Klimaatdag

Samen voor fossielvrij

2 mei 2024 | Heusden-Zolder

vvsg heusden zolder Vlaanderen is energie en klimaat

Sessie A.1

De zin en onzin van waterstof door Pieter Vingerhoets

Pieter Vingerhoets | Energie-expert, Vito

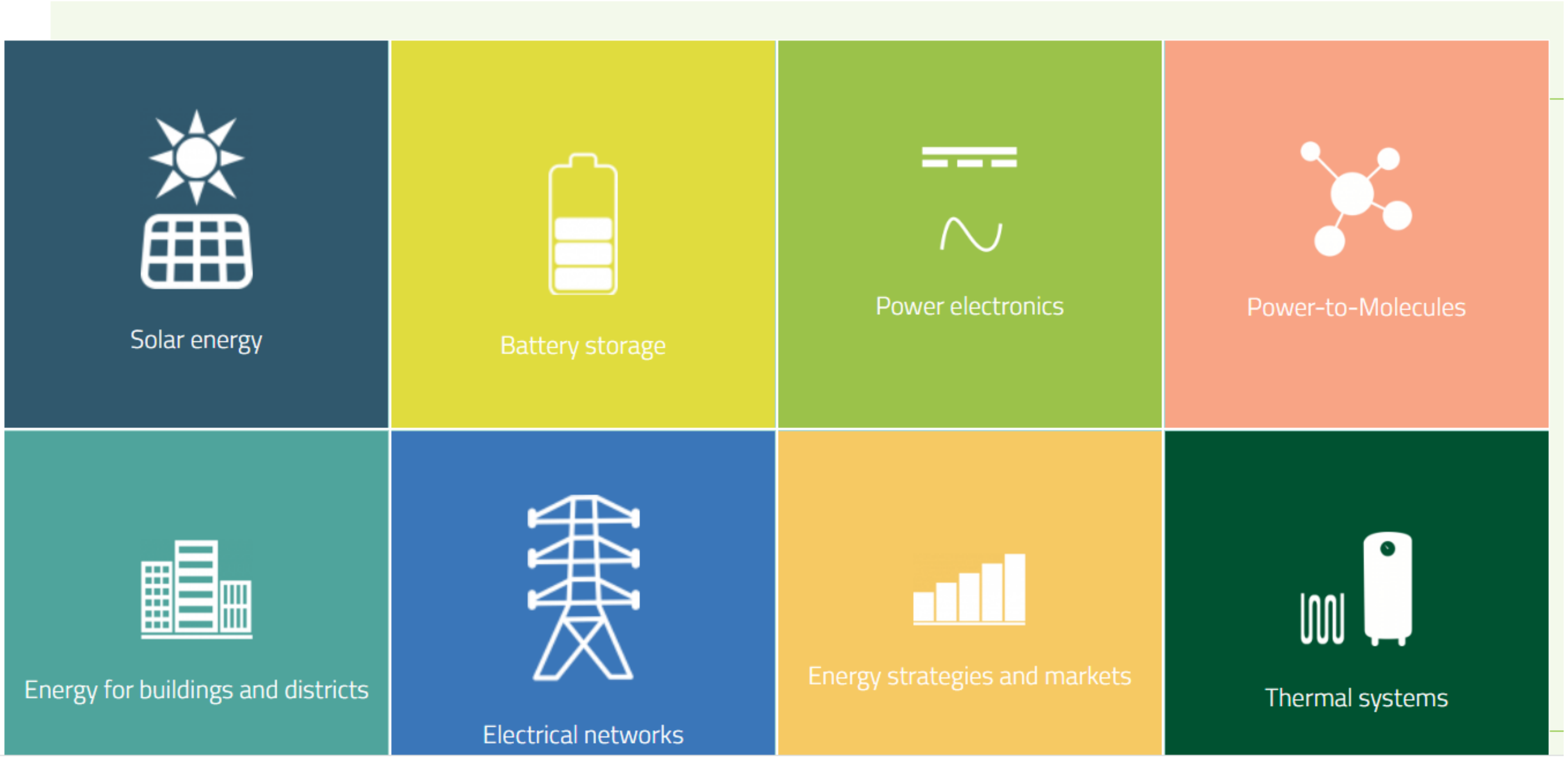
The role of hydrogen in the energy system

Pieter Vingerhoets

23/04/2024

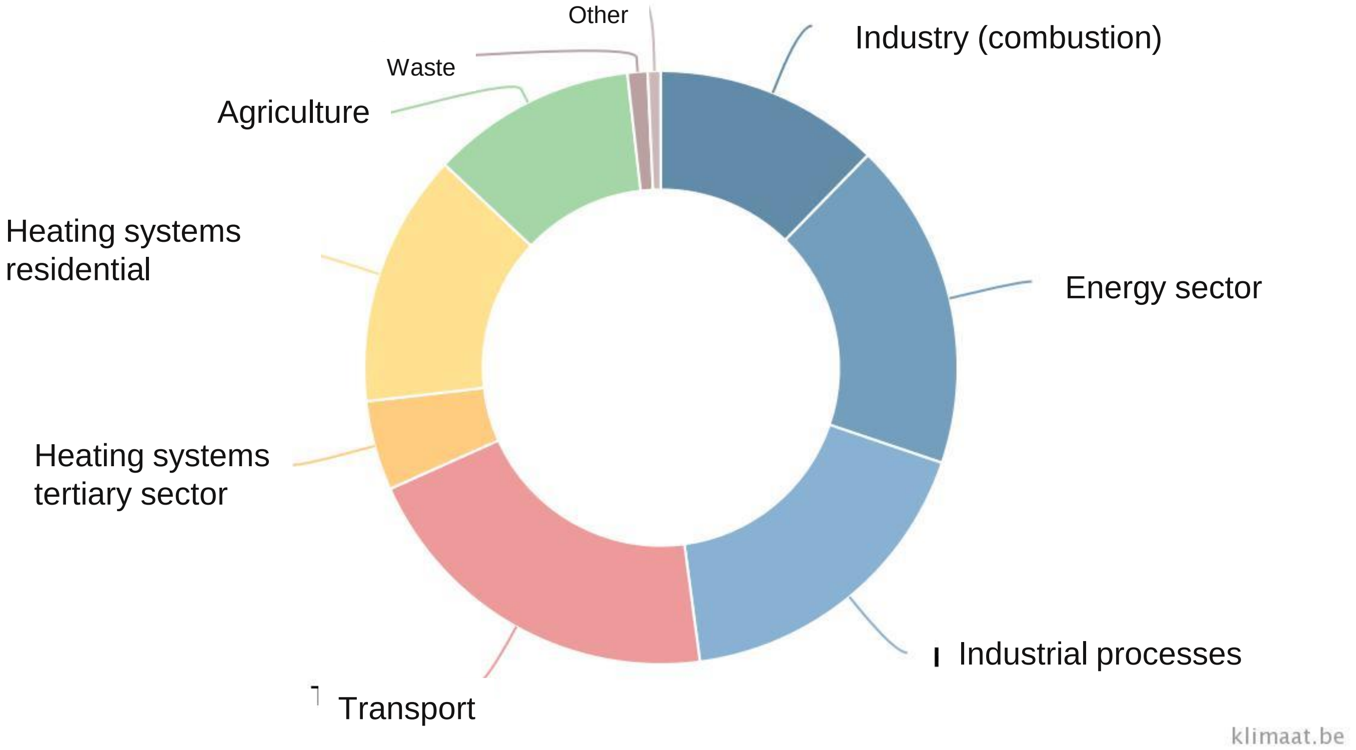
EnergyVille

- Energy teams of VITO, KULeuven, Imec and Uhasselt
- www.energyville.be
- Pieter.vingerhoets@energyville.be



The challenge in Belgium and EU

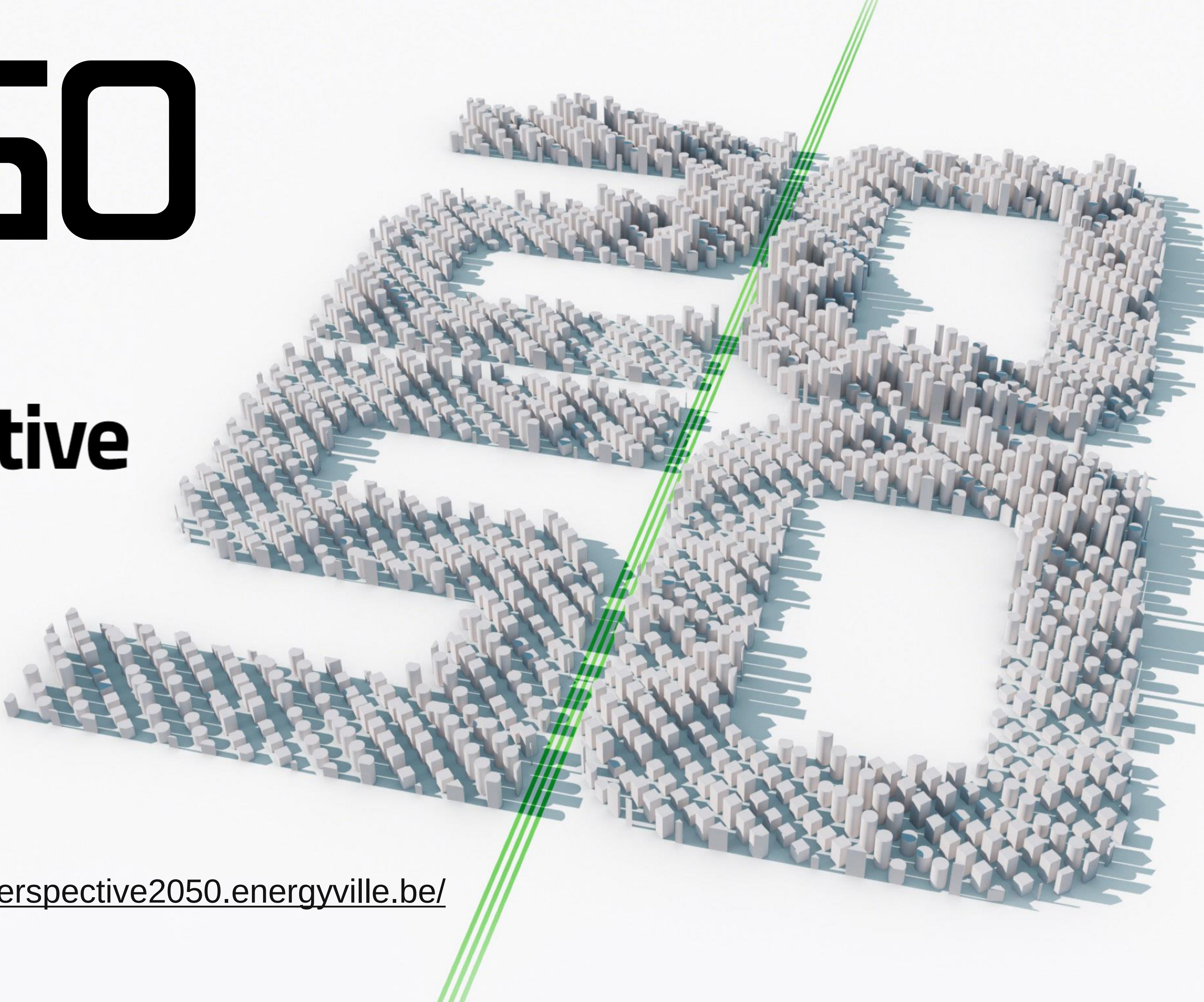
Percentage of different sectors in Belgian emissions 2021 (111 Mton CO_{2eq})
Not including emissions for international shipping and aviation



Energy balance 2019 (TWh)	EU (TWh)	BE (TWh)
Gross available energy	~17000	~750
Primary energy supply	~16000	~640
Final energy consumption	~11000	~420
Final non-energy consumption	~1000	~84
Final electricity consumption	~2500	~82

PATHS 2050

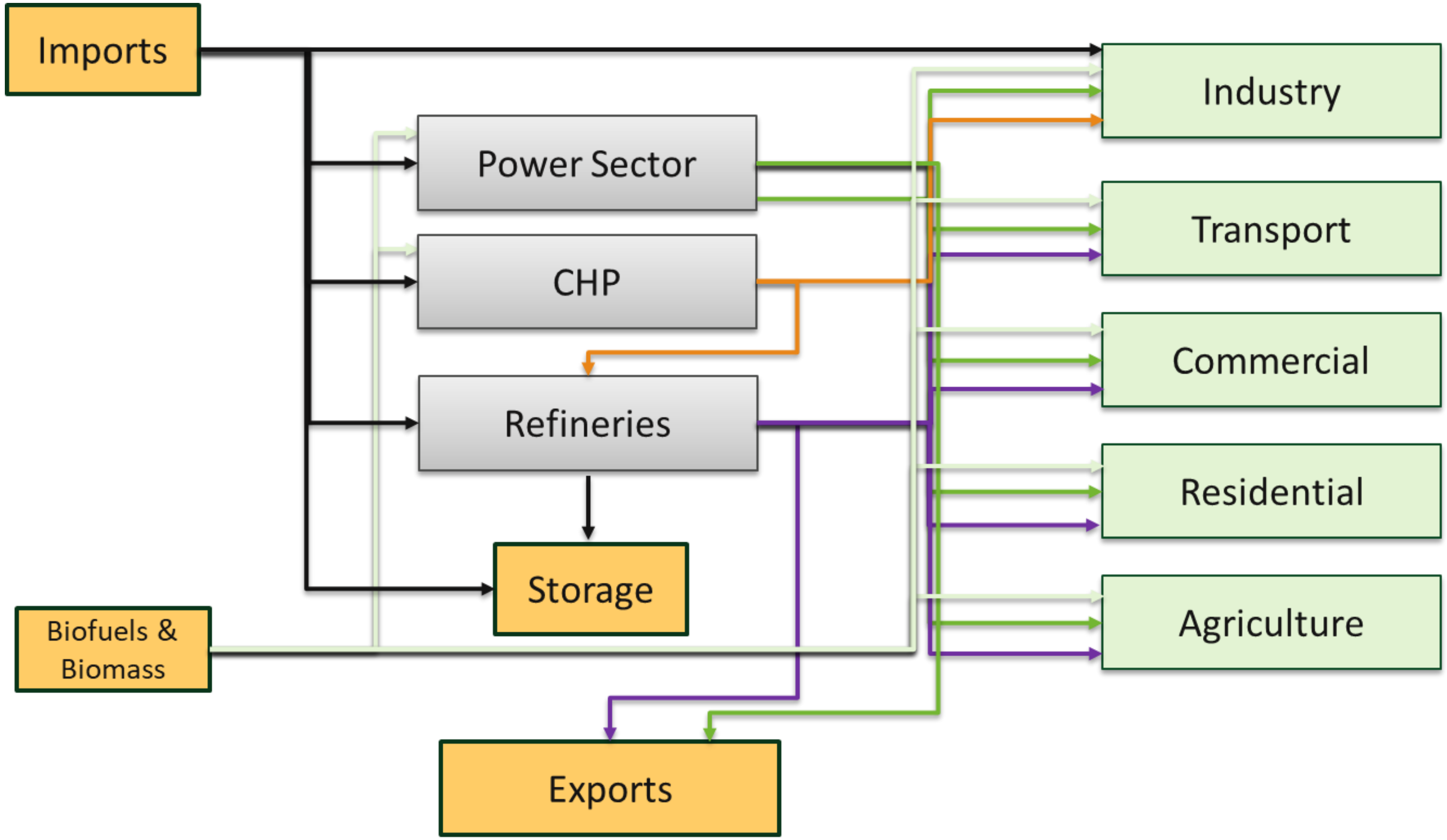
The Power of Perspective



Energy Ville

https://perspective2050.energyville.be/

The BE - TIMES model



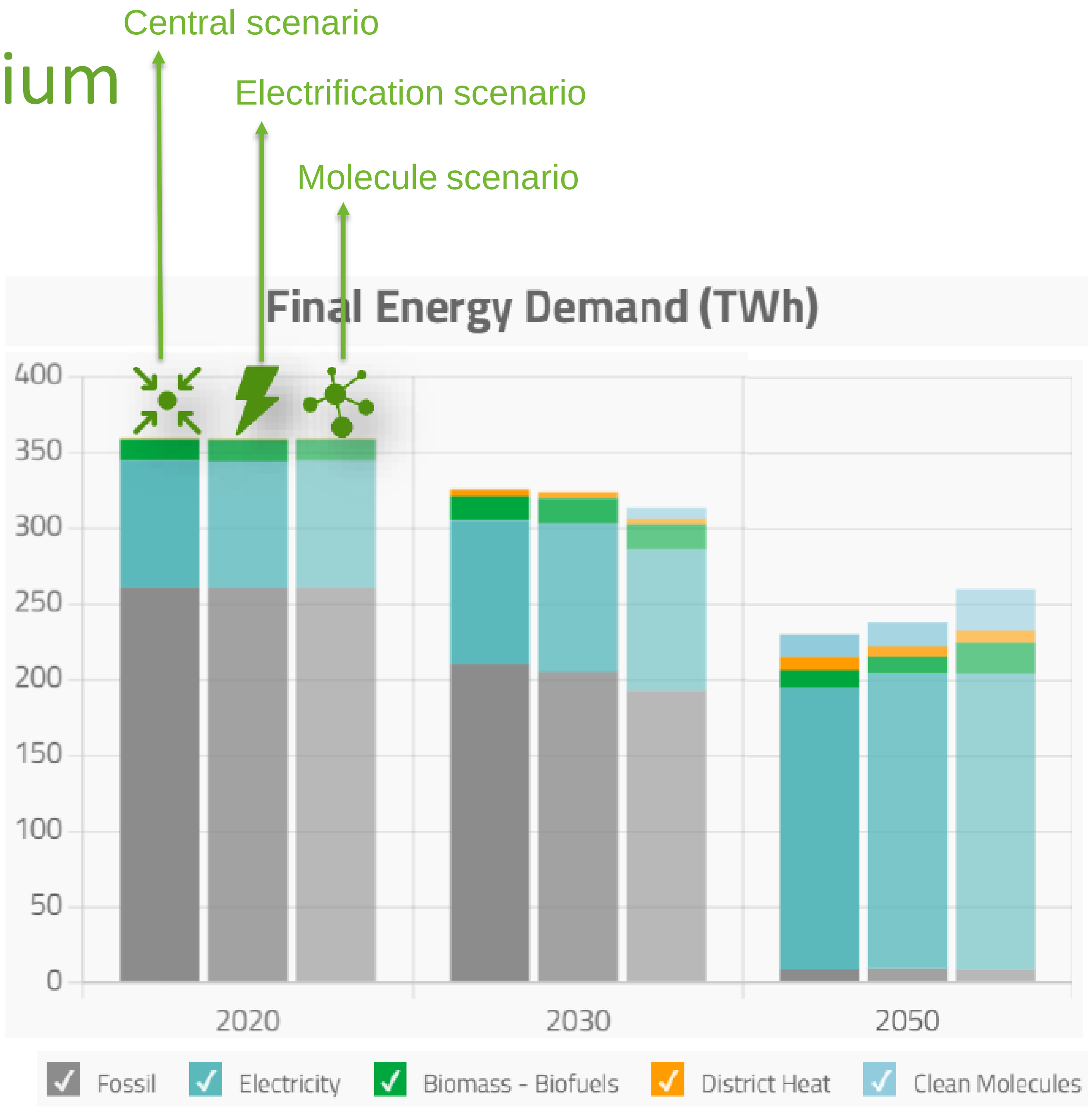
- Cost optimization over all sectors and time horizon
- No subsidies/taxes, only underlying techno-economic costs
- Optimization model ≠ prediction, 'What should be' ≠ 'What will be'

