Joint Methodology for individual EU Case Studies

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Revision History

Revision	Revision date	Summary of changes
0	27 September 2022	Initial version
1	15 June 2023	Methodology update

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1. Introduction

The main objective of the WP8 is to assess the feasibility of implementing large-scale storage of renewable hydrogen in depleted gas fields and other types of geological stores at selected sites in the European Union. This assessment will be based on detailed case studies for selected Member States and sites. Thus, the specific objectives of this work package include:

• Development of a joint methodology providing a consistent toolbox for all case studies enabling their techno-economic comparison.

• Identification of potential business cases for the use of large-scale underground renewable hydrogen storage at potential sites in selected Member States.

• Comparison of different European case studies to obtain common conclusions about the profitability of the technology.

This report describes the joint methodology for selected European case studies which has been developed in the framework of Task 8.1. For this purpose, a toolbox to analyse the profitability of the various largescale hydrogen storage technologies and business models for single large-scale hydrogen underground stores from the perspective of single operators is the form that is methodology is implemented and it would be perform the analysis of specific European case studies.

This toolbox will be used in the Task 8.2 by the following project partners, who will lead country case study teams, to carry out the study of the specific case studies:

- France (carried out by GK)
- Germany (by LBST)
- Spain (by FHa)
- Poland (by MEERI)
- One additional case study defined as "promising Member State" will be also selected from the remaining EU-27 member states and carried out by FHa.

Each case study will consist of three consecutive steps. Firstly, each case study team will define the most promising, hypothetical geological storage site, by using the technical parameters of the cost model described in Deliverable 7.2. Then, a fine-tuning of the data and possible local constraints will be conducted considering the input from the industry in the Advisory Board and other local stakeholders, if needed. Finally, each study will provide the actual site-specific profitability analysis and business model valuation considering site specific costs.

In a next step, Task 8.3 will consolidate and align the results from the individual case studies into a benchmarking of selected Member States drawing conclusions on the profitability of the technology at single sites for large-scale underground hydrogen storage in Europe. It will provide insights into the different and common interests across Europe, indicating the representativeness of the individual approaches and highlighting the potential European-wide impact. The results and conclusions of this task will be used to define the implementation plan for underground renewable hydrogen storage in the EU in WP9.

Keeping in mind the above-reported considerations, this first WP8 deliverable reports the methodology on which the subsequent work will be developed, which will make it possible to achieve the proposed objectives and results, as explained above, and which is presented in the form of a guide to the toolbox developed.

2. Scope of the methodology

The joint methodology developed is based on current underground natural gas storage business models, assuming that underground hydrogen storage will inherit this business model in future scenarios with increased hydrogen penetration in the European Union.

Thus, the business model is based on the underground storage service provided by a generic gas operator for third party companies interested in storing their own hydrogen. The methodology does not consider the production of renewable hydrogen from each country renewable resources, but it does consider the storage service and its related revenues according to the annual hydrogen throughput of the storage site.

The methodology considers the nature of the underground storage (salt cavern or porous storage), as well as technical parameters of each case study, which will be defined in detail within this report.

The economic evaluation of the business model is based on the results of the D7.2-1 Costs analysis & LCCA [1]. This work includes the development costs or capital expenditure (CAPEX), i.e., the costs related to engineering, procurement, construction, commissioning, and start-up of the project. In addition, cost estimates for operating costs (OPEX) over the life cycle of the hydrogen storage facility as well as abandonment expenditures (ABEX) were included.

Moreover, the tool provides qualitative information for the selection of the specific case study. These considerations are intended as an optional guide for partners wishing to select a case study from among several options. However, this quantitative information does not include geological parameters. Hence, it is recommended to apply it to the selected sites will be published within the “D 7.3 Ranking of geological sites” scope.

3. Definition of the methodology

This section provides an overall description of the business tool developed for the techno-economic analysis of specific business cases studies within preselected Member States.

