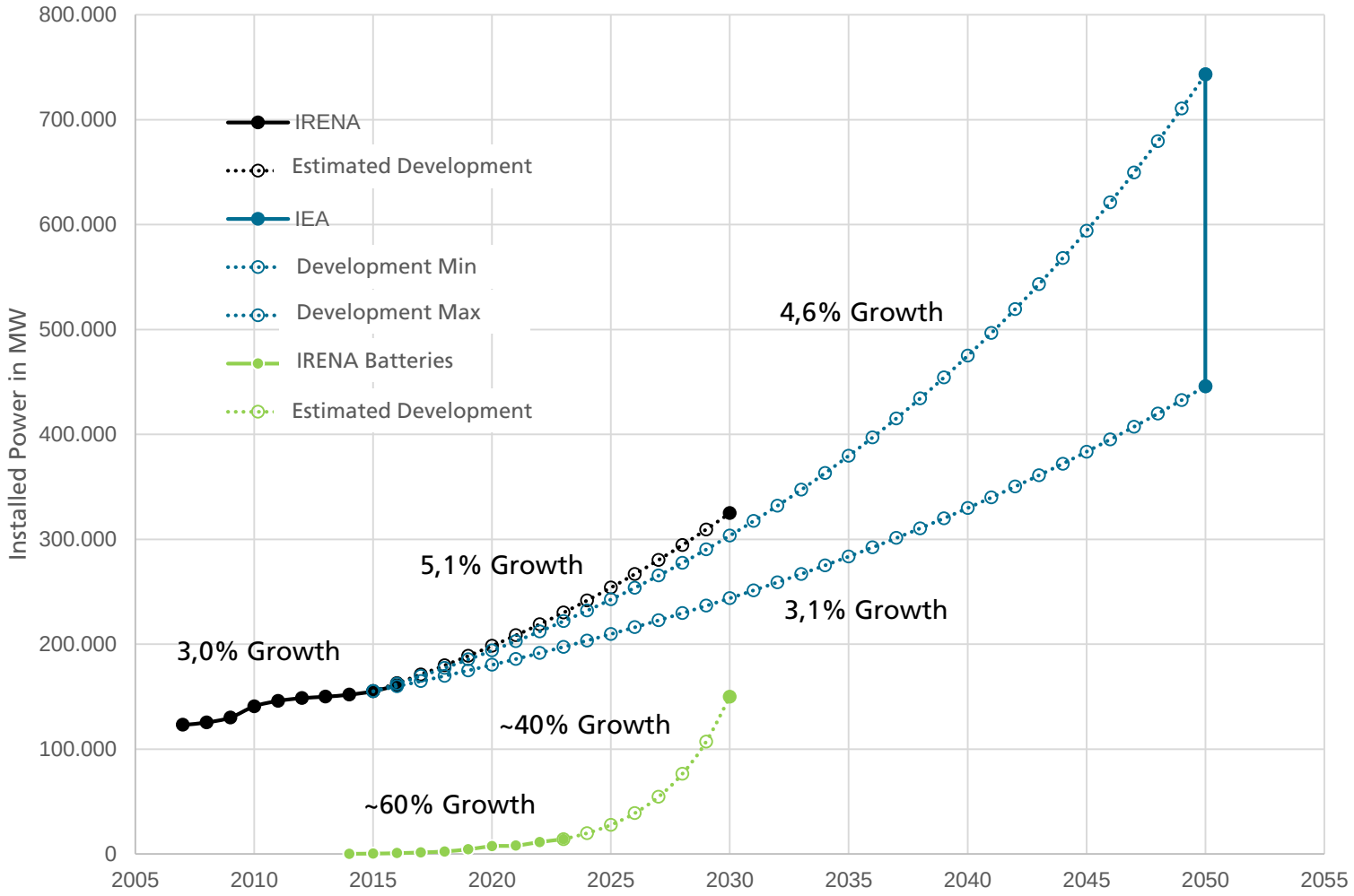
Pumped Hydro (PHS): Global Trend



Sources: IRENA, IEA

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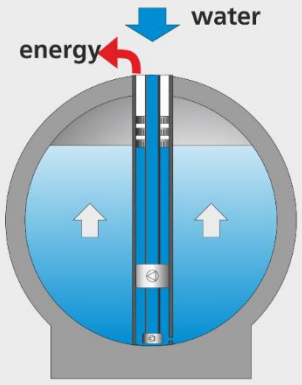
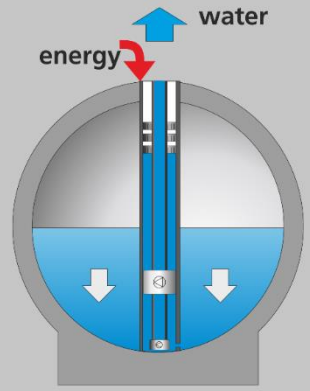
The functional principle corresponds to that of a pumped storage power plant



Discharging

- Water flows into the sphere and drives the turbine
- The turbine produces electricity until the sphere is filled with water
- Once the sphere is filled with water, it is filled and "discharged".



Charging

- Electricity is taken from the grid to drive the pump