Final energy demand Belgium

ALL scenarios: industry constant

ALL scenarios: no major behavior shift

- Central:
  - GIS potentials for wind/solar
  - Unlimited CCS
- Electrification
  - Access to +16GW of offshore wind
  - New nuclear investments possible in 2045
- Molecules
  - Cheap import of hydrogen (1.7€/kg in 2050)
  - Limit on CCS (5Mton/year)

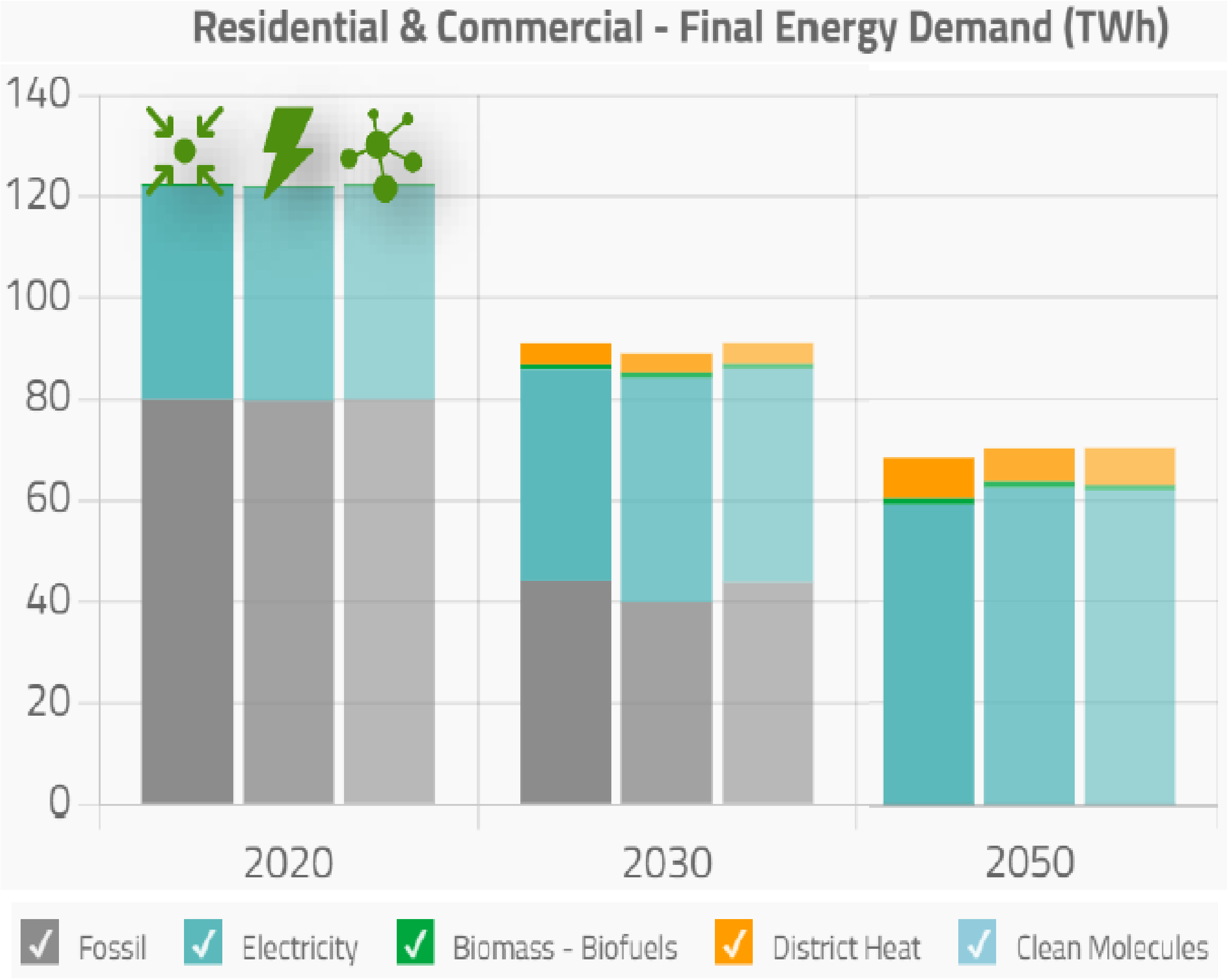


Electrification and energy efficiency reduce the energy needs for the same services

Residential & commercial

Renovation & electrification

- Large deployment of heat pumps
- Immediate renovation of old building stock
- Not all houses renovated conform with EPC A.
- District heating has higher transport losses, but allows connecting waste heat sources in high demand areas (e.g. one geothermal heat pump at the corner of the street).
- NO gas distribution grid anymore in 2050
- NO or very marginal role for hydrogen or biofuels

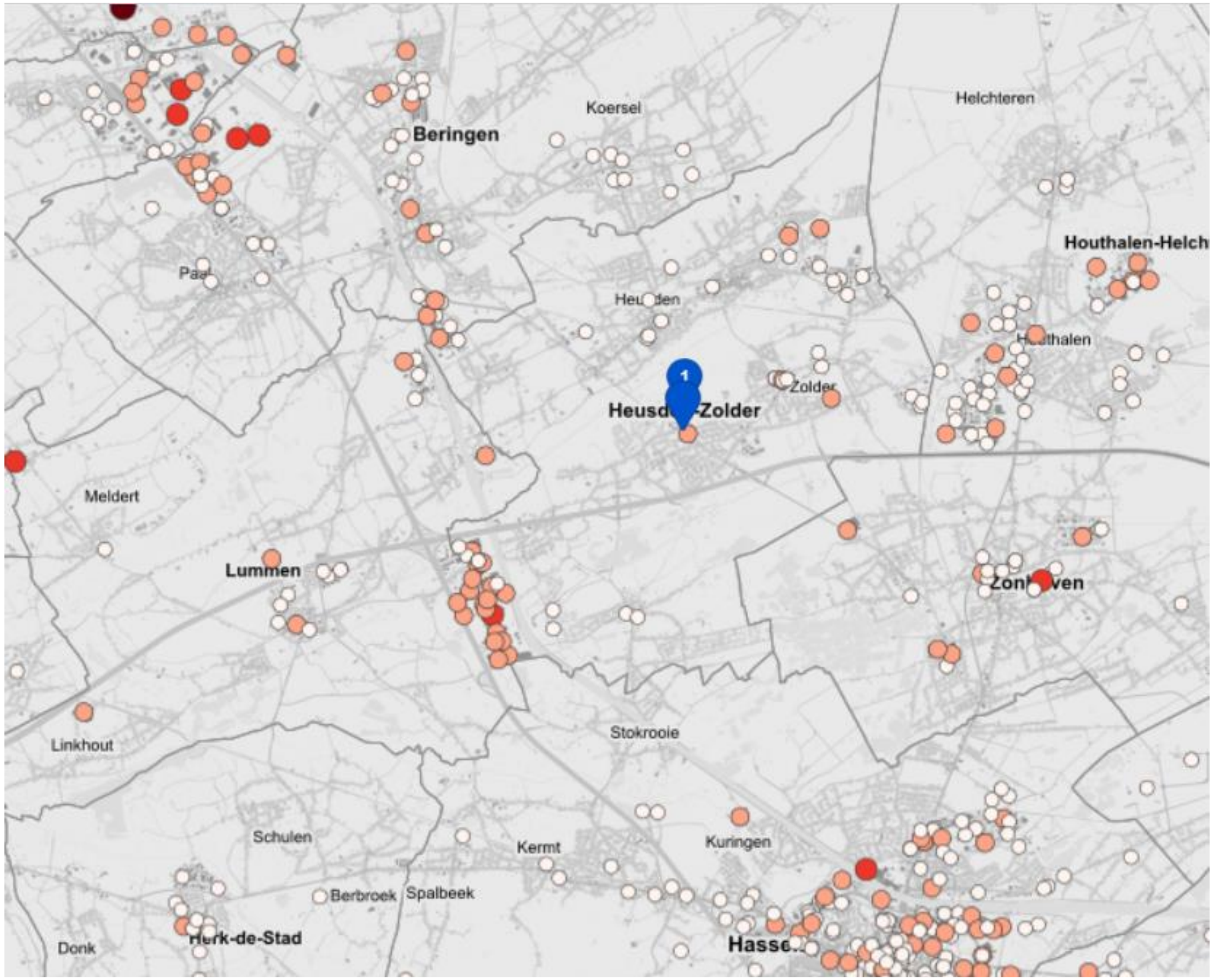


Residential & commercial

Heating grids

- Where are the possible supply and demand points for district heating?
- Warmtekaart Vlaanderen, available at
- https://www.geopunt.be

id	F_I0500267857
naam	DATS 24 NV
sector_sub	TERTIAIR/HANDEL
categorie	1 - 20 GWh/jaar

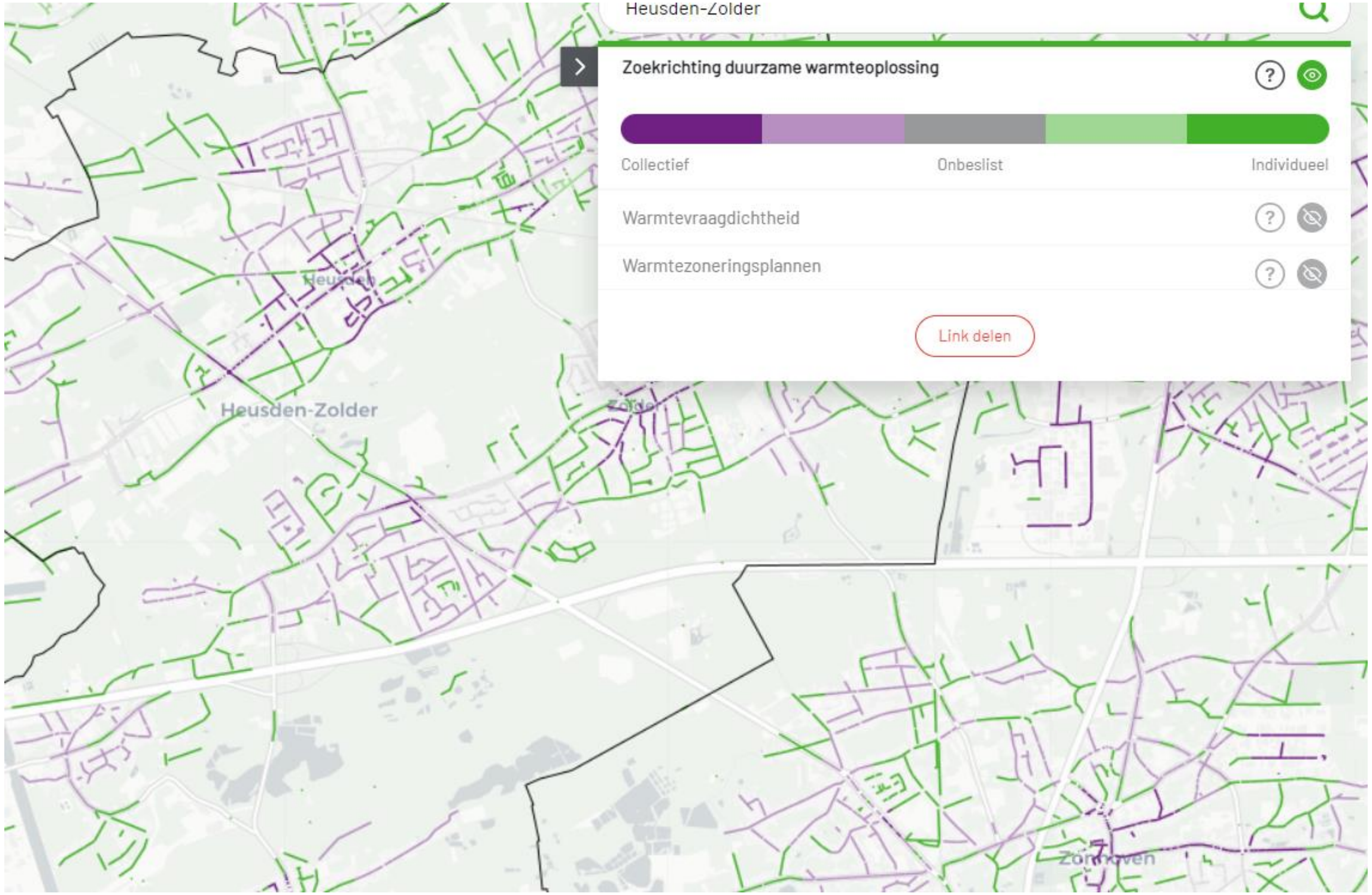


Bron: VITO iov VEKA, 2020

Residential & commercial

Warmte inspiratiekaart

- Where to build heating grids?



Bron: VITO iov VVSG

Hydrogen in the built environment: a no go

Highlights

- Comprehensive meta-review of 54 independent studies on heating with hydrogen
- No studies support heating with hydrogen at scale
- Evidence suggests heating with hydrogen is less efficient and more costly

Volume 1, Issue 1, 26 January 2024, 100010

Article

A meta-review of 54 studies on hydrogen heating

Jan Rosenow [1 2]

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https://doi.org/10.1016/j.crsus.2023.100010 Get rights and content

Brussel lonkt naar waterstof voor verwarming oude huizen

Inne Mertens, CEO Sibelga in De Tijd

EnergyVille

Transport

- Two transport applications you might not have in mind

Transport

By 2030, investing in more than

2 million

electric person vehicles would be cost effective and puts us on track to net-zero 2050.

By 2050, electrification leads to an efficiency improvement of

76%

Total energy demand decreases from 100 TWh today to 34 TWh.

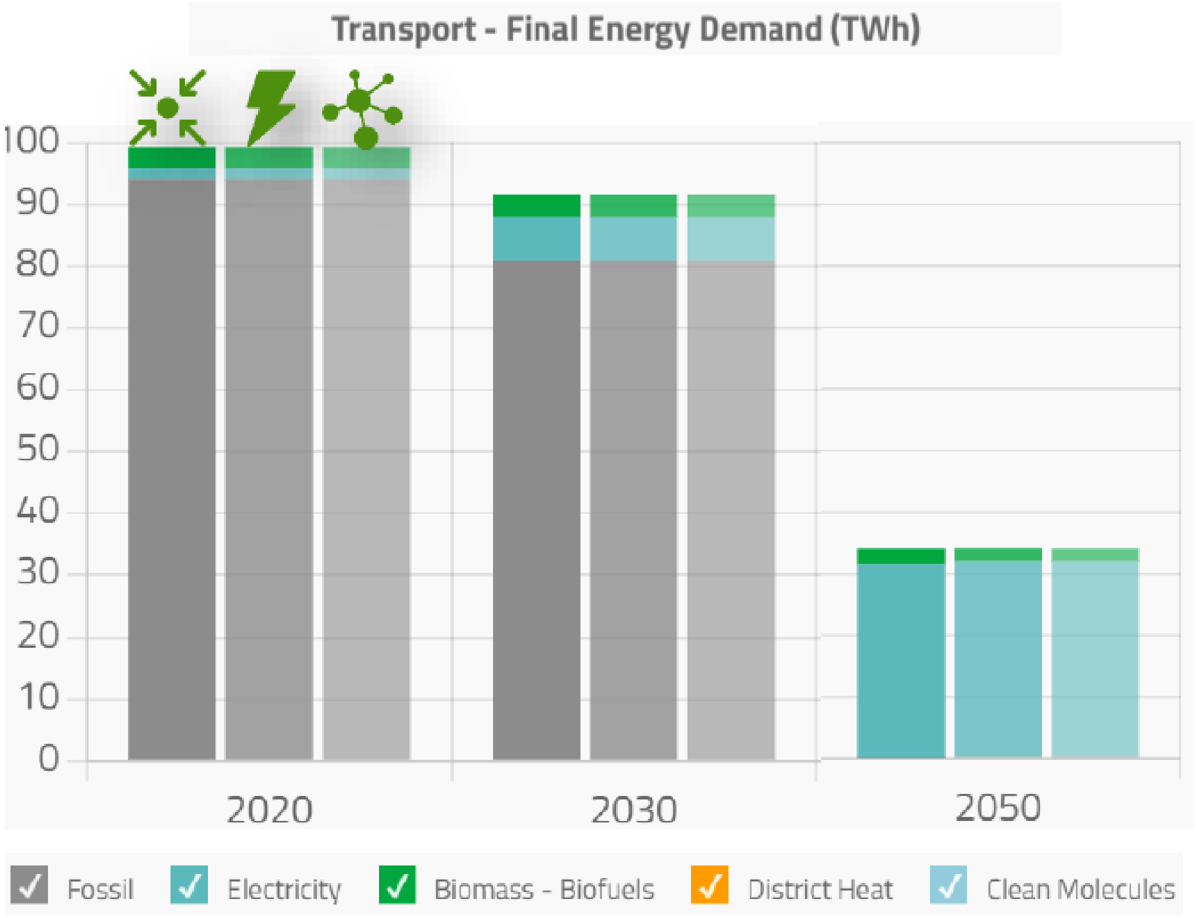
By 2050 our road transport is

fully electrified

By 2050, at least

1,1 million

smart charging stations (average 7,5 kW peak) are needed to provide demand flexibility.