3.1. Excel tool

Given the techno-economic differences existing between a salt cavern and a porous media, two different models were built for the business cases analysis, one for each type of underground hydrogen storage (UHS). Both the models were implemented as tool in Excel software and organised following the same layout:

1. Instructions for the user
2. UHS site qualitative assessment (optional)
3. Summary
4. Hydrogen Price & Demand
5. Finance
6. Techno-economical worksheets

The first worksheet contains short but straightforward instructions of the tool to make the beginner user familiar with it. Such instructions are displayed as text format, helping the user to distinguish the modifiable elements of the tool from those which are beyond the reach. As general rule, the Excel tool contains green worksheets which can be modified by the user, where proper values for each specific parameter can be selected. On the other side, worksheets marked in red are not modifiable; their only function is reading the parameters values inserted by the user and generating results by automatic computations, according to the equations reported in D7.2-1 [1].

In *UHS site qualitative assessment (optional)*, an intuitive table collects qualitative aspects about the underground site (Figure 1) in terms of energy integration, natural gas system, hydrogen demand, politics and regulations. The main objective is to help the user to select the most proper UHS site, among others, from a market perspective. The qualitative parameters in the above-mentioned table are divided in four groups:

i. Integration into the energy system
    a. Availability of renewable resource in the region
    b. Availability of high-voltage power grids in the region
    c. Projects planned in the region for renewable hydrogen production
ii. Hydrogen distribution system
iii. Availability of hydrogen transmission networks nearby (new 100% H_2 dedicated networks or existing natural gas networks)Hydrogen Demand
    a. Transport demand in the region
    b. Industry demand in the region
    c. Re-electrification demand in the region
    d. PtG in the region
iv. Politics and regulations
    a. Country ranking position according D6.1
    b. Availability of regional plans supporting UHS
    c. Possibility of national or regional subsidies

The user will be then able to qualitatively rank each reported aspect by choosing one among three levels: low (in red), medium (in orange) or high (in green) if the aspect under evaluation can be considered unfavourable, regular, or favourable, respectively. It is important to observe that this optional sheet do not consider neither geological nor technical parameters. It was designed as optional, helpful tool to complement the site ranking methodology, which will be successively reported in D 7.3.

UHS site qualitative assessment
Ranking position according to Task 7.3

	Site 1	Site 2	Site 3	Site 4	Site 5
Integration into the energy system					
Availability of renewable resource in the region	High	Medium	Medium	Medium	Low
Availability of high-voltage power grids in the region	Medium	Medium	High	Medium	Medium
Projects planned in the region for renewable hydrogen production	Medium	Low	Medium	Low	High
Hydrogen distribution system					
Availability of hydrogen transmission networks nearby (new 100% H2 dedicated networks or existing natural gas networks)	Medium	Medium	Medium	Medium	Medium
Hydrogen demand (2030)					
Transport demand in the region	High	High	Medium	Medium	High
Industry demand in the region	Medium	High	Medium	High	Medium
Re-electrification demand in the region	Low	High	Low	Low	Medium
PtG in the region	Medium	Low	Medium	Medium	Low
Politics and regulations					
Country ranking position according D6.1	Medium	High	Medium	Low	Low
Availability of regional plans supporting UHS	Low	Medium	Medium	Medium	High
Possibility of national or regional subsidies	Low	High	Medium	High	Medium

High	Favourable
Medium	Regular
Low	Unfavourable

Figure 1. Table included in *UHS site qualitative assessment (optional).*

Figure 2 shows how the *Summary* will appear to the user, for both salt cavern (Figure 2a) and porous media (Figure 2b) cases. All the techno-economic voices are grouped in two macro-clusters: “Geology and subsurface facilities” and “Operating costs and surface facilities”. The parameters which are subject to the arbitrary user decision are marked in green, whilst those which should require an expert opinion are marked in yellow. Finally, the parameters directly correlated to the red worksheets (i.e., whose numeric value is calculated by red worksheets) are marked in red. In addition, various inputs suggestions —in line with the assumptions made in D 7.2 [1] — in the corresponding parameters windows were included, in order to help the user in defining the business case. On the right hand of the *Summary* page, detailed breakdown cost tables are reported (Figure 3) for the subsurface CAPEX (i.e., inherent to cavern construction or reservoir development), surface CAPEX (i.e., inherent to the above-ground facilities), OPEX and ABEX.

