THE POWER OF UNDERSTANDING
DEFOSSILISATION VS. DECARBONISATION

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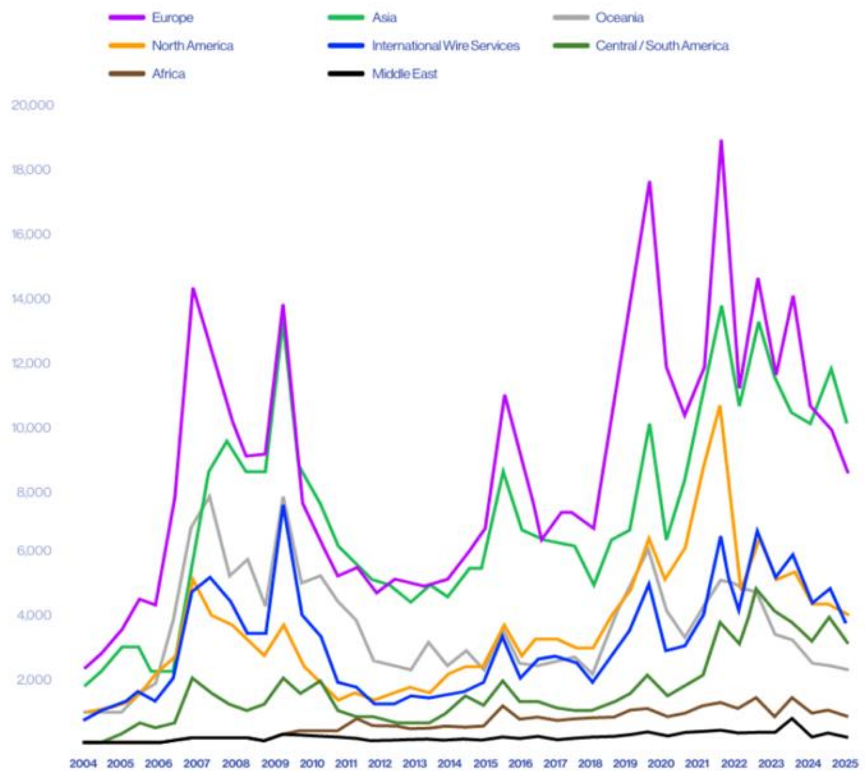
Ghent

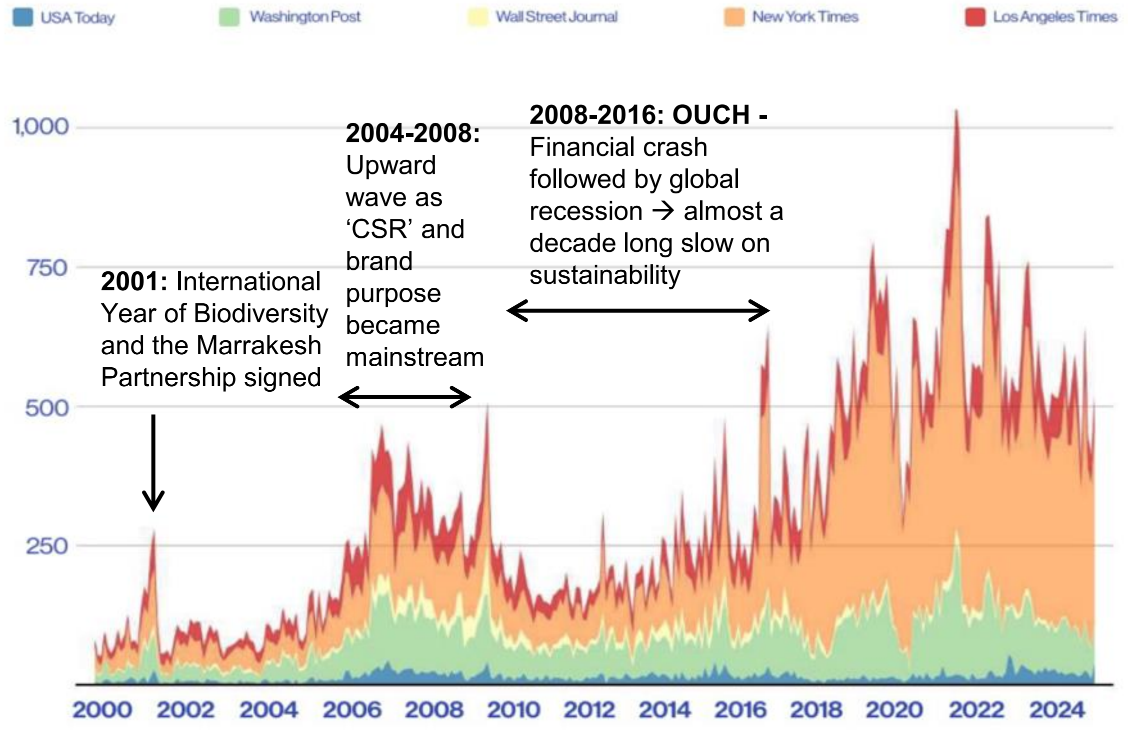
Sustainability comes in waves...

Total media articles mentioning climate change or global warming[1]



Growing US newspaper coverage or climate change, 2000 through early 2025[2]

The New York Times and Washington Post contribute the largest number of articles



Data shows the number of articles per month based on NexisUni searches for articles mentioning either climate change or global warming

1 Source: Media and Climate Change Observatory
2 Source: Boykoff et al, "united States Newspaper Coverage of Climate Change or Global Warming 2000-2025 University of Colorado

And then the good years came!!!

2019 to 2022 were boom years for sustainability:

Public interest in sustainability-relevant topics peeked. Purposeful brands thrived. Millennials and GenZ were active in a green revolution.

ESG started to transform markets, green energy outpaced expectation, universities trained thousands of sustainability experts and business sustainability rocketed.

Crash started in 2023

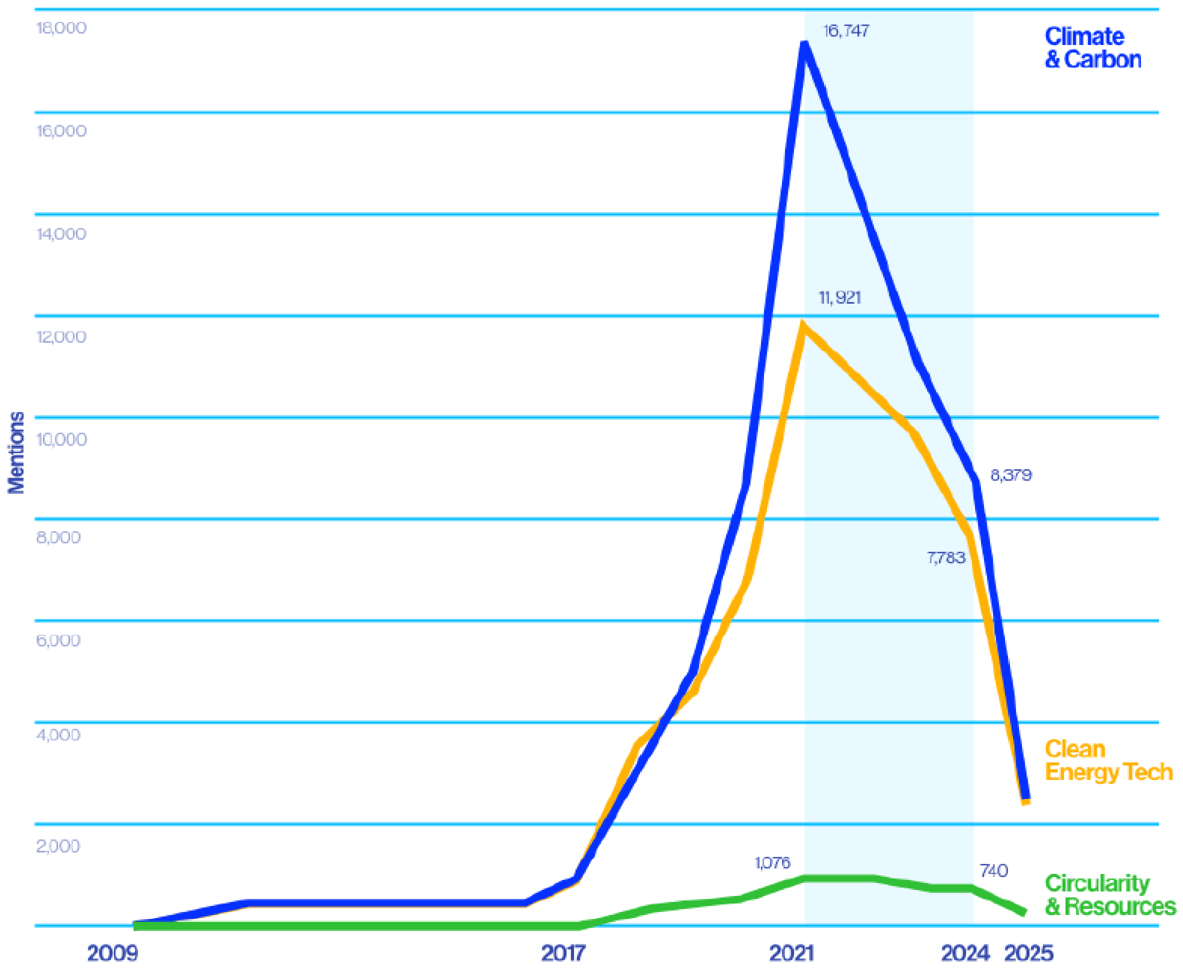
→ By late 2024/2025, the wave had swung way down…