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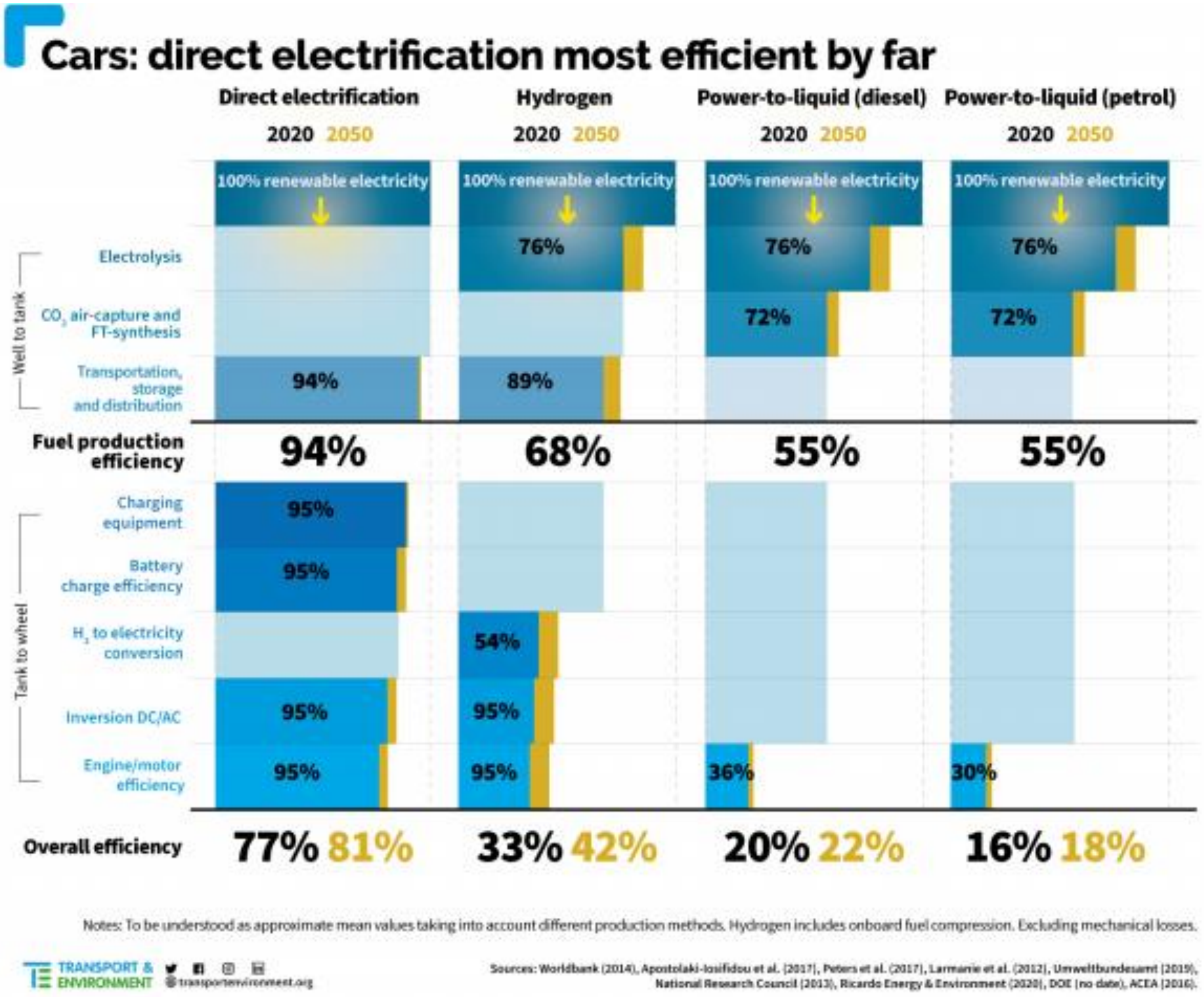
Transport

- Electric if you can,
- Hydrogen if you have to,
- Synthetic molecules if you must

Source:https://www.transportenvironment.org/sites/te/files/publications/2020_12_Briefing_feasibility_study_renewables_decarbonisation.pdf



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Shipping + Aviation => Hard to abate, not a done deal

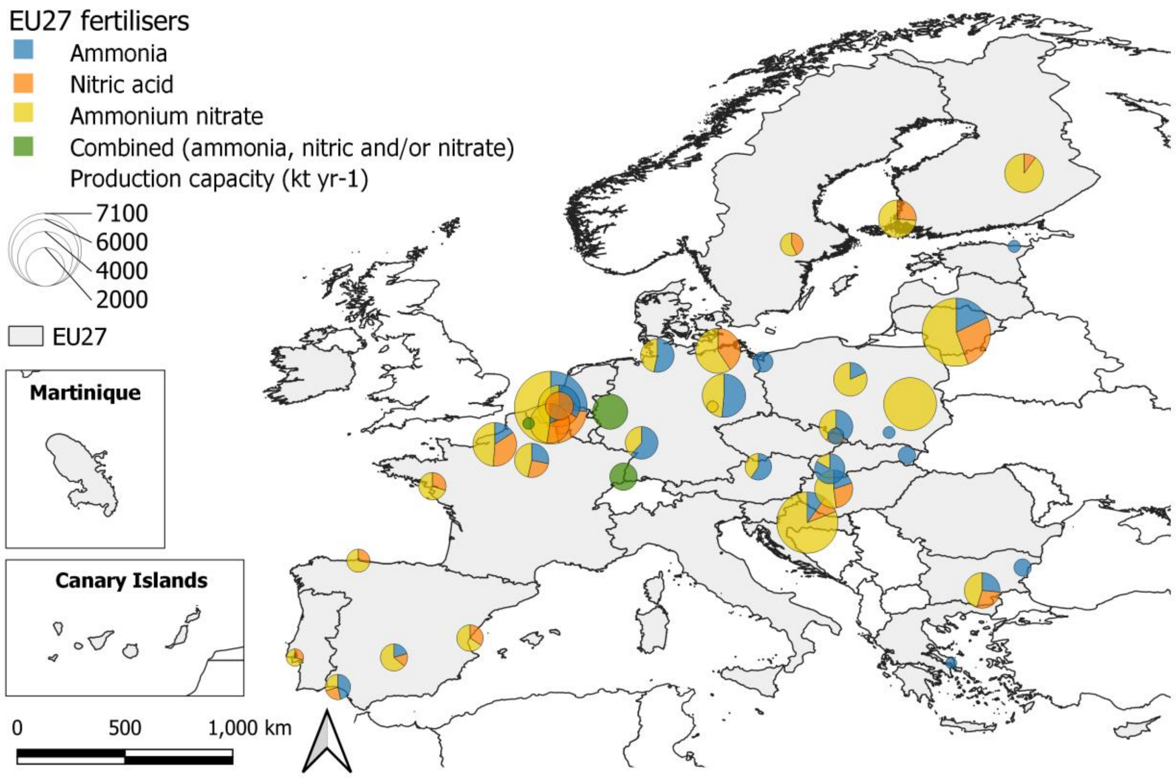
- Aviation: Some short distance electric, **biofuels, synthetic kerosene**, (hydrogen)
- International shipping, Some short distance electric, **biofuels, ammonia, methanol**, (hydrogen)

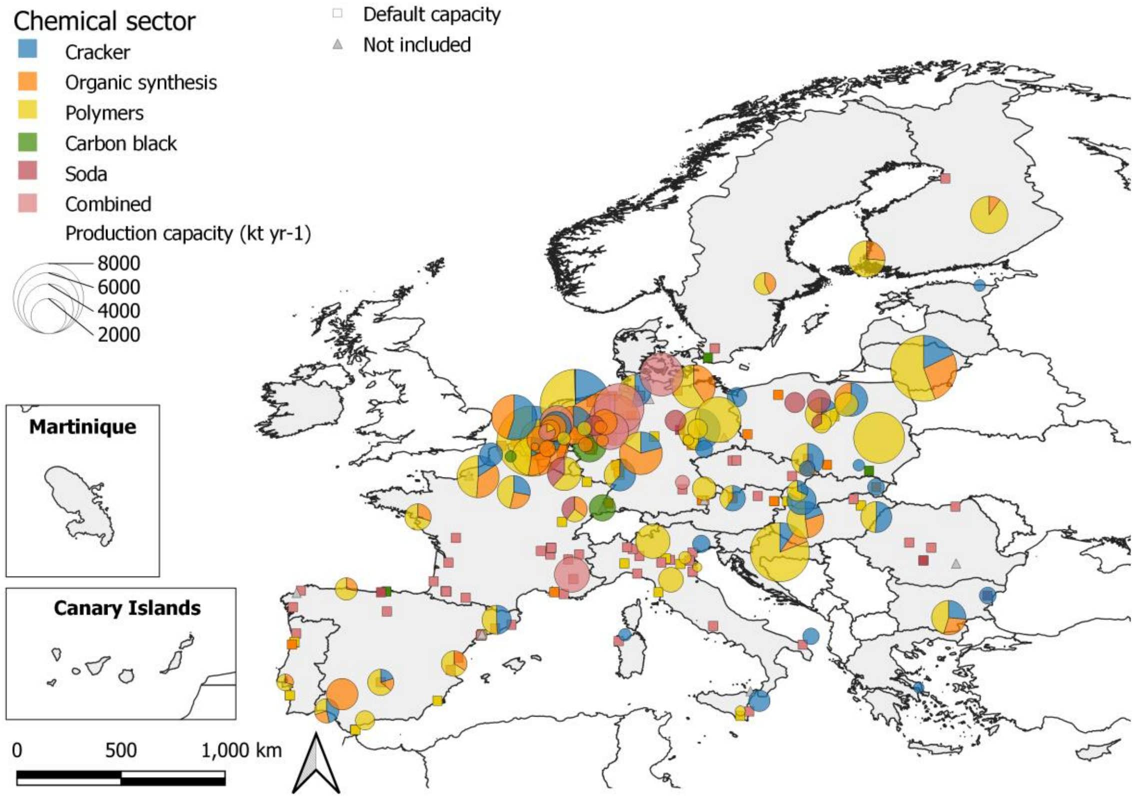
- Some short distance flights/shipping may electrify, but for large distances, molecules will be needed.
- More likely hydrogen derivates than pure hydrogen

Source: hydrogen - central aerospace industry

Industry: e.g. The chemical sector in Europe

Largest petrochemical cluster in Europe





Source: the AID-RES project, VITO - EnergyVille

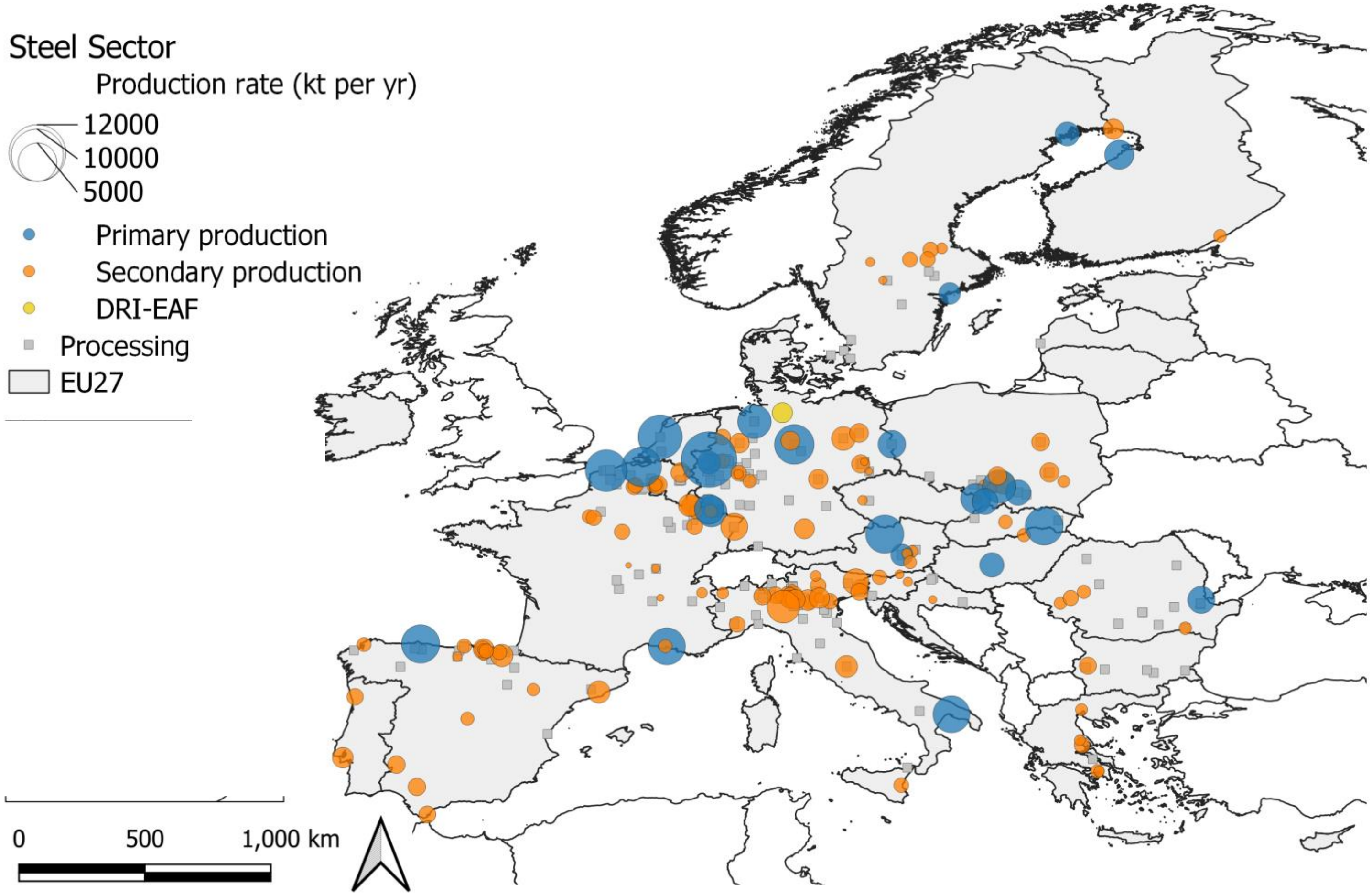
~8Mton (=> 264TWh$_{LHV}$) total H2 demand in EU, most of which in petrochemical industry

Industry: Steel sector

Decarbonisation of steel sector

- Primary – secondary steel routes
  94 Mton + 63 Mton = 157 Mton

- Steel clusters, share per country
  - Germany 25,1 %
  - Italy 14,8 %
  - …
  - Belgium 4,9 % (6th place)



Source: VITO-EnergyVille AidRES project, 2021

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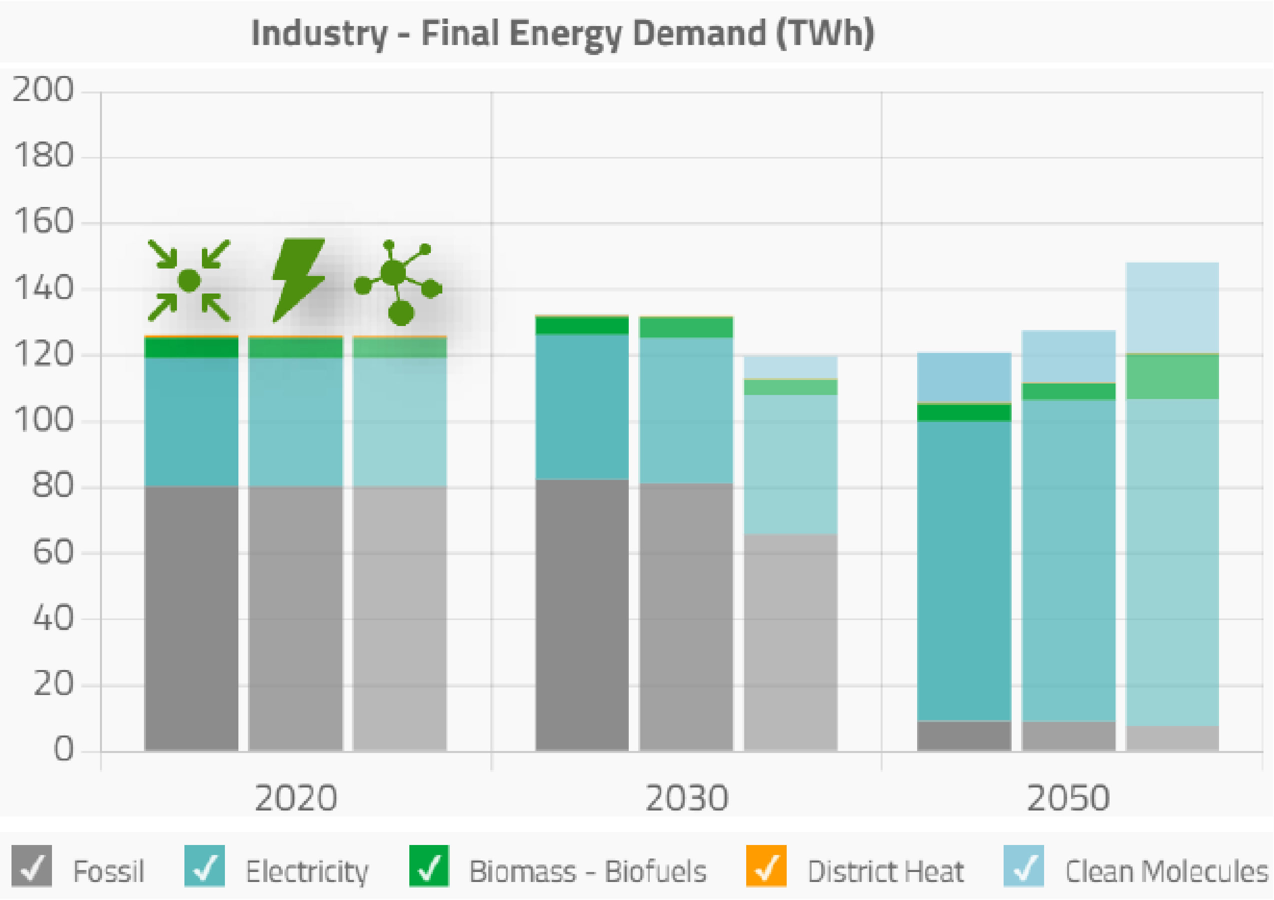
Industry – final energy use

Electrification generally more efficient



By 2050, clean molecules amount to

21-25 %

of the final energy demand in industry.

