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Facilitating energy storage to allow high penetration of intermittent renewable energy

Recommendations for furthering the Sustainable Development of Bulk Energy Storage Facilities

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Acronyms

AA	–	Appropriate Assessment
CAES	–	Compressed Air Energy Storage
CCGT	–	Combined Cycle Gas Turbines
CCS	–	Carbon Capture and Storage
CIS	–	Common Implementation Strategy
DOE	–	Department of Energy
EC	–	European Commission
EIA	–	Environmental Impact Assessment
EST	–	Energy Storage Technology
EU	–	European Union
GEP	–	Good Ecological Potential
GES	–	Good Ecological Status
GHG	–	Greenhouse Gas
GW	–	Gigawatt
HMWB	–	Heavily Modified Water Body
HTSO	–	Hellenic Transmission System Operator
IEA	–	International Energy Agency
IHA	–	International Hydropower Association
JRC	–	Joint Research Centre
MEP	–	Maximum Ecological Potential
MS	–	Member State
MW	–	Megawatt
NGO	–	Non-Government Organisation
NREAP	–	National Renewable Energy Action Plan
NTUA	–	National Technical University of Athens
OCGT	–	Open Cycle Gas Turbine
PHES	–	Pumped Hydro Energy Storage
PV	–	Photovoltaic
RBD	–	River Basin District
RBMP	–	River Basin Management Plan
RES	–	Renewable Energy Source
RES-E	–	Renewable Energy Sources for Electricity generation
RD&D	–	Research, development and demonstration
SEA	–	Strategic Environmental Assessment
TSO	–	Transmission System Operator
WFD	–	Water Framework Directive

Executive Summary

Introduction

The stoRE project aims to facilitate future bulk energy storage to allow for large scale penetration of variable renewable energy. The bulk energy storage technologies (EST) considered in this report are Pumped Hydro Energy Storage (PHES) and Compressed Air Energy Storage (CAES). The report aims to provide policy makers, planners and developers with recommendations to further the sustainable development of bulk EST projects by eliminating or reducing adverse environmental effects. While sustainable development incorporates the three essential components of environment, social and economic considerations, this report focuses solely on the environmental aspects. The discussions in the report focus on two bulk EST, mainly on PHES as it is a more common and proven storage technology but also CAES**.** Regulatory and electricity market conditions are other factors that influence future development of energy storage facilities; however, these issues are dealt with in a separate stoRE report, which is currently under development.

Methodology

The work is based on a wide stakeholder consultation process, three round table discussions with relevant stakeholders, previous stoRE report Wänn et al., (2012), extensive literature review and expert input from the assessment team.

Structure of the Report

The report is structured into four main parts: a brief technology description, review of main directives, discussion on the interaction between policy, plans, programmes and projects, and provision of recommendations to further the sustainable development of bulk EST. Each section also refers to a number of examples that have been chosen to highlight specific issues. The list of examples and text can be found in full in Annex 1.

Technology Overview

The main bulk ESTs available are PHES and CAES. PHES can be categorised further according to water management as closed-loop, semi-open and open-system. Two new PHES projects currently in the planning process are the closed-loop PHES project Atdorf in Germany and the semi-open PHES project Kaunertal in Austria. PHES is currently the only commercially proven large scale (5 MW – 2 GW) energy storage technology with over 300 plants installed worldwide with a total installed capacity of over 95 GW (Roberts, 2009).

The two known CAES in operation today are both hybrids, which means they require some natural gas to operate. However, the natural gas requirement is a third that of what a conventional gas turbine uses (Akorede et al., 2010). Research into adiabatic CAES is currently underway. This type of CAES would eliminate the need for natural gas. Both CAES types use salt caverns. Theoretically, other geological structures, such as sandstone aquifers, could be used.

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Relevant Directives for Project Development

This report has identified key electricity and environmental legislation that affects new PHES and CAES projects. These are:

- Renewable Energy Directive (Directive 2009/28/EC)
- Water Framework Directive (Directive 2000/60/EC)
- Directives Relating to Biodiversity and Natura 2000 Network
    - Habitat Directive (Directive 92/43/EEC)
    - Birds Directive (Directive 2009/147/EC)
- Directives Relating to Environmental Assessment
    - SEA Directive (Directive 2001/42/EC)
    - EIA Directive (Directive 2011/92/EEC)

Interaction of policy, plans & programmes and projects

Without clear bulk EST policy, no strategic plans or programmes can be adopted increasing the difficultly associated with project development. Currently, project development is a lengthy and costly process as it is generally developer driven. The main conclusion of this report is that to facilitate the further and sustainable development of PHES and CAES project, and indeed any storage project, appropriate policy and strategic plans and programmes need to be in place.

Recommendations

The recommendations of this report are:

1. Establish a Need	
Recommendation to: European Commission Member States	As policy informs plans and programmes, an absence of favourable policy will lead to an absence of plans and programmes for bulk EST. **It is recommended that if a need for energy storage is identified that this need is clearly expressed in energy policy and that clearly discernible objectives are developed at EU and MS level.** The legislation and policy will help inform plans and programmes levels, which in turn should facilitate decision-making procedures at project level, which is the last stage in the decision-making cycle. Specific policy for individual storage technologies (e.g. PHES) is not advisable as this may only prove to be a hindrance for other technologies (e.g. CAES, batteries, flywheels, etc) that still need RD&D effort and that could have future potential.

2. Develop Plans and Programmes	
Recommendation to: Member States	For successful project development, it is important that project proposals are considered at the early stages of the decision-making cycle, or strategic planning stage, by suitably competent authorities who have the required resources. An absence of energy storage plans & programmes will lead to a bottom-up developer led, and potentially unsustainable, development approach. **It is recommended that where MS acknowledge the need for energy storage in their NREAP they should consider this technology at a strategic planning level, the early stage of the decision-making cycle, and develop sustainable plans and programmes to facilitate the national and regional deployment of bulk EST as appropriate.** The development of energy storage plans provides an opportunity to identify and assess alternatives. SEA and AA tools can be employed to weigh up alternatives against environmental objectives. Incorporating PHES into strategic plans will likely give assurances to the planning approval authority and may lead to an increased acceptance among the locally affected community. It will reduce the delay and cost risks associated with project development, as well as encourage more developers to undertake development of PHES. The existence of PHES plans will also facilitate consideration and integration with other plans.

3. Identify viable sites at strategic level	
Recommendation to: Member States	The specific siting requirements of PHES and CAES limit the number of physically viable sites that exist. The scope for examining alternatives to achieve a policy objective is significantly reduced at the project level planning stage. While the EIA process requires developers to examine alternatives, the extent of alternatives is limited in EIA compared to SEA due to the level at which each of these processes are conducted. **It is recommended that physically viable sites be identified and tested (subject to environmental assessment) at a strategic level during the development of PHES plans and programmes.** Identifying sites can be done using GIS modelling with expert input from relevant disciplines. Many developers and the Joint Research Centre (JRC) have already developed GIS models to identify suitable PHES sites (Fitzgerald et al., 2012, Lacal-Arantegui et al., 2012). These sites should in turn be subject to environmental assessment where alternatives and individual and cumulative environmental effects are considered and where the most environmentally sensitive sites are excluded ('no-go') and the least environmentally sensitive sites are included ('preferred'). While the assessment of sites at the strategic level contributes to sustainable development, all potentially feasible sites will need to be tested at the project level for further assurances as to their viability e.g. project level AA may be required at an early stage of project development.

4. Develop Clear Guidelines and Document Best Practice	
Recommendation to: European Commission Member States	In the current regulatory environment developers have limited experience in developing new Bulk EST projects while similarly decision-making authorities have limited experience in the approval of such projects. Therefore **it is recommended that clear MS guidelines for sustainable project development, best practice guidelines and guidelines for planning are established to further the sustainable development of bulk EST**. Establishing clear guidance, especially regarding the relationship with European environmental legislation, has been recommended in the Commissions Communications (COM (2005) 627) (EC, 2005). Sharing best practice and experience amongst developers could also prove to be beneficial; especially regarding project development, planning and approval procedures (see Example 4 and Example 8) Development of sustainable development guidance for PHES and CAES can assist in determining the viability of a project. For example, Austria has developed specific sustainability criteria as a means to test Article 4.7 of the WFD on hydropower projects.

5. Facilitate planning and approval procedures	
Recommendation to: Member States	The development of large scale strategically important projects such as PHES involves a complex and prolonged process from inception through to planning approval. Currently, development is developer driven and in many cases the planning approval process can add significant delays and costs for a number of reasons. **It is recommended that the efficiency and speed with which bulk EST projects are considered during the planning approval stage be improved with the establishment of appropriate mechanisms.** This could be achieved in a number of ways including the creation of legislation to accelerate the planning approval process or the consideration of the proposal by a higher or dedicated competent authority e.g. Irish Strategic Infrastructure Act or the Grid Expansion Acceleration Act. Another solution for PHES is to develop a water criteria catalogue similar to that of Austria that would allow developers, local authorities and all interested parties to assess a project in a consistent and transparent manner.

1. Introduction

The objective of the stoRE project is to facilitate future energy storage to allow greater penetration of variable renewable energy. The bulk energy storage technologies (EST) considered in this report are Pumped Hydro Energy Storage (PHES) and Compressed Air Energy Storage (CAES). Other bulk ESTs[1], such as hydrogen fuel cell storage are not considered. One of the principal issues influencing further development of energy storage is the environmental considerations of new development. The published stoRE report on the environmental performance of existing energy storage installations by Wänn et al. (2012) describes the operational environmental impact of PHES and CAES.

While sustainable development encompasses the three constituent parts of environment, social and economic, this report focuses solely on the environmental aspects. The report aims to provide policy makers, planners and developers with recommendations to further the sustainable development of bulk EST projects by eliminating or reducing adverse environmental effects. The discussions in the report focus on two bulk EST, mainly on PHES as it is a more common and proven storage technology but also CAES**.** Regulatory conditions and the electricity market structure are other factors influencing further development of energy storage facilities; however, these issues are dealt with in a separate stoRE report, which is currently under development.

This report is structured into four main parts. Section 2 provides a brief introduction to PHES and CAES technology. Section 3 discusses some of the main energy and environmental directives relevant to their project development. Section 4 discusses the role of bulk ESTs, how policy, plans, programmes and projects interact, and the issues associated with project level planning. Section 5 provides recommendations for furthering sustainable development of these bulk EST projects. References are made to certain examples that shed light on specific issues. This text can be found in full in Annex 1.

A more comprehensive technology description is provided in Annex 2. A summary of the environmental impacts associated with the two technologies is presented in Annex 3. The report methodology comprised extensive stakeholder consultation, expert input and literature review with further details provided in Annex 4.

2. Technology overview

PHES is currently the only commercially proven large scale (5 MW – 2 GW) energy storage technology with over 300 plants installed worldwide with a total installed capacity of over 95 GW (Roberts, 2009). Between 1970 and 1990, 42 facilities were installed in the EU compared with 8 plants between 1990 and 2009 (Deane et al., 2010). This significant reduction in new installed capacity in the EU partly reflects the preference for lower cost and easier implementation of gas turbine technology over PHES in the previous two decades (Denholm et al., 2010). In recent years there has been a renewed interest in PHES technology resulting in the planning and building of a number of new plants in Europe and Japan mainly as a result of the increase in variable renewable generation such as wind (Deane et al., 2010) and photovoltaic (PV). PHES is an area of significant growth for the hydropower sector in Europe, especially in the central and peninsular regions of the continent (Eurelectric, 2011a).

[1] For further information regarding (bulk) energy storage technologies see Zach et al. (2011)

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In contrast, only two CAES facilities are in operation worldwide; Huntorf, Germany and McIntosh, Alabama, USA, commissioned in 1978 and 1991, respectively. One of the reason that has been cited for the low development activity is that the anticipated return on investment is too small to compete with other (more proven) opportunities for the capital invested (Pickard et al., (2009)).

Both PHES and CAES are resource driven facilities that require very specific site conditions to make a project viable. For PHES the most essential criterion is the availability of locations with a difference in elevation and access to water (Deane et al., 2010). For CAES the availability of suitable geology/cavern sites for storing compressed air is essential; the preferred geology is salt domes. This geology type is also favourable for natural gas storage and carbon capture and storage (CCS) technology to name a few (Gillhaus, 2007). Therefore, a limited number of sites suitable for the development of new PHES and CAES exist. For example, in Ireland it is estimated that there may be less than 20 physically viable freshwater PHES sites that are limited to mountainous areas[2], while greater potential for physically viable PHES sites exist in countries such as Austria due to suitable topography. Furthermore, potential PHES sites are often associated with environmental and access constraints, which further limits the number of suitable sites. In contrast, wind farms are physically viable in a wide variety of topographies provided an exploitable wind resource exists.

Traditionally, PHES (and CAES) has been utilised to help balance the production curve of non-flexible base-load generators such as coal and nuclear power. PHES pumped during the night when there was low demand (i.e. off peak hours) and generated electricity during times of high demand (i.e. peak hours). However, this mode of operating PHES plants has radically changed since larger amounts of variable wind and pv have become available on the electricity market. More recently the main functions of PHES include the provision of ancillary services[3], and can therefore pump and generate at all hours of the day depending on the particular demands of the grid at any given time.

Open cycle gas turbines (OCGT) and hydropower can in the same way as PHES and CAES provide flexibility on the generation side delivering upward adjustment services. However, they are not energy storage as they are unable to 'consume' electricity (i.e. pump) to charge a reservoir (Vasconcelos et al., 2012). As a result of these benefits bulk ESTs are seen as Renewable Energy Source (RES) enablers particular for bulk input of variable Renewable Energy Source-Electricity (RES-E) such as wind and PV (Zach et al., 2011).

2.1. PHES

PHES is classed under the hydropower family alongside run-of-the-river and hydropower. Run-of-the-river is subject to seasonal river flows and usually has little to no storage possibilities (maximum 48 hours). These plants are most often found on rivers that have a consistent and steady flow and therefore provide base-load to the electricity system. On the other hand hydropower facilities have the capacity for water storage that require a dam behind which water is stored for daily, weekly, monthly or annual water supply needs. Usually these facilities will store water during the wet season for later use during the dry or cold/hot season, but can also be partially discharged on a daily basis to provide peak load and ancillary services. Hydropower can thus function as base-load and also as peak-load as required. A hydropower facility's ability to store water is sometimes mistakenly referred to as 'energy storage'. However, experts call this

[2] Pers. Comm. Sean Doyle, Chartered Engineer, Associate Director of Malachy Walsh and Partners

[3] Other services include but are not limited to, grid balance, grid flexibility, supply smoothing, black start capabilities, spinning reserve, peak shavings, regulation control, security, etc. (Foley et al.,2010)

ability 'fuel piling' (similar to heaping wood by a stove). In contrast, the pumping capability of PHES 'stores' excess electricity from the grid by pumping water from a lower to a higher reservoir and releases the energy again as required. PHES is classed as energy storage because of its ability to act either as an electricity producer when the electricity system is in need of electricity or as load (i.e. uses its pumps) when there is too much electricity on the grid and not enough demand.