Media coverage has fallen, investor concern evaporated.

Greenhushing* gained traction.

And much of the world no longer centers on sustainability.

Sustainability terms have faded away from earning call conversations (ie. quarterly year results presentations) since their 2021 peak



- Greenhushing is the practice where organizations deliberately under-report or withhold information about their sustainability initiatives and environmental goals. Often to avoid scrutiny or criticism. Unlike greenwashing, which involves exaggerating sustainability claims, greenhushing involves a strategic silence regarding genuine efforts.
- Graph source: UNGC/PWC CEO Survey 2025

After every drop... Another peak starts building

But it might get worse before it gets better

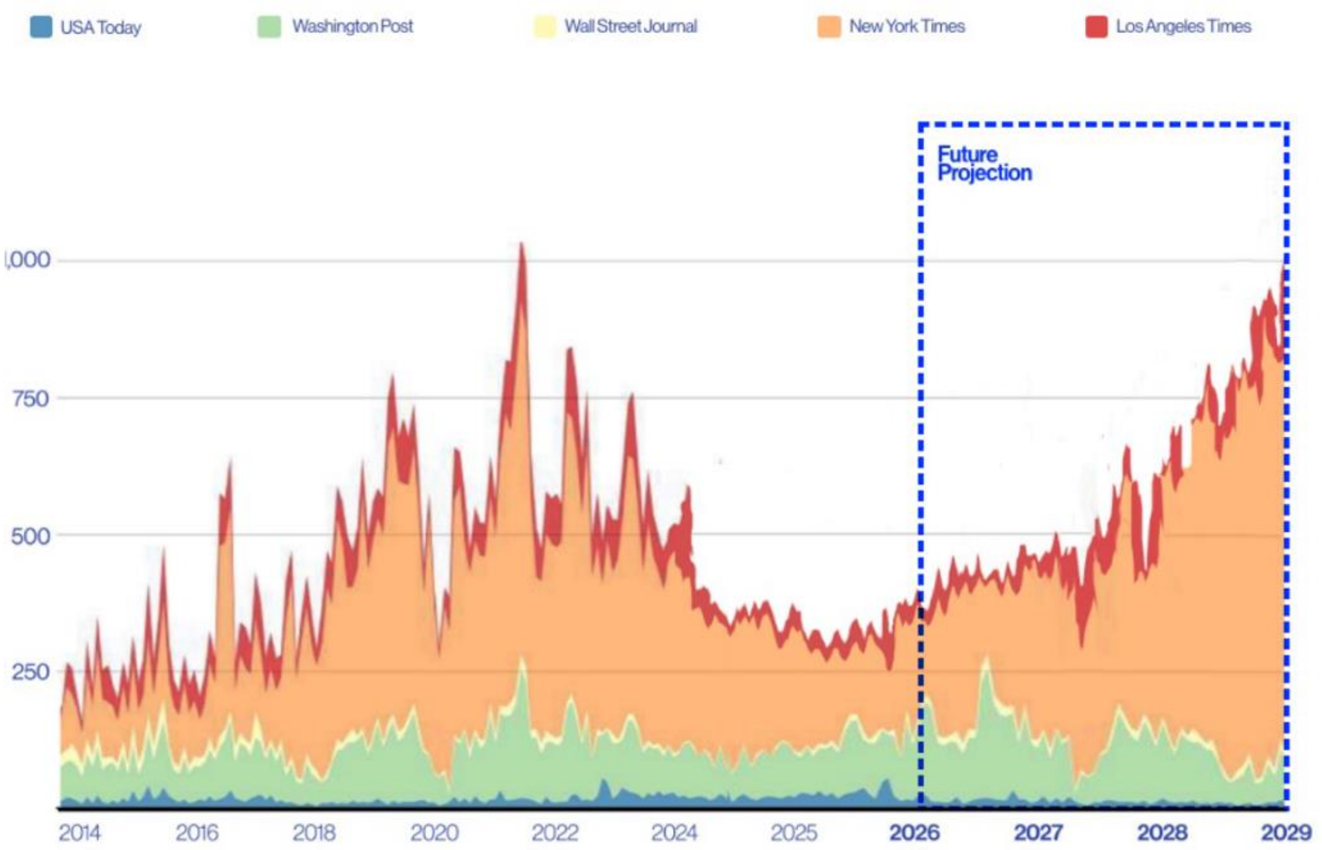
These waves are tracked for over 50 years. On that trajectory, **we won't see today's down wave reverse into an upwave until 2027**, with the climb speeding in 2028.

The down waves moments are hard.

But also, the best time to reset.

Transformations started in previous down waves, so it is an **opportunity moment, for those with vision.**

Growing US newspaper coverage or climate change, 2000 through early 20252



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Source: Boykoff et al, "united States Newspaper Coverage of Climate Change or Global Warming 2000-2025 University of Colorado

From ‘climate change is not real’ to ‘it is not human made’ to today’s: ‘it is too late anyway’!

Communicating the six key truths about climate change has the potential to help build public and political will for climate solutions:

It’s real
(Climate change is happening)

It’s us
(Human activity is causing climate change)

Experts agree
(There is a scientific consensus about human-caused climate change)

It’s bad
(Climate change harms people)

Others care
(Most people are concerned about climate change and support action)

There’s hope
(Actions can be taken to limit the harm)

Table 3 Summary of current belief in the six key truths showing the relative percentage of ‘correct’ and ‘incorrect’ beliefs based on the science behind the truth

Key truth	‘Correct’ belief	‘Incorrect’ belief
It’s real	73.0%	26.9%
It’s us	58.6%	33.6%
Experts agree	26.0%	53.5%
It’s bad	64.7%	30.1%
Others care (desc.)	38.9%	51.4%
Others care (injunc.)	40.3%	46.2%
There’s hope (efficacy)	40.3%	58.6%
There’s hope (opportunity)	80.5%	13.8%

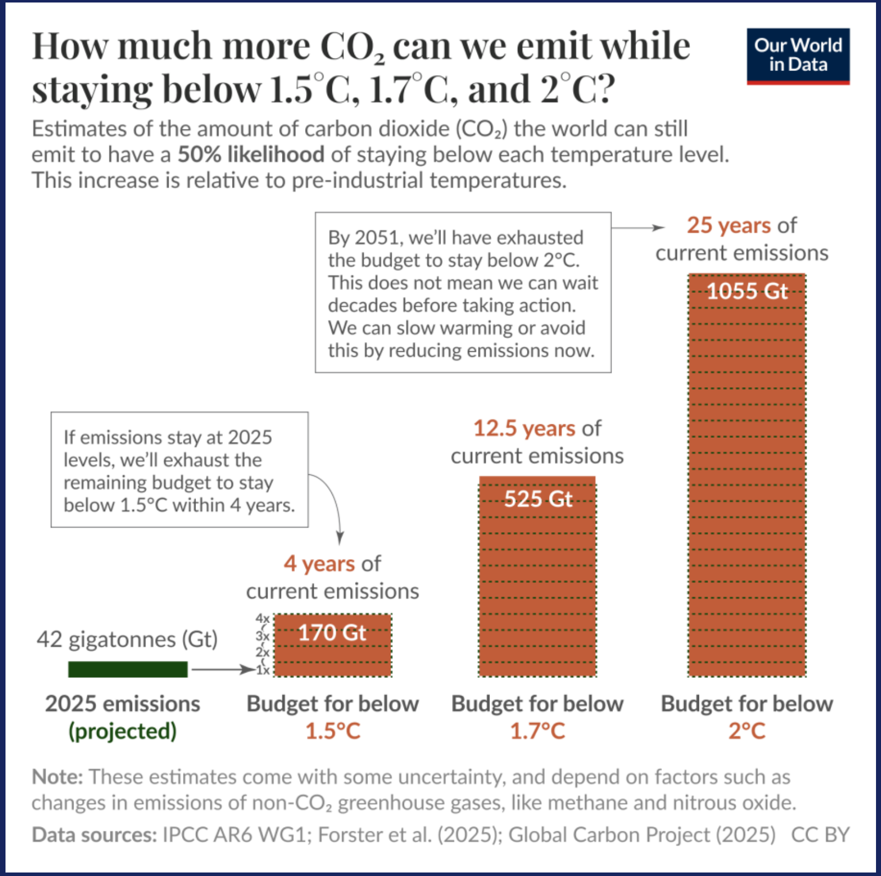
Percentages may not total 100% due to missing data

