# PrepareBE (Buoyant Energy) – Exploratory Project Presentation

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## Abstract

*Buoyant Energy* (BE) is a new approach to store electrical energy offshore in a distributed and decentralised way, based on the well-established technologies of pumped-storage hydropower. The following work presents the basic storage concept and describes the outline of the exploratory project *PrepareBE* [8], which is about to start in July 2016. *PrepareBE* will clarify whether the *Buoyant Energy* principle is technically feasible and economically viable. Furthermore, the most promising application field will be determined.

## 1 Buoyant Energy (BE) storage concept

Energy storage and regulation becomes increasingly important in electrical networks with a growing share of renewable energies with fluctuating generator characteristic. The storage of electrical energy in the power grid occurs almost exclusively with proven pumped storage power stations (PSW) for decades. A new approach consists of hydraulic, offshore floating systems for the conversion and storage of electrical energy (principle "*Buoyant Energy*"). The core idea is well described as "floating pumped storage power plant" (Figure 1 and 2).

With this principle, water is moved back and forth between a floating body (e.g. build out of concrete) and the surrounding lake or ocean, depending on energy requirement (surplus electricity / electricity demand). The electrical energy is stored completely in the form of potential energy. A detailed description can be found in [1] and [2].

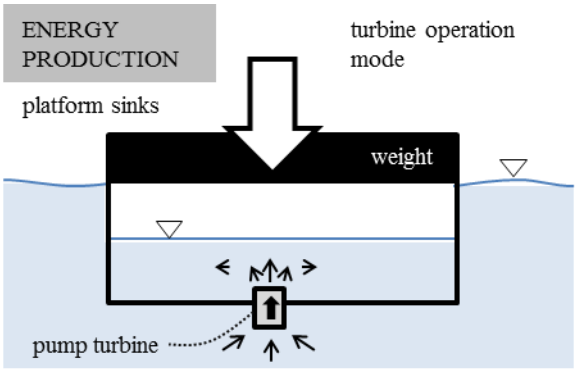


Figure 1: Basic technical concept (Energy production)

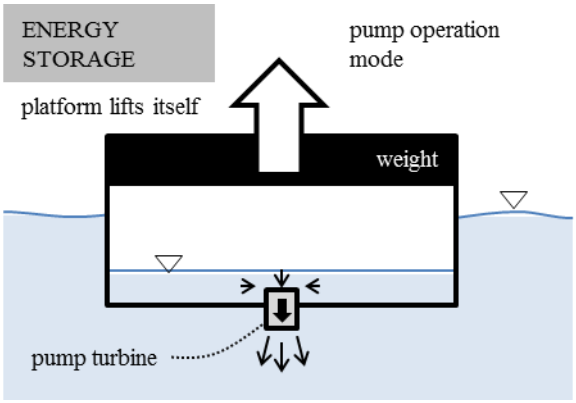


Figure 2: Basic technical concept (Energy storage)

The University of Innsbruck has filed a patent for the idea in DE, EP and US. All three cases are pending in grant good prospects.

The outstanding aspect of the BE energy storage concept compared to other emerging systems is its variety of embodiments. Thus, a possible combination with renewable energy sources or/and with floating infrastructure leads to beneficial synergies.

*Integration into offshore wind farms*

Offshore wind farms today are normally installed in relatively shallow seas. The wind turbine support structures are bottom-mounted on the seabed. BE structures could be placed between the wind turbines or in close proximity. At best, this would provide enough decentralised energy storage capacity to operate the wind farm in a demand driven way. Thus the performance of the whole power generation system would be enhanced significantly. The electrical connections to the wind turbines and to the coast can be realised with flexible sea cables.

There is increasing interest to install existing and to develop new floating wind turbine technology for deep water offshore sites. The integration of the BE concept in the support structure of floating wind turbines is a logical next step for further research. If every floating wind turbine has access to its own energy storage unit the overall system becomes more flexible and cost effective. Additionally the floating platforms provide enough space for electromechanical installations needed to perform energy conversion.