- The pump pumps water out of the sphere
- Once the water has been pumped out of the sphere, the sphere is empty and "charged".

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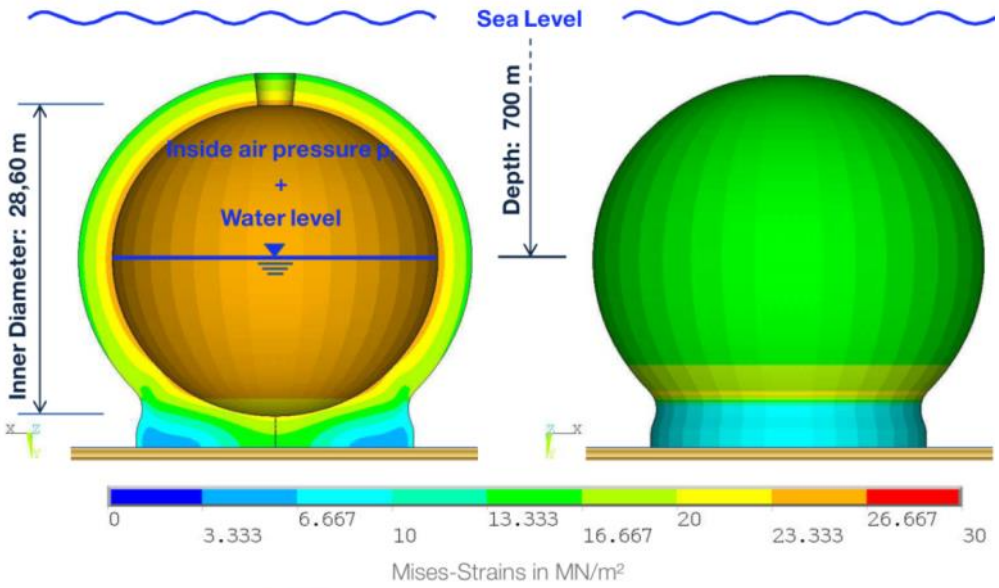
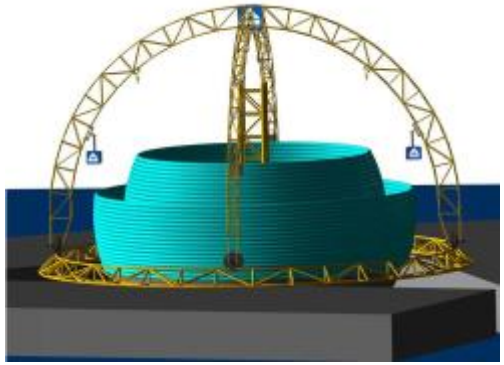
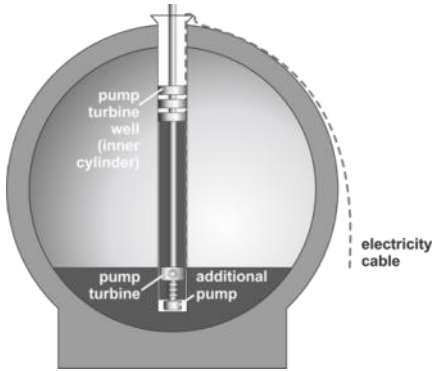
Technical Data STENSEA Concept

Material:	Concrete
Turbine power:	5 MW
Discharge time:	4 h
Capacity:	20 MWh
Efficiency:	75-80 %
Diameter:	30 m (100ft.)
Wall thickness:	2,70 m
Storage volume:	12.000 m³
Pressure:	70 bar/700m
Weight:	> buoyancy!