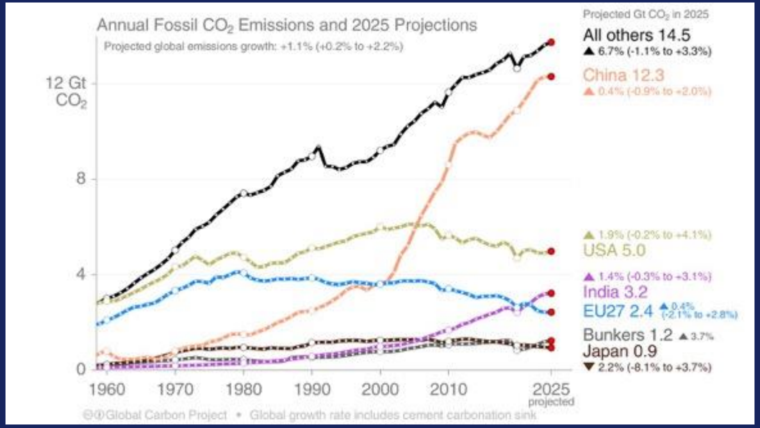
Badullovich, N., Kotcher, J., Myers, T. A., Rosenthal, S. A., Leiserowitz, A., & Maibach, E. (2025). Understanding six “key truths” about climate change predicts policy support, discussion, and political advocacy. Climatic Change, 178. https://doi.org/10.1007/s10584-025-03934-3

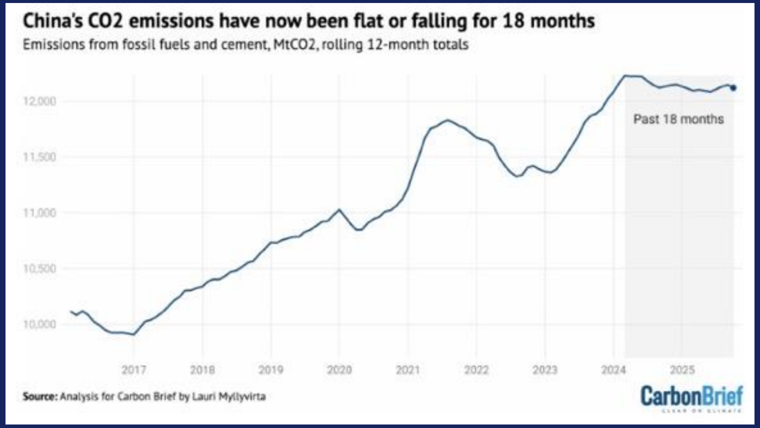
“Dans la vie, rien n’est a craindre, tout est a comprendre. Il est temps que nous comprenions plus afin que nous craignions moins.”

Marie Curie

1.5 °C is dead but 2°C is still very much to 'play for' but will require a big step up in world's efforts since under current policies, we are headed for 2.5 to 3°C



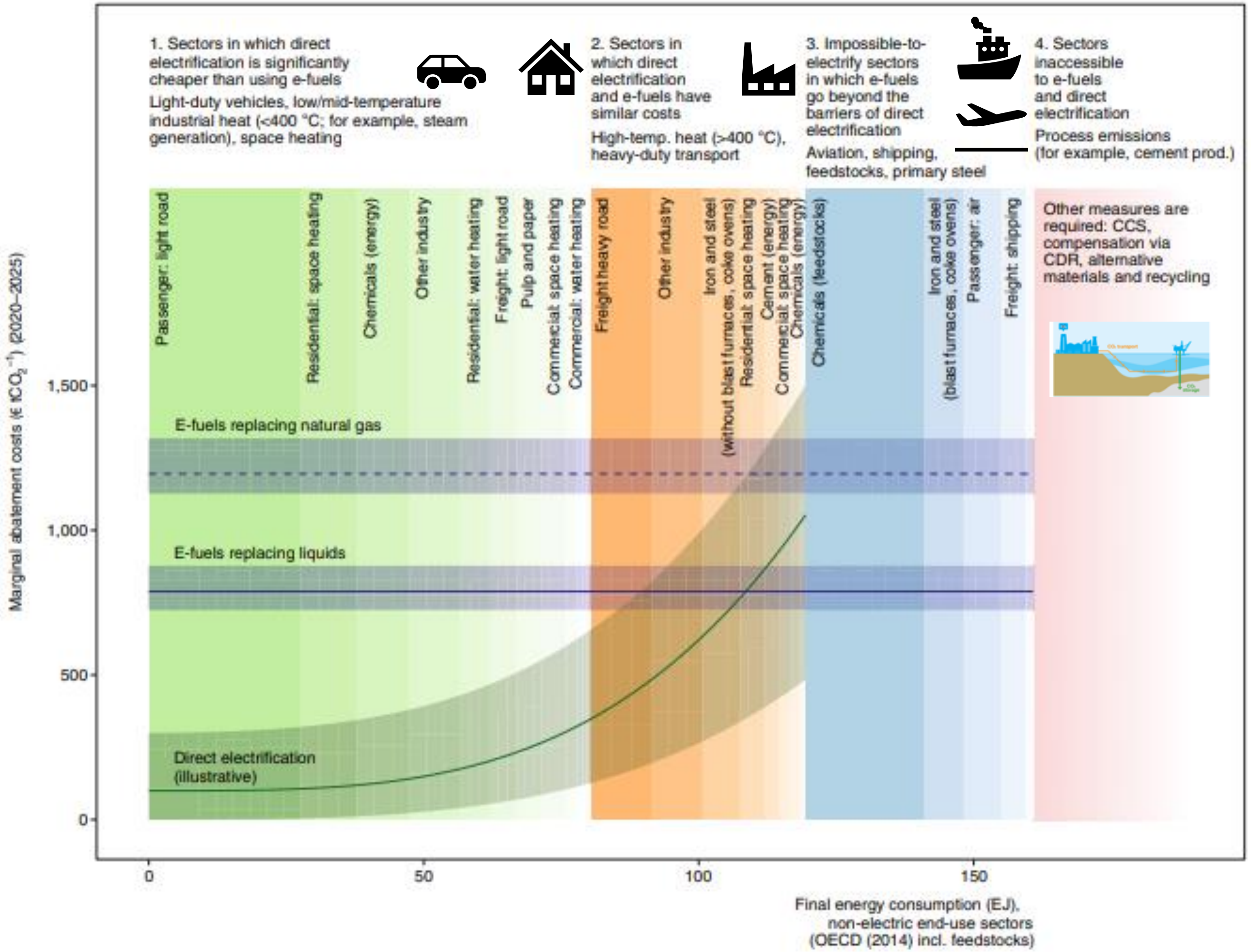




Three technological routes to reach reduce emissions (and the order is important):

3 technological routes towards carbon neutrality **(order is important!):**

- **1** Increase efficiency
- **2** Electrify what is possible (far beyond our cars)
- **3** Need for molecules (both bio and e-based!) → CCU & CCS



Molecules will remain crucial for some industries AND to store energy over long time periods or transport it over long distances!
--> CCU