The stoRE project distinguishes between three different types of PHES according to their water management (Malachy Walsh and Partners, 2011):

- Open-system PHES (commonly known as pump-back PHES)
- Semi-open PHES
- Closed-loop PHES

It is important to note that PHES is generally not seen as RES, as it is a net user of electricity but is rather seen as a RES enabler. The exception is the pump-back PHES since this type of PHES can revert back to being a regular hydropower facility due to the natural inflow of the upper reservoir. The other two PHES systems cannot function without utilising their pumps, therefore needing a primary source of electricity to pump the water from the lower to the upper reservoir. Although PHES is a net user of electricity the cycle efficiency (75-85%) is considered high in comparison to other storage technologies (Vennemann et al., 2011).

Further information on the different types of PHES is presented in Annex 2.

2.2. CAES

A CAES facility is essentially a gas turbine power plant that stores compressed air in underground caverns. CAES is considered to be a hybrid system since it still requires natural gas to operate: to reheat the air during discharge. However, the natural gas requirement is a third that of what a conventional gas turbine uses (Akorede et al., 2010).

There is ongoing research into adiabatic CAES systems, for example the ADELE project in Germany, where the excess heat released during air compression can be temporarily stored until the heat is needed again during discharge. This principal differs from conventional CAES in that it eliminates the need for natural gas, which will increase cycle efficiency from the current 42-54% to 70% (RWE Power AG, 2010).

Salt caverns are the favoured geological structures, as these structures are solid yet plastic and permeable. Other structures that can be used are existing empty caverns, aquifers, depleted natural gas fields (King and Moridis, 2009). A CAES project in Iowa, USA planned to use a sandstone aquifer. In 2011, the project was cancelled due to geological limitations (Schulte et al., 2012). See, Example 8 in Annex 1.

Further information on the (adiabatic) CAES is presented in Annex 2.

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3. Relevant directives for project development

This report is concerned with the environmental issues associated with the development of new PHES and CAES plants for which there are a number of key EU Directives that may have a bearing on project development. A list of the key electricity and environmental legislation that affects new PHES and CAES projects is provided below:

- Renewable Energy Directive (Directive 2009/28/EC)
- Water Framework Directive (Directive 2000/60/EC)
- Directives Relating to Biodiversity and Natura 2000 Network
    - Habitat Directive (Directive 92/43/EEC)
    - Birds Directive (Directive 2009/147/EC)
- Directives Relating to Environmental Assessment
    - SEA Directive (Directive 2001/42/EC)
    - EIA Directive (Directive 2011/92/EEC)

3.1. Renewable Energy Directive

Directive 2009/28/EC of the European Parliament and of the Council of the 23 of April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

This directive is commonly referred to as the Renewable Energy Directive or the RES Directive and can be found at

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=Oj:L:2009:140:0016:0062:en:PDF

This is an ambitious directive addressing two of the most pressing challenges to date; energy security and climate change. The RES-E target for the EU's total electricity consumption set by the RES Directive is 34% by 2020. The directive also required each Member State (MS) to submit a detailed plan of how targets will be met in the form of a National Renewable Energy Action Plan (NREAP) by June 2010. From the combined NREAPs it is envisaged that the 34% will consist of approximately 14% wind, 10.5% hydro, 6.7% biomass, 2.4% solar PV, 0.5% concentrated solar power, 0.3% geothermal and 0.2% tidal, wave and ocean. This stands in contrast to 2009 when the existing RES-E share was 17% consisting of 10% hydro, 3% biomass and waste, 4% geothermal, wind and solar (Wilkes et al., 2011).

Although PHES is not generally RES and does not contribute to net hydro production, PHES has been identified as a RES enabler as it can help integrate variable RES such as wind and PV. As the main increases in RES-E required to meet the EU targets are expected to come from wind and PV, identifying the role of energy storage in each MS will be important. This issue is examined in further detail in a separate stoRE report on possible PHES and CAES contribution to the future electricity system by Zach et al., (2012).

According to the NREAP undertaken by MS as part of the EU RES Directive 2009, the installed capacity of PHES will increase by 16.1 GW from 18.7 GW in 2005 to 34.8 GW by 2020, led by new plants in Germany, Portugal, Spain, France and Italy (Eurelectric, 2011a). Table 1 presents a

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snapshot of the RES-E targets in the NREAPs of each of the stoRE project partner countries and their position on energy storage; four out of six countries see a future need for bulk EST.

Table 1: National Renewable Energy Action Plans and Energy Storage

Country	RES-E target 2020	What the NREAP says on Energy Storage
Austria	70.6%	Energy storage (i.e. pumped hydro) has been identified as a means to reach RES targets. However, the required installed capacity and timeline has been left to system operators and electricity companies to decide in their investment plans.
Denmark	51.9%	Energy storage is not foreseen in the Danish NREAP. Instead it points at a greater symbiosis between wind power, heat pumps and electric vehicles.
Ireland	40.0%	Refers to a study carried out by the TSO Eirgrid on the need for large scale energy storage. This study shows that with up to 40% wind penetration there is low value in adding bulk EST, however in excess of 50% the option for bulk EST may be useful. The NREAP therefore requests further work from Eirgrid regarding the need for large scale energy storage.
Germany	38.6%	In Table 10a of the German NREAP it states that in 2005 there was an installed capacity of 4,012 MW of PHES in Germany. An increase of 2,482 MW is expected by 2010 and a further increase of 1,406 MW by 2020. This means an overall increase of 3,888MW of PHES by 2020.
Greece	39.8%	1,580 MW of PHES is expected by retrofitting existing large hydro plants and constructing new PHES. Study by NTUA indicates that the development of PHES exceeding 1,000 MW is technically possible. The Hellenic TSO has commissioned a number of studies to determine the optimal RES energy mix and the optimal PHES size needed to minimise curtailment of wind.
Spain	40.0%	PHES has to be promoted as a way to allow for full integration of electricity from renewable sources, especially wind. An additional 3,000 MW of PHES is envisaged by utilising existing reservoirs, including refurbishing existing installations. No new construction of PHES is envisaged.

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Box 1: Some important policies on RES in the EU

Renewable Energy – Targets by 2020

http://ec.europa.eu/energy/renewables/targets_en.htm

Roadmap for moving to a low-carbon economy in 2050

http://ec.europa.eu/clima/policies/roadmap/index_en.htm

Energy Roadmap 2050

http://ec.europa.eu/energy/energy2020/roadmap/index_en.htm

3.2. Water Framework Directive

Directive 2000/60/EC of the European Parliament and of the Council of the 23 of October 2000 establishing a framework for the Community action in the field of water policy.

This directive is commonly referred to as the Water Framework Directive (WFD) and can be found at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2000:327:0001:0072:EN:PDF

The WFD provides a legal framework to protect and restore clean water across Europe, providing a more holistic approach than previous water policies, and ensuring its long-term, sustainable use. The general objective of the WFD is to achieve 'good status' for all surface water bodies by 2015. 'Good status'[4] incorporates both 'good ecological status' (GES) and 'good chemical status'; this includes inland surface waters, transitional waters, coastal waters and groundwater. The WFD aims to protect all high status waters, prevent further deterioration of all waters and to restore degraded surface and ground waters to good status by 2015. River Basin Management Plans (RBMP), which need to be prepared for all river basins every 6 years, provide a detailed account of how the objectives set for each river basin will be met. The plans are an implementation tool to manage and develop water resources in a sustainable manner while integrating environmental objectives with other policies and economic activities such as development of hydropower/PHES, agriculture, navigation etc.

For PHES (and hydropower in general) the most relevant water bodies are surface waters. Pressures from these facilities are linked to the ecological status of surface water bodies. The environmental objectives set by article 4(1a) of the WFD for surface waters include reaching good ecological and chemical status. The elements for reaching GES are defined in Annex V No. 1. of the WFD and include biological elements, hydromorphological, chemical and physic-chemical elements that support the biological elements. For those water bodies that have been designated as heavily modified water bodies (HMWB) (as per Article 4.3) alternative objectives of reaching good ecological potential (GEP) are set. GEP are derived from the objectives of maximum ecological potential (MEP), which is determined by the same elements as for GES of the closest

[4] Assessment of quality is based on the extent of deviation from reference conditions, following the definitions in the Directive. 'Good status' means 'slight' deviation, 'moderate status' means 'moderate' deviation, and so on.

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comparable water category. For example, if a river has been modified to closely resemble a lake (i.e. impoundment), the relevant quality elements will be those specified for lakes rather than those for rivers (as per Annex V) (CIS, 2003b).

Hydropower (and therefore also open-system PHES) has been identified as one of four[5] main causes of hydro-morphological changes in river systems; hydro-morphological pressures have been deemed a main risk for not reaching the WFD targets (CIS, 2006). The session paper "Better coordinate water and sustainable energy policies" from the 6th World Water Forum (2012) stresses that hydropower is one of the cleanest sources of energy and should therefore be one of the main pillars for RES production. The paper calls for reconciliation between the protection of water resources and the development of hydropower generation using an integrated approach to arrive at sustainable solutions. The Water Directors (2010) issued a statement stressing "that whilst the development of renewable energy, including hydropower, should be strongly supported, it is equally important that such development take place in a manner which is compatible with environmental protection requirements".

New developments can be exempted from the environmental objectives as long as each of the requirements of Article 4.7 are met:

- all practicable steps are taken to mitigate the adverse impact on the status of the body of water;
- the reasons for those modifications or alterations are specifically set out and explained in the river basin management plan required under Article 13 and the objectives are reviewed every six years;
- the reasons for those modifications or alterations are of overriding public interest and/or the benefits to the environment and to society of achieving the objectives set out in paragraph 1 are outweighed by the benefits of the new modifications or alterations to human health, to the maintenance of human safety or to sustainable development; and
- the beneficial objectives served by those modifications or alterations of the water body cannot for reasons of technical feasibility or disproportionate cost be achieved by other means, which are a significantly better environmental option.

Future PHES developments will be guided by the characterisation of the river basin along with its particular pressures and impacts. Deterioration of status or failure to achieve the WFD objectives will be taken into account when determining whether Article 4(7) is applicable.

Since PHES is part of the hydro family, similar issues that apply to hydropower also apply to PHES. Retrofitting a hydro power plant with pumping capacity may not invoke the need for Article 4.7 as this may be considered as "replacing one activity with another" (CIS, 2009). Similarly, a semi-open PHES and a closed-loop PHES may or may not invoke Article 4.7. However, this depends on a number of factors including site selection and the design of the facility, all of which needs to be assessed on a case-by-case basis. It is also worth pointing out that a water body cannot be designated as a HMWB before the new modifications have taken place. The CIS (Common Implementation Strategy) workshop "Water Management, Water Framework Directive &

[5] Other hydro-morphological pressures are attributed to navigation, flood protection and agriculture

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Hydropower" that was held in Brussels in 2011 found that a majority of MS have yet to apply Article 4.7 for hydropower developments. Importantly, it concluded that hydropower projects are not automatically considered of overriding public interest because they will generate renewable energy (Kampa et al., 2011). As PHES facilities do not contribute to net hydro production (except for most pump-back PHES) but rather provide important support to variable and intermittent RES (Eurelectric, 2011b) these project may perhaps be deemed as 'overriding public interest'.

Article 9 of the WFD takes account of the principle of cost recovery of water services, which includes environmental and resource costs, according to the "polluter pays" principle. The directive distinguishes between water services and water uses. Cost recovery is relevant to water services. However, water uses should adequately contribute to the recovery of the costs of water services. PHES is defined as a service under Article 2 (38a) of the WFD:

- Abstraction, impoundment, storage, treatment and distribution of surface water or groundwater,

"Water uses" is defined under Article 2 (39) of the WFD:

- Water services together with any other activity identified under Article 5 and Annex II having a significant impact on the status of water.

Article 9 was highlighted as one of the 'hot topics' for the hydropower sector during one of the stoRE round table discussions. Hydropower/pump-back PHES will most likely have a hydro-morphological impact on rivers while semi-open and closed loop may have a hydro-morphological impact on rivers or lakes. One can therefore infer that as a "polluter" and a "user" the operator should pay for this service. However, it is difficult to establish an appropriate cost for such impacts. The WFD asks each MS "to implement water pricing policies that enhance the sustainability of water resources" (CIS, 2003a). "Win-win" situations can be achieved if new projects use technical solutions that do not cause deterioration of status for already deteriorated aquatic ecosystems and if the project is designed to improve the ecosystem concerned (CIS, 2006).

The blueprint to safeguard Europe's waters is due to be published in November 2012. It will form the water milestone for the Resource Efficiency Roadmap (Europe 2020, 2012). The 'Blueprint' "will provide the knowledge base for the development of policy options aiming to deliver better implementation, better integration and completion of EU water policy" (Ecologic, 2012). Hydropower and PHES will likely feature among several other water uses and services due to ongoing discussions to streamline the objectives of the RES Directive and WFD within Europe.

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Box 2: Policies and relevant documents on the WFD

WFD – integrated river basin management for Europe

http://ec.europa.eu/environment/water/water-framework/index_en.html

Blueprint to safeguard Europe's waters

http://ec.europa.eu/environment/water/blueprint/index_en.htm

Relevant CIS documents have been listed below, these and all CIS documents are available at:

http://circa.europa.eu/Public/irc/env/wfd/library?l=/framework_directive/guidance_documents

Economics and Environment – The implementation challenge of the Water Framework Directive (WATECO – Guidance document no.1)

Analysis of Pressures and Impacts (Policy Summary to Guidance document no.3)

Identification and Designation of Heavily Modified and Artificial Water Bodies (Guidance Document no. 4)

WFD and hydro-morphological pressures – Focus on hydropower, navigation and flood defence activities – Recommendations for better policy integration (Policy Paper)

Guidance document on exemptions to the environmental objectives (Guidance document no.20)

3.3. Directives relating to Biodiversity and Natura 2000 Network

Habitats Directive

Council Directive 92/43/EEC of 21 of May 1992 on the conservation of natural habitats and of wild fauna and flora.

