Hiilidioksidin hyötykäytön teknistaloudellinen kannattavuus – Case sellutehdas

BioCO$_2$-projektin loppuseminaari -
30. elokuuta 2018, Jyväskylä

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Kestävää kasvua ja työtä -ohjelma

Vipuvoimaa EU:lta 2014–2020

Euroopan unioni
Euroopan aluekehitysrahasto

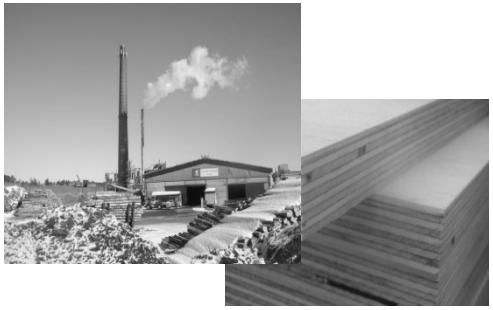
KESKI-SUOMEN LIITTO
Regional Council of Central Finland

Case studies

Purpose: study the economic feasibility of CCU processes at different biobased industry sectors

Case 1: Sawmill case

a) Methane
b) Methanol
c) Formic acid



[Previous cases presented in the first workshop on September 7th 2017]

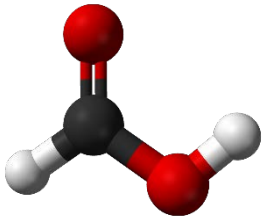
Case 2: Boosting biogas production

a) Stand-alone biowaste digester
b) Waste-water treatment plant

- **Case 3: Pulp mill**
  a) Formic acid
  (b) Methanol)

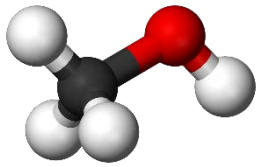
Why these products?

a) Formic acid (HCOOH)



- High-value chemical with low risk of substitution: used e.g. in animal feed, leather tanning, textile dying and for producing de-icing agents
- 15% of global (=30% of European) production in Finland
- Theoretically attractive synthesis route from CO_2 and H_2
  (no by-products, $CO_2+H_2 \rightarrow HCOOH$)
- Currently limited market size & low technology readiness level (TRL3-4)

b) Methanol (CH_3OH)



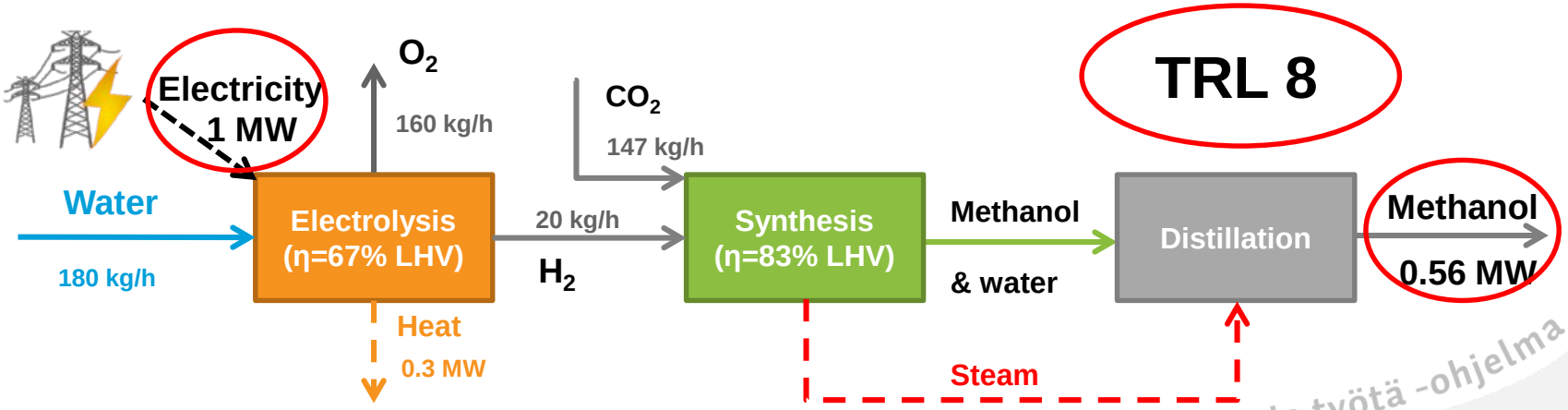
- Large market: important bulk chemical & chemical intermediate, can also be as fuel
- Methanol is used in production of resins/adhesives for wood industry & as a reducing agent in making bleaching chemicals at pulp mills
- Methanol is imported to Finland
- High technology readiness level (TRL8)
  –demonstrated at relevant scale already