CCS makes sense for some industries with 'unavoidable' emissions

Falko Ueckerdt, Christian Bauer, Alois Dirnaichner, Jordan Everall, Romain Sacchi, Gunnar Luderer. Potential and risks of hydrogen-based e-fuels in climate change mitigation. Nature Climate Change, 2021; DOI: 10.1038/s41558-021-01032-7

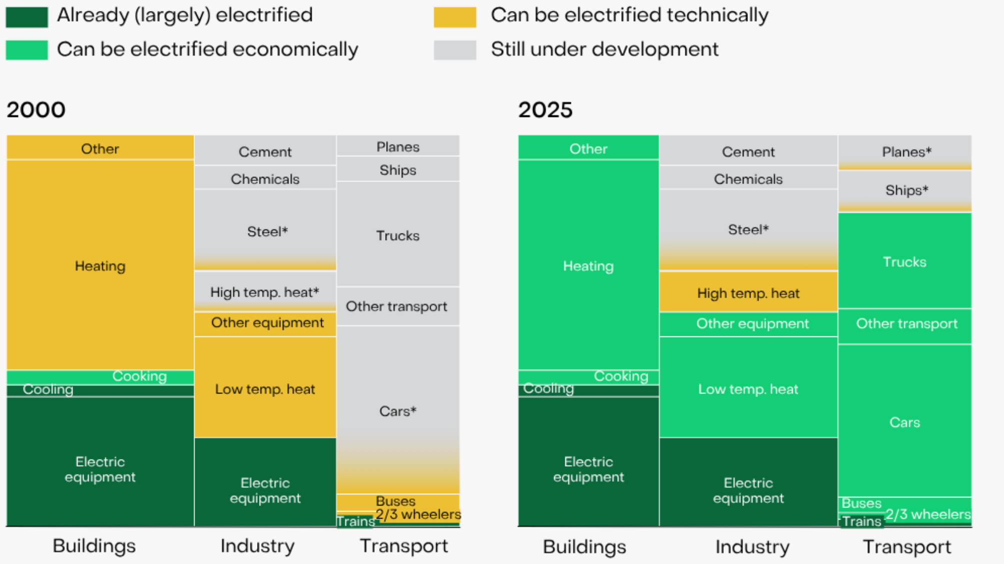
Studies differ in share of electrons versus molecules, but many seem to converge to between 50 and 75 % of the energy use will be electricity by 2050*

→ **Electrons and molecules will be needed!**

→ **Road transport and low-temperature heating — are now open to electrification. Together, they account for almost 50% of global final energy demand.**

Most of the energy system can now be electrified

Share of final energy demand by subsector and electrification potential (%)

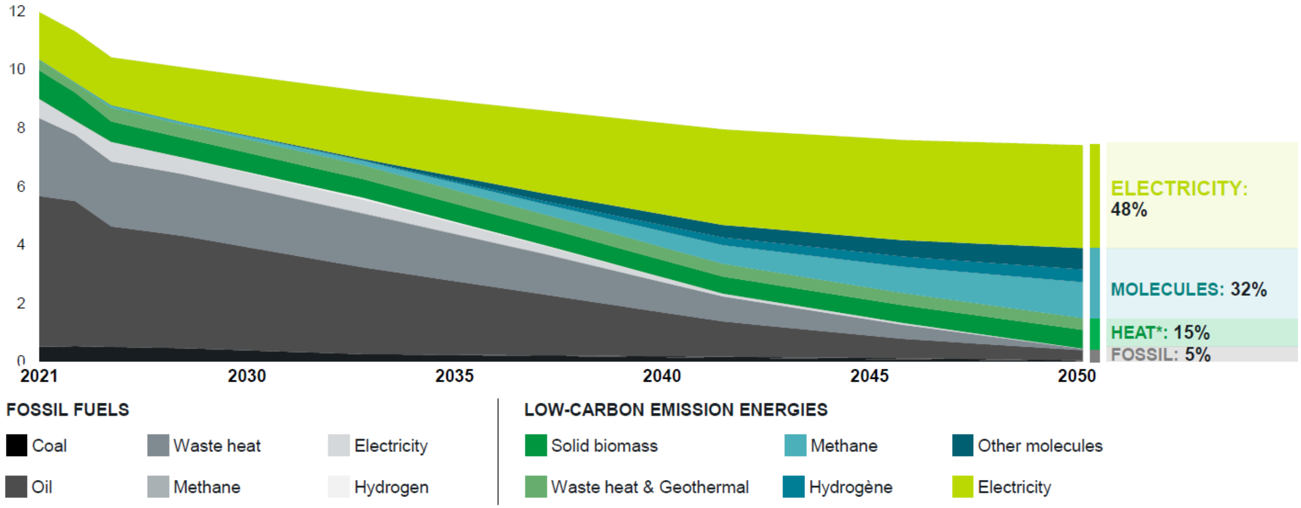


Sources: IIASA; IEA; BloombergNEF; Ember analysis – Note: excluding feedstock
*Technologies available for subset of total end-use (e.g., only for shorter ranges in cars)

EMBER

Final energy demand reduces significantly, with strong electrification complemented by decarbonized gases and heat

Optimized Final energy mix | Europe-15



* **Heat**: Biomass, Waste Heat and Geothermal. Electricity and Molecules includes energy to produce heat consumed via DHC
Methodology review vs 2023 exercise, excluding Non energy uses from energy mix
Low carbon methane accounts for biomethane, NG + CCS & e-methane, while other molecules correspond to ammonia, e-methanol & kerosene

* assuming we meet our climate ambitions!

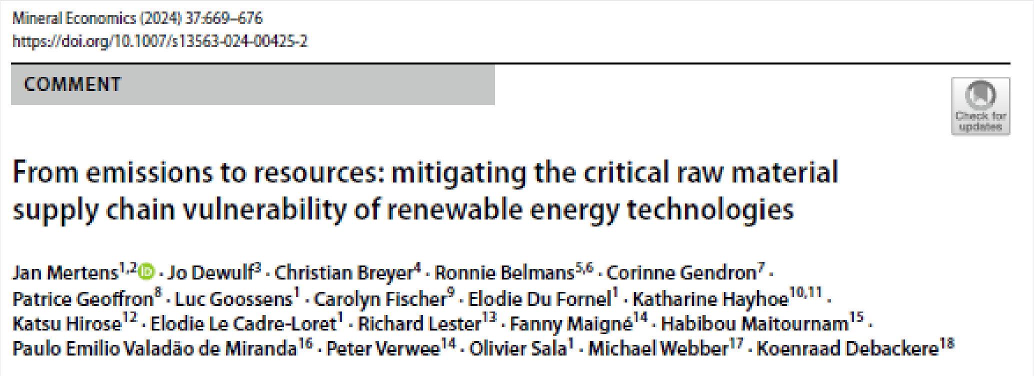
Crude oil and gas today not only serves as energy source in today's refinery but also as carbon feedstock supply for all products leaving the refinery

Smaller Future Refineries (2050)

Future refineries based on renewable carbon will be alsmost half their current size due to the electrification of personal transport, reducing the need for gasoline

Renewable Energy and Material Needs

Replacing crude oil with biomass, CO_2, and recycled plastics will require **vast amounts of renewable energy**, (Gigwatt scale per refinery).
This scale of deployment **demands significant materials and metals**, which must be sourced sustainably

