Assessment of the Potential of the Proposed Technology for Seasonal Storage of Energy (D4.4)

Within the Horizon Europe project CEEGS (CO_2-based Electrothermal Energy and Geological Storage), the potential of the energy storage system concept (Carnot battery) for seasonal storage of renewable energy in conjunction with large-scale subsurface salt cavities for the storage of CO_2 was explored. Regional deployment scenarios for the reference regions of Germany and Spain were studied via multi-criteria decision analyses (MCDA) employing a large variety of georeferenced criteria and parameters relevant to the successful deployment of future CEEGS systems. Based on the output of the MCDA, simulation studies were conducted to characterise the stationary and dynamic operational behaviour of the CEEGS energy storage system and its surface (charge and discharge cycles) and subsurface (salt cavity) components in detail for fluctuating inputs from renewables at specific deployment sites. A schematic representation of the analyses' methodology is depicted in Figure 1.

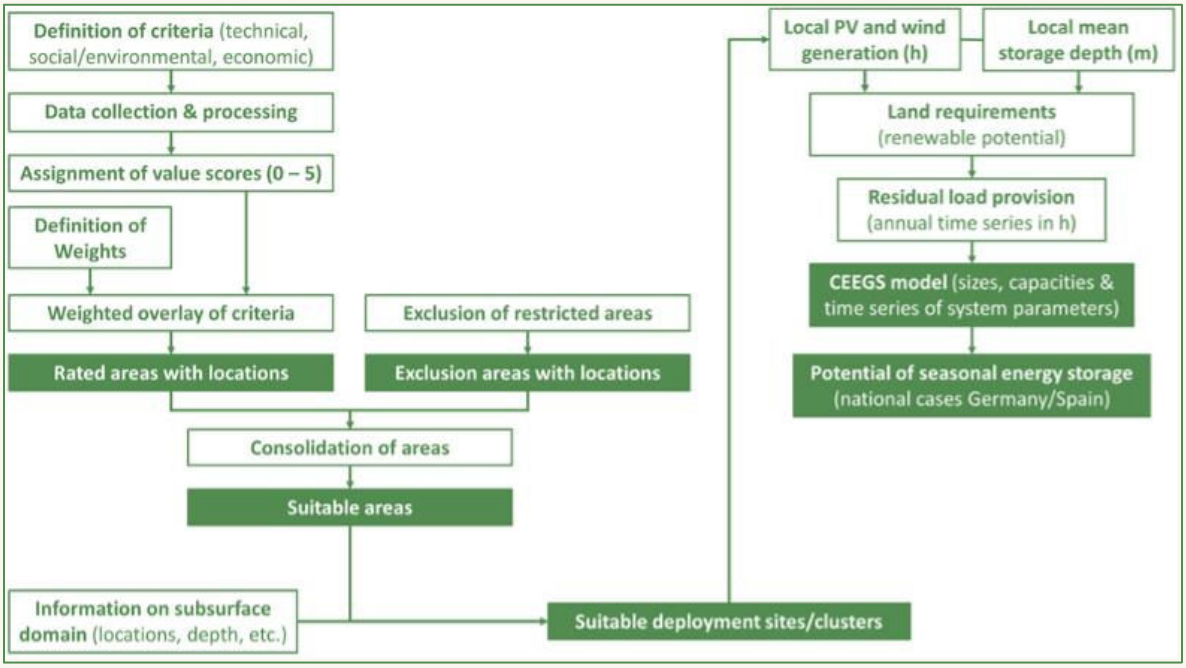

Figure 1. Applied study methodology and workflow.

Three different CEEGS supply/input cases were examined:

1. PV supply only,
2. Onshore wind supply only, and
3. PV & offshore wind supply combined.

Based on specifically chosen technical, social, and economic assessment criteria, suitable deployment regions were identified based on a standardised scoring system (Figure 2, left). The employed assessment criteria classes comprise the geospatial datasets of:

- **technical/physiographic** (wind speed, direct normal irradiation, topography, land use/land cover data, rivers, water bodies, digital elevation models, terrain slope, terrain elevation, etc.),

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- **environmental** (residential/urban/rural areas, protected areas, agricultural areas, forests, wetlands, buffer areas to environmental features, population density, etc.), and
- **economic** (location of and distance to roads, rail lines, transmission lines, airports, CO_2 emitters, settlements, etc.) domains or subsets relevant to the studied problem.

The resulting scores indicate different degrees of suitability for a potential CEEGS deployment region, with orange areas indicating moderate suitability, red areas good suitability, and dark red areas very good suitability. Utilising inputs of existing salt formations and commercial cavities (depth, volume, position) as well as the best scoring sites of each case, specific deployment clusters and their corresponding locations were computed as representative inputs to the subsequent process simulations and the conducted analyses. The outputs combine crucial information on the surface and subsurface characteristics alongside other information (renewables deployment potential, land requirements, etc.). Moreover, each of the identified and selected deployment clusters are employed to provide localised renewable production datasets (MERRA2 dataset) with an hourly resolution as site-specific input to the system simulation studies.

