Scenario definition for modelling of the European energy system

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Revision History

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1. Introduction and Work Package overview

The major objective of Work Package (WP) 5 “Modelling of the European energy system“ is to investigate the role of a widespread deployment of underground renewable hydrogen storage in the European Union (EU) and the United Kingdom (UK) in future scenarios across the period 2025-2050. It is based on existing scenarios and roadmaps as well on the consortium’s expertise from previous projects and studies notably conducted for the EU and Fuel Cell and Hydrogen Joint Undertaking (FCH JU).

In this context, WP5 will model and analyse optimal design and operation of different elements of the future energy system including renewable electricity supply, production of renewable hydrogen, associated gas compression and hydrogen pipeline networks to transfer hydrogen to/from the storage. As an output the model will identify how to match renewable supply with energy demand at all times by appropriately sizing and operating the technologies involved in producing, storing, distributing and using renewable hydrogen. Moreover, the outcome of the modelling exercise will allow for mapping of the proximity of suitable underground stores with existing and future onshore and offshore wind/solar farms at country level.

The work package includes 6 tasks corresponding to steps of the proposed analysis of the future energy system in Europe (see Figure 1):

- **Task 5.1:** Definition of future scenarios for a widespread deployment of underground renewable hydrogen storage;
- **Task 5.2:** Pre-analysis of expected techno-economic requirements for underground renewable hydrogen storage to provide a valuable input for the screening criteria (e.g. orders of magnitude of the cycling frequency and of the capacity of the H_2 storage demand) as well as assessment of sites and technologies in other Work Packages;
- **Task 5.3:** Adaptation of the model of the integrated energy system in Europe to capture the defined scenarios and the characteristics of the technologies of renewable hydrogen underground storage;
- **Task 5.4:** Collection of relevant input data for scenario calculations to conduct quantitative analysis of the future energy system;
- **Task 5.5:** Techno-economic assessment of future scenarios for a widespread deployment of underground renewable hydrogen storage with major results from the modelling exercise;
- **Task 5.6:** Sensitivity analysis to test the robustness of the modelling results in respect to predefined input parameters.

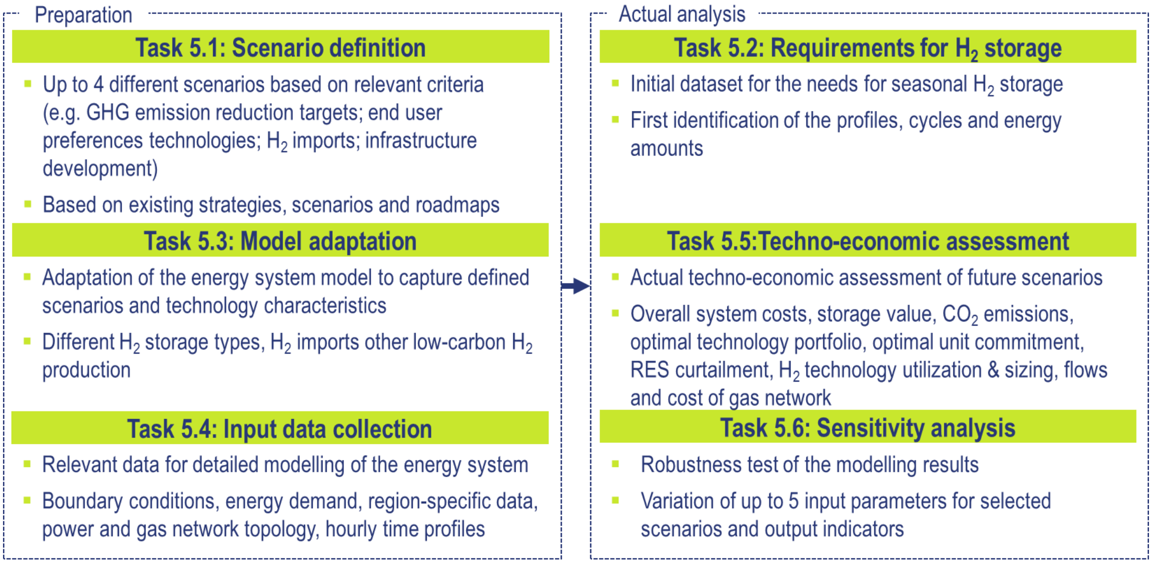

Figure 1: Structure of Work Package 5 including 6 tasks corresponding to steps of the proposed analysis

2. Scenario definition

Task 5.1 presented in this report lays the foundation for the in-depth techno-economic assessment by describing future scenarios for the deployment of underground renewable hydrogen storage. Based on existing strategies, scenarios and roadmaps for the EU and general objectives of the Hystories project the scenario definition in this Task takes following relevant criteria into account:

- **Hydrogen production pathways:** since the future hydrogen supply pathways are still under discussion and are not clearly defined in the existing strategies, scenarios and roadmaps we will differentiate between domestic hydrogen production and imports from different non-EU regions.
- **Hydrogen storage technologies:** next to salt caverns and other aboveground H_2 storage possibilities, which have been already analysed in more detail in other projects and studies, we will explicitly model and investigate the impact of hydrogen storage in porous media (i.e. depleted fields and aquifers) on the European energy system.
- **Spatial distribution across Europe:** depending on technology availability the facilities for underground hydrogen storage and/or H_2 production sites can be distributed across Europe in different ways (e.g. more centralized or more decentralized).