Methanol production from CO_2 and H_2

Mass and energy balances (1 MW_e electrolyser)

- Catalytic chemical conversion of carbon dioxide and hydrogen
  - **$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$**
  - Copper and zinc based catalysts, at ~250°C and 50-100 bar

- Distillation to separate methanol and water



- Based on Carbon Recycling International/Mitsubishi Hitachi Power Systems Europe process.

Formic acid production from CO_2 and H_2

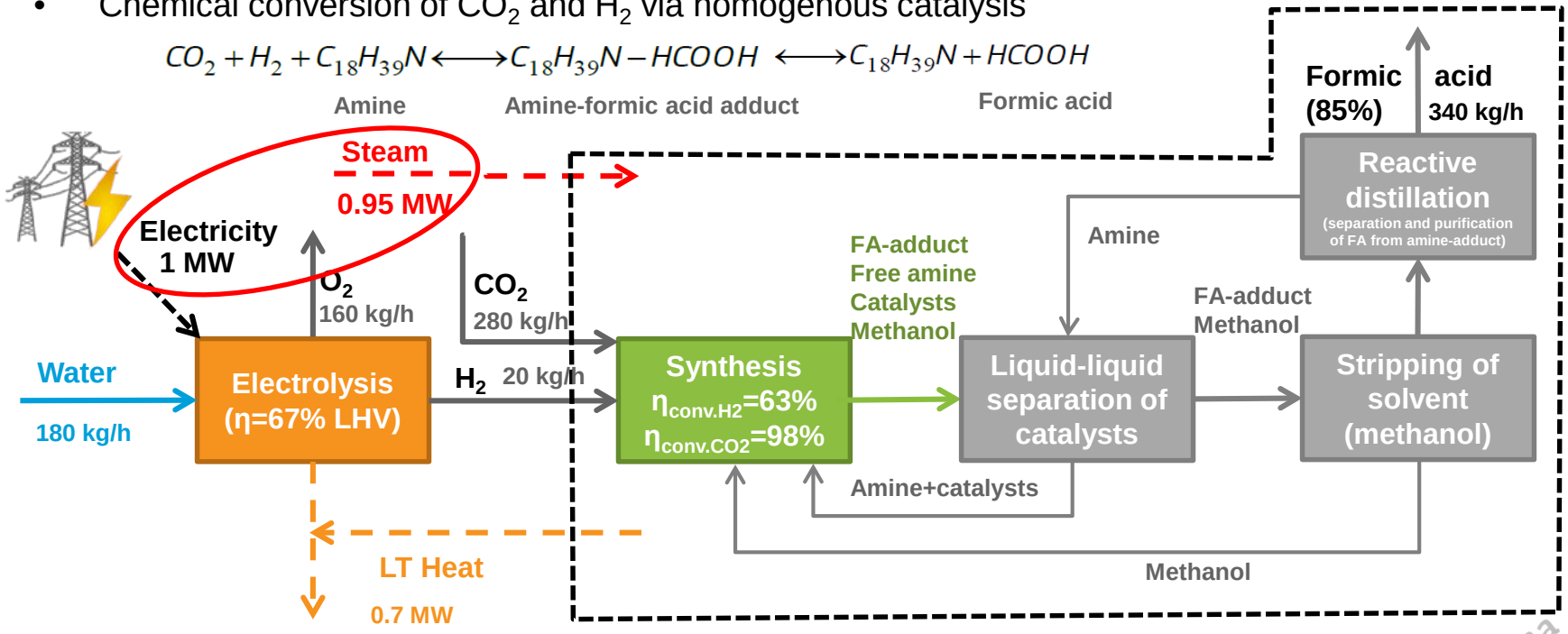
Simplified block diagram (1 MW_e electrolyser)

