WP1 TASK 1.3b

Investment modeling of PtX value chains

ABSTRACT

Task 1.3b had two main research questions: (Q1) What kind of capital investment model can be established for analyzing investments in novel hydrogen-based PtX value chains? (Q2) How investment opportunities for PtX products can be studied in the Finnish context by applying modeling and case study approaches? The first research question (Q1) was covered by creating an investment model of PtX value chains using design science research process. The second research question (Q2) was addressed with an e-methanol value chain case study. A multi-role investment model was achieved and applied to the case study. The findings indicate that e-methanol production close to point source CO_2 is economically more feasible than the utilization of atmospheric CO_2. For point source CO_2, one-time investment generates greater cashflows while being more capital intensive, and involving higher risks, as compared to the alternative approach, investing in phases. Feasibility differences between the value chain roles emerged, H_2 production being the least viable part of the chain across the scenarios. Another important factor seems to be subsidization that plays a significant role for investment feasibility, especially in H_2 production. Discount rates naturally also influence the results.

MOTIVATION

PtX value chain investment modeling is essential for optimizing the transition to sustainable energy systems. By forecasting costs, returns, and potential risks, these models enable stakeholders in different value chain roles to make informed decisions about capital investments in technologies that convert renewable energy into valuable products, such as hydrogen, synthetic fuels, and chemicals. This kind of modeling approach not only enhances understanding of economic viability, but also accelerates the adoption of green technologies, reduces carbon emissions, and supports global efforts to combat climate change.

RESULTS

The value chain case study compared investments in e-methanol and related hydrogen production close to point source CO_2 (Case1) and using atmospheric CO_2 (Case2). Case 1 illustrates that the two scenarios, **one-time investment** and **investing in phases**, perform very differently (see **Figure 1** and **Table 1**). Net cashflow (NCF) for one-time investment ranges between -340 M€ ($Case1_{on}$-10) and 463 M€ ($Case1_{oll}$-10), while investing in phases sees less variation in NCF ranging from -168 M€ ($Case1_{pn}$-10) to 199 M€ ($Case1_{pll}$-10). The cashflow generating potential of one-time investment is evidently greater than that of investing in phases, especially in case of the lowest electricity price that approaches an average price of 27 €/MWh. Plotting NCF over time enables different analyses, such as how each value chain role fares in comparison to others, what is the total investment expenditure, and how much subsidization of H_2 production influences the results.

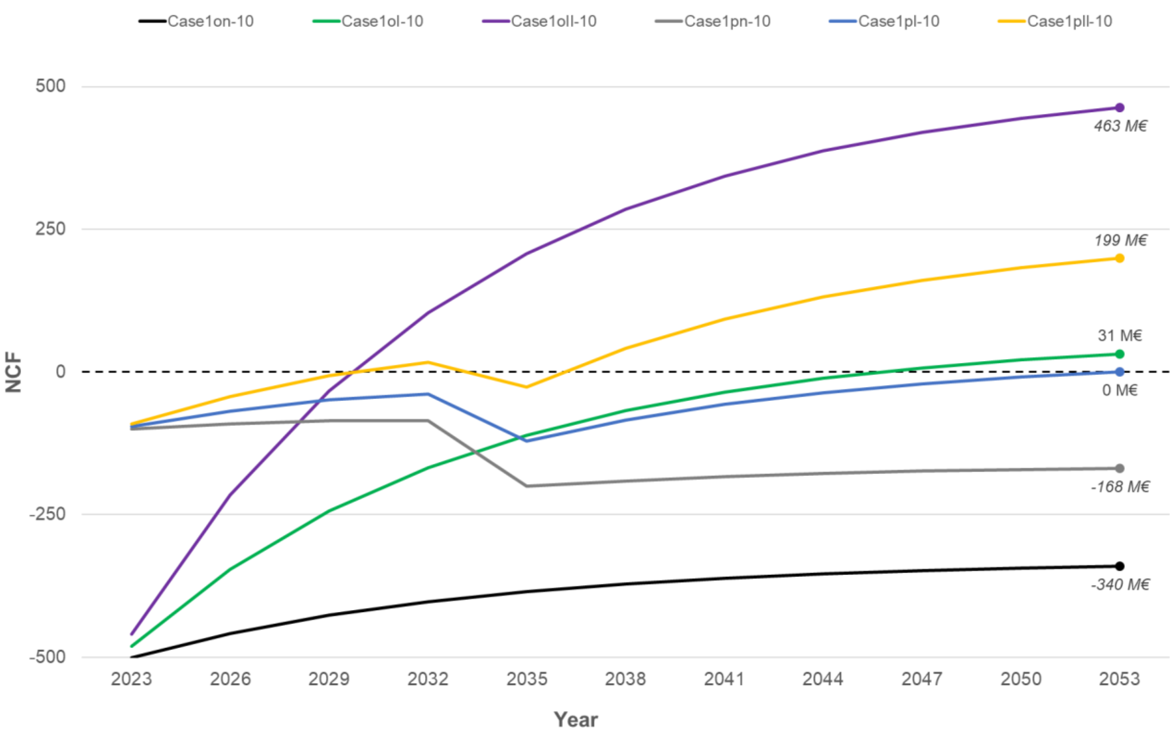


Figure 1. One-time investment vs. investing in phases

$Case1_{on}$: one-time investment, normal electricity price (black)
$Case1_{ol}$: one-time investment, low electricity price (green)
$Case1_{oll}$: one-time investment, lowlow electricity price (purple)
$Case1_{pn}$: investing in phases, normal electricity price (grey)
$Case1_{pl}$: investing in phases, low electricity price (blue)
$Case1_{pll}$: investing in phases, lowlow electricity price (gold)

