Breaking free from fossil gas

A new path to a climate-neutral Europe

Deep dive industry and refineries – Agora Online Event

«Breaking free from fossil gas»

Climate neutrality means an end to the burning of fossil fuels. A new Agora Energiewende project has modelled a robust fossil gas phase-out pathway for the EU.

Project scope and basic settings:

- → Decarbonisation pathways until 2050, with Russian gas phase out as quickly as possible (by 2027).
- → Focus on long-lasting demand reductions, as opposed to short-term behavioural changes.
- → Cost-optimized balance between direct electrification and “no-regret” applications of hydrogen.
- → Modelled sectors in 5-year steps: power, buildings, industry + infrastructure including interconnectors and storage (transport and agriculture sectors covered by existing studies).
- → EU energy system is modelled country per country. Energy demand modelled bottom-up by TEP Energy (buildings) and Wuppertal Institute (industry); power sector and energy supply modelled for the whole EU with an optimisation model by Artelys.

«Breaking free from fossil gas»

The EU-27 modelling work was accompanied by “deep dives” in 9 focus countries with 1 partner per country

National partners:

- **Bulgaria:** Center for the Study of Democracy (CSD)
- **Czechia:** Nano Energies
- **Greece:** FACETS S.A.
- **Croatia:** University of Zagreb – Faculty of Mechanical Engineering and Navel Architecture)
- **Hungary:** Regional Centre for Energy Policy Research (REKK)
- **Italy:** ECCO Climate
- **Poland:** Forum Energii
- **Romania:** Energy Policy Group (EPG)
- **Slovenia:** University of Ljubjana – Laboratory of Energy Policy (LEST)

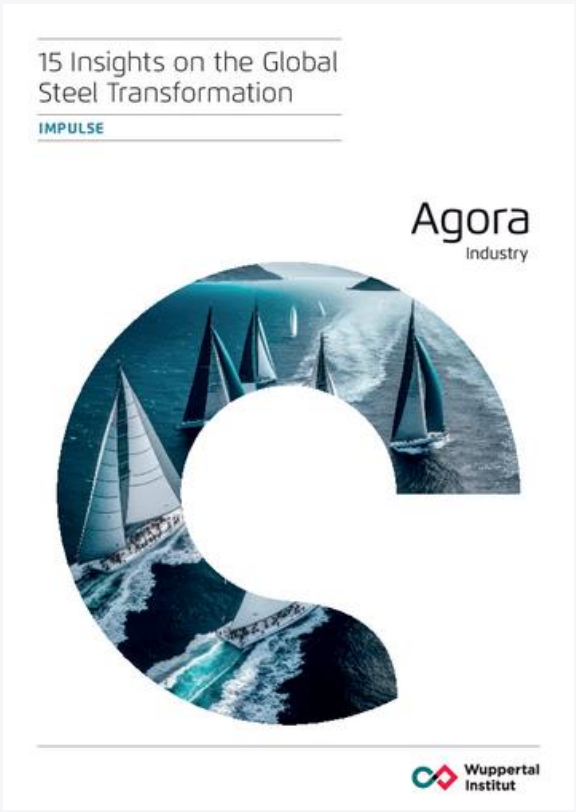
«Breaking free from fossil gas»
Key messages

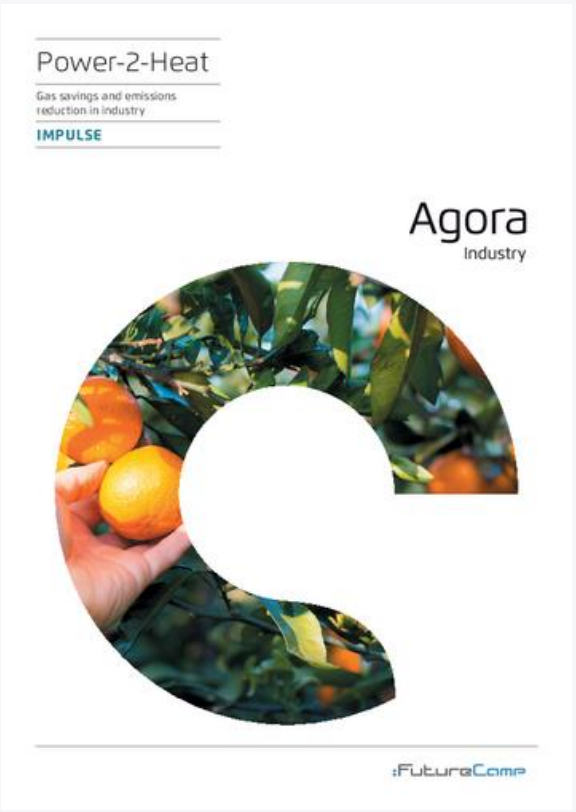
1	Fossil gas use in Europe can be halved by 2030 and completely phased out by 2050. This is possible while maintaining today's level of industrial production and fully ensuring security of supply, without disruptive behavioural changes.
2	By 2040, EU greenhouse gas emissions could decline by 89% relative to 1990 levels, with a projected remaining Union greenhouse gas budget for the 2030-2050 period of 14.3 Gt.
3	Europe will need a significant amount of renewable hydrogen to become climate neutral, but the demand by 2030 could be only a fifth of that foreseen in REPowerEU.
4	EU rules on gas, hydrogen, and infrastructure planning must reflect the projected rapid decline in fossil gas demand.

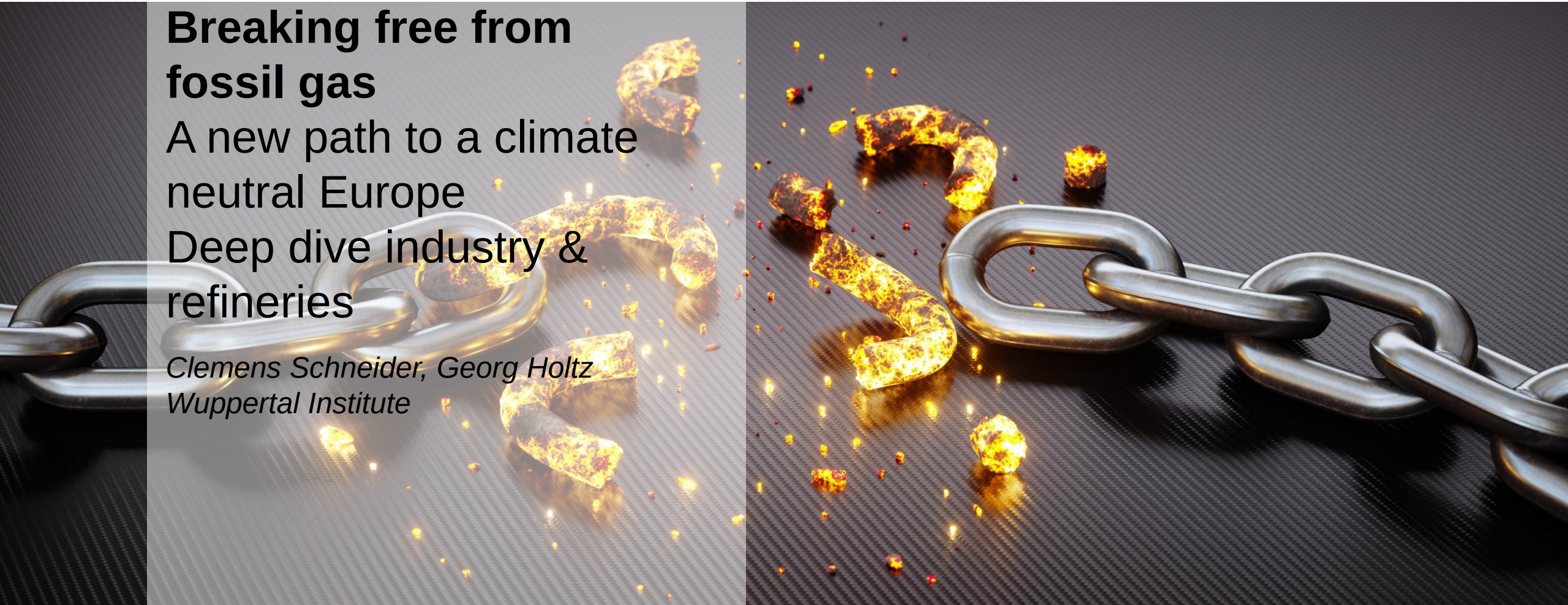
«Breaking free from fossil gas»
The webinar series

- → *4 May – Study launch webinar*
- → *24 May – Deep dive power sector and energy supply (with Artelys)*
- → ***20 June – Deep dive industry and refineries (with Wuppertal Institute)***
- → *22 June – Deep dive buildings and district heating (with TEP Energy)*

Check out some of our recent publications!







Breaking free from fossil gas

A new path to a climate neutral Europe

Deep dive industry & refineries

Clemens Schneider, Georg Holtz
Wuppertal Institute

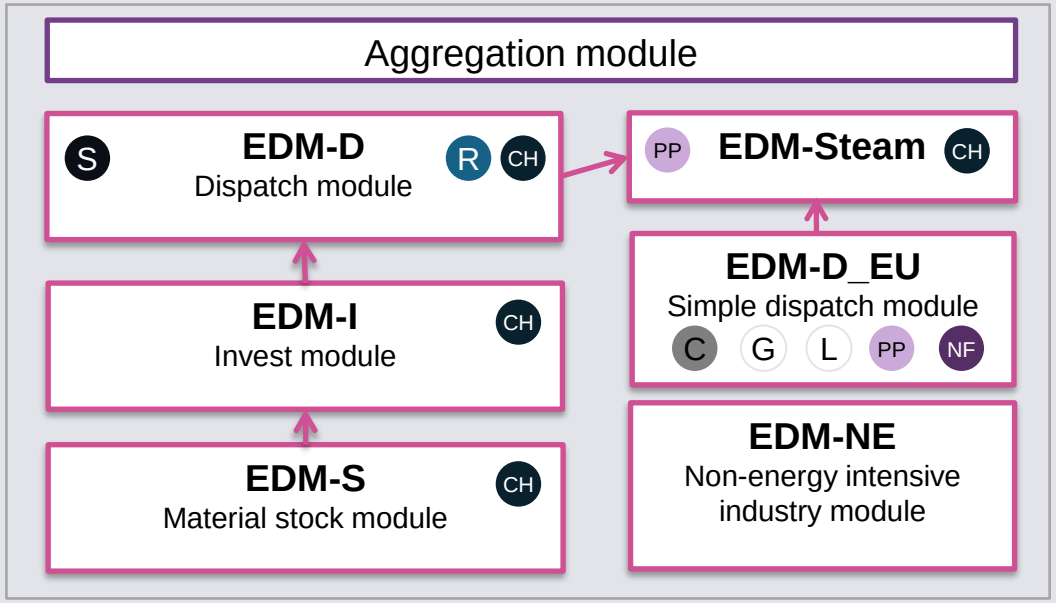
Methodology & Key assumptions

Assumptions on the industry sector

- → Only slight relocation of production:
  - The industrial structures and value chains in the EU countries are stable.
  - Some extra-EU ammonia imports (compared to 2021 and earlier) and relocation of ammonia production within the EU
- → Fast electrification via heat pumps and electric boilers to displace fossil gas
- → Industrial ovens are replaced by electric devices after 2030
- → Use of fossil gas as a bridge in the transformation of integrated steel mills only in locations without supply bottlenecks.
- → No distribution grid for hydrogen, only chemical parks and steel sites are supplied via backbone
- → The role of hydrogen as an energy carrier is limited to the use in hybrid steam supply systems (chemical parks)
- → In 2050, biomethane (and biogas where possible) is used only in local grids.

