Energy transition of the industry – It's about time

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Online

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Together   Trust-based   Factual   Independent
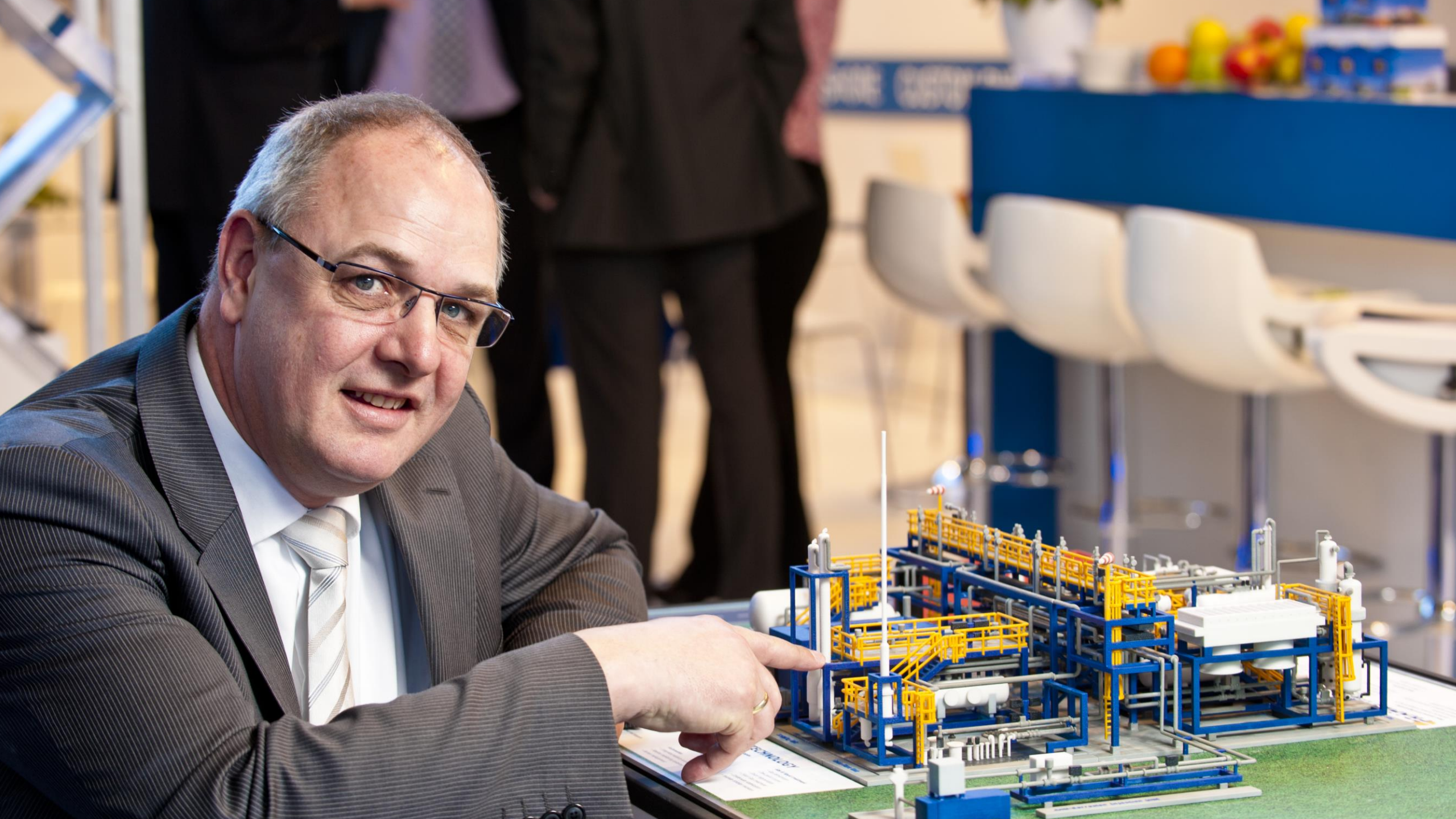
February 11th *De Correspondent – Jelmer Mommers*
…what you may expect from De Correspondent…but…

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From *IEA??*
May 17 – IEA Net Zero -- stop exploration of fossil

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May 26 – Shell convicted in court for Climate Policy

Financial sector is getting serious…

Moment voor harde keus voor beleggers in fossiel komt dichterbij

Klimaatverandering

Steun van 90 procent van de aandeelhouders voor de ingeslagen weg naar een duurzamer toekomst. Wie oppervlakkig kijkt zou denken dat de aandeelhoudersvergadering van Shell is uitgelopen op applaus voor de raad van bestuur. Voor het eerst, en tot nu toe als enige, legde Shell afgelopen dinsdag een resolutie voor aan de aandeelhouders met daarin de transitie naar een klimaatvriendelijke toekomst en die kon op massale instemming rekenen. Dank u voor de steun, tot over drie jaar.

Maar onder de oppervlakte smeult er iets. Beleggers tonen zich in toenemende mate kritisch op het klimaatbeleid van oliebedrijven als Shell. Dat bleek deze week uit twee voorvallen. Ten eerste maakte

Dit is het dagelijkse commentaar van NRC. Het bevat meningen, interpretaties en keuzes. Ze worden geschreven door een groep

And ETS plays along…

Daily EU ETS carbon market price (Euros)

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How?

