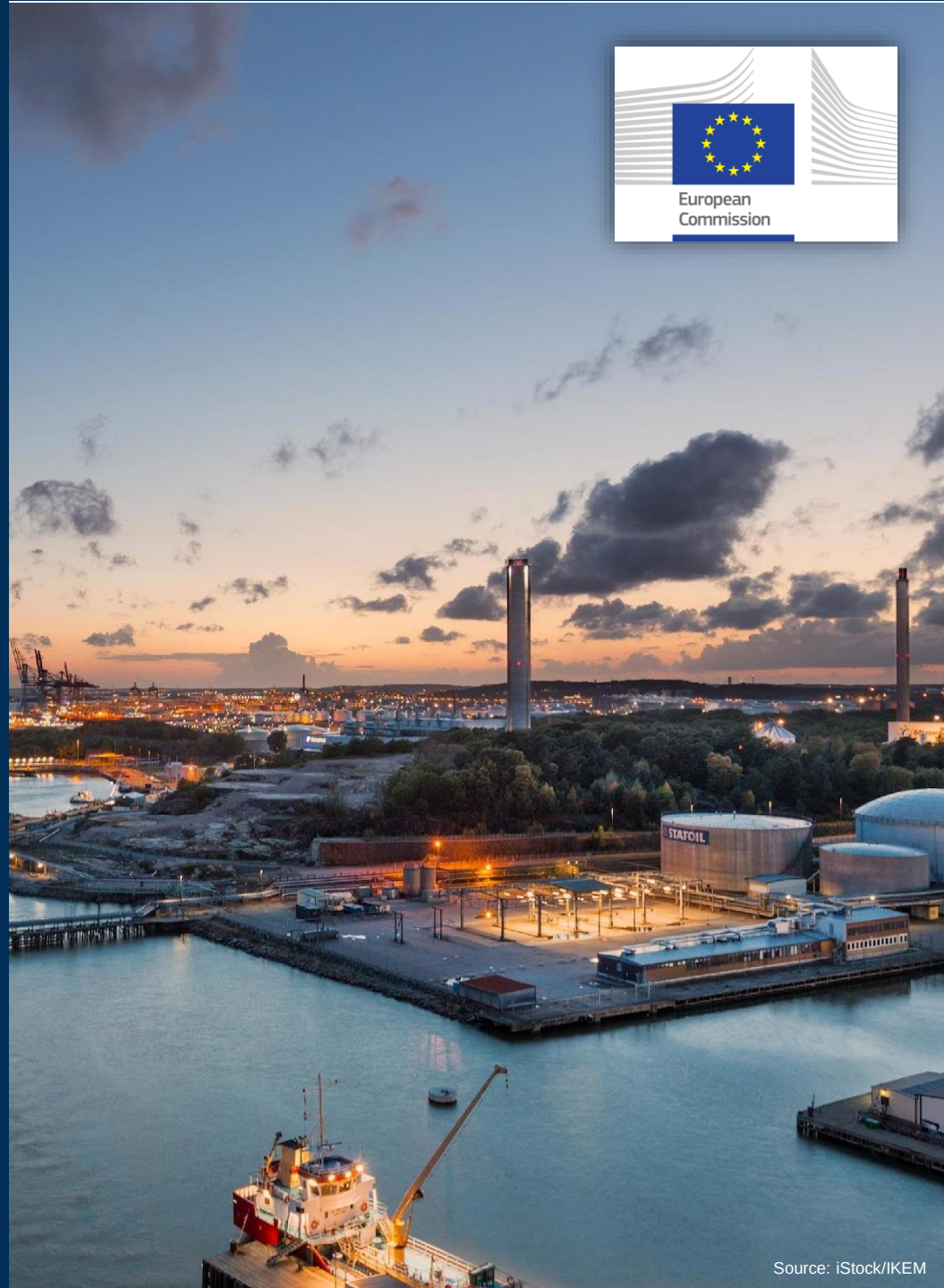
AIDRES

Advancing **I**ndustrial **D**ecarbonisation by assessing the future use of **R**enewable energies in industrial processe**S** (ENER-2020-OP-0011)

Project Results, ECEEE 31 January 2024

Speaker:

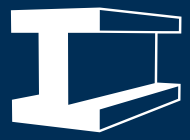
Joris Valee, VITO-Energyville



Source: iStock/IKEM

AIDRES

"**A**dvancing **I**ndustrial **D**ecarbonization by assessing the future use of **R**enewable **E**nergies in industrial processe**S**"



STEEL



CHEMICAL



CEMENT



GLASS



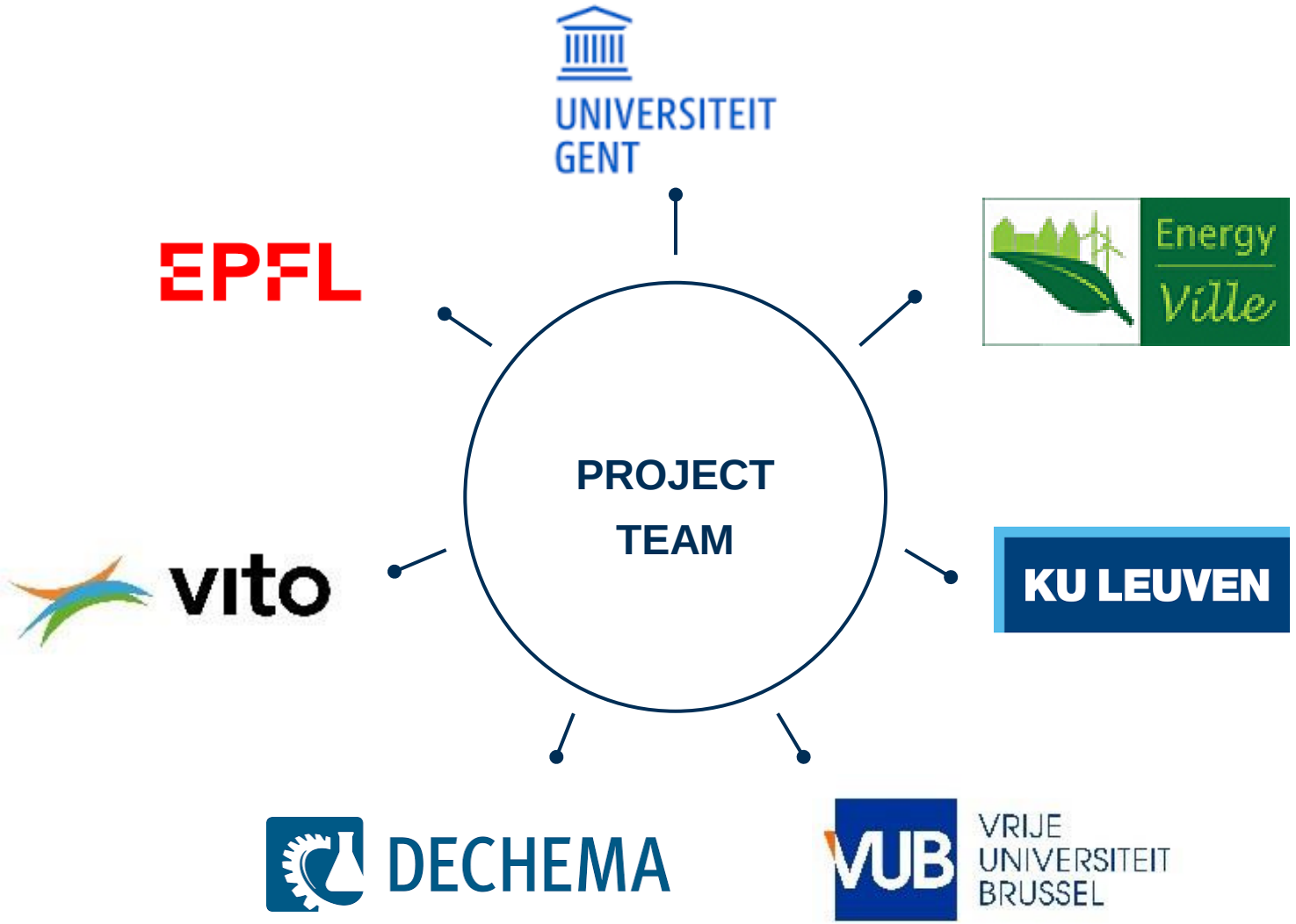
FERTILIZER



REFINERY/ FUEL MANUFACTURING

Source: noun project

AIDRES Project - TEAM



AIDRES Project – Expert reviewers

AIDRES sector	Sector federation & companies
steel	ESTEP, ArcelorMittal
glass	Glass for Europe, Institut du Verre, VUB Vrije Universiteit Brussel
cement	Febelcem, Cembureau, Cemex, VUB Vrije Universiteit Brussel
chemical	Ineos, Cefic, essenscia, Dechema
fertilizers	Yara, VUB Vrije Universiteit Brussel, Dechema
refineries	Concawe, Ineos

