Analysis of a UHS business case in Italy

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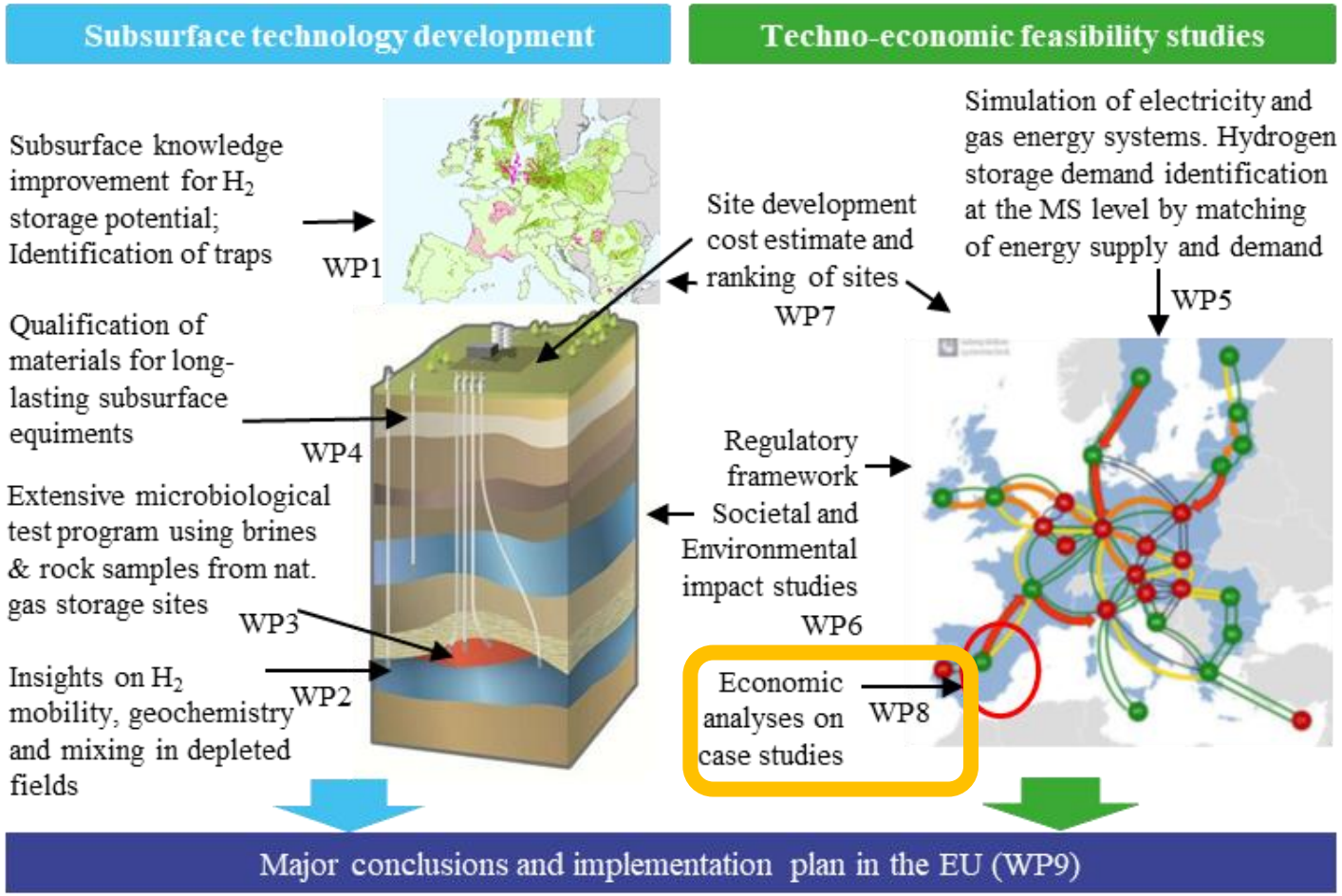
1: Aragon Hydrogen Foundation

Acknowledgment

The Project Is co-founded by European Union

Introduction

Assessing the economic feasibility of UHS at European level



Work Package 8: European Case Studies

T8.1: Development of a **joint methodology** providing a techno-economic toolbox for all case studies

T8.2: Identification of potential **UHS business cases** in France, Germany, Spain, Poland and Italy

T8.3: **Benchmarking** of different European case studies

https://hystories.eu/publications-hystories/

Joint Methodology

Parameters	Description	Value
	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]	