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Simple scheme of poly-ethylene production

Naphtha (crude oil)

Steam

Steam Cracker

~~CO_2~~

Ethylene

Polymerisation

Poly-ethylene (plastic)

Light gases (Methane, Hydrogen,…)

Other products (Propylene, Butadiene,…)

Getting rid of CO2? Option 1 - CCS

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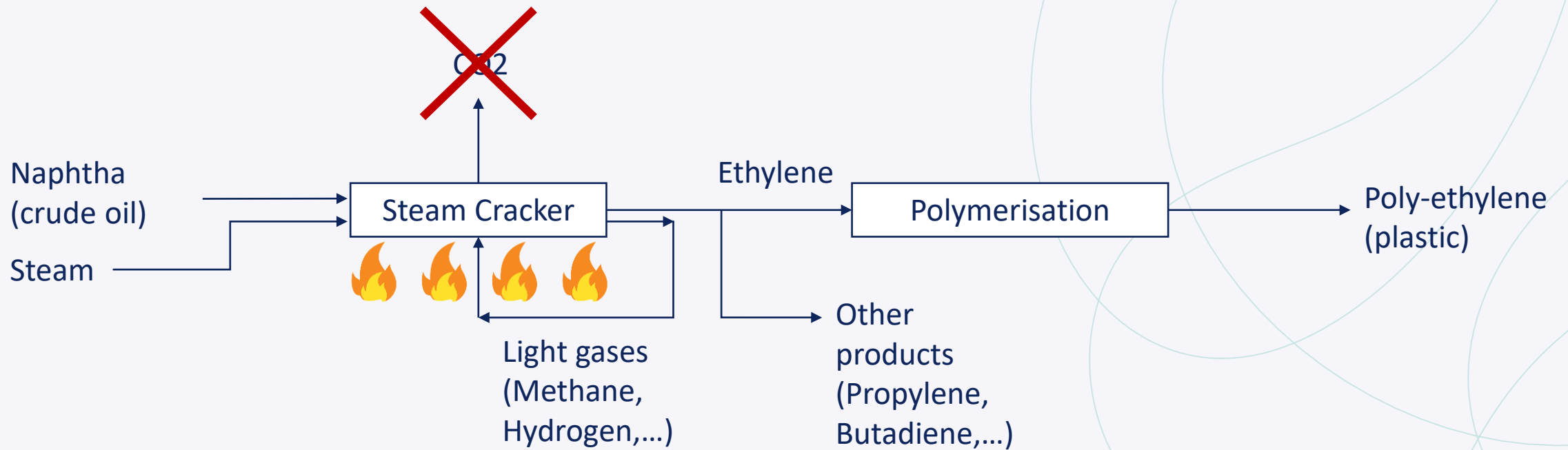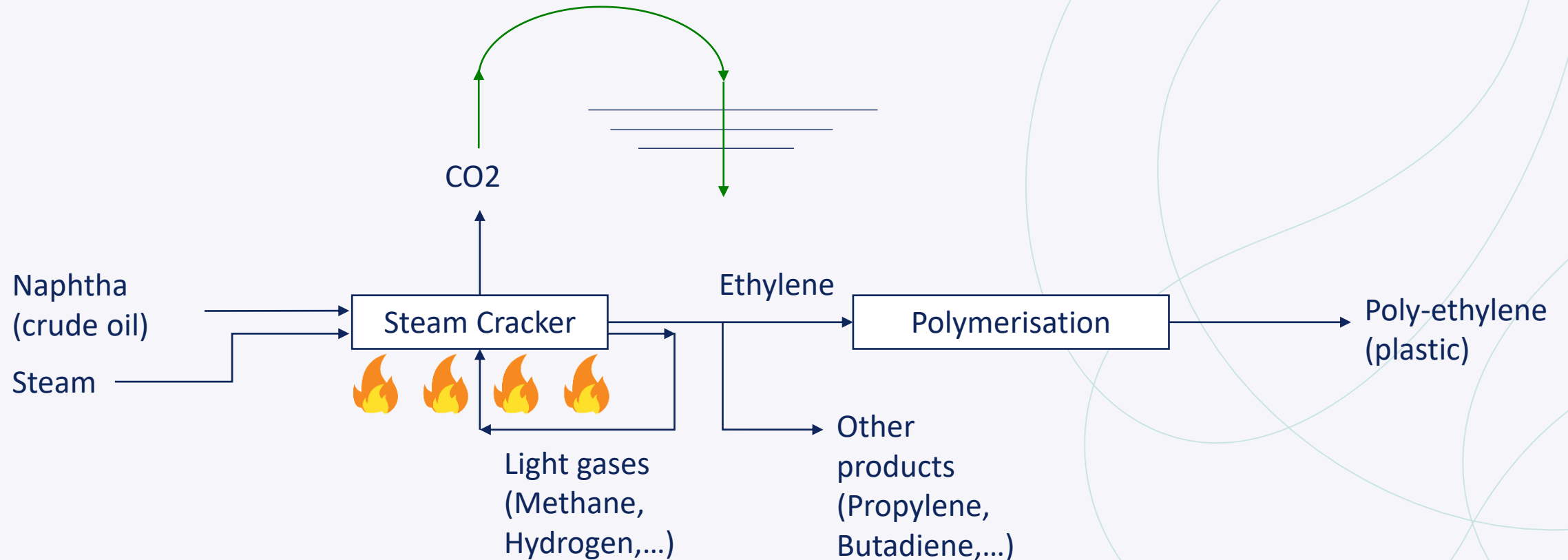
Getting rid of CO2? Option 2 - electricity

Naphtha
(crude oil)

Steam

Steam Cracker

Ethylene

Polymerisation

Poly-ethylene
(plastic)

Other
products
(Propylene,
Butadiene,…)