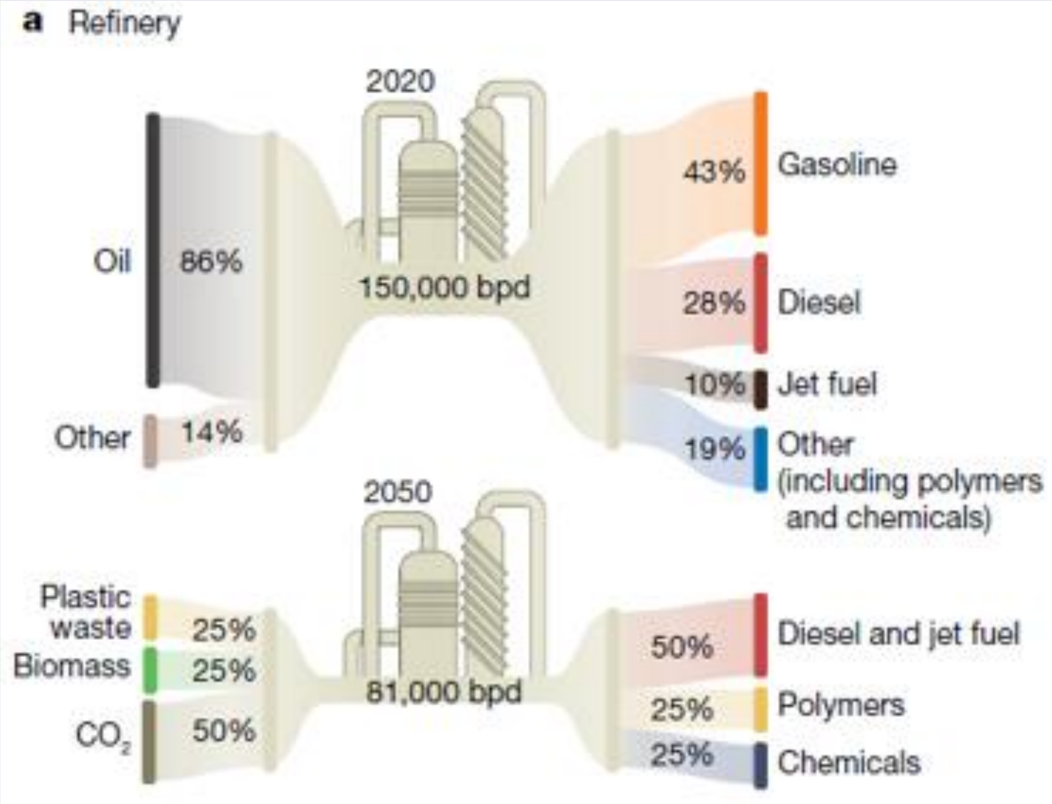

Mineral Economics (2024) 37:669–676
https://doi.org/10.1007/s13563-024-00425-2

COMMENT

Check for updates

From emissions to resources: mitigating the critical raw material supply chain vulnerability of renewable energy technologies

Jan Mertens[1,2] · Jo Dewulf[3] · Christian Breyer[4] · Ronnie Belmans[5,6] · Corinne Gendron[7] · Patrice Geoffron[8] · Luc Goossens[1] · Carolyn Fischer[9] · Elodie Du Fornel[1] · Katharine Hayhoe[10,11] · Katsu Hirose[12] · Elodie Le Cadre-Loret[1] · Richard Lester[13] · Fanny Maigné[14] · Habibou Maitournam[15] · Paulo Emilio Valadão de Miranda[16] · Peter Verwee[14] · Olivier Sala[1] · Michael Webber[17] · Koenraad Debackere[18]



Vogt, E.T.C., Weckhuysen, B.M. The refinery of the future. Nature 629, 295–306 (2024). https://doi.org/10.1038/s41586-024-07322-2

Where to do what? Shipping intermediates (not hydrogen!), between EU renewable rich areas to renewable scare areas makes a lot of sense!

Shipping intermediates makes more sense that shipping hydrogen.

Restricting imports to Europe captures half of the global benefit which offers a compromise between supply chain security and competitiveness.

This allows Western **EU to retain both the further processing of the precursors into steel, fertilisers and plastics**, as well as the high value-added parts of the supply chain like automobile production and other manufacturer goods.

Physics > Physics and Society

[Submitted on 1 Oct 2025]

Balancing Cost Savings and Import Dependence in Germany's Industry Transformation

Toni Seibold, Fabian Neumann, Falko Ueckerdt, Tom Brown

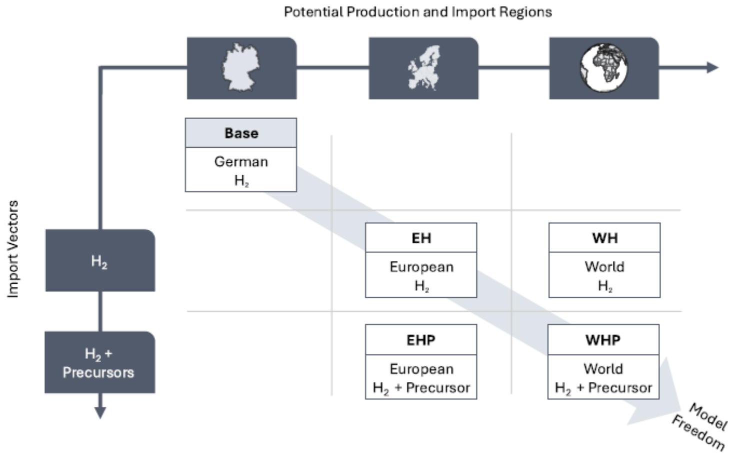


Fig 1. Scenario framework to explore the influence of imports on the German industry and energy system. While the Base scenario represents a domestic industry with hydrogen self-sufficiency, the geographic scope of allowed imports expands on the horizontal axis, while the diversity of import products increases on the vertical axis.

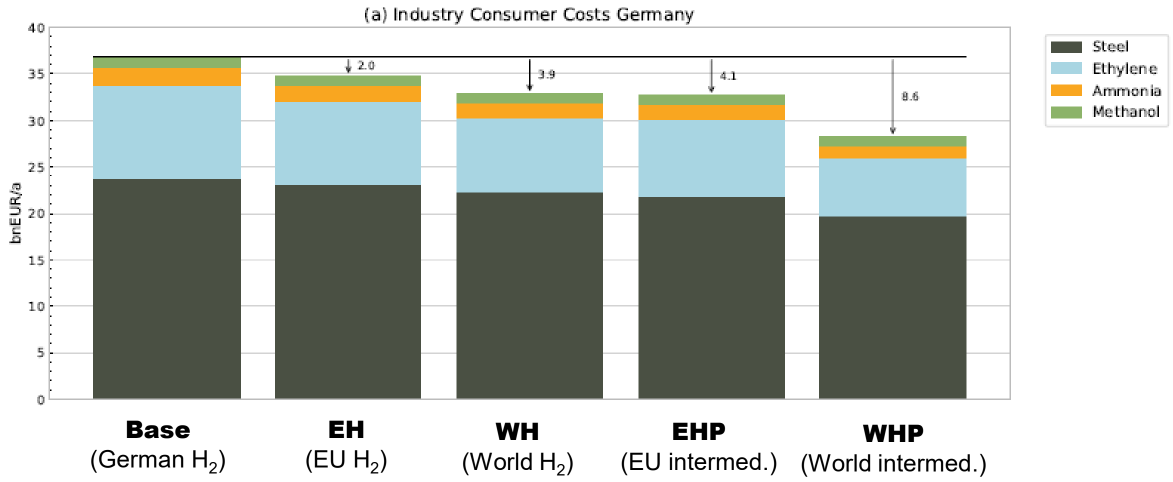


Fig 2. Consumer costs to meet industrial demand in Germany with savings across different levels of independence (a), relative cost savings overall and the industrial sector compared to the Base scenario (b) and prices of industry precursors in Germany (c).

Key recommendations for policymakers and industry

To what extent can **electrification** be a key lever to defossilise the chemical sector?

