HYGCEL research presentation

Perspectives to sustainability, safety and profit sharing in green hydrogen value chains

Lappeenranta, May 22, 2024

Presentations in this session

1. Profit sharing in PtX investment, case methanol value chain
   - Antti Ylä-Kujala, Post-Doctoral Researcher, LUT University

2. Sustainability and safety in PtX value chains
   - Jani Sillman, Post-Doctoral Researcher, LUT University

Profit sharing in PtX investment, case methanol value chain

Topics of this presentation

- The role of hydrogen provider in the value chain
- Assessment of economic uncertainties in the value chain
  - The impact of electricity price, subsidization and interest rates

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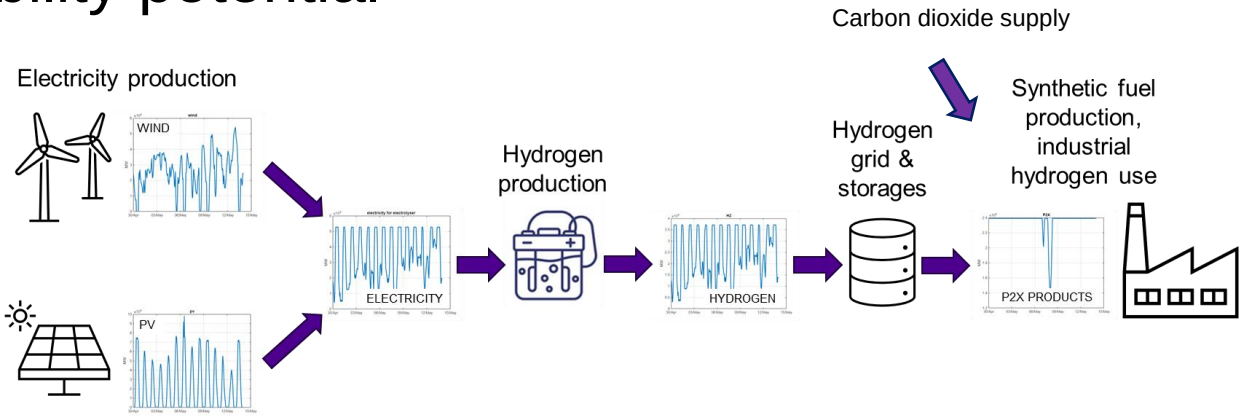
Life cycle costing (LCC) was used to study profitability potential



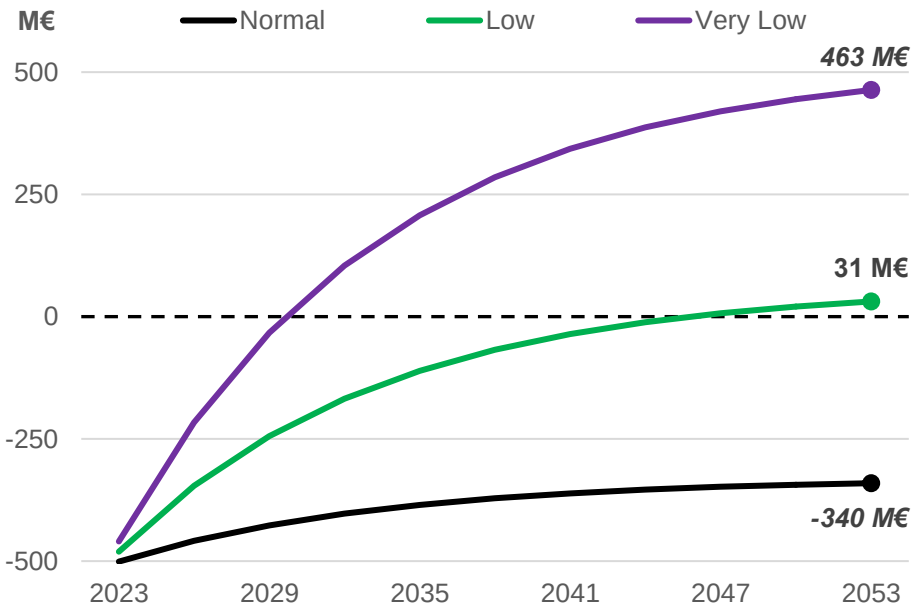
- Industrial PtX value chain is a complex chain of unit operations, and all entities are looking for profitable business.
- Case e-methanol was formed to estimate the profitability of individual operations in the value chain using fixed pricing.
- Life-cycle costing (LCC) approach based on the discounted cashflow method was used.