Source: Pictures on top and bottom left Hochtief

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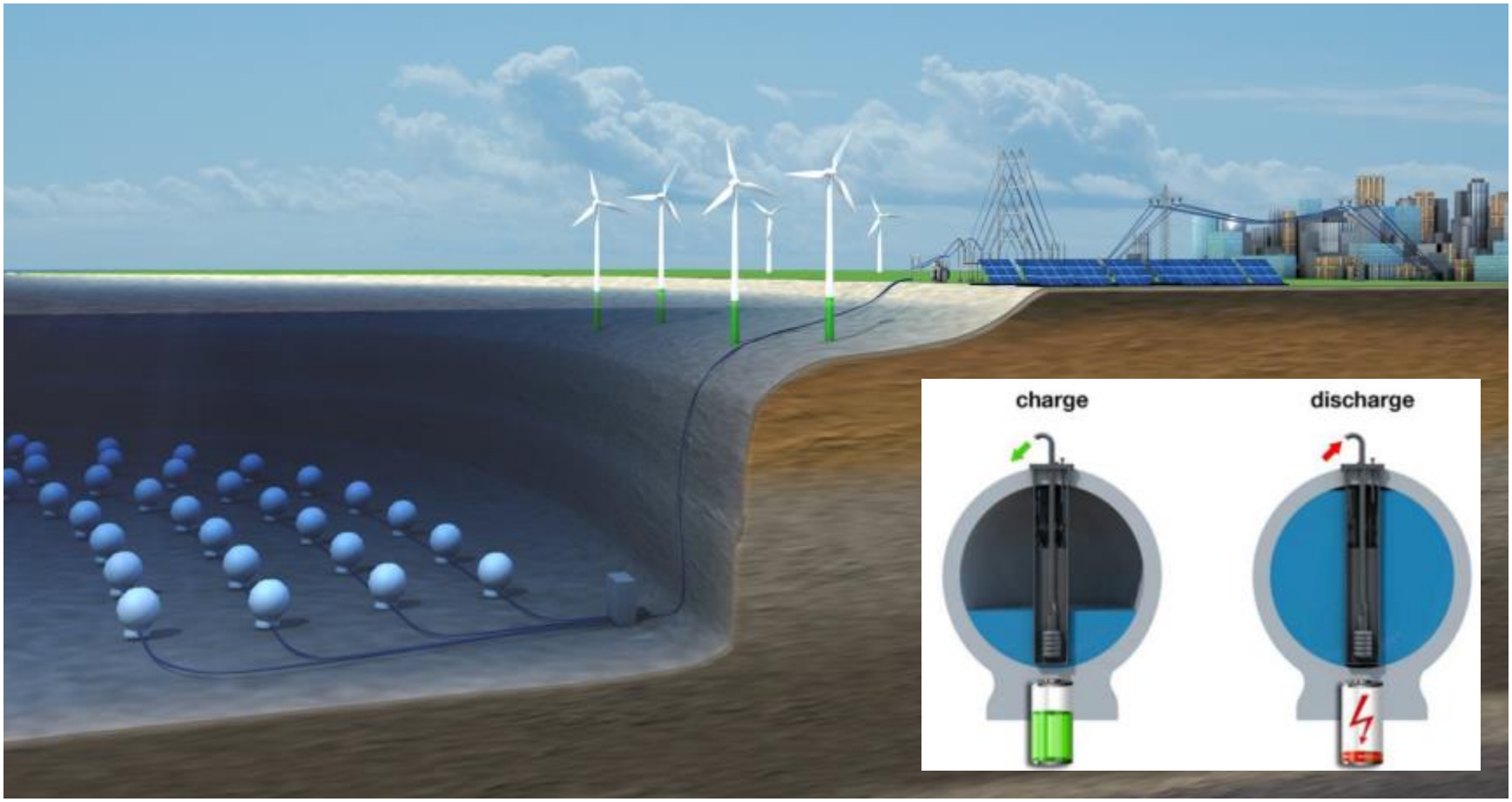
StEnSea plant: 50 – 500 spheres



→ Concrete sphere corresponds to the lower reservoir of a PHS.