Industry modelling: country and technology specific

Overview of the WISEE-EDM modelling system



CH (Petro-) Chemicals
R Refineries
S Steel
C Cement
L Lime
G Glass
NF NF-metals
PP Pulp and paper

Wuppertal Institute

Tiered modelling approach:

- → Full site-specific European value chains are modelled for the petrochemical sector.
- → Other chemicals, iron & steel as well as refineries are modelled technology- and site-specific
- → Non-metallic minerals, non-ferrous metals and the paper industry are modelled technology specific.
- → Other industry branches are modelled in an econometric manner, with real gross value added (GVA) as a driver and assumptions about temperature level distribution of heat demand.

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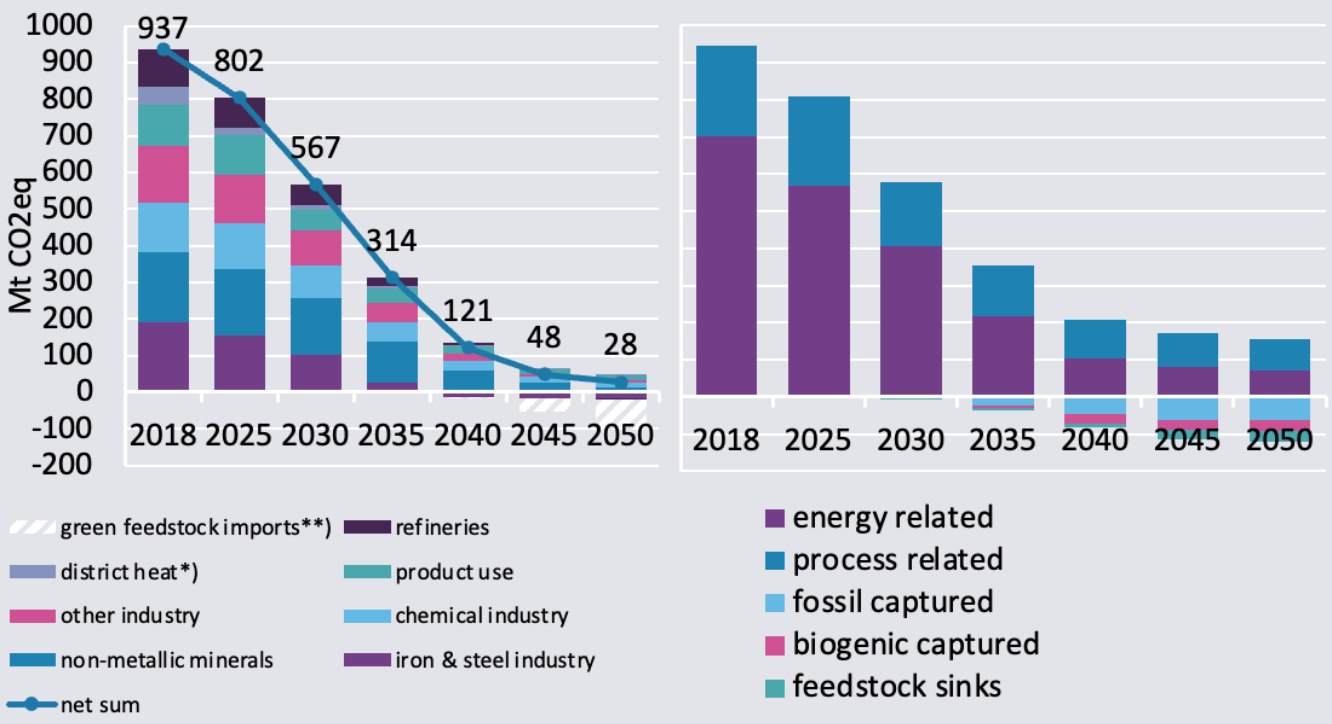
Agora Energiewende

Results

Greenhouse gas emissions

GHG emissions from industry & refineries in the EU-27



Wuppertal Institute (2023)
*) district heat = external heat supply in sectors other than chemicals and refineries

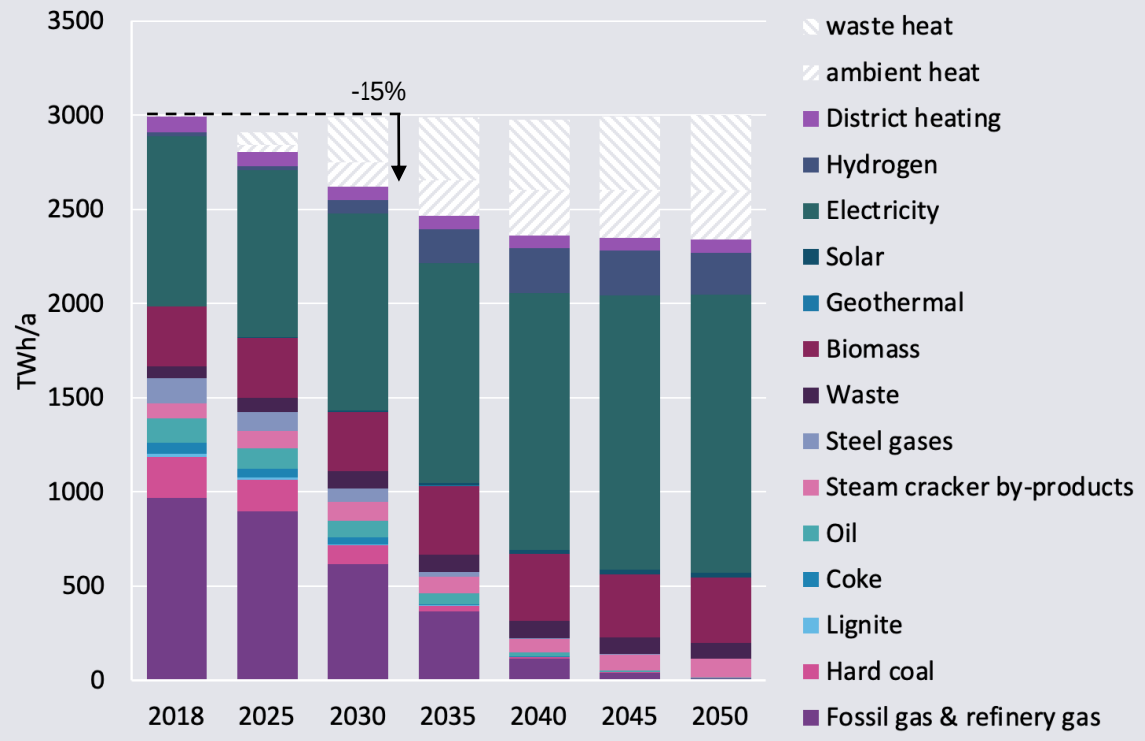
- The trajectory for Green House Gas emissions of the industry and crude oil refining sector shows a steep decline until the year 2040.
- In 2040, the defossilisation of energy supply is almost accomplished, the main remaining part are process related emissions, that are increasingly captured.
- After 2040 negative emission contributions are added via green feedstock and BECCS.

Until 2030, …

- ...the bulk of emission reductions are achieved in the iron & steel industry (89 Mt CO_{2eq} or 47%).
- … the non-GHG intensive industries achieve a reduction by 61% by 2030, mainly by phasing-out natural gas.
- Chemical industry and refineries reduce their GHG emissions by 45 and 46 million tons (33% / 45%).

Final energy demand declines mostly due to electrification and the use of waste heat

Final energy demand in industry in the EU-27

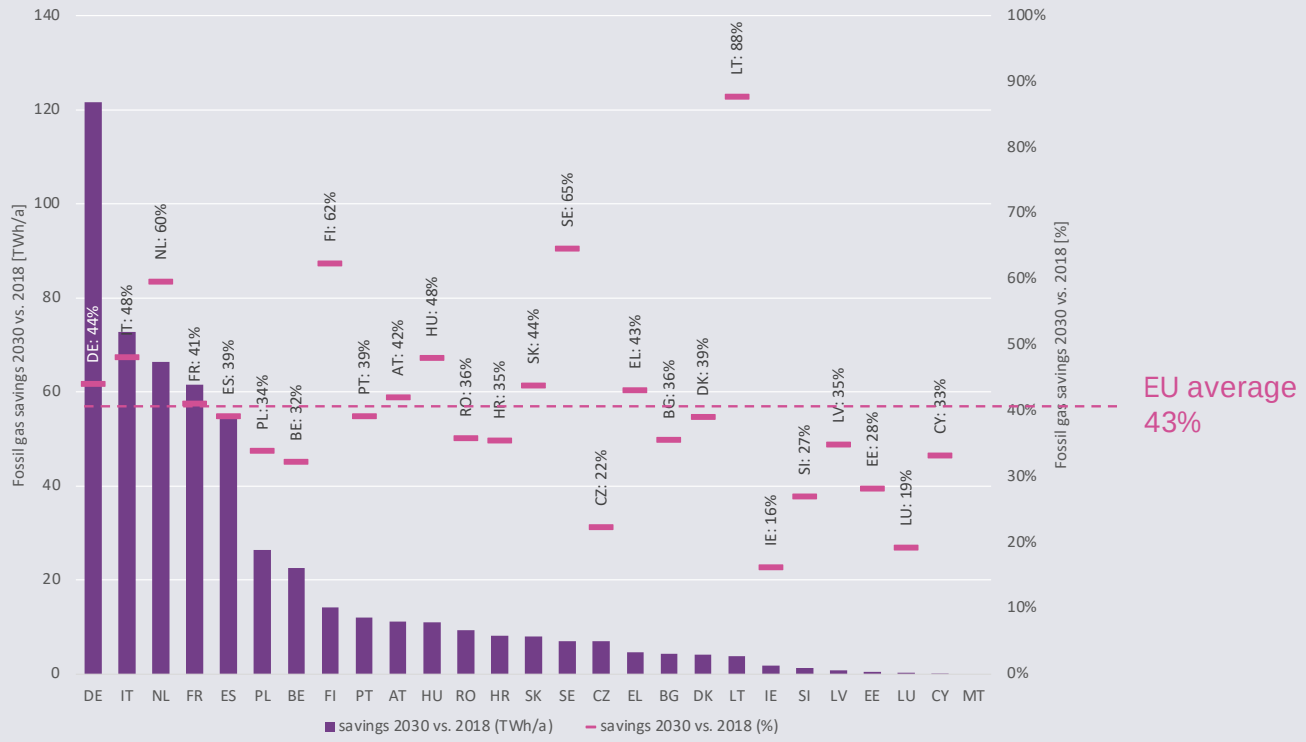


Wuppertal Institute (2023)

- Final energy demand in the sector declines by 15% by 2035 and stagnates until 2050 (not including ambient heat and waste heat).
- Fossil fuels decline from 53% in 2018 to 38% in 2030 (direct use in industry). It further declines to 9% in 2040 with a limited remainder of oil consumption by 2050 (4%, 100 TWh), which represents the energetic use of by-products in the chemical industry. Fossil gas can be almost phased out by 2045.
- Electrification as primary fuel switch strategy: from 30% of total in 2018, 40% by 2030 and about 55% by 2040 and beyond.
- Energetic biomass and waste are restricted to high temperature generation and are mainly used in plants with carbon capture.
- Solar thermal energy plays an important role in big chemical parks in the Mediterranean and Black Sea region where it is part of hybrid steam supply systems.