Inform

Consult

Review

Adjust

PROJECT TEAM

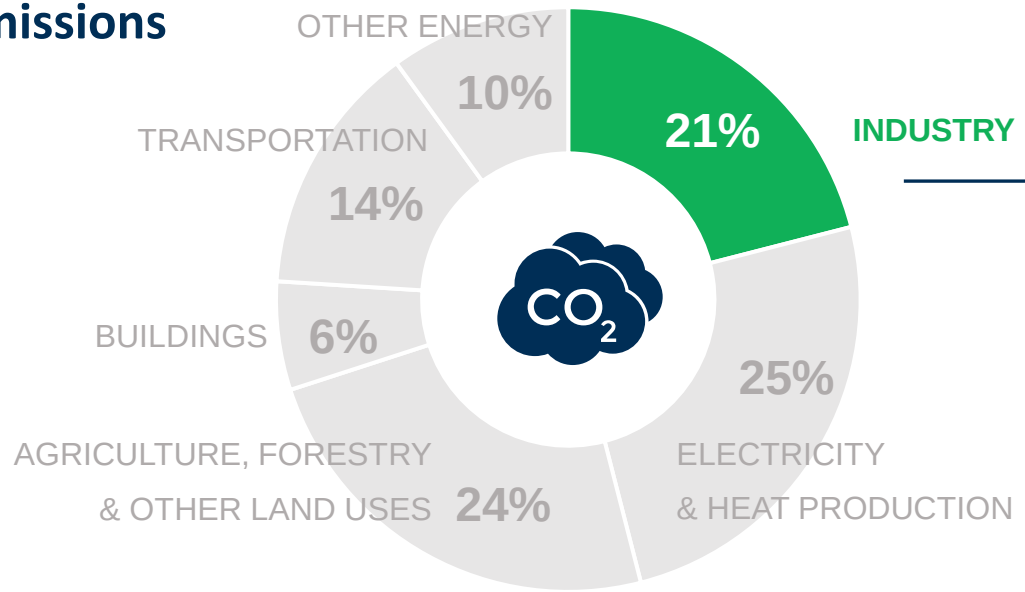
AIDRES Mission

Essential database
to create a sharper picture of potential pathways for EII.

Renewable energy
- demand
- CO_2 emissions
- cost

European Union
For all member states and regions of the EU

CO_2 emissions in EU



Data and concept: The Chemical Engineer/IPCC

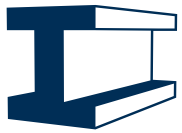
INDUSTRY

CO_2 reduction
- Energy efficiency
- Process integration
- Electrification of heat
- Electrification of processes
- Use of hydrogen
- CCU-S
- Use of biomass

vito

vito.be

SCOPE: 6 energy intensive industries / 14 products



STEEL

- Primary
- Secondary

Excl. steel finishing sites



CHEMICAL

- Olefins
- Polymers
- Organic synthesis

Excl. Other basic chemicals and downstream products



CEMENT

- Portland cement II
- LC3 cement



GLASS

- Flat
- Container
- Fibre glass



FERTILIZER

- Ammonia
- Urea
- Nitric acid



REFINERY/ FUEL MAN.

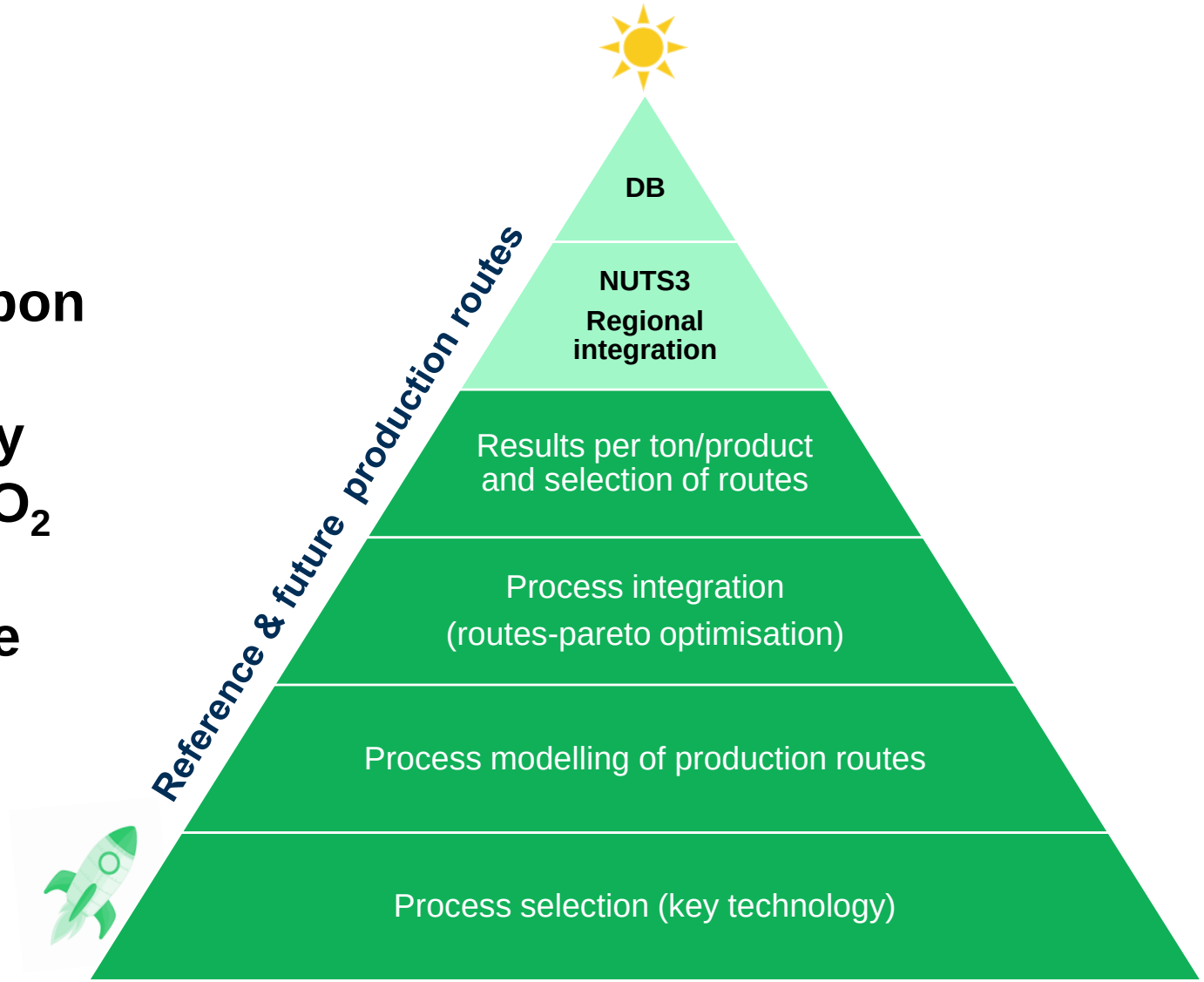
- Light liquid fuel

(63,8% of product out of crude oil)

Excl. naphta, heavy fuel, other

AIDRES Approach

- Assessment of **industrial technology pathways to carbon neutrality**
- Quantification of **future energy and feedstock needs, and CO_2 captured**
- **Geographical mapping of the needs** at facility and NUTS3 levels.