Fig.: Hochtief

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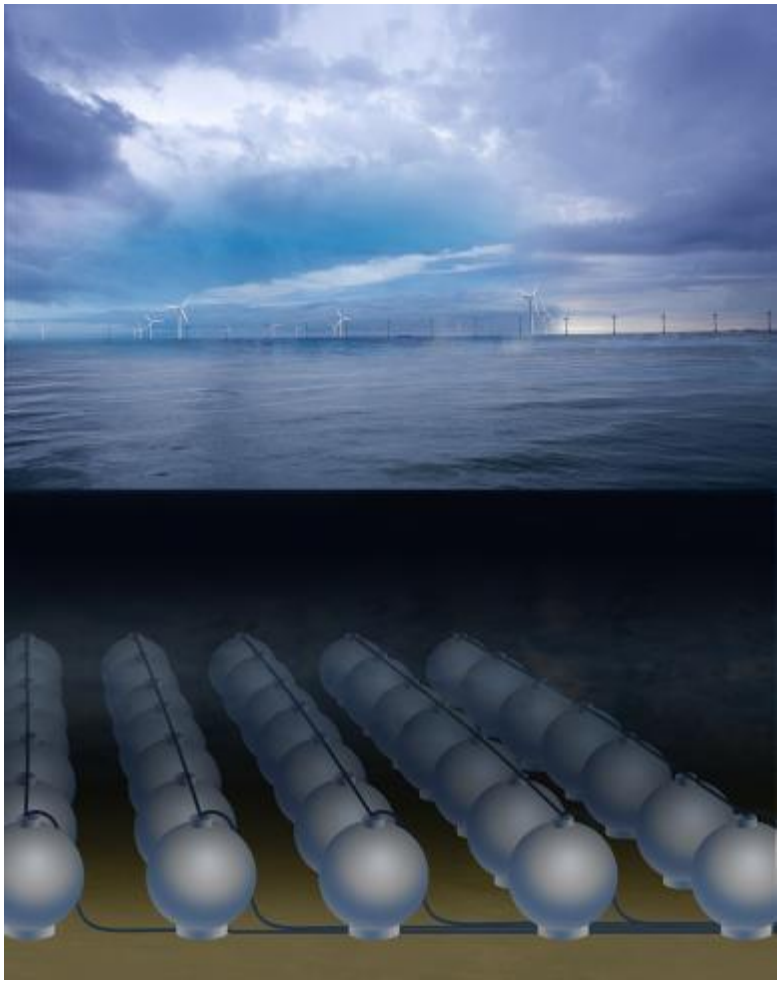