Positive net cash flow (NCF) for PtX methanol is difficult to achieve

NCF	Electricity price: Normal	Low	Very Low
Carbon Dioxide	76 M€	81 M€	88 M€
Hydrogen	-856 M€	-514 M€	-128 M€
Methanol	440 M€	464 M€	503 M€
Value Chain	**-340 M€**	**31 M€**	**463 M€**

NCF for the value chain is clearly positive only with very low electricity prices

NCF for the H_2 producer remains negative in all scenarios



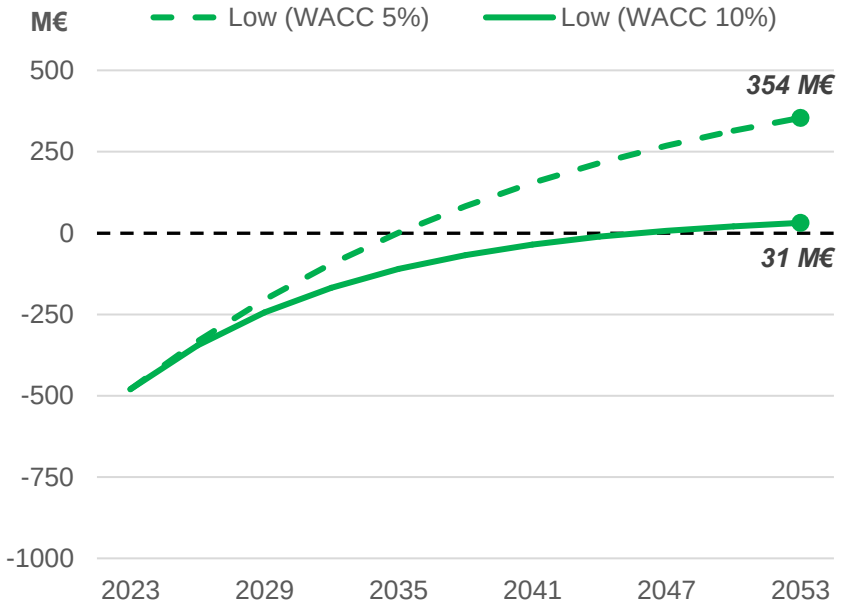
Sources: Ylä-Kujala et al., Silman et al. (both articles in review)
Prices: normal ~47 €/MWh, low ~ 37 €/MWh, very low ~ 27 €/MWh

Subsidies and interest rate are powerful mechanisms

NCF	Electricity price: Normal	Low	Very Low
Value Chain (Subsidy)	**-340 M€**	**31 M€**	**463 M€**
Total Investment	518 M€	518 M€	518 M€
Value Chain (No Subsidy)	**-631 M€**	**-258 M€**	**173 M€**
Total Investment	808 M€	808 M€	808 M€

Investment subsidy (here: 60%) to H_2 production improves profitability significantly

Lowering the interest rate, i.e., WACC, was found to have a significant effect



Profit sharing in PtX investment, case methanol value chain

Key messages

- The role of the H_2 provider is challenging, because profitability lies in value added products
- The value is created in the whole PtX value chains and therefore the value chain should be looked as one business entity instead of separate operations
- The value chain should be measured as one entity in which profits are shared
- Incentives (e.g., subsidization) and collaborative models (e.g., PPA or PPP) are key factors to start investment activity

Sustainability and safety in PtX value chains

Topics of this presentation

- Sustainable transition of PtX – what is it about?
- Results from safety study
- Potential climate benefits