Sub-indexes are as follows:
o - one time investment
p - investment in phases
n – normal electricity price scenario (wind 45 €/MWh, solar PV 55 €/MWh)
l – low electricity price scenario (wind 35 €/MWh, solar PV 45 €/MWh)
ll - very low (low low) electricity price scenario (wind 25 €/MWh, solar PV 35 €/MWh)

The number after the dash indicates the discount rate applied in the scenario.

Table 1. A summary of results for the different scenarios

NCF	$Case1_{on-10}$		$Case1_{ol-10}$		$Case1_{oll-10}$		$Case1_{pn-10}$		$Case1_{pl-10}$		$Case1_{pll-10}$	
CO_2 provider	76	M€	81	M€	88	M€	33	M€	34	M€	37	M€
H_2 provider	-856	M€	-514	M€	-128	M€	-392	M€	-233	M€	-55	M€
e-methanol producer	440	M€	464	M€	503	M€	191	M€	200	M€	217	M€
Value Chain with Subsidy	**-340**	**M€**	**31**	**M€**	**463**	**M€**	**-168**	**M€**	**0**	**M€**	**199**	**M€**
Tot. Investment	518	M€	518	M€	518	M€	245	M€	245	M€	245	M€
Profit. Index	-66 %		6 %		89 %		-69 %		0 %		81 %	
No Subsidy	**-631**	**M€**	**-258**	**M€**	**173**	**M€**	**-289**	**M€**	**-120**	**M€**	**82**	**M€**
Tot. Investment	808	M€	808	M€	808	M€	368	M€	368	M€	368	M€
Profit. Index	-78 %		-32 %		21 %		-79 %		-33 %		22 %	

Note: profitability index = NCF / total investment, subsidy = 60% of technical investment (H2 production)

Although one-time investment performs better in absolute terms (i.e., in NCF), it also carries a heavier CAPEX burden compared to investing in phases (518 M€ vs. 245 M€), which translates to similar profitability indexes across the different scenarios. The higher uncertainty inflicted by heavy CAPEX should be factored in investment decision making, thus making investing in phases an attractive alternative considering the state of the PtX market.

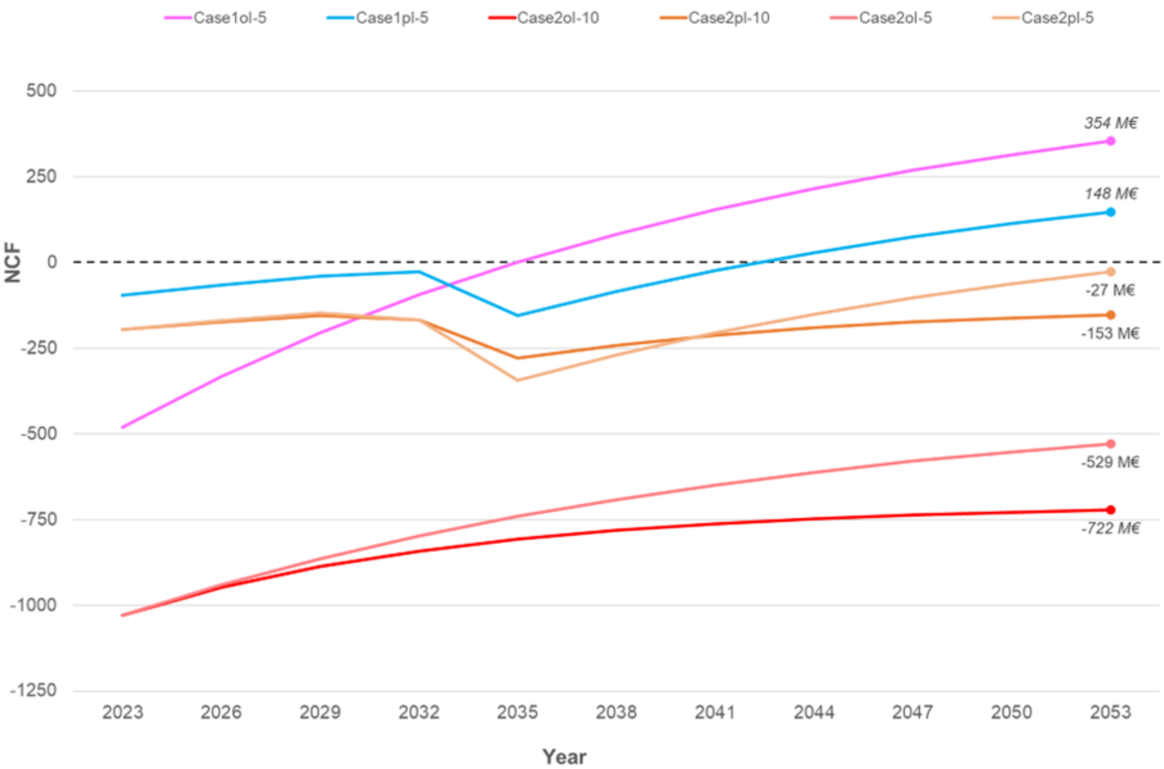
Investment subsidy for the technical investment in H_2 production impacts NCF significantly, moving the point of profitability towards lower prices of electricity. **Subsidization is hence another factor** that may impact the soundness of PtX investments.