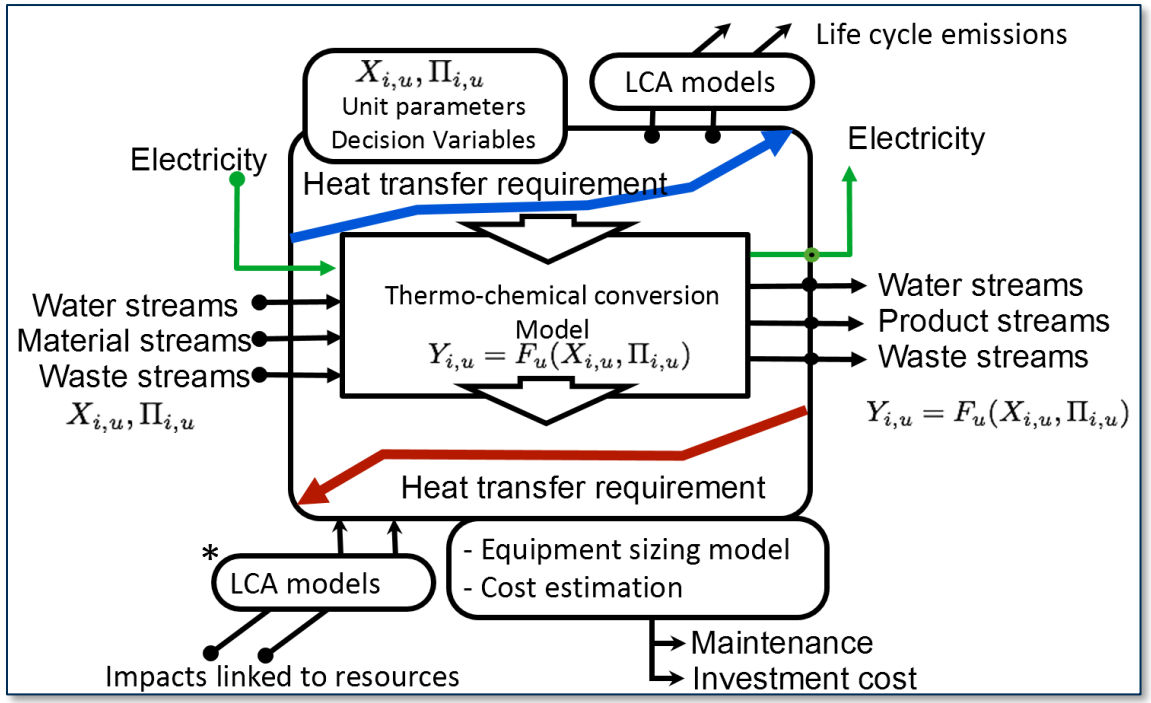


**The model does not optimise over the full time horizon 2018-2050.*

Industrial production routes approach

BLUEPRINT

A representative profile of an industrial process as a collection of its sub-processes, including energy and resource interfaces.



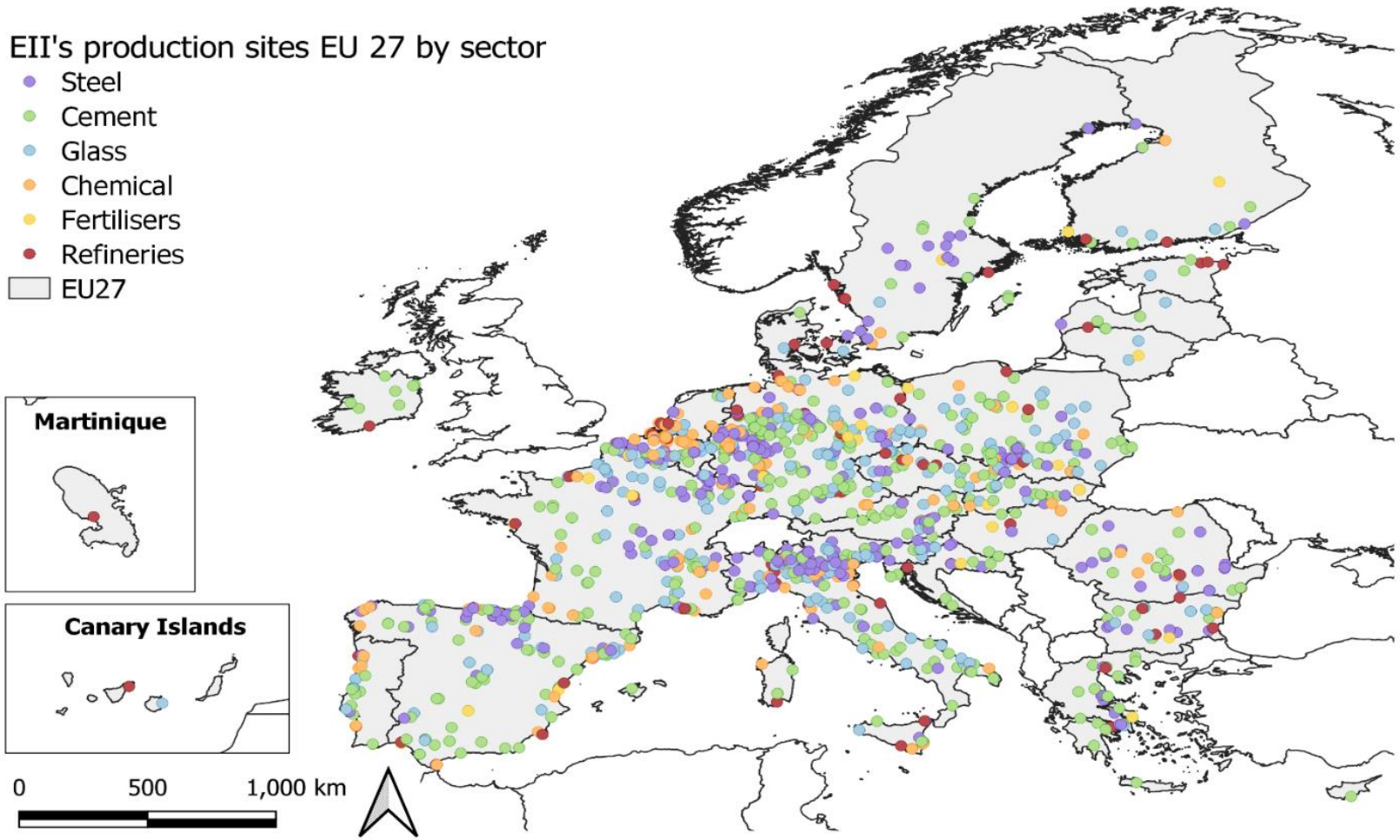
AIDRES approach:

- Current industrial energy and feedstock inputs.
- Improvement of mature processes with novel technologies.
- Consideration of future alternatives.
- Generating a solution space of options and scenarios.

Industrial plants mapping approach: per sector

sector	#production sites
Steel	372
Cement	436
Glass	319
Chemical	258
Fertiliser	39
Refinery/Fuel Man.	112
Total	**1536**

A **production site** is the geographical unit that combines production installations from one sector and specific company in space. E.g., a chemical production site (BASF Ludwigshafen) can group more than 40 production installations from the chemical sector at one site.

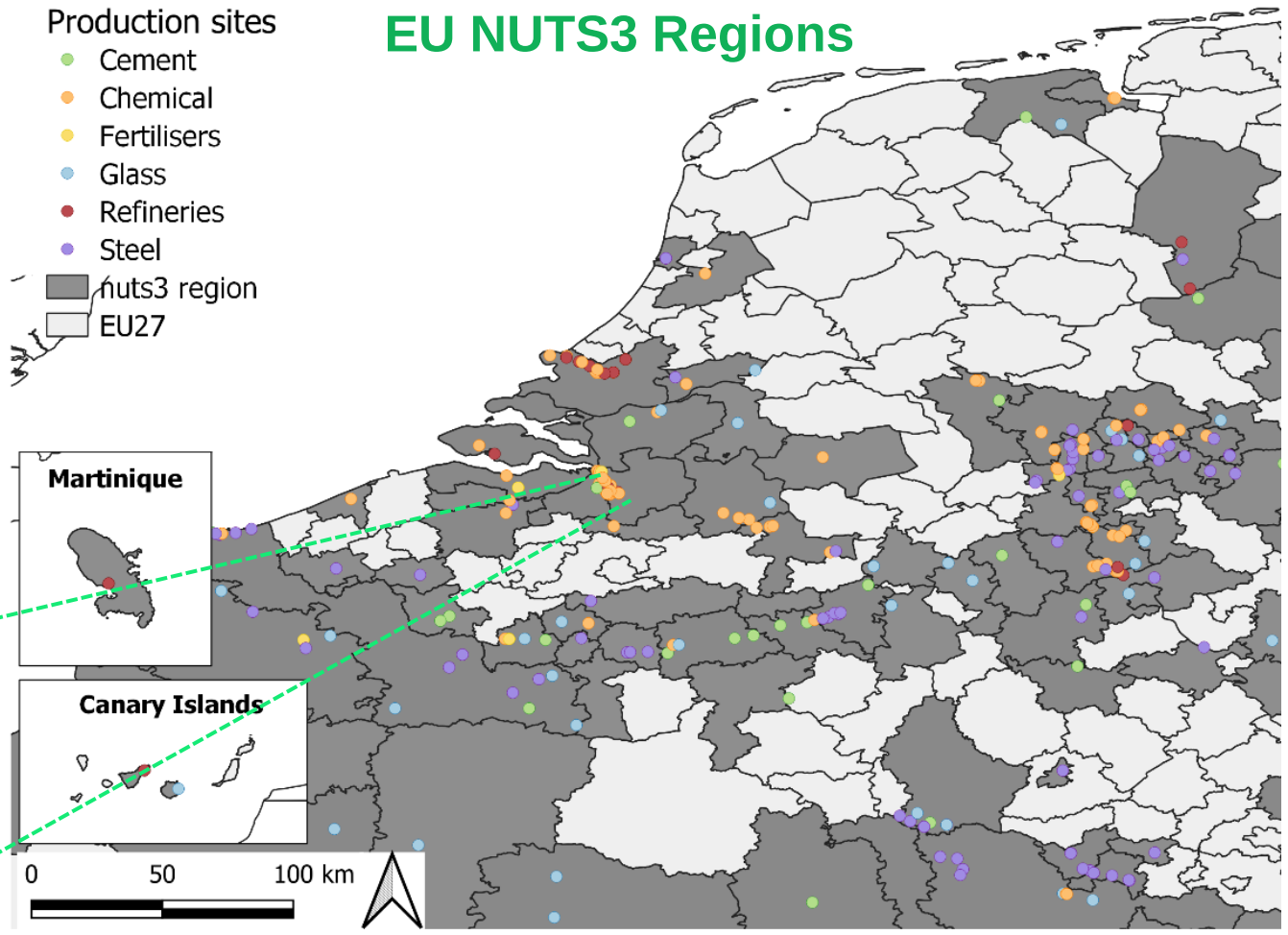


Industrial plants mapping approach: Regionalisation

sector	#production sites
Steel	372
Cement	436
Glass	319
Chemical	258
Fertiliser	39
Refinery	112
Total	**1536**