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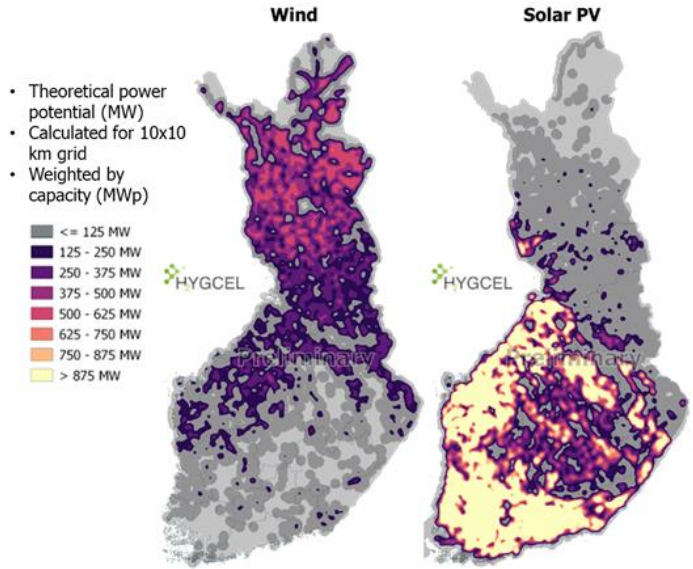
The sustainable transition needed is about realizing benefits and managing risks

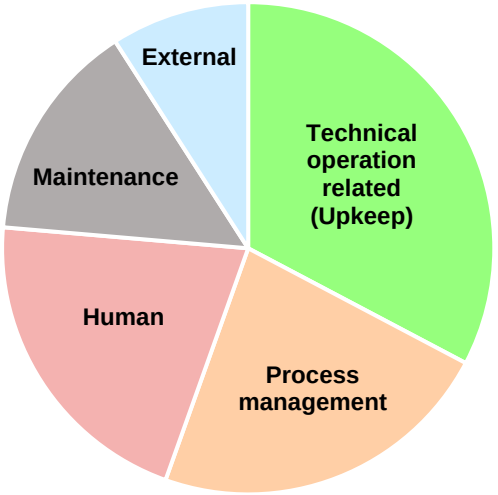
- Examples of benefits and risks on three pillars of sustainability:

  - Economic aspects [1)]
    - Benefits through profitable business
    - Risks caused by, such as, regulation, new technology and material and energy costs
  - Environmental aspects
    - Benefits achieved through climate mitigation[2)]
    - Risks caused by potential loss of biodiversity (forest land)
  - Social aspects
    - Benefits achieved by new jobs, tax incomes and knowledge
    - Risks caused by unsafe operations [3)] and unfair transition

  - Examples provided in this session [1), 2), 3)]