Light gases
(Methane,
Hydrogen,…)

To other
uses…

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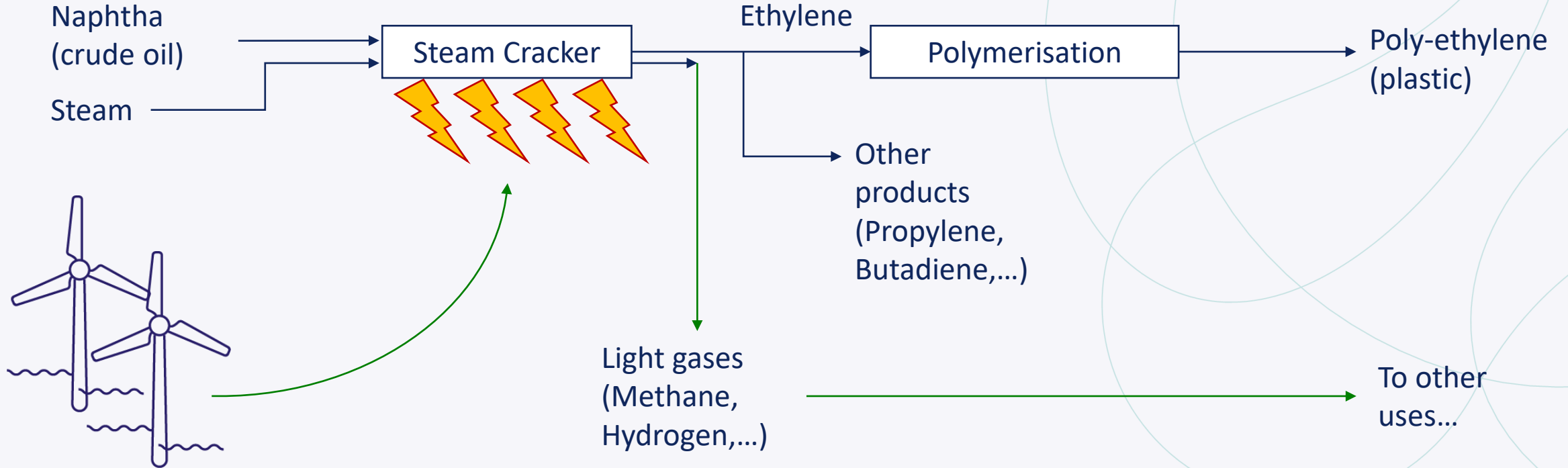
Getting rid of CO2? Option 3 – Green Hydrogen

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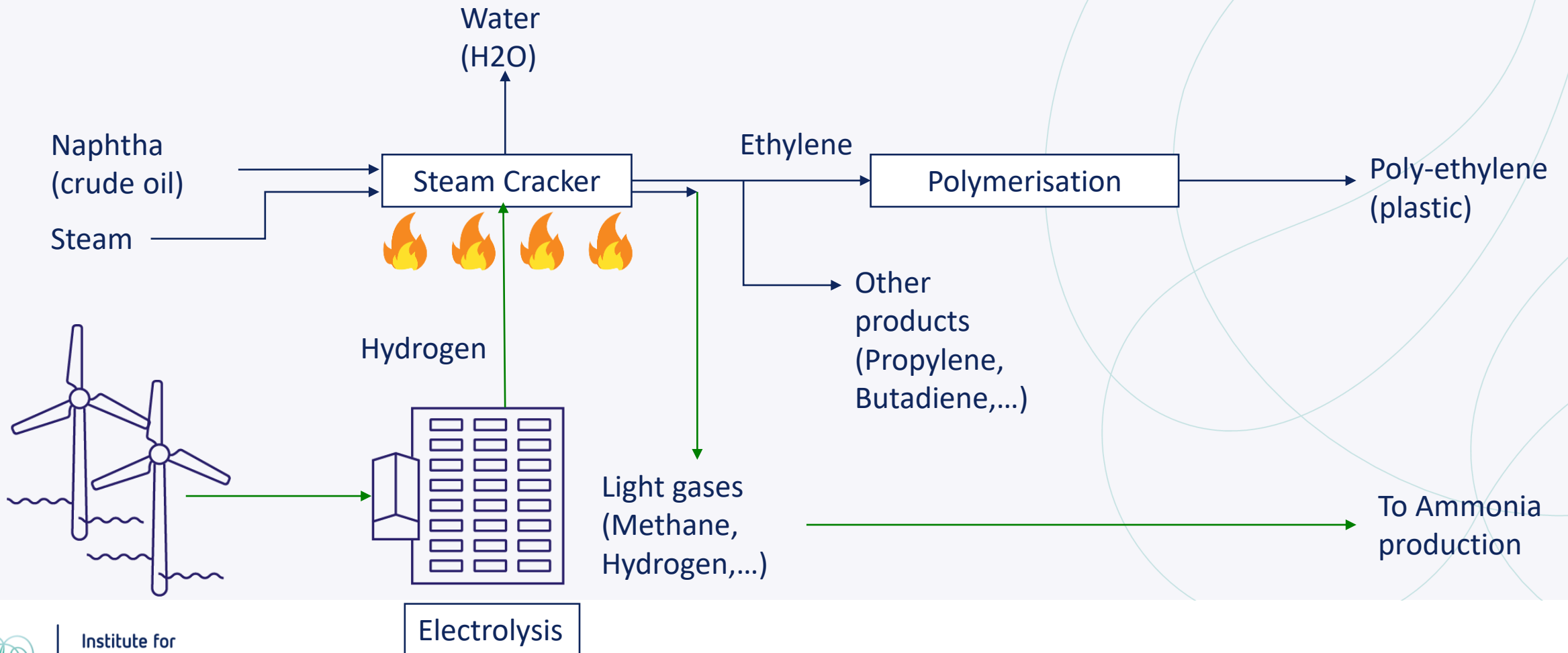
Linear models of the investments
Yield & Expense - Baseline

