Ariadne@Brussels, 9 December 2025

RECONCILING INDUSTRY AND CLIMATE: EU INDUSTRIAL GEOGRAPHY IN A LOW-CARBON FUTURE

Darius Sultani and Michael Pahle
based on joint work with Sebastian Osorio and Frank Best

With funding from the:

Federal Ministry of Research, Technology and Space

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1 SETTING THE SCENE

2 COMPETITIVENESS AND INDUSTRIAL POLICY IN EU STEEL

3 FOUR CHALLENGES FOR PUSHING THE POLICY FRONTIER

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CLEAN INDUSTRIAL DEAL URGENTLY NEEDS A SUCCESS STORY

- Industry has signaled readiness to transform – under the assumption that certain conditions are met
- Now: Uncertainty over whether these conditions can be met in time

All eyes on steel (and chemicals): Can it (still) be done?


BUSINESS | GERMANY

ArcelorMittal's pullout plunges German green steel in doubt

Insa Wrede
07/19/2025

Despite being offered billions in subsidies, steel giant ArcelorMittal has suspended plans to transition to green steel production in Germany. Is this an isolated case — or a warning sign for the entire industry?

Big steelmaker ArcelorMittal pulled out of Germany's ambitious plan to make the industry carbon-neutral

Image: Schoening/Bildagentur-online/picture alliance

Source: DW (2025)

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COMPETITIVENESS, GREEN INDUSTRIAL POLICY, AND TRADE

"[G]overnment support for green industries is rampant […]. Often, the motive seems to be to give the domestic industry a leg up in global competition. […] Normally, **we consider these competitive motives to be of the beggar-thy-neighbor type** […].

However, […] national efforts to boost domestic green industries **can serve to offset [spillover effects and emissions externalities]**, even if the motives are narrowly national and carry beggar-thy-neighbor connotations. [In this case], boosting green industries for competitive reasons **is largely a good thing, not a bad thing**. However, by the same token, when these national strategies take the form of […] **restricting market access to *foreign* green industries, they have to be considered triply damaging**."

2014

Dani Rodrik: Green industrial policy

2025

EU Clean Industrial Deal

"[…] This is why **Europe needs a transformational business plan**. The **Clean Industrial Deal brings together climate action and competitiveness** under one overarching growth strategy. It is a commitment to accelerate decarbonisation, reindustrialisation and innovation, all at the same time and across the entire continent […].

This will be **achieved by nurturing competitive manufacturers who drive decarbonisation** through innovation, create quality jobs and contribute to our open strategic autonomy […]."

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