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Technology evaluation
Variable Costs
Hydrogenprodcution
With co-products

Proud partners

Sitech Services
TNO
Maastricht University
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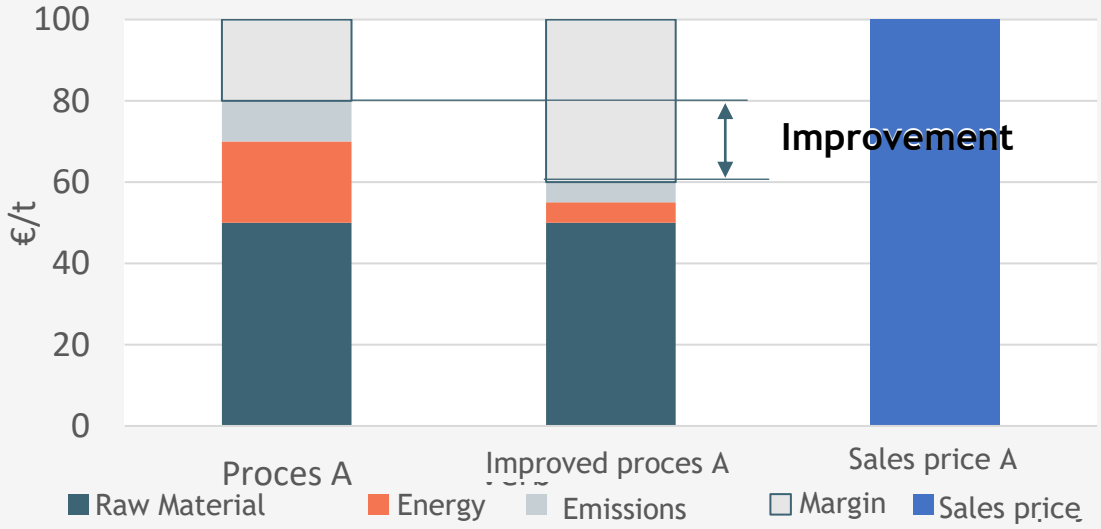
Problem and objective

Delta analysis is a useful and often applied method to quantify the financial costs and benefits of a technology-improvement.

The benefit of delta analysis is that sales market conditions do not play a role in the cost and benefits.



Multiproduct processes such as naphtha cracking, MILENA and methane decarbonization produce many by-products.

The common method of calculating the cost price of the desired product from a multi-product process is by subtracting all by-products from the raw material costs at their market price.

Sales market conditions play an undesired, but major role in determining the product cost price for these processes with coproducts.

A new method is desired in which sales market conditions do not play a role for evaluations on variable costs

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Methodology

1. Determine technology parameters

What:

Production and consumption of:

- Main product;
- Co-products;
- Raw materials; and
- Energy

Sources:

- Literature;
- Assumptions; and
- inhouse AspenPlus Models

2. Converting co-products into avoided raw material, energy and emissions

What:

Convert technology parameters to net consumption of:

- Electricity;
- CO_2-emission allowances (ETS);
- Natural gas;
- Naphtha;
- Propane;
- Wood pellets; and
- Metallurgical coal.

(all mature, global markets)

Methods:

- Brightsite Technology evaluation

3. Collecting and processing price information

What:

Gather price information for products from the previous step

Sources:

- Stock market prices of futures of tradable products;
- Converting (Electricity, Pellets, household waste, additional transport costs, etc)

4. Technology evaluation

What:

Variable production costs of hydrogen for:

- Different technologies
- Historical energy and commodity prices
- Expectations of future energy and raw material prices (PBL Climate & Energy Outlook)
- Sensitivity analysis

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Evaluated hydrogen production technologies