This directive is commonly known as the 'Habitats' Directive and can be found at

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1992L0043:20070101:EN:PDF

Birds Directive

Directive 2009/147/EC of the European Parliament and the Council of 30 November 2009 on the conservation of wild birds (codified version of Directive 79/409/EEC).

This directive is commonly known as the 'Birds' Directive and can be found at

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:020:0007:0025:EN:PDF

The Birds and Habitats Directives form the cornerstone of the EU's nature conservation policy that is built on two pillars: the Natura 2000 network of protected sites and the strict system of species protection. Together the two directives protect over 1,000 animals and plant species and over 200 "habitat types" that are deemed to be of European importance.

The most important article in the Habitats Directive is Article 6 as it defines how to manage and protect Natura 2000 sites. Articles 6(3) and 6(4) are especially important when considering new developments as these articles outline the procedures to be followed for plans and projects that may affect a Natura 2000 site/s. Article 6(3) sets out the requirement for a project to be subject to an appropriate assessment[6] (AA (stage 2)) of its implications for Natura 2000 site/s in view of the site's conservation objectives. A project does not have to be within or even adjacent to a Natura 2000 site/s for it to have an adverse effect on a sites conservation objectives. For example, a project may be a distance upstream of a site or within the same groundwater body and still have an adverse effect. The competent authority shall only approve or authorise a PHES or CAES project having ascertained that it will not adversely affect the integrity of the site/s concerned.

The Waddenzee judgement case C-127/02[7] ruled that where reasonable scientific doubt or uncertainty remains as to the absence of adverse effects on the integrity of a site linked to a project, the competent authority must refuse authorisation.

With a negative assessment (i.e. a PHES or CAES project cannot demonstrate beyond reasonable scientific doubt that an adverse effect on Natura 2000 site/s will not occur) a project can only proceed once it has been determined that no alternative to the project exists (stage 3). The project may then only proceed on the basis of 'imperative reasons of overriding public interest' (IROPI), including social, economic or public safety, depending on the priority status of the habitats or species (stage 4). According to the EC (2000) it is clear that the IROPI of a social and economic nature refers only to public interests and not solely private interests, promoted either by public or private bodies; only public interests can be considered against the conservation aims of the directive. The word imperative suggest a project of vital or essential importance or that is indispensible. In the absence of viable alternative solutions (i.e. the services that a PHES can provide cannot be achieved by other means) to a proposed PHES, a project may be deemed of national public interest, however, the long-term advantages to the public would need to outweigh the conservation aims of the directive.

The "no alternative solutions" and IROPI tests are arduous and difficult to pass. Derogations from the requirements of Article 6 are interpreted in a restrictive way by the courts (MMO, 2011). If all alternative solutions have been ruled out and the project is deemed to be IROPI i.e. both test have been passed, the proponent will be required to provide compensatory measures. Such measures would be in addition to the proper implementation of the Habitats and Birds Directives and may be in the form of measures to mitigate the negative impact on the affected Natura 2000 site/s or may be independent of the project. The project proponent must bear the cost of compensation measures (EC, 2000).

The Birds and Habitats Directives can thus have a significant bearing on the success or otherwise of a new PHES or CAES development. There is sector specific guidance available on the proper

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[6] An appropriate assessment (stage 2) is undertaken subsequent to a plan/project being subjected to a screening exercise (stage 1). It is a decision-making tool to assess the impact of a plan/project on the integrity of the Natura 2000 site/s, either alone or in combination with other plans/projects, with respect to the sites ecological structure and function and its conservation objectives. It can be commonly referred to as a Natura Impact Assessment (NIA) or a Habitats Directive Assessment (HDA) or a Habitats Regulation Assessment (HRA).

[7] Judgment of the Court of 7 September 2004 in case C-127/02, paragraphs 57 and 61

implementation of the Habitats Directive objectives with regard to port development, wind energy development and non-energy mineral extraction. As part of the stoRE project a guidance document on the development of PHES and Natura 2000 sites will be published in 2013. The purpose will be to provide guidance on how best to ensure that PHES and CAES developments are compatible with the provisions of the Habitats and Birds Directive with particular focus on Article 6 procedures. The guidance will be designed for use by competent authorities, developers and consultants and will be of interest to Non-governmental Organisations and other stakeholders.

Box 3: Background information on Birds and Habitat Directives

Information on Birds Directive

http://ec.europa.eu/environment/nature/legislation/birdsdirective/index_en.htm

Information on Habitats Directive

http://ec.europa.eu/environment/nature/legislation/habitatsdirective/index_en.htm

EU Biodiversity Strategy 2020

http://ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm

EC Guidance Document, 2001

Assessment of Plans and Projects Significantly Affecting Natura 2000 Sites. Methodological guidance on the provisions of Article 6(3) and 6(4) of the Habitats Directive 92/43EEC

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3.4. Directives Relating to Environmental Assessment

Strategic Environmental Assessment Directive

Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment.

This directive is commonly known as the strategic environmental assessment (SEA) Directive and can be found at
http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2001:197:0030:0037:EN:PDF

Environmental Impact Assessment Directive

Directive 2011/92/EU of the European Parliament and of the council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment (codified version of Directives 85/337/EEC and its three amendments; Directive 97/11/EC, 2003/35/EC and 2009/31/EC).

This directive is commonly known as the EIA Directive and can be found at

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:026:0001:0021:EN:PDF

A Strategic Environmental Assessment (SEA) is a tool for determining the positive or negative impact that a proposed plan or programme may have on the environment. The SEA Directive provides high level protection of the environment and contributes to the integration of environmental considerations into the preparation of plans and programmes. SEA is a formal systematic evaluation of the likely significant environmental effects of implementing a plan or programme in order to make an informed decision before adopting a plan or programme. As a result a plan may be modified prior to its adoption (DoEHLG, 2004). The SEA Directive is mandatory for plans/programs that are prepared for agriculture, forestry, fisheries, energy, industry, transport, waste/ water management, telecommunications, tourism, town and country planning or land use. These plans set the framework for future development consent of projects listed in Annex I and II of the EIA Directive. SEA is also required for plans and programmes that have been determined to require an assessment under the Habitats Directive.

An Environmental Impact Assessment (EIA) is a tool for determining the positive or negative impact that a proposed project may have on the environment. The EIA consists of gathering, analysing and presenting information on the likely environmental impacts of a project; it is an instrument to help improve the basis on which decisions are taken. EIA focuses on the significant environmental impacts associated with a project. The EIA Directive applies to a wide range of defined public and private projects, which are defined in Annexes I and II. All projects listed in Annex I of the directive are considered as having significant effects on the environment and require an EIA. Projects listed in Annex II require the discretion of MS to determine the need for EIA through a screening process, which determines the effects of projects on the basis of thresholds and criteria or case by case.

Future PHES projects may come under one or more of the following:

Annex I projects -

(15) Dams and other installations designed for holding back or permanent storage of water, where a new or additional amount of water held back or stored exceeds 10 million cubic metres.

(19) Quarries and open-cast mining where the surface of the site exceeds 25 hectares, or peat extraction, where the surface of the site exceeds 150 hectares.

Annex II projects:

(2a) Quarries, open-cast mining and peat extraction (projects not included in Annex I)

(2b) Underground mining

(3h) Installation of hydroelectric energy production

(10g) Dams and other installations designed to hold water or store it on a long-term basis (projects not included in Annex I)

For a PHES to be liable for an EIA under Annex I, it needs a dam that will permanently store a volume of water in excess of 10 million cubic meters. A pump-back PHES is the most likely to do this; for example the Thissavros PHES in Greece. Very large artificial reservoirs constructed for a semi-open PHES and/or closed-loop PHES that need to excavate material may fall under the definition (19) of Annex I. A good example of a large semi-open PHES is Goldisthal in Germany; the upper reservoir has an active capacity of 12 million cubic meters and surface area of 55 hectares.

Those PHES projects that do not fall within Annex I would most likely be subject to Annex II depending on the thresholds or screening requirements within that country.

Future CAES projects could come under the following:

Annex II projects -

(2b) Underground mining

(2d) Deep drillings

(3c) Surface storage of natural gas

CAES projects would most likely fall under Annex II by one of the above listed definitions. Although not listed as one of the possible end uses for deep drilling, salt cavern creation requires deep drilling of an average 600-800m. The method used for salt cavern excavation is “solution mining” and would therefore also be classified under the umbrella term of 2b: Underground Mining. A conventional CAES facility requires natural gas and may not be located on the gas grid, thereby needing onsite natural gas storage.

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Under Annex I(24) an EIA is required where any change to or extension of projects listed are proposed, where such a change or extension in itself meets the thresholds set out in Annex I. This project category was introduced by the 2003/35/EC amendments while changes or extensions of existing projects not included in Annex I(24) fall within Annex II(13a). Upgrading of existing PHES may not be subject to EIA. On the other hand, if an improvement to the status of the water body requires a change/extension to a project listed in Annex I or Annex II and the change/extension is likely to have a significant adverse effect on the environment an EIA will be required (CIS, 2009).

In rulings related to the EIA Directive, the European Court of Justice has consistently emphasised the fundamental purpose of the Directive as expressed in Article 2(1), i.e. those projects "likely to have significant effects on the environment by virtue, *inter alia*, of their nature, size or location are made subject to a requirement for development consent and an assessment with regard to their effects"(EC, 2011).

Since the EIA directive was adopted over 25 years ago it has been under review by the European Commission, to better reflect the experiences gained and the changes in European policy and legislation (EC, 2012b). In 2009 the EC published a report "On the application and effectiveness of the EIA Directive" (2009) followed a year later by a wide consultation process covering a broad variety of issues regarding the EIA. The consultation process was concluded by a conference on the "25th anniversary of the EIA Directive: Successes – Failures – Prospects". The key issues revolved around the scope of the EIA Directive, the quality of the EIA process and links of EIA with international conventions.

A SEA applies to plans and programmes whereas the EIA Directive applies to project level planning. Similar to EIA its objective is to protect the environment and promote sustainable development. The SEA Directive was introduced in response to growing criticism of the EIA directives limited consideration of: alternatives[8], cumulative impacts and lack of contribution to the achievement of wider global environmental and sustainable development aims (Carroll and Turpin, 2009). SEA is undertaken at earlier stages in the decision-making cycle and aims to prevent adverse environmental impacts. EIA on the other hand is generally carried out once strategic decisions have been taken and is therefore undertaken at a later stage in the cycle. SEA considers a wider range of alternatives and cumulative impacts on a broad scale with an emphasis on meeting environmental objectives. EIA can only address a limited range of alternatives. SEA also consults widely with the public and environmental authorities. The SEA process can however have limited information and a greater level of uncertainty than project EIA. The process focuses on national or regional issues with less focus on impacts at a local level.

Box 4: Background information on the SEA and EIA Directive

Information on the SEA and EIA Directives

http://ec.europa.eu/environment/eia/home.htm

Conference "25th anniversary of the EIA Directive: Successes – Failures – Prospects"

http://ec.europa.eu/environment/eia/conference.htm

[8] Alternatives usually means the examination of alternative ways to achieve the same objectives or alternative means (alternative sites, processes or management) to deliver the project

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4. Furthering Sustainable Development of Bulk Energy Storage

4.1. Role of Bulk Energy Storage

With the greatest increase in RES-E expected to come from variable sources of wind and PV by 2020, the energy system will naturally shift from a centralised to a more decentralised system; this will put extra pressure on the electricity grid making grid extensions essential. In parallel, grid operators will need to operate the existing grid closer to its limits. Technologies that can help integrate and balance the electricity grid are rapidly taking centre stage such as conventional generation (e.g. OCGT), RES (e.g. hydropower), storage (e.g. PHES, CAES), demand side management, etc. Putte et al. (2011) concludes that a European need exists for energy storage alongside demand management and grid extensions as a means to improve the European RES-E mix. The stoRE report by Zach et al. (2012) provides an overview on the possible contribution of bulk EST in future European electricity systems facilitating large-scale expansion of RES-E generation. The communication of the EC (2012a) highlights the importance of developing the relevant infrastructure urgently for the integration of renewable energy.

In the case of the stoRE partner countries five of six mention PHES in their NREAPs; however, only four have identified a need so far. These NREAPs are also quite clear on what to expect from PHES developers. In Spain for example, retrofitting and upgrading will be the main solution, whereas in Greece a combination of retrofitting and new PHES is expected. CAES is only mentioned as an alternative bulk storage technology in the Irish NREAP.

4.2. Interaction of Policies, Plans, Programmes and Projects

A very clear interaction and hierarchy exists between policies, plans, programmes and projects progressively becoming more specific in time and place. The EU and MS develop and implement policies, which essentially are broad statements of intent presenting a set of views, objectives and instructions. A plan is a more specific strategy for implementing a policy while a programme comprises proposals for how, when and where specific actions will be carried out, often through individual projects (Natural Capital Project, 2010). This top-down strategy reflects the decision-making cycle and contributes to sustainable development.

Figure 1: Interactions between policy, plans, programmes and projects

Plans can be developed at national, regional and local level and there can be an interrelationship between plans at different levels. National plans focus on strategic levels while plans lower down in the hierarchy focus on more detailed issues. Regional and local level plans must operate within national frameworks and be informed by the plans and strategies formed by government. Plans, programmes and projects are subject to environmental assessment. The diagram below is a simplified depiction of the components of the hierarchy, each of which inform the level beneath. The legislation & policy, and plans & programmes levels should facilitate decision making procedures at project level, which is the last stage in the decision-making cycle. At the plan and programme level it is important to involve all relevant stakeholders and interested parties to ensure that all relevant opinions and concerns are incorporated.

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Figure 2: Planning hierarchy

NREAPs are plans that are intended to pave the way for how MS are planning to achieve their mandatory national targets. They set the framework for future development consent of projects (Dixon et al., 2010). The targets set by MS in the NREAPs may not yet have filtered into more specific plans and programmes either at national or regional level. In those cases where the need for storage (e.g. PHES) has not been identified at policy level or in the NREAP, it is unlikely that specific plans and programmes will make provisions for future PHES. If developers in these countries still wish to pursue PHES projects in this policy and strategic planning 'vacuum' they will be adopting a developer led approach i.e. bottom-up approach commencing at the project level. Currently, in the absence of strategic plans and programmes, energy storage development within the EU is primarily developer led. This has resulted in an increased financial and planning approval risk due to lengthy and onerous planning approval procedures.