The industry and refinery sectors can save on average 43% of fossil gas by 2030

Savings in fossil gas use in industry and oil refining in the EU-27, 2030 vs. 2018

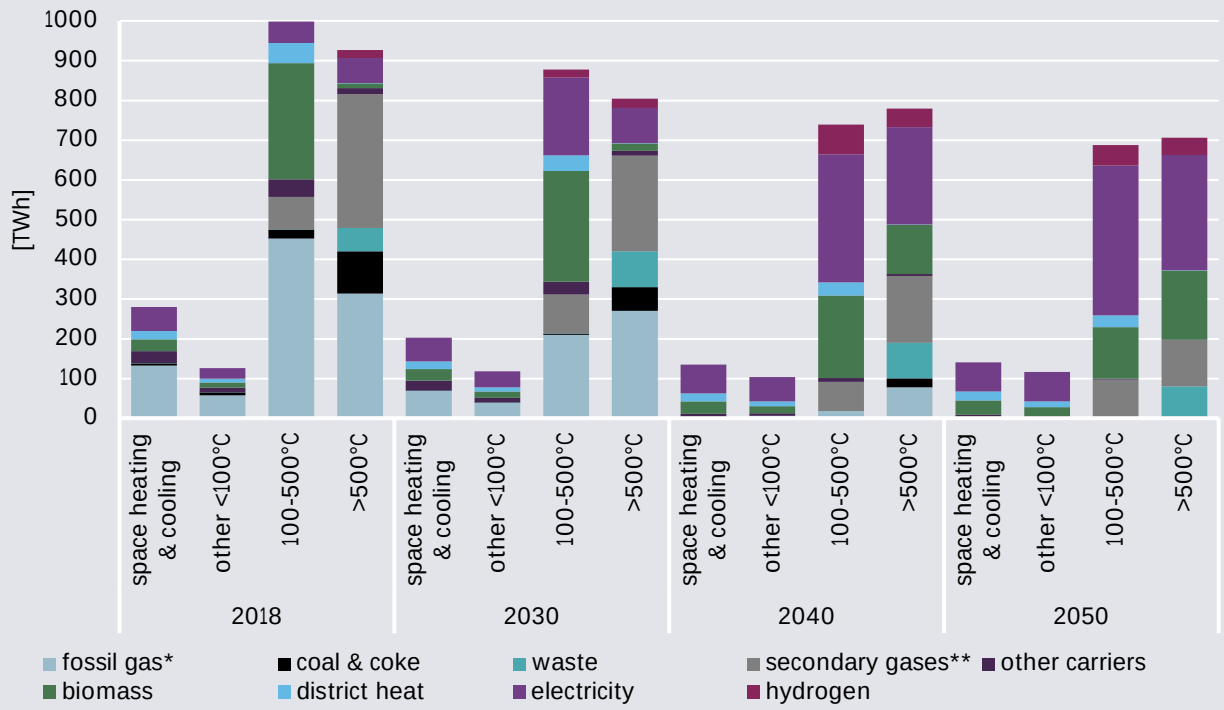


Wuppertal Institute (2023)

- Savings stretch from 16 to 88% according to the Member State.
- The largest savings are achieved in Germany, Italy, the Netherlands, France and Spain, together representing 70% of the industrial savings in volume.

Fossil gas can be displaced by direct electrification at all temperature levels, complemented by biomass, hydrogen, waste and district heat

Final energy use for heat in the industry sector per temperature level

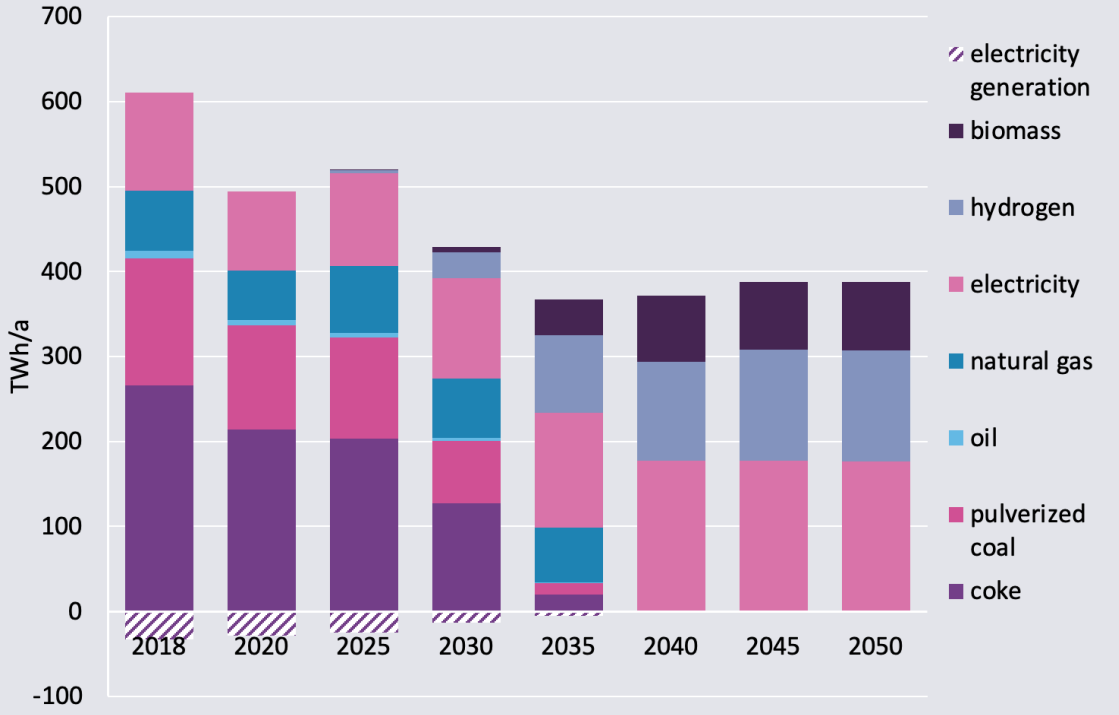


Wuppertal Institute (2023) * "fossil gas" includes fossil gas, refinery gas and LPG; **"secondary gases" include coke oven gas, blast furnace gas, basic oxygen furnace gas and steam cracker by-products

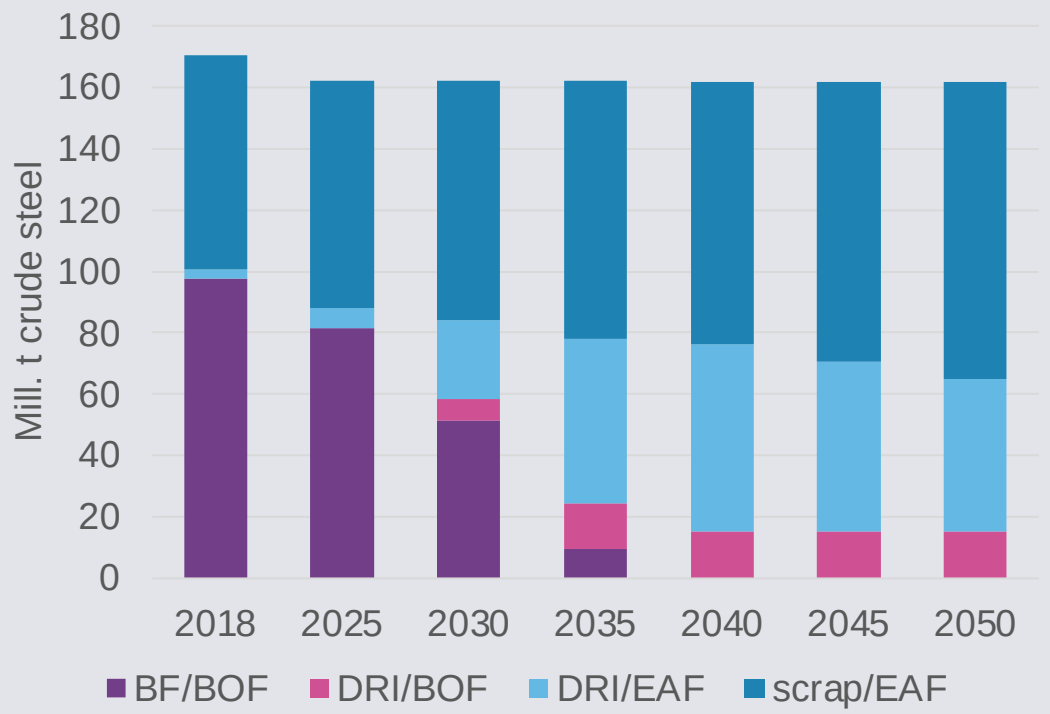
- → Rapid gas demand reduction until 2030 in the low- to mid-temperature segments including steam production. Further decline in all segments after 2030, the remainder in 2040 being mostly in high temperature processes.
- → Electrification plays a significant role in all temperature levels.
- → Biomass gain in importance starting in 2030, especially in higher temperature segments.
- → Hydrogen is used in a limited manner starting in 2040 in high temperature segments. Hydrogen remains mostly used as a feedstock at any time.
- → The use of secondary gases as by-product of industrial processes declines with the transition of those production processes to cleaner alternatives.