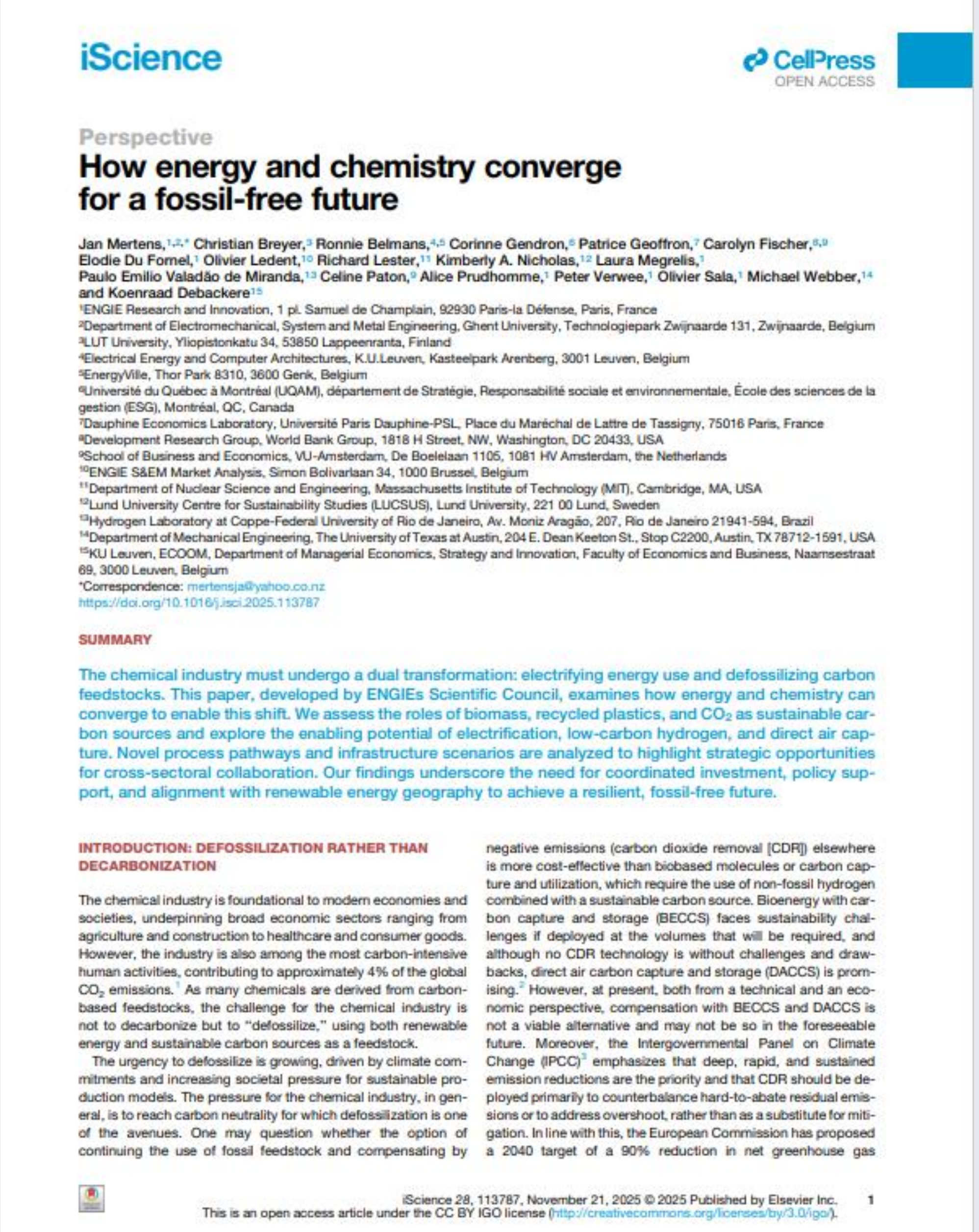
Recommendations: Electrify high-temperature processes. Invest in grid upgrade and pilot projects to accelerate deployment. Where renewables are limited, look into the import of intermediates from energy-rich regions.

What could be the role of **hydrogen** in the defossilisation of the chemical industry?

Recommendations: Deploy low-carbon hydrogen, prioritizing ammonia and methanol synthesis, and integrate with CO2 utilization for platform chemicals. Build hydrogen infrastructure and foster cross-sector partnerships, starting with low-carbon hydrogen and transitioning to green hydrogen as renewables expand.

What are the impacts of competition and opportunities for collaboration on **sustainable carbon**?

Recommendations: Invest in DAC for long-term carbon supply and integrate with renewable energy and hydrogen. Leverage existing infrastructure for biomethane and CO2 transport and adapt supply chains to regional realities.



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Perspective

How energy and chemistry converge for a fossil-free future

Jan Mertens,[1,2,*] Christian Breyer,[3] Ronnie Belmans,[4,5] Corinne Gendron,[6] Patrice Geoffron,[7] Carolyn Fischer,[8,9] Elodie Du Fornel,[1] Olivier Ledent,[10] Richard Lester,[11] Kimberly A. Nicholas,[12] Laura Megrelis,[1] Paulo Emilio Valadão de Miranda,[13] Celine Paton,[9] Alice Prudhomme,[1] Peter Verwee,[1] Olivier Sala,[1] Michael Webber,[14] and Koenraad Debackere[15]

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https://doi.org/10.1016/j.isci.2025.113787

SUMMARY

The chemical industry must undergo a dual transformation: electrifying energy use and defossilizing carbon feedstocks. This paper, developed by ENGIEs Scientific Council, examines how energy and chemistry can converge to enable this shift. We assess the roles of biomass, recycled plastics, and CO_2 as sustainable carbon sources and explore the enabling potential of electrification, low-carbon hydrogen, and direct air capture. Novel process pathways and infrastructure scenarios are analyzed to highlight strategic opportunities for cross-sectoral collaboration. Our findings underscore the need for coordinated investment, policy support, and alignment with renewable energy geography to achieve a resilient, fossil-free future.

INTRODUCTION: DEFOSSILIZATION RATHER THAN DECARBONIZATION

The chemical industry is foundational to modern economies and societies, underpinning broad economic sectors ranging from agriculture and construction to healthcare and consumer goods. However, the industry is also among the most carbon-intensive human activities, contributing to approximately 4% of the global CO_2 emissions.[1] As many chemicals are derived from carbon-based feedstocks, the challenge for the chemical industry is not to decarbonize but to "defossilize," using both renewable energy and sustainable carbon sources as a feedstock.

The urgency to defossilize is growing, driven by climate commitments and increasing societal pressure for sustainable production models. The pressure for the chemical industry, in general, is to reach carbon neutrality for which defossilization is one of the avenues. One may question whether the option of continuing the use of fossil feedstock and compensating by negative emissions (carbon dioxide removal [CDR]) elsewhere is more cost-effective than biobased molecules or carbon capture and utilization, which require the use of non-fossil hydrogen combined with a sustainable carbon source. Bioenergy with carbon capture and storage (BECCS) faces sustainability challenges if deployed at the volumes that will be required, and although no CDR technology is without challenges and drawbacks, direct air carbon capture and storage (DACCS) is promising.[2] However, at present, both from a technical and an economic perspective, compensation with BECCS and DACCS is not a viable alternative and may not be so in the foreseeable future. Moreover, the Intergovernmental Panel on Climate Change (IPCC)[3] emphasizes that deep, rapid, and sustained emission reductions are the priority and that CDR should be deployed primarily to counterbalance hard-to-abate residual emissions or to address overshoot, rather than as a substitute for mitigation. In line with this, the European Commission has proposed a 2040 target of a 90% reduction in net greenhouse gas