If the decision-making authority (which is generally at regional or local level) does not find relevant or supporting national/regional plans or policies that indicate a need for bulk EST, the project is more likely to be rejected. The example of Gortavehy PHES (see Example 1) illustrates how the local competent authority assessed the acceptability of the principle of the project in the absence of national policy or plans for PHES. The authority decided that PHES supported RES integration and that the project in principle was acceptable because it was in accordance with the County Development Plan's renewable energy objectives. Ultimately, the authority refused approval for the project based on the grounds of unacceptable impacts to a Natura 2000 site.

In order to facilitate development of storage projects, energy sector plans (including grid development) should incorporate future bulk EST development where the need has been identified at policy level or in the NREAP by MS. Plans set the context for individual project development, such as PHES or CAES. Although PHES is mentioned in some of the NREAP, provisions for the development of bulk EST are often not accommodated within strategic energy plans at either the national or regional level. However, due to their functionality and scale, these projects are nearly always of strategic importance either at a national or regional level and their development should inform strategic planning.

Such strategic energy plans will be subjected to the SEA process where the environmental performance of the plans is tested against environmental objectives. SEA can identify areas/sites that are sufficiently robust to accommodate PHES/CAES and those where the environment is sensitive and should be avoided. The SEA process requires us to understand the vulnerabilities and sensitivities in our environment (including cumulative impacts) and to seek alternative solutions to integrate environmental concerns with broader social and economic needs (Carroll and Turpin, 2009). The strategic planning process will assist in determining priority objectives at national and regional level (Kampa et al., 2011). Plan-making involves consideration of alternative strategies for achieving the plan objectives; however, SEA undertakes a more systematic and explicit appraisal of such alternatives (DoEHLG, 2004). The SEA process will also assist in determining the ability of the environment to absorb such development. In relation to SEA for NREAP, unless the plan comprises specific compliance measures then the NREAP is not subject to SEA. However, SEA will be required when implementing the NREAP's more specific plans (Dixon et al., 2010)

Plans developed at a strategic level are also subject to Habitats and Birds Directive assessment (i.e. AA), which would highlight any possible interactions between Natura 2000 sites and a proposed project site/area. Currently, most developers are avoiding Natura 2000 sites for PHES development (Lacal-Arantegui et al., 2012). A proposed project must prove beyond reasonable scientific doubt that the project will not have a significant impact on Natura 2000 site/s. It may not be clear at an early stage in project development how the project, regardless of distance, may impact on a protected site. The SEA process can help determine the 'zone of impact influence' for PHES development which will likely extend beyond the project footprint. The process can be used as a tool to determine suitable and unsuitable deployment areas for PHES projects. The example of Gortavehy PHES illustrates the planning risk associated with developing projects in Natura 2000 sites. Furthermore, characterization of river basins with the assessment of status, pressures and impacts can also help determine the most suitable locations for PHES deployment.

The following example is available in Annex 1

Example 1: Gortavehy PHES Project, Ireland

Energy sector plans with provisions for bulk EST projects should also be considered within the strategic planning framework of other plans, for example RBMPs, nature conservation plans, grid development plans and land-use plans. These plans should be subject to the SEA and AA process. Preferably these plans should be coordinated and integrated with the objectives of renewable energy, water management and nature conservation policies (Kampa et al., 2011). The WFD provides for management at river basin district (RBD) level and allows for proper integration of all activities relating to water that are currently in place, but also for future project and activities. All these should be included in the RBMP, which is the main tool for integrated water management and which is to be reviewed and subject to public consultation every six years. The difficulty of plan integration arises since each plan has a different planning cycle. Integration is therefore likely to be a gradual process with progressive improvements when each individual plan is under review (CIS, 2006).

Some MS have expressed a need for storage in policy but that policy has generally not yet filtered into strategic plans. As mentioned, PHES development is currently developer driven and without suitable plans for PHES, the onus is sometimes on the project proponent to undertake studies at project level that should be carried out by a higher authority at the plans & programmes level. Such studies include but are not limited to: national search for best alternatives for PHES and studies on the importance of PHES for that MS. While the EIA process requires developers to also look at alternatives, the extent of alternatives is limited in EIA compared to SEA due to the level at which each of these processes are conducted. The example of the Atdorf PHES project in Germany highlights the delays and difficulties that may arise at project level when relevant plans are not in place.

The following example is available in Annex 1

Example 2: Atdorf PHES project, Germany

4.3. Project level Planning

4.3.1. Limitations to a Bottom-up Developer Led Approach

Provisions for the development of bulk EST are generally not accommodated within strategic energy plans at either the national or regional level. For this reason development tends to be developer driven – a bottom-up approach – commencing at the project level, which is the last stage of the planning decision-making cycle. A limitation of this approach is that the project has not been tested at a strategic planning level. However, due to their functionality and scale (PHES) projects are nearly always of strategic importance either at a national or regional level.

The alternative - top-down approach – is to create a bulk EST plan at national/regional level and subjecting it to the SEA process, where individual and cumulative impacts are assessed and where the environmental performance of the plan are tested against environmental objectives. SEA can identify areas/sites that are sufficiently robust to accommodate PHES and those where the environment is sensitive and should be avoided. The SEA in turn informs the project level planning, a step which is missing in a developer driven bottom-up approach to project planning. The testing of the project at a strategic planning level by an appropriate competent authority (national or regional level) gives assurances to, and facilitates evaluation by, the local competent authority. Consultation for SEA takes place at a wider level focusing on more strategic issues. Plans for PHES that are subject to SEA may also increase the acceptance among the local authority and local community. The same criteria on which the strategic plans are based can be used as framework criteria for project level decision, which should assist in focusing project development (Kampa et al., 2011).

Plans developed at a strategic level are also subject to Habitats and Birds Directive assessment (or AA), which would highlight any possible interactions between Natura 2000 sites and a proposed project site/area. Where significant effects to the project are identified these sites can be avoided, or further investigation may be warranted at the strategic level to determine if adequate mitigation can be implemented. Only sites where it can be demonstrated beyond all reasonable scientific doubt that no significant effects are likely should be considered to proceed to project level, or a project AA may be required to further test the viability of a site.

The scope for examining alternatives to achieve a policy objective is significantly reduced at the project level planning stage, which in the hierarchy of planning is considered to be at the end of the decision-making cycle. During the EIA stage of any development, the scope for assessing alternatives, particularly sites, is limited. It is unreasonable to expect a developer or a competent

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authority to consider alternatives on a national or regional scale at the project level (see Example 2, Atdorf PHES). Realistically, these can only be considered by a higher authority at an early stage in the decision-making cycle.

4.3.2. Approval Process

The regulatory environment is generally not familiar with the assessment of new bulk EST developments. For example the EIA Directive does not have direct mention of PHES or CAES projects in Annex I or II. Therefore, projects fall under dams, quarries (excavations) or hydroelectric categories. PHES projects are likely to have significant effects on the environment by virtue, *inter alia*, of their nature, size or location and would therefore in almost all cases be subject to EIA.

Generally, there is a lack of recent experience of developing bulk EST among prospective developers. For example, many recent developers of PHES have little to no experience of developing PHES in the current regulatory environment. Much of the current EU environmental legislation was transposed into national legislation in the last two decades. Due to the low number of PHES developed during this period, experience in developing these large and often complex infrastructural projects in the current regulatory environment is limited, both on the side of the developer and decision-making authorities. Most of the existing PHES plants were developed between 1960 and 1990. No current specific project development or planning guidelines exist for PHES (or CAES) to meet the renewed interest in bulk EST development. Due to the low number of plants developed in the EU in the past 20 years (less than 10) most developers and decision-making authorities have no recent experience in bringing a project from inception through to operation.

Very few examples of PHES EIA exist that reflect the current regulatory environment. While the environmental effects of PHES are similar to those of hydropower they are ultimately different technologies with different impacts. Environmental impacts of PHES will vary considerably depending on the type of PHES system (closed, semi-open, open), project siting and degree of man-made modification of the existing natural environment. Some of the environmental impacts of CAES may be comparable to the construction of natural gas storage that use salt caverns. These circumstances combined make it difficult to anticipate the environmental effects of the construction and operation of these large infrastructural projects.

Decision-making may take place at a local level where authorities have limited capability and resources to deal with these projects and therefore a reactive approach to development is adopted. In the absence of recent experience of project development, and relevant guidelines and EIA literature, the initial reaction of the competent authority may be positive and encouraging for the developer, and therefore possibly misleading, or may be negative from the outset. In both situations the scope of the EIA can significantly increase due to the lack of experience and uncertainty on the side of the authority in assessing PHES applications. This can lead to increased cost and effort for the developer and a delay in submission of the application to the competent authority with no guarantee of success. The example of Atdorf (see Example 2) illustrates this problem.

In Germany, it has been recognised that grid expansion will be critical in order to bring about the policy shift away from nuclear power to RES (‘Energiewende’). In order to reduce planning delays, under the new Grid Expansion Acceleration Act for Transmission Networks (NABEG) the responsibility for grid extension approval has been transferred from the regional authorities to the Federal Network Agency (Bundesnetzagentur - BNetzA). In other words the two different regional authorities are in charge of two different approval process steps, which usually leads to double examination (see Example 2), and will be replaced by BNetzA for future grid extension projects

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(Sander, 2011). In Ireland, the Strategic Infrastructure Act has been introduced into legislation to accelerate projects deemed of strategic infrastructural importance through the planning approval process (see Example 3).

The following example is available in Annex 1

Example 3: Strategic Infrastructure Act, Ireland

The general lack of experience of PHES development amongst developers in the current regulatory environment could be bridged by documenting and sharing best practice and experience regarding the project development and planning approval process, construction, mitigation and operation (see Example 8). The development of sustainability criteria, project development and/or planning guidelines would also assist in improving the planning process.

The International Energy Agency (IEA) Hydropower published a report in 2006 on environmental mitigation measures and benefits (IEA Hydropower, 2006). The report is based on 60 case studies including 7 case studies on PHES, mostly from Japan (see Example 4). Furthermore, the UK have published good practice guidelines for hydropower (UK Environmental Agency, 2009) and also best practice for construction works (Natural Scotland and SEPA, 2012). The International Hydropower Association (IHA) have published an assessment protocol, which is a tool to determine the sustainability of new and existing hydropower projects (IHA, 2010).

The following example is available in Annex 1

Example 4: IEA Hydropower, Best Practice PHES Case Studies

4.3.3. Development Timescales

Bulk EST developments are large infrastructural projects involving major civil, mechanical and electrical engineering works. They can take several years to develop and design. Once construction begins on a PHES project, it can take a minimum of 5 years. Therefore the full development of a PHES project can take approximately 15 years from time of inception to commissioning; more than half the time is allocated to project development, planning process and approval procedure. For CAES, the main issue is the availability of suitable geological structures for storage of compressed air. The most preferable geology type is salt domes that can take up to 6 years to mine. Therefore, development of a CAES project will most likely take roughly the same amount of time as a PHES project due to the time spent on project development, planning process and approval procedures.

To summarise, these bulk EST projects may experience delays and take up to 15 years from project inception, development to commissioning due to: (1) lack of consideration and testing of these projects at the strategic planning level, (2) dearth of experience of developing these projects in the current regulatory environment, (3) limited ability and resources of competent authorities, particularly on a local level, to evaluate these large and often complex projects.

4.3.4. WFD and PHES

All PHES systems require water and therefore will interact with the WFD at project level. In very general terms, new pump-back PHES is most likely to impact on the status of a water body, a semi-open PHES is less likely to impact on the status of a water body, and a closed-loop PHES is least likely to affect a water body if artificial of highly modified lakes are used. The implications of the WFD for new PHES developments will vary depending on the project design and siting. Therefore each project needs to be determined on a case-by-case basis (Wänn et al., 2012). Article 4.7 is invoked only when deterioration of status and failure to achieve WFD objectives may be a result of the modifications resulting from a new or refurbished PHES. If Article 4.7 applies the project then needs to be deemed of overriding public interest and/or the benefits to the environment and to society of achieving the objectives set out in paragraph 1 are outweighed by the benefits of the new modifications or alterations to human health, to the maintenance of human safety or to sustainable development (as per Art.4.7(c) of the WFD). PHES could in most cases provide multi-purpose uses as well as other important benefits to the electricity grid (see section 2.1) and may perhaps on these grounds be considered to be of overriding public interest (CIS, 2006, Kampa et al., 2011). A case by case assessment would however be necessary. It is important to note that exemptions from the WFD environmental objectives cannot be used to deviate from objectives set by other pieces of EU legislation (e.g. Habitats Directive).

Some countries, such as Scotland and Austria have developed specific criteria as a means to test Article 4.7 of the WFD on hydropower project. The Scottish criteria are for hydropower projects but clearly state there is a need to investigate the needs of, and for, PHES (SNIFFER, 2006). The Austrian criteria (see Example 5), published in 2012, have been designed to test run-of-river and hydropower projects, including PHES projects (Lebensministerium, 2012). The Kaunertal PHES project, although in project development since 2004, was tested against criteria set by Tirol, Austria in 2011, and again tested by the National criteria in 2012 (see Example 6). It was found that the project met the terms of the criteria and was allowed to continue project development.

The following examples are available in Annex 1

Example 5: Austria and the “water criteria catalogue”

Example 6: Kaunertal PHES project, Austria

4.3.5. CAES Project Development

The preferred geology for CAES facilities is salt caverns as these underground structures are plastic, yet solid and impermeable (BBC Brown Boveri). Suitable salt deposits are also quite rare (Gillhaus, 2007). Obtaining sites for future CAES development may prove to be the limiting factor as salt caverns are already being used for the storage of natural gas as well as for liquid and liquefied hydrocarbons, industrial wastes, chemical products, hydrogen and for carbon capture and storage (CSS). In Europe there is a clear trend showing an increase in natural gas demand, which has led to an increased demand for natural gas storage. As stated previously, conventional generation (e.g. OCGT) is an alternative way to balance strong fluctuations in seasonal demands and peak shaving to provide security in energy supply (Gillhaus, 2007). In the UK, for example, the Overarching National Policy Statement for Energy (EN-1) (2011) states that although “reliance on fossil fuels will fall, the transition will take some time and gas will continue to play an important part in the UK’s fuel mix for some years to come”. The Eurogas Roadmap 2050 (Eurogas, 2011) describes the increased role of natural gas in Europe while still achieving a reduction in GHG emissions of 80% compared with 1990.

From an environmental perspective salt cavern construction uses the same methods whether it is for natural gas storage or CAES caverns. A common method for constructing salt caverns is known

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as 'leaching' where seawater is taken in to flush the salt dome to the desired size cavern(s) and the brine is returned to the sea. The process can take several years and the brine has to be diluted to comply with the established salt concentrations before being released back into the environment.