	Geology and subsurface facilities			
V_{cavern}	Free gas volume per cavern [millions m^3]			
V_{max}	Working Gas volume per cavern [millions Sm^3]			
n_{WH}	Number of caverns (assumption: one well head per cavern)			
LCCS	Last cemented casing shoe [m]			
DC_i	Drilling complexity index			
L_{fw}	Fresh water pipeline length [km]			
L_{bd}	Brine disposal pipeline length [km]			
x_{salt}	Cushion gas / Total gas ratio			
V_{wg}	Working Gas volume [millions SM^3]	-		
V_{wg}/Q_w	Working gas volume/Total storage maximum withdrawal flowrate capacity [days]			
$Q_{debrining}$	Debrining flowrate per cavern [m^3/h]			
$d_{full\ cycle}$	Duration of one full storage of the cycle [days]			
		2030	*2040*	*2050*
N_{fc}	Number of full cycles per year			
$N_{fc,\ MAX}$	Maximum number of full cycles per year			
$d_{T,L}$	Leaching duration [year]			
$d_{T,C}$	Debrining duration [year]			
		2030	2040	2050
LF	Load Factor			
	Operating costs and surface facilities			
MCF_i	Material cost factor for injection (compression) stream			
MCF_w	Material cost factor for withdrawal stream			
Q_w	Total storage maximum withdrawal flowrate capacity [millions SM^3/day]			
τ	Overall compression ratio (ratio of discharging pressure over suction pressure)			
n	Number of required compression stages			
WTIR	Withdrawal to injection capacity ratio			
netOP	Minimum suction pressure of compression stream (pipeline operating pressure) [barg]			
MOP	Maximum storage operating pressure [barg]			
minOP	Minimum storage operating pressure [barg]			
L_{fl}	Field lines size [km]			
K_{purif}	Purification coefficient (Only for porous media)			
COE	Cost of Electricity [€/MWh]			

a)

Parameters	Description	Value		
	Geology and subsurface facilities			
V_{max}	Working Gas volume per cavern [millions Sm3]			
V_{CG}	Cushion Gas Volume [millions m^3]			
$n_{WH,prod}$	Number of development (storage) wells			
$n_{WH,obs}$	Number of observation wells			
LCCS	Last cemented casing shoe [m]			
DC_i	Drilling complexity index			
x_{porous}	Cushion gas / Total gas ratio			
V_{wg}	Working Gas volume [millions SM^3]			
V_{wg}/Q_w	Working gas volume/Total storage maximum withdrawal flowrate capacity [days]			
		2030	*2040*	*2050*
N_{fc}	Number of full cycles per year			
$N_{fc,\ MAX}$	Maximum number of full cycles per year			
d_{FGF}	Total duration of First Gas Fill [years]			
		2030	*2040*	*2050*
LF	Load Factor			
	Operating costs and surface facilities			
MCF_i	Material cost factor for injection (compression) stream			
MCF_w	Material cost factor for withdrawal stream			
Q_w	Total storage maximum withdrawal flowrate capacity [millions SM^3/day]			
τ	Overall compression ratio (ratio of discharging pressure over suction pressure)			
n	Number of required compression stages			
WTIR	Withdrawal to injection capacity ratio			
netOP	Minimum suction pressure of compression stream (pipeline operating pressure) [barg]			
MOP	Maximum storage operating pressure [barg]			
minOP	Minimum storage operating pressure [barg]			
L_{fl}	Field lines size [km]			
K_{purif}	Purification coefficient (Only for porous media)			
COE	Cost of Electricity [€/MWh]			

b)

Figure 2. Table of techno-economic parameters reported in *Summary* for (a) salt cavern and (b) porous media, respectively.

CAPEX - subsurface		
Costs breakdown	Description	€
EPC_1	EPC cost main parameters and cost breakdown for Leaching facilities	69.850.000,00 €
EPC_2	Leaching operation and mainteinance costs	53.029.333,33 €
EPC_3	Salt cavern debrining and conversion costs	18.791.205,48 €
EPC_4	Development Drilling and leaching completion costs	39.726.000,00 €
CG	Cushion gas for salt caverns	7.650.000,00 €
$CONT_{subsurface}$	Contingencies related to subsurface	37.809.307,76 €
Total		**226.855.846,58 €**

CAPEX - surface		
Costs breakdown	Description	€
EPC_1	EPC cost main parameters and breakdown for filtering, drying & compression, and metering uni	186.609.798,95 €
EPC_2	EPC costs for interconnection WH - Gas Plant	8.457.270,00 €
EPC_3	EPC cost per additional kilometre between Gas Plant and nearest WH	13.398.266,70 €
EPC_4	EPC cost estimate for hydrogen purification at storage outlet	- €
EPC_5	EPC cost main parameters and cost breakdown for Balance of Plant	18.423.266,78 €
$CONT_{surface}$	Contingencies related to surface facilities	45.377.720,49 €
Total		**272.266.322,91 €**

