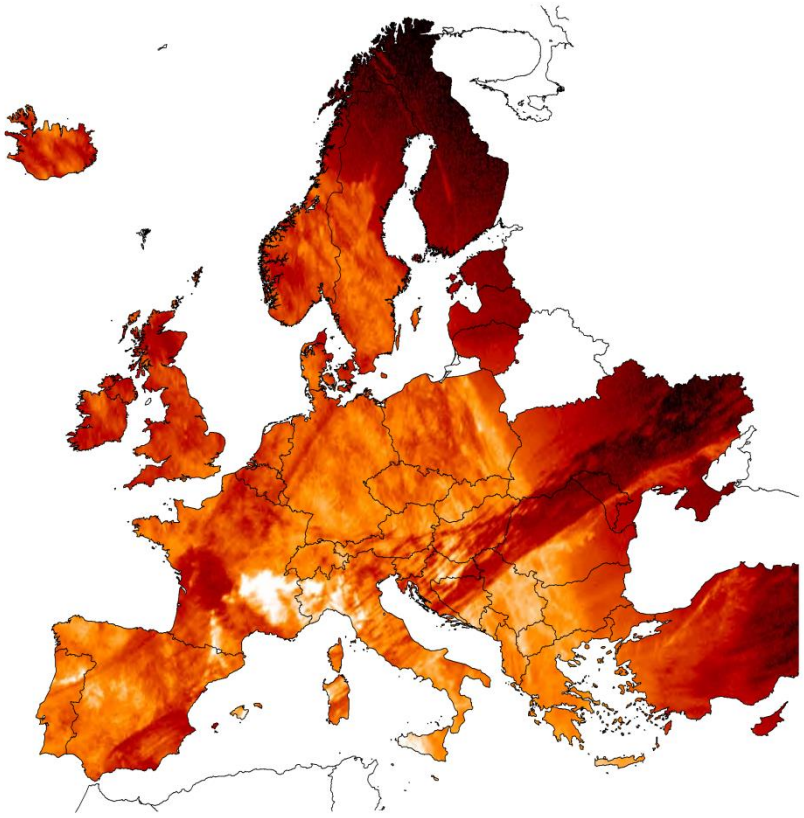


ESTMAP
Public Project Summary

As part of EC Service Contract no.: ENER/C2/2014-640/S12.698827

Prepared by: Serge van Gessel (TNO)
Frank Meinke Hubeny (VITO)

Checked by: Florence Jaudin (BRGM)
Edwin Haesen (Ecofys)
Vit Hladik (CGS)

Approved by: TNO: Jan Hopman,
ESTMAP coordinator

Table of Content

1 Introduction 2
2 The ESTMAP project 2
3 Scope 2
4 Energy storage specification 3
5 Data collection and processing 3
6 Database results and recommendations 3
7 Analysis storage parameters 4
8 Analysis 4
9 Conclusions and recommendations 5

1 Introduction

Although large-scale energy storage is, to a certain extent, a mature technology (e.g. Pumped Hydro Storage has been deployed for large scale storage of electricity since the 19th century), a renewed scope for research in this area emerges. This development is largely driven by some of the fundamental changes that influence our energy system at present. As flexible, primary energy sources for base-load power generation (e.g. coal, nuclear) are gradually being replaced by renewable and intermittent sources of production, it becomes more and more challenging to constantly match supply and demand. An additional trend is the ongoing growth of de-centralized energy production (e.g. residential solar PV), which potentially leads to grid congestion and stability problems (e.g. fluctuations in voltage and frequency).
Energy storage encompasses a broad set of solutions to alleviate these problems. These solutions can be deployed for many types of services at various scales. The ESTMAP project investigates the distributed potential to deploy energy storage and demonstrates how this information can be used for analyzing future energy scenarios.

2 The ESTMAP project

The ESTMAP project started in January 2015 and is finalized in December 2016. The project includes three major elements:

1. collection and compilation of public available spatial information on existing energy storage sites and future storage potential;
2. development and population of a harmonized spatial database that is capable of maintaining, integrating and disseminating this information; and
3. demonstration of how the database can be used for pan-European and regional energy system modeling studies.

This document briefly summarizes the main results and recommendations.