CO2

Naphtha
(crude oil)

Steam Cracker   →   Ethylene

Steam

🔥 🔥 🔥 🔥

Light gases
(Methane,
Hydrogen,...)
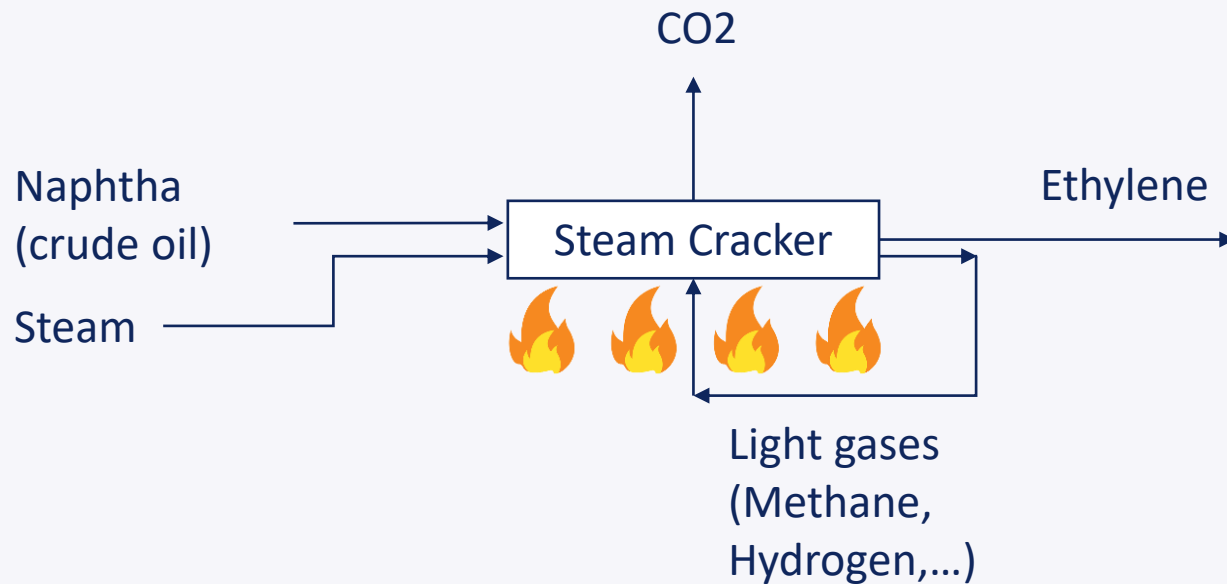
Modeling basics

- Mass balances of the process unit

- Yields for product, by-products, utility requirements per unit feedstock; pricing and fixed costs

Capex costs

- Installed base depreciated

Opex costs

- Feedstock costs

- Utilities costs

- CO_2 – to air charged at ETS or CO_2 tax price

Linear models of the investments
Yield & Expense - Alternative option – electric cracker

Naphtha
(crude oil)

Steam

Steam Cracker

Ethylene

Light gases
(Methane,
Hydrogen,...)
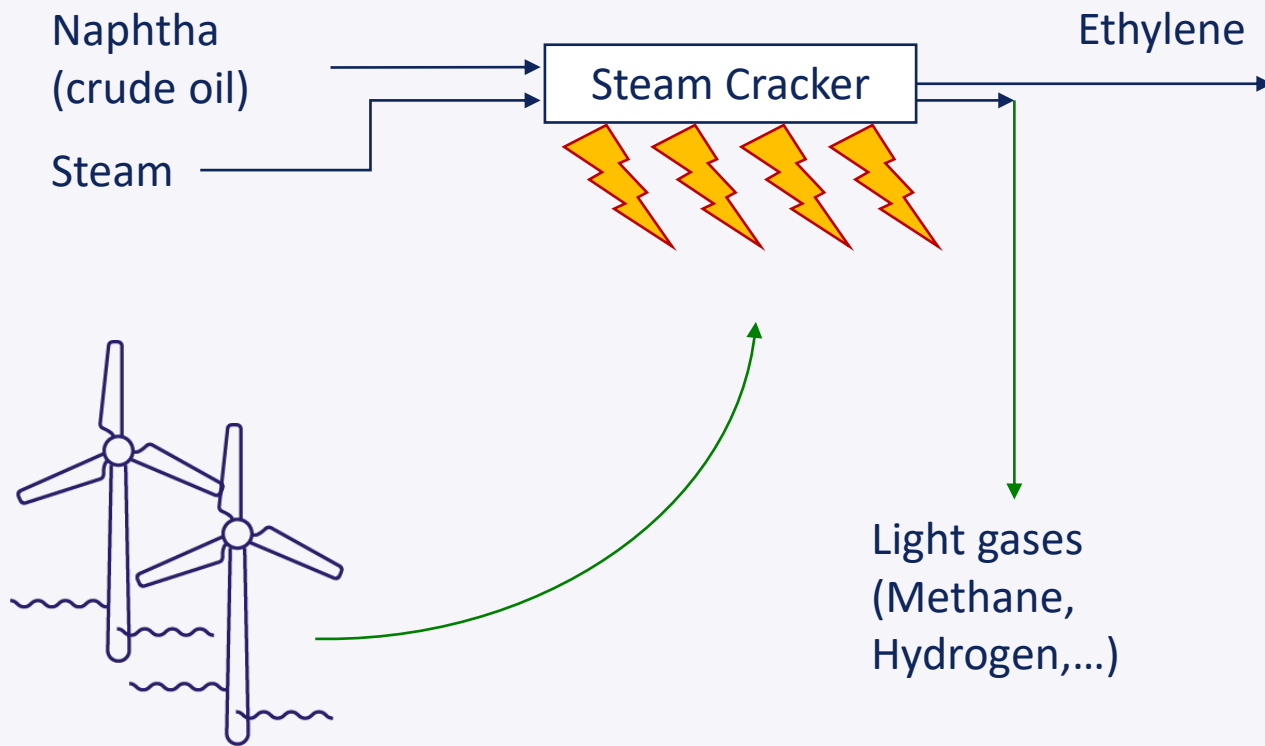
Technology under development - timing and learning curves
- first full demo mid 20-ies
- Full scale by 30-ies
- cost reduction by 40 – ies