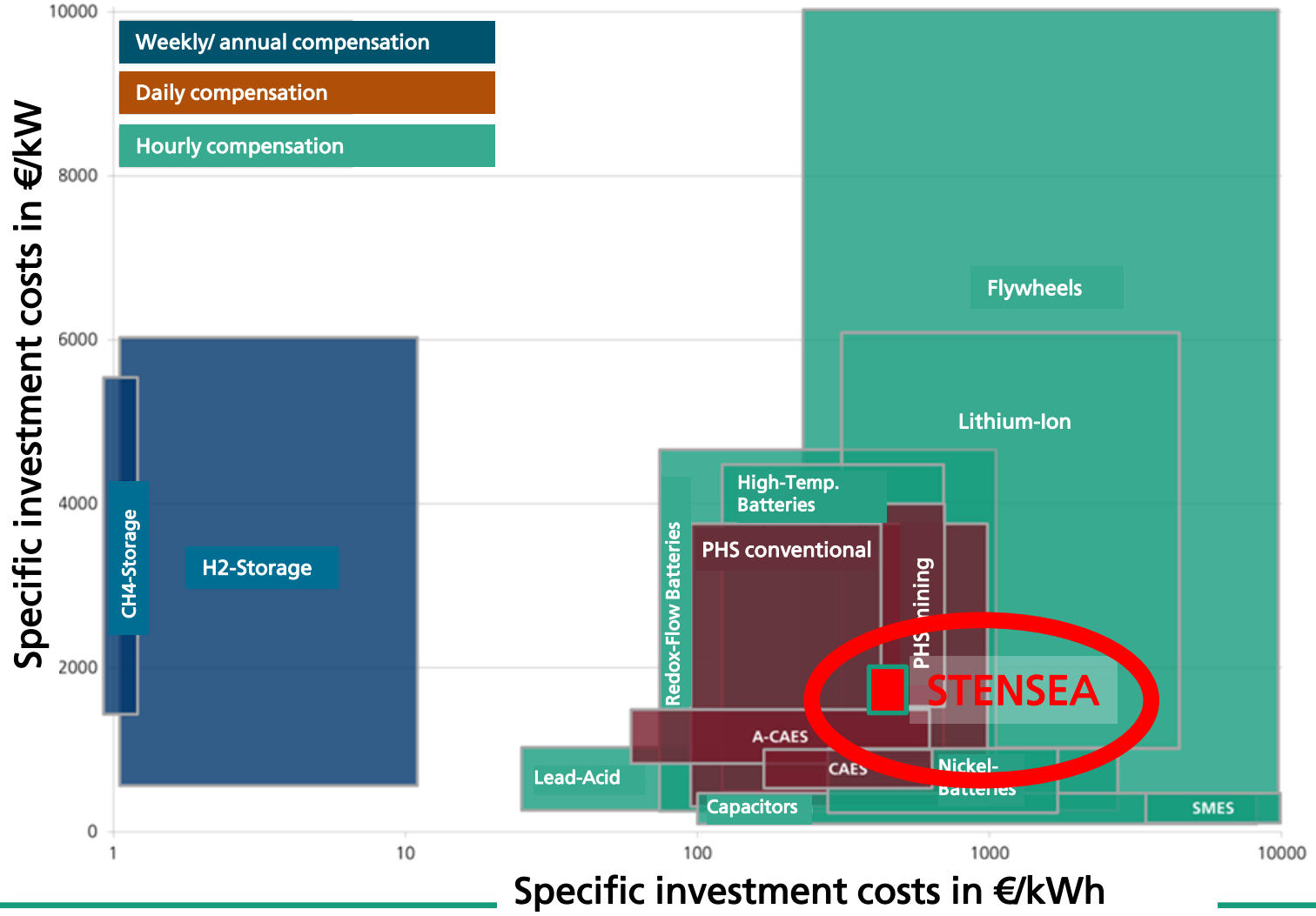
GIS-based resource assessment (600-800m water depth)