Sub-sector transformation: Iron & steel

Primary energy use of the steel industry in the EU-27



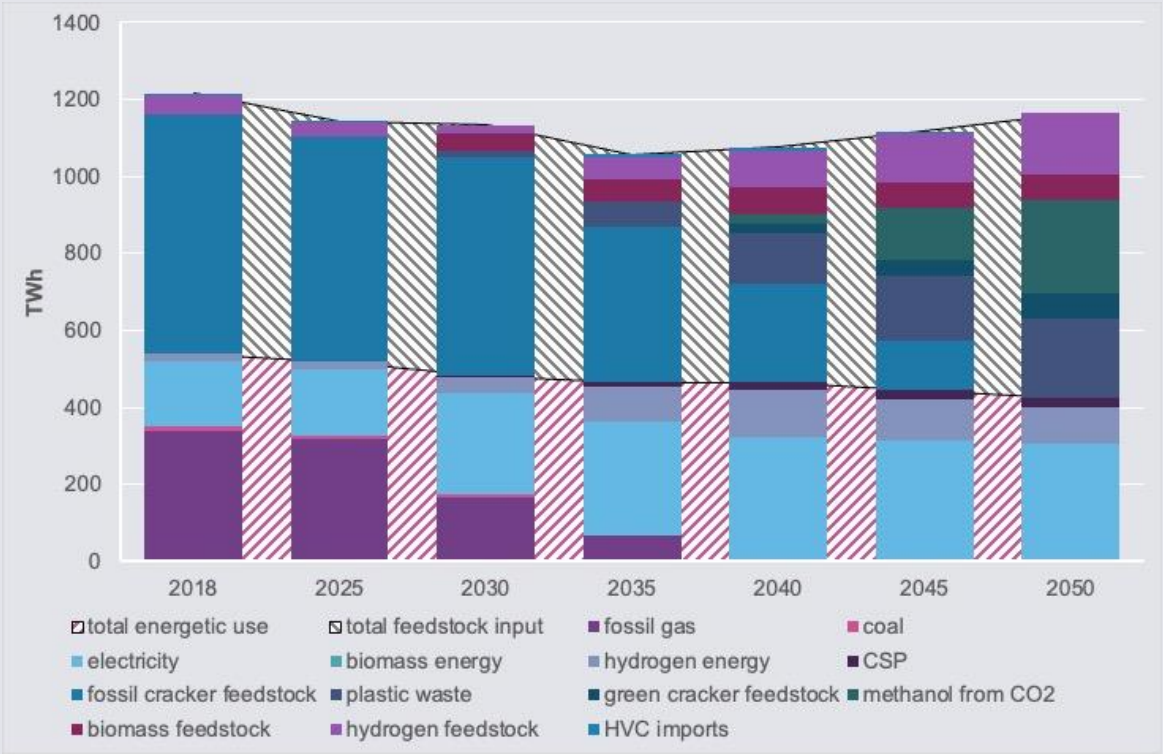
Crude steel production by process



Wuppertal Institute (2023)

Sub-sector transformation: Chemicals

Final energy use and feedstock input in the chemical industry in the EU-27

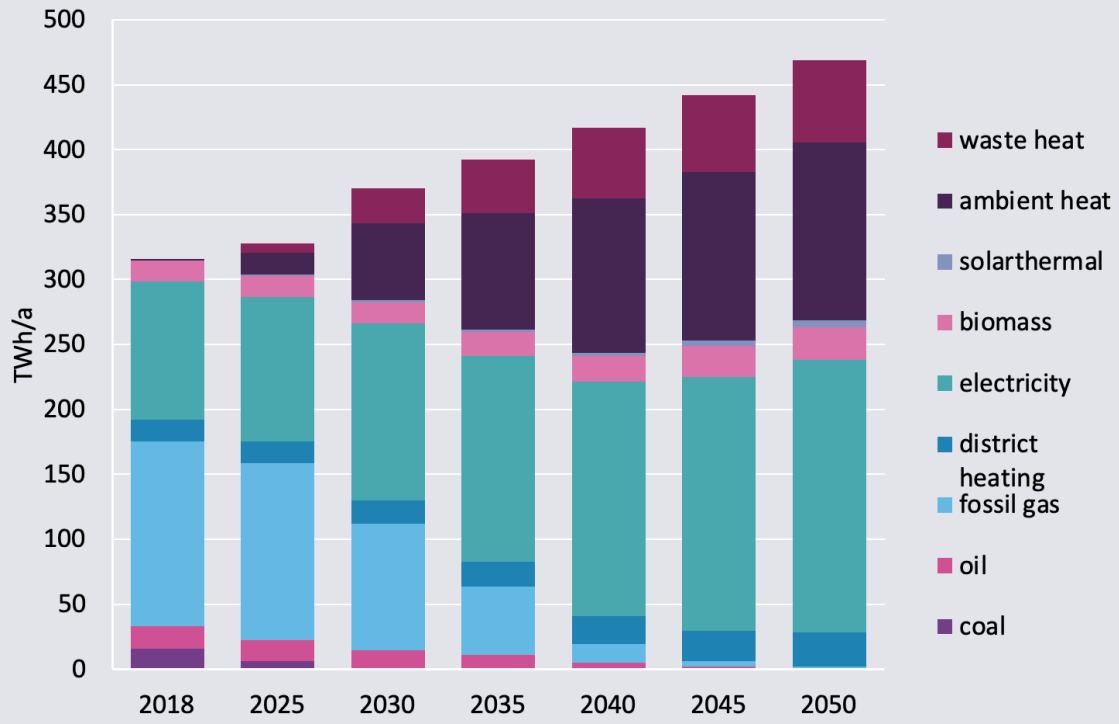


Wuppertal Institute (2023)

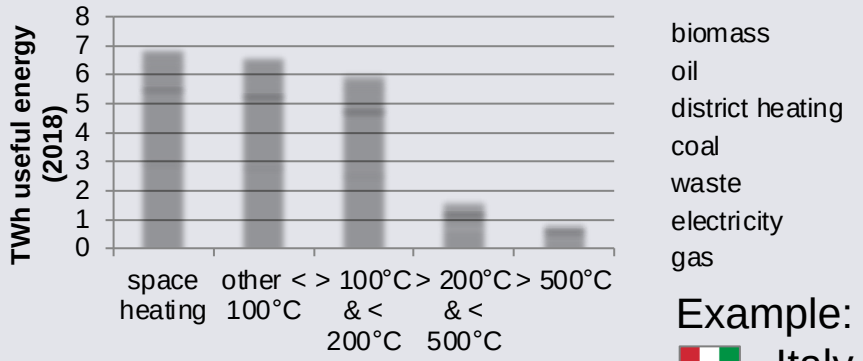
- Thanks to efficiency increases and electrification, final energy demand declines by 7% by 2030 and 16% by 2050 (excluding ambient and waste heat).
- The sub-sector is fossil-gas free in terms of energy use by 2040: it is being replaced mostly by electricity (about 80% of energy demand in the long run) and renewable hydrogen.
- Fossil steam cracker feedstock currently representing more than 90% of feedstock use next to fossil-based hydrogen is being replaced starting 2030, starting with biomass and green hydrogen. On the way towards a circular economy the complete feedstock supply is defossilized by 2050.
- The green feedstock (e.g. methanol from atmospheric CO_2 and hydrogen from water electrolysis) serves as a carbon sink delivering net negative emissions. Green refineries in Europe and CCU in Southern Europe (e.g. from cement plants) help to diversify the feedstock supply.
- Massive investments in waste treatment plants and in methanol-based production routes are required.

Sub-sector transformation: Food, Beverages & Tobacco

Final energy demand in the manufacturing of food, beverages & tobacco



Wuppertal Institute (2023)



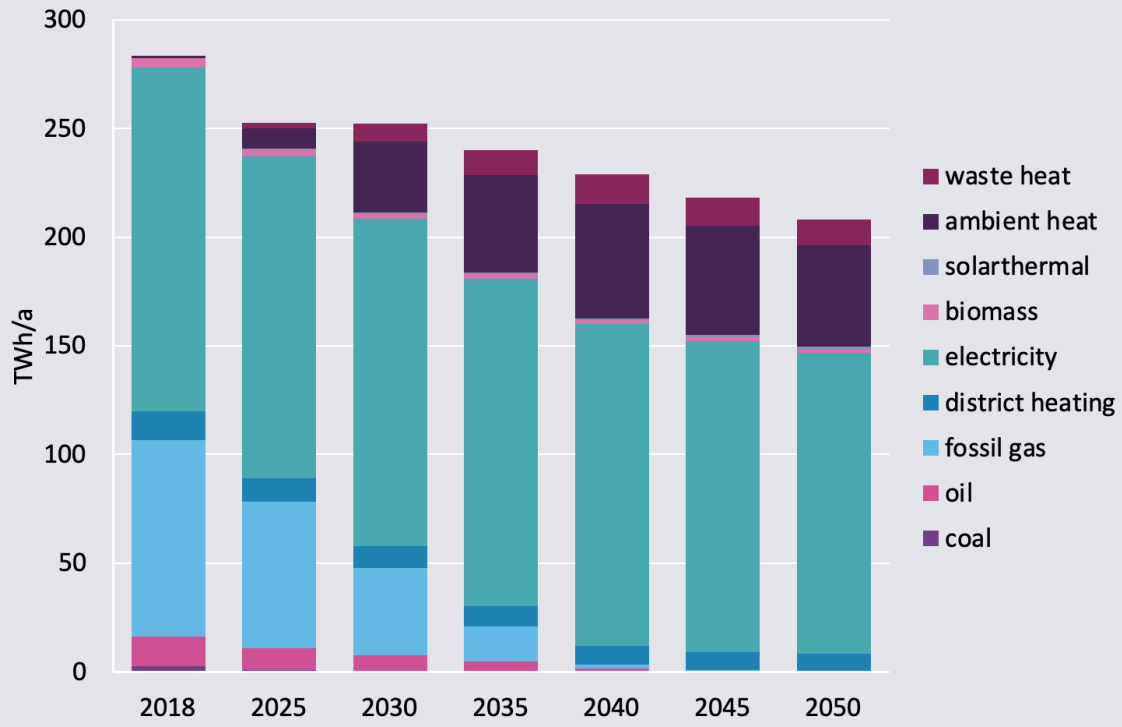
Example: Italy

Wuppertal Institute (2023) based on FH ISI project data

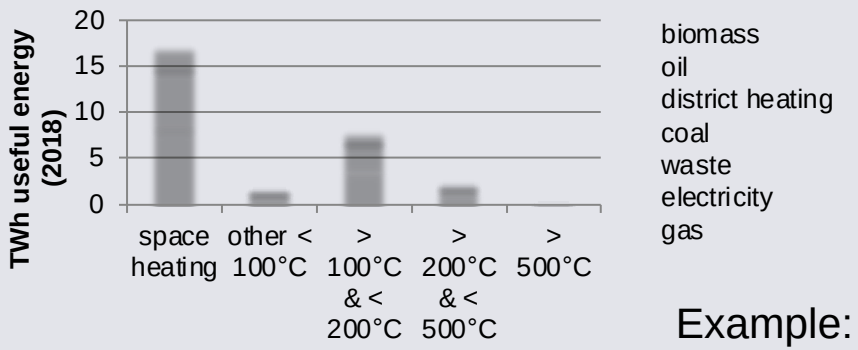
- → Strong economic growth.
- → Current technologies can be substituted by heat pumps making use of ambient heat and waste heat, the sub-sector having a large production of low temperature waste heat.
- → Biomass and district heat use motivated by the local availability of these options.