Industry – CO_2 emissions

By 2030, Carbon Capture and Storage (CCS) removes

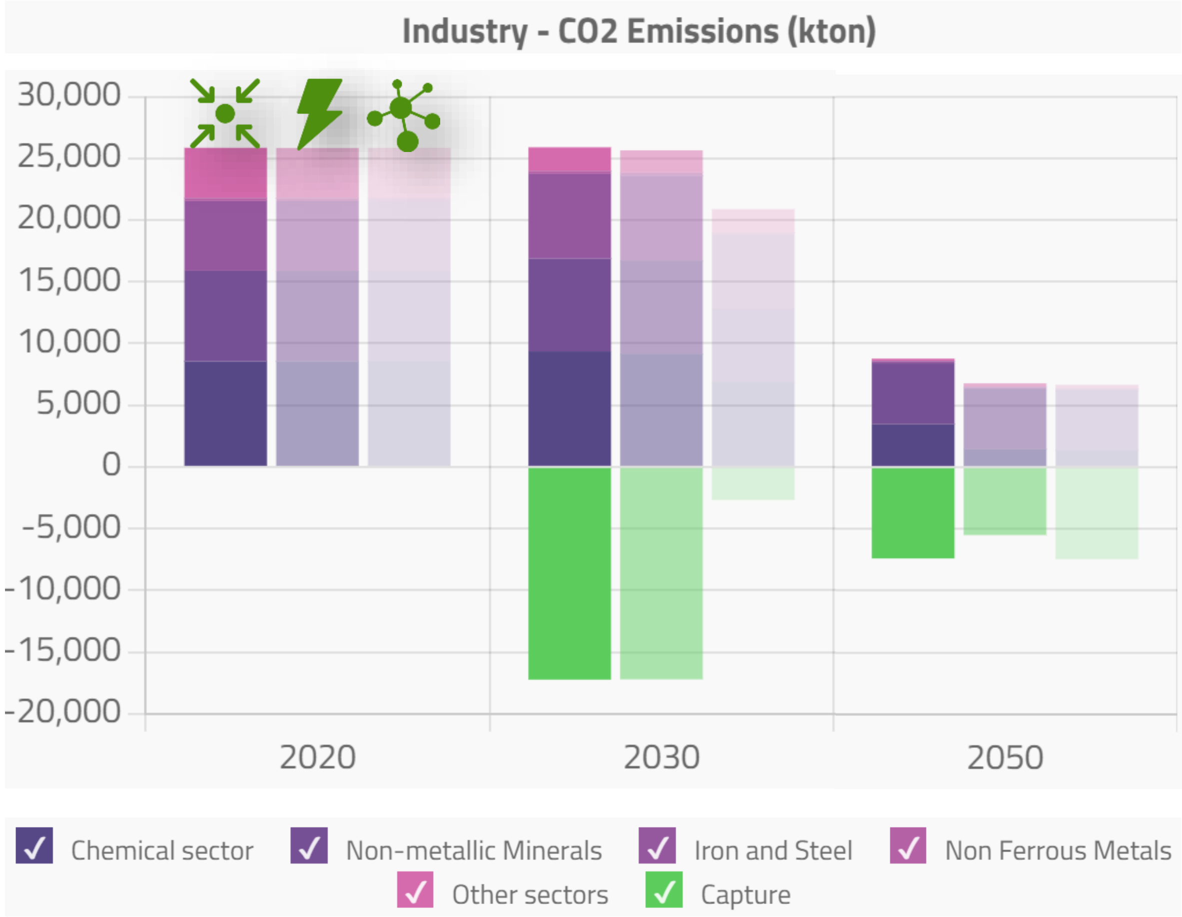
20 Mton

of CO_2 emissions from the atmosphere

By 2050, CCS is limited to

9,4 Mton

and applied in cement, lime, high value chemicals and supply sector.



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Industry: Carbon capture as a long term solution


18 Analyse

UN INVESTISSEMENT DE PLUS DE 500 MILLIONS D'EUROS

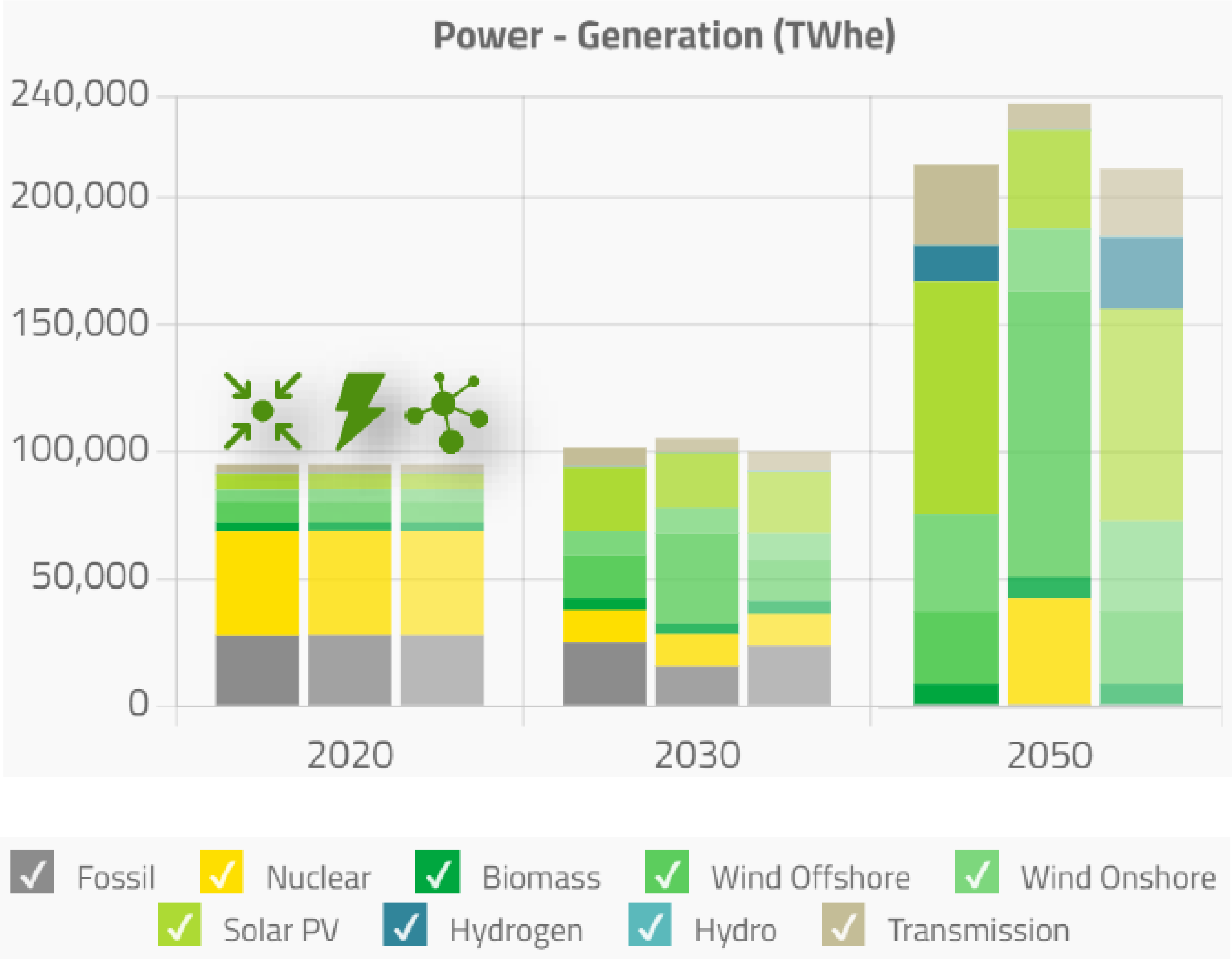
A Obourg, Holcim repense totalement le cycle du béton

Energy Ville

Source: Totalenergies/Holcim

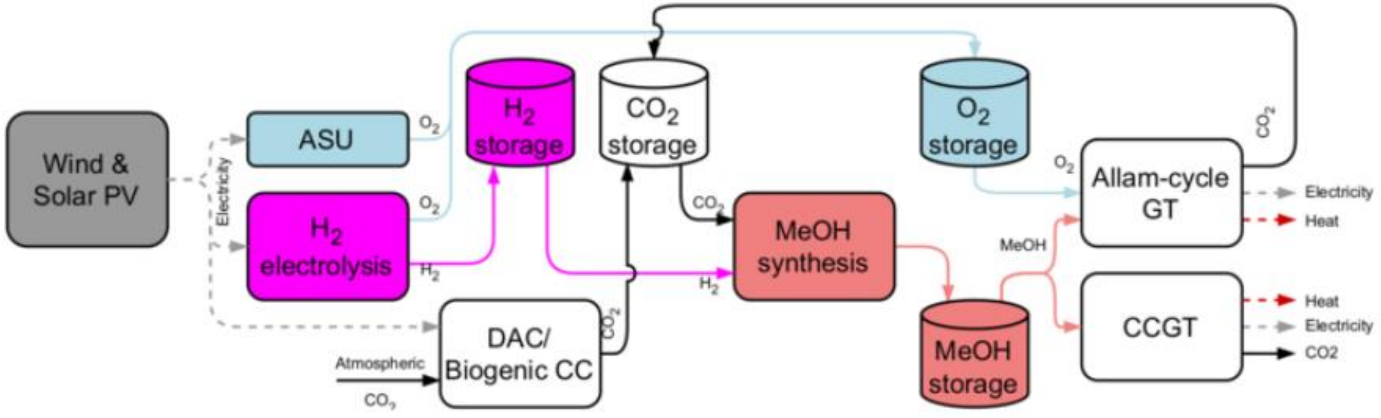
Power sector - Generation

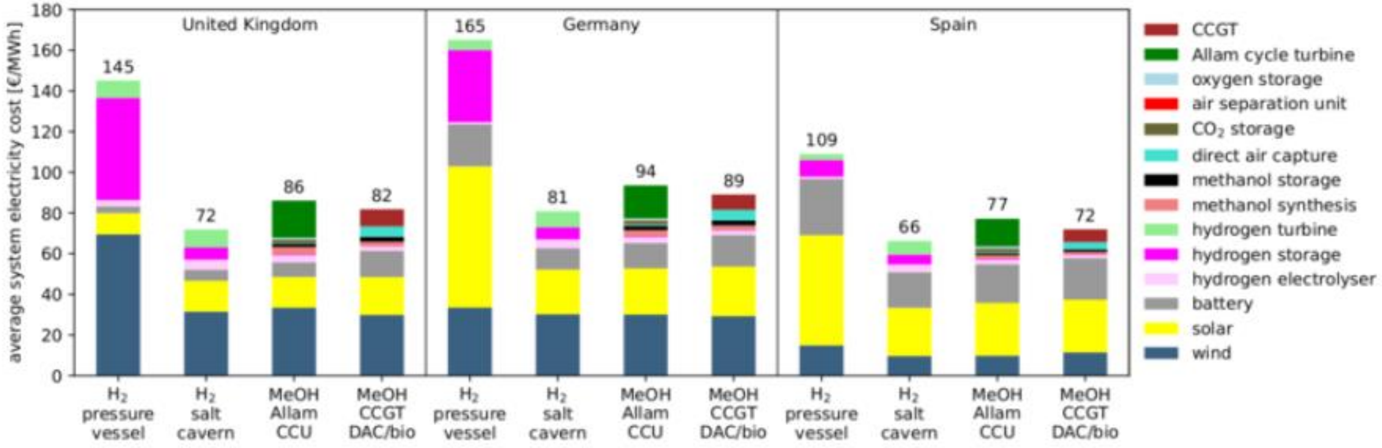
- Hydrogen as a long term backup



How the electricity backup will look like is uncertain

- Pure hydrogen backup
- Methanol + oxygen combustion
- Bio/synthetic methane
- Heat storage
- Advances in battery technologies?

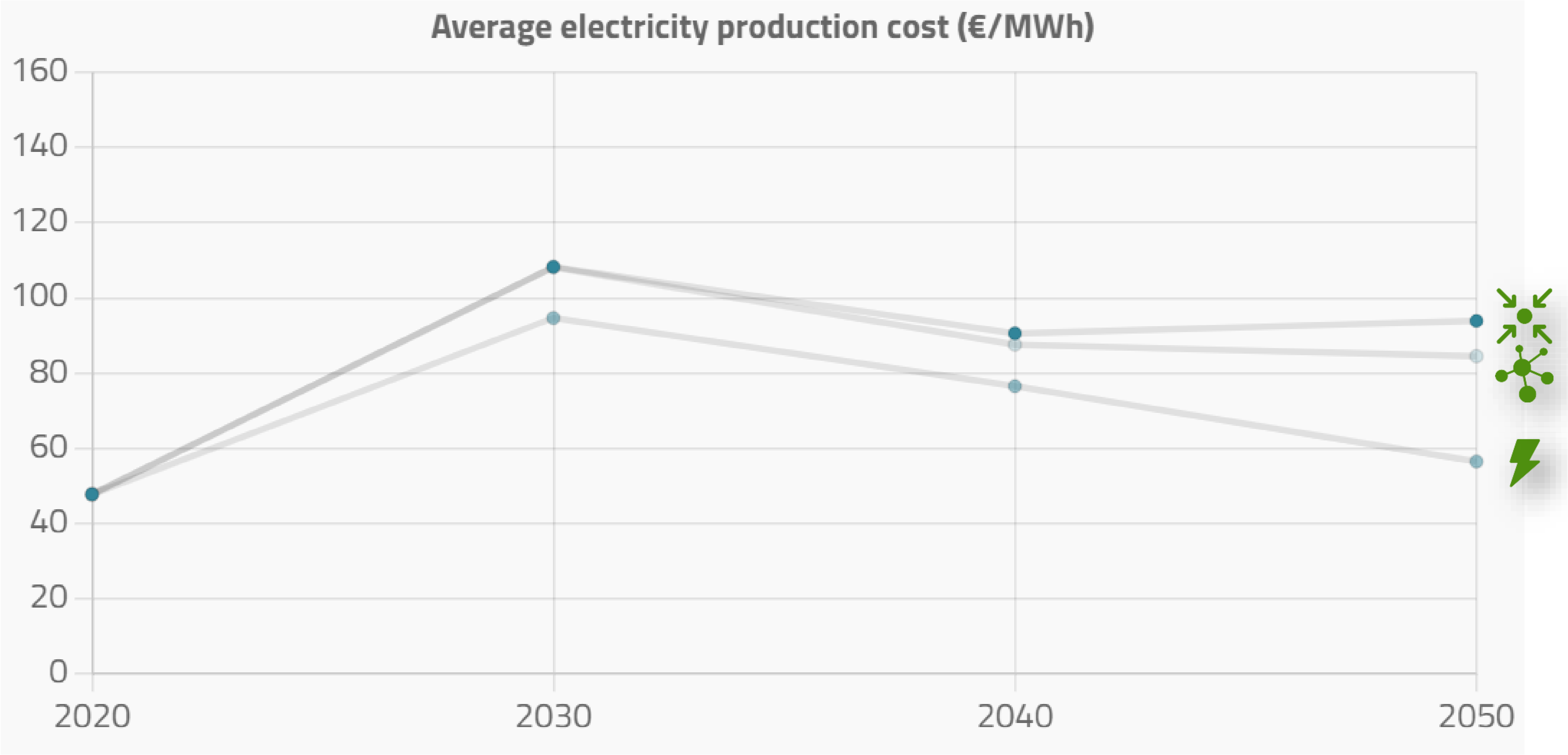




Source: TU Berlin: A closed-loop storage-plus-power system stockpiles renewable energy wherever it's needed