Referring to the time frames mentioned by the EU hydrogen strategy (COM (2020) 301 final)[1] the analysis will be conducted for the time horizons 2025, 2030 and 2050. In order to ensure comparability of the scenarios we will assume same greenhouse gas (GHG) reduction targets for EU-27 in comparison to 1990 levels, i.e. -37.5% until 2025, -55% until 2030 and climate neutrality until 2050. Similar, the expected preferences for end user technologies and thus the hydrogen demand levels will remain unchanged for all scenarios. Moreover, for the sake of simplicity, only power and hydrogen infrastructures will be considered in order to focus on major objectives of the Hystories project.[2]

In this context we define following four scenarios for further analyses based on the abovementioned criteria and assumptions:

- **Scenario A** is used as a basis for comparison with other scenarios. Hydrogen production is mainly produced domestically and stored either in salt caverns or in aboveground facilities. Underground hydrogen storage in porous media is not available in this scenario. Due to limited availability of favourable geological conditions across Europe the large-scale underground hydrogen storage in salt caverns occurs only in selected countries and is hence more centralized from the

[1] COM (2020) 301 final : Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions - A hydrogen strategy for a climate-neutral Europe. Brussels, 8.7.2020.

[2] Note that all other input data and assumptions will be described in more detail in Deliverable D5.4 “Assumptions and input parameters for modelling of the European energy system“.

European perspective (HyUnder, 2014). Nevertheless, the domestic hydrogen production is distributed across EU-27 and the UK more equally.

- **Scenario B** is similar to Scenario A but with a broader range of hydrogen storage technologies. Next to salt caverns and aboveground facilities it takes into account explicitly underground storage in porous media (i.e. depleted fields and aquifers). Hence, both hydrogen storage and production facilities are well distributed across Europe.
- **Scenario C** assumes different hydrogen supply pathways in comparison to the previous scenarios. Domestic hydrogen production is moderate whereas the share of hydrogen imports from outside the EU is much larger. Salt caverns are the only option for large-scale underground storage and their location is again limited by the availability of suitable geological conditions. In this way we assume large hydrogen storage hubs in central Europe.
- **Scenario D** is characterized by similar production pathways (more imports, less domestic production) as in Scenario C. However, it takes into account all hydrogen storage technologies including salt caverns, depleted fields, aquifers and aboveground facilities which are widely distributed across Europe.

Table 1: Selected scenarios for modelling of the European energy system

	Scenario A	Scenario B	Scenario C	Scenario D
General assumptions				
GHG emission reduction targets for EU-27 from 1990 levels	**2025:** -37.5% | **2030:** -55% | **2050:** -100%			
Hydrogen demand	**Identical for all scenarios** to ensure comparability			
Scenario differentiation				
Hydrogen production pathways: Domestic vs. imports from non-EU v	**Mainly domestic**, limited imports	**Mainly domestic,** limited imports	Moderate domestic, **larger imports**	Moderate domestic **larger imports**
Hydrogen storage technologies: Salt caverns, porous media and aboveground technologies	**Salt caverns,** aboveground technologies	**Salt caverns, porous media,** aboveground technologies	**Salt caverns,** aboveground technologies	**Salt caverns, porous media,** aboveground technologies
Spatial distribution across Europe: Centralized/distributed H_2 production and storage	**Centralized storage** (where possible), distributed H_2 production	**Distributed** H_2 production and storage	**Centralized storage** (hubs in central Europe), distributed H_2 production	**Distributed** H_2 production and storage

3. Abbreviations

EU	European Union
FCH JU	Fuel Cell and Hydrogen Joint Undertaking
GHG	Greenhouse gas
UK	United Kingdom
WP	Work Package

4. References

COM (2020) 301 final. Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions - A hydrogen strategy for a climate-neutral Europe. Brussels, 8.7.2020.

HyUnder, 2014. Assessment of the Potential, the Actors and Relevant Business Cases for Large Scale and Long TermStorage of Renewable Electricity by Hydrogen Underground Storage in Europe – Exectuive Summary. 24.06.2014.

Hystories project consortium

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