TRL 3-4

- Chemical conversion of CO_2 and H_2 via homogenous catalysis

$$CO_2 + H_2 + C_{18}H_{39}N \longleftrightarrow C_{18}H_{39}N - HCOOH \longleftrightarrow C_{18}H_{39}N + HCOOH$$

Amine | Amine-formic acid adduct | Formic acid



- 105 bar & ~90 °C, ruthenium- and phosphino-based catalysts
- Tertiary amine for adduct-formation and polar solvent (methanol-water)
- Steam required for separation of solvent and amine from the product

Perez-Fortes&Tzimas (2016). Technoeconomic and environmental evaluation of CO2 utilisation for fuel production – Synthesis of methanol and formic acid, Joint Research Centre, Report EUR 27629 EN, 86 p.

Pulp mill

Attractive integration possibilities for formic acid production

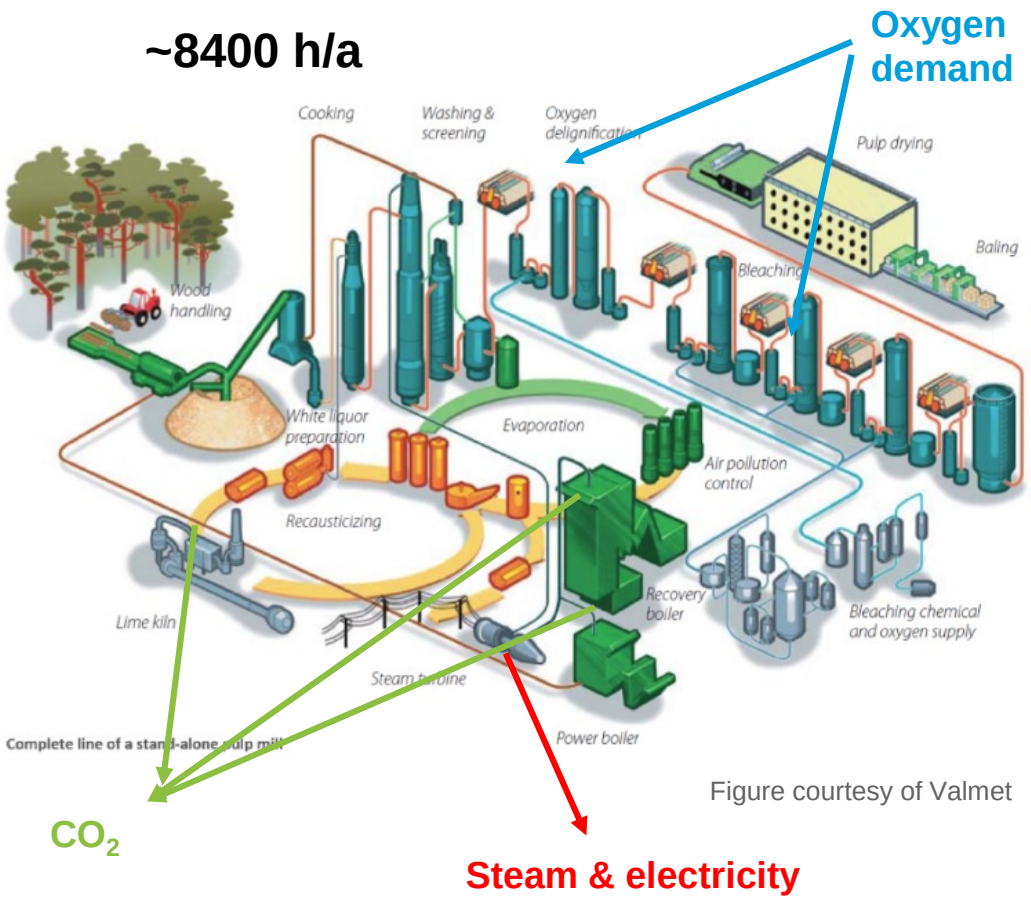


Figure courtesy of Valmet

- Demand for oxygen (delignification & bleaching)
- Low-cost steam available
- Several CO_2 sources and CO_2 could be used also for other purposes (pH control, lignin precipitation, production of PCC*…)
- As formic acid production is less dependent on the electricity price, high capacity factor of pulp mills can be made use of