Average electricity production cost

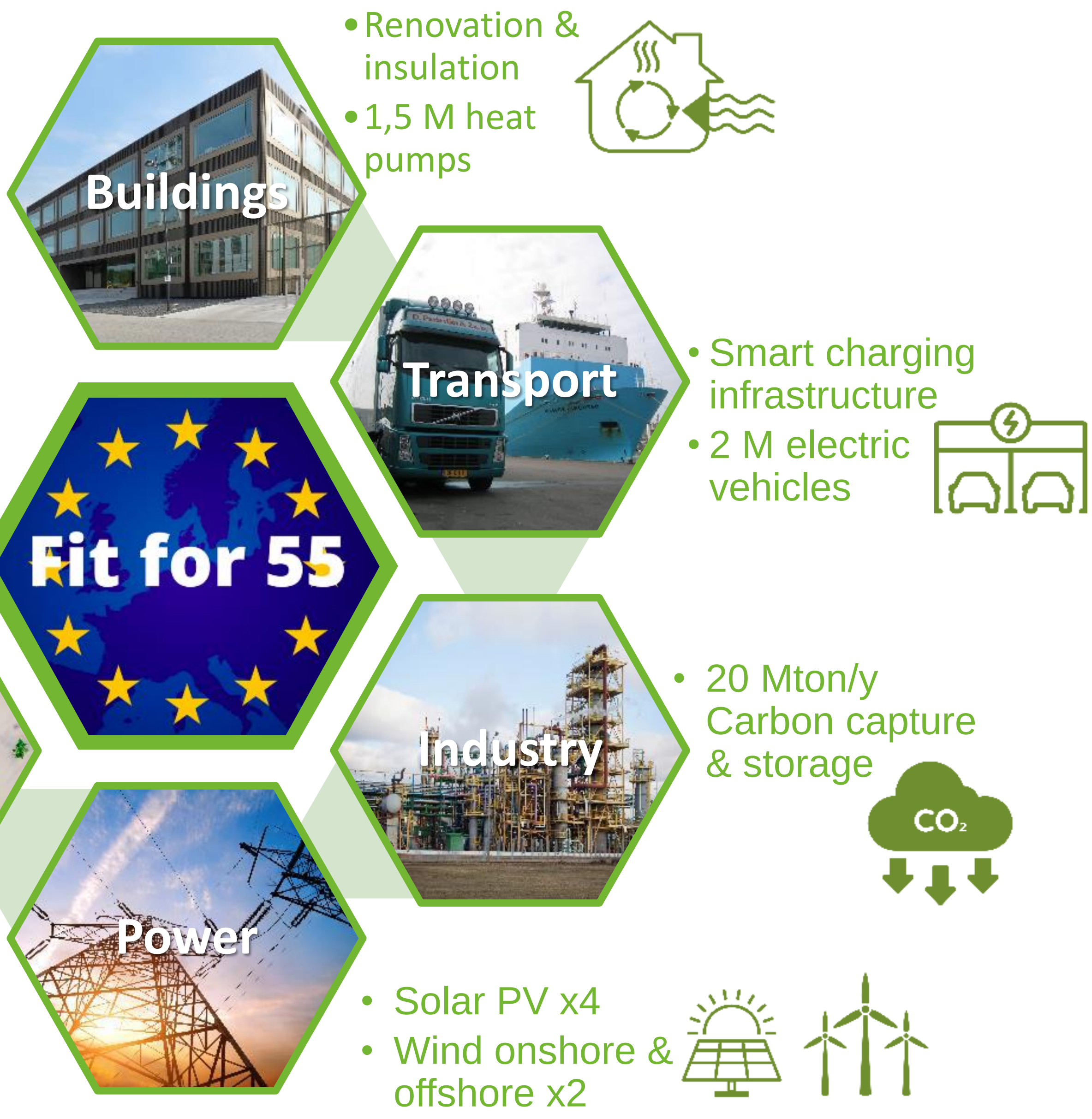
Access to more offshore wind and SMR leads to lower production costs



Fit-for-55 by 2030 ?

Evaluation limited to CO_2 emissions

- This study does not present policy projection or prognosis
- Belgian CO_2 emissions 1990: **120 Mton** CO_2 emissions excluding net CO_2 from LULUCF
- Central scenario 2030: **52 Mton**
  → **reduction of -57%**



2030 climate targets: still feasible?
=> In the model, yes!
=> In real world, will energy intensive processes move to regions with higher renewable potential?

European level: the same ambitions

- RepowerEU communication:

Increasing the renewable ambitions of Fit for 55:

Wind: 467 GW => 510 GW

Solar: 530 GW => 592 GW

Table 4: Investment by 2030 for reaching the RePowerEU objectives

Investment areas	REPowerEU	Ff55	Difference	Diff. due to high prices
Installed wind capacity (GW)	510	469	41	13
Installed solar PV capacity (GW)	592	530	62	16
Installed heat pumps in residential and services (million units)	41.5	39.9	1.7	3.4
Installed electrolyser capacity (MW hydrogen)	65	44	21	1.6
Net imports of hydrogen (Mt)	6.16	0.05	6.11	0
Biogas used in power plants (Mtoe)	12.3	11.8	0.5	0.9
Biogas as transformation input in industry and district heating (ktoe)	6.9	3.3	3.6	42
Electricity grid investments over the decade (bn€'22)	583.8	554.4	29.4	37
Annual renovation rate in 2030 (as % of entire housing stock)	2.3	2.0	0.2	0
Annual renovation rate - medium and deep renovation in 2030 (as % of entire housing stock)	2.1	1.9	0.2	0
Investment expenditure in residential buildings in 2021-2030 (bn €'22)	2068	2023	45	-

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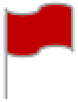
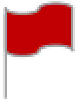
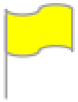
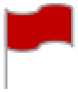
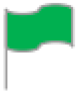
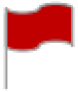
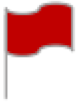
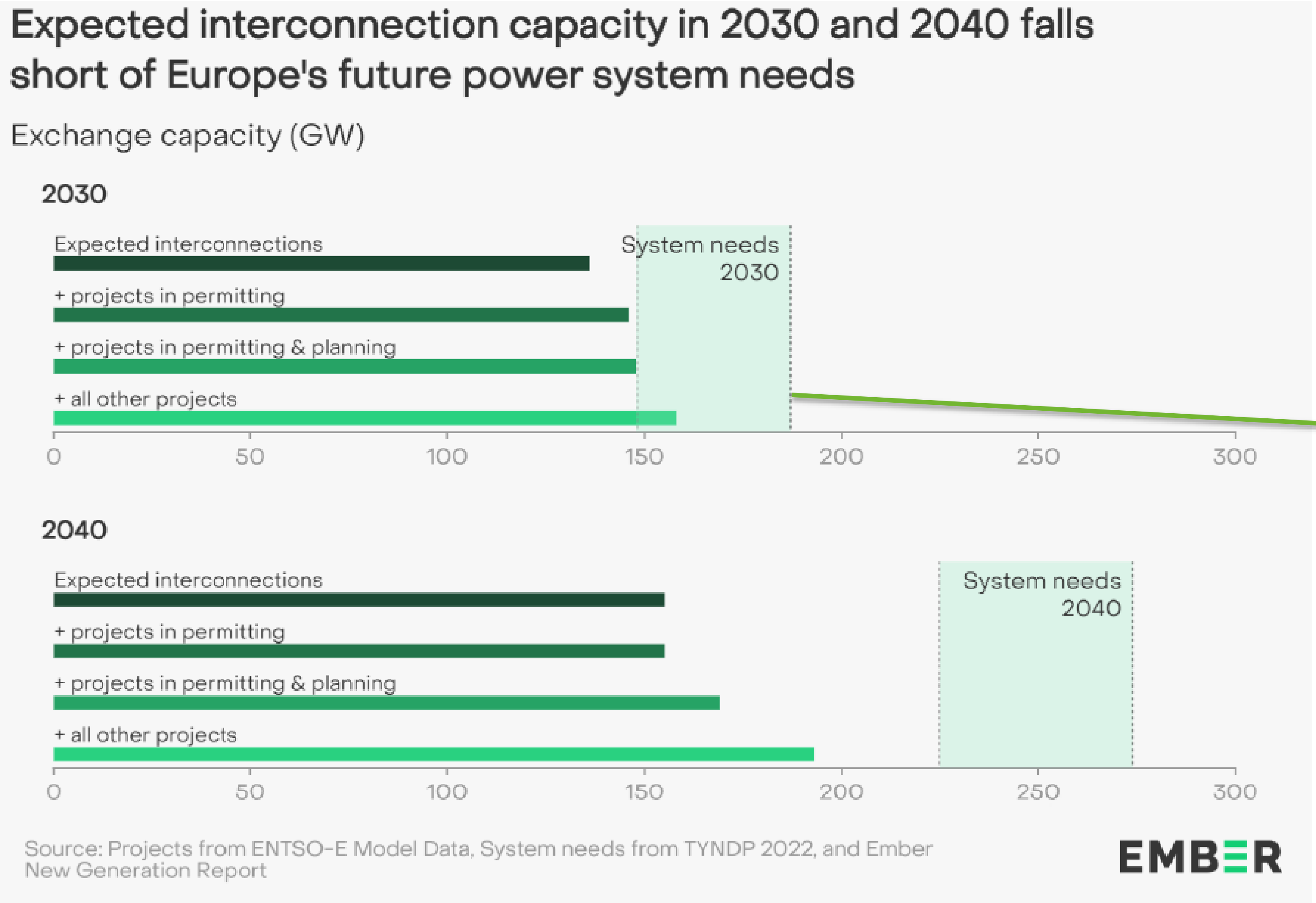
Realistic targets for wind?

- Wind Europe, *the state of the European energy supply chain*, 2023
- Competition for projects with USA
- Grid deployment and manufacturing capacity
- The material challenge

Segment	Industry	Sub-segment	2022-2030 demand growth*	Time to action*	Urgency assessment
Turbines	Onshore & Offshore wind	Total market	**~3X** *Capacity (MW)*	**2024-2025**	
	Offshore wind	>12 MW turbines	**0-29 GW**	**2024**	
Towers	Onshore & Offshore wind	All	**~2.5X** *Metric tons*	**2025**	
Foundations	Offshore wind	Monopiles	**~12X** *Metric tons*	**2024-2025**	
		Other grounded	**~7X** *Metric tons*	**None**	
		Floating	**~23X** *Metric tons*	**2024**	
WTIVs	Offshore wind	Total market	**~7.5X** *Vessel years*	**2024-2025**	
		>12 MW turbines	**0-25 vessel years**		

Shortage of grid capacity



- Source: Ember policy brief:

E. Cremona, *Breaking borders: the future of Europe is in its interconnectors*

ENTSO-E TYNDP2022 scenario has +/- same renewables than RepowerEU

RepowerEU: 510GW wind 592GW sun

IEA: supply chain tightness

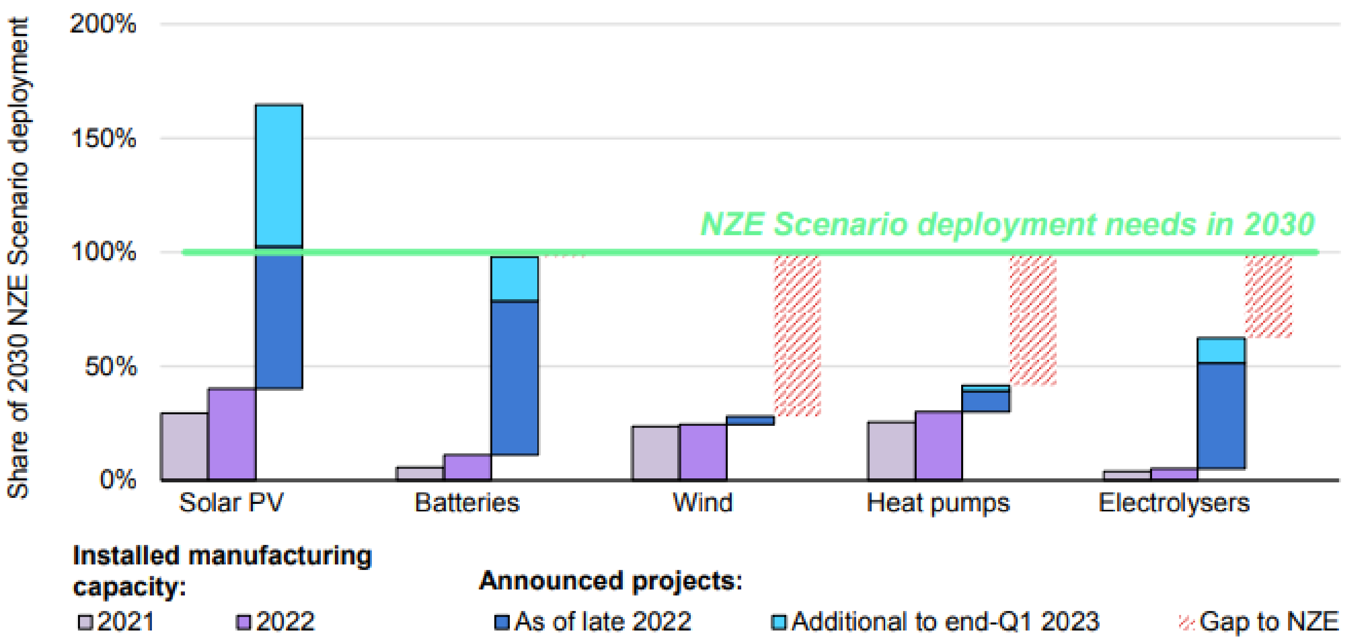
- The State of Clean Technology Manufacturing: An energy technology perspecives special briefing

Lack of ambition and attention risks making electricity grids the weak link in clean energy transitions

Source: IEA: Electricity Grids and Secure transitions, 2023

https://www.iea.org/news/lack-of-ambition-and-attention-risks-making-electricity-grids-the-weak-link-in-clean-energy-transitions

Figure 1 **Announced project throughput and deployment for key clean energy technologies in 2030 in the Net Zero Emissions by 2050 Scenario**



Notes: PV = photovoltaic; NZE Scenario = Net Zero Emissions by 2050 Scenario. "Announced projects: late 2022" corresponds to the project pipeline assessed for ETP-2023, including project announcements through to the end of November 2022. "Announced projects: Additional to end-Q1 2023" corresponds to projects announced between the end of November 2022 and the end of March 2023. Deployment and throughput are expressed in physical units, normalised to 2030 NZE Scenario deployment needs.

Work to be done

Offshore infrastructure

- 300-> 450 GW of offshore wind by 2050
- Offshore requires massive investments (EC: 2/3rd of 800 Billion by 2050)
- Meshed HVDC grids are the only realistic option:
  - Connections increasingly further offshore
  - Needs to be integrated in the existing system (hybrid AC/DC)
  - Towards new backbone grid

We need to start thinking about our electricity grid infrastructure of the future, it is important.

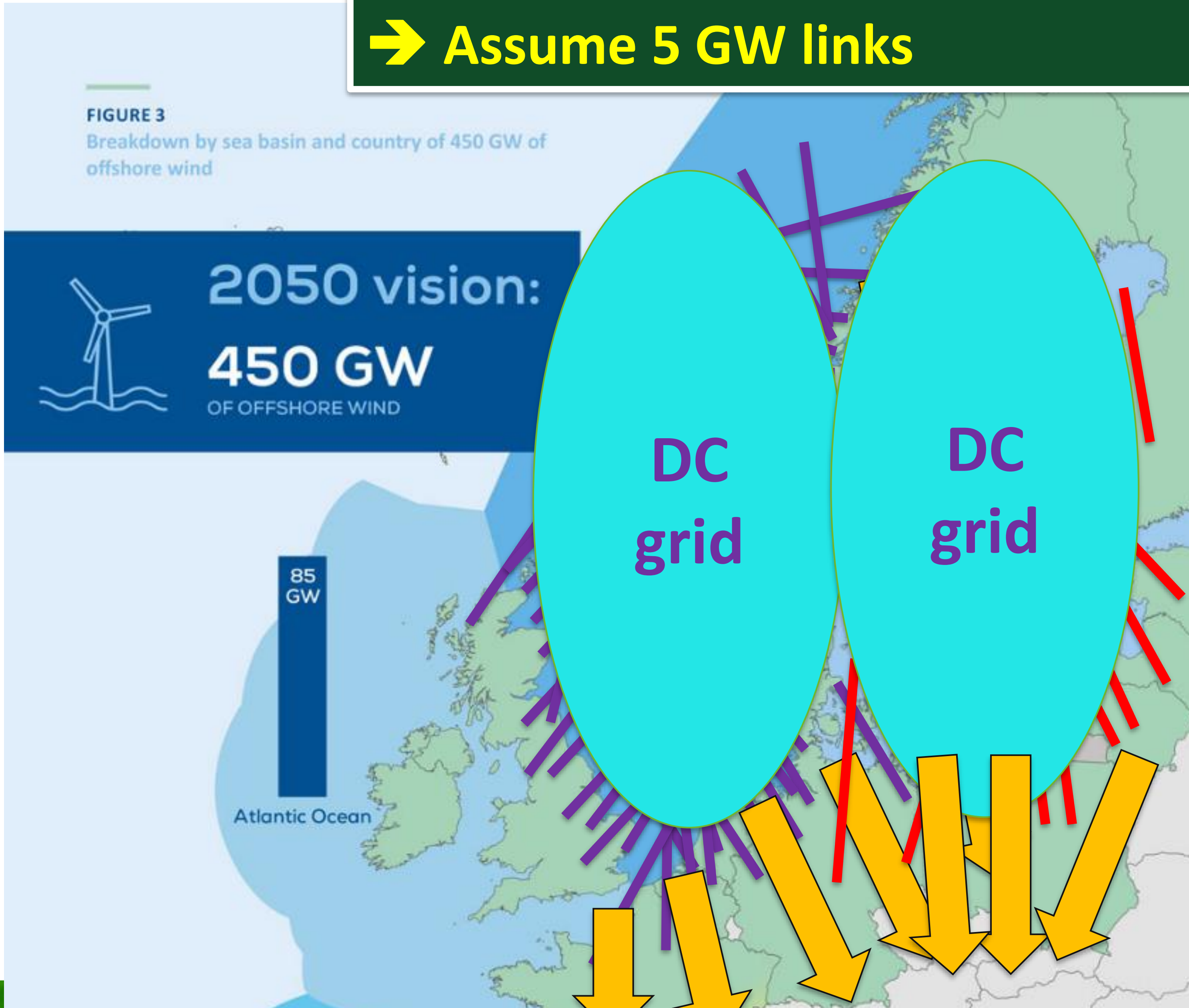


Figure: WindEurope

We need to connect 200 GW from the north sea
➔ Assume 5 GW links

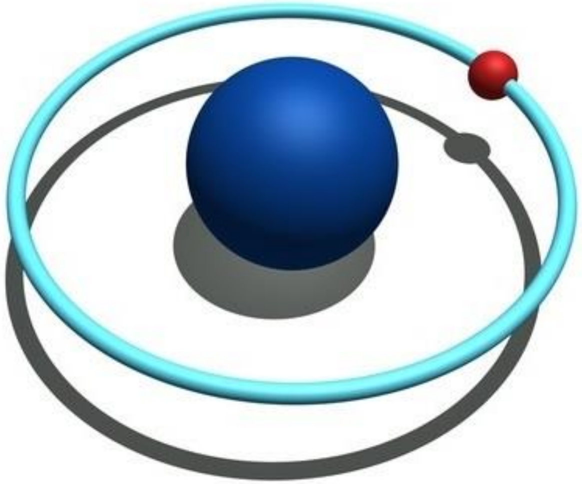
The role of hydrogen in the energy system