BE211 - Antwerp

- Energy, feedstock, material, demand.
- Production rates, product and co-product flows
- Emission rates
- CAPEX/OPEX



Industrial production routes: scenario's

Nr	Year	Description	€/t_{CO_2}	€/MWh electricity	kg_{CO_2}/MWh electricity	€/kg H_2	kg_{CO_2}/kg H_2	€/MWh NG
0	2018	Reference	25	125	231	1.8	8.2	24.4
1	2030	low H_2 price	150	71	120	3	0	25
2	2030	low H_2 - high NG price	150	71	120	3	0	50
3	2030	high H_2 price	150	71	120	5	0	25
4	2030	high H_2 - high NG price	150	71	120	5	0	50
5	2050	low H_2 price	350	71	0	1.5	0	35
6	2050	low H_2 - high NG	350	71	0	1.5	0	50
7	2050	high H_2 price	350	71	0	2.5	0	35
8	2050	high H_2 - high NG price	350	71	0	2.5	0	50

[1]ETS, 150 €/tCO2 (2030), 350 €/tCO2 (2050) based on respective Fit for 55 MIX Scenario values.
Natural gas (NG) prices 0.025 €/kWh (2030), 0.035 €/kWh (2050) based on respective Fit for 55 Scenario values.
Source: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12265-2030-Climate-Target-Plan_en

Electricity CO2 intensity, 0.12 tCO2/MWh (2030), '0' tCO2/MWh (2050) based on respective Fit for 55 MIX Scenario values and as agreed with EC.
H2 prices Derived from range: 2.7-5.7 €/kg (2030), 1.2-2.9 €/kg (2050).
Own calculation based on technical parameters from EC Ref Scenario (07/2021)
Electricity price, 71 €/MWh based on Fit for 55 'Mix Scenario' (2030) and EC Ref Scenario (2050); 40 €/MWh as sensitivity for regional and technology specific context.
Source:https://energy.ec.europa.eu/system/files/2021-07/ref2020_energy-transport-ghg_0.xlsx

H2 impact [kgCO2/kgH2] to be assumed '0', as 'green' molecule.
H2 based on fossil fuels (SMR process) represented in AIDRES Blueprint model.

Industrial plants mapping approach: database essentials

AIDRES DATABASE



Industrial site

- Sector
- Production capacity or rate [kt/y]

NUTS 3

- Sector
- Scenario conditions
- Production routes
- 16 Final energy vectors
- TOTEX = OPEX + CAPEX [m€/y]
- Direct and indirect emissions [$ktCO_2/y$]
- Captured CO_2 [$ktCO_2/y$]

AIDRES: Blueprint methodology

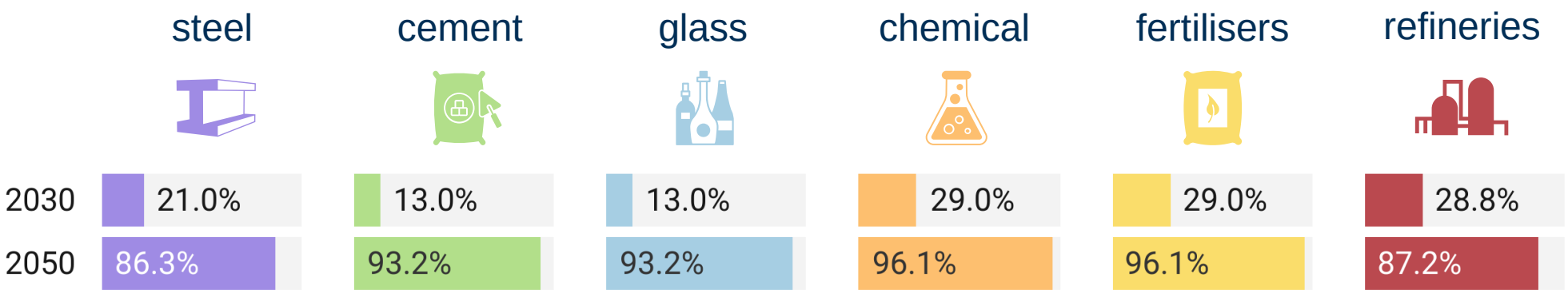
DG ENER/JRC-EIGL: Publication & visualisation

Energy vectors [PJ/y]

- Electricity
- Hydrogen
- Natural gas
- Naphtha
- Methanol
- Biomass
- Biomass waste
- Coal
- Plastic mix
- Coke
- Crude oil
- Biodiesel
- Spent solvent mixture
- Solid recovered fuel
- Alternative fuel mixture
- Plastic mix

Industrial production routes: emission reduction targets

- Direct CO_2 emissions target by sector, related to process and energy, based on **EU PRIMES MIX** scenario[1].
- Targets for 2030 and 2050 compared to yearly reported average 2015-2019.
- CO_2 emission reduction progress from 1990 till 2015-2019 are considered.



Created with Datawrapper

[1] https://climate.ec.europa.eu/eu-action/european-green-deal/2030-climate-target-plan_en#documents

AIDRES EU Mix routes

Several production routes have been selected in line with EU CO_2 reduction pathways (2030, 2050).

Why?

- **Uncertainty of future production routes** for each industrial plant.
- Inspired by **sector reports and studies**.
- One **AIDRES EU Mix route** has been created **for each product.**
- A **balanced hypothetical alternative** to represent values of **energy and feedstock inputs**.



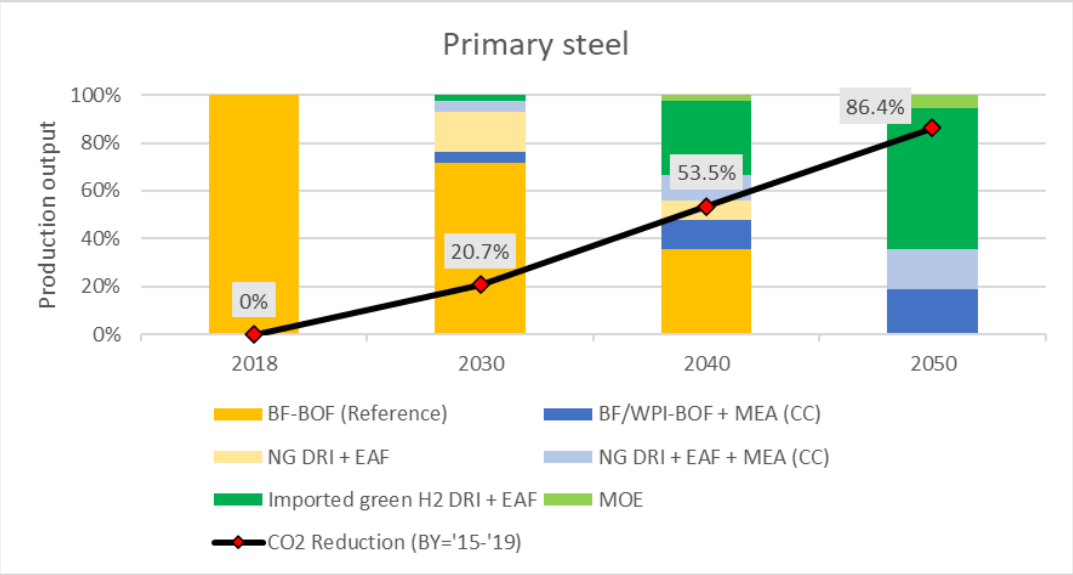
Source: Tales of the cocktail foundation