*Precipitated calcium carbonate (used in paper making)

Pulp mill

Reference pulp mill

- Reference **Nordic pulp mill** with annual capacity of 800 000 ADt/a bleached **softwood kraft pulp (BSKP)** as described in IEAGHG (2016) **scaled to Äänekoski capacity (1 300 000 ADt/a)**

- Full load hours ~8400 h/a
  - Forced two-week shutdown in the summer time

- Specific oxygen demand 35 kg/ADt
  - Based on Äänekoski environmental permission

IEAGHG (2016). TECHNO-ECONOMIC EVALUATION OF RETROFITTING CCS IN A MARKET PULP MILL AND AN INTEGRATED PULP AND BOARD MILL

Pulp mill
Formic acid plant scale

	CO_2 available from pulp mill			CO_2 demand for formic acid			
	Recovery boiler	Bark boiler	Lime kiln	Electrolyser 10 MW_e	Electrolyser 50 MW_e	Electrolyser 100 MW_e	
Total CO_2	318	58	42	2.8	14	28	t/h

- There is plenty of CO_2 available
  → Capacity for the formic acid plant selected based on the O_2 demand of the mill
  → **32.5 MWe electrolyser (9.2 t_{CO2}/h)**

→**Formic acid plant capacity ~100 000 t/a** **(@ 85% concentration, 8760 h/a)**
~75% of Oulu plant capacity

CO_2 balances scaled from IEAGHG (2016). TECHNO-ECONOMIC EVALUATION OF RETROFITTING CCS IN A MARKET PULP MILL AND AN INTEGRATED PULP AND BOARD MILL

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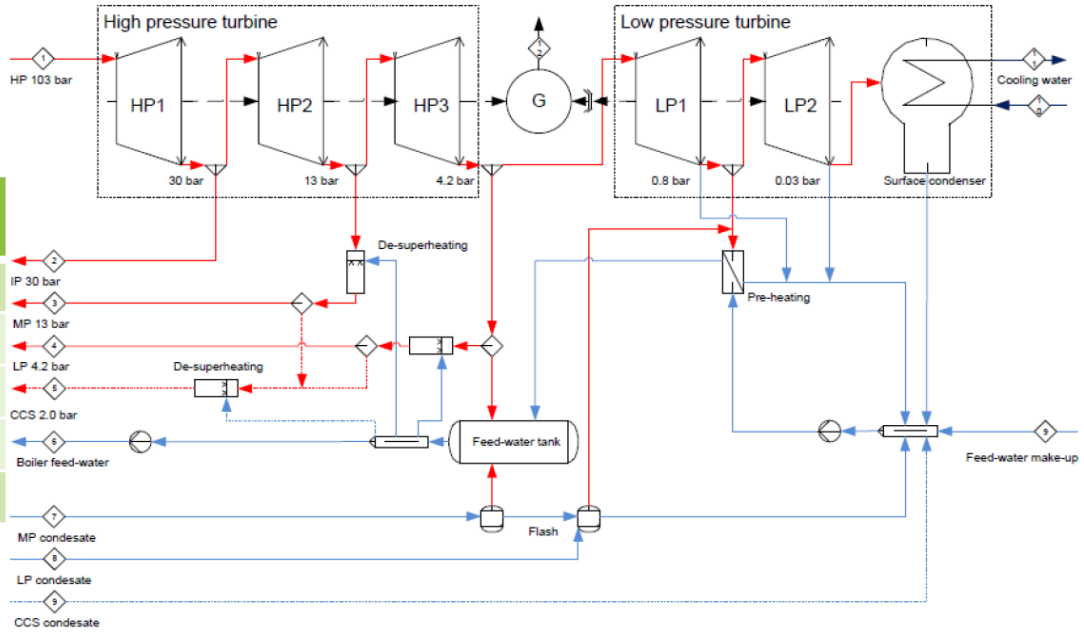
Pulp mill