NCF of H_2 production is critically dependent on the price of electricity consumed in the electrolysis. When the price of H_2 is set at 1200 €/t, **the H_2 production is never feasible**. $Case1_{pll}$-10 can reach NCF of only -55 M€ at the lowest electricity price. This is noteworthy as all PtX value chains will involve this role and thus making hydrogen production attractive is important for the successful development of the hydrogen economy. Lastly, it should be noted that the transportation and storage expenditure in relation to the overall electricity expenditure is minimal. These costs ranged from 0.97% to 1.16% depending on the scenario.

When comparing Case2 (atmospheric CO_2) against Case1 (point source CO_2), one-time investment as well as investing in phases **demonstrate rather poor economic performance** (see **Figure 2** and **Table 2**). When CO_2 is captured from the atmosphere, NCF of $Case2_{ol}$-10 is very low at -722 M€ and remains quite low at -153 M€ for $Case2_{pl}$-10. Even at a 5% weighted average cost of capital (WACC), the atmospheric CO_2 route is not economically feasible, although Case2$_{pl}$-5 comes relatively close at -27 M€ NCF. At 5% WACC, atmospheric CO_2 cannot match point source CO_2 at the initial 10% capital cost either. As can be seen, **the cost of capital has a considerable influence** on the economic feasibility of PtX investments.

The investment **utilizing atmospheric CO_2 is significantly more CAPEX intensive** than investment close to point source CO_2, which is seen in both one-time investment (1029 M€ vs. 518 M€) and investing in phases (691 M€ vs. 245 M€). Heavy CAPEX of atmospheric CO_2 results in negative NCFs and poor profitability indexes. Removing the subsidy from H_2 production makes the situation worse as even the best performing scenario, Case2$_{pl}$-5, declines from -27 M€ to -182 M€. We can conclude that investment utilizing atmospheric CO_2 is nowhere near economically feasible when the value chain is not subsidized.

Figure 2. Comparison of alternative CO2 sources: point source vs. atmospheric



Case2$_{ol}$: one-time investment, low electricity price (red)
Case2$_{pl}$: investing in phases, low electricity price (orange)
Case1$_{ol}$: one-time investment, low electricity price (magenta)
Case1$_{pl}$: investing in phases, low electricity price (blue)

Sub-indexes are as follows:
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ll - very low (low low) electricity price scenario (wind 25 €/MWh, solar PV 35 €/MWh)

The number after the dash indicates the discount rate applied in the scenario.

Table 2. A summary of results for the different scenarios

NCF	$Case1_{ol-5}$		$Case2_{ol-10}$		$Case2_{ol-5}$		$Case1_{pl-5}$		$Case2_{pl-10}$		$Case2_{pl-5}$	
CO_2 provider	172	M€	-749	M€	-842	M€	89	M€	-147	M€	-142	M€
H_2 provider	-683	M€	-554	M€	-747	M€	-400	M€	-246	M€	-423	M€
e-methanol producer	865	M€	581	M€	1060	M€	459	M€	240	M€	538	M€
Value Chain with Subsidy	**354**	**M€**	**-722**	**M€**	**-529**	**M€**	**148**	**M€**	**-153**	**M€**	**-27**	**M€**
Tot. Investment	518	M€	1029	M€	1029	M€	245	M€	691	M€	691	M€
Profit. Index	**68 %**		**-70 %**		**-51 %**		**60 %**		**-22 %**		**-4 %**	
No Subsidy	**64**	**M€**	**-1010**	**M€**	**-817**	**M€**	**-8**	**M€**	**-272**	**M€**	**-182**	**M€**
Tot. Investment	808	M€	1317	M€	1317	M€	368	M€	910	M€	910	M€
Profit. Index	**8 %**		**-77 %**		**-62 %**		**-2 %**		**-30 %**		**-20 %**	

Note: profitability index = NCF / total investment, subsidy = 60% of technical investment (H_2 production)

APPLICATIONS/IMPACT

PtX production plants are waiting for investment decisions due to economic and other types of uncertainties. Investment modeling of PtX value chains produces economic insights into elements of investment decision making. The findings highlight investment viability under different conditions, such as varying electricity price and investment subsidization, for one-time investment versus investing in phases using point source and atmospheric CO_2 in e-methanol production. The modeling approach provides guidance for stakeholders in different value chain roles in making informed investment decisions.

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