#	Technologie
01	SMR (Steam Methane Reforming)
02	ATR + CCS (Autothermal reforming + Carbon Capture and Storage)
03	Methane pyrolysis, Hüls (H_2 + C_2H_4)
04	Methane pyrolysis, BASF (H_2 + C(s))
05	Elektrolysis SOE
06	Elektrolysis PEM
07	Elektrolysis AEM
08	High temperature wood gasification (partial oxidation)
09	Mild wood gasification, with carbon co-product (partial oxidation)
10	Milena wood gassification (pyrolysis)
11	High temperature domestic waste gasification (partial oxidation)

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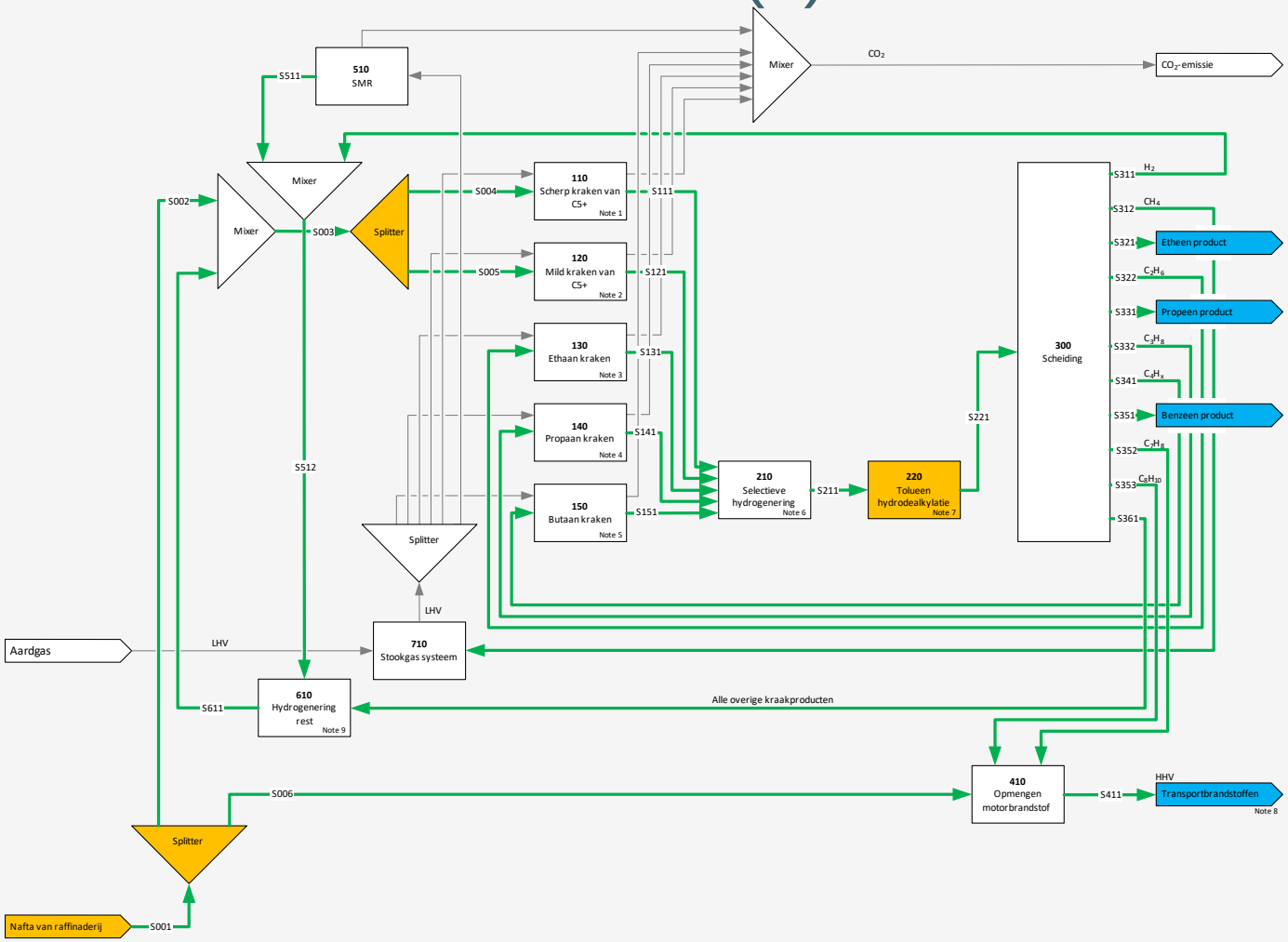
Method: Delta analysis of transportfuels + steam cracker (1)