There are two known CAES projects currently under investigation. One is the Larne project, Northern Ireland that is being proposed by Gaelectric. This CAES facility will be using similar technology to that in Huntdorf, Germany and McIntosh, Alabama, USA (Gaelectric, 2011). The other is the already mentioned adiabatic CAES project, Adele, proposed by RWE. There are more examples available of natural gas storage projects that propose leaching salt to construct salt caverns such as the one in Lille Torup in Denmark (see Example 7). In this case, several issues regarding the environmental impact of salt dispersion and heavy metal content on the nearby fjord, its mussel population in particular but also its fish life are ongoing concerns among stakeholders. The Lille Torup example highlights the environmental issues associated with salt cavern construction and the need for public acceptance (see Example 7). The main issue with Lille Torup is its distance from the sea; the closest recipient is the brackish waters of Lovns Bredning, which forms part of Limfjorden. It is an area of high recreational value, used as fishing grounds and mussel farming. Mussels in particular are sensitive to any ecosystem change. In contrast, the salt cavern natural gas storage proposal at Whitehill, UK is located right by the sea which makes the leaching process less complicated because salt concentrations are naturally higher and the brine will quickly dilute (E.On, 2011).

CAES can theoretically use other structures for air storage, such as sandstone aquifers. An interesting CAES project in the USA, the Iowa Energy Storage Park, was abandoned after more thorough geological surveys of the selected sandstone structure. The report prepared for the US Department Of Energy (DOE) Energy Storage System Program by Sandia National Laboratories (Schulte et al., 2012) showcases the lessons learned during the 8 years spent investigating the area. In this report, the developers share their project experiences in terms of cost calculations, project management, energy policy, geological surveys, etc. More detailed information about the lessons learned from geological surveying on this particular project is presented in Example 8.

The following example is available in Annex 1

Example 7: Environmental Constraints associated with salt domes at Lille Torup, Denmark

Example 8: Lessons Learnt at Iowa Energy Storage Park, USA

5. Recommendations

The recommendations of this report are outlined in the following tables.

1. Establish a Need	
Recommendation to: European Commission Member States	As policy informs plans and programmes, an absence of favourable policy will lead to an absence of plans and programmes for bulk EST. **It is recommended that if a need for energy storage is identified that this need is clearly expressed in energy policy and that clearly discernible objectives are developed at EU and MS level.** The legislation and policy will help inform plans and programmes levels, which in turn should facilitate decision-making procedures at project level, which is the last stage in the decision-making cycle. Specific policy for individual storage technologies (e.g. PHES) is not advisable as this may only prove to be a hindrance for other technologies (e.g. CAES, batteries, flywheels, etc) that still need RD&D effort and that could have future potential.

2. Develop Plans and Programmes	
Recommendation to: Member States	For successful project development, it is important that project proposals are considered at the early stages of the decision-making cycle, or strategic planning stage, by suitably competent authorities who have the required resources. An absence of energy storage plans & programmes will lead to a bottom-up developer led, and potentially unsustainable, development approach. **It is recommended that where MS acknowledge the need for energy storage in their NREAP they should consider this technology at a strategic planning level, the early stage of the decision-making cycle, and develop sustainable plans and programmes to facilitate the national and regional deployment of bulk EST as appropriate.** The development of energy storage plans provides an opportunity to identify and assess alternatives. SEA and AA tools can be employed to weigh up alternatives against environmental objectives. Incorporating PHES into strategic plans will likely give assurances to the planning approval authority and may lead to an increased acceptance among the locally affected community. It will reduce the delay and cost risks associated with project development, as well as encourage more developers to undertake development of PHES. The existence of PHES plans will also facilitate consideration and integration with other plans.

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3. Identify viable sites at strategic level	
Recommendation to: Member States	The specific siting requirements of PHES and CAES limit the number of physically viable sites that exist. The scope for examining alternatives to achieve a policy objective is significantly reduced at the project level planning stage. While the EIA process requires developers to examine alternatives, the extent of alternatives is limited in EIA compared to SEA due to the level at which each of these processes are conducted. **It is recommended that physically viable sites be identified and tested (subject to environmental assessment) at a strategic level during the development of PHES plans and programmes.** Identifying sites can be done using GIS modelling with expert input from relevant disciplines. Many developers and the Joint Research Centre (JRC) have already developed GIS models to identify suitable PHES sites (Fitzgerald et al., 2012, Lacal-Arantegui et al., 2012). These sites should in turn be subject to environmental assessment where alternatives and individual and cumulative environmental effects are considered and where the most environmentally sensitive sites are excluded ('no-go') and the least environmentally sensitive sites are included ('preferred'). While the assessment of sites at the strategic level contributes to sustainable development, all potentially feasible sites will need to be tested at the project level for further assurances as to their viability e.g. project level AA may be required at an early stage of project development.

4. Develop Clear Guidelines and Document Best Practice	
Recommendation to: European Commission Member States	In the current regulatory environment developers have limited experience in developing new Bulk EST projects while similarly decision-making authorities have limited experience in the approval of such projects. Therefore **it is recommended that clear MS guidelines for sustainable project development, best practice guidelines and guidelines for planning are established to further the sustainable development of bulk EST**. Establishing clear guidance, especially regarding the relationship with European environmental legislation, has been recommended in the Commissions Communications (COM (2005) 627) (EC, 2005). Sharing best practice and experience amongst developers could also prove to be beneficial; especially regarding project development, planning and approval procedures (see Example 4 and Example 8) Development of sustainable development guidance for PHES and CAES can assist in determining the viability of a project. For example, Austria has developed specific sustainability criteria as a means to test Article 4.7 of the WFD on hydropower projects.

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5. Facilitate planning and approval procedures	
Recommendation to: Member States	The development of large scale strategically important projects such as PHES involves a complex and prolonged process from inception through to planning approval. Currently, development is developer driven and in many cases the planning approval process can add significant delays and costs for a number of reasons. **It is recommended that the efficiency and speed with which bulk EST projects are considered during the planning approval stage be improved with the establishment of appropriate mechanisms.** This could be achieved in a number of ways including the creation of legislation to accelerate the planning approval process or the consideration of the proposal by a higher or dedicated competent authority e.g. Irish Strategic Infrastructure Act or the Grid Expansion Acceleration Act. Another solution for PHES is to develop a water criteria catalogue similar to that of Austria that would allow developers, local authorities and all interested parties to assess a project in a consistent and transparent manner.

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Annex 1 – List of Examples

Example 1: Gortavehy PHES Project, Ireland
In 2010 Enerco Energy Ltd. submitted a planning application to the local decision making authority, Cork County Council, seeking permission to construct and operate a 90MW (closed loop system) PHES scheme (planning reference: 104887). In Ireland, county development plans provide one of the key policy contexts for individual project planning decisions. Specific reference to PHES or bulk energy storage did not exist in the Cork County Development Plan. Despite this, the Council considered that the proposal was acceptable in principle and deemed to be in accordance with national and county renewable energy policies and objectives. The proposed site was located within an upland mountainous area in north County Cork in the southwest of Ireland. The lower reservoir was an existing natural corrie lake, Lough Gortavehy, which would require impoundment, and the upper reservoir was to be manmade and excavated on an elevated area. The connection between the reservoirs would be via an underground penstock tunnel. The site was located entirely within the eastern extent of the ‘*Killarney National Park, Macgillycuddy’s Reeks and Caragh River Catchment*’ Special Area of Conservation or SAC (it is worth clarifying that the project was not located within the national park part of the SAC). An ‘appropriate assessment’ statement of the potential impacts of the project on the SAC and other Natura 2000 sites was prepared by the applicant. The assessment proceeded through the four stages of appropriate assessment, namely (1) Screening, (2) Appropriate assessment, (3) Assessment of alternative solutions and (4) Assessment where no alternative solution exists and where adverse impacts remain. The assessment indicated that the proposal would be considered to cause localised severe negative impacts to priority habitat, upland blanket bog, which prohibits approval of the project. Reference was made by the applicant to the absence of alternative solutions. Before carrying out Stage Four, it is necessary to establish if imperative reasons of overriding interest (IROPI) exist. The statement reasoned that IROPI did exist in that the project would contribute to direct environmental benefit and to strategic economic benefit. The specific

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IROPI put forward included improved grid management, the addition of value to the nearby wind energy projects and reduction in wind energy curtailment. Furthermore, it maintained that compensatory measures could be provided such as restoration or enhancement of new or existing sites.

Cork County Council refused planning permission principally because of the negative impact it considered the proposal would have on the SAC. They were not satisfied that an adequate assessment of likely significant effects was carried out. Four alternatives had been proposed, three of which were in the SAC and one of which supported features of ecology importance. The Council did not consider any of these alternatives viable.

The decision to refuse was appealed by the applicant to An Bord Pleanála (commonly known as "The Board"), the national planning authority (case reference: PL04 .237061). The Board's Inspector did not agree with the assertion in the applicants statement that the proposal could be considered IROPI as other alternative projects could proceed in other locations where nature conservation issues did not exist.

The Board ordered that the proposal be refused on the grounds that the proposal would be contrary to the provisions of the Habitats Directive, and that the proposal did not satisfactorily address the assessment of alternative solutions (i.e. Stage 3) and does not specify appropriate compensatory measures.

In conclusion, the major reasons for the failure of this project have been the:

- Location of the project with a Natura 2000 site that hosted priority habitat
- Lack of alternative viable options
- Non-compliance of the project with the requirements of the habitats directive.

In summary, it was considered by the planning authorities that the potential ecological damage arising from the project outweighed the environmental and energy benefits and services offered by the PHES.

Example 2: Atdorf PHES project, Germany

The Project and Developer

Schluchseewerk is a specialised pumped storage operator in the South West of Germany that was set up in 1928. Due to the growing need for electricity at the time the obvious solution was to utilize the water potentials in the Black Forest. The company owns 5 PHES facilities with a total of 20 pumps/turbines that together generate 1,836MW and pump 1,604MW. Out of the 5 PHES the last one was commissioned in 1976. In 2007, the idea of developing an additional PHES facility was brought to the table again and in 2008, it was publicly announced that the company were planning to develop the Atdorf PHES project.

The Atdorf project will be a closed loop PHES with a head of 600m. Both the upper and the lower reservoir will be newly constructed greenfield sites and will be able to hold a volume of 9 million m^3 of water. The new PHES will contribute with an additional 1,400MW to the Schluchseewerk PHES family.

While Schluchseewerk is highly competent as an operator, the company had no recent experience of developing PHES in a regulatory environment that has fundamentally changed since the last projects were completed in the 1960s and 1970s. The original plan was to begin construction in 2012 with completion in 2018; however, the expected completion date has since been extended to 2026 due to delays in the planning process and the regulatory market. The following sections outline some of the problems encountered by the project during planning process.

Regional Planning Procedure (ROV)

In Germany a two stage planning procedure exists, first the regional planning procedure (Raumordnungsverfahren - ROV) where the competent authority, the regional planning authority (Regierungspräsidium) of the relevant German state, examines whether the proposed project is in line with the Regional Plan. Following EIA scoping by the authority the developer prepares the EIA and submits the EIS; this along with the plan is placed on public display and the public and other groups are given opportunity to make submissions. After extended consultations and considerations to all issues raised, the approved Regional Planning Permission (Raumordnungsbeschluß) is then published.

During the ROV stage the various stakeholders realised that the project was more complicated than originally envisaged and it took over two years (2008 – 2010) to complete. A significant amount of additional information was sought. For example several public hearings were conducted, which is unusual at this stage. Schluchseewerk financed an independent study on PHES and alternative storage technologies, which was undertaken by the German energy agency, DENA. Besides many other studies, an assessment of alternative sites was also conducted at this stage where 18 different sites were examined.

The final supporting documentation had 6,000 pages of text contained in 14 folders, an indication of the substantial nature of the additional information sought by the authority, resulting in significant delays and additional costs to the project.

Plan Approval Procedure (PFV)

The second stage is the project approval procedure (Planfeststellungsverfahren - PFV) where the competent authority, the local authority (Landratsamt), gives the final approval of the project. A second EIA is prepared with public participation a core component, and the project is refined. The authority confirms the completeness of the application submitted by the applicant and all documentation including the EIS is put on public display and the public and other groups are given opportunity to make submissions. This will be followed by a public hearing.

At PFV stage for Atdorf PHES the local authority was initially positive towards the development and optimistic of the timeline for planning application. It soon became apparent that the local authority had little to no experience in developing large scale complicated projects like PHES in the current regulatory environment. Therefore, the knowledge, capacity and resources of the local authority to deal with the application was limited and proved to be a learning experience. Several technical experts, as well as units from higher level authorities, were therefore drafted in to assist in the regulatory process, while the local authority retained overall management of the process.

As a voluntary measure to increase acceptance and outreach to a wide range of stakeholders, Schluchseewerk supported a Round Table on the project that was prepared during the first half of 2011, and conducted six plenary meetings and many side meetings and workshops between June-December 2011. More than 40 stakeholders had been included in this independently organised and moderated process, which was successful in bringing the discussions to a more objective level. This process, so far unique in Germany and financed by the developer at a cost of more than 1 million Euros, also had the support of the state government.

The process was slower and more complex than originally envisaged. While considerable consultation has been undertaken with the authority, the application has only been submitted in June 2012, after more than 2 years of preparation. Currently, several key studies are being revised after initial feedback from the authorities. Once a full set of application documents is finally submitted, the authority will determine and formally declare its completeness. The applicant expects that this process could take 9 months to complete. Following this, they expect that it will take another 15 months before the public hearing will take place, which will be followed by a 9 month period during which the authority will consider the application further before making its final decision, now expected in the summer of 2015. This means the approval procedure will have taken at least 8 years since inception of the Atdorf PHES project, a timeframe that was not envisaged at the early stages of project development.

While two EIA's are required, the scope of these is not necessarily identical. The results of the ROV stage EIA was used to extend the scope of the PFV stage EIA, which increased from approximately 600 to 3,000 pages. The second stage application comprised approximately 90 separate documents contained in approximately 70 folders, again an indication of the substantial amount of documentation required by the local authority.

Widespread consultation was undertaken during the course of preparing the planning application. Once the application is submitted it will be distributed to over 150 different consultees for comment. Each will receive a full copy of the planning application documentation. The extent of the stakeholder consultation process has considerably increased during the preparation period and as a result it has become unwieldy and difficult to manage.

