Spheric Under Water Energy Reservoirs

Introduction:
The Role of Energy Storage

Ongoing Research:
The StEnSea Project

Outlook:
Offshore Energy Storage

Conclusion

Source: 5)
Introduction: The Transition to Renewable Energy and the Relevance of Energy Storage

The EU's Renewable energy directive:
- 20% from renewable energy sources by 2020
- 27% from renewable energy sources by 2030

Introduction: The Transition to Renewable Energy and the Relevance of Energy Storage

Electrical generation from renewables in Germany

Introduction: The Transition to Renewable Energy and the Relevance of Energy Storage

Fluctuations from Solar & Wind Energy:
- Season
- Daytime
- Weather

Demand for Stabilization:
- Grid Expansion
- Computational Grid Optimization
- Energy Storage

June 2012

Dezember 2012

Source: Physik konkret, Konrad Kleinknecht, Helmut Alt, 18 (2013)
Introduction: The Transition to Renewable Energy and the Relevance of Energy Storage

**Mechanical**
- Compressed Air
- Flywheel
- Pumped Hydro

**Electrical**
- Capacitor
- Superconductor

**Thermal**
- Power to Liquid (e.g. methanol)
- Power to Gas (e.g. fuel cell)

**Chemical**
- Battery (e.g. NiCd, NiMH, Li, LiPo...)

**Electrical Storage**
- ↑ High Efficiency
- ↓ Small Capacity
- ↑ Fast and Flexible
- ↓ Lifetime
- ↑ Efficient/Economical/Scalable
- ↓ Impact to Environment
- ↑ Simple
- ↓ Low Efficiency
Introduction: The Transition to Renewable Energy and the Relevance of Energy Storage

Worldwide Installed Electrical Grid Power Storages

Introduction: The Transition to Renewable Energy and the Relevance of Energy Storage

\[
E_{\text{el}}(\text{surplus}) \downarrow \quad E_{\text{pot}} = V \cdot \rho \cdot \Delta h \cdot g \downarrow \quad E_{\text{el}}(\text{required})
\]

Efficiency:

\[
\frac{E_{\text{el}}(\text{required})}{E_{\text{el}}(\text{surplus})} = 80\text{-}85\%
\]

Source: [http://www.powerelectronicsnews.com/uncategorized/the-search-for-large-scale-energy-storage-solutions](http://www.powerelectronicsnews.com/uncategorized/the-search-for-large-scale-energy-storage-solutions)
The StEnSea (Stored Energy in the Sea) Project

Potential Energy:

\[ E_{pot} = V \cdot \rho \cdot \Delta h \cdot g \]
\[ = V \cdot \Delta p \]

Efficiency:

\[ \eta = 80-85\% \]

Pressure increase under water:
1 bar per 10 meter

Source: 1)
The StEnSea Project

Conclusion

Prof. Schmidt-Böcking (Frankfurt, Germany)

Dr. Gerhard Luther (Saarbrücken, Germany)

Idea and patents


Speicherung elektrischer Energie am Meeresboden
Das Meer-Ei

Prof. Schmidt-Böcking | Gerhard Luther | Christoph Leit | Jochen Bar

The StEnSea Project is a research project that focuses on the concept of underwater energy reservoirs for the storage and retrieval of electrical energy from the ocean. The project is led by Prof. Schmidt-Böcking and Dr. Gerhard Luther from Germany.

The project timeline spans from 2011 to 2017, with key milestones and contributions from various experts in the field.

Source: 2)
The StEnSea Project

Pilot Study


concrete structure specialist

ocean energy and storage specialist from Kassel

HOCHTIEF SOLUTIONS AG

Fraunhofer IWES

Frontiers in energy research
Spheric Underwater Energy Reservoirs
The StEnSea Project

Assuming a sphere with a diameter of 30m lying at an ocean-depth of 700m

### Costs for common pumped hydro power stations:

<table>
<thead>
<tr>
<th></th>
<th>€/unit</th>
<th>€/kW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Building materials</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Concrete, framework and strengthener)</td>
<td>2,065 Mio</td>
<td>413</td>
</tr>
<tr>
<td><strong>Installation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,5 Mio</td>
<td>300</td>
</tr>
<tr>
<td><strong>Pump turbine with electro mechanics</strong></td>
<td>2,625 Mio</td>
<td>525</td>
</tr>
<tr>
<td><strong>Target costs per installed kW</strong></td>
<td></td>
<td>1238</td>
</tr>
</tbody>
</table>