1. Equation Oriented AspenPlus Model for mass balance
2. Excel for fuel gas and CO_2-emissions
3. 4 + 1 products (blue) and 4 + 1 degrees of freedom (yellow).
4. Delta analysis on:
    1. Ethylene
    2. Propylene
    3. Benzene
5. Validation

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Method: result specefic raw materials and energy consumption

Product	Naphtha $t_{naphta}/t_{product}$	Fuel Gas $GJ_{LHV}/t_{product}$	Elektricity $MWh_e/t_{product}$	Direct CO_2-emission $t_{CO2}/t_{product}$
Hydrogen	-	170	-	9,62
Ethylene	1,55	-9,24	0,077	0,861
Porpylene	0,847	29,2	0,11	1,32
Benzene	1,05	-5,88	0,000	0,250

Oxygen: 0,25 MWh_e/t_{O2}

This is a novel method and in particular of interest in the field of Lice Cycle Assesment (LCA) of polymers. A scientific publication is in preparation.

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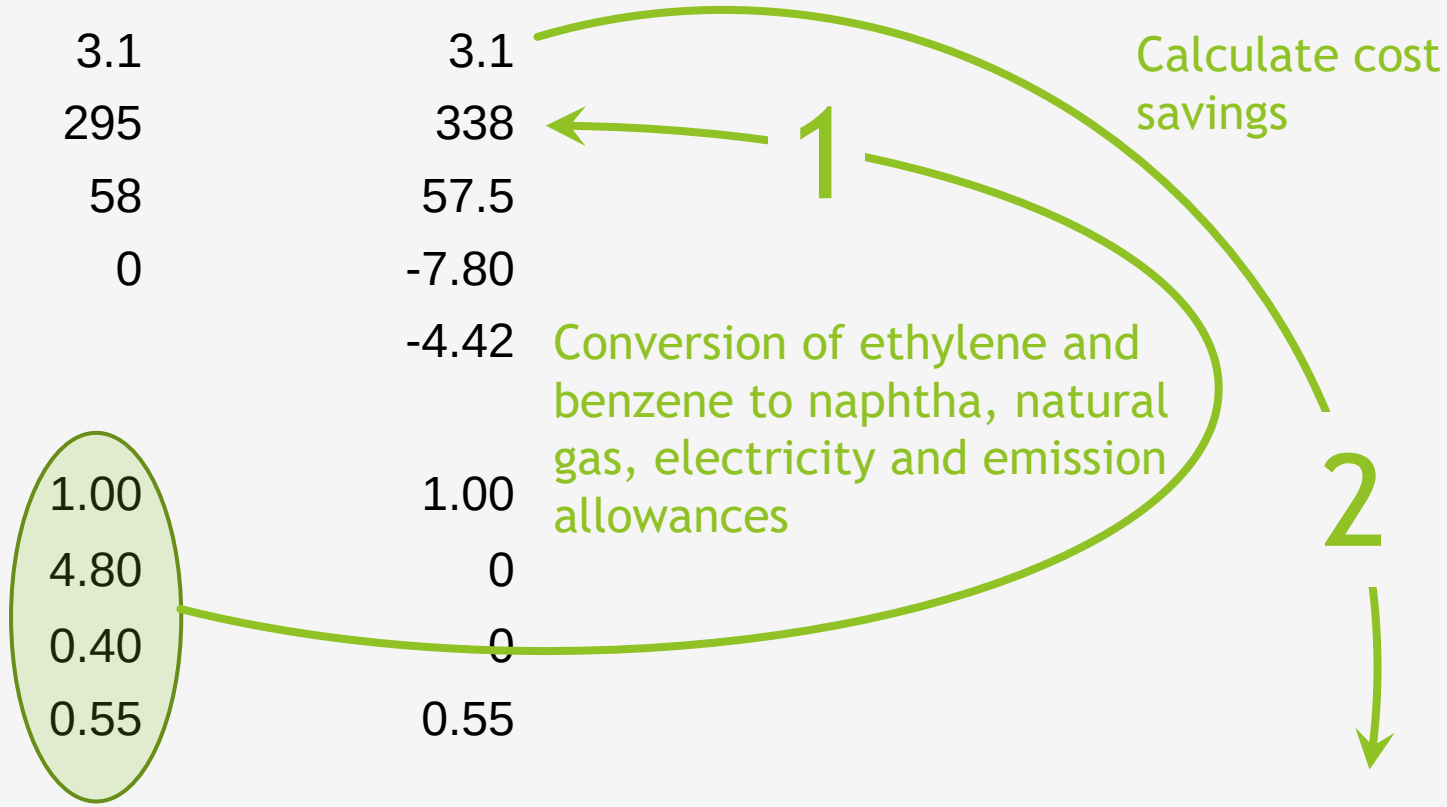
Exercise: evaluation of hydrogen from Hüls