Sub-sector transformation: Machinery & Transport equipment

Final energy demand in the manufacturing of machinery & transport equipment



Wuppertal Institute (2023)



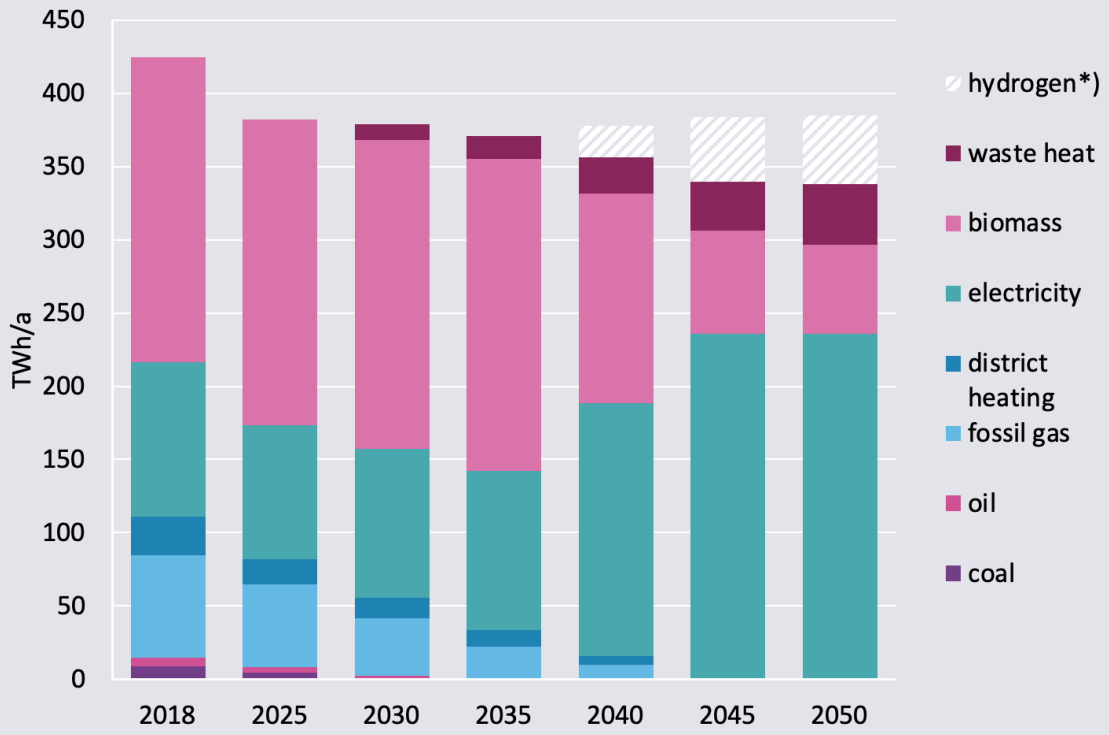
Example: Italy

Wuppertal Institute (2023) based on FH ISI project data

- The sub-sector already relies largely on power today (up to 56% of final energy demand). Thanks to efficiency increases and electrification, final energy demand declines by 25% by 2030 and 47% by 2050 (excluding ambient and waste heat).
- Even with an increased electrification the use of heat pumps allows to reduce power demand overall by 12% between 2018 and 2050.

Sub-sector transformation: Pulp & paper

Final energy demand in the manufacturing of pulp and paper

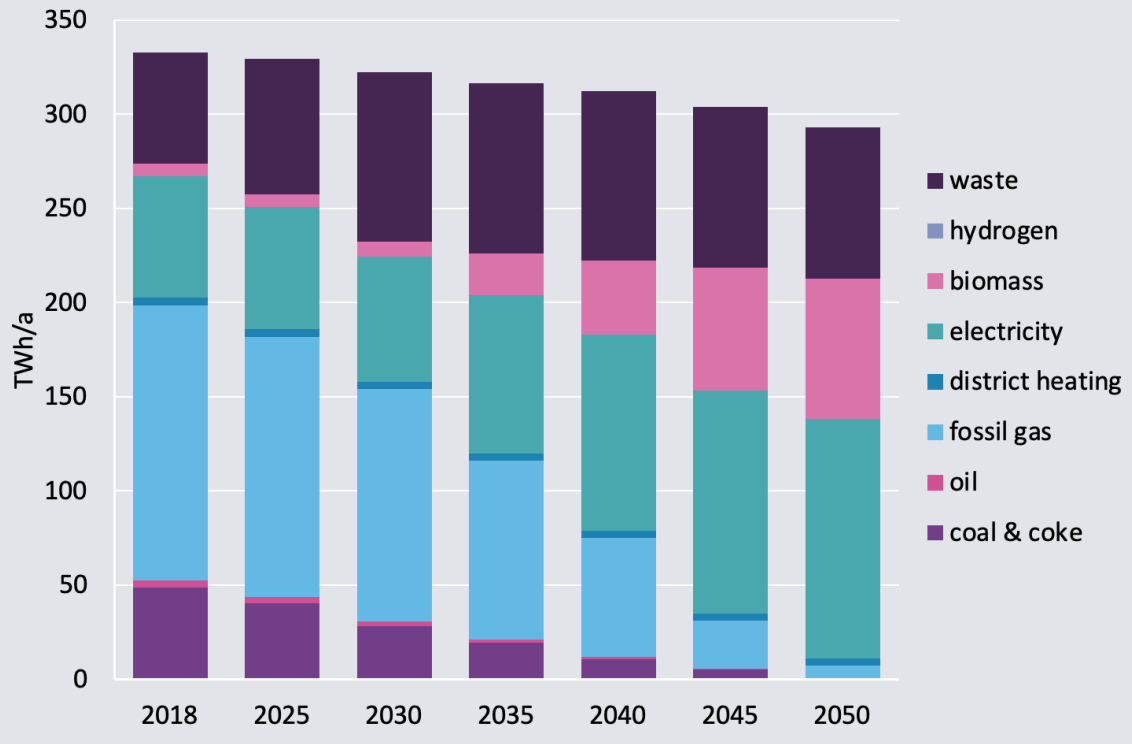


Wuppertal Institute (2023)
*) hydrogen is used for black liquor upgrading to methanol

- Thanks to efficiency increases and electrification, final energy demand declines by 13% by 2030 and 30% by 2050 (excluding waste heat).
- A relatively small fossil gas consumer compared to the other sub-sectors, it can be close to fossil-gas free by 2040, phasing out its relatively small share of oil and coal as well at the same time.
- Fossil gas is used mostly in mid-temperature ranges for steam production, especially in the paper production step.
- Biomass represents about half the FED in the sub-sector today. Biomass residues (bark, black liquor) are available in pulping plants, which are highly concentrated in Sweden and Finland. Biomass will be heavily substituted by electric heat, which allows a shift in biomass use towards more efficient uses.
- Power demand will scale up to represent up to 80% of final energy demand by 2050 (excluding waste heat, up from 25%). The remainder will be supplied by biomass residues.

Sub-sector transformation: Non-metallic minerals

Final energy demand in the processing of non-metallic minerals

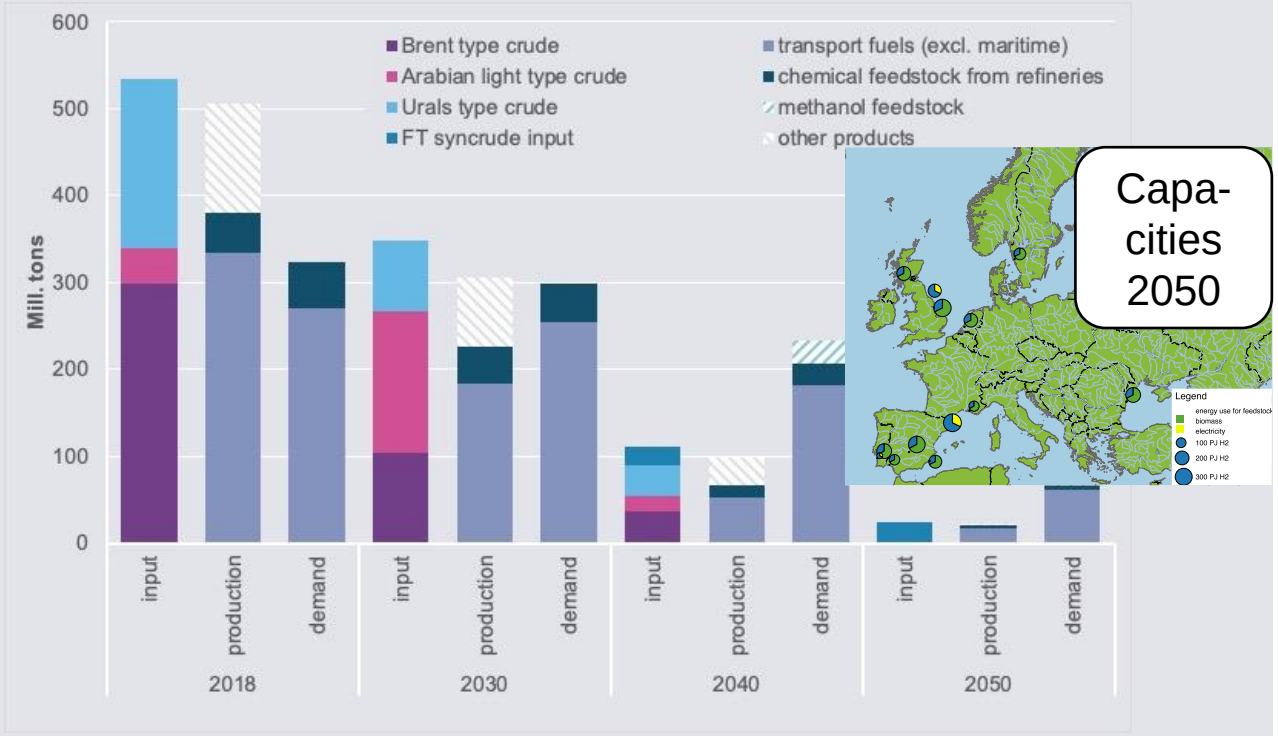


Wuppertal Institute (2023)

- Final energy demand will decline steadily in this sub-sector to reach 12% by 2050.
- Due to the high temperature heat demands and production locations near to raw materials rather than to energy infrastructures the non-metallic industry branch is a real hard-to-abate sector.
- Fossil gas demand will decline by only 5% by 2030 but the bulk of its demand reduction will take place until 2045, making this sub-sector the last one to phase out fossil gas. Coal, coke and oil will be almost phased out in parallel until 2040.
- Easy measures like the increased use of waste are quickly adopted, but the further defossilisation of energy supply requires rather high investments into the core technologies of the sector, i.e. the ovens.
- Waste and biomass fired ovens are equipped with carbon capture wherever possible and (partial) electrification is fostered after 2030, in particular in the glass industry or the cement industry (calcination).