Costs for common pumped hydro power stations: **1300-1600 €/kW**

*Source: 3*
The StEnSea Project

Foundation of StEnSea


Finances

HOCHTIEF SOLUTIONS AG

Project Leader

Fraunhofer IWES

Project Developer

Researcher

Collaborators

Universität Stuttgart

Pump-turbine Technologie

Bundesministerium für Wirtschaft und Energie

Project Funding

Dip.-Ing. Matthias Puchta

Executive Project Leader

Consultant

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Prof. Dr. Horst Schmidt-Böcking

Prof. Dr. rer. nat. Gerhard Luther

UNIVERSITÄT DES SAARLANDES

(Idea and Patent Application)
The StEnSea Project

Technical feasibility studies

- Material: Concrete
- Turbine: 5 MW
- Discharge Time: 4 h
- Capacity: 20 MWh
- Efficiency: 80-85 %
- Diameter: 30 m
- Shell thickness: 2.70 m
- Storage Volume: 12,000 m³
- Min. water depth: 700 m
- Pressure: 70 bar

Source: 1)
The StEnSea Project

Technical feasibility studies

Optimizations

Operation Depth (700m):
- suitable for present pumping technologies
- comparable to conventional pumped hydro

Design (Spherical):
- optimal pressure distribution

Sphere Size / Shell Thickness (30m/3m):
- weight always higher than uplift
- volume suitable for daytime energy storage

Turbine (5MW):
- comparable with typical offshore wind turbine
The StEnSea Project

Technical feasibility studies

1) All mechanical gear is inside the cylinder which can be retrieved with a remotely operated vehicle.
2) Reduced corrosion because of low O₂ concentration and low temperatures at 700m ocean depth

Easy, few and cheap maintenance

To get a power of 5MW the water pipe need to have a diameter of only 10cm

Compact cylinder design

Protective grid + diffuser for flux reduction

Animal protection

Water flows into the sphere and starts the turbine thus generating power when needed
Water is pumped out of the sphere if there is surplus power

Source: 1)
The StEnSea Project

Double cladding construction design.
Inner cladding with composite fabric

Big scale spherical construction technologies do already exist

Source: 1)
The StEnSea Project

Construction of a model

- **2011**
- **2012**
- **2013**
- **2014**
- **2015**
- **2016**
- **2017**

**Scale:** 1:10  
**Diameter:** 3m  
**Weight:** 21.4t  
**Shell thickness:** 30cm

Construction by contractor Hochtief near Frankfurt

First function tests in Bad Hersfeld

Source: 4)
The StEnSea Project

Model experiment at the Bodensee

08.11.2016:
Model sphere was set into the water at the harbor of Konstanz

09.11.2016:
Model was sunk to 100m water depth - 200m away from the lakeshore of Überlingen

03.03.2017:
Model got retrieved

Source: Google Earth

Frontiers in energy research
Spheric Underwater Energy Reservoirs
The StEnSea Project

Model experiment at the Bodensee

Source: 5)
The StEnSea Project

Evaluation of the model experiment


First results from the model experiment:
- Transport, installation and construction ✓
- The impact of different pressure conditions on the turbine pump ✓
- “proof of concept” ✓

Further Analysis:
- Improve theoretical sphere simulations with gained data
Outlook: Offshore Energy Storage

What’s happening next?
- Geographic information system of seas in Europe (inclination, sediment, …)
- Infrastructure (distance to coast, grid connection)
- Construction scaling

Most Promising:
- Norwegian trench
- Spanish Sea

Goal: Realizing a 30m pilot project in Europe in 3-5 years

Source: Google Image Search for “Geographic information system”
Outlook: Offshore Energy Storage

Source: 6)
Conclusion

- The concept of pumped hydro is efficient, scalable and economical.
- The demand for energy storage will progressively increase.
- Energy production from offshore wind parks will strongly increase.
  “80% of the people live closer than 100km to a sea”
  (2010, United Nations Environment Program)
  That means: Energy storage close to a sea can be beneficial.
- In contrast to conventional pumped hydro, StEnSea has big advantages in terms of: “Impact to people and environment.”
- Global potential for 30m StEnSea spheres in 700m water depth: 893GWh
- Bigger spheres and deeper ocean depth are in principle possible.
Sources