3 Scope

From the beginning onward, ESTMAP has regarded energy storage in a broad context and covers gas-, heat- and electricity-related services, as well as various carriers used to capture and transport energy (e.g. hydrogen, compressed air, etc.). Energy storage technologies are nowadays deployed for a variety of uses and scales, ranging from small batteries up to stored quantities of natural gas serving the energy demand of hundreds of thousands of households during an entire

winter season. ESTMAP primarily focuses on larger-scale technologies that are relevant for either centralized energy grids or national to local energy distribution networks. Although not included in the scope, it should be noted that, by its design, the database is also capable of incorporating smaller scale (household) storages, as long as they have a geographically fixed location (thus excluding storage services in transport).

4 Energy storage specification

In the ESTMAP database an energy storage site is described by two interlinked components: 1) the actual storage facility or storage plant that is responsible for operating and regulating intake, conversion and output of energy, and 2) one or more, natural or artificial reservoirs that act as a physical containment for the energy carriers. These reservoirs can either be situated in the subsurface (porous formations, caverns, etc.) or above ground (lakes). Some technologies (e.g. batteries, flywheels, LNG) are not depending on such reservoirs and are thus defined by the facility only.

While existing energy storage sites in ESTMAP cover any type of technology, all future potential is being based on technologies that rely on natural reservoirs (e.g. hydrocarbon fields, aquifer traps, lakes) or site-specific conditions that allow for the development of artificial reservoirs (e.g. salt caverns, rock caverns). This future potential may comprise multiple options for deployment in case the reservoir is suitable for operating more than one technology. Salt caverns may for example define a potential for natural gas, hydrogen or compressed air energy storage.

5 Data collection and processing

Geological and technical research institutes associated under the flag of ENeRG and EuroGeoSurveys have collaborated as partners in ESTMAP in order to deliver presently available knowledge and information on subsurface-related energy storage development as well as a characterization and evaluation of reservoirs that are considered potentially suitable for future storage development. The information on above ground lakes is provided by the 2013 JRC-IET Pumped Hydro Storage assessment study. Complementary information regarding existing and planned storage facilities and plants is obtained from several public databases including GIE - Gas Infrastructure Europe (LNG and gas storage) and the DOE global energy storage database. All information has been collected and processed for consistent integration and documentation in a harmonized database concept.

6 Database results and recommendations

The database now contains the information of more than 4200 reservoirs and subsurface formations in 33 European countries (including Turkey) that are either already deployed for storage, or that may represent a potential for future storage development. In addition to this, information has been gathered for approximately 700 existing or planned energy storage facilities, ranging from batteries and thermal installations to pumped hydro and gas storage plants (some of which are expansions to existing capacities). Each site is characterized by a comprehensive set of attributes that describe the geographical, geological and physical aspects as well as the current utilization and assessed potential for various energy storage technologies (underground gas storage, hydrogen storage, compressed-air-energy storage, underground thermal storage and pumped hydro storage). Roughly two thirds of these entries represent above ground lakes for pumped hydro storage. In the subsurface the dominant types of reservoirs are aquifers, hydrocarbon fields and salt formations (caverns), most of which are deployed or planned for underground gas storage. Detailed evaluations of the gathered data are described on a country-by-country basis.

7 Analysis storage parameters

The spatial GIS database with existing energy storage sites, potential sites and capacities for future large-scale centralized energy storage are deployed in pan-European and regional energy systems analyses. In preparation of these analyses the data has been processed in order to:

1. ensure that cost and performance attributes of existing facilities comply to the analysis tool requirements, and;
2. translate the information of potential storage reservoirs into parameterized future storage facilities.

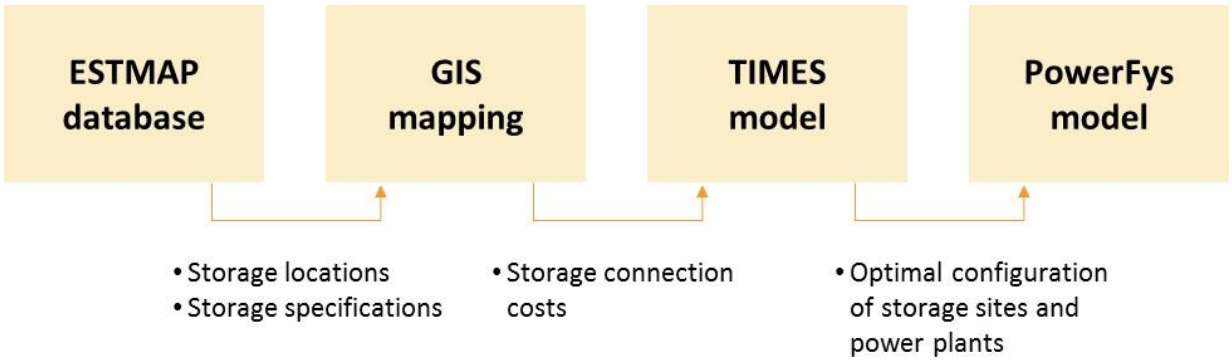
The data model for the analysis storage parameter specifications includes performance and cost parameters that are tailored for the analyses tools TIMES and POWERFYS. The parameterization of the future facilities is determined from the reservoir data and by literature-based values, which are specified in so-called generic notional development designs. The storage parameter workflow has resulted in a pan-European analysis input dataset that was successfully deployed in the Analysis.