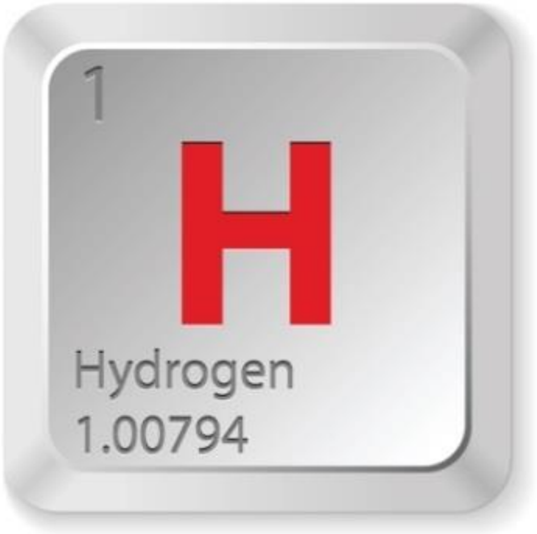
Pieter Vingerhoets

What with hydrogen? Hydrogen basics

- H_2
- When burnt, no CO_2 emissions
- Not naturally occurring in practical quantities
- Flammable and explosive
- Colorless, oderless and tasteless
- Lightest atom in universe => low weight
- High volumetric density => difficult to compress
- Liquid form -253degrees C
- 33kWh/kg lower heating value
- 39kWh/kg higher heating value

Great! Can we replace all natural gas with hydrogen? Energy transition done?





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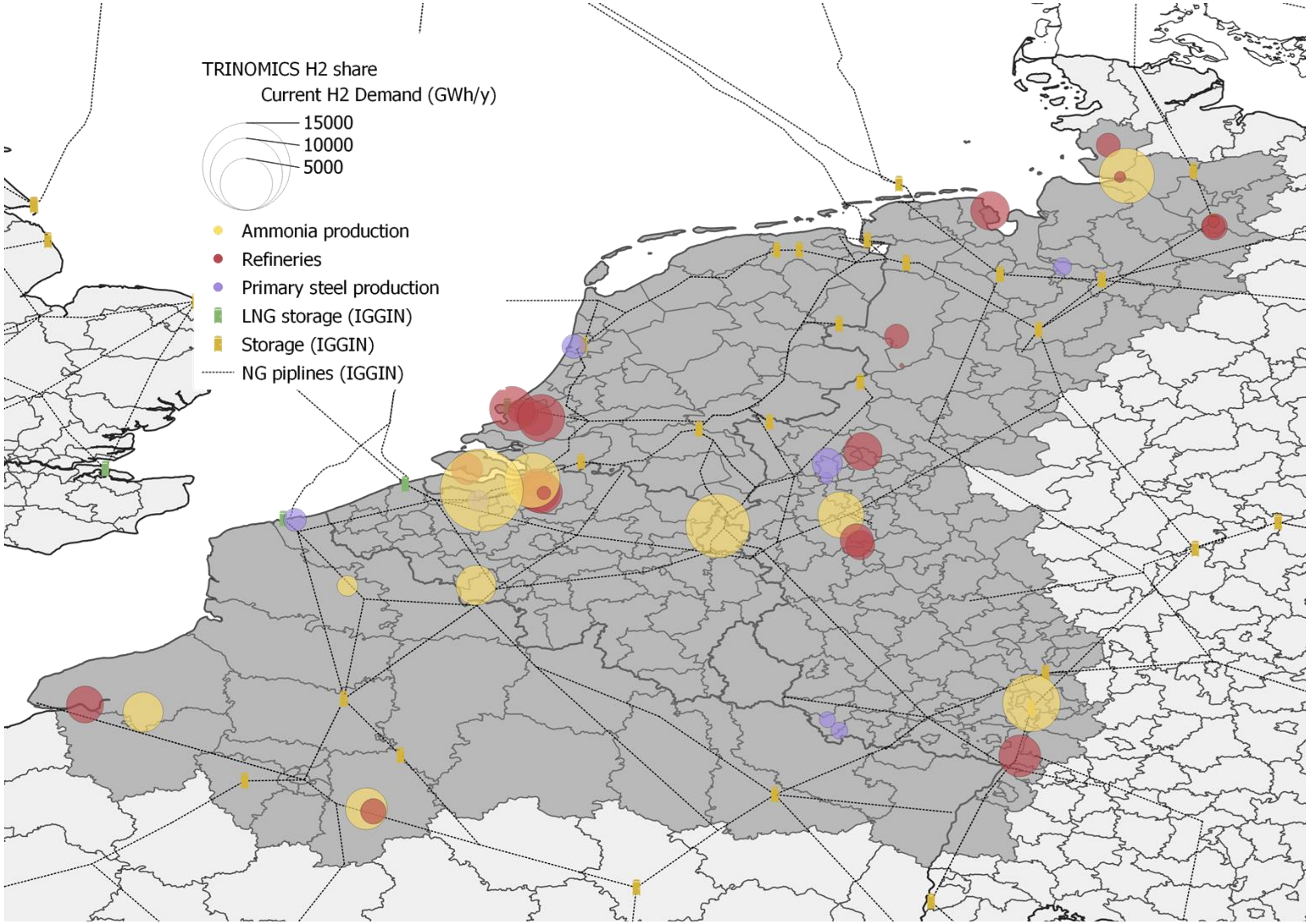
Hydrogen demand today

- ~80TWh of H_2 in figure
- Ammonia and refineries
- Byproduct in Cl production



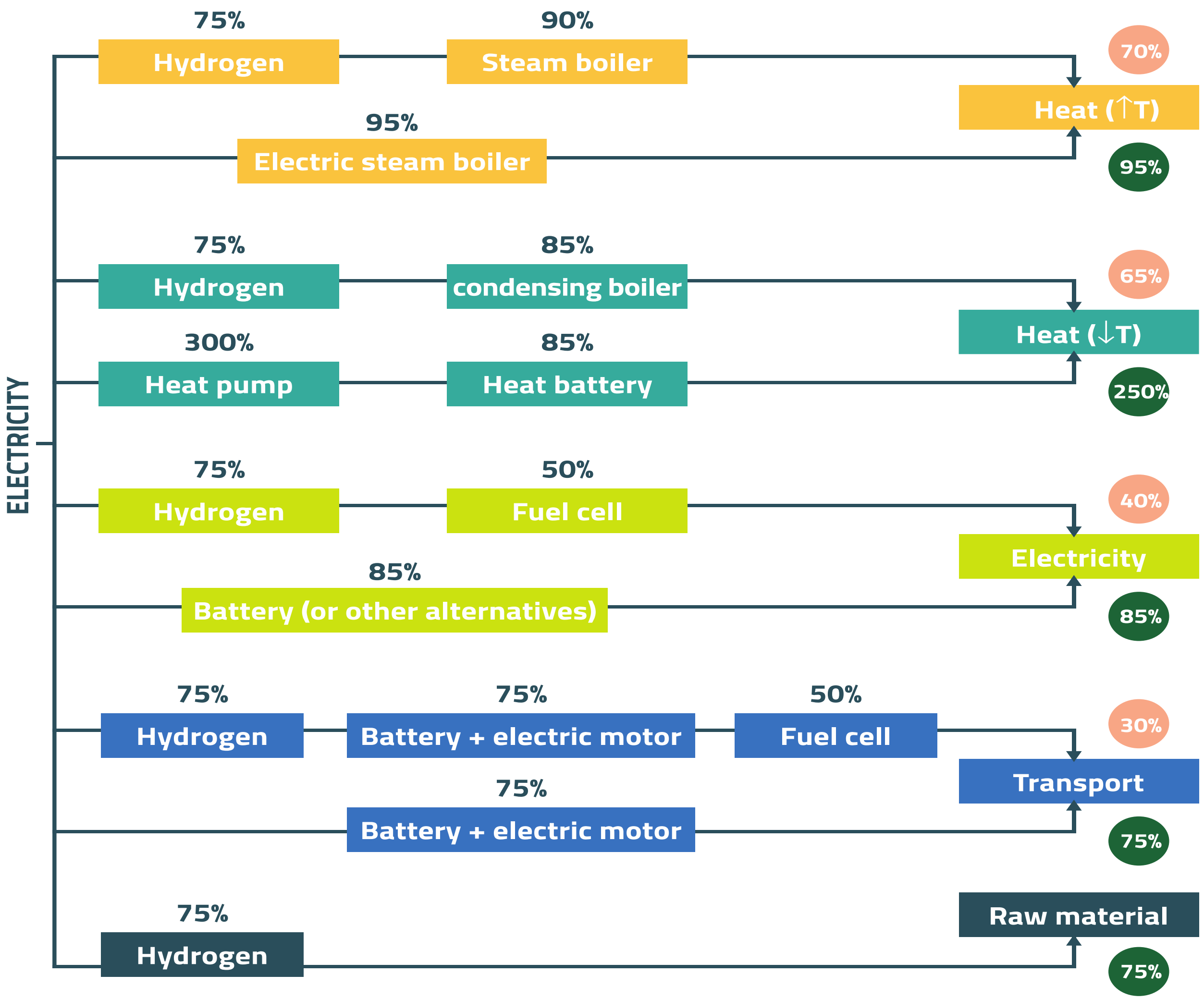
Source: VITO - Trinomics

What with hydrogen? Efficiency of green hydrogen

EC Communication 299: "**Powering a climate-neutral economy: An EU Strategy for Energy System Integration**"

1. A more circular energy system, with '**energy-efficiency-first**' at its core
2. Accelerating the **electrification** of energy demand, building on a largely renewables-based power system
3. Promote renewable and **low-carbon fuels**, including hydrogen, for **hard-to-decarbonise sectors**
   - Biofuels and biogas
   - Green hydrogen: electrolysis by green power
   - Transitional phase: other sources of low carbon hydrogen
   - CO2 capturing and use
   - Synthetic fuels

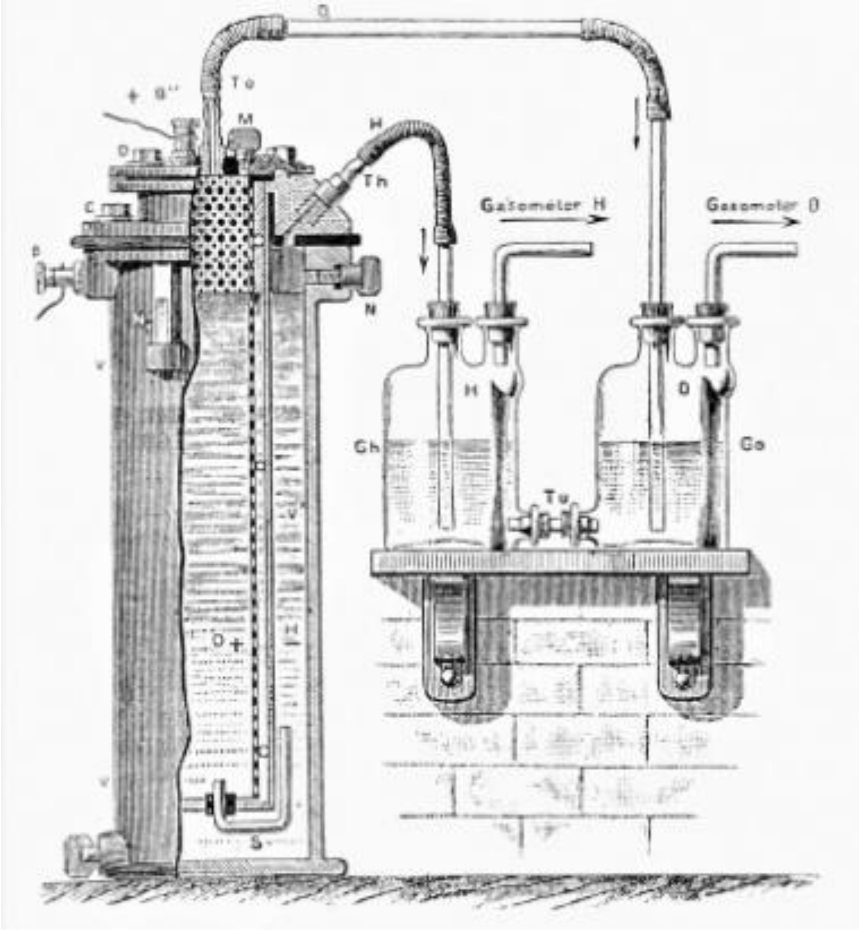
ELECTRICITY ROUTES WITH AND WITHOUT HYDROGEN



Source: De positie van waterstof in de energietransitie: een nuancering van de belofte
Auteur: Over Morgen; Tomas Mathijsen, Ingrid Giebels, Peter-Paul Smoor

Green hydrogen, known since the eighties

The 1780s!



Van Troostwijk and Deiman

ELSEVIER

Fundamentals, Systems, and Applications

Hydrogen Production by Water Electrolysis

2022, Pages 83-164

Chapter 4 - The history of water electrolysis from its beginnings to the present

Tom Smolinka [a], Henry Bergmann [b], Juergen Garche [c], Mihails Kusnezoff [d]

Hydrogen supply: 50 shades of hydrogen

	Terminology	Technology	Feedstock/ Electricity source
PRODUCTION VIA ELECTRICITY	Green Hydrogen	Electrolysis	Wind | Solar | Hydro Geothermal | Tidal
	Purple/Pink Hydrogen	Electrolysis	Nuclear
	Yellow Hydrogen	Electrolysis	Mixed-origin grid energy
PRODUCTION VIA FOSSIL FUELS	Blue Hydrogen	Natural gas reforming + CCUS Gasification + CCUS	Natural gas | coal
	Turquoise Hydrogen	Pyrolysis	Natural gas
	Grey Hydrogen	Natural gas reforming	Natural gas
	Brown Hydrogen	Gasification	Brown coal (lignite)
	Black Hydrogen	Gasification	Black coal

$$2\,H_2O(l) \rightarrow 2\,H_2(g) + O_2(g)$$

$$CH_4 + H_2O \rightleftharpoons CO + 3\,H_2$$

$$CO + H_2O \rightleftharpoons CO_2 + H_2$$

+ white hydrogen: naturally occurring hydrogen or collected as a by-product

HYDROGEN HAS NO COLOR!