Sub-sector transformation: Refineries

Refinery balance vs. fuel and feedstock demand in the EU-27

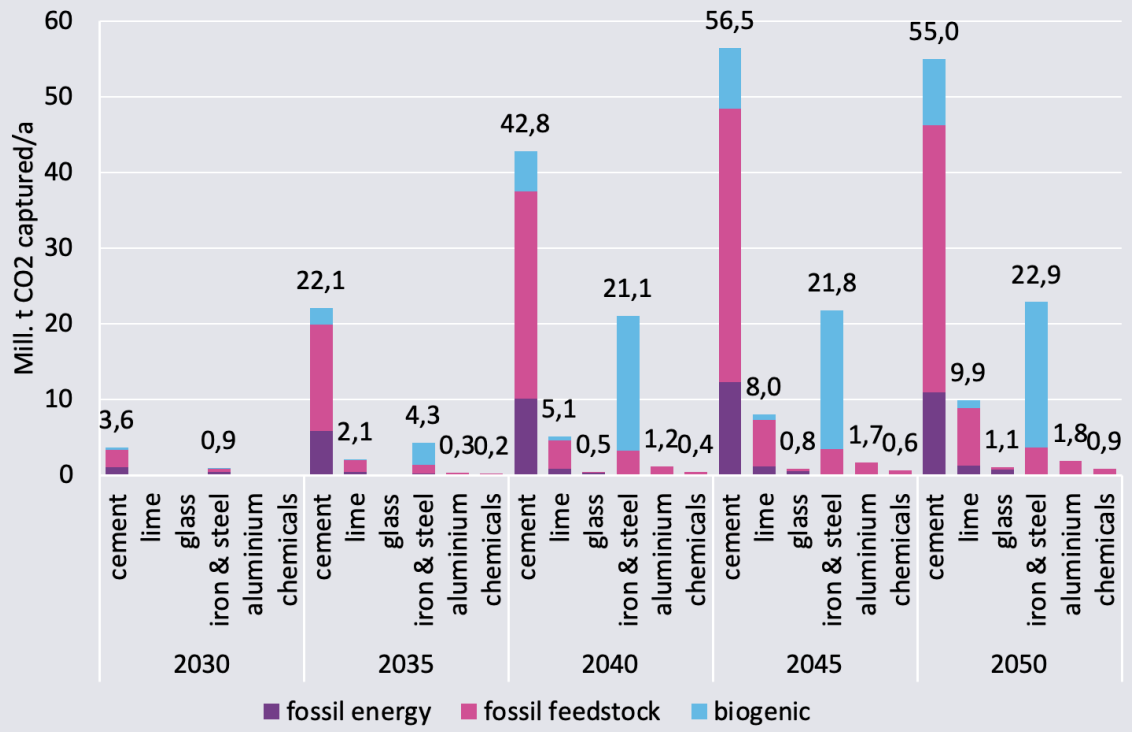


Wuppertal Institute (2023)

- Europe has overcapacities in crude oil refining, but many refineries are old and not well integrated.
- A decline in hydrocarbon transport fuel demand should thus result in refinery closings or massive scale-downs, starting around 2030.
- Refinery closings together with a switch in crude oil supply to lighter feedstock improves the gas balance.
- The future of the European refining sector is still very open, but we assume a partial coverage of European remaining demands (in aviation and shipping) by domestic Fischer-Tropsch fuel production at sweet spots on the Iberian Peninsula and smaller units at the North, Baltic and Black Sea.

The role of CCS in industry

CO_2 captured in industrial processes

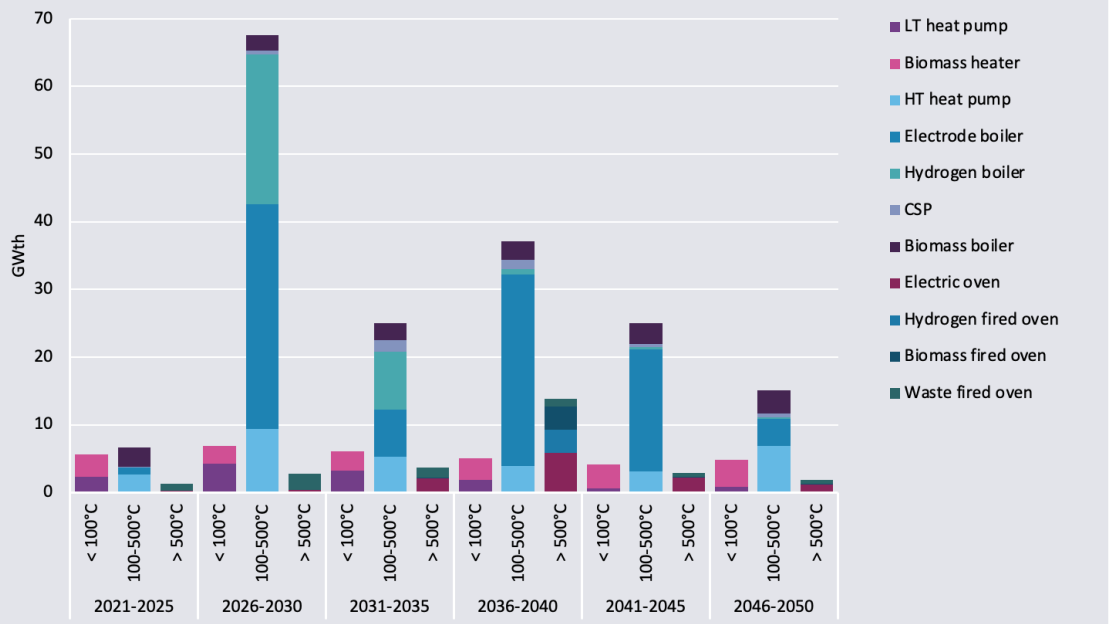


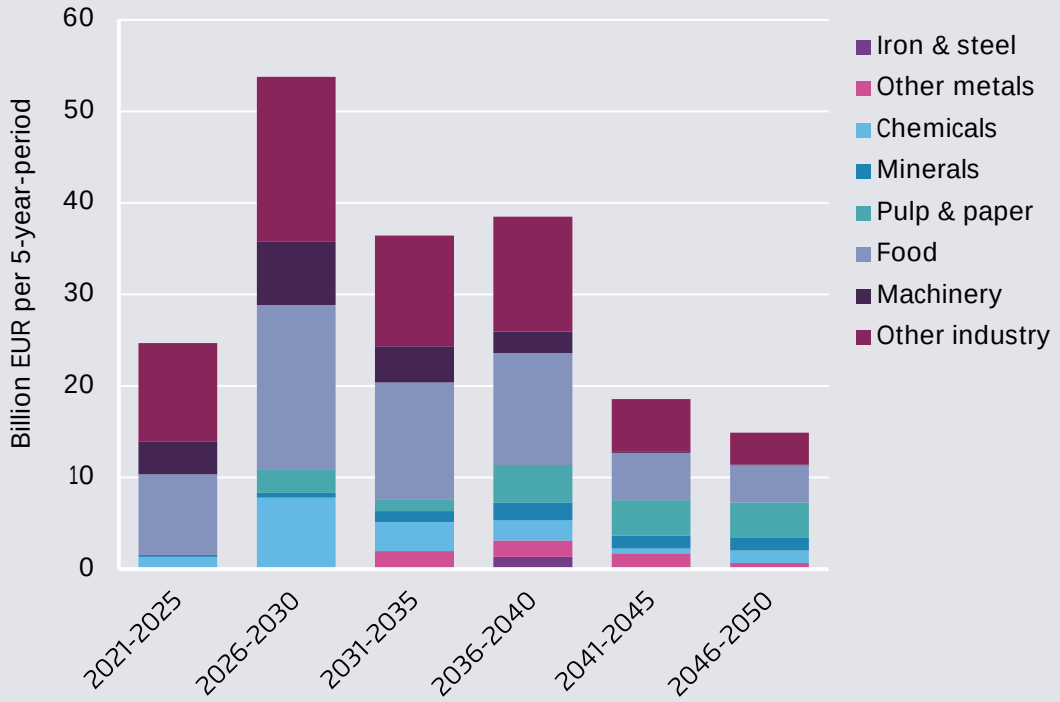
Wuppertal Institute (2023)

- Carbon capture is exclusively used at industrial plants that have process related emissions and/or require high temperatures.
- Most of the CO_2 captured is assumed to be stored in suitable geological formations, only little amounts are used to produce methanol at sweet spots with very low expected electricity prices (especially in Spain).
- The bulk of captured CO_2 comes from the processing of limestone in combination with waste and biomass energetic use.
- A particular case for BECCS is foreseen in the steel industry, where biomass could deliver parts of the reducing gas in shaft furnaces and energy for downstream operations (hot rolling plants).

Invest in fuel switch for heat supply

Invest in GW_{fuel} (left) and billion Euros in EU-27 industry (right)*





Wuppertal Institute (2023) - *excl. investments in new technologies such as DRI plants, new steam crackers or oxyfuel cement clinker ovens

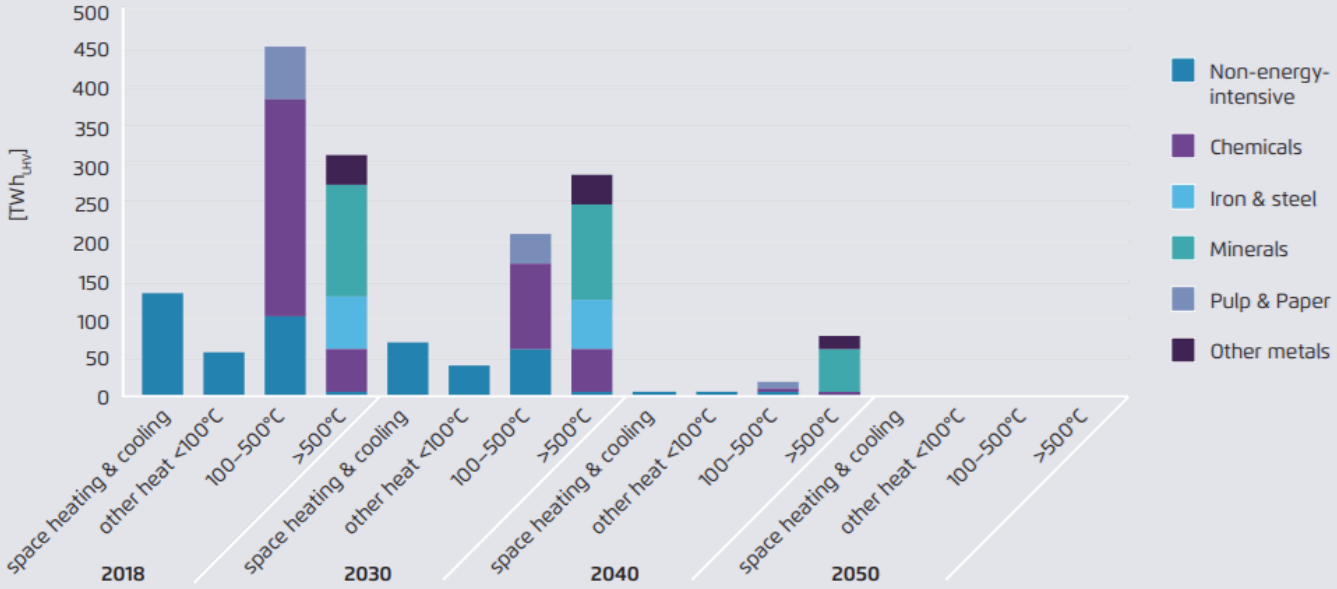
Backup

Industry modelling: A detailed analysis of assumptions and results was carried out in five countries