OPEX		
Costs breakdown	Description	€/year
$OPEX_{fix, UG}$	OPEX - Subsurface	1.191.780,00 €
$OPEX_{fix, AG}$	Fixed OPEX - Surface	11.175.544,10 €
$OPEX_{var, AG}$	Variable OPEX - Surface	11.415.495,52 €
Total		**23.782.819,61 €**

ABEX		
Costs breakdown	Description	€
$ABEX_{subsurface}$	Abandonement Expenditure for subsurface	36.279.307,76 €
$ABEX_{surface}$	Abandonement Expenditure for surface facilities	54.453.264,58 €
Total		**90.732.572,35 €**

Figure 3. Costs breakdown table reported in *Summary*. All the numerical values visible in Figure are illustrative.

In *Hydrogen Price&Demand* (Figure 4), the hydrogen storage cost and its local demand are defined. The storage cost (€/kg) represents the minimum underground storage operator's revenue to reach the breakeven point for the proposed economic model. Eventually, the final storage service price is obtained by applying a given storage service margin profit to the storage cost. It is worth to mention that, similar to the current gas storage market, the next hydrogen storage market will likely be a regulated market. In this sense, the storage service margin profit has been introduced in this model as gap between the real storage cost and the selling price. It is a percentage representing the truly revenues of the gas service operator, and it might be included among the main parameters to be taken into account for defining the raising hydrogen, regulated market. In this model, its sum with the hydrogen production cost and "other costs" (i.e., marginal costs such as transport from the production facility to the storage site) is defined as minimum hydrogen selling price, and must fall within the values range comprised between the hydrogen production cost (i.e., 6,29 €/kg was set as reference value according to the available literature [3]; however, it is modifiable by the user) and the final selling price, defined as the sum of the minimum hydrogen selling price and the margin profit. Consequently, the price spread (i.e., the difference between hydrogen selling price and its production cost, expressed as %) is automatically calculated. It is important to specify that selecting a proper value of the storage service margin profit is pivotal in this model, since it will directly affect the resulting revenues generated by the cash flow analysis. On the other hand, hydrogen production cost and selling price are not included in cash flow analysis, since hydrogen production and selling are out of the scope of the present methodology. They must rather be considered as reference values by the user, as lower and upper limits for defining ideal hydrogen prices range for the market.

Concerning the second section visible in Figure 4, theoretical storage capacity and hydrogen demand scenarios for 2030, 2040 and 2050 for a specific country are defined from the outputs coming from Work Package 5. Furthermore, a technical storage throughput is defined too, resulting from the specifics of the geological site (i.e., working gas volume and number of cycles per year), which directly affects the revenues in the cash flows of the model.

Hydrogen price			
Hydrogen production cost (€/kg)			
Other costs (€/kg)			
Storage cost (€/kg)			
Storage service margin profit (%)			
Storage service price (€/kg)			
Minimum Hydrogen selling price (€/kg)			
Margin profit (%)			
Hydrogen selling price (€/kg)			
Price spread			
Hydrogen Demand	**2030**	**2040**	**2050**
Capacity of storage per country [TWh]			
Hydrogen storage throughput [TWh/y]			
Hydrogen input capacity [GW]			
Hydrogen output capacity [GW]			
Capacity of storage per country [kg]			
National Hydrogen storage throughput [kg/y]			
Technical storage throughput (kg/y)			
National throughput/technical throughput (%)			

Figure 4. Input table reported in *Hydrogen Price&Demand*.

In *Finance* (Figure 5), the user will be able to evaluate the viability and profitability of a specific business case through the cash flows analysis. The model foresees an investment phase (from 2022 to 2029), where possible leaching, debrining, drilling, conversion operations are carried out in order to prepare the geological site be operative from 2030, when the venture period will begin. Similarly to what is described in *Summary*, the user can modify several economic parameters (those in green) to generate a proper business case. Among them, the user will have the possibility to choose a potential subsidy, the venture period (set to 30 years as default value), the residual value of the overall plant at the end of the venture period, the hydrogen storage price, corporate taxes, the discount rate, and consider subsidies and/or financing funds during a certain period, with interest's calculations included.