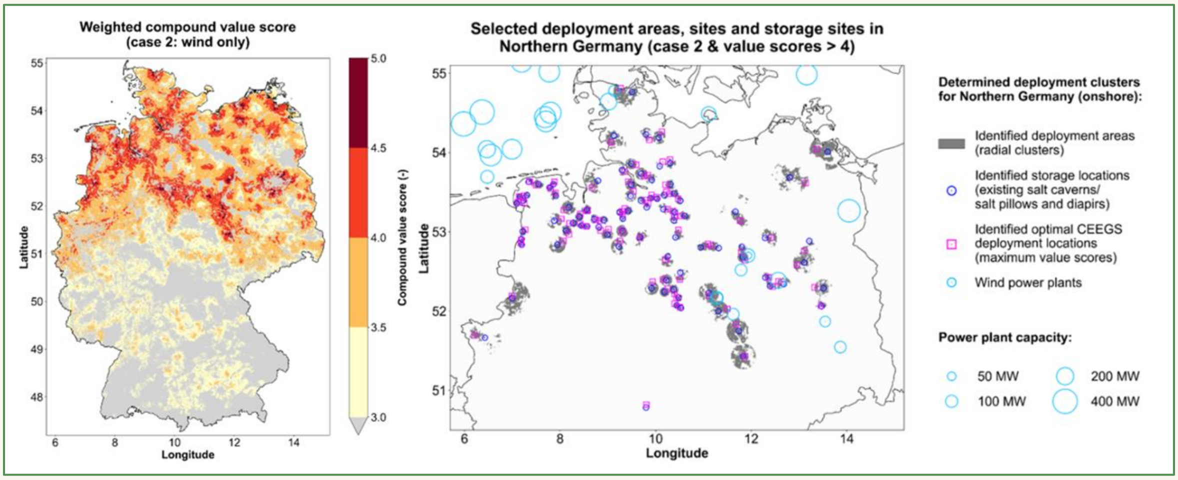

Figure 2. Weighted compound value score (left) and determined potential CEEGS deployment clusters (right) for Germany for case 2 (wind supply only).

Subsequent modelling and simulation studies were conducted based on the locational study results with particular focus on:

- system sizing of the CEEGS system for seasonal energy storage applications via steady-state modelling,
- optimisation of the system's thermal storages and of the salt cavity for CO_2 storage,
- dynamic simulation of the energy storage system for distinct seasonal time periods and corresponding renewable production and residual load time series.

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Dynamic simulation and analysis of the CEEGS energy storage system was conducted for two characteristic time periods (duration of four days; spring time with predominantly charging & autumn/winter time with predominantly discharging operation). Figure 3 shows the dynamic simulation results for the German onshore wind supply case.

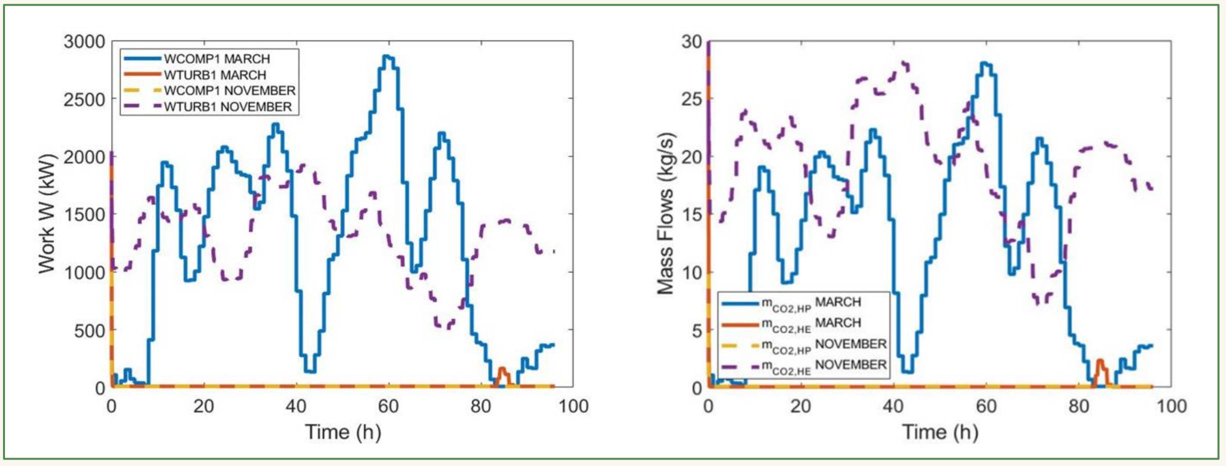

Figure 3. Outcome of the dynamic simulations for system work (left) and the respective CO_2 mass flows (right) of the CEEGS system for case 2 (wind supply only) and deployment in Germany.

Based on the conducted assessments and simulations the following conclusion were derived for the potential of the CEEGS technology for seasonal storage of energy: (1) numerous potential deployment sites with viable conditions can be found in both Germany and Spain, (2) all studied renewable supply cases of the CEEGS storage system show good dynamic behaviour, highlighting the viability of the technology for seasonal storage with respect to system capacities and control, and (3) the best performance (CEEGS roundtrip efficiency) was achieved for wind onshore supply (case 2). In conclusion, the models developed can be applied to the CEEGS system within different regions with varying (time-dependent) renewable production and demand profiles, as well as different geological storage conditions.

How do I find out more about the project?

Video teaser: https://youtu.be/fvH5HlrsJME?si=d1-IGwywE8CAJZN3
Project Brochure: https://tinyurl.com/2p9hc9n4
Project Website: https://ceegsproject.eu/

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