Five deep dive countries for industry	Key parameters
→ **Bulgaria:** Center for the Study of Democracy (CSD) → **Hungary:** Regional Centre for Energy Policy Research (REKK) → **Italy:** ECCO Climate → **Poland:** Forum Energii → **Romania:** Energy Policy Group (EPG)	Industrial production: consistent at EU-27 level → GVA of industry and its branches → Evolution of production volumes for energy intensive products (and market shares within the EU) → Assumptions on the ramp-up of and market penetration of new heat supply technologies → Assumptions / simulation results for core (re-)invests such as Fischer-Tropsch refineries, iron reduction or steam crackers Industrial sites & infrastructure: → Evolution of the H_2 backbone in the country and connection dates for important sites (chemicals, refineries, steel) → Evolution of the CO_2 grid in the country and connection dates for important sites

The use of fossil gas differs according to the subsector, requiring a mix of technologies to displace

Evolution of fossil-gas* consumption in the industry sector by sub-sector and heat type, EU-27

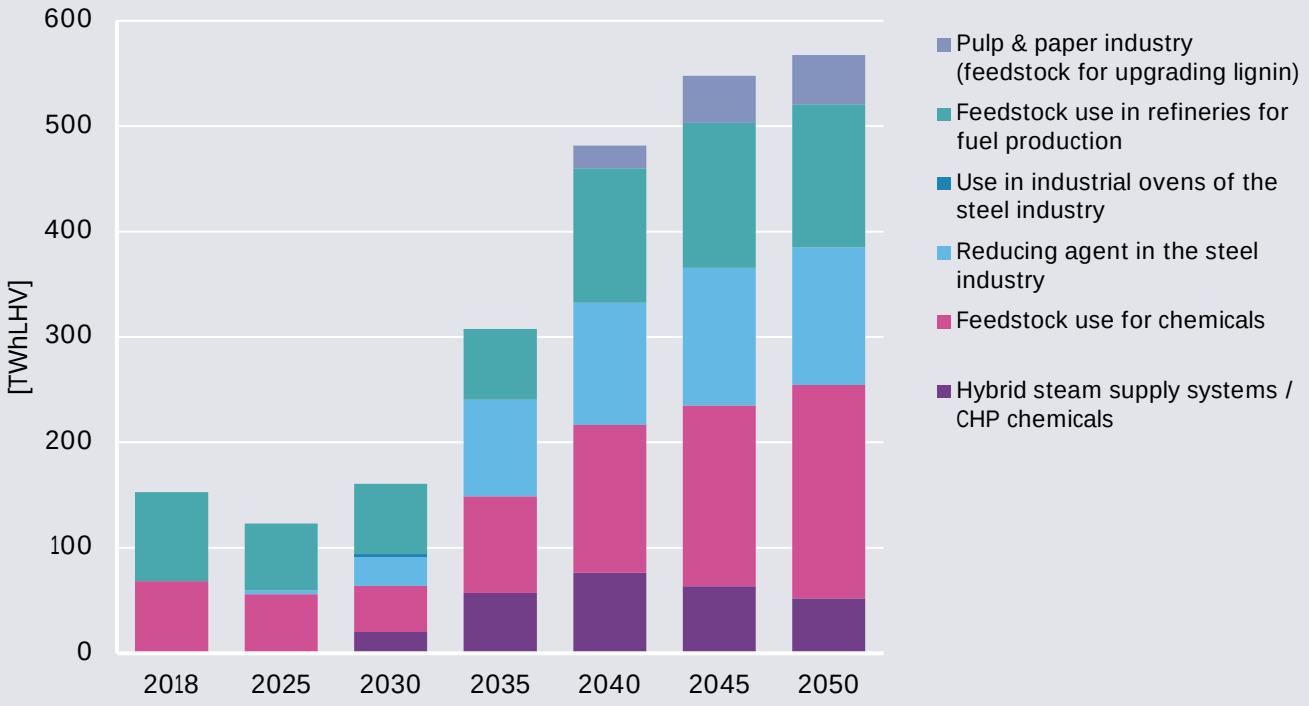


Wuppertal Institute (2023).
* Fossil gas includes fossil gas, refinery gas and LPG.

- The non-energy-intensive sectors consume fossil gas to produce heat up to 500°C. The largest share goes into low-temperature heat up to 100°C, which can be easily electrified with heat pumps already today.
- The chemical industry consumes most of its fossil gas to produce mid-temperature heat, as well as the pulp and paper industry.
- High-temperature heat, last to phase out fossil gas, is spread between Minerals, Iron & steel, other metals and the chemical industries. Nearly half of the residual fossil gas consumption in 2040 is found in the non-metallic minerals sub-sectors such as glass, lime and cement.

Hydrogen demand will increase after 2030 to cover for new applications replacing fossil fuels

Net* hydrogen demand per sector and appliance in industry and refineries

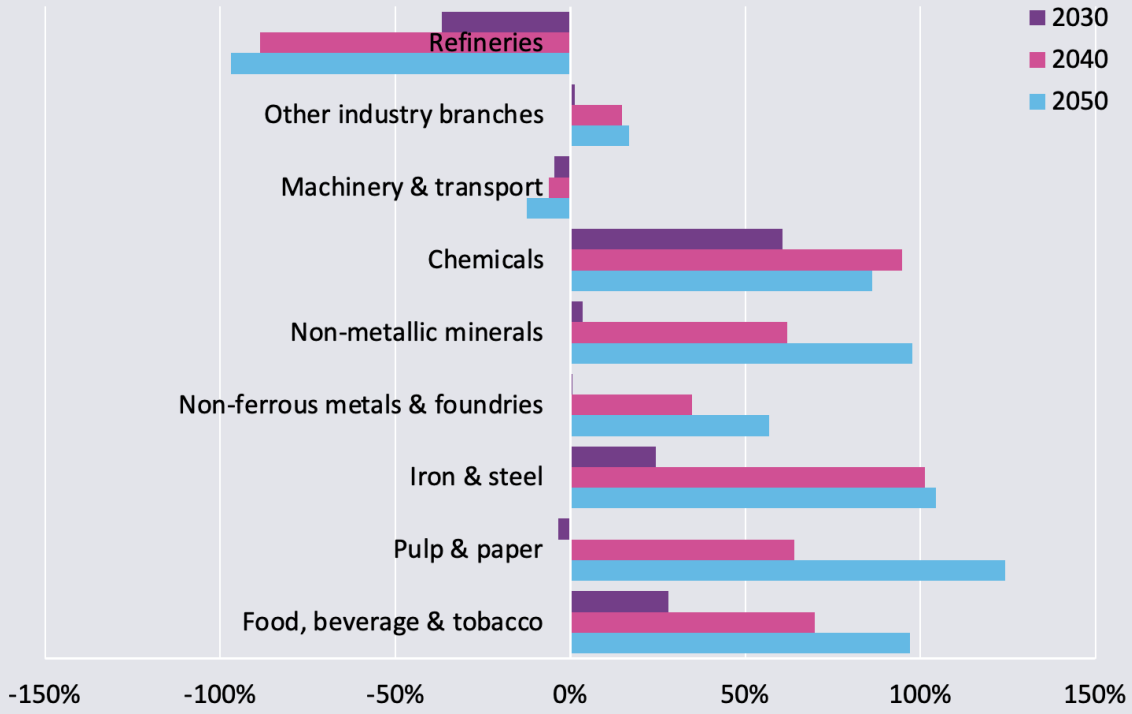


Wuppertal Institute (2023) * Gross hydrogen demand and gross by-production (e.g. by chlorine production) are balanced out, leaving only net demand to be covered by sources such as SMR or water electrolysis.

- → Despite some new applications in 2030, total H2 demand will remain stable as part of the ammonia demand will be imported, substituting the EU domestic production as already started in 2022.
- → Demand only increases after 2030 if direct electrification is prioritised as a more mature and efficient technology to displace fossil fuels.
- → Production in refineries will shift from the current oil-based products to Fischer-Tropsch fuels in the 2030s, H2 also shifting from fossil to renewable. Some refineries will start closing in the 2020s, reflecting a declining demand in conventional transport fuels.
- → Iron and steel production will partly shift to H2-based direct reduction starting after 2025.
- → Hybrid steam supply systems are introduced quickly in chemical parks with electric boilers using existing fired boilers as a back-up. The back-up carrier fossil gas is replaced over time by hydrogen and the utilisation rates of the electric boilers increase over time.

Power demand will almost double by 2050 in most of the sub-sectors of the industry

Gross power demand evolution compared to 2018 in the EU-27 industry branches

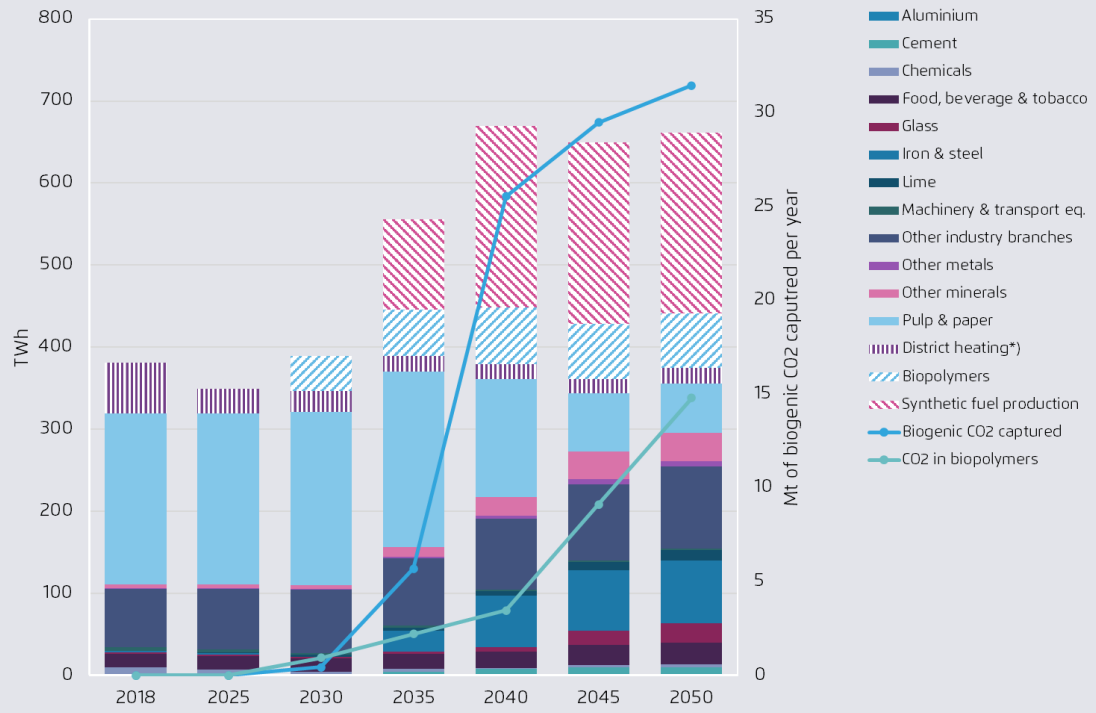


Wuppertal Institute (2023)

- Electricity use increases in the energy-intensive branches by ca. 100% until 2050.
- The non-ferrous metals & foundries branch is an exemption, but its electricity share is already high today.
- The chemical industry is a frontrunner in electrification.
- The actual increase in connected loads is even higher when companies switch from generating their own electricity to buying electricity from external sources (steel, chemicals, paper, food).