Energy Ville

Hydrogen supply

- External assumption:

- No relocation industrial activity

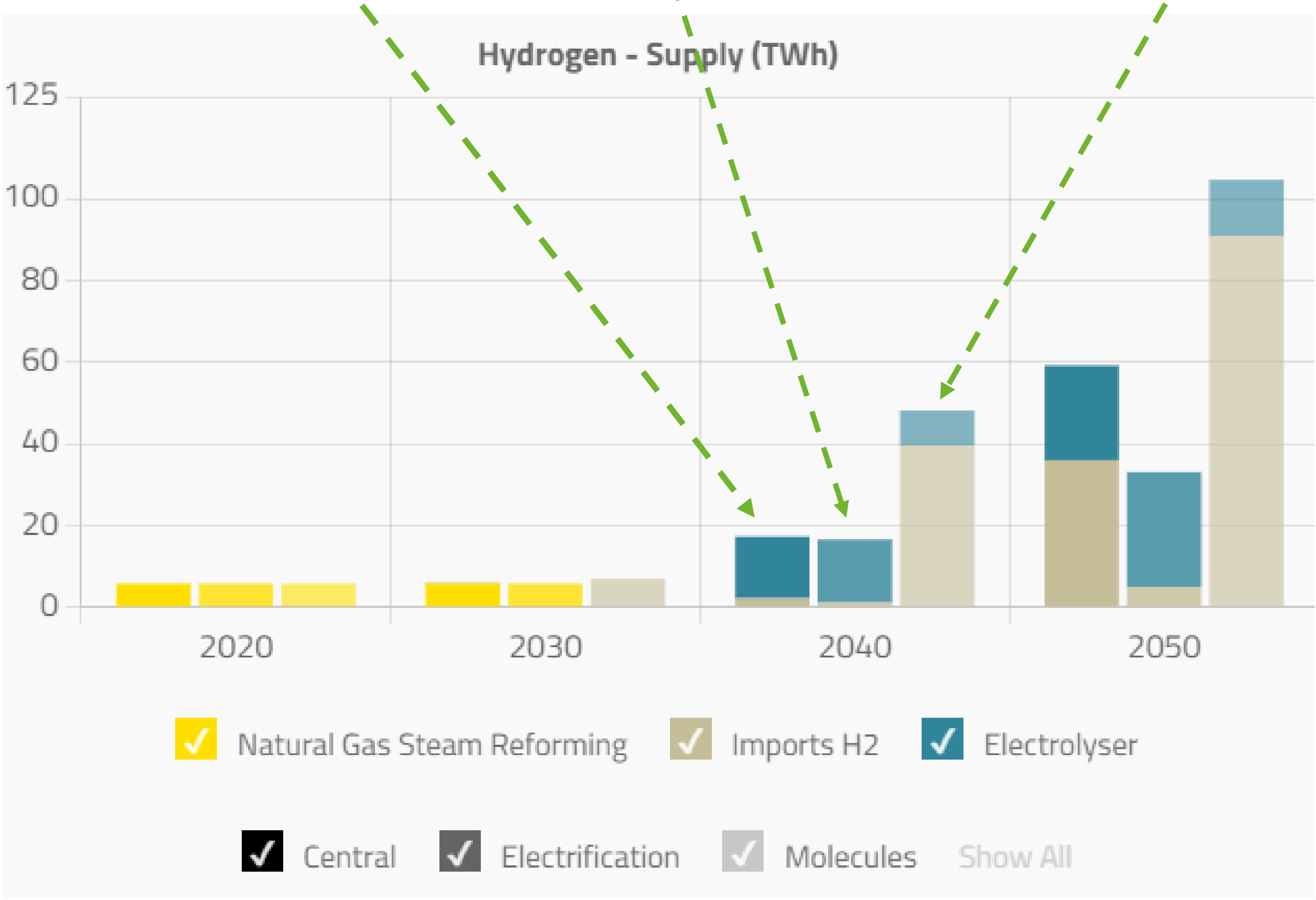
Scale-up of local electrolysis after 2030 only

Balance import vs local production very sensitive to assumptions

‘Central scenario’

Scenario with more access To cost effective electricity (offshore wind, nuclear in 2045)

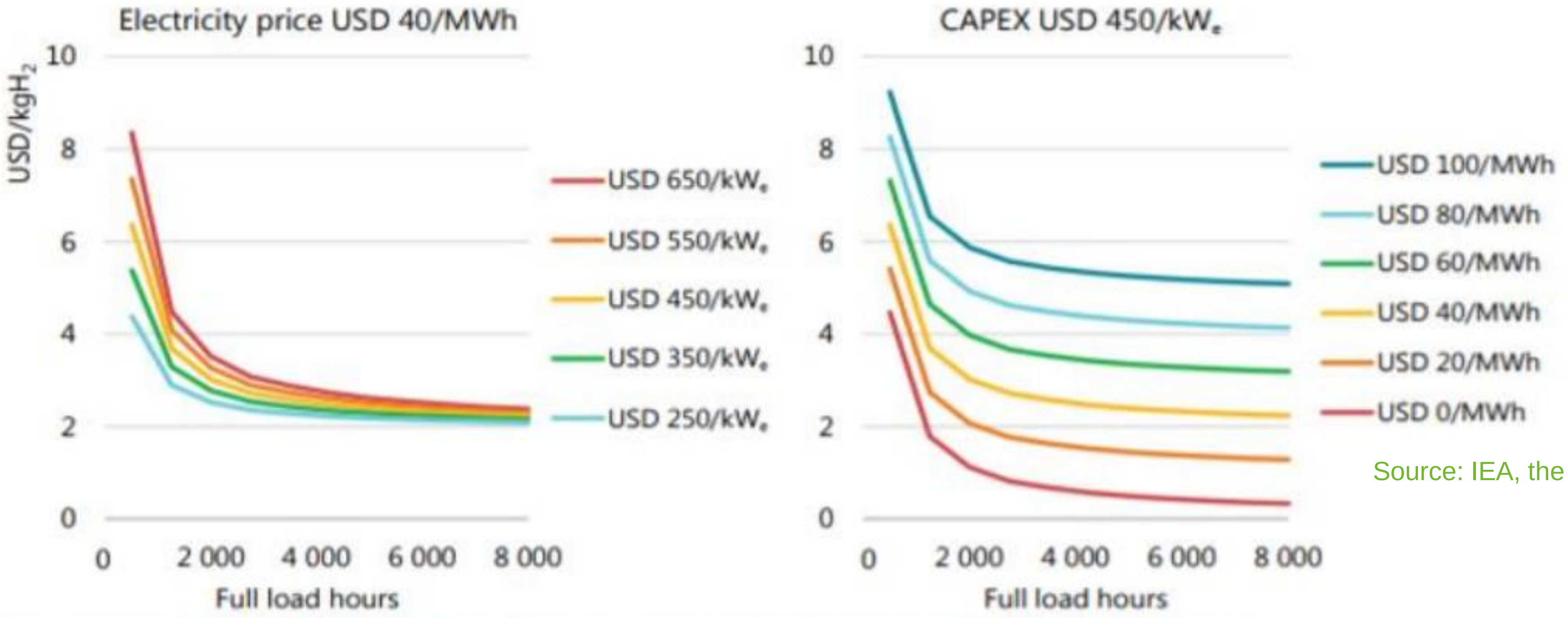
Scenario with very cheap Hydrogen import assumed



https://perspective2050.energyville.be/hydrogen

Cost of hydrogen with electrolysis

Figure 7.6 Future levelised cost of hydrogen production by operating hour for different electrolyser investment costs (left) and electricity costs (right), IEA (2019)



Source: IEA, the future of hydrogen, 2019

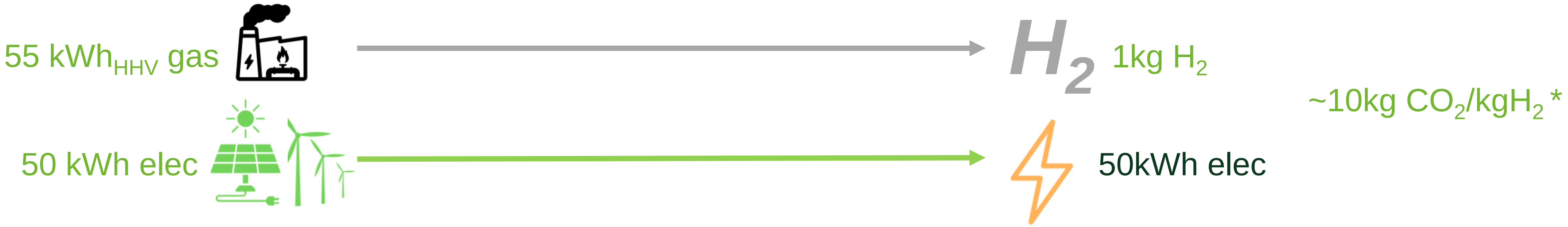
Notes: MWh = megawatt hour. Based on an electrolyser efficiency of 69% (LHV) and a discount rate of 8%.

Electrolysers need +3000-4000 operating hours to be commercially viable

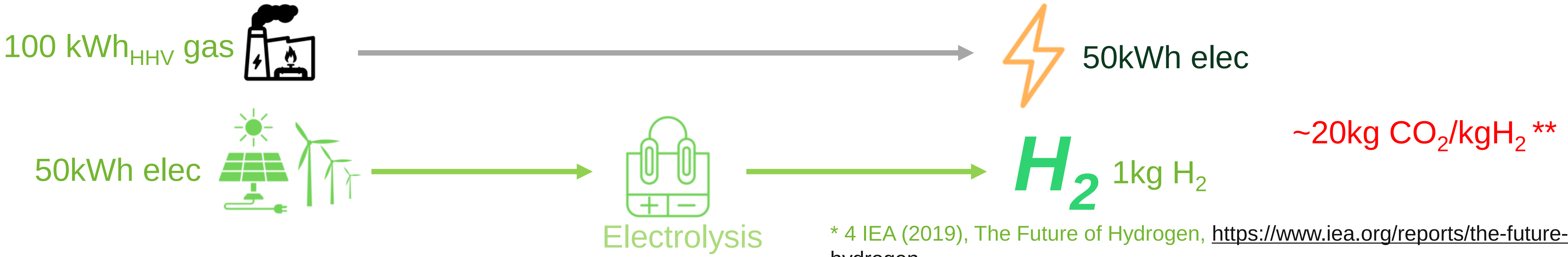
Beyond 3000-4000 operating hours, electricity is the most important cost factor

Why we need to decarbonize electricity production before hydrogen production

1. Gas produces grey hydrogen, sun/wind produces renewable electricity



2. Sun/wind for green hydrogen, gas for power production

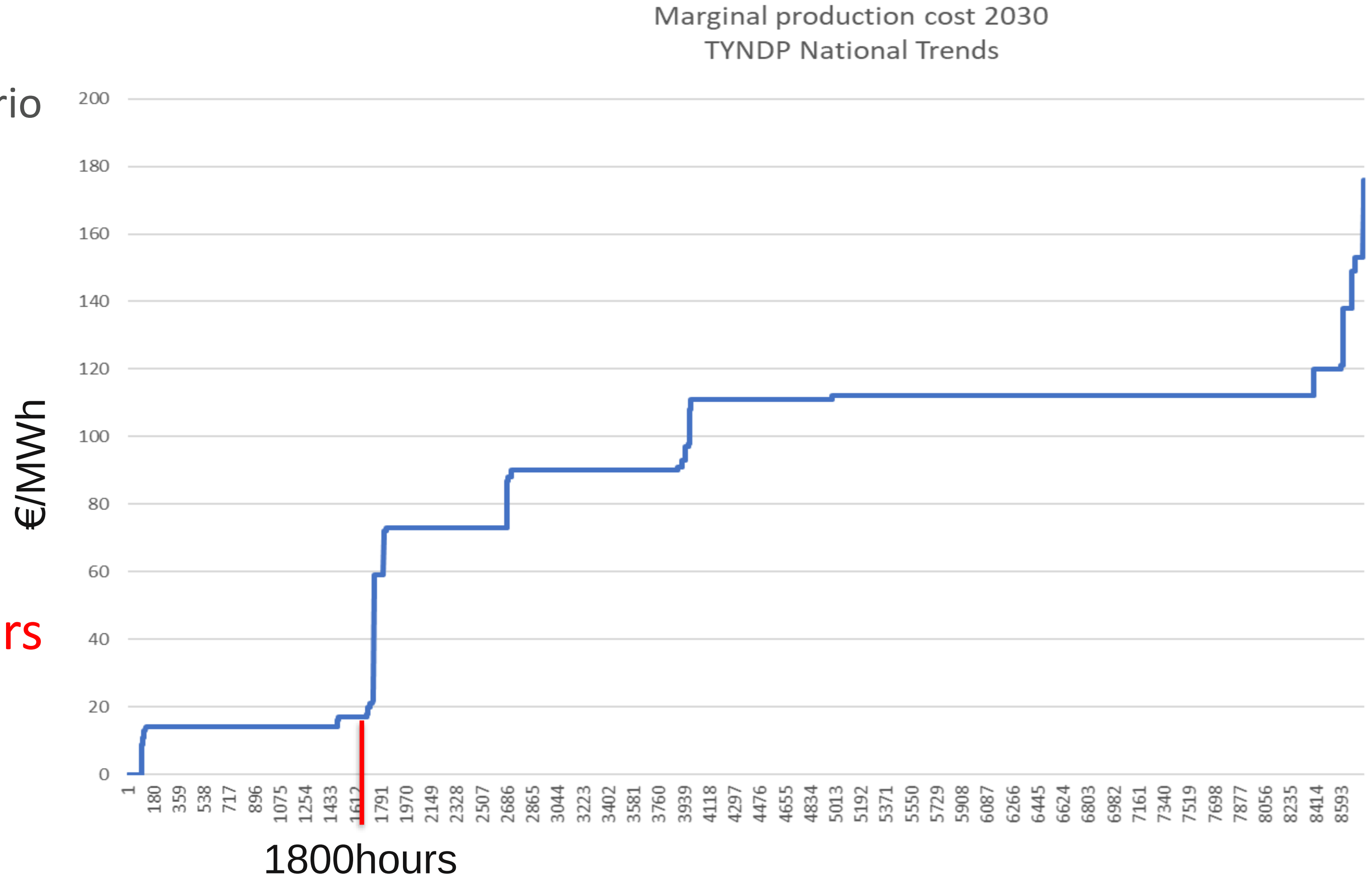


* 4 IEA (2019), The Future of Hydrogen, https://www.iea.org/reports/the-future-of-hydrogen.

** Based on 400gCO_2/kWhel CCGT

Green hydrogen: ‘excess’ electricity supply

- TYNDP national trends 2030 scenario
- ~1800hours with cheap electricity



Not enough for commercially
Viable operation of electrolysers

Source: EnergyVille dispatch model on TYNDP 2030 capacities

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Electricity for green hydrogen production

- How much hours of cheap green electricity is available?

Table 17: Amount of hours per year with electricity spot price <40EUR/MWh for electrolysis. The TYNDP National Trends number is based on EnergyVille own calculation based on TYNDP National Trends. *For the Agora Energiewende and the PBL results, it is unclear from the report how their number was calculated. **Elia reports marginal generation costs below 20EUR/MWh, but explicitly mentions it is including all hours with renewable as the marginal generation unit in the merit order.

#hours of the year with cheap electricity<40€/MWh for electrolysis	2030	2033	2035	2040	2045-2050
TYNDP 2020 National Trends	1800			4300	
TYNDP 2018/2020, Distributed Generation			1500	4300	
TYNDP 2018 in Denmark (Energynet), GCA			1900	5700	
PBL KEV2021		4334*			
Agora Energiewende	1900*			1757*	1920*
Elia Adequacy and Flexibility**	400-1000				

Data gathered by VITO/Trinomics for DG Reform

⇔ RepowerEU: 5000 – 6000 operating hours for electrolysers

Literature is scarce and PRIMES model cannot be run by research institutes => more scenario work is needed

Hydrogen 2030 ambitions: RepowerEU

Table 8: Hydrogen use by sector in 2030 (kt hydrogen)

Sector	RePowerEU	Fit-for-55
Bunker fuels	0	0
Refineries	2273	613
Industrial Heat	3629	756
Transport	2319	882
Petrochemicals (Ammonia)	3232	1306
Blast furnaces	1520	1152
Synthetic fuels	1788	1870
Power generation	105	0
Blending	1335	0
Total	**16200**	**6579**

Note: conversion from ktoe to kt H2 uses a 2.87 factor.

Hydrogen not targeted for cost efficient applications, hybrid optimization – policy projection approach

https://commission.europa.eu/publications/key-documents-repowereu_en

Other hydrogen related policy

- Net Zero Industry Act
  - Affirms hydrogen ambitions in RepowerEU
  - CCS ambition: 50Mton CO2,eq by 2030
  - No finance specified, link to other elements such as the innovation funds
- European hydrogen bank
  - Auction system to subsidize the gap between supply cost and demand willingness-to-pay
  - Start with 800M€ auction for local electrolysis, contract for differences of 10 years
  - In consequent auctions, import hydrogen may be targeted specifically as well
- Renewable Energy Directive III (Provisional)
  - Renewable energy share of 42.5% (of non-low carbon H_2)
  - 1% renewable fuels of non-biological origin (RNFBO) in transport
  - 42% of hydrogen should come from RFNBO by 2030, 60% by 2035
- Commission impact analysis in 2040
  - Less hydrogen production in RepowerEU than in 2030 (104TWh)
  - More hydrogen by 2040 (700 – 1200 TWh), even more by 2050 (2200 TWh)

(more info https://energyville.be/en/blogs/climate-goal-for-2040-a-new-milestone-for-the-eu/)

Import of hydrogen

Het bezoek van de koning moet de expertise van de Belgische bedrijven en de samenwerking rond hernieuwbare energie tussen België en Namibië in de verf zetten.