Human activity is the main cause for hydrogen incidents and accidents

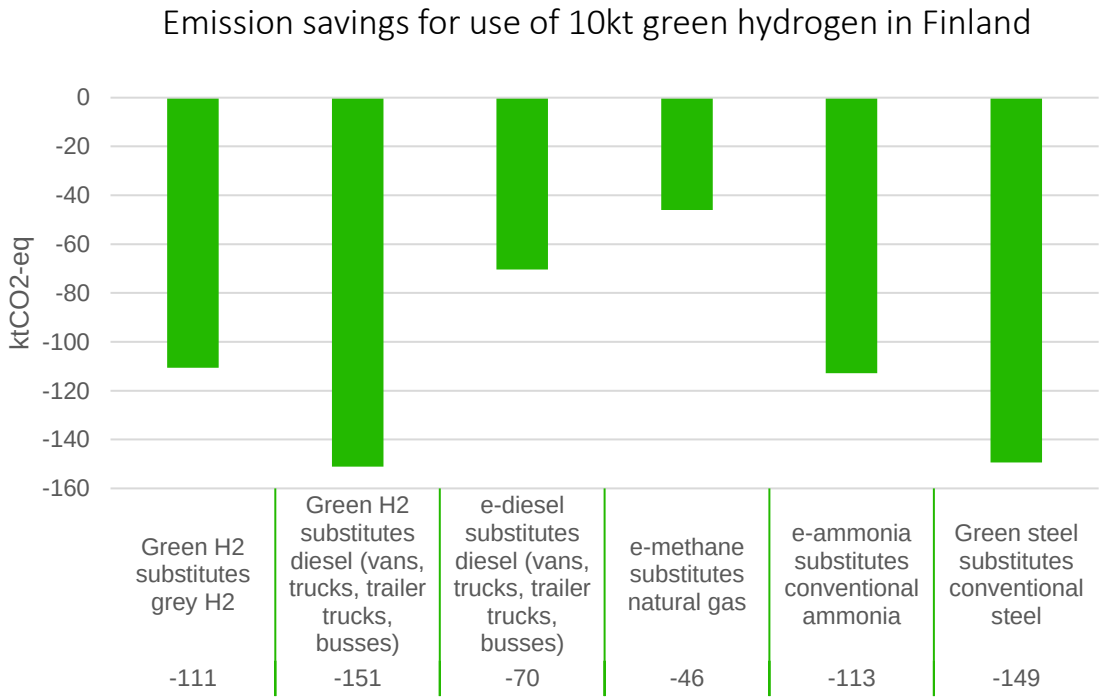


- Human factor is present in most of the root causes of hydrogen incidents and accidents
- Most of the hydrogen incidents and accidents are related to:
  - **Technical operation**
    - tools and equipment failures with pipes, valves, connection joints etc.
  - **Process management**
    - E.g., lack of protocols, procedures and guidelines to run the facility
  - **Human activity**
    - E.g., failure to follow procedures and training issues
- About half of the hydrogen incidents were related to organizational and managerial issues

Source: Alfasfos et al.2024 HYGCEL results page https://www.lut.fi/en/hygcel

PtX products provide low-carbon alternatives to fossil economy

- Emission savings modelled using LCA as a tool
- Typical conventional products used as a reference product
- Assumed final PtX product manufacturing and consumption in Finland
- Results show that renewable electricity based H_2 and PtX products are radically better than conventional fossil-based ones in terms of their impact to climate.



Source: Sillman et al. 2024 (article in review), HYGCEL results page https://www.lut.fi/en/hygcel

Sustainability and safety in PtX value chains

Key messages and findings

Safety

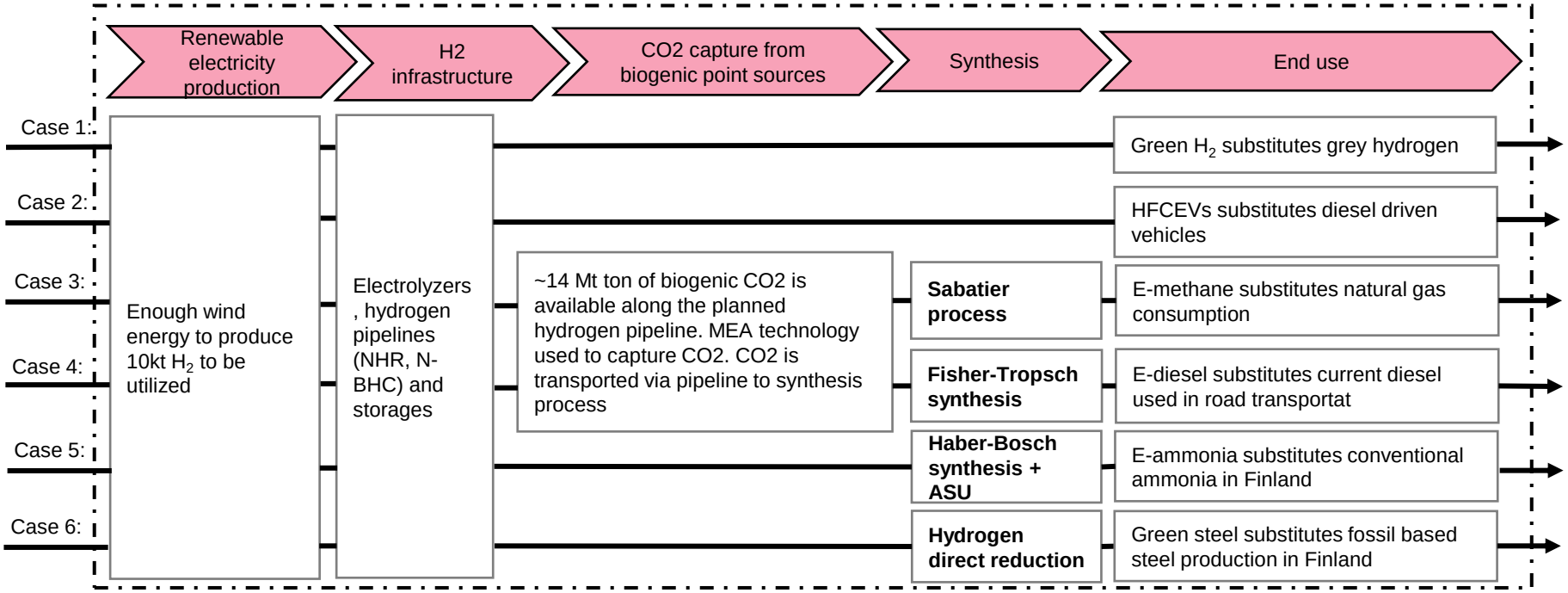
- H_2 has been used safely for decades
- **Larger** scale H_2 infrastructure increases the **accident probability** and/or the **consequences**
- With a careful **risk management** accidents can be prevented. Severe accidents can **prolong** PtX economy and cause reputational damage.
- Workforce training (**education**), better guidelines and improved regulation for H_2 handling are a key for success