Biomass use in industry & refineries will increase through the transition as an efficient alternative to fossil fuels to decarbonise

Biomass use for final energy, district heating and synthetic hydrocarbons



Wuppertal Institute (2023)

- Biomass demand will shift from pulp & paper production to the glass, iron & steel, minerals and other industry branches, mostly combined with CCS to achieve negative emissions.
- Starting 2030, the production of biopolymers replacing carbon-based polymers will create new demand, as well as the production of synthetic fuels, replacing the conventional transport fuels being phased out. This will require up to a third of total demand for biomass in the industry.
- This will allow to capture more than 30 Mt of biogenic CO_2 per year by 2050, compared with about 100 Mt through CCS in the industry.

EU steel industry

Crude steel production per process in the EU-27

Wuppertal Institute (2023)

- Blast furnaces are quickly phased-out avoiding additional relinings.
- Electric arc furnaces become the standard steel production units throughout Europe, basic oxygen furnaces remain a little share to ensure the availability of all steel qualities.
- Scrap becomes the main iron input in steel making and reaches 67% in 2050 (compared to ca. 50% today).
- The second iron input is DRI, which is mainly produced in Europe.
- The EU is a frontrunner in DRI production, but imports are accepted, starting with 8% in 2030 and reaching a peak in 2040 at 27% (8% in 2050).

Chemicals in the EU
Characterization of the general development

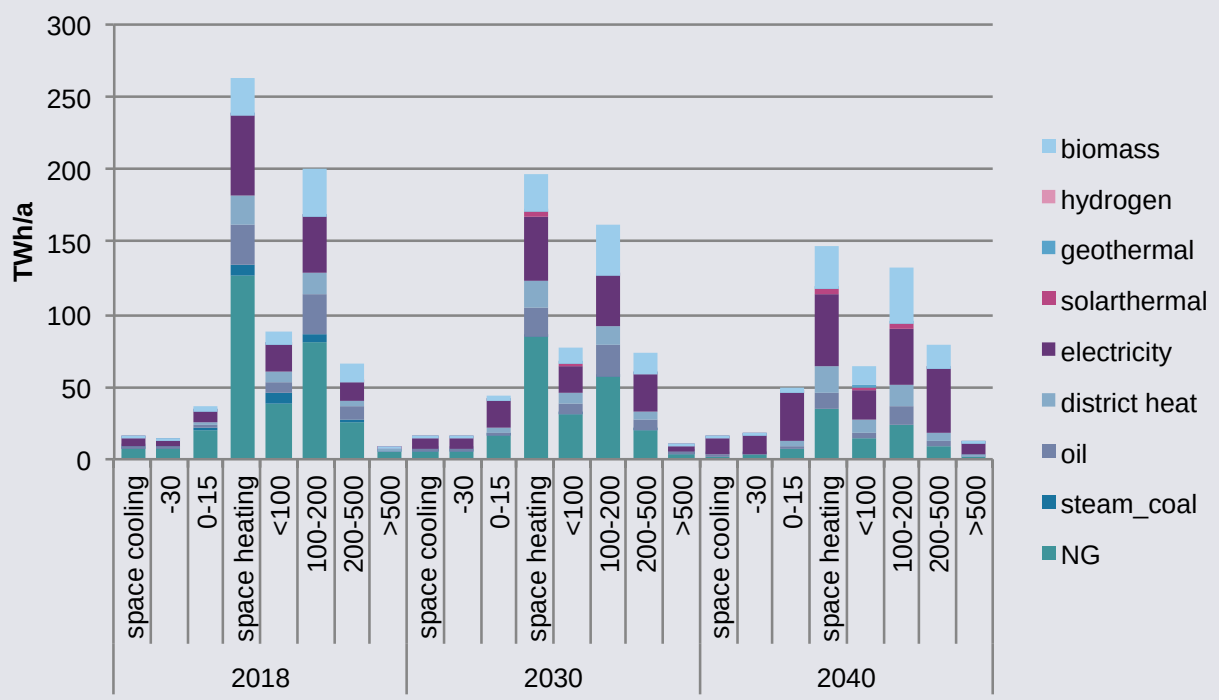
- In the mid-term (until 2030) ammonia production in the EU-27 is concentrated at sites with good fossil gas access and partly substituted by imports.
- Fossil refineries are closed throughout the EU, starting in the 2020s (not converted to feedstock refineries).
- Petrochemical sites come thus under pressure to search for new sources. In the mid-term shale gas and Extra-EU naphtha imports increase, but chemical recycling as well.
- Until 2040 new Fischer-Tropsch refineries are opened-up at selected sites in Europe (ES, NL, RO, SE, UK).
- CCU-methanol is produced in Spain and the UK.
- In 2040 green methanol can be imported from the world market, afterwards also synthetic feedstock (naphtha) comes available.

Non-metallic minerals in the EU
Characterization of the general development

- The challenge in these branches is the transformation of high-temperature heat supply.
- Electrification is a challenge as the respective ovens are in most cases not market ready at scale and efficiency gains are often relatively low, compared to lower temperatures.
- Electrification does not adress process-related emissions.
- Focus in therefore on:
  - Efficiency gains and waste firing (in the short term)
  - Biomass firing, (partial) electrification and CCS in the mid- and long-term

Final Energy use in the less-energy intensive industries*)

Final energy use for different heat applications (temperature ranges)



Wuppertal Institute (2023)

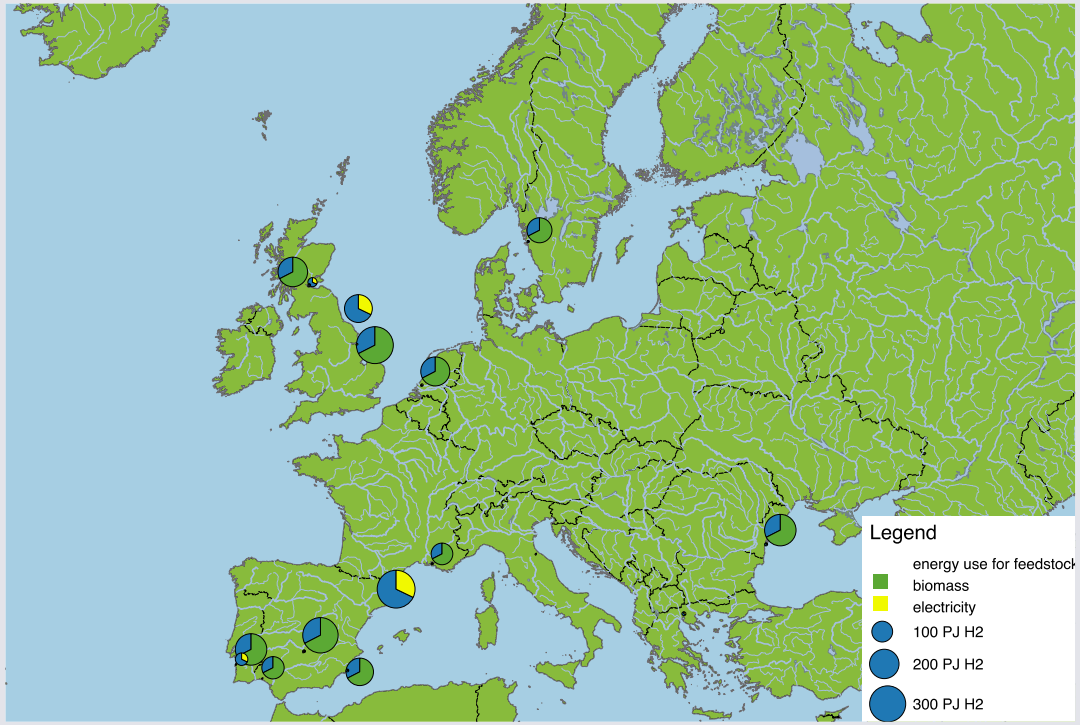
- The quick introduction of heat pumps to phase-out gas boilers in low-temperature applications is crucial.
- Quick coal phase-out also to achieve the 2030 emissions reduction targets.
- Acceleration of investments towards 2027 + keep the pace until gas phase-out is achieved in low-temperature heat supply (by 2030-2035)

EU refineries
Characterization of the general development

- Due to electrification of the transport sector, fuel demand will decline quickly throughout the EU.
- Processing of crude oil is completely phased-out in Europe until 2050.
- Refineries are assumed to be closed according to their age (typical lifetime of 60 years)
  → need for refinement to account for regional supply security within the EU

EU refineries
Fuels & feedstock in 2050

Site specific energy use



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EU28 fuel and feedstock balance 2050 [Mt/a]

	production	consumption
kerosene	21.1	47.8
navigation fuel (gasoil)	14.2	24.5
cracker feedstock	12.6	22.1
chemicals from FT refineries (HVC)	1.3	NA
MeOH from CO_2	17.3	43.3

Wuppertal Institute based on T&E (2023)

Assumptions: Technology costs

Overnight Investment costs*)

Technology	new/retrofit	overnight invest [€/kW] (useful)	Source
LT Natural Gas boiler (condensing)	new built	179	PRIMES
LT heat pump	new built	637	PRIMES
HT heat pump	new built	549	IFSME**) Study
Natural Gas heater	new built	256	IFSME Study
Hydrogen heater	converted NG	66	IFSME Study
Hydrogen heater	new built	308	IFSME Study
Plasma heater	new built	1017	IFSME Study
Natural Gas boiler	new built	220	IFSME Study
Hydrogen boiler	converted NG	66	IFSME Study
Hydrogen boiler	new built	264	IFSME Study
Electrode boiler	new built	146	IFSME Study

*) Technical lifetimes are assumed to be 25 years
**) Industrial Fuel Switching Market Engagement Study

Compilation Wuppertal Institut (2023)