Salt cavern

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
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]	

Porous media

Joint Methodology

CAPEX - subsurface		
Breakdown costs	Description	€
EPC_3	First Gas Fill (FGF) costs	4.244.876,71 €
EPC_4	Development Drilling cost breakdown and main parameters	158.484.000,00 €
CG	Cushion gas for salt caverns	294.057.500,00 €
$CONT_{subsurface}$	Contingencies related to subsurface	91.357.275,34 €
Total		**548.143.652,05 €**

CAPEX - surface		
Breakdown costs	Description	€
EPC_1	EPC cost main parameters and breakdown for filtering, drying & compression, and metering ur	119.914.890,79 €
EPC_2	EPC costs for interconnection WH - Gas Plant	86.706.364,58 €
EPC_3	EPC cost per additional kilometre between Gas Plant and nearest WH	5.193.442,80 €
EPC_4	EPC cost estimate for hydrogen purification at storage outlet	181.472.445,57 €
EPC_5	EPC cost main parameters and cost breakdown for Balance of Plant	27.664.357,19 €
$CONT_{surface}$	Contingencies related to surface facilities	84.190.300,19 €
Total		**505.141.801,12 €**

OPEX		*2030*
Breakdown costs	Description	€/year
$OPEX_{fix,\ UG}$	OPEX - Subsurface	4.754.520,00 €
$OPEX_{fix,\ AG}$	Fixed OPEX - Surface	18.938.060,04 €
$OPEX_{var,\ AG}$	Variable OPEX - Surface	6.561.242,54 €
Total		**30.253.822,58 €**

ABEX		
Breakdown costs	Description	€
$ABEX_{subsurface}$	Abandonement Expenditure for subsurface	49.968.255,07 €
$ABEX_{surface}$	Abandonement Expenditure for surface facilities	101.028.360,22 €
Total		**150.996.615,29 €**

Joint Methodology

CAPEX	1.053.285.453,17 €
Subsidy	20.000.000,00 €
Venture period [years]	30
Residual value	20%
H2 storage price [€/kg]	4,84 €

	2030	2040	2050
Yearly Stored H_2 [kg/year]	48.785.000	48.785.000	48.785.000
Yearly OPEX	30.253.822,58 €	30.253.822,58 €	30.253.822,58 €

Corporate tax	25%
Financing fund	
Interests	5%
Financing duration [years]	30
Rate of return (Discount rate)	5,75%

Investment phase + venture period (years)

CAPEX(n) + OPEX (n)

$$LCOS = \frac{\sum_{n=1}^{N} \frac{Cost(n)}{(1+WACC)^n}}{\sum_{n=1}^{N} \frac{T_{out}(m)}{(1+WACC)}}$$

Yearly H_2 throughput (kg/a)

Weighted Average Cost of Capital

Year	2022	2023	2024	2025	2026	2027	2028	2029	2030
	0 - Investment phase								1
CAPEX	- 190.180.800,00 €	- 190.180.800,00 €	- €	- €	- €	- €	- 505.141.801,12 €	- 1.221.067.505,23 €	
Subsidy/Financing fund	20.000.000,00 €								
Yearly revenues									236.318.906,43 €
Yearly OPEX									- 30.253.822,58 €
EBITDA									206.065.083,86 €
Accounting amortization									1.349.209,69 €
EBIT									207.414.293,54 €
Financing interests									- €
Corporate tax									- 51.853.573,39 €
Net profit									**155.560.720,16 €**
Accounting amortization									- 1.349.209,69 €
Operating cash flow									**154.211.510,47 €**
Investment cash flow									
Financing cash flow									0,00 €
ABEX									
Net cash flow	-170.180.800,00 €	-190.180.800,00 €	0,00 €	0,00 €	0,00 €	0,00 €	-505.141.801,12 €	-1.221.067.505,23 €	**154.211.510,47 €**

Net Present Value (NPV)	**0,00 €**
IRR	**5,75%**
Net Present Cost (NPC)	**1.745.709.339,17 €**
LCOS [€/kg]	**3,96 €**