	Potential [TWh]
World wide	~817
Top 10	~628
Top 10 EU	~166
USA	~75
Japan	~70



Specific Investment Costs of Storage Technologies
Meta study Energy Storage



Source: UMSICHT, IWES; Metastudie Energiespeicher for BMWi

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Costs of Storage Technologies

Comparison StEnSea with battery

Assumptions:

Whole system incl. grid connection, system size: 30 MW, 120 MWh, 520 cycles per year (2 cycles per day, Mon-Fri)

StEnSea

Investment costs (power):	1354 €/kW
Investment costs (energy):	158 €/kWh
Lifetime:	20 years
Efficiency:	75-80 %
Storage costs:	4.6 €ct/kWh

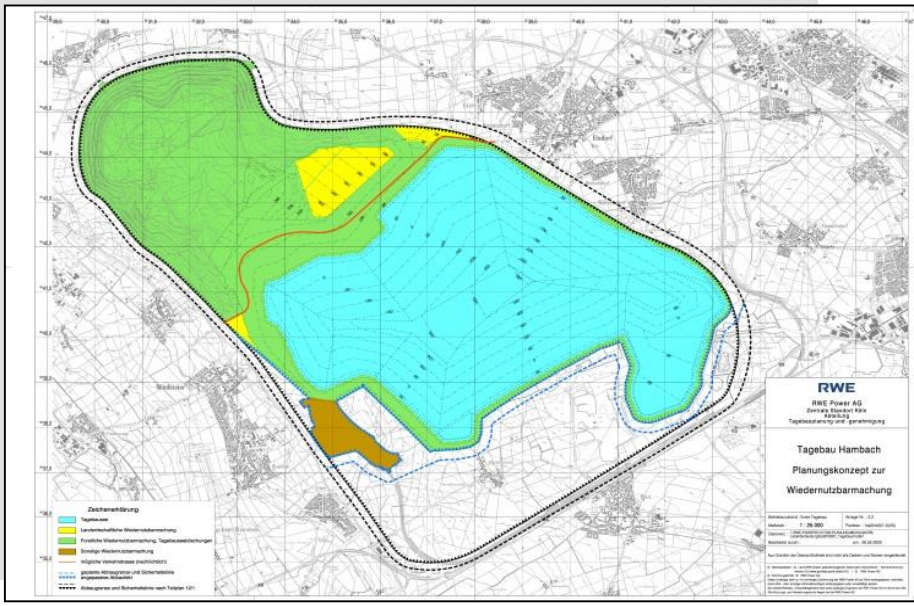
Li-Ion Battery

Investment costs (power):	175 €/kW
Investment costs (energy):	550 €/kWh
Lifetime:	15 years
Efficiency:	87.5 %
Storage costs:	7.3 €ct/kWh

The Hambach open-pit mining lake is a very promising application due to its structure

The Hambach open-pit mining lake

- Surface of 40,000m²
- Deepest point 355m below water level
- Distances to shore is 3km in each direction
- 688 StEnSea spheres
- 8.2 GWh discharge capacity
- 2.1 GW power output
- Barely profitable on **2019** market data
- Earliest completion of the lake 2070



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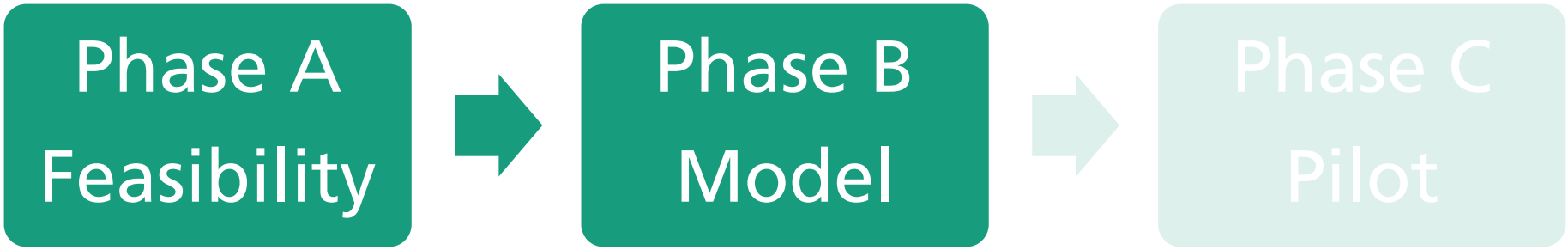
Development phases of the StEnSea project



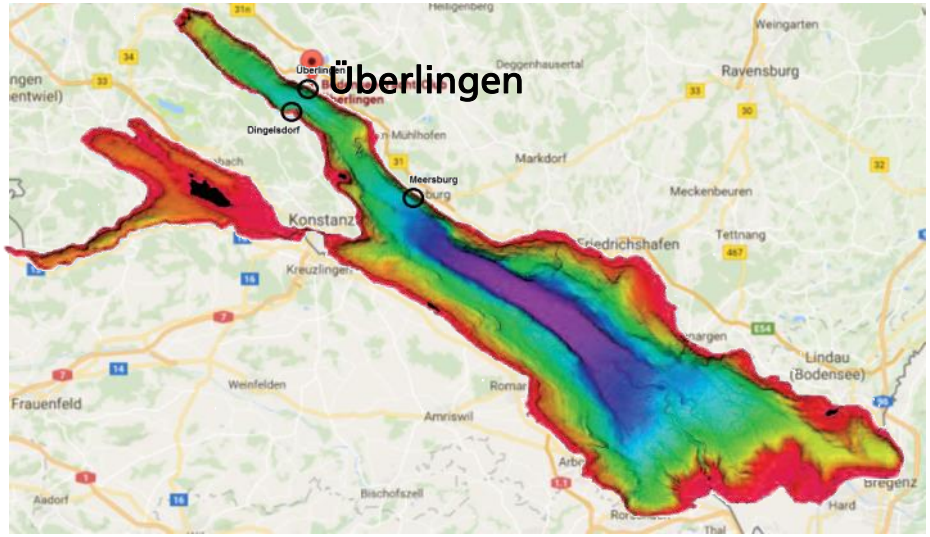
- Involved partys: Fraunhofer IEE, Hochtief, Uni-Stuttgart
- Idea: Prof. Horst Schmidt-Böcking, Prof. Gerhard Luther
- 1st BMWi-funded project ran untill 06/2017 (Phases A und B)
- 2nd BMWi-funded started in 07/2022 with pre-research phase