Opex costs
- Renewable power availability and cost?
- Conversion efficiency ?
- Value of by-products?

CO_2 – degree of emission reduction – cost-savings

A cracker is not a stand-alone unit operation

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Superstructure for integral site transformation
Based on options considered by the industry
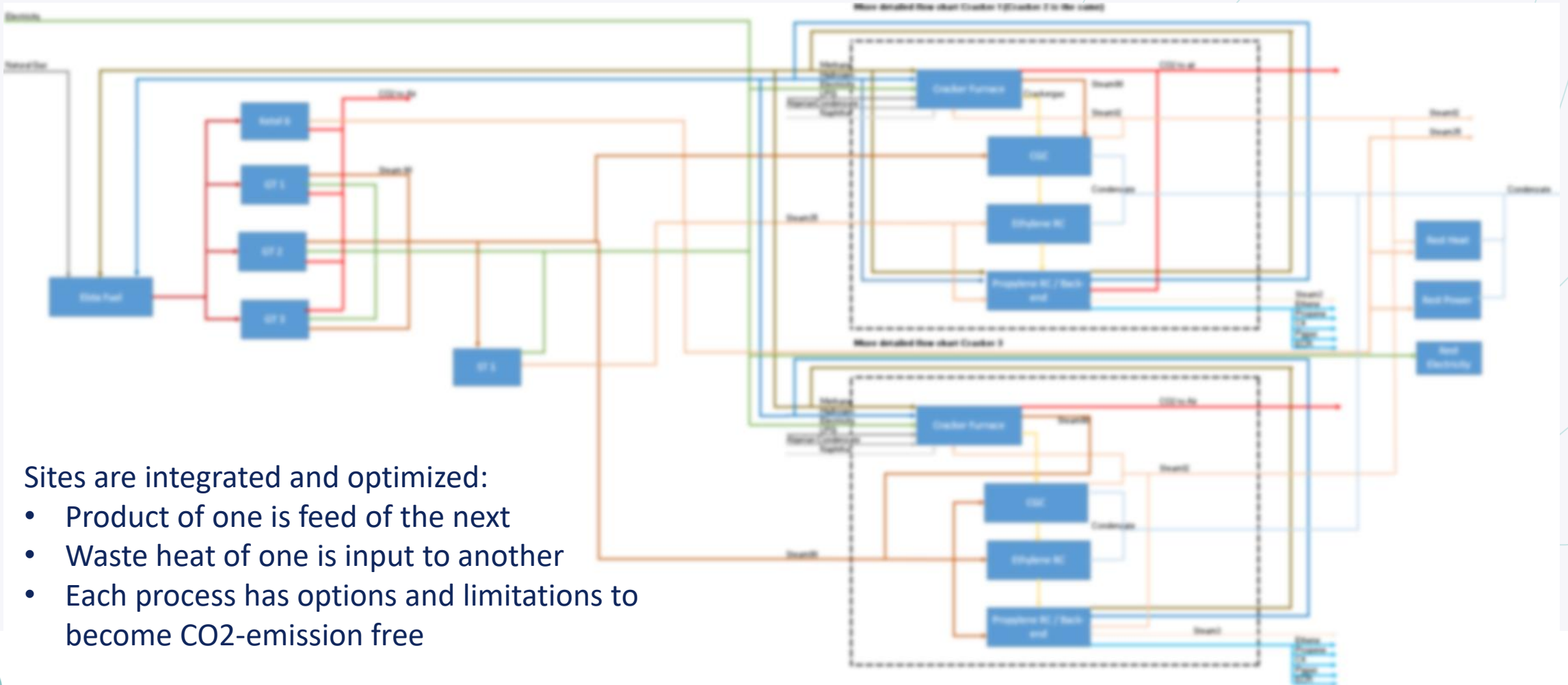
Sites are integrated and optimized:
- Product of one is feed of the next
- Waste heat of one is input to another
- Each process has options and limitations to become CO2-emission free

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Dependencies along the value-chain and in clusters

CCS

| CO2 Capture installation at plant | CO2 Storage infrastructure | CO2 transport infrastructure |

Electric

| Renewable power Production (Windpark) | Power transport infrastructure | Electrified Cracker |

Hydrogen

| Renewable power Production (Windpark) | Power transport infrastructure | Hydrogen production plant | Hydrogen transport and storage infrastructure | Hydrogen-ready cracker furnace |

Industrial clusters
- Many companies who need to reach their emission targets
- Joint use of infrastructure
- Synergies and limitations – space, sufficient green power, timing of delivery of infrastructure...