*Integration of intermittent electrical energy from other offshore renewables*

There is a number of other possibilities to harvest offshore renewable energy (tidal energy, wave energy, floating solar power plants) and new ideas still are under development. A common characteristic is the lack of inbuilt energy storage capacity. Due to their intermittent energy output, a connection to the grid may lead at worst to problems of the grid stability. BE platforms could provide a solution and therefore facilitate the extension and integration of offshore renewable technologies.

*Integration of intermittent electrical energy from onshore renewables*

Many onshore wind farms and other renewables are located next to the coast, far away from conventional pumped-storage power stations. There is good reason to link the intermittent feed-in of those renewables with *Buoyant Energy* structures. This solution could be very advantageous especially for islands with isolated grids. Thus, important foundations for the installation of renewable energy sources within the island´s interior could be laid. Furthermore the use of *Buoyant Energy* is technically possible in lakes or in remaining open brown coal pits filled with water.

*Synergies*

There are important potential synergies of large *Buoyant Energy* structures (Figure 3) and directly linked technologies (e.g. additional use as service and operation platform for offshore wind farms) or other economic sectors (industry, fishery, leisure, housing). For a reliable economic assessment these aspects have to be considered.

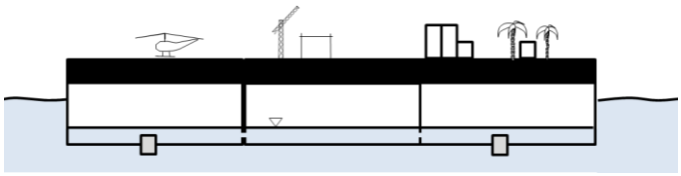

Figure 3: Potential synergies with other directly linked technologies (e.g. wind farms) or other economic sectors.

*Transdisciplinary considerations*

The implementation of BE requires comprehensive cooperation between experts for

- pumped-storage hydropower systems,
- floating offshore structures,
- wind farms (offshore and onshore),
- other emerging offshore renewable energy sources,
- electrical grids,
- energy markets and new business models.

Existing and proven technologies will serve as basis for an accelerated development.

## 2 Progress of BE beyond the state of the art

*Pumped-storage hydropower technology*

In terms of practical application the state of the art in energy storage systems are pumped-storage hydropower systems. This well-established technology has outstanding features, but is restricted to mountainous regions. Furthermore, obtaining permissions for new power plants becomes increasingly difficult. The core of *Buoyant Energy* is the combination of well-experienced hydro power concepts with robust offshore technologies. The scope of application of pumped-storage hydropower technologies will be enlarged significantly.

*Integration of offshore renewable energy sources*

For the first time *Buoyant Energy* will allow a comprehensive energy storage next to offshore renewable energy sources.

*Progress of Buoyant Energy compared to other non-conventional pumped-storage hydropower concepts*

There are a number of other non-conventional approaches based on pumped hydro storage power technologies.

- Some of these projects are still in a very early concept phase and are facing potential technical problems due to their challenging concepts – mainly in terms of typical locations or dimensions (e. g. Stensea [3] or Heindl's Hydraulic Rock Storage [4]). In comparison *Buoyant Energy* is more simple (e. g. much better accessible, better assessable in terms of dimensions, no pipes or penstocks required, no dependency on geology or deep water conditions) and almost without any doubts in terms of the fundamental technical functionality.
- Others are very much limited to onshore applications (e. g. underground pumped-storage hydropower plants [5], Powertower [6], Gravity Power [7]).

*Progress of Buoyant Energy compared to other emerging energy storage technologies*

There is a lot of ongoing research in energy storage. In terms of storage of electrical energy among others different types of batteries, compressed air energy storage, power-to-gas, super-capacitors, superconducting magnetic energy storage and flywheels are under development. *Buoyant Energy* follows a different development route, based on well established and efficient pumped-storage hydropower technology.

Compared to other emerging energy storage BE is supposed to be

- more simple,
- more robust,
- equal or much more efficient,
- equal or even faster available,
- more durable,
- more sustainable and
- ideally suited to be linked with other purposes.