A further issue that only emerged during the latter PFV stage is the impacts of the project on several nearby Natura 2000 sites. This was not highlighted as an obstacle at the ROV stage. Due to the level of tunnelling required (the project requires a total of 26km of tunnels), there are potential hydrogeological impacts to the Natura 2000 sites (several partial areas of the two sites "Weidfelder bei Gersbach und an der Wehra[9]" and "Murg zum Hochrhein[10]"). Among other problems recently realised, it seems that for several priority habitats significant impacts can't be ruled out with the necessary certainty. Examples include *6230 Borstgrasrasen[11] and *91E0 Auwälder mit Erle, Esche, Weide[12], as well as several "non priority" habitat types.

In conclusion the major obstacles to this project have been the:

- Lack of experience of the local authority in dealing with large complicated projects such as PHES
- Lack of experience of the applicant and local authority developing projects in new regulatory environment
- Significant expansion of the original requirements of the planning process to include substantive amounts of additional information (studies, surveys, tests etc) leading to

[9] English Translation: 'pastures or hay meadows near Gersbach and by the Wehra River'
[10] English Translation: 'Murg upon Upper Rhine'
[11] English Translation: species-rich nardus grassland
[12] English Translation: alluvial forests alder, ash, willow

unexpected delays and costs at both the ROV and PFV stages

- Increased level of stakeholder consultation that now has expanded to the extent it is difficult to manage
- Compliance with the Habitats Directive

At this stage Schluchseewerk has invested significant financial resources into this project with a number of obstacles only becoming evident during the later PFV stage. The late identification of potential obstacles to planning approval is probably the biggest disincentive to developers of this technology.

Example 3: Strategic Infrastructure Act, Ireland

The Planning and Development (Strategic Infrastructure) Act 2006 was introduced to provide a fast-track planning procedure for major public and private infrastructure projects. Under the Act certain classes of infrastructure development require direct application for permission to An Board Pleanála, (commonly known as “The Board”), Ireland’s higher planning authority, instead of the local planning authority. Developments must be considered of strategic economic or social importance to the State or the region in which it would be situated, contribute substantially to the National Spatial Strategy, or have a significant effect on the area of more than one planning authority.

Only certain developments can qualify as strategic development and these must comply with set thresholds. While PHES projects are not referred to specifically, a PHES project could come under the following threshold for hydroelectric energy:

‘*An installation for hydroelectric energy production with an output of 300 megawatts or more, or where the new or extended superficial area of water impounded would be 30 hectares or more, or where there would be a 30 per cent change in the maximum, minimum or mean flows in the main river channel*.’

In Ireland, few viable freshwater PHES sites would qualify as strategic infrastructure based on these thresholds. Large saltwater PHES projects would qualify. It is unlikely that CAES would qualify under existing threshold criteria.

It is believed that the advantages of applying for planning permission under the Act would include:

- Fast-tracking the decision making process as Board are required to make decision within specific timeframe
- Applying directly to the Board who would have greater experience and confidence in assessing large complex applications with greater access to the required expertise
- Pre-planning consultation with the Board who while not commenting on the merits of the project can provide feedback and advice
- EIS scoping with the Board helping ensure a complete EIS and planning application

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- A decision may contravene the County Development Plan though the Board give importance to placing the proposed project in its plan and policy context, particularly the hierarchy of plans

Example 4: IEA Hydropower, Best Practice PHES Case Studies
In May 2006, the International Energy Agency (IEA) Hydropower published the report "Hydropower Good Practices: Environmental Mitigation Measures and Benefits". The aim of the study was to document successful mitigation measures for ten key issues (KIs) in design and operation of hydropower projects. The report consists of a 26 page summary and 60 case studies collected from 20 countries. Among these are seven case studies for PHES facilities. These case studies have been listed below under the relevant KIs. For details on the IEA report and the specific cases please see: http://www.ieahydro.org/Case_Studies.html KI-3 Fish Migration and River Navigation • 0301 Daini Numazawa Power Plant (Japan) – acoustic fish entrainment prevention system KI-5 Water Quality • 0501 Asahi Dam (Japan) – diversion of sediment and turbid water during flood • 0506 Mingtan Pumped Storage Power Plant (Taiwan) – water quality and ecology in lake reservoir famous with tourists for its clear water KI-6 Reservoir Impoundment • 0601 Numappara Pumped Storage Power Plant (Japan) – marshland conservation KI-11 Benefits due to Power Generation • 1102 TEPCO Large Scale Pumped Storage Plant (Japan) – improvement in power system performance KI-1 Biological Diversity • 0101 The Okinawa Pumped Stored Project (Japan) – ecosystem conservation • 0105 Palmiet Pumped Storage Power Plant (South Africa) – ecosystem conservation by Environmental Management Plan

Example 5: Austria and the "water criteria catalogue"

The guidance document "Österreichischer Wasserkatalog Wasser schützen - Wasser nutzen[13]" (2012) was published in January, 2012 as one of the measures set by the "Nationale Gewässerbewirtschaftungsplan 2009[14]" (NGP). The guidance document, also known as the water catalogue or criteria catalogue, includes a list of criteria to assess the sustainability of hydropower projects. The catalogue was developed in close cooperation between the water regulation and water management department of the 9 Länder (regional administration). The work also involved stakeholders from the energy sector and NGOs. The guidance is applicable to all hydropower, including PHES, projects.

The non-binding guidance is primarily intended to be a tool for all authorities that are involved in the decision making process of approvals, modifications or re-awarding procedures of hydropower projects that are likely to deteriorate the status of surface water bodies or fail to achieve environmental objectives set by the National Water Management Plan 2009 (NGP). The goal of the guidance document is to assist authorities in structuring, analysing and presenting the information necessary to make consistent and objective decisions in a transparent and verifiable manner. The guidance document is also of interest to those preparing projects (i.e. developers) as it provides an overview of the evaluation criteria and use of assessment methods.

The guidance catalogue is not meant to substitute for the planning and approval process rather it is a tool i.e. a set of criteria, against which a project proposal can be assessed and evaluated by the decision making authority. Furthermore, it can provide an early indication to project developers on the viability of a future project. Criticism that has been brought against the guidance document including that it is non-binding, not a strategic planning tool and does not include 'no-go' areas. The critics fear that the decision tool will be used to promote hydropower projects for the electricity market projects, rather than developing sustainable hydropower. Those positive to the catalogue praise the fact that hydropower will be subject to consistent assessment throughout Austria and hope for faster decision making.

The criteria have been organised into three different assessment areas that in turn have a set of criteria that need to be assessed. The specific criteria list requiring assessment is divided according to facility type: run-of-the-river and hydropower plants with storage (including PHES). Following the list of criteria is a more detailed definition and description of each criterion and also how to grade each. The assessment criteria are listed below with specific sub-criteria for PHES (and hydropower) in brackets.

Energy management and hydropower related water management criteria

- security of supply (production volume)
- quality of supply (provision of peak power, storage option, pumped storage)
- climate protection (avoidance of CO_2, supporting integration of variable RES)
- technical efficiency (grid connections, usage level of potential, degree of construction)

[13] English translation: Austrian Water Catalogue Protecting Water – Using Water
[14] English translation: National Water Management Plan 2009

Ecological criteria

- naturalness
- rarity
- ecological key functions
- spatial expansion of the negative environmental impacts

Other water management criteria

- local/regional impact during flood water situations
- impacts on sediment transport
- impact on ground water quantity
- impact on ground water quality
- impact on water supply
- Impact on emissions
- Impact on already restored areas
- Impact on other user interests (recuperation, tourism, fisheries, water sports)

The guidance document (only available in German) can be found at http://www.lebensministerium.at/wasser/wasser-oesterreich/wasserrecht_national/planung/Kriterienkatalog.html

A powerpoint slide presentation summarizing the main details and criteria in English has been produced by Fenz and Koller-Kreimel (2012)

Example 6: Kaunertal PHES project, Austria

The Project and Developer

TIWAG-Tiroler Wasserkraft AG is a state owned company in the West of Austria that was set up in 1924 to build the largest hydropower facility in Austria at the time. Shortly after that they cooperated with the state of Bayern, Germany to build the first cross-border 110 kV-line. Today the company own 9 large and medium sized hydropower parks (some including PHES facilities) and 36 small hydropower facilities. Currently the TIWAG are in the approval process for two PHES facilities, Kühtai and Kaunertal. This example will expand further on the Kaunertal project.

In Kaunertal[15] a hydropower facility already exists at Prutz that uses the stored water in the Gepatsch reservoir situated 900m above. The Kaunertal project will add another hydropower

[15] English translation of "tal" is valley. The name of the area is Kaunertal.

facility at Prutz, the Prutz 2. Above the Gepatsch reservoir another reservoir will be constructed called Platzertal. Between the Platzertal – Gepatsch reservoirs is where the Kaunertal PHES will be located; it has a head of about 600 m and will generate 400MW and be able to pump 390MW. The Kaunertal PHES will be a semi-open PHES facility according to the stoRE definition, due to significant water flow through the reservoir Gepatsch.

The planning and approval process

TIWAG and other developers all over Austria began a search for potential hydropower sites around 2004. This was in response to the EU and its policies for more RES. Austria is ideal for hydropower due to its location in the Alps. In 2006, TIWAG had identified Kaunertal as a potential site. During the following years alternative sites and designs including Kaunertal were assessed. Two other sites were identified as alternatives to Kaunertal. These two sites were located in Natura 2000 sites a fact that did not deter as the project proponent felt that the project might be accepted under Imperative Reasons for Overriding Public Interest (IROPI). What stopped them from continuing the investigations of the Natura 2000 sites was that geological probing showed that there was high geological risk at both of these sites.

The EIA for the Kaunertal project was submitted to the local authorities during the summer of 2012. TIWAG expects the first step of the approval process to take 3 years and the second step of the approval process to take 2 years. If the project is approved the construction is planned to start in 2018. Construction is estimated to take 6.5 years and the project will be commissioned in 2023. If all goes to plan it will have taken 17 years from project inception to completion.

Natura 2000 sites

To increase the amount of water in the Gepatsch reservoir thus increasing generated power, the project is proposing to abstract and transfer water from the neighbouring valley Ötztal. There are two large and two smaller catchment areas associated with the two abstraction points. All four of the catchment areas are in the Natura 2000 site; the points of abstraction are just outside the Natura 2000 sites. The transfer tunnels will go through the mountains and will be constructed in a manner that does not impact on the ground water.

The Environmental NGO's (Non-Government Organisation) have stated their opposition to the entire project as they feel that the rivers within the area of Ötztal have not been obstructed by dams up until now and therefore should be protected for their naturalness.

The local community

There are few people living within the project area that will directly impact from the expansion. There are however, several towns in close proximity. The local public in the Kaunertal were at first split 50/50 when the project was announced. At this stage in the project however, there are more people positive towards the project. They see the opportunities that the project will bring in terms of jobs, money and future development in the area. The community of Kaunertal have set up several committees to discuss and plan for the future of Kaunertal. Further information can be found at http://www.kaunertal.eu/.

Further information on the Kaunertal (PHES) project can be found at http://www.tiroler-wasserkraft.at/de/hn/wasserkraftausbau/ausbau_kw_kaunertal/projektvorstellung/index.php

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Example 7: Environmental Constraints associated with salt domes at Lille Torup, Denmark

Denmark does not have any PHES due to its flat topography. Currently, Denmark does not have any existing CAES facility though reasons are unrelated to topography. The feasibility for CAES in Denmark has been thoroughly investigated and salt domes, which are the preferred geological structure[16], have mostly been found in the North West. Any plans for CAES development have however never come close to realisation. The main reason given during an interview[17] was that there is no convincing business case for CAES available. Denmark has two natural gas storage facilities, Lille Torup and Stenlille. The former is located in salt caverns and the latter in sandstone.

Lille Torup was established in 1987[18] and comprises of 7 large salt caverns that are located at a depth of between 1000-1700 m, are about 200-300 m high and 40-60 m in diameter (Danish Energy Agency, 2012). In 2007, the facility owner Energinet.dk, applied for permits to flush the existing caverns for maintenance and to construct 9 new caverns within the area to expand the amount of natural gas stored. In total 16 million m^3 of salt was to be flushed out. This initial plan was met with great opposition from several stakeholders. Opponents gathered under the umbrella organisation 'Fjord venner'[19] and together with the Danish Society for Nature Conservation have appealed the plans.

When flushing (i.e. for maintenance) or leaching (i.e. during construction) it is an advantage to be close to the ocean as developers can use the salt water and return the brine, at established salt concentrations, back to the sea. Lille Torup facility is however located inland with over 50km to either the North Sea to the West or the Kattegat to the East. The closest possible recipient of the brine is Lovns Bredning, which forms part of the Limfjord. Lovns Bredning was also the original recipient during the leaching process of the existing caverns in the 1980's. Lovns Bredning and Limfjord are of high recreational value. Over the past two decades several initiatives have been put in place to improve the water quality of the entire Limfjord. The first phase focused on point sources such as urban and industrial wastewater treatment plants. The second phase focuses on dispersed sources, mainly nutrients from agriculture. In recent years reoccurring cases of hypoxia have occurred in large parts of Limfjord including Lovns Bredning. In addition to this, a causeway dividing Lovns Bredning and Hjarbæk fjord was built in the 1960's that tipped the ecological balance in Hjarbæk fjord, creating a freshwater lagoon where the water had previously been brackish. A few years ago however, the causeway gates were partly opened and the environmental problems such as fish deaths, rotting weeds, mosquito plagues, loss of recreation value, etc. have since been considerably reduced.

The fear at Lille Torup is that the salt in the domes contain heavy metals such as manganese, chromium, mercury and zinc that will be flushed out with the salt. With large salt quantities to be discharged, the risk is that large quantities of heavy metals may pose significant environmental impact. The heavy metals may have severe impacts on the mussel population, which is sensitive towards changes. It may impact on fish populations and in the worst case destroy fishing opportunities. Local fishermen recall that life in the fjord was badly hit 25 years earlier during the construction of the salt caverns. Environmentalists' further fear that the brine may be a 'hypoxia bomb', as the leach water from the salt domes may contain significant amounts of organic material that will need sufficient amounts of oxygen to decompose. Further objections to the project include consequences to Natura 2000 sites, terms of operation, monitoring requirements, assessment

[16] Salt caverns have the right structural properties for CAES as the structure is plastic, yet solid and impermeable
[17] Interviewee is anonymous
[18] The second salt cavern, Stenlille, was established in 1994
[19] English translation: Friends of the Fjords

methodologies, foam creation, nutrients, etc.