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Modeling through TEACOS
(Techno-Economic Analysis of Complex Option Spaces)

Strategic Input
- Aspired portfolio of products
- Supply & Demand scenarios
- Outlook on Prices & Costs

(4)

Simulation & Optimization
- Economic Valuation (NPV)
- Investment over time analysis
- Margin or Cost

(5)

Credible, Affordable, and Competitive Value Chain Options

(6)

(1) **Supply**
- Resource availability, quality
- Availability of utilities
- Prices of resources & utilities
- Supply logistics & costs
- Time horizon (years)

(2) **Conversion Infrastructure**
- Yields
- Capital data
- Variable & Fixed Costs

(3) **Demand**
- Definition of demand areas
- Product demand & prices
- Distribution network
- Transport options & costs
- Time horizon (years)

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Key features…

Basics

- Data driven templates → equations are generated; No data → no equation
(spin-off: a transparent & consistent data depository)

Model Definition

- Network of feedstock sourcing options

- Superstructure of "conversion options"

Basic Data

- Feedstock & utility costs

- Yields & Capex for conversion options

- Product demand & prices: market studies & scenario analysis

- Product distribution costs

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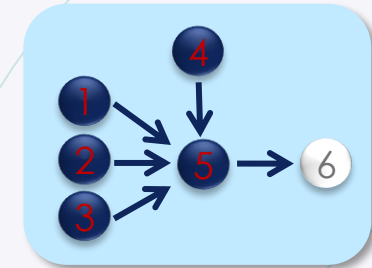
…key features

Mathematics

- Multi-Period – Mixed Integer Linear Programming optimization (MP-MILP)

  - MP – selection and timing of investments – 2020 – 2050 @ 1-year intervals

  - MILP – on/off-decisions on investments

- AIMMS and CPLEX advanced optimization solvers

- Structured (parametric) sensitivity analysis e.g. through Monte Carlo analysis
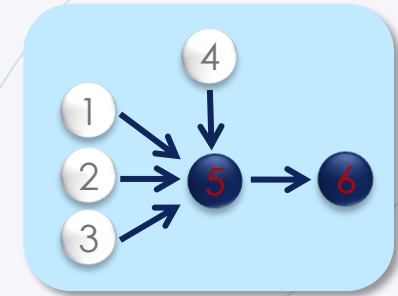
Objectives

- Optimal investments over time (Max NPV of the system under given scenario)

Constraints

- e.g. CO_2 emission targets over time – can be forced, or can follow

Outcomes

- Relative attractiveness of value chains → preferred value chain

- Tested for robustness assuming uncertainties in the external environment

Modeling in practice – example explorative scenario's

Scenario	Description	Main driver
Reference Case	As-Is scenario (no investment to decarbonize allowed)	-
FreeChoice	All investments are allowed	CO_2 tax from 20€/ton in 2020 to 160€/ton in 2050
ForceH2Use	Force hydrogen-use options	CO_2 tax from 20€/ton in 2020 to 160€/ton in 2050
ForceElectrification	Force electrification options	CO_2 tax from 20€/ton in 2020 to 160€/ton in 2050
ForceCCS	Force CCS options	CO_2 tax from 20€/ton in 2020 to 160€/ton in 2050
CO2ReductionLinear	All investments are allowed	CO_2 reduction with 50% of initial emission in 2030 and 10% in 2050

CO2 emission reduction

CO2 Emission [kt /year]

Investment decisions over time…
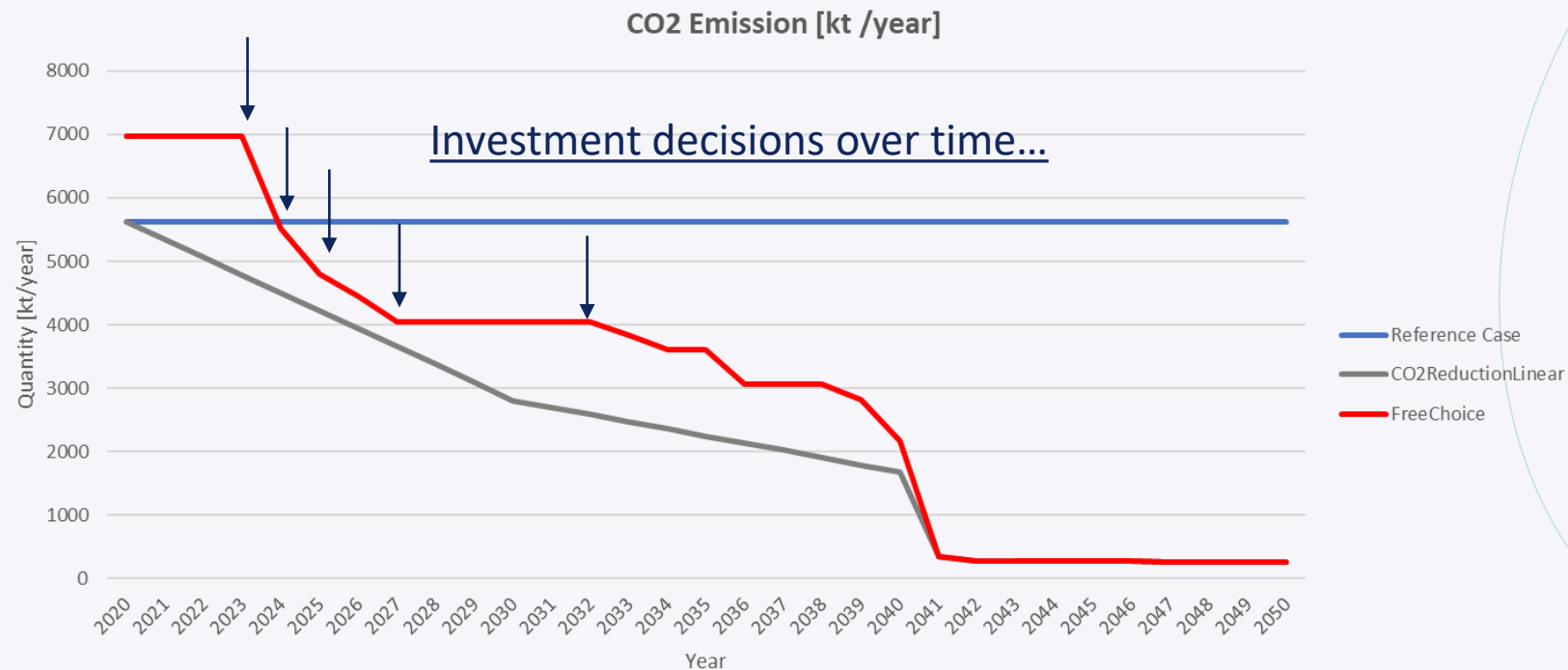
Scenario	NPV
Reference Case	31520
CO2ReductionLinear	36265
FreeChoice	36525