Climate mitigation

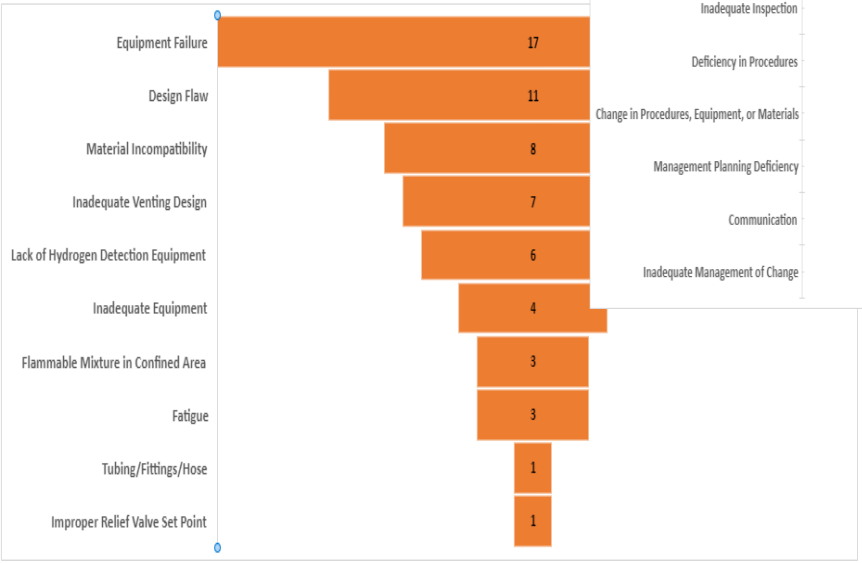
- PtX value chains can help to **achieve** national carbon neutrality targets
- Finland can help **other countries** to achieve their climate targets by providing PtX products (positive carbon handprint) creating also export potentials for Finland
- H_2 should be **first** utilized in those sectors that can achieve **the highest** emission reductions (steel, ammonia, grey H_2) or are, so called, **hard to abate sectors** (aviation fuel, steel)

Additional reading - LCA modell to assess climate benefits

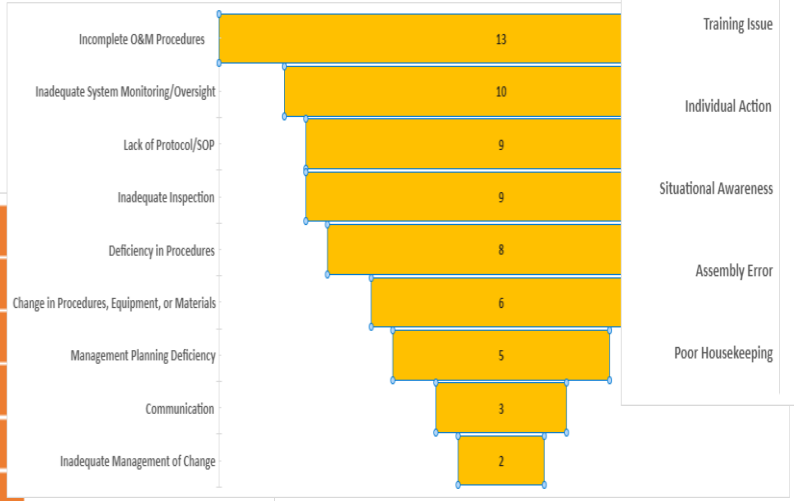
- Assumptions:
  - Hydrogen leakage 3% in Finland
  - 65% (LHV) electrolysis using 100% wind energy to produce H_2.
  - Average gridmix used in synthesis processes (green steel uses nuclear)
  - Input-output analysis values from literature
  - Cradle-to-use phase
  - Transportation considered