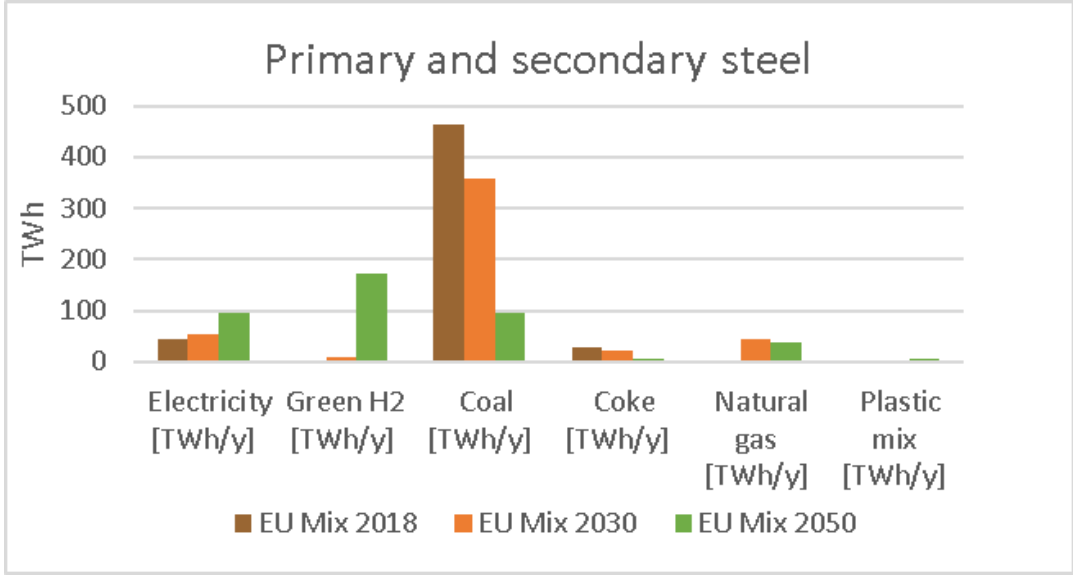
Industrial production routes: sector results

steel

AIDRES EU mix primary steel production routes[1]:

- Hydrogen direct reduced Iron (H-DRI): **59%**
- Carbon capture-based routes: **26%**
- Other technologies e.g. MOE: **5%**





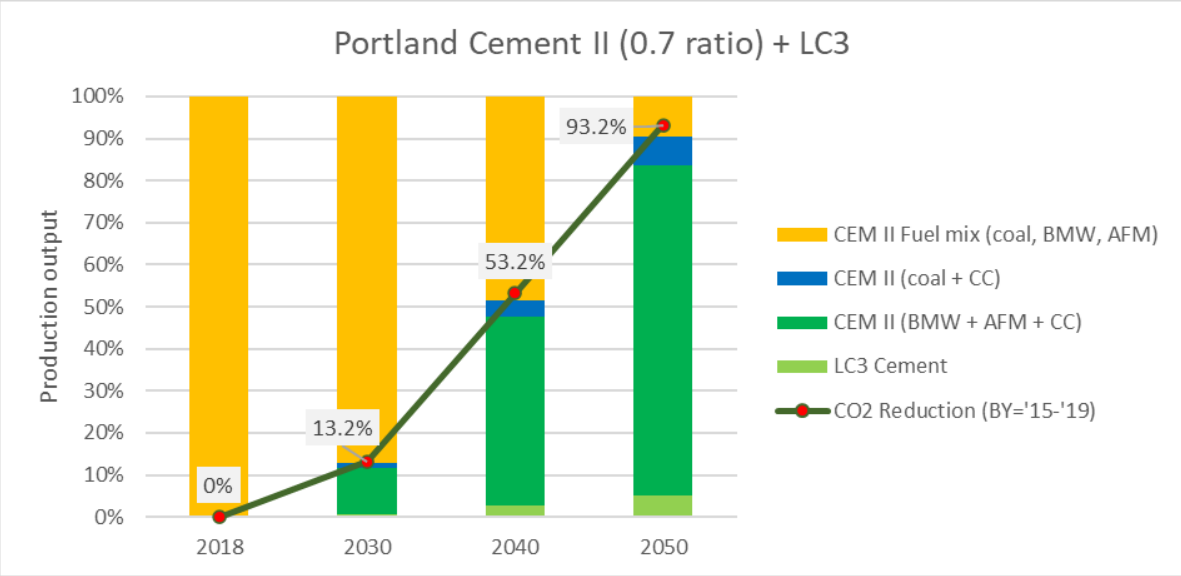
[1]Sources:
https://www.eurofer.eu/assets/Uploads/EUROFER-Low-Carbon-Roadmap-Pathways-to-a-CO2-neutral-European-Steel-Industry.pdf
https://www.estep.eu/assets/Uploads/D1.7-Decarbonisation-Pathways-2030-and-2050.pdf
https://iea.blob.core.windows.net/assets/eb0c8ec1-3665-4959-97d0-187ceca189a8/Iron_and_Steel_Technology_Roadmap.pdf

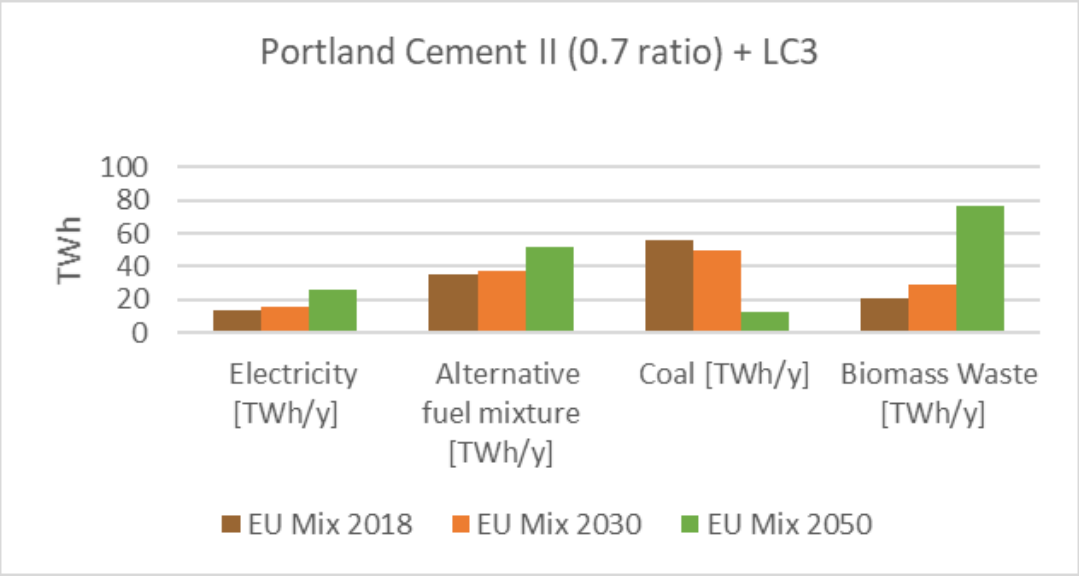
Industrial production routes: sector results

cement

AIDRES EU mix cement production routes[1]:

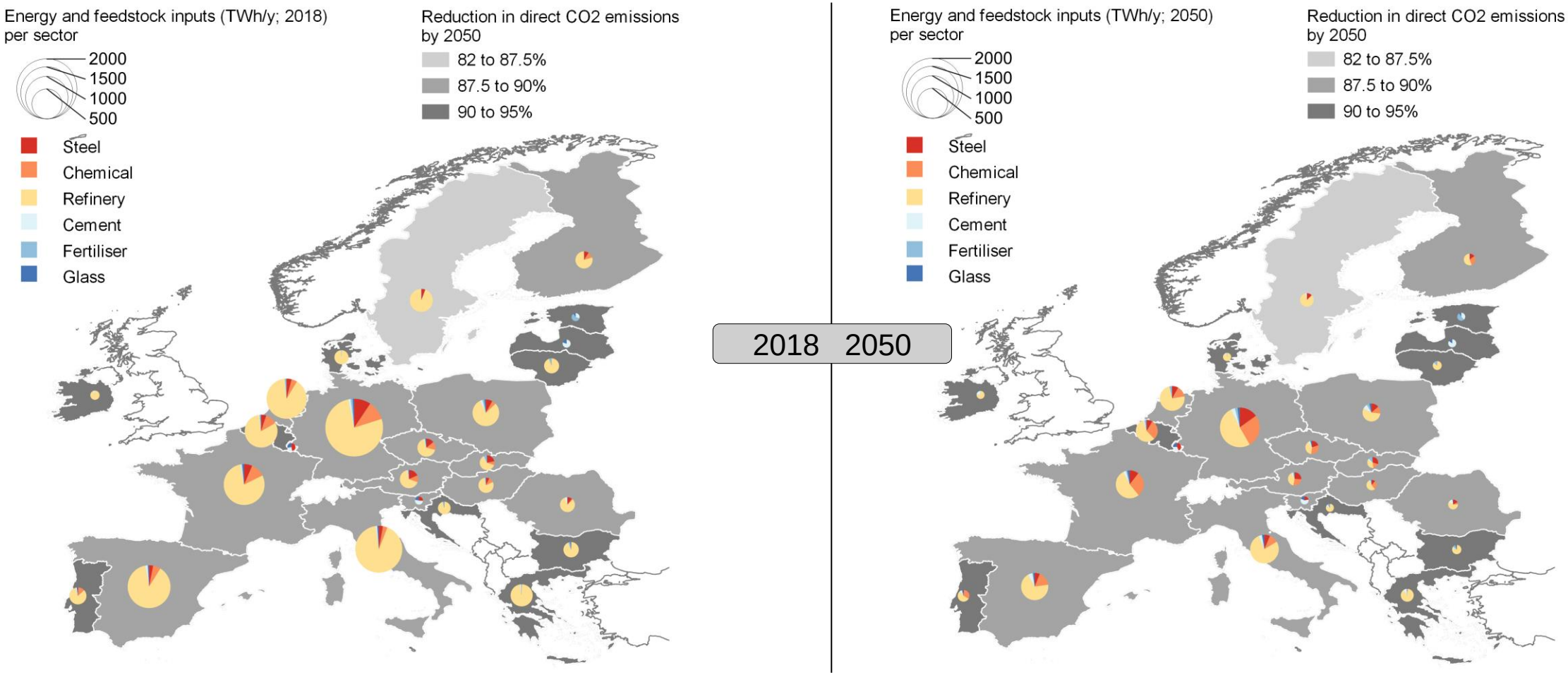
- Fuel replacement to alternative fuels (AFM) biomass waste (BMW) in combination with carbon capture: **85%**
- Coal + carbon capture: **5%**
- Limestone Calcined Clay Cement (LC3): **5%**





[1]Sources:
T. E. C. A. CEMBUREAU, "Cementing the European Green Deal, Reaching Climate Neutrality along the Cement and Concrete Value Chain by 2050," 2020.
https://cembureau.eu/media/kuxd32gi/cembureau-2050-roadmap_final-version_web.pdf

Industrial AIDRES EU mix production routes: EU27 by sector



Based on AIDRES EU Mix Reference and 2050 routes. Scales of Luxembourg, Estonia, Latvia and Slovenia x 3

Key findings, AIDRES EU mix routes

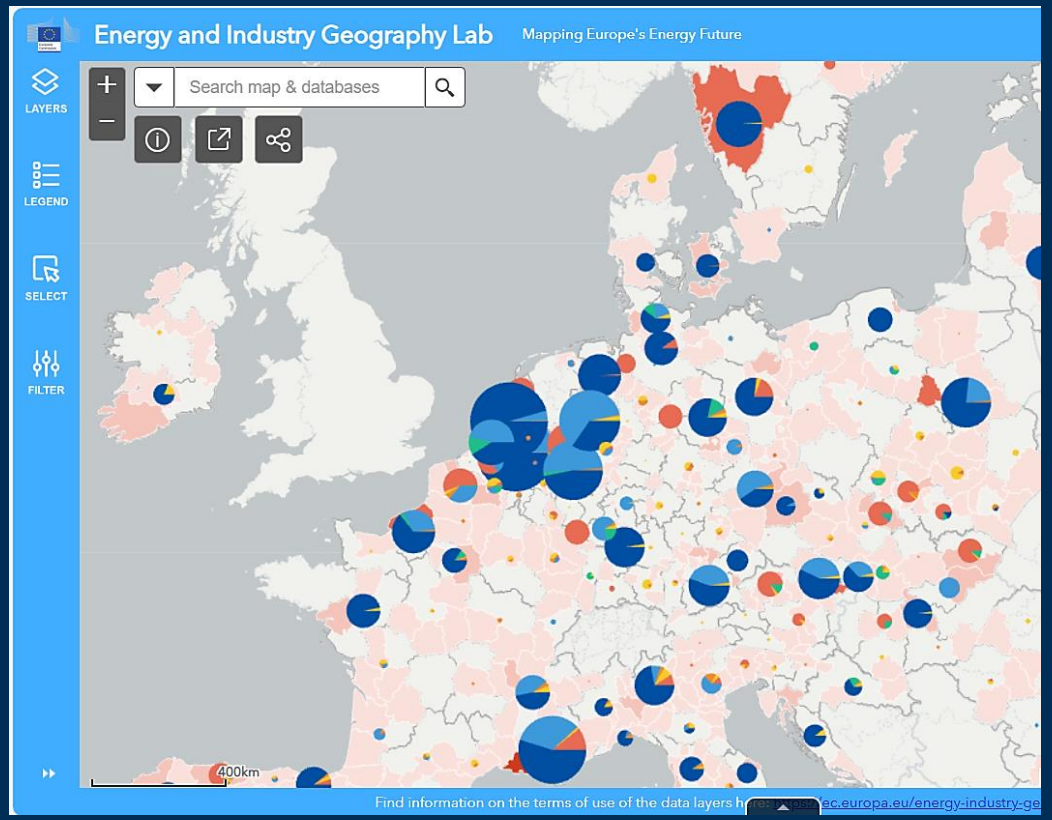
- By 2050, around **2000 TWh** additional new renewable energy and feedstock inputs.
- **Biomass could have a significant role** (> 900 TWh) in the chemical and refinery sectors by 2050.
- The cement sector to rely on **biomass waste and alternative fuel mixtures**, along with **carbon capture** technologies such as oxy-fuel combustion and calcium looping.
- **Green hydrogen to become an essential energy vector** for steel, fertilizer and chemical sectors.
- **Methanol** to replace naphtha as vital feedstock for the chemical sector.
- **Strong decline of coal and natural gas**, however, they can still have a role in some sectors combined with **carbon capture**.

Go out there, use the AIDRES database, and build your own scenarios!

Keep in touch!

AIDRES RESULTS

[Project final report]
[Database SQL format]
[Database XLS format]
[Visualisation on JRC EIGL website]