8 Analysis

The primary work within the ESTMAP project consists of collecting data on potential energy storage sites on transmission level in Europe and making it available in a database. In addition, and with the aim to demonstrate how this database can be used for energy system analysis and scenario work, it was used in an energy system modelling exercise for 2050.

As a first step, the grid-connection costs of facilities in the ESTMAP database have been calculated using GIS modelling. As a second step, the functionality of the ESTMAP database has been tested in energy system modelling, using the European TIMES model that computes an economic optimum configuration for the total energy system over the period up to 2050. Next, a more detailed regional TIMES model with a higher temporal resolution has been used to get insights on a more detailed level for the region comprising of Germany, The Netherlands and Belgium. The outputs on the optimal configuration of power generation and storage facilities of the regional TIMES model for the year 2050 have been used as an input in the PowerFys dispatch model. This model has calculated the optimum dispatch and operation of the future electricity system, while minimising operational costs.

The way in which the database and these models have been combined, is schematically depicted in the figure below.



The modelling exercise shows that the European energy storage database developed in the ESTMAP project can be successfully coupled to and applied for comprehensive energy system modelling work.
The results of the modelling test case illustrate the fact that the outcomes of energy system analysis strongly depend on key storage technology parameters, such as cost projections of different storage technologies. The set-up of the database allows one to vary these parameters, so that these can be updated when new insights or updated projections materialise over time. Due to its flexible set-up, the ESTMAP database forms a valuable tool for future energy system modelling.

9 Conclusions and recommendations

The ESTMAP database provides a first-time comprehensive overview of energy storage potential across Europe. The project has successfully demonstrated that this information can be used in energy system analyses. One of the novel features is the opportunity to include geographical and site-specific aspects into the pan-European modelling context (e.g. geographically matching storage potential with regional demand, incorporating locally defined grid connection costs in the equation, identifying possible conflicts for future deployment). But maybe more importantly, by maintaining and upgrading the information, the ESTMAP database may become a common agreed standard for future energy modelling studies. This will certainly help to improve the understanding of results, as one does not have to wonder anymore whether differing outcomes are due to incompatible input or not.
The dataset can be used in a regional context but is not suited for site-specific modelling and storage development. The assumed generic (notional) facility parameters used in the analysis however do not necessarily represent optimal or even viable solutions for local development. Such determination requires further detailed and site-specific investigation of techno-economic viability and performance, taking into account local subsurface (parameterization and modelling) and above-ground (e.g. environmental) conditions, as well as an analysis of specific demand requirements. Before we arrive at this point, however, there are still certain efforts required to improve the data itself. The evaluation of subsurface energy storage potential is still an evolving research area and the progress differs from country to country. The ESTMAP project results assist in identifying and prioritizing areas where significant upgrades are needed in order to achieve a more levelled overview of potential across Europe. In this regard a further harmonization of assessment methodologies and implementation of common workflows across all borders, as well as a more detailed and site-specific assessment of critical attributes are certainly key aspects for improvement.
Due to its flexible set-up, the ESTMAP database forms a valuable tool for future energy system modelling as has been showcased in the energy system analysis work package. Interesting follow-up work based on this database includes:

- Distill relationships and key drivers for the growth of large-scale energy storage, including the size of renewable energy in the energy mix, infrastructure inter-connectivity, and competing flexibility options.
- Quantify the growth trajectory for large scale energy storage in the energy system, considering various scenarios on cost of technologies and policy drivers, as well as how these may influence the mix of storage technologies in the energy system.
- Quantify the business case robustness for large-scale energy storage projects, exploring key drivers of revenues, operational costs / efficiency and risk.