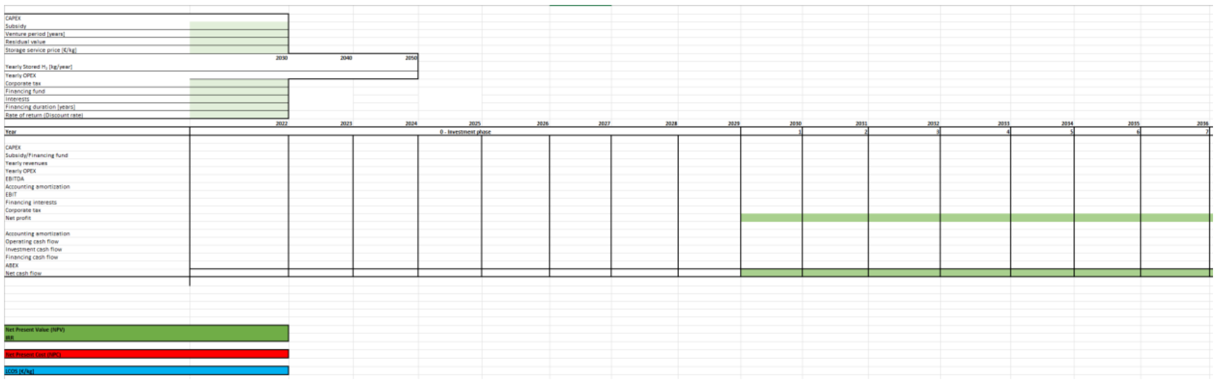

Figure 5. Cashflow analysis worksheet included in *Finance*.

As explained before, *Techno-economical worksheets* are all the red-marked worksheets present in the Excel tool. Their purpose is to provide output results starting from the input parameters selected by the user, through the implementation of the techno-economic equations generated in D 7.2 [1] to outline a conceptual design of an underground storage site. In detail, the Excel tool contains eight red worksheets, as following:

- *Calculations – Finance*, including functions to calculate the interests for potential financing funds requested by the user.
- *CAPEX – subsurface*, containing all the equations for the calculation of costs related to the site construction. For salt caverns, the breakdown cost structure comprises leaching operation and maintenance, salt cavern debrining and conversion, cushion gas and subsurface contingencies. On the other hand, the breakdown cost structure related to porous media takes into account development drilling step, first gas fill, cushion gas and subsurface contingencies.
- *Assumptions – CAPEX subsurface*, reporting useful details regarding the assumptions made for the related equations when they were developed, guiding the user to use them properly.
- *CAPEX – surface*, containing all the equations for the calculation of costs related to the required above-ground facilities. The breakdown cost structure is almost the same for both the types of underground site, comprising filtering, drying, compression and metering units, as well as well head – gas plant interconnection, balance of plant,

hydrogen purification at storage outlet (only for porous media), and surface contingencies.

- *Assumptions – CAPEX surface*, same as described for *Assumptions – CAPEX subsurface*.
- *OPEX*, including all the equations for the calculation of operating costs related to the underground site.
- *Assumptions – OPEX*, same as described for *Assumptions – CAPEX subsurface* and *Assumptions – CAPEX surface*.
- *ABEX*, which embraces all the calculations related to the costs to safely decommission and remove the above-ground facilities from the hydrogen storage site, to ensure that the reservoir remains isolated from the long-term overlying geological layers, and to safely plug and abandon production/injection wells, preventing the uncontrolled release of fluids to the surface.

3.2. Input parameters in the tool

In the present section, all the input parameters required by the user for building a specific business case scenario are described and reported in Table 1, 2 and 3.