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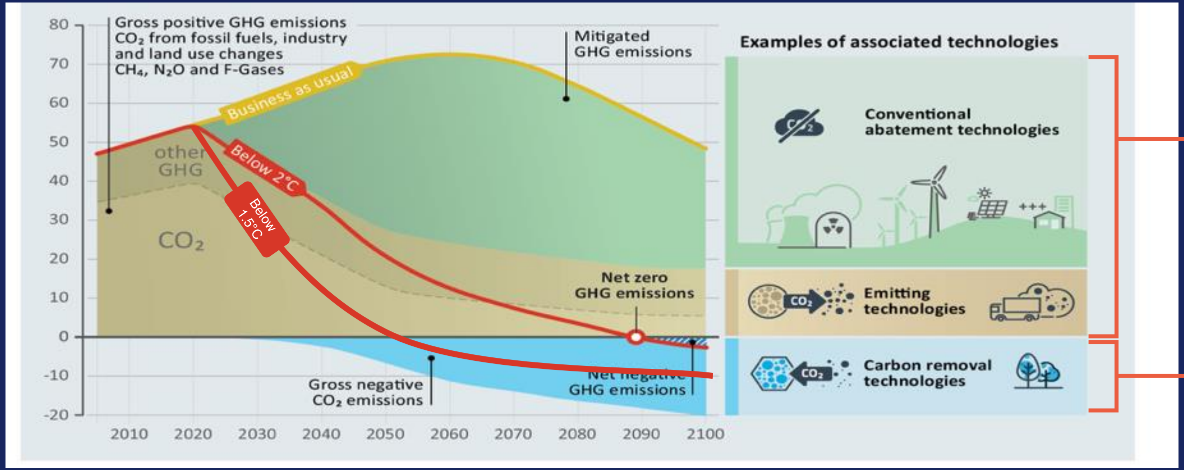
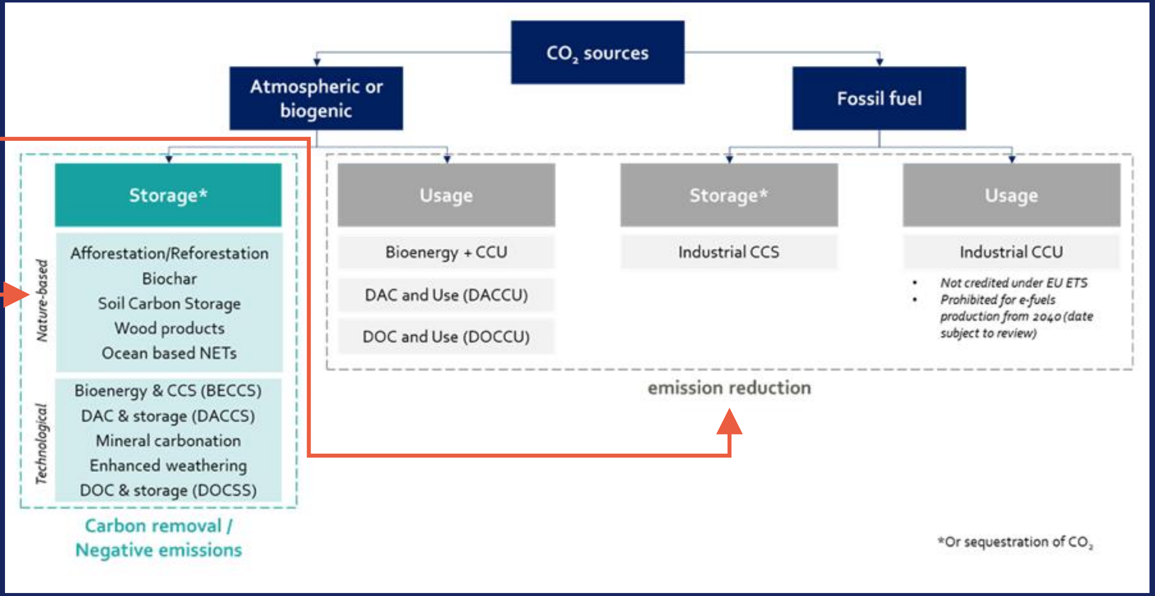
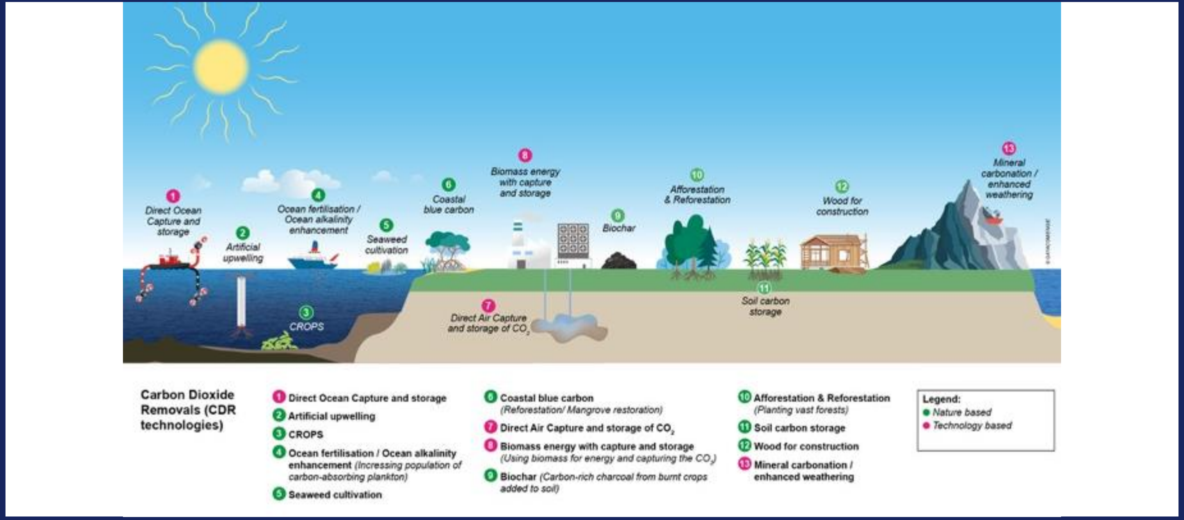
CO2 management technologies target either emission reduction or carbon removal. Two dimensions structure the technological landscape: biogenic vs fossil and storage vs use





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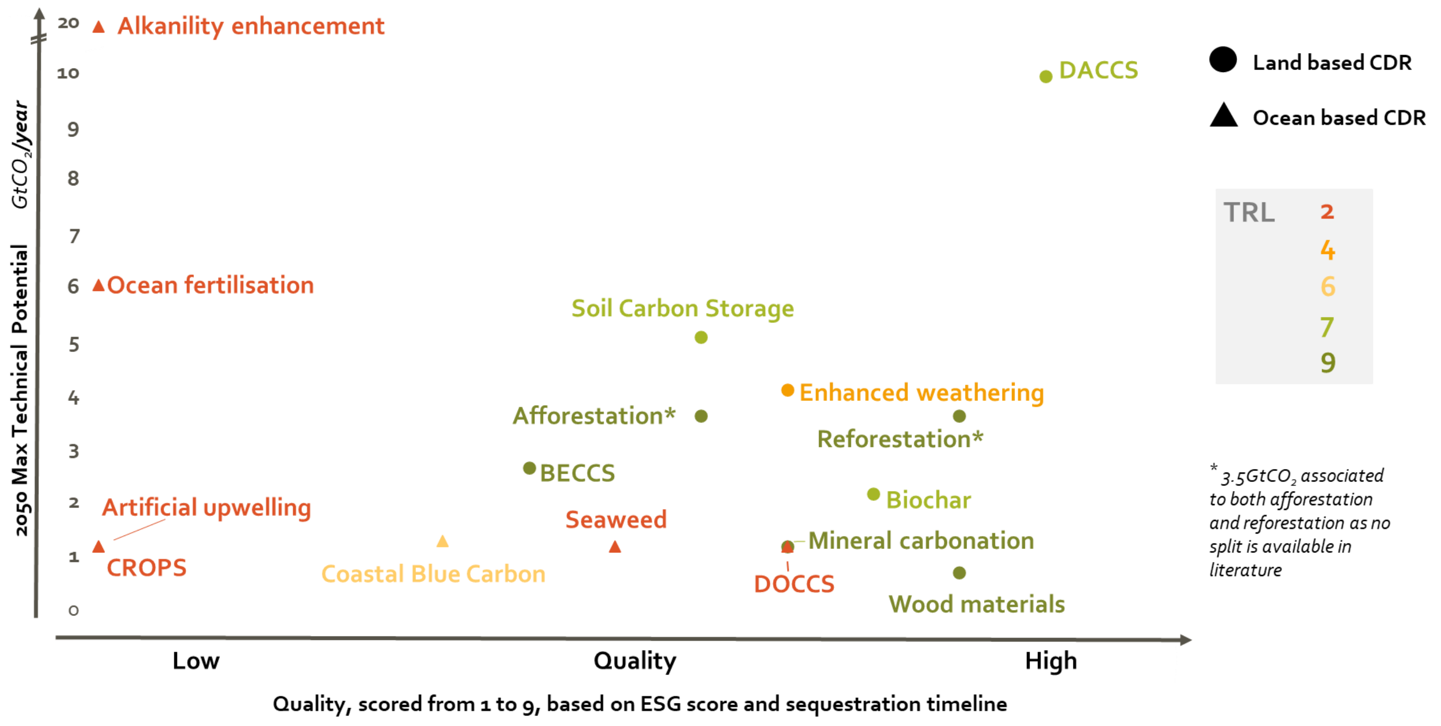
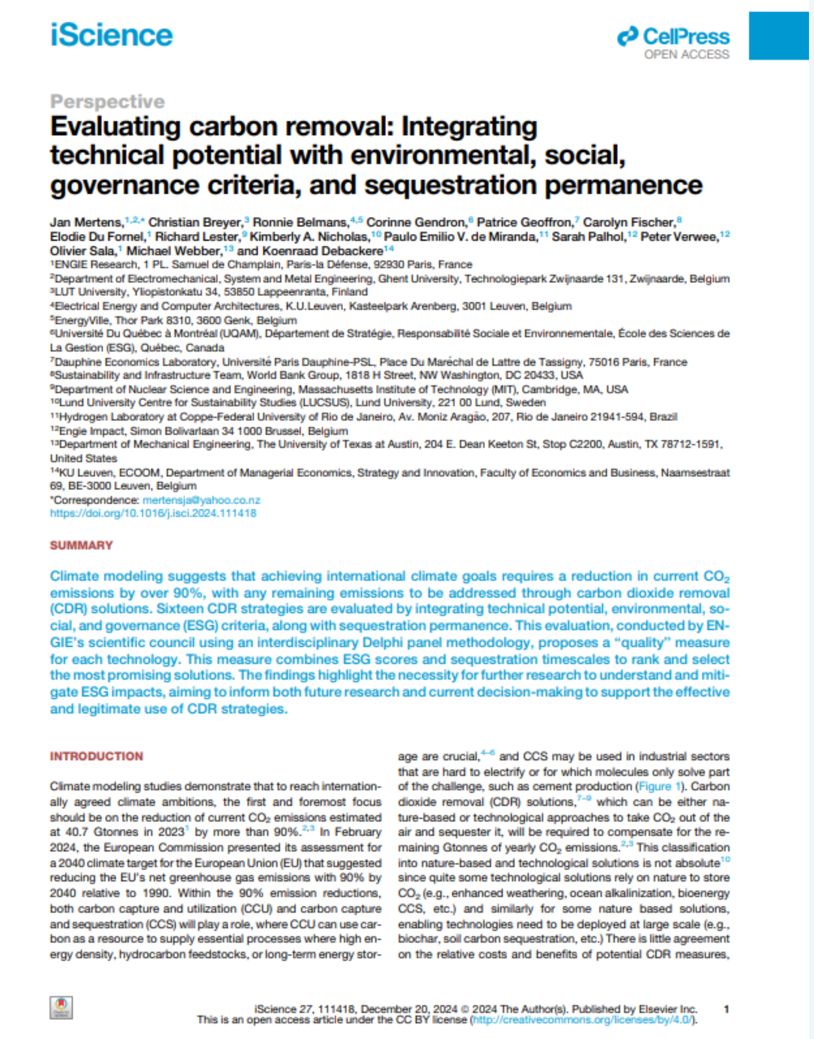
Perspective