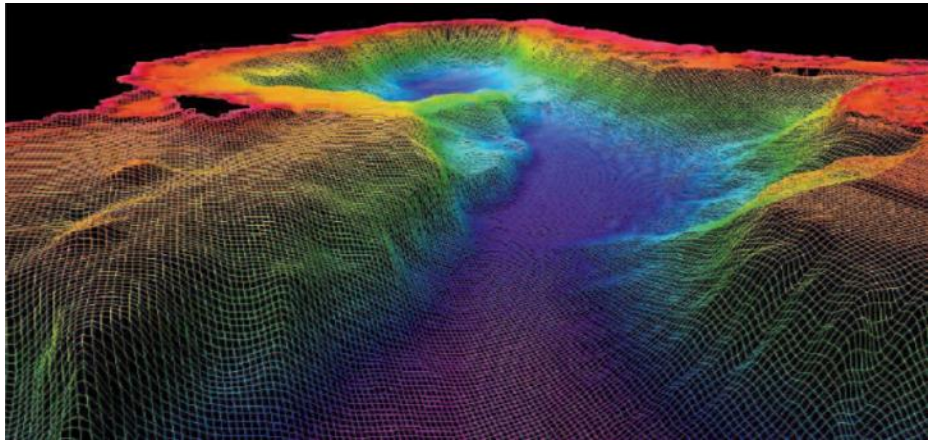
Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

Model Experiment at Lake Constance (1:10)

- Technology testing
- Testing time 11/2016-12/2016 (around 4 Weeks)
- 100m water depth
- Site identification with maps from project „Tiefenschärfe“
- TRL2 →TRL 5/6

Goal: Gain experience for full-scale pilot





Source Street map on top: Google Maps, Source height profiles (top, bottom) project Tiefenschärfe ISF

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Transport to test field

Model experiment at Lake Constance

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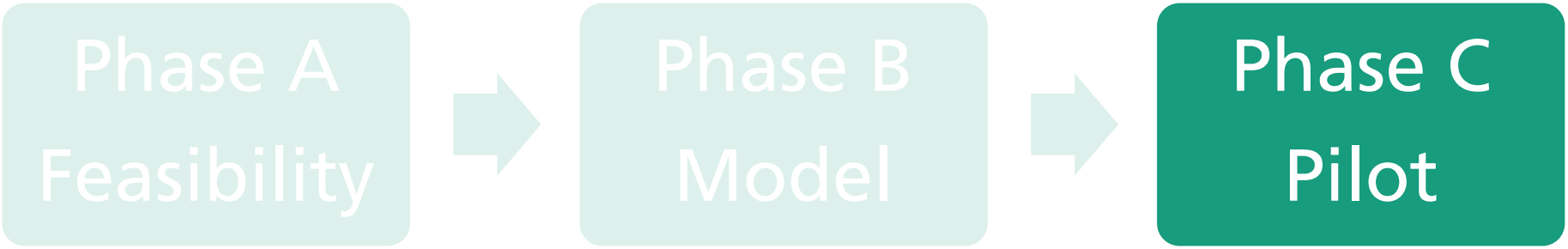

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Phase C: Pilot project (1:3) in deep water

The pilot project

- Diameter: 10 m
- Weight: ≈1000 metric tons
- Power: ≈1 MW
- Capacity: ≈1 MWh
- Depth: 600m-700m
- Pre-reseach ongoing (location, international economic studies)
- Manufacturing and installation planed for 2024