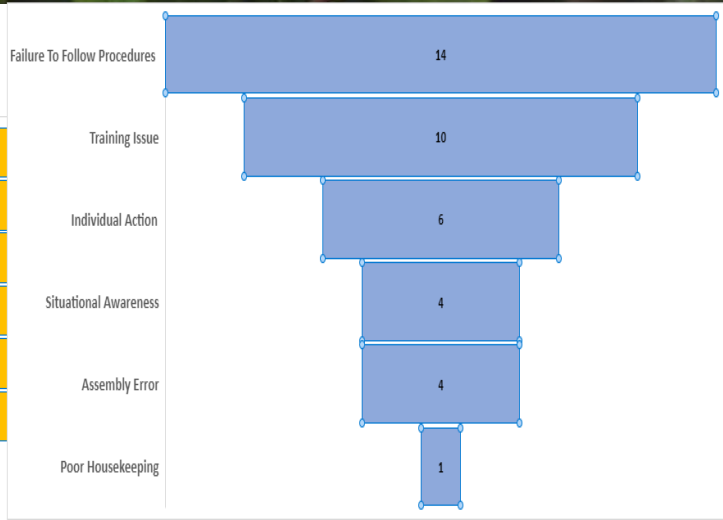
Additional reading - safety



Events caused by technical operation related (upkeeping operations).



Events caused by process management.

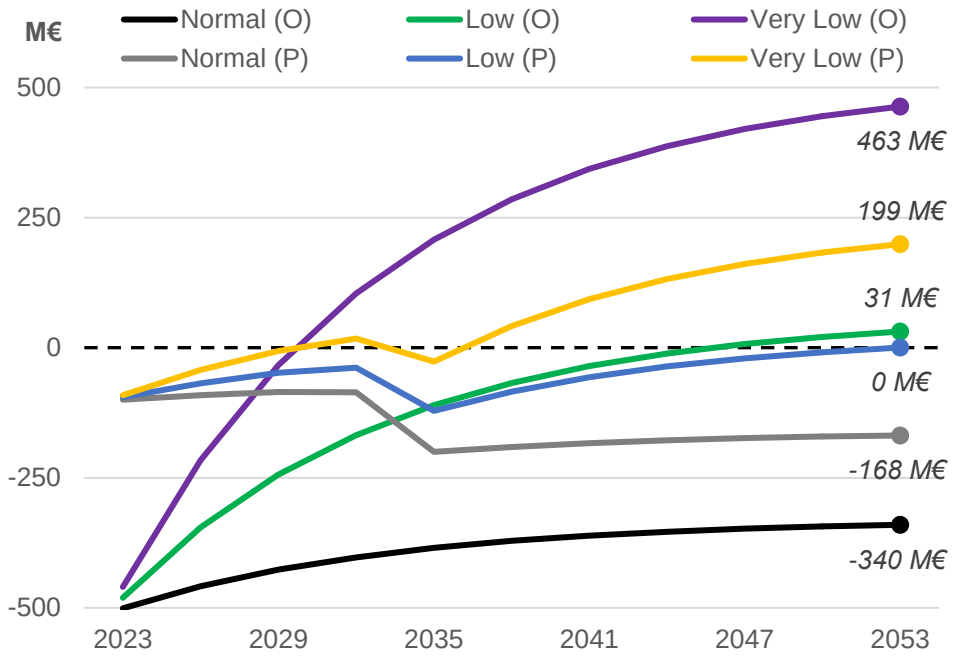


Events caused by human error.

Source: Alfasfos et al.2024 HYGCEL
results page https://www.lut.fi/en/hygcel

Additional reading: Economic vs. environmental goals

Discounted cash flow of one-time investment (O) vs investing in phases (P)



Cumulative emission reductions during 30-year operation

	PtMeoh		
Emission reduction (LCA, End use)	Normal	Low	Very low
One-time Investment [MtCO2-eq/30y]	-19,1	-20,2	-21,9
Investing in phases [MtCO2-eq/30y]	-13,3	-14,0	-15,0

Investing can be made in phases. A case study was made first to invest in 150MW electrolyzer, and then scaled up to 750 MW after 10 years.

Capital intensive one-time investments are challenging (economic uncertainty). Investing in phases reduces capital required.

However, the investing in phases reduces cumulative GHG emission savings.

If fast emission reductions are wanted, one-time investments to PtX value chains are desirable