Table 1. Input parameters included in *Summary.*

		Summary	
Input	UHS Type	Expert opinion required	Description
V_{cavern}	Salt cavern	Yes	Free gas volume per cavern [thousands m^3]
V_{max}	Salt cavern, porous media	Yes	Maximum Gas Inventory of the site [thousands m^3]
n_{WH}	Salt cavern	Yes	Number of caverns (assumption: one well head per cavern)
$n_{WH,prod}$	Porous media	Yes	Number of development wells
$n_{WH,obs}$	Porous media	Yes	Number of observation wells
LCCS	Salt cavern, porous media	Yes	Last cemented casing shoe [m]
DC_i	Salt cavern, porous media	Yes	Drilling complexity index
L_{fw}	Salt cavern	No	Fresh water pipeline length [km]
L_{bd}	Salt cavern	No	Brine disposal pipeline length [km]

x_{salt}	Salt cavern	No	Cushion gas / Total gas ratio for salt cavern
x_{porous}	Porous media	No	Cushion gas / Total gas ratio for porous media
$Q_{debrining}$	Salt cavern	No	Debrining flowrate per cavern [m^3/h]
N_{fc}	Salt cavern, porous media	Yes	Number of full cycles per year
MCF_i	Salt cavern, porous media	No	Material cost factor for injection (compression) stream
MCF_w	Salt cavern, porous media	No	Material cost factor for withdrawal stream
Q_w	Salt cavern, porous media	Yes	Total storage maximum withdrawal flowrate capacity [millions SM^3/day]
n	Salt cavern, porous media	No	Number of required compression stages
WTIR	Salt cavern, porous media	No	Withdrawal to injection capacity ratio
netOP	Salt cavern, porous media	No	Minimum suction pressure of compression stream (pipeline operating pressure) [barg]
MOP	Salt cavern, porous media	Yes	Maximum storage operating pressure [barg]
minOP	Salt cavern, porous media	Yes	Minimum storage operating pressure [barg]
L_{fl}	Salt cavern, porous media	No	Field lines size [km]
K_{purif}	Porous media	No	Purification coefficient
COE	Salt cavern, porous media	No	Cost of Electricity [€/MWh]

Table 2. Input parameters for both salt cavern and porous media included in *Hydrogen Price&Demand.*

Hydrogen Price&Demand	
Input	Description
Hydrogen production cost	The reference value of the production cost is set to 6,29 €/kg, according to recent literature [3] as default value (modifiable by the user)
Other costs	Marginal costs to be added to the hydrogen production cost, such as transport from the production facility to the storage site. It is defined as 30% of the hydrogen production cost; however, its value can be modified
Storage cost	Price paid by the hydrogen owner to store it in the underground site
Storage service margin profit (%)	Margin profit applied to the storage cost, which defines the economic revenues of the storage service provider

Storage service price (€/kg)	Final price resulting from the margin profit applied to the storage cost
Minimum hydrogen selling price	It is calculated as the sum of hydrogen production cost, other costs, and hydrogen storage cost
Margin profit	It is defined as a variable percentage of the minimum hydrogen selling price
Hydrogen selling price	Final price paid by the consumer. It is calculated as the sum of minimum hydrogen selling price and margin profit
Price Spread	It is defined as the difference between the price paid by the consumers and the production cost: $\text{Price Spread}=\frac{H_2 \text{ selling price-}H_2 \text{ production cost}}{H_2 \text{ selling price}}\cdot 100\%$
Capacity of storage per country	Overall capacity of hydrogen storage for a specific country [available in TWh or kg]
Hydrogen storage throughput	Amount of hydrogen stored during an entire year in a specific country [available in TWh/y or kg/y]
Technical storage throughput	It is obtained as the product of working gas volume and number of full cycles per year [kg/y]

Table 3. Input parameters for both salt cavern and porous media included in *Finance*.

Finance Input	Description
Subsidy	Public money granted to promote UHS CAPEX. Subsidy employed for the investment phase
Venture period	Business period selected for a specific case scenario [years]
Residual value	Expected value of the UHS site at the end of its venture period [% of the initial value]
Storage service price	Hydrogen storage service price available for the hydrogen owner [€]
Yearly Stored H_2	Overall amount of hydrogen stored during an entire year [kg/y]. It coincides to the technical throughput of the storage site
Corporate tax	Tax on the profits of a corporation [% of the profits]
Financing fund	Financing fund employed for the investment phase
Interests	Interest related to the financing fund [% of financing fund]
Financing duration	Time duration of the financing period [years]
Rate of return	Net gain or loss of an investment over a specified time period [% of the overall CAPEX]

3.3. Output parameters in the tool

In the present section, all the output parameters generated by the Excel tool for a specific business case scenario (either for salt cavern or for porous media) are described and reported in Table 4 and 5.