Business case in Italy

Technical parameters

Parameters	Description	Units	Value
Geology and subsurface facilities			
V_{max}	Working Gas volume per well	[millions Sm^3]	22,00
V_{CG}	Cushion Gas Volume	[millions m^3]	550,00
$n_{WH,prod}$	Number of development (storage) wells	[nr.]	25
$n_{WH,obs}$	Number of observation wells	[nr.]	6
—	H_2 yearly throughput	[kg/yr.]	48.785.000
LCCS	Last cemented casing shoe	[m]	1200
DC_i	Drilling complexity index	[-]	1
L_{fw}	Fresh water pipeline length	[km]	15
L_{bd}	Brine disposal pipeline length	[km]	30
x_{porous}	Cushion gas/ Total gas ratio	[-]	0,5
V_{wg}	Working Gas volume	[millions Sm^3]	550,00
V_{wg}/Q_w	Storage to withdrawal capacity ratio	[days]	110,00
$Q_{debrining}$	Debrining flowrate per cavern	[m3/h]	200
N_{fc}	Number of full cycles per year	[cycle/yr.]	1
$N_{fc,MAX}$	Maximum number of full cycles per year	[cycle/yr.]	1,58
d_{FGF}	Total duration of First Gas Fill	[years]	0,9
LF	Load factor	[-]	0,63
Operating costs and surface facilities			
MCF_i	Material cost factor for injection (compression) stream	[-]	1
MCF_w	Material cost factor for withdrawal stream	[-]	1
Q_w	Total storage maximum withdrawal flowrate capacity	[millions Sm^3/day]	5
t	Overall compression ratio (ratio of discharging pressure over suction pressure)	[-]	2,34
n	Number of required compression stages	[nr.]	1
WTIR	Withdrawal to injection capacity ratio	[-]	1,1
netOP	Minimum suction pressure of compression stream (pipeline operating pressure)	[barg]	55
MOP	Maximum storage operating pressure	[barg]	130
minOP	Minimum storage operating pressure	[barg]	60
L_{fl}	Field lines size	[km]	2
K_{purif}	Purification coefficient (Only for porous media)	[-]	1,5
COE	Cost of Electricity [€/MWh]	[€/MWh]	66

Economic and financial parameters

Parameters	Units	Value
H_2 production cost	[€/kg]	6,29
H_2 cushion gas	[€/kg]	6,29 (same as H_2 prod. cost by assumption)
Other costs	[€/kg]	1,89 (30% of hydrogen prod. cost by assumption)
Subsidy	[€]	20.000.000,00
Venture period	[years]	30
Residual value	[%]	20
Storage cost	[€/kg]	3,96
Corporate tax	[%]	25
Financing fund	[€]	0
Interests	[%]	5
Financing duration	[years]	30
Rate of return (Discount rate)	[%]	5,75
Storage service margin profit	[%]	22,40

NPV = 0, achieved by adjusting the storage service margin profit to the H_2 storage cost (= LCOS by initial assumption)

Business case in Italy

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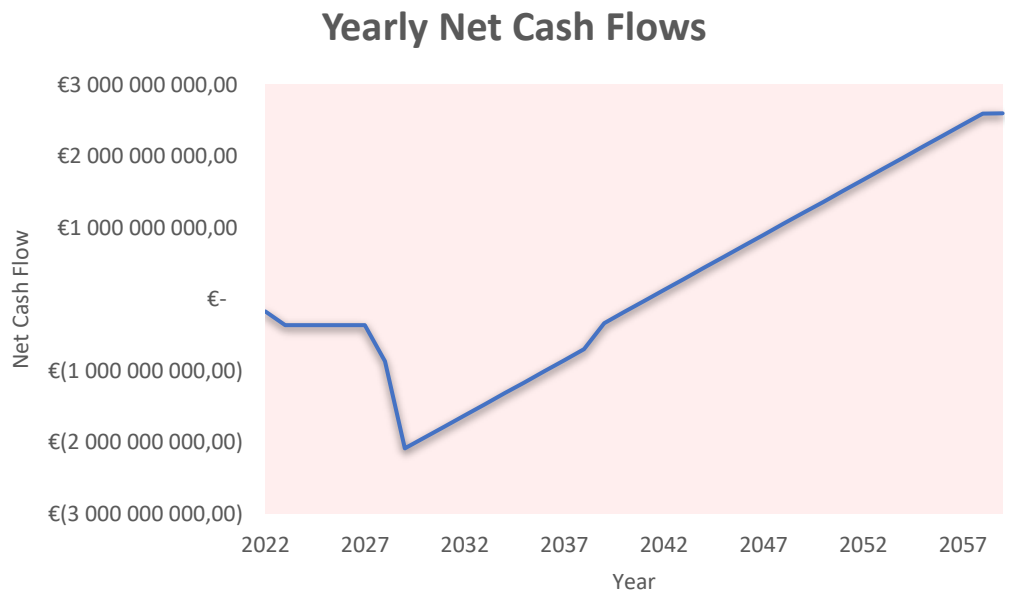
Total		**150.996.615,29 €**