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AIDRESProject@vito.be

BACKUP SLIDES

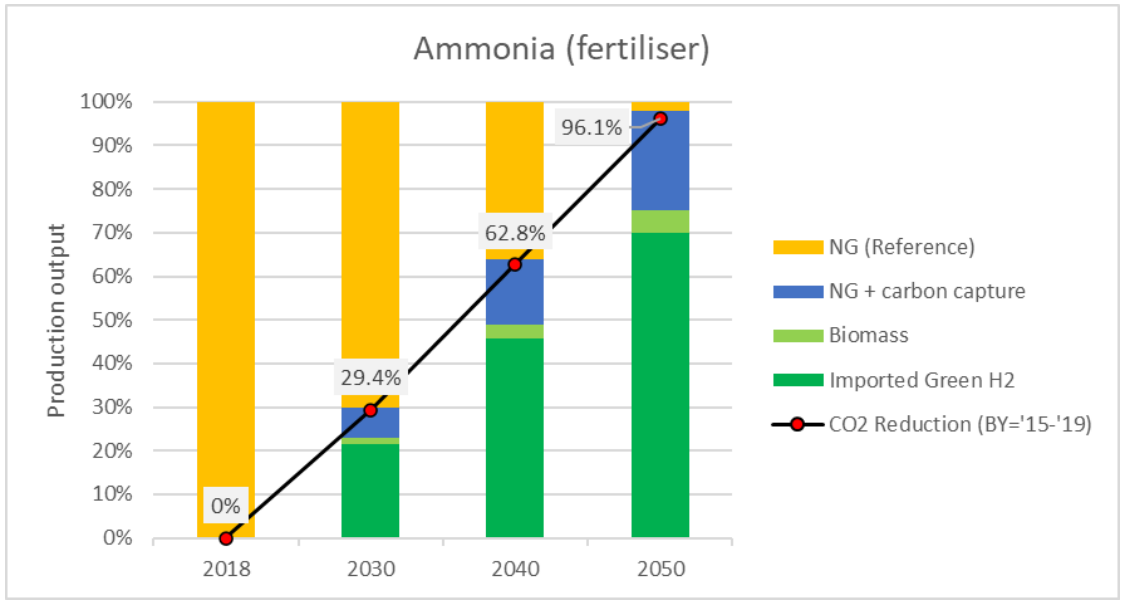
Other AIDRES Sectors results

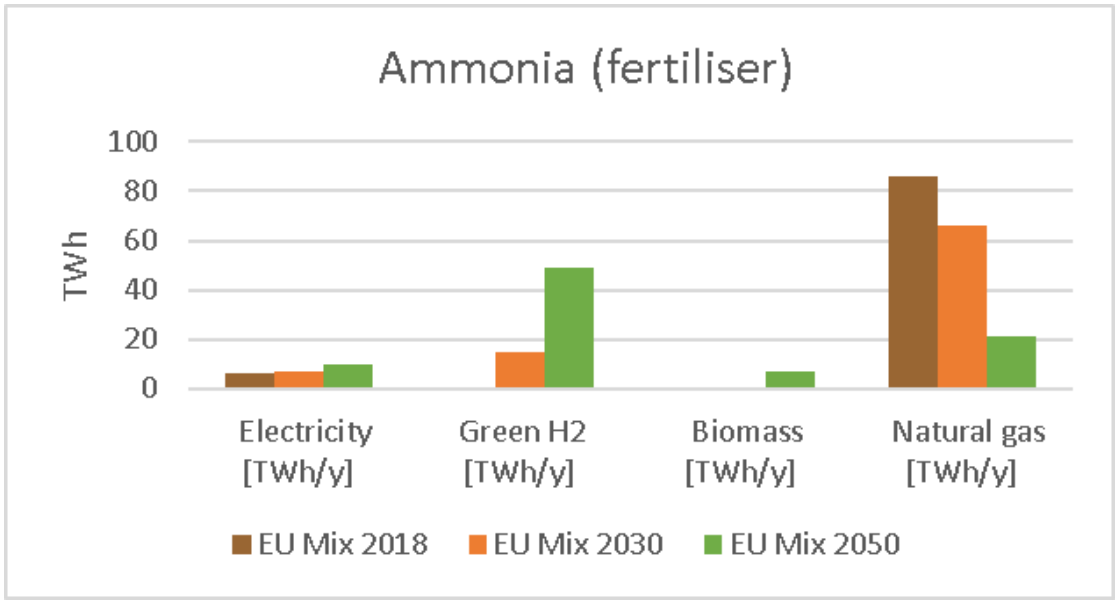
Industrial production routes: sector results

fertiliser

AIDRES EU mix fertiliser production routes[1]:

- Green hydrogen: **70%**
- SMR route, partially coupled with carbon capture and pyrolysis: **25%**
- Role of biomass is limited, however could appear in selected regions: **5%**





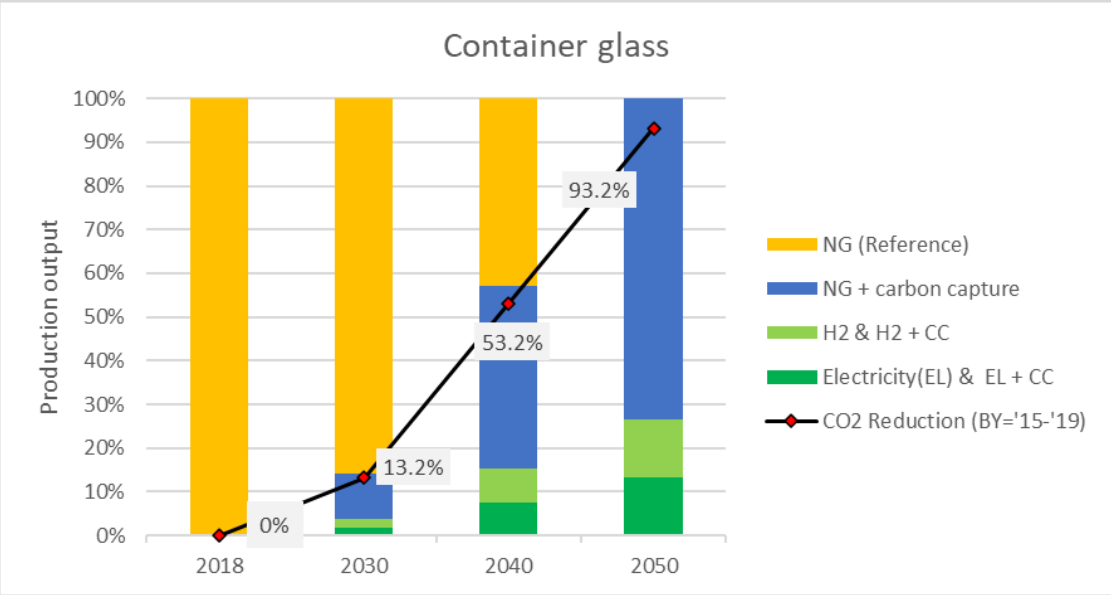
[1]Sources:
International Energy Agency, Ammonia Technology Roadmap: Towards more sustainable nitrogen fertiliser production. OECD, 2021
10.1787/f6daa4a0-en

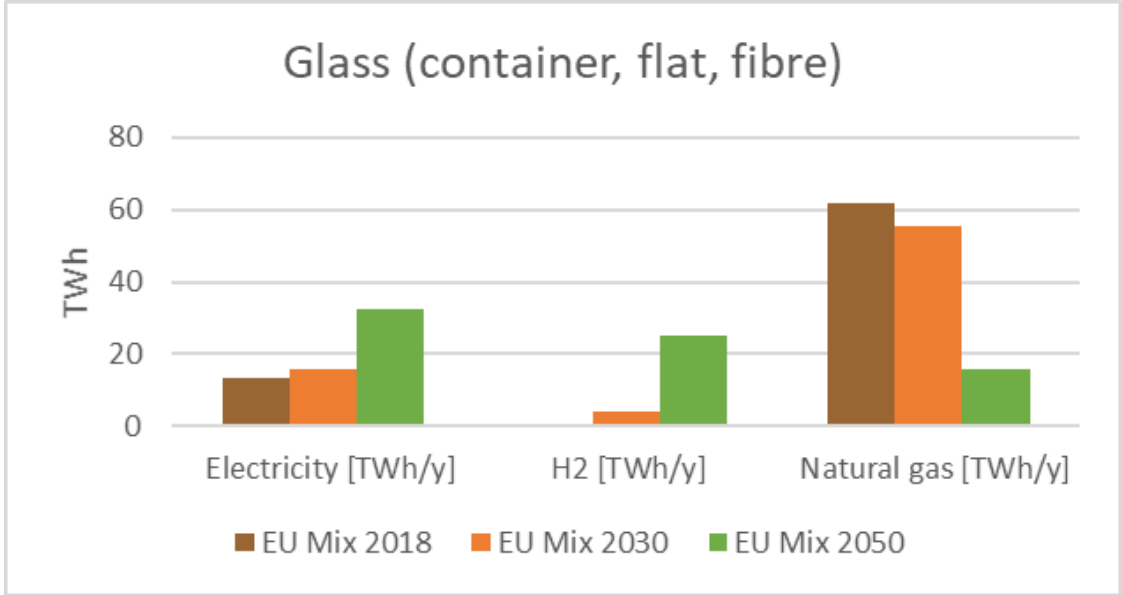
Industrial production routes: sector results

glass

AIDRES EU mix 2030 and 2050 glass production routes[1]:

- Electrification +/- CC: **13%**
- Green hydrogen +/- CC: **13%**
- Natural gas +/-CC: **73%**





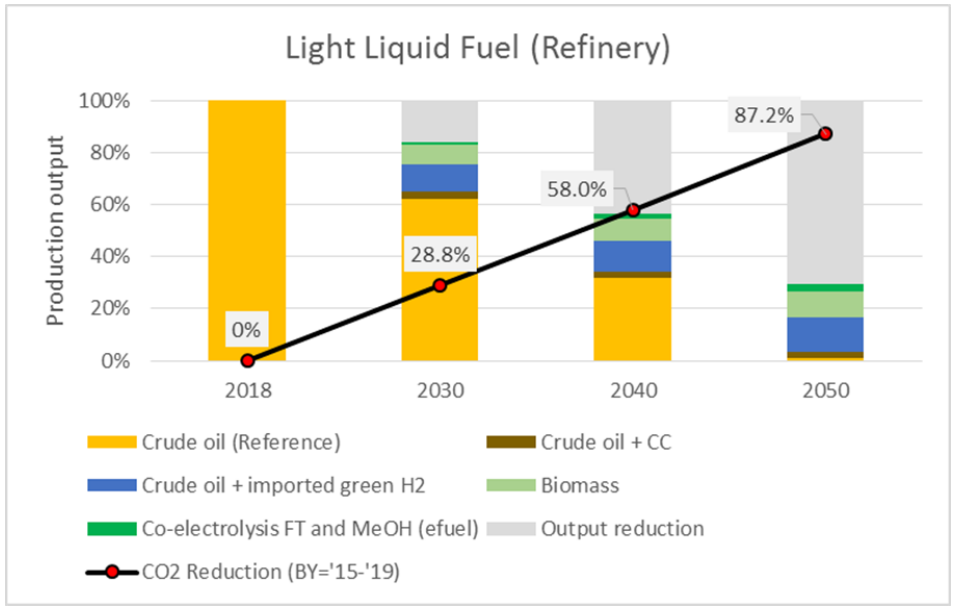
[1]Sources:
Glass for Europe, "2050 Flat glass in a Climate-Neutral Europe," Brussels, 2020. https://glassforeurope.com/wp-content/uploads/2020/01/flat-glass-climate-neutral-europe.pdf
The European Container Glass Federation (FEVE), "Furnaces of the Future - A Fundamental Milestone Towards Climate-Neutral Glass Packaging," 2023. https://feve.org/glass-industry/projects/furnace-future/
The European Container Glass Federation (FEVE), "Container Glass To Reduce Co2 By 50%,". https://feve.org/wp-content/uploads/2020/03/Furnace-of-the-Future-Press-Statement-Final-Version-16032020-for-distribution.pdf
AGC and Saint-Gobain, "AGC and Saint-Gobain Partner for the Decarbonization of Flat Glass Manufacturing, https://www.saint-gobain.com/sites/saint-gobain.com/files/media/document/20230206_AGC_Saint-Gobain_VA.pdf