- FreeChoice is more profitable

- Decarbonization investments have a positive margin (costs are lower than avoided CO2 tax)

- Forced emission goals require more investments than free choice

CCS, H2 and Electrification

CO2 Emission [kt /year]
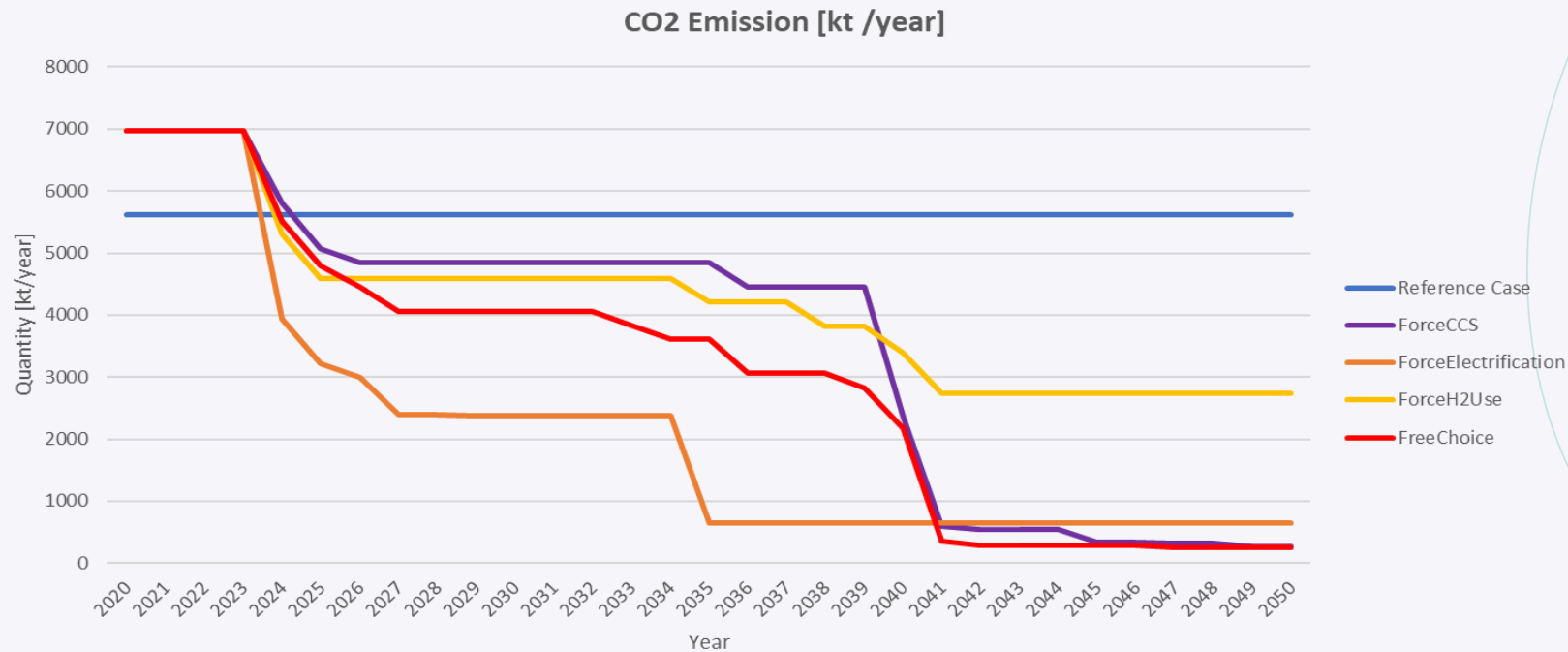
Scenario	NPV
Reference Case	31520
ForceCCS	36143
ForceElectrification	29465
ForceH2Use	34331
FreeChoice	36265

- ForceCCS has the highest NPV, however a relatively late reduction of CO_2
- ForceH2 has high NPV but doesn't lead to CO2 emission reduction
- ForceElectrification decarbonizes fastest at a lower NPV

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So… modeling is all fine, but…

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We aim for *IMPACT*…

- We describe processes and model investment decisions…

- Decisions are made by people…

- Decisions are connected…

- Connection makes complex…

- We embrace complexity and try to provide *actionable insights for decision makers* across companies, along and across new valuechains and at different geographic scales

- To achieve this our models are embedded in lively ecosystems of stakeholders...