The outcome of the permitting process was that Energinet.dk were not allowed to flush the 16 million m^3 into Lovns Bredning nor construct any new caverns. Instead permission was granted for a pilot project whereby 1 million m^3 of salt is allowed to be leached as maintenance measures of the existing caverns. Strict regulations and environmental monitoring will be put in place to see the effects of the brine in Lovns Bredning. If further appeals to this permit are rejected, work on the pilot project aims to begin during august of 2012.

Example 8: Lessons Learnt at Iowa Energy Storage Park, USA

The project

Project development of the Iowa Stored Energy Park (ISEP) began in 2003. It was a proposed 270 MW compressed air energy storage (CAES) facility that would utilize a sandstone aquifer. The site chosen was ideally located on the edge of a favourable wind energy regime. The company intended operating the facility as an "intermediate" supply available up to 12 to 16 hours per day on weekdays, all year. Providing ancillary services to the regional market was considered a secondary goal. Unfortunately, in 2011, after eight years of project development, it was cancelled due to geological limitations associated with the site.

The lessons learned by the developers

In the SANDIA report "Lessons from Iowa: Development of a 270 Megawatt Compressed Air Energy Storage Project in Midwest Independent System Operator", the lessons learned by the people involved have been documented. The lessons relate to costs and long-term economics of CAES, transmission, markets and tariffs, renewable policy and legislation, siting and community participation, project management, geology and recommendations for follow-on work. For the purpose of this example however, only the lessons learned from geology will be explored in more detail as the CAES was planned to use a sandstone aquifer instead of a salt cavern[20].

Geology

From a technical geology perspective, the lesson learned from the project was that site selection and geologic analysis for an aquifer-based CAES site that has not been in use previously or where no previous data exists, is time-consuming and challenging. In the case of the Iowa CAES project lengthy, preliminary investigation showed there was less capacity and porosity than had been envisaged. It was much more difficult to investigate this type of structure than other potential underground storage opportunities, such as existing empty caverns, defined salt formations, or depleted natural gas reservoirs for which some production or reservoir data is already available.

According to Sandia National Laboratories the geological exploration process followed was probably correct, though it could have been done in a significantly shorter time period; however, the project was limited by funding, relative complexity and natural conservatism amongst developers and investors.

Sandstone aquifers are solid, porous structures, with permeability and transmissivity

[20] The two existing CAES facilities, Huntorf, Germany and McIntosh, Alabama, USA, use salt caverns.

characteristics that affect the flow of water. For an aquifer to function for a CAES facility, a certain degree of permeability is required. It also needs a caprock and a lower confining layer that encloses the sandstone aquifer. The selected primary site only showed its true size, permeability and porosity late in the project development, after large investments had been made in three test wells.

The process of site selection

Geological studies began in 2004 with an initial review, by Fairchild & Wells, Inc., of Special Publication no. 27 site geology for use as natural gas and/or CAES. In 2005, The Hydrodynamic Group, LLC, conducted a reservoir selection study of potential CAES geological storage structures in Iowa to acquire geological data, develop high-level reservoir screening criteria and high-level reservoir screening of geological structures. This resulted in the selection of two main structures for further investigation. In 2006, the report showcasing the results of seismic surveys on the two sites was published; one site was selected as the primary site. In 2007, a revised edition of the report was published recommending a multi-phase approach, to the further investigation of the primary site, including test wells, air injection testing, and CAES design efforts. The report also included key issues associated with aquifer-based reservoirs: water encroachment, matching reservoir air pressure cycles to turbo-machinery requirements, air bubble deliverability, oxygen depletion, oxidation issues, caprock integrity and structure integrity with faulting. A report issued in 2007 by EASE, providing supplemental seismic surveys, confirmed a dome structure at the primary site. In 2008, funding was received for the test well drilling program. Three test wells were drilled between 2008 and 2011. The main results showed that:

- the structure was a saucer-shaped dome rather than the envisioned bowl shape;
- the structure had approximately 20 meters to closure (instead of the expected 45 m) representing an approximate reduction in air storage capacity of 25% compared to the estimates made in 2007; The size would have now perhaps accommodated a smaller CAES project of about 65 MW instead of the contemplated 270 MW.
- the structure's porosity was between 16% to 17%; low pump test results indicated that permeability of the sandstone was a primary concern.

In 2011, the project was cancelled due to these geological limitations. Further investigations would have cost too much and would have not guaranteed success.

For further information please read the report by Schulte et al. (2012) and the powerpoint slide presentation by King and Moridis (2009).

Annex 2 – Technology Description

The stoRE report by Wänn et al., (2012) thoroughly describes the technologies, which will be summarized in this section, to provide the reader with an overview.

PHES

PHES is classed under the hydropower family alongside run-of-the-river hydropower, and (storage) hydropower. Run-of-the-river usually has little to no storage possibilities (maximum 48 hours) and is therefore subject to seasonal river flows. These plants are most often found on rivers that have a consistent and steady flow and therefore provide base-load to the electricity system. Hydropower facilities on the other hand have water storage capacities that require a dam that store large quantities of water for daily, weekly, monthly or annual water supply needs. Usually these facilities will store water during the wet season for later use during the dry or cold/hot season; but can also be partially discharged on a daily basis to provide peak load and ancillary services. Hydropower can thus function as base-load but also as peak-load and also provide other grid services when needed. A hydropower facility's ability to store water is sometimes mistakenly confused with 'energy storage'. However, experts call this ability 'fuel piling' (similar to heaping wood by a stove). In contrast, the pumping capability of PHES 'stores' excess electricity from the grid by pumping water from a lower to a higher reservoir and releases the energy again as required.

PHES is classed as energy storage because of its ability to act either as an electricity producer when the electricity system is in need of electricity or as load (i.e. uses its pumps) when there is too much electricity on the grid and not enough demand. Where, hydropower and run-of-the-river power plants can provide certain flexibility on the generation side delivering upward adjustment services, they are not considered electricity storage in the narrow sense as they are unable to 'consume' electricity to charge a reservoir (Vasconcelos et al., 2012). For this reason PHES is a very viable technology to help integrate variable RES, such as wind and pv. PHES is therefore also not considered to be RES but rather a RES enabler, whereas the other two hydropower technologies are. Exception to this definition should perhaps be made for pump-back PHES that are most like (storage) hydropower and only operate the pumps when needed as there usually is significant volumes of water passing the turbines and makes this type of facility able to operate independently of the pumps. The other two types of PHES cannot operate without the use of pumps and turbines. The separate technologies will be looked at more closely below.

PHES has the highest cycle efficiency of 75%-80% compared to other storage technologies (Vennemann et al., 2011). Losses occur during pumping and generating. Furthermore, PHES provides the electricity grid with invaluable services such as: grid balance, grid flexibility, supply smoothing, black start capabilities, spinning reserve, auxiliary reserve, peak shavings, regulation control, security, etc. (Foley et al., 2010). Historically, PHES has operated together with conventional base-load generation (e.g. nuclear, lignite, coal) that are more efficient when generating at a constant rate and are therefore traditionally associated with peak (i.e generating) and off-peak (i.e pumping). More recently PHES has become more important for its grid balancing capability rather than for its peak power/off-peak consumption capabilities.

Another issue with PHES is that these facilities, in the same way as hydropower, require very specific site conditions to make a project viable i.e. high head, favourable topography, good geotechnical conditions, access to the electricity transmission networks and water availability. It may therefore not come as a surprise that the majority of PHES facilities in Europe are concentrated in the Alpine regions of France, Switzerland and Austria (Deane et al., 2010). With

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most of the viable sites already in use, developers are now looking at other solutions that previously were thought to be unviable.

As alluded to above, the stoRE project distinguishes between three different types of PHES according to their water management (Malachy Walsh and Partners, 2011):

- Open-system PHES
- Semi-open PHES
- Closed-loop PHES

Open-system PHES

The open-system PHES, more commonly known as pump-back, is a system where there is continuous flow of water through both the upper and lower reservoir. A schematic description of the pump-back PHES is shown Figure 3. This type of PHES is the most comparable to a hydropower facility of the three. An already existing hydropower plant can be retrofitted with a reversible pump-turbine thus turning the facility into a pump-back, or the facility can be constructed as a pump-back directly, as in the case of the Thissavros PHES facility in Greece. The difference between a pump-back and the other two PHES types is that if the pumps were to be switched off for a long period of time, the facility can still operate and generate power; in effect it ‘becomes’/reverts to a hydropower facility.

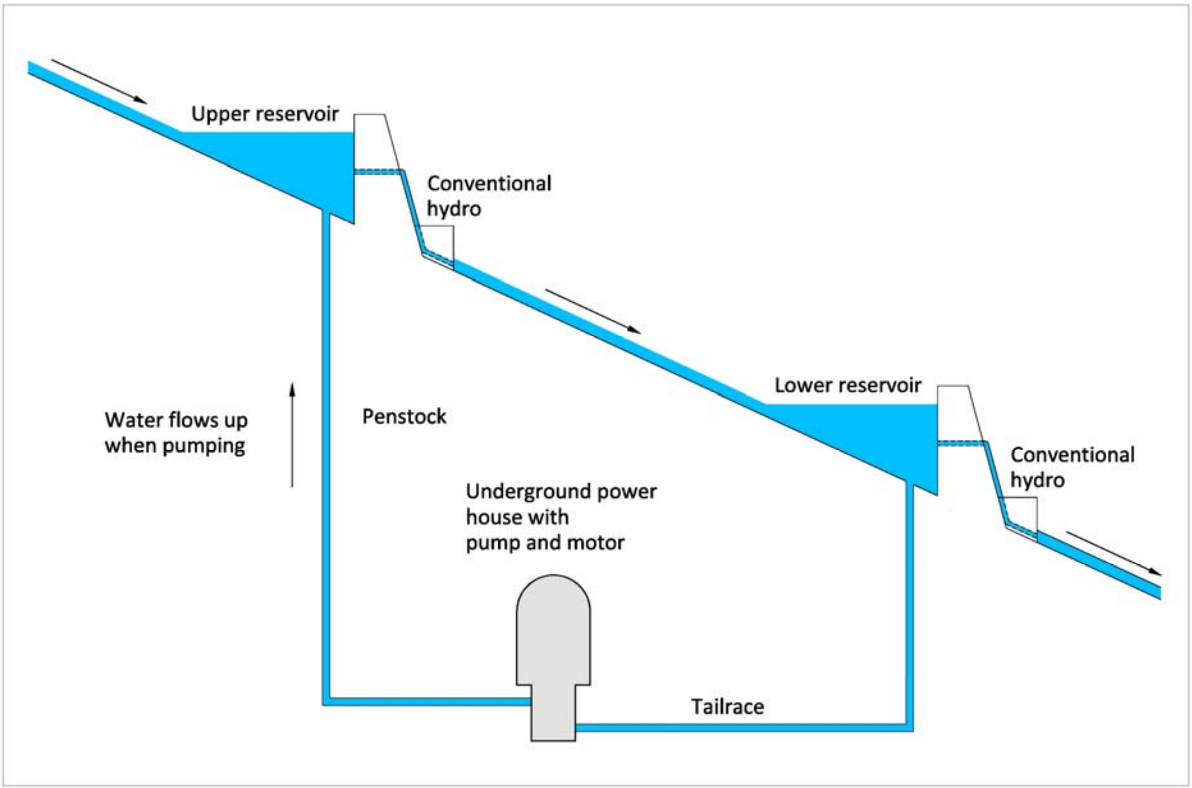

Figure 3: Schematic description of the pump-back PHES. Source: (Malachy Walsh and Partners, 2011)

Closed-loop PHES

The closed-loop PHES is constructed using two reservoirs that are separated by vertical distance. These reservoirs may both be natural, or one may be natural and the other artificial or both may be artificial. A schematic description of a closed-loop PHES is shown in Figure 4. Where pump-back PHES is situated in a river system and directly impacts the river, the closed-loop PHES will be closed off from other water bodies once in operation. However, the initial filling of the reservoir from its own catchment or a nearby water body is most likely needed. There is usually also a catchment area associated with one of the reservoirs to allow the reservoirs to be “topped up” once in a while as water will evaporate from the reservoirs.

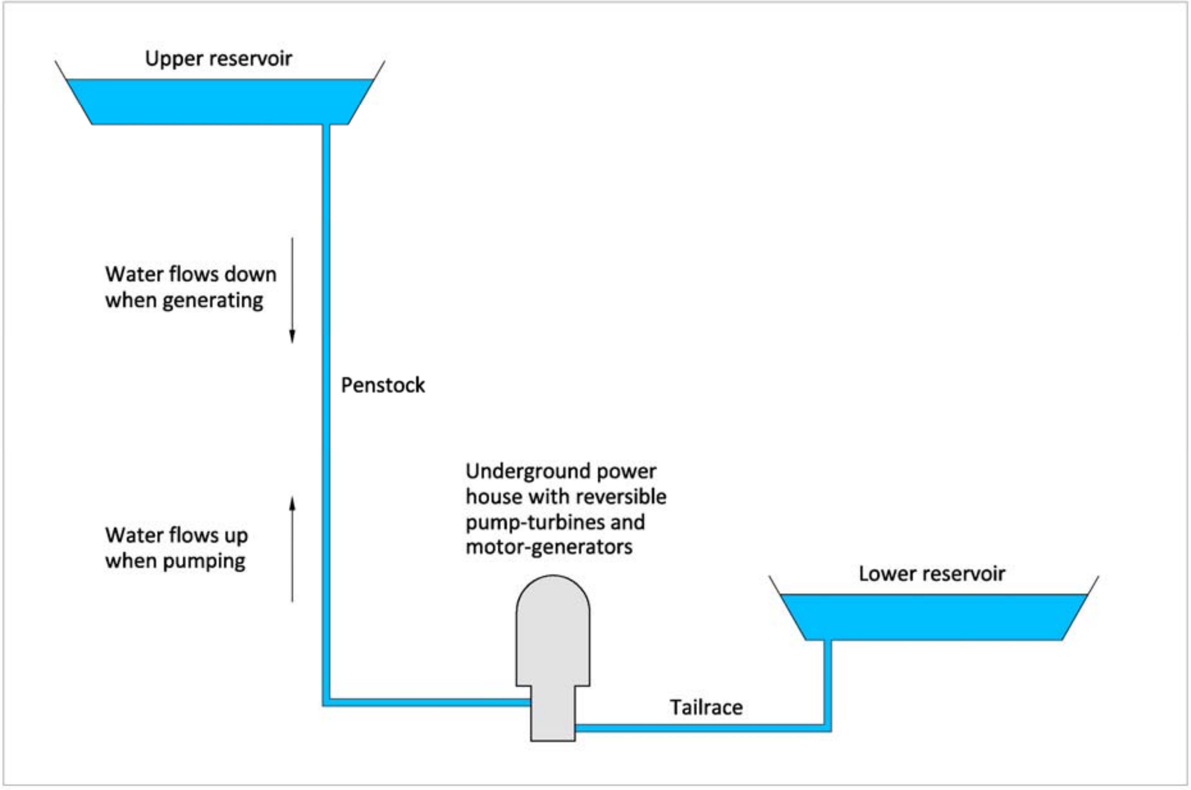

Figure 4: Schematic description of the closed-loop PHES. Source: (Malachy Walsh and Partners, 2011)