Finance		
Parameter	Description	Value
NPV	Net Present Value	0 €
IRR	Internal Rate of Return	5,75%
NPC	Net Present Cost	1.745.709.339,17 €
LCOS	Levelized Cost of Storage	3,96 €/kgH_2
—	Storage service margin profit	22,40%
—	H_2 storage service price	4,84 €/kgH_2



Sensitivity analysis

65 scenarios resulting from the 2^6 full factorial design

Minitab® 17

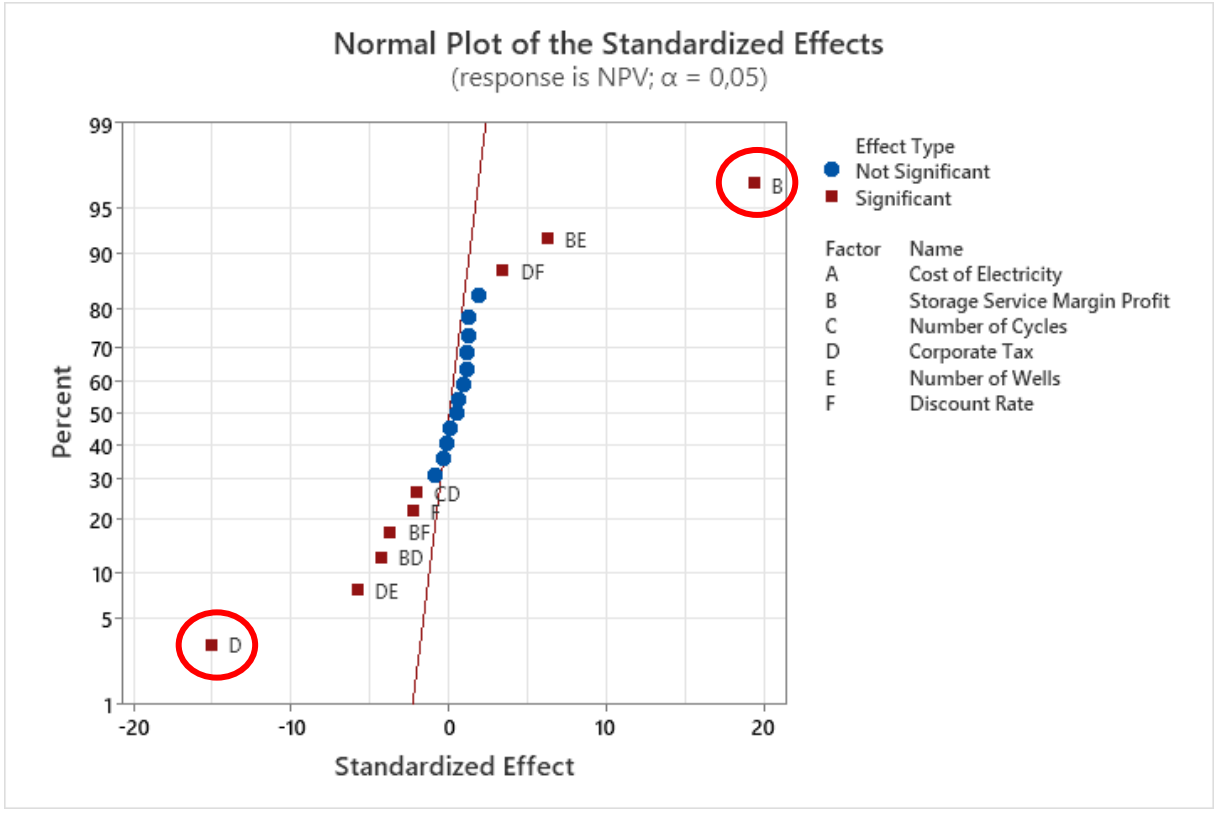
Parameter	–1	0	1
Cost of Electricity **(A)**	33 €/MWh	66 €/MWh	99 €/MWh
Storage Service Margin Profit **(B)**	5,75%	32,87%	60%
Number of Cycles **(C)**	0,5	1	1,5
Corporate Tax **(D)**	12,5%	25%	37,5%
Number of Depleted Wells **(E)**	12	25	37
Discount Rate **(F)**	2,8%	5,75%	8,6%