Consortium of the HyChain project

Hydrohub

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Kalavasta
Climate Neutral Strategies

Royal HaskoningDHV
Enhancing Society Together

FRAMES

YARA

Nouryon

OCI NITROGEN

DOW

gasunie

QUINTEL INTELLIGENCE

Port of Rotterdam

Vopak

PROTON VENTURES

STEDIN.NET

ECN/TNO
Your energy. Our passion.

TUDelft
Delft University of Technology

Rijksdienst voor Ondernemend Nederland

Scope of the HyChain project

Delfzijl
Eemshaven

Emmen

Amsterdam
Noordzeekanaalgebied

Rotterdam
Moerdijk

Zeeland
Vlissingen Terneuzen

Geleen-Chemelot

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Topquants Spring Event — Energy transition of the industry – It's about time

Aiming for a trusted distributed decision-support-tool

Company

Regional

National

Options
H₂?
Electric?
CCS?

Delfzijl
Eemshaven

Amsterdam
Noordzeekanaalgebied

Emmen

Rotterdam
Moerdijk

Zeeland
Vlissingen Terneuzen

Geleen-Chemelot

Data

Chain model
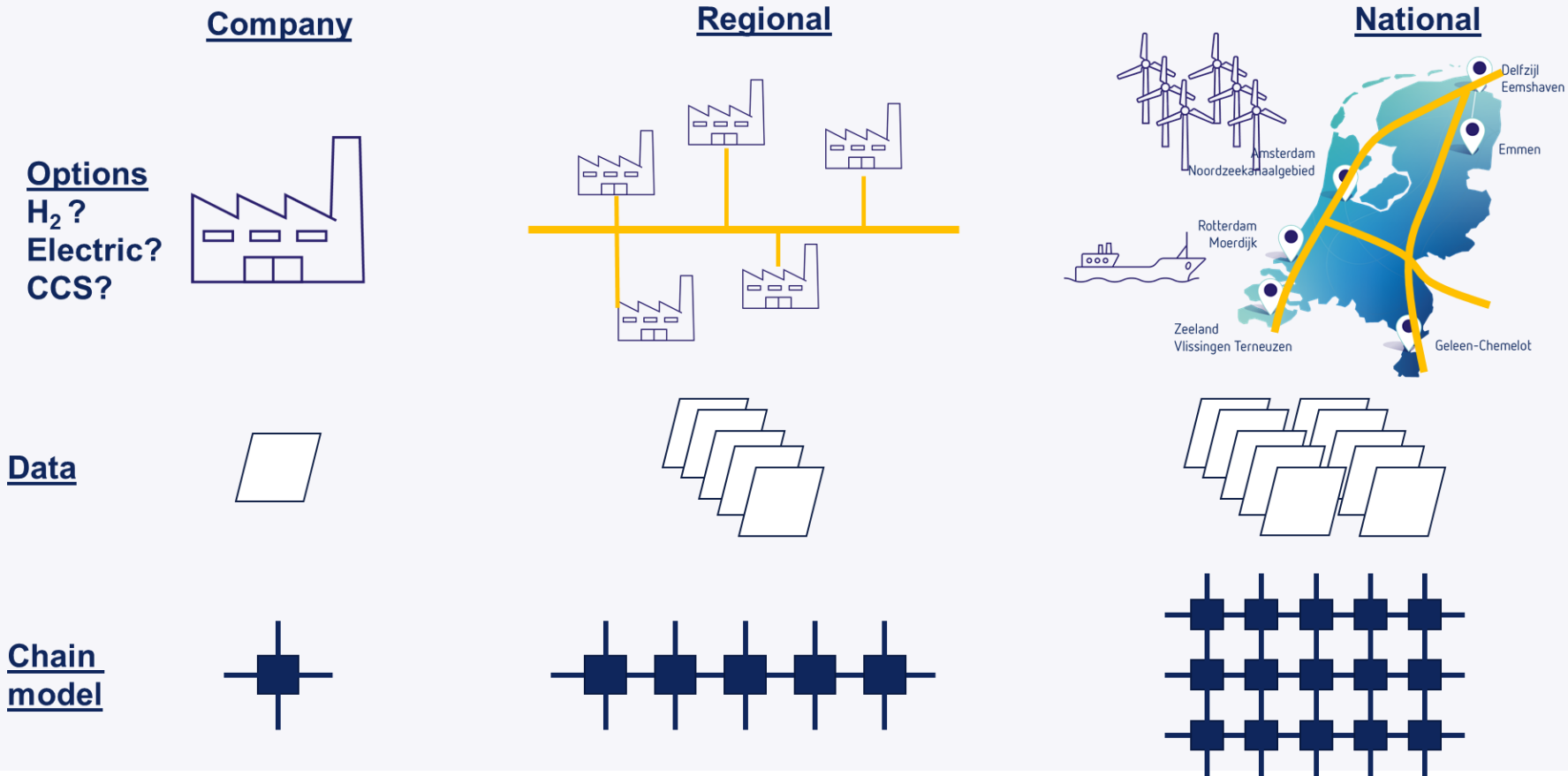
…only just today this came out…

PRESS RELEASE • WIND • 24 JUNE 2021, 11:31 CET • 5 MIN

Vattenfall to sell 49.5% of the offshore wind farm Hollandse Kust Zuid to BASF

Thank You

Contact information

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