*Challenges*

The challenges of the technology are

- the technical adaption of the pumped-storage hydropower system based on a floating platform to the offshore conditions and
- a comprehensive cost optimization, which will ultimately determine the competitiveness of *Buoyant Energy* and as a consequence its future role in the integration of renewable offshore energies.

## 3 Exploratory project

The basic energy storage approach *Buoyant Energy* is simple, scalable and can be used for various fields of application. However, ensuring the floating stability in wind and waves requires comprehensive scientific research and intensive development work. The exploratory project *PrepareBE* will clarify whether the *Buoyant Energy* principle is technically feasible and economically viable. Furthermore the most promising application field will be determined.

The Hydraulic Engineering Unit of the University of Innsbruck is joint by the Vienna University of Technology (Institute for Energy Systems and Thermodynamics) and is supported by the University of Edinburgh (Institute for Energy Systems) to carry out the early stage scientific work. The exploratory project duration is limited to 12 month. The main aims of *PrepareBE* are to investigate the BE system's usefulness and to prepare a future research, development and innovation project (R&D&I).

The preliminary study *PrepareBE* will

- evaluate and analyse the potential of a future R&D&I project,
- facilitate decision-making by objective and rational explanation of its strengths and weaknesses and the opportunities and threats associated,
- determine what resources its implementation would need and
- determine what chances of success the R&D project would have.

The consortiums ambition is to give evidence on the innovation potential and the expected beneficial synergies. Furthermore the progress beyond the state of the art will be determined. The main goal of this project is to provide a recommendation for future research activities.

## 4 Project design

*Overall structure of the work plan*

The project is organised in four technical and one distinct work packages on the project management and dissemination (Figure 4).

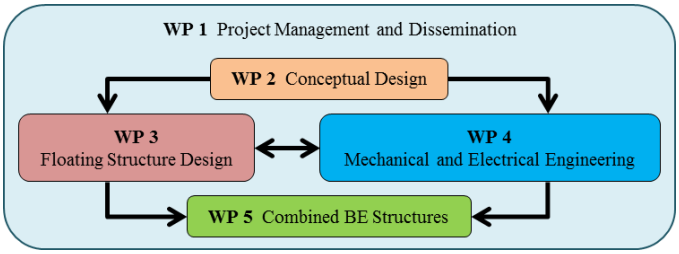


Figure 4: *PrepareBE* work packages (WP)

At first, WP 2 will be dedicated to define the best conceptual design approaches. Early interim results will influence WP 3 that addresses the floating structure design and WP 4 that covers the mechanical and electrical engineering. WP 5 will assess promising possibilities for the combination of BE with renewable energies and multi-purpose floating platforms.

*Conceptual design (WP 2)*

The objective of WP 2 is to focus on the adaption and the optimization of the *Buoyant Energy* concept to possible and promising areas of application.

Description of work:

- Assessment of exploitable existing offshore know-how:
  - Summary and assessment of applicable results from previously-funded EU projects (e. g. Mermaid, Tropos, Marina Platform).
  - Review of engineering design theory used in the offshore industry e. g. on hydrodynamic loads and dynamics of offshore floating structures, mooring design and ultimate limit strength, fatigue analysis and offshore concrete structures.
- Evaluation and selection of areas of application:
  Search for the most promising areas of application and estimation of potential boundary conditions; Both, energy storage requirements and most likely metocean conditions on suitable sites for BE structures will result and serve as a basis for the subsequent tasks.
- Conceptual design:
  Work out of BE storage design approaches matching the selected areas of application. Different sizes, shapes, pressure heads, weights and stored water volumes of BE platform designs will be analysed and assessed.

*Floating structure design (WP 3)*

Work package 3 focuses on the floating structural design and the floating stability of selected BE conceptual designs.

Description of work:

- Preliminary structural design of the most promising conceptual designs identified in WP 2.
- Simulation and analysis of floating platform(s) under steady state and dynamic conditions.