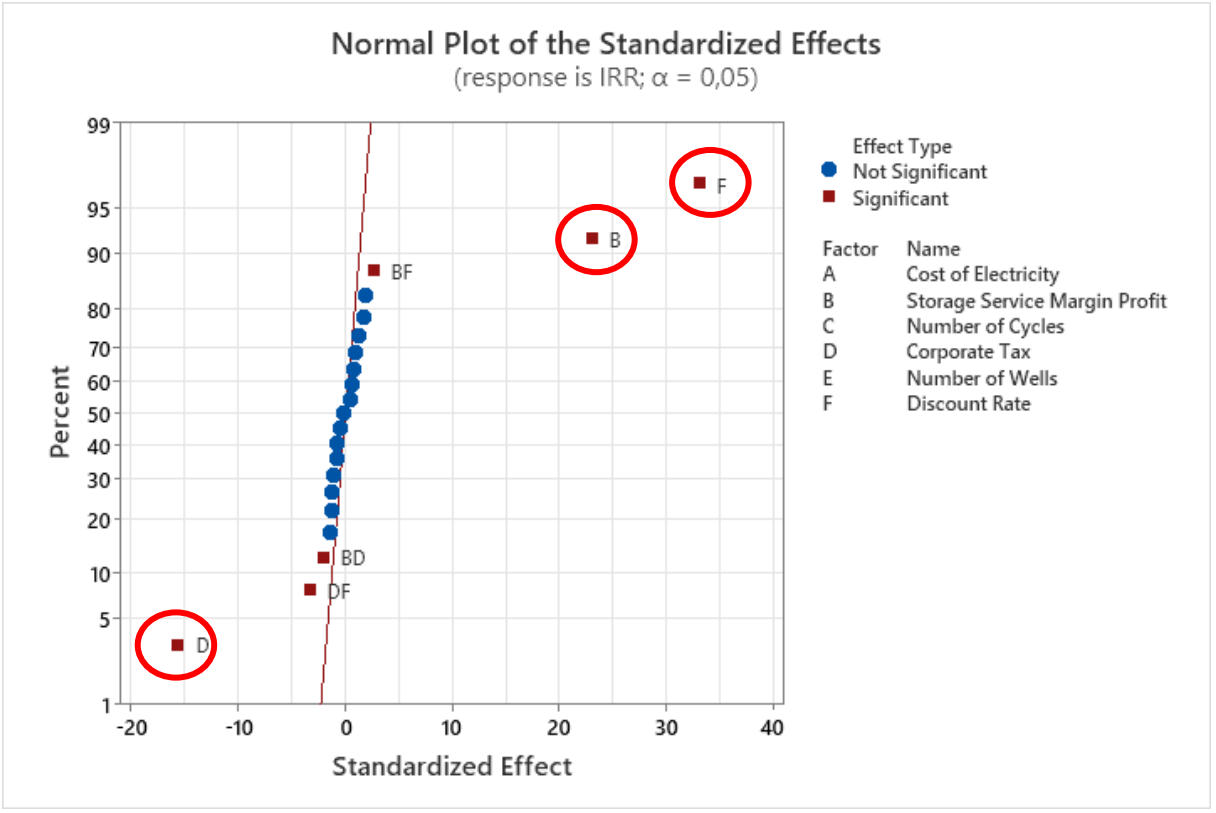
$$\hat{y}=\beta_0+\beta_1 A+\beta_2 B+\beta_3 C+\beta_4 D+\beta_5 E+\beta_6 F+\beta_{12} A\cdot B+\beta_{13} A\cdot C+\beta_{14} A\cdot D+\beta_{15} A\cdot E+\beta_{16} A\cdot F+\beta_{23} B\cdot C+\beta_{24} B\cdot D+\beta_{25} B\cdot E+\beta_{26}$$

$$B\cdot F+\beta_{34} C\cdot D+\beta_{35} C\cdot E+\beta_{36} C\cdot F+\beta_{45} D\cdot E+\beta_{46} D\cdot F+\beta_{56} E\cdot F$$