Evaluating carbon removal: Integrating technical potential with environmental, social, governance criteria, and sequestration permanence

Jan Mertens,[1,2,*] Christian Breyer,[3] Ronnie Belmans,[4,5] Corinne Gendron,[6] Patrice Geoffron,[7] Carolyn Fischer,[8] Elodie Du Fornel,[1] Richard Lester,[9] Kimberly A. Nicholas,[10] Paulo Emilio V. de Miranda,[11] Sarah Palhol,[12] Peter Verwee,[12] Olivier Sala,[1] Michael Webber,[13] and Koenraad Debackere[14]

Combining potential, ESG score, storage timescale and TRL allows evaluating the different CO_2 management technologies





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SUMMARY

Climate modeling suggests that achieving international climate goals requires a reduction in current CO_2 emissions by over 90%, with any remaining emissions to be addressed through carbon dioxide removal (CDR) solutions. Sixteen CDR strategies are evaluated by integrating technical potential, environmental, social, and governance (ESG) criteria, along with sequestration permanence. This evaluation, conducted by ENGIE's scientific council using an interdisciplinary Delphi panel methodology, proposes a "quality" measure for each technology. This measure combines ESG scores and sequestration timescales to rank and select the most promising solutions. The findings highlight the necessity for further research to understand and mitigate ESG impacts, aiming to inform both future research and current decision-making to support the effective and legitimate use of CDR strategies.

INTRODUCTION

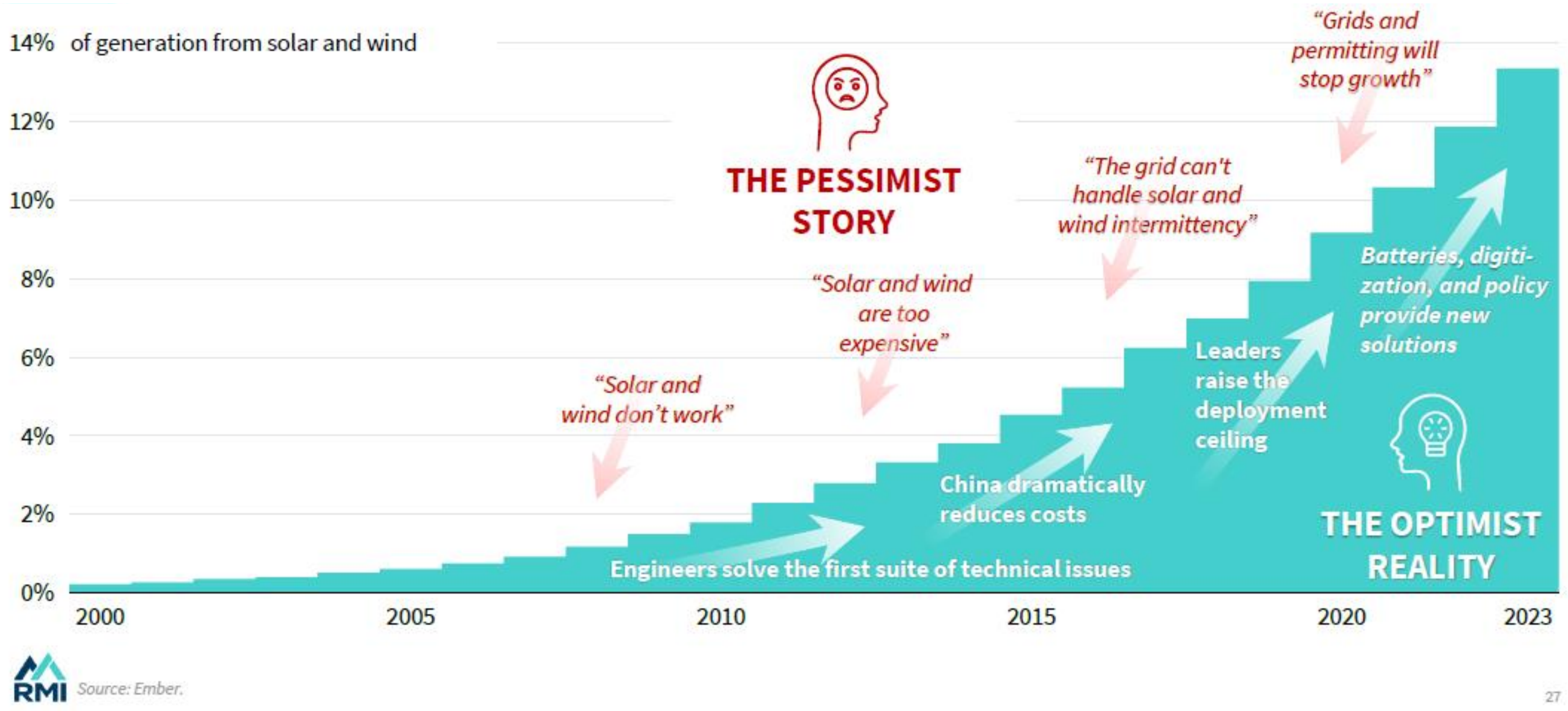
Climate modeling studies demonstrate that to reach internationally agreed climate ambitions, the first and foremost focus should be on the reduction of current CO_2 emissions estimated at 40.7 Gtonnes in 2023[1] by more than 90%.[2,3] In February 2024, the European Commission presented its assessment for a 2040 climate target for the European Union (EU) that suggested reducing the EU's net greenhouse gas emissions with 90% by 2040 relative to 1990. Within the 90% emission reductions, both carbon capture and utilization (CCU) and carbon capture and sequestration (CCS) will play a role, where CCU can use carbon as a resource to supply essential processes where high energy density, hydrocarbon feedstocks, or long-term energy storage are crucial,[4–6] and CCS may be used in industrial sectors that are hard to electrify or for which molecules only solve part of the challenge, such as cement production (Figure 1). Carbon dioxide removal (CDR) solutions,[7–9] which can be either nature-based or technological approaches to take CO_2 out of the air and sequester it, will be required to compensate for the remaining Gtonnes of yearly CO_2 emissions.[2,3] This classification into nature-based and technological solutions is not absolute[10] since quite some technological solutions rely on nature to store CO_2 (e.g., enhanced weathering, ocean alkalinization, bioenergy CCS, etc.) and similarly for some nature based solutions, enabling technologies need to be deployed at large scale (e.g., biochar, soil carbon sequestration, etc.) There is little agreement on the relative costs and benefits of potential CDR measures,

Pessimists sound clever, optimists change the world

The incumbents have been predicting the end of the transition for decades.

→

Pessimist's and optimist's take on solar and wind uptake



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