Semi-open PHES

The semi-open PHES is the least known of the three categories and forms a hybrid between the two other PHES types. One reservoir is closed off from other water sources and is usually artificial; the other reservoir will usually be part of a river, i.e. a substantial amount of water still flows through this reservoir. A schematic description of the semi-open PHES is shown in

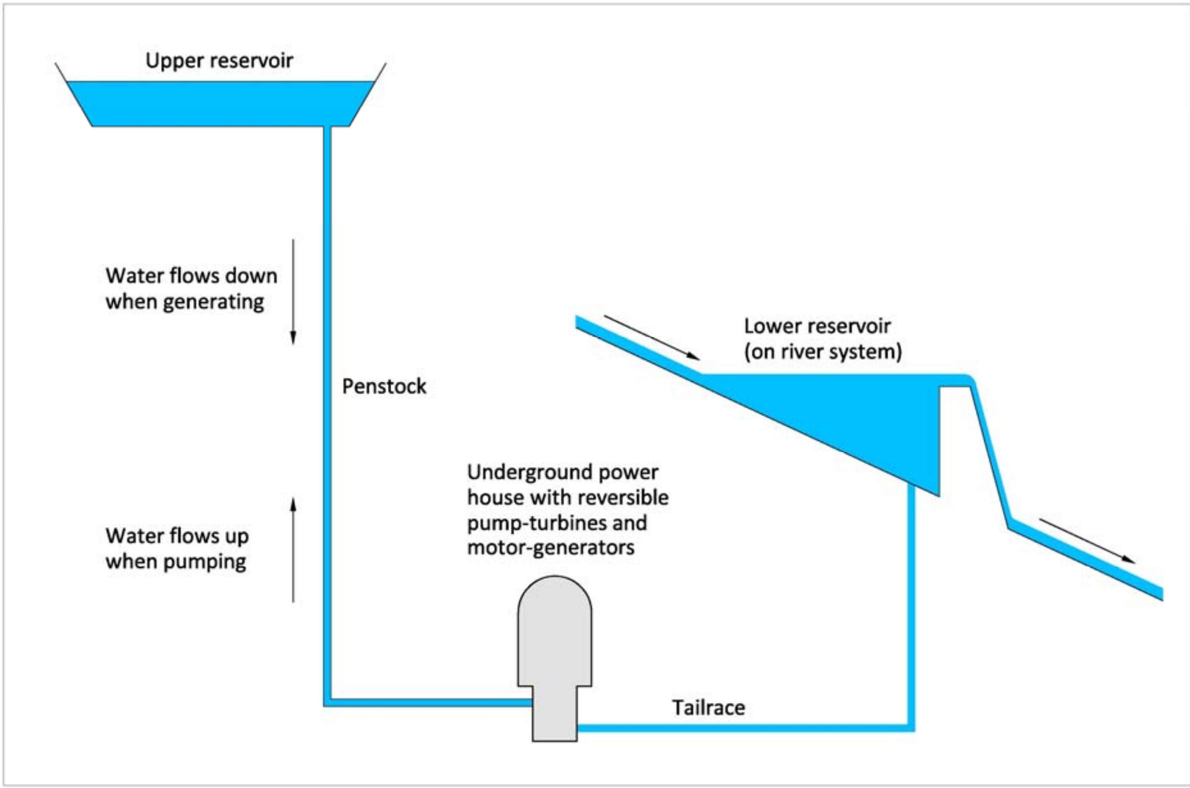

Figure 5: Schematic description of the semi-open PHES. Source: (Malachy Walsh and Partners, 2011)

CAES

A (conventional) CAES facility is similar to gas turbine power plants with one addition; it stores compressed air in salt caverns. In the same way as hydropower, gas turbine power plants can provide certain flexibility to electricity grid on the generation side delivering upward adjustment services; they are not considered electricity storage in the narrow sense as they are unable to 'consume' electricity to charge a reservoir.

The main principle of a (conventional) CAES system is that it utilises excess electricity from the grid to compress air and store it in large underground salt caverns. When the need for additional electricity arises on the grid the air in the caverns is discharged, mixed with natural gas and fed through the generator to produce electricity. A schematic description of a CAES is shown in Figure 6. CAES is therefore considered to be a hybrid energy storage system. The advantage is that CAES only requires a third of the natural gas requirement of a conventional gas turbine power plant during generation.

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There are only two CAES facilities in existence worldwide; Huntorf, Germany and McIntosh, Alabama, USA, commissioned in 1978 and 1991, respectively. Pickard et al., (2009) believes the reason for the low development activity is that the anticipated return on investment (not yet made) is too small to compete with other (more proven) opportunities for investment capital. Currently, the main alternatives to CAES are PHES and open cycle gas turbines. As mentioned before however, the latter cannot store energy. Currently in Europe there is one known CAES site under investigation located in Larne, Northern Ireland. This CAES will use the same technology as the two existing facilities.

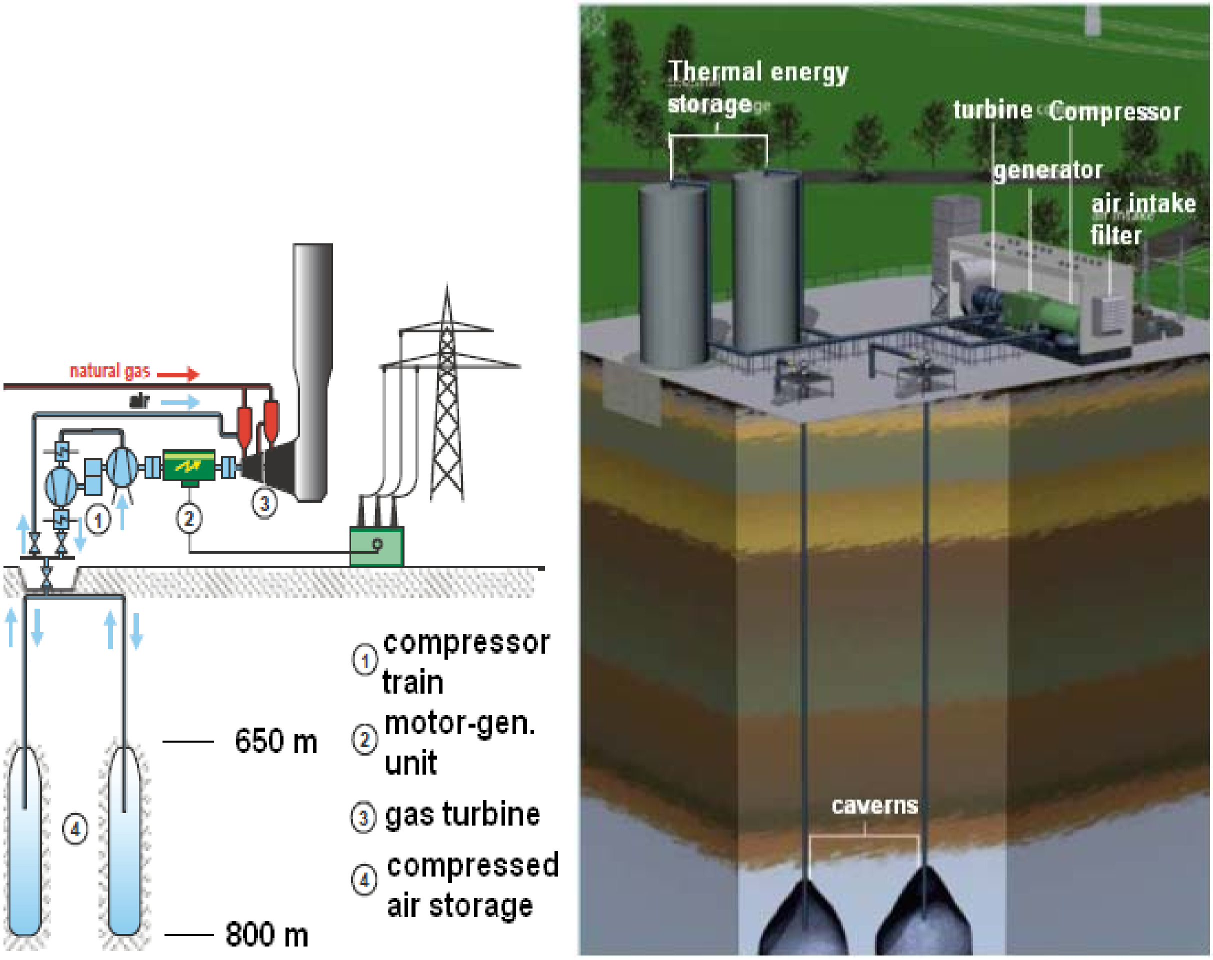

Figure 6: Schematic description of the (conventional) CAES (left) and adiabatic CAES (right). Source: (Crotogino et al., 2001) and (RWE Power AG, 2012).

There is ongoing research into adiabatic CAES systems where the excess heat released during air compression is temporarily stored until the heat is needed again during decompression. Managing to store the heat for later use will eliminate the need for natural gas. The ongoing RWE project ADELE in Germany, using the adiabatic CAES should reach a cycle efficiency of up to 70% (Vennemann et al., 2011), compared to Huntorf CAES cycle efficiency of 42%-55% (Woyke, 2008). This would make adiabatic CAES only slightly less efficient than PHES. A schematic description of an adiabatic CAES is shown in Figure 6.

Like PHES, CAES also has specific site requirements. The advantage of CAES is that it is a storage technology that can be used in flat areas, where PHES cannot function. The caverns used

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in both existing facilities are salt caverns. Salt domes are also the geology of choice due to its geological properties; plastic yet solid and permeable (BBC Brown Boveri). However, salt domes are only found in certain places. In the US for example, there are a few CAES facilities that have been proposed recently where the caverns were going to be in sandstone. However, upon closer inspections the geology was deemed suitable (Schulte et al., 2012). The cavern type also determines the storage type; sliding pressure or constant pressure. Both existing CAES facilities use sliding pressure.

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Annex 3 – Environmental Impact

The first stoRE report on environmental issues discussed the environmental impact of bulk energy storage technologies (EST), namely pumped hydro energy storage (PHES) and compressed air energy storage (CAES), during operation (Wänn et al., 2012). PHES has been further distinguished according to water management as closed-loop, semi-open and open system. The results for CAES are based on conventional technology, which is the hybrid system that uses natural gas. The results are supported by six case studies, extensive literature review and expert opinion. The authors emphasize the limitation of case studies (range of number, choice and lack of information) and recommend that the summary table of negative impacts during operation (see ***Table 2***) should be read in combination with the individual case studies. For the purpose of this report, only the most significant impacts (highlighted in red) generally applicable during construction (C) and operational (O) phases are included. PHES and CAES facilities are large civil constructions that are very site specific and therefore need to be assessed on a case by case basis e.g. significant cultural heritage impacts may arise in sensitive archaeological areas.

Table 2: main negative environmental impact during construction (C) and operation (O) of CAES and PHES

Potential Issues/EIA terms of reference		CAES	Open-system PHES	Semi-open PHES	Closed-loop PHES
Human Impact	Population				
	Traffic				
	Cultural Heritage				
	Material Assets				
Ecology and Natural Systems	Biodiversity		C/O	C/O	C/O
	Fisheries		C/O	C/O	C/O
	Air and Climate	C/O			
	Landscape and Visuals				
	Water Resources & Quality	C	C	C	C
Physical Environment	Noise & Vibration				
	Soils, Geology & Sediment Transport				
	Hydrology & Hydrogeology		C/O	C/O	C/O

Annex 4 – Methodology

Task

The aim of this report is to provide recommendations for furthering the sustainable development of PHES and CAES projects. The work is based on a stakeholder consultation process across the stoRE project partner countries (Austria, Denmark, Germany, Greece, Ireland and Spain), three round table discussions with relevant stakeholders, previous stoRE report Wänn et al., (2012), extensive literature review and expert input from the assessment team.

Assessment Team

The assessment team consisted of engineers, environmental engineers, environmental consultants, ecologists, and EIA practitioners from Malachy Walsh and Partners and UCC.

The team held regular meetings to discuss the findings of the stakeholder consultation and round table discussions, highlights from literature and any emerging issues.

Stakeholder Consultation

The assessment team identified six specific stakeholder groups, created tailored questionnaires for each and asked the stoRE partners[21] for assistance in identifing at least two organisations or competent bodies within each stakeholder group to whom the questionnaires could be sent. The total number of responses was 43. Table 3 shows identified six stakeholder groups and the distribution of responses.

Table 3: Responses to stakeholder questionnaire for each project partner country and EU. Total amount of responses: 43

	Austria	Denmark	Ireland	Germany	Greece	Spain	Europe
Decision Makers	3	1	1		1		
Developers/ Utilities/ TSO	1	2	3	6	1	3	1
Energy Organisations			1		2	2	3
Environmental Organisations	1	1		2	2	1	
Planning/Environmental Watchdogs		1	1				
Community Representatives		2		1			

[21] Wirtschaft und Infrastruktur GmbH & Co Planungs-KG, Germany (WIP), European Small Hydropower Association (ESHA), National Technical University of Athens, Greece (NTUA), University College Cork, Ireland (UCC), Helmut-Schmidt-Universität, Germany (HSU), National Renewable Energy Centre, Spain (CENER), Energy System Department, Denmark (EMD), Energy Economics Group, Austria (EEG) and Malachy Walsh and Partners, Ireland (MWP)

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Round table discussions

As part of the consultation process and in addition to the stakeholder consultation, three round table discussions were organised by the stoRE project. The round tables targeted environmental NGO’s, environmental organisations, PHES (and CAES) developers, energy organisations and other interested stakeholders. Two of the round tables were organised by the stoRE project in Brussels, Belgium at the Renewable Energy House. One was substituted for a PHES workshop organised by the Joint Research Centre (JRC).

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