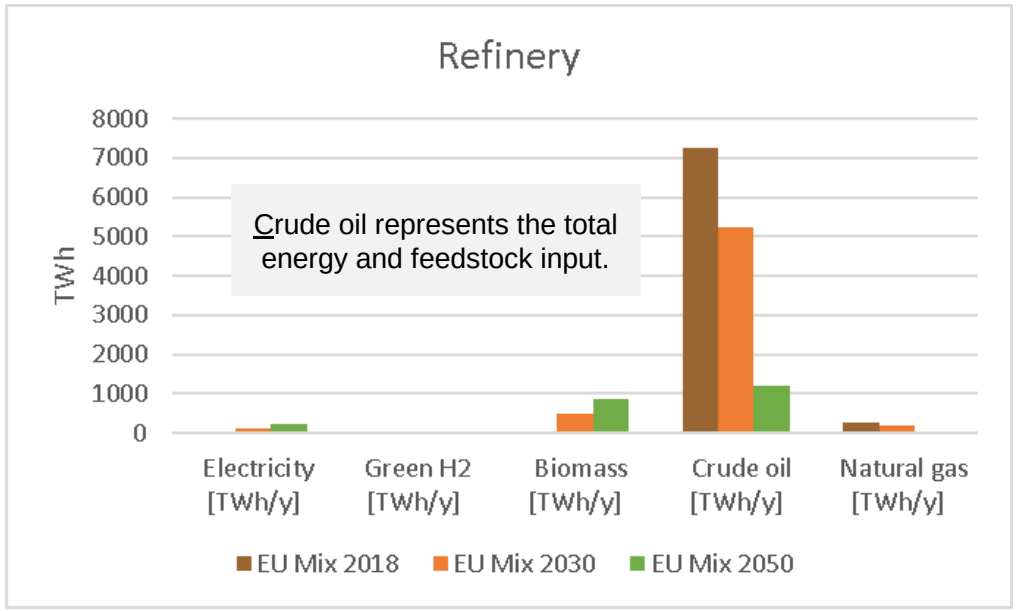
Industrial production routes: sector results

refineries

AIDRES EU mix light liquid fuel production routes[1]:

- Refinery activities are heavily influenced by decreasing fossil fuel consumption in the transport sector, leading to a reduction in output of roughly **70%** by 2050.
- Efuels (**27%**), advanced biofuels (**22%**) , fossil fuels, partly produced with green H2 (**51%**)





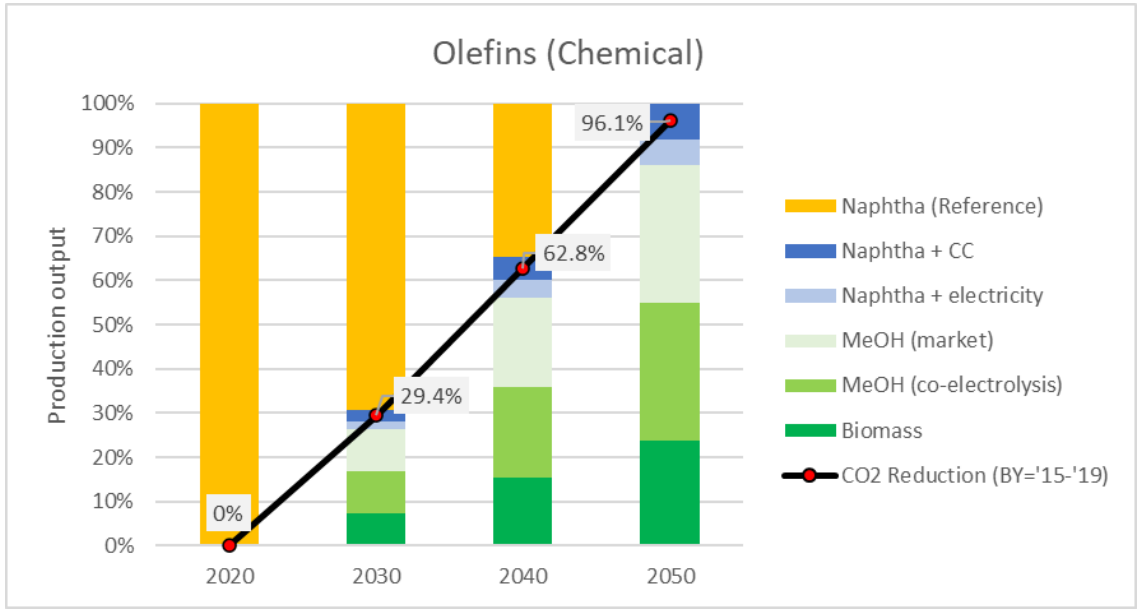
[1]Sources:
Concawe, "Transition towards Low Carbon Fuels by 2050: Scenario analysis for the European refining sector," Brussels, 2021. https://www.concawe.eu/wp-content/uploads/Rpt_21-7.pdf

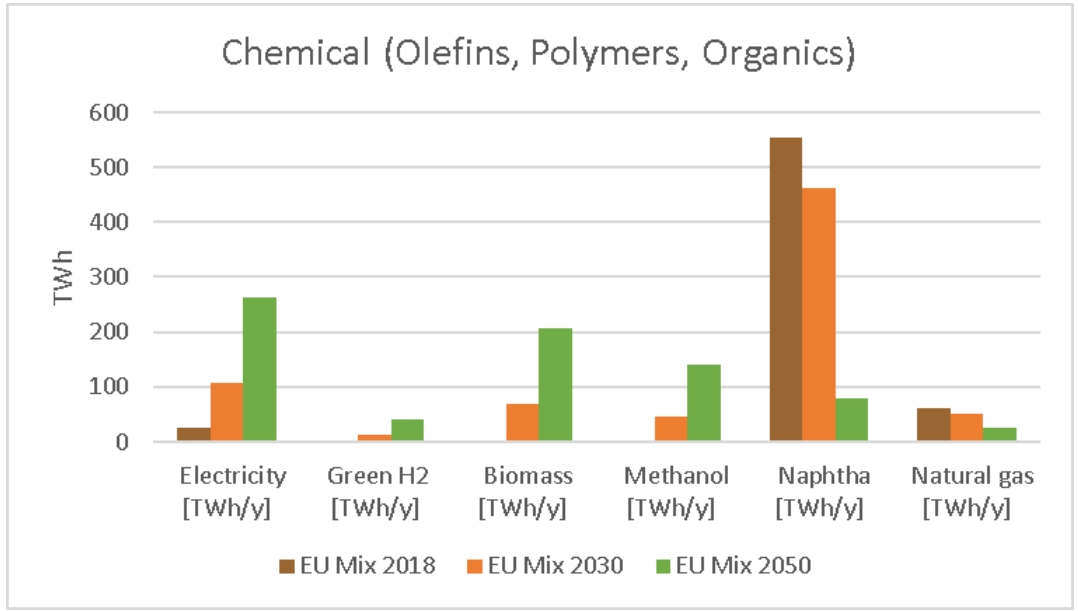
Industrial production routes: sector results

chemical

AIDRES EU mix chemical production routes[1]:

- Since olefins are linked to polymers, it is assumed the starting point for the products in the chemical sector.
- Naphtha + CC: (**8.1%**), electrification of crackers (**6%**), methanol market (**31.1%**), methanol biomass (**23.7%**), methanol CO-electrolysis (**31.1%**)





[1]Sources:
BloombergNEF, "$759 Billion Required for a Net-Zero Petrochemicals Sector by 2050," May 24, 2022.Available: https://about.bnef.com/blog/759-billion-required-for-a-net-zero-petrochemicals-sector-by-2050/