Electricity and steam

Electricity	Value	Unit
Consumption	61	MW
Gross production	168	MW
-HP section	*130*	*MW*
-LP section	*38*	*MW*
Net production	**107**	**MW**



- Mill could easily provide the needed electricity & process steam (13 & 4.2 bar)

Scaled from IEAGHG (2016). TECHNO-ECONOMIC EVALUATION OF RETROFITTING CCS IN A MARKET PULP MILL AND AN INTEGRATED PULP AND BOARD MILL

Pulp mill

Values of by-products and utilities

- Value of **steam** is calculated based on lost electricity production due to process steam bleeding
- There is no use for the **low-temperature heat** → 0 €/MWh
- Value of **oxygen**: Total production costs of oxygen with on-site VPSA oxygen plant (=replacing the old oxygen plant or a greenfield mill)
- Value of **electricity** is Nordpool spot price (2016) + net tax
  - Assumption: no transmission costs (pulp mill provides the electricity)

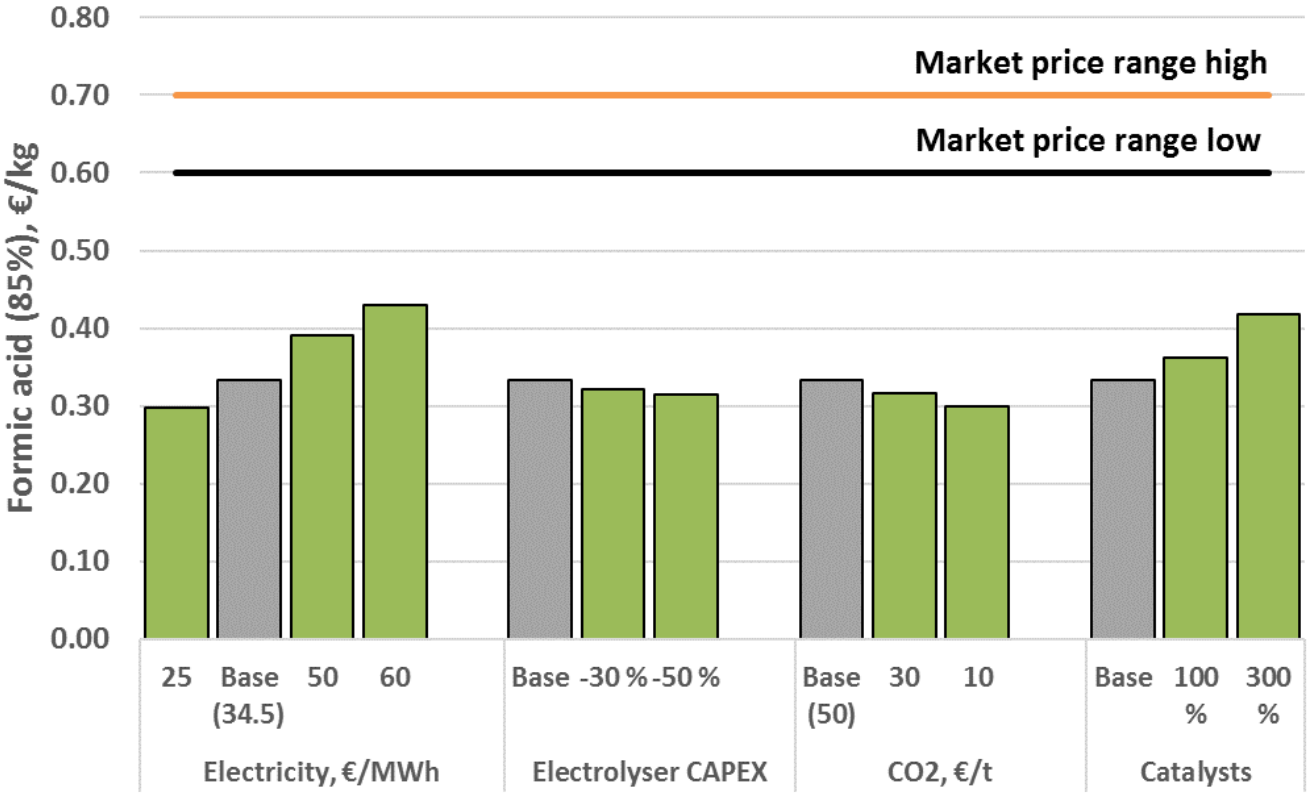
Pulp mill

Main market parameters

Parameter	Value
Electricity spot price scenario*	Finland 2016 (avg. price 32.0 €/MWh)
Electricity transmission + net taxes	2 €/MWh (only net tax after 85% tax return)
FCR scenario	-
CO_2 capture+purification*	50 €/t_{CO2}
O_2 utilisation	Avg 41 €/t_{O2}
Heat utilisation	0 €/MWh
Cost of steam**	Avg 8.1 €/MWh

Results

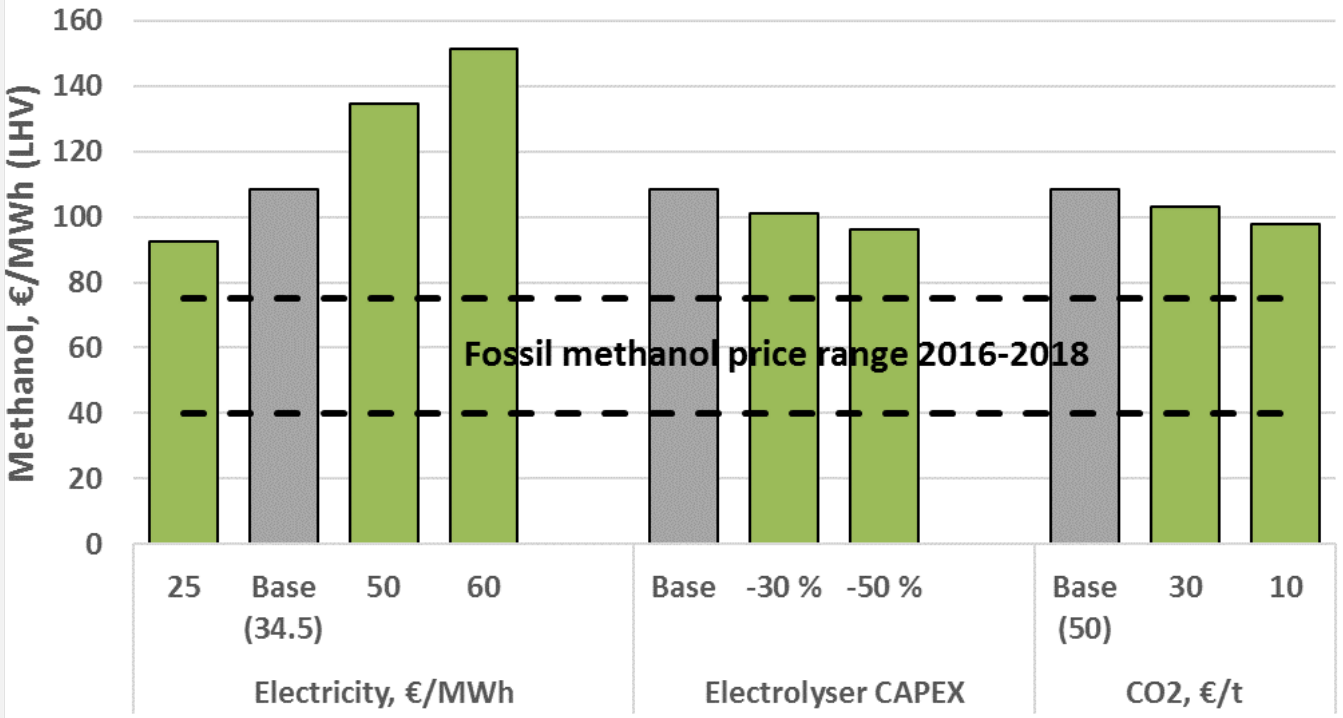
Production costs – Formic acid



- Production costs only around half of the market prices
- If electricity price would be 50 €/MWh, product value 500 €/t and catalyst costs 100% higher, payback time would be ~7 years (corresponding to 425 €/t production cost)