Raw material and energy		**Huls H2**	**Converted**
Propane	t	3.1	3.1
Natural gas	GJ_{LHV}	295	338
Electricity	MWh_e	58	57.5
Naphtha	t	0	-7.80
CO2-allowances	t		-4.42
Products			
Hydrogen	t	1.00	1.00
Ethylene	t	4.80	0
Benzene	t	0.40	0
Carbon	t	0.55	0.55



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RESULT STEP 2: All co-products converted into avoided raw material, energy and emissions

	Eenheid	01 – SMR	02 - ATR + CCS	03 - Methane pyrolysis, Hüls (H2 + CxHy	04 - Methane pyrolysis, BASF	05 - Elektrolysis SOE	06 - Elektrolysis PEM	07 - Elektrolysis AEM	08 - High temperature wood gasification (partial oxidation)	09 - Mild wood gasification, with carbon co-product (partial oxidation)	10 - Milena wood gassification (pyrolysis)	11 - High temperature domestic waste gasification (partial oxidation)
Hydrogen production	t	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
Netto grondstof- en energieconsumptie												
Electricity	MWh_e	0,15	1,29	57,49	24,40	40,80	48,55	50,64	1,60	1,40	0,02	1,18
CO2 ETS allowances	t	9,50	0,00	-4,23	0,00	0,00	0,00	0,00	-1,19	-0,13	-8,31	8,06
Natural gas	GJ_{LHV}	169,00	169,00	341,71	199,00	0,00	0,00	0,00	-21,05	-2,30	-101,03	-28,25
Naphtha	t	0,00	0,00	-7,88	0,00	0,00	0,00	0,00	0,00	0,00	-3,62	0,00
Propane	t	0,00	0,00	0,85	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Wood Pellets	t	0,00	0,00	0,00	0,00	0,00	0,00	0,00	10,32	11,95	27,88	0,00
CO_2 to CCS	t	0,00	9,50	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
RDF pellets 50% biobased	t	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	5,79
Metallurgical Coke	t	0,00	0,00	-0,55	-3,00	0,00	0,00	0,00	0,00	-1,50	0,00	0,00

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RESULT STEP 3:
Collecting and processing price information