Table 4. Output parameters for both salt cavern and porous media generated in *Summary.*

Summary	
Output	Description
CAPEX – subsurface estimation	Overall costs breakdown of CAPEX related to subsurface, resulting from *CAPEX – subsurface* red worksheet.
CAPEX – surface estimation	Overall costs breakdown of CAPEX related to surface facilities, resulting from *CAPEX – surface* red worksheet.
OPEX estimation	Overall costs breakdown of OPEX, resulting from *OPEX* red worksheet.
ABEX estimation	Overall costs breakdown of ABEX, resulting from *ABEX* red worksheet.

Table 5. Output parameters for both salt cavern and porous media generated in *Finance.*

Finance	
Output	Description
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortization indicator [€/y]. It is calculated as: EBITDA = Yearly revenues - Yearly OPEX - H_2 buying price
Accounting amortization	Indicator of the capital cost amortization over the entire venture period considered for a specific business case, taking into account the final residual value of the facility [€/y].
EBIT	Earnings Before Interest and Taxes indicator [€/y]. It is calculated as: EBIT = EBITDA + Accounting amortization
Net profit	Net profit = EBIT - Financing interests - Corporate tax
Operating cash flow	Operating cash flow = Net profit + Accounting amortization
Investment cash flow	Indicator visible in the cash flow results of the last venture year, which takes into account the final residual value of the facilities [€].
Financing cash flow	Cash flow indicator related to the financing funds (if any) and their interests [€/y].
Net cash flow	Amount of cash generated or lost over the selected venture period. It is calculated as: Net cash flow = Operating c.f. + Investment c.f. - Financing c.f. - ABEX
NPV	Net Present Value of the business case cash flows. It is calculated by the NPV function implemented in Excel.

IRR	Internal Rate of Return, metric used to estimate the profitability of potential investments. It represents the discount rate value which makes the NPV of all cash flows equal to 0. It is calculated by an implemented Excel function.
NPC	Net Present Cost is the present value of all the costs the UHS site incurs over its venture period (calculated with the same implemented Excel function used for NPV), minus the present value of all the revenue earned in the same period.
LCOS	Levelized Cost Of Storage, calculated as: $$LCOS = \frac{\sum(CAPEX_t + OPEX_t + ABEX_t) \cdot (1+r)^{-t}}{\sum H2througput_t \cdot (1+r)^{-t}}$$ Where t refers to a given year, while r is the rate of return

4. Limitations of the methodology

The main constraints of the joint methodology proposed in the present work are related to the initial assumptions made in D 7.2 [1] to build the techno-economic equations of the model. In the absence of specific site data, such equations were designed to provide a general estimation of CAPEX, OPEX and ABEX costs of a UHS site. This high-level costs estimation, which typically yields figures within 30 to 50% accuracy, is not constrained by site-specific requirements or limitations, covering, hence, the general engineering behind the development and operation of a UHS site, including depleted fields, aquifers, and salt caverns. More details are given in D 7.2 [1].

5. Conclusions

In conclusion, a joint methodology to assess the economic feasibility of large-scale storage renewable hydrogen in salt caverns or porous medias was developed. To this end, a consistent toolbox implemented in Excel was provided, allowing the techno-economic study and consequent comparison of different business case studies at selected sites in the European Union.

The next step of Work Package 8 will foresee the analysis of several case studies across different Member States (i.e., Spain, Poland, Germany, France and Italy), within the scope of T 8.2; the resulting findings will be reported in the D8.2 – 8.6. For this purpose, a meticulous sensitivity analysis for each case study will be conducted by employing specific graphs, which will be implemented in the developed Excel tool in a next step. Finally, the results generated in T 8.3 will be reported in the last deliverable, D 8.7, embracing the main conclusions of the work and the benchmark of the case studies carried out during the next months.

6. References

[1] D 7.2-1 Costs analysis & LCCA, HyStories Project, Geostock, 2022.

[2] D 6.1 Assessment of the Regulatory Framework, HyStories Project, Foundation for the Development of New Hydrogen Technologies in Aragon, 2021.

[3] Levelised Cost of Hydrogen, Fuel Cells and Hydrogen Observatory, https://www.fchobservatory.eu/observatory/technology-and-market/levelised-cost-of-hydrogen-green-hydrogen-costs.

Hystories project consortium

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