Foto: Belga

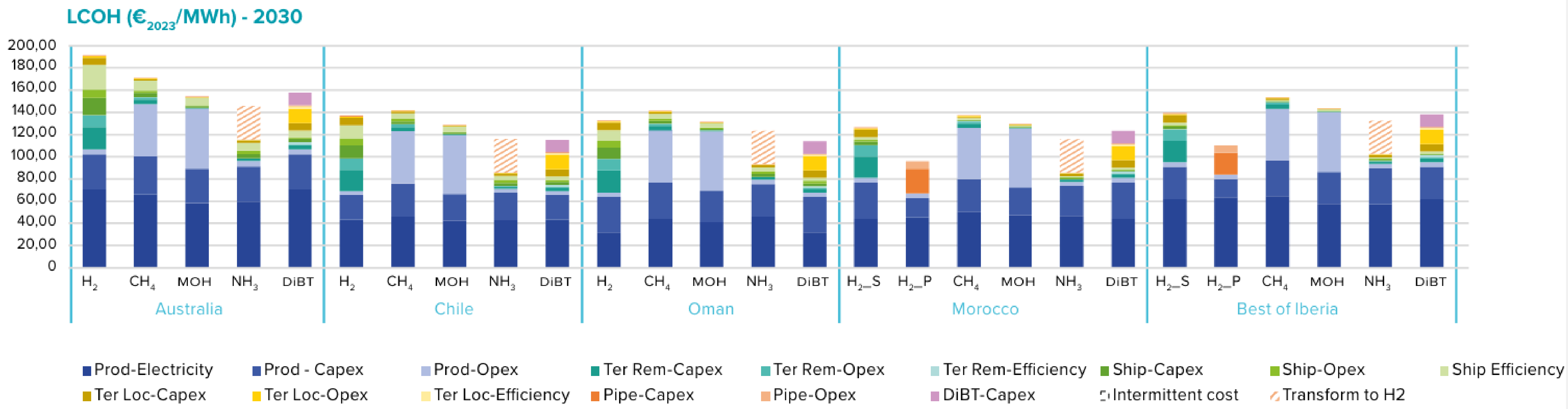
Import of hydrogen via ship

Via liquid hydrogen	Production efficiency	Shipping volume	Import
Liquid hydrogen	75-80% for production *70% liquefaction (-253°C)	Density 40% of LNG Boil off losses no fleet available	Regasification possible, more expensive than LNG New infrastructure needed
Via Ammonia	75 – 80% (green H2) * 70% (Haber Bosch) *~90% liquefaction	Existing fleet Density 59% of LNG	~20 - 30% losses for Ammonia to hydrogen reconversion/cracking process
LOHC	75 – 80% (green H2) * ~70%	Density ~25% of LNG Carrier weight	~30-40% losses for regasification
Synthetic methane	Where to get the CO2??		Still emits CO2 if not converted to H_2 Shipping back CO2 is not evident

Irena 2022: Technology review of hydrogen carriers
https://www.irena.org/publications/2022/Apr/Global-hydrogen-trade-Part-II

Shipping hydrogen will not be able to be competitive, hydrogen derivates should be used as derivates

Import of hydrogen via ship



- Source: The Hydrogen Import Coalition
- Hydrogen via pipeline is more cost effective than hydrogen via shipping

Out of the blue

- RepowerEU => NO blue hydrogen
- 1GW scale, Auto Thermal Reforming => 95% capture rate

ENGIE and Equinor have decided to sign a joint development agreement (JDA), progress H2BE to the next development phase and further mature towards concept selection in 2023.

Blue hydrogen can be cost competitive (depending on gas/CO2 prices), it is however not part of European ambition

A.O. Oni, K. Anaya, T. Giwa, G. Di Lullo, A. Kumar, *Comparative assessment of blue hydrogen from steam methane reforming, autothermal reforming, and natural gas decomposition technologies for natural gas-producing regions, Energy Conversion and Management, 2022* https://doi.org/10.1016/j.enconman.2022.115245.

Blue hydrogen must be done properly

Received: 24 March 2022

DOI: 10.1002/ese3.1232

Jostein Pettersen | Rosetta Steeneveldt | David Grainger | Tyler Scott | Louise-Marie Holst | Espen Steinseth Hamborg

Possibility of relocating value chains

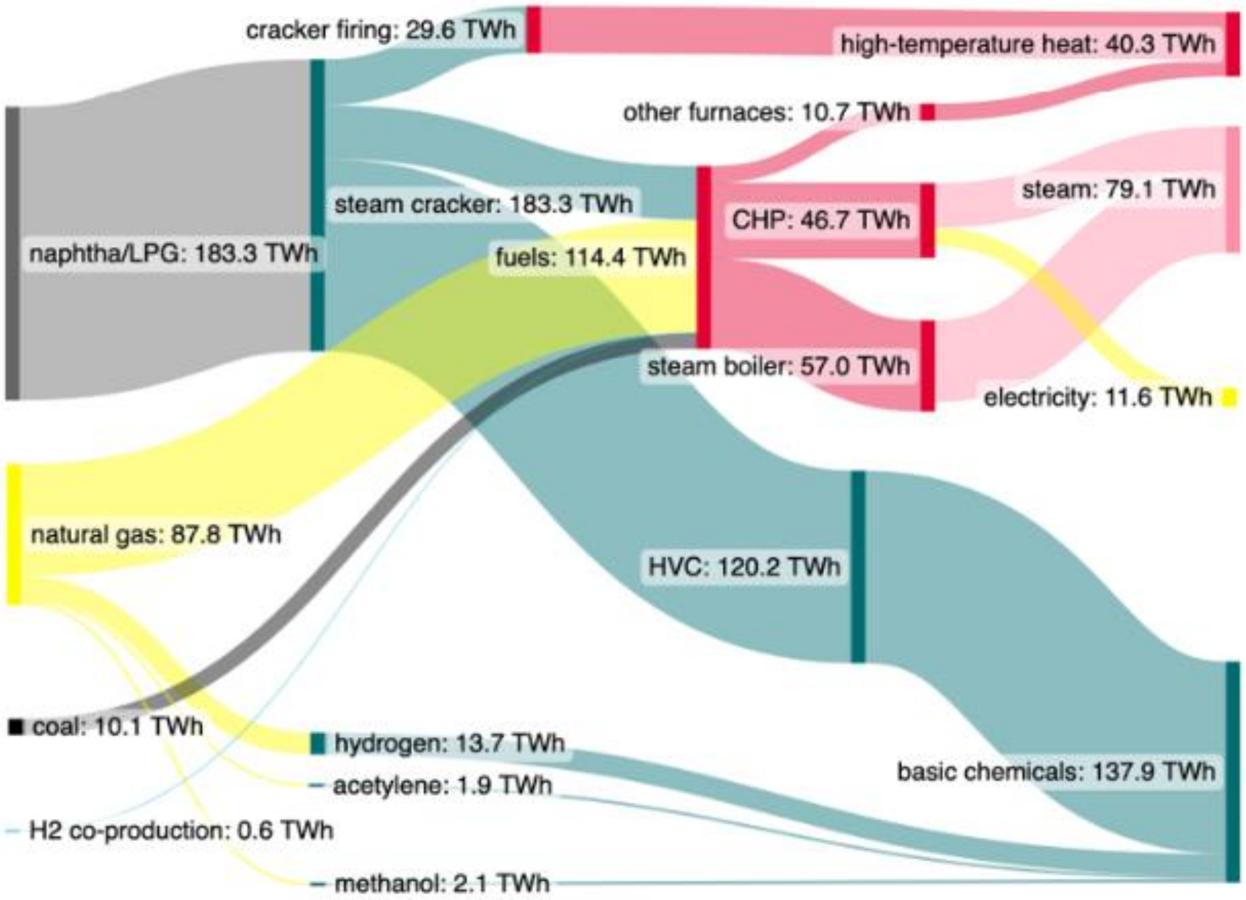


Figure 3 Sankey diagram of modeled primary energy demand for the production of basic chemicals in Germany in 2018. Data refers to the complete chemical industry without pharmaceuticals. External electricity procurement is not included here. Source: Translation of previous work (Scholz et al. 2023).

Scholz et al. *Structural analysis of petrochemical clusters in Germany: What can be learned for the transformation towards climateneutrality?*, Wuppertal 2024

EU, also an energy importer on long term?

Source	'Min potential', depending on scenario (TWh)	'Max', depending on scenario (TWh)	Comment
Offshore wind	1300	1300	Could be more adding floating wind turbines
Onshore wind	4950	8400	Min is 1200m distance, realistic potential could be less
PV on roof	1200	2100	
PV on land	0	11000	Max is with 3% of surface
Biomass	2300	2300	

Source JRC ENSPRESO - an open data, EU-28 wide, transparent and coherent database of wind, solar and biomass energy potentials

W. Nijs et al 2019, https://www.sciencedirect.com/science/article/pii/S2211467X19300720

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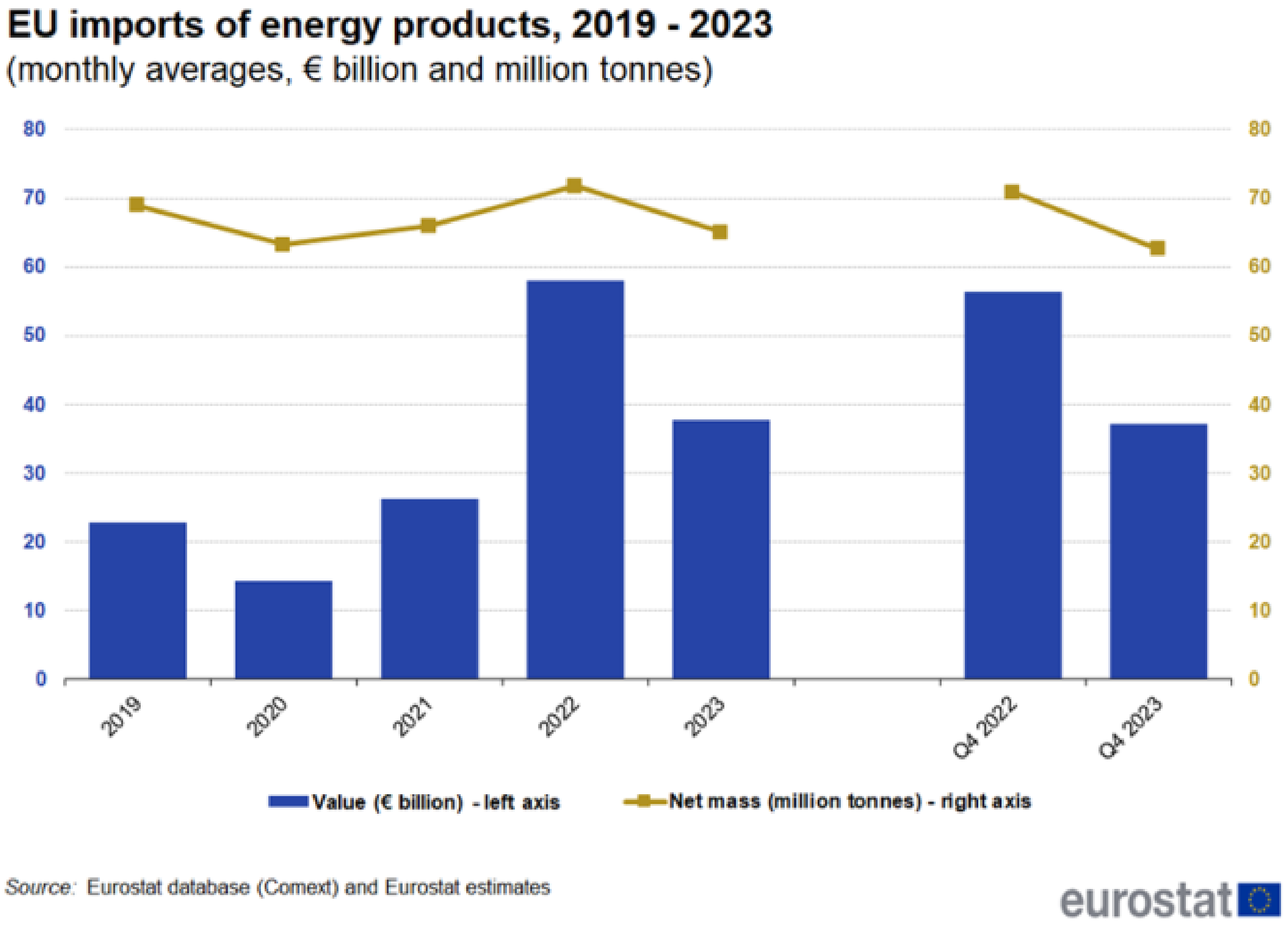
EU self sufficient with renewables => Possible, but not a walk in the park

Dependending on imported energy

Strategic decisions are needed:

- Which processes do we need in Europe?
- How much of the processes do we need?
- What can it cost in terms of public funding?
- How will industry be supported?
- What will be the rules for competition between member states to attract investments?



Critical materials act

Ambitions for independent Europe

Funding???

Picture: mobilitynotes.com

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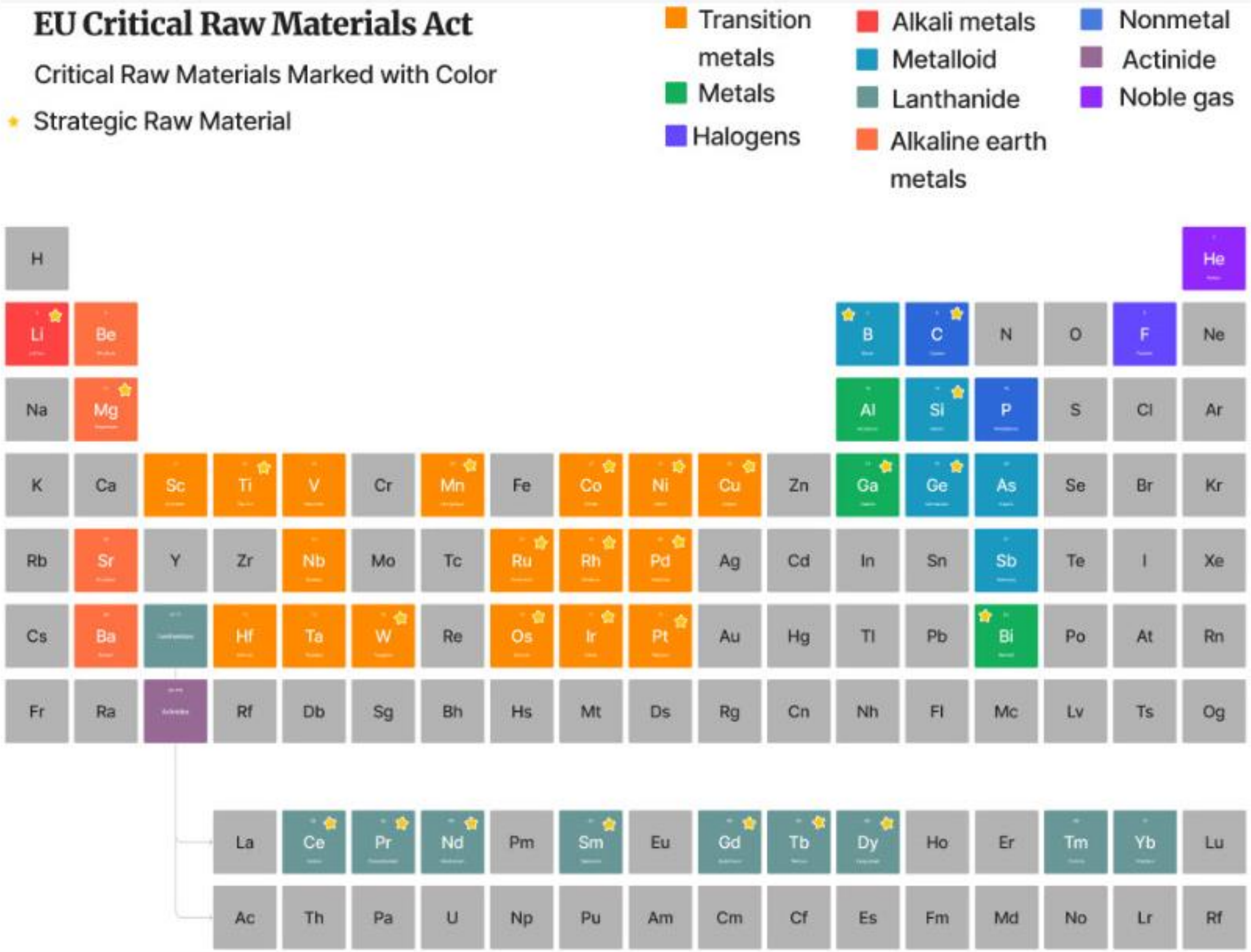
Critical materials act

- Quid steel?
- Quid fertilizer?



Picture: mobilitynotes.com

(a) Antimony
(b) Arsenic
(c) Bauxite
(d) Baryte
(e) Beryllium
f) Bismuth
g) Boron
h) Cobalt
i) Coking Coal
j) Copper
k) Feldspar
l) Fluorspar
m) Gallium
n) Germanium
o) Hafnium
p) Helium
q) Heavy Rare Earth Elements
r) Light Rare Earth Elements
s) Lithium
t) Magnesium
u) Manganese
v) Natural Graphite
w) Nickel – battery grade
x) Niobium
y) Phosphate rock
z) Phosphorus
aa) Platinum Group Metals
bb) Scandium
cc) Silicon metal
(dd) Strontium

Also National Plans are uncertain to deliver

Little information on financing and policy impact

The Commission and member states have sparse information on the cost and effects of actions to reach the targets

70 According to the 2021 EEA report, the level of quantitative information reported is low because member states do not use common evaluation approaches and methodologies, find it difficult to separate the effects of individual policies from others, and are only rarely interested in communicating the actual effects of past actions.

73 As regards **private funding**, neither the Commission nor the authorities interviewed in the five member states could provide data on the amount of private funds mobilised to reach the 2020 targets, or estimate the reduction in greenhouse gas emissions achieved as a result of private action.

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European Court of Auditors: Special report 18/2023: EU climate and energy targets – 2020 targets achieved, but little indication that actions to reach the 2030 targets will be sufficient

Conclusions: what should happen in the coming years

- **Currently**:
  - Incentives reflecting underlying techno-economics
  - Target support programs maximally to those in need of it
- **Towards 2030:**
  - Install renewables as fast as possible
  - Facilitate CO2 storage infrastructure
  - Design the offshore and onshore grid infrastructure
  - Take decisions on industrial competitivity
- **Towards 2050**:
  - Innovations such as small modular nuclear, deep geothermal, Carbon capture and utilization, synthetic molecules in transport… can help

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Conclusions hydrogen

- The most important challenge to tackle for scaling up green hydrogen is an abundant supply of clean and affordable electricity
  - ⇒ And we are not there yet
- For applications like person vehicles, local buses, low-temperature heating, electricity is more efficient and cost effective option
- Import of hydrogen should be focused on hydrogen derivates, as the ammonia dehydrogenation step is a problem for the business case
- Studies are needed on industrial competitivity and infrastructure needs

Thank you!

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Bedankt voor de aandacht!

Vlaanderen
is energie en klimaat

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