		Avergage 2011-2019	2030 forecast	Source 2030 forecast
Electricity	€/MWh_e	50	51	KEV[1] 2020
CO2 ETS	€/tCO_2	10	46	KEV 2020
Natural gas	€/GJ_{LHV}	6,4	7,28	KEV 2020 (€0,23/Nm3) @ 31,596 MJ_{LHV}/Nm^3)
Naphtha	€/t	632	669	KEV 2020 Brent crude * 9,2 @ 1,21 US$/€
Propane	€/t	409	435	65% naphtha
Wood pellets	€/$t_{dry,ashfree}$	136	135	Woodpellet [€/$t_{dry,ashfree}$]= (El_{price} [€/MWh_e] * 50% * 19 / 3,6
CO_2-storage	€/t	60	60	SDE++
RDF pellets 50% bio	€/t	97	91	50% LHV-basis natural gas
Metallurgical Coke	€/t	143	143	Average 2011-2019

Note 1: KEV = Climate & Energy Outlook, PBL

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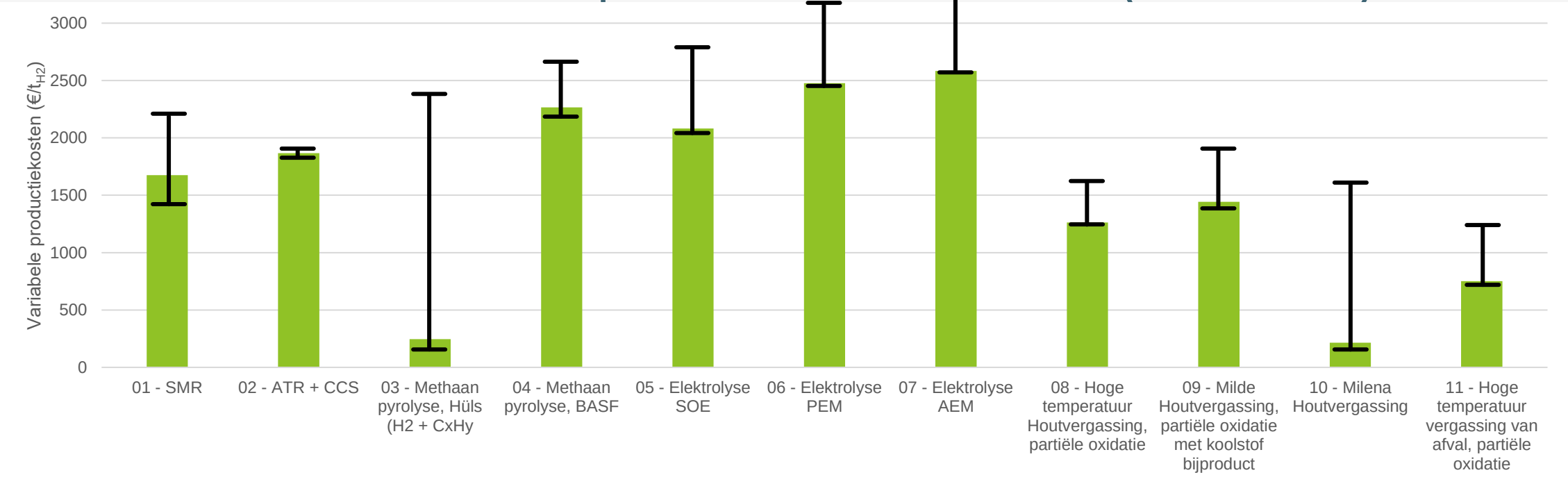
RESULT STEP 4 (1): Variabele production costs 2030 (KEV2030)



- KEV forecasts a high oil price (88 US$/BBL), this promotes technologies (03, 10) with ethylene co-product.
- Wood pellets: assumed price 36 €/$t_{dry,ashfree}$. (average over 2011-2019)

1: Klimaat- en Energieverkenning 2020 | PBL Planbureau voor de Leefomgeving

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Conclusions & next steps

- This is a novel method and in particular of interest in the field of Lice Cycle Assesment (LCA) of polymers.
- A scientific publication about this novel method is in preparation.
- These analysis have also been made for other Chemical Intermediates (ethylene).
- Sensitivity analysis have been made and detailed insights have been obtained.
- All based on information from the public domain.
- If there is sufficient interest a session of approximately 2 hours will be planned in which the results and insights will be presented in depth.