- Analysis of design approaches for wave damping: Fluid sloshing inside the BE system will significantly influence the structure's seakeeping behaviour (Figure 4). The motion of the water inside the structure can either be a damping or an amplifying factor of the overall motion of the structure. The sloshing natural frequency depends on the geometrical features and on the filling height.
- Analysis and evaluation of different anchoring options for the moorings (Figure 5).
- Material studies for the buoyant platforms and studies on suitable construction methods.

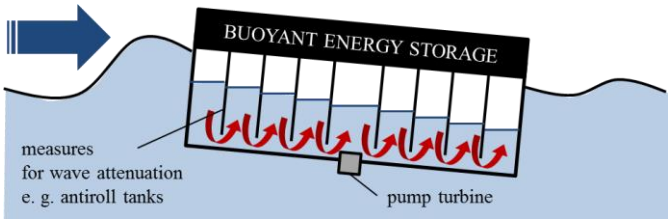

Figure 4: Exemplary design approaches for wave damping.

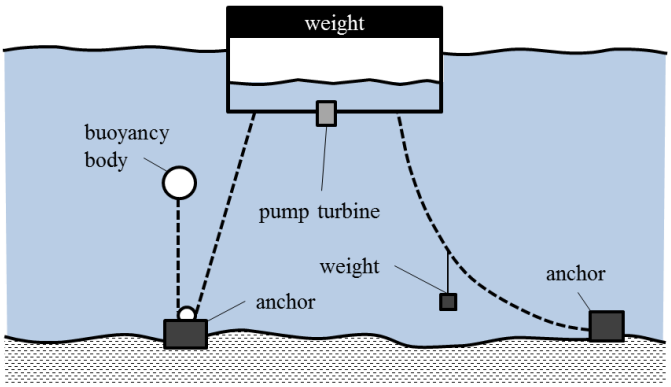

Figure 5: Exemplary mooring options.

*Mechanical and Electrical Engineering (WP 4)*

The objective for WP 4 is to find appropriate solutions for the energy conversion from electric to kinetic (pump/turbine) and finally potential energy vice-versa. Pump/turbine systems of common pumped-storage hydropower systems are designed for relatively high pressure heads and high discharge rates. In contrast pump/turbine systems for BE have to be adapted to other hydraulic boundary conditions and additionally to the marine environment that they will operate in. *Buoyant Energy* is striving for economic and modular solutions. Therefore a distributed approach with a high number of standardized BE storage devices could be a favourable option.

Description of work:
- Literature study on appropriate hydraulic energy conversion concepts for low heads and sea water.
- Preliminary design study of suitable machine concepts: e. g. non-regulated reverse operated pumps.
- Preliminary electrical and mechanical engineering design of the most promising variants.
- Study on corrosion protection measures.
- Economic feasibility study.

*Combined Buoyant Energy structures (WP 5)*

Following the ideas of multi-use platforms this work package is dedicated to assess opportunities that result out of the combination of BE storage with other approaches.

Description of work:
- Integration of *Buoyant Energy* in floating wind platforms: A preliminary engineering assessment will be conducted to evaluate the technical feasibility of coupling BE structures with offshore wind turbines. The evaluation will identify the sizing and operational requirements of the BE structures subject to different energy storage capacity demands, sea depth limits, wind turbine power capacity and weight as well as stability requirements. The various engineering challenges shall be identified. The task will take into consideration the latest and expected future developments in offshore wind turbine technologies.
- Conceptual design of multi-purpose floating platforms: An effective way to improve the economic efficiency is to combine BE platforms with other purposes.
  - The usability as a multi-purpose platform depends on technical–environmental aspects. The expected wave heights and wind velocities determine the floating structure and the mooring system design and with that the possible liveability on the platform.
  - Another influencing factor is related to the socio-economic circumstances. If advantages due to the erection of a multi-purpose platform are expected then the economic feasibility is likely. Next to offshore wind parks e. g. service or accommodation facilities could be interesting. At urban locations the need of residential, office or parking space or recreational areas could be reasonable.

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