Response variables: **NPV, IRR, NPC, LCOS**

Sensitivity analysis

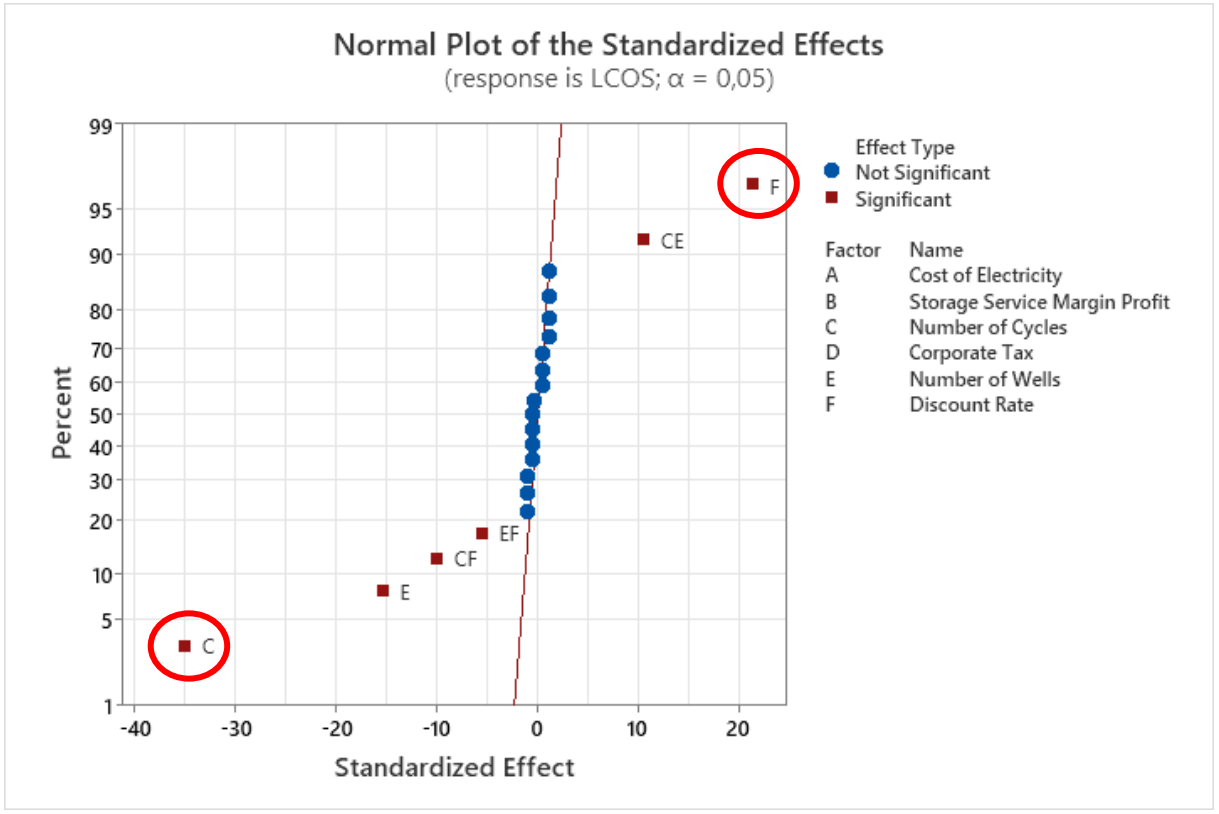




The margin profit of the storage service was among the most influencing factor on the business case NPV.

The Internal Rate of Return (IRR) was strongly affected by the discount rate and the storage service margin profit, as well as negatively influenced by higher corporate taxes.

Sensitivity analysis



A higher number of wells led to an increase in the resulting Net Present Cost (NPC)

The Levelized Cost of Storage (LCOS) was visibly reduced by both number of cycles and number of wells, as a consequence of a larger H_2 throughput processed per year

Sensitivity analysis

Optimized case scenario	
Cost of Electricity	99 €/MWh
Storage Service Margin Profit	60%
Number of Cycles	1,5
Corporate Tax	37,5%
Number of Depleted Wells	12
Discount Rate	2,8%
NPV	**729.354.976,22 €**
IRR	**6,62%**
NPC	**1.556.053.289,51 €**
LCOS	**2,75 €/kgH_2**
CAPEX - subsurface	275.013.949,81 €
CAPEX - surface	448.331.791,04 €
OPEX	21.947.320,35 €
ABEX	115.772.689,87 €

Hystories project consortium

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The Project is co-founded by European Union

Clean Hydrogen Partnership

Thank you!

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Hydrogen Storage in European Subsurface