- Project partner: PLEUGER Industries GmbH

PLEUGER

Sponsors, awards, contact

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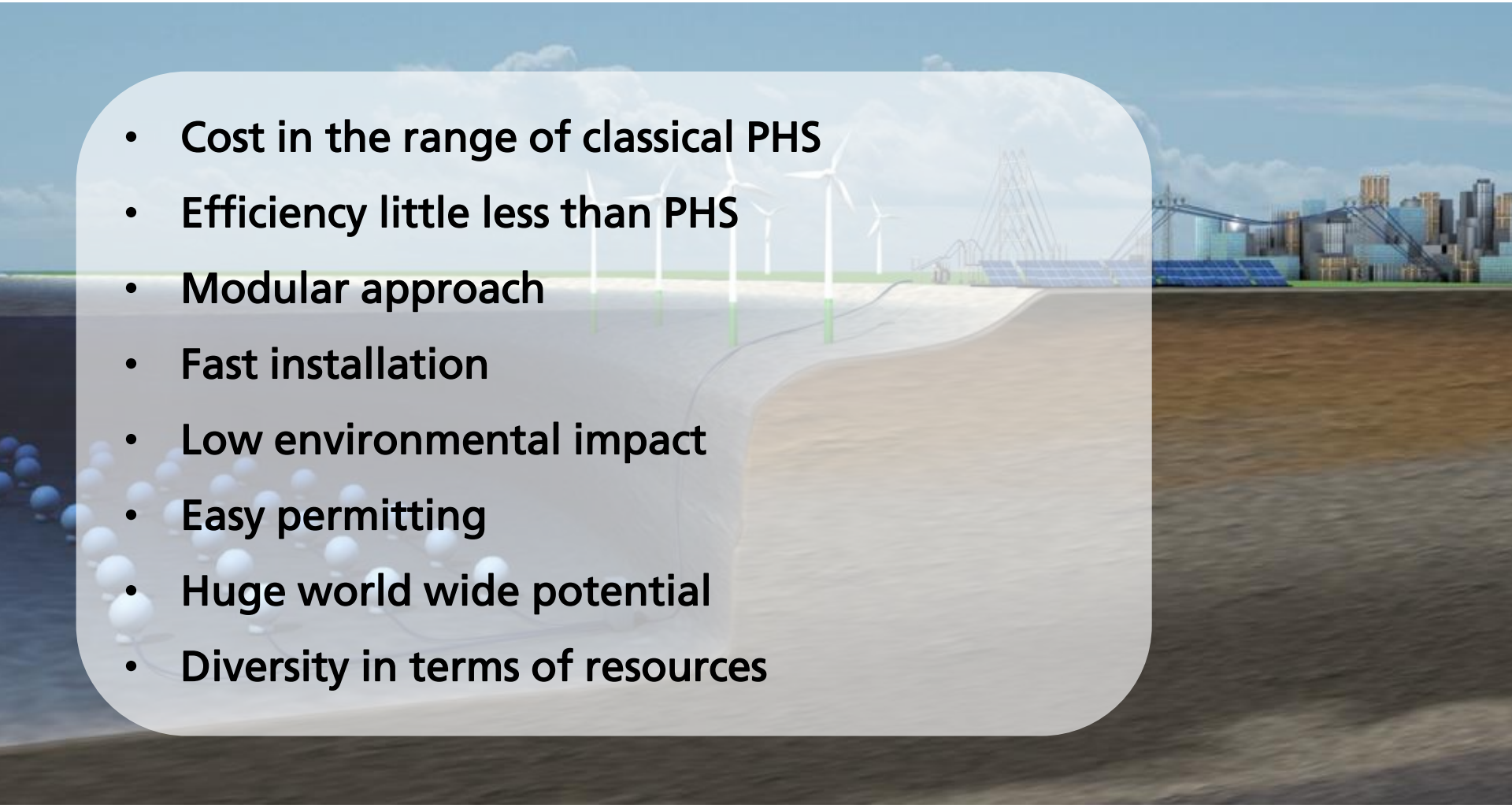
Conclusions



- Cost in the range of classical PHS
- Efficiency little less than PHS
- Modular approach
- Fast installation
- Low environmental impact
- Easy permitting
- Huge world wide potential
- Diversity in terms of resources

Announcement

Offshore Energy and Storage Society

OSES 2023 MALTA
7th Offshore Energy and Storage Symposium
JULY 12-14, 2023

https://www.osessociety.com/oses2023

The symposium is being hosted by the University of Malta, in collaboration with

- the Offshore Energy and Storage Society,
- the University of Nottingham,
- the University of Windsor and
- **Fraunhofer IEE**

Fraunhofer IEE