Results

Production costs – Methanol



- Production cost ~1.5-2.5 times more than the price of fossil methanol in 2016-2018

→ Required premium for 'green' methanol in the range of 35-70 €/MWh for the base case

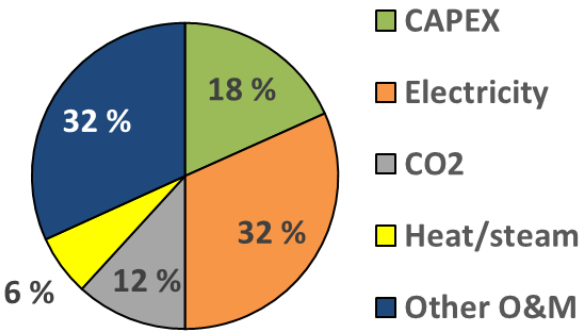
- Electricity price is the dominant factor

Results

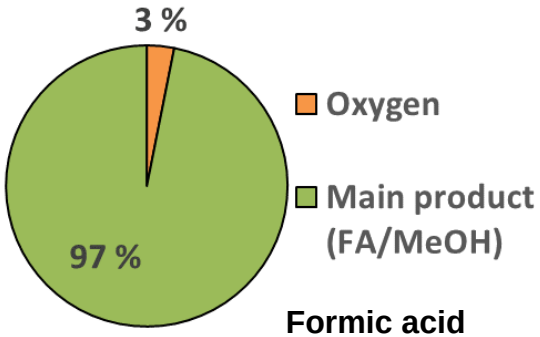
Cost and income breakdowns

Formic acid

Production cost breakdown

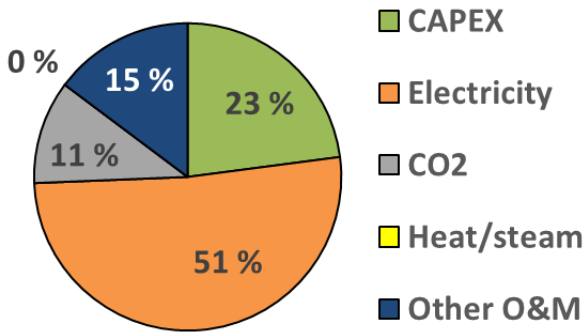


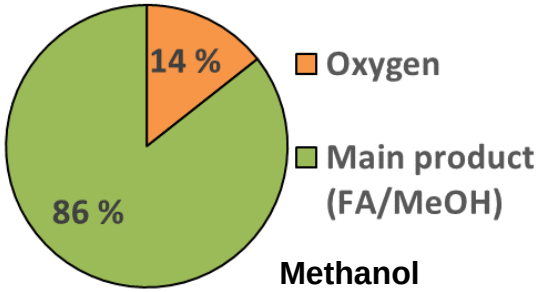
Income breakdown



Formic acid @ 600 €/t

Methanol





Methanol @ 70 €/MWh

- Catalyst and amine costs cause high other O&M costs for formic acid production
- Electricity accounts for half of the costs for methanol
- Oxygen income clearly more important for methanol: lower value end-product

Conclusions

- CO_2-to-formic acid process integrated to a pulp mill showed promising economics but..
  - Technical feasibility of CO_2 hydrogenation to formic acid still not proven
  - Limited market demand: new formic acid plants are mainly of interest when a current plant is at the end of its lifetime?

- Methanol production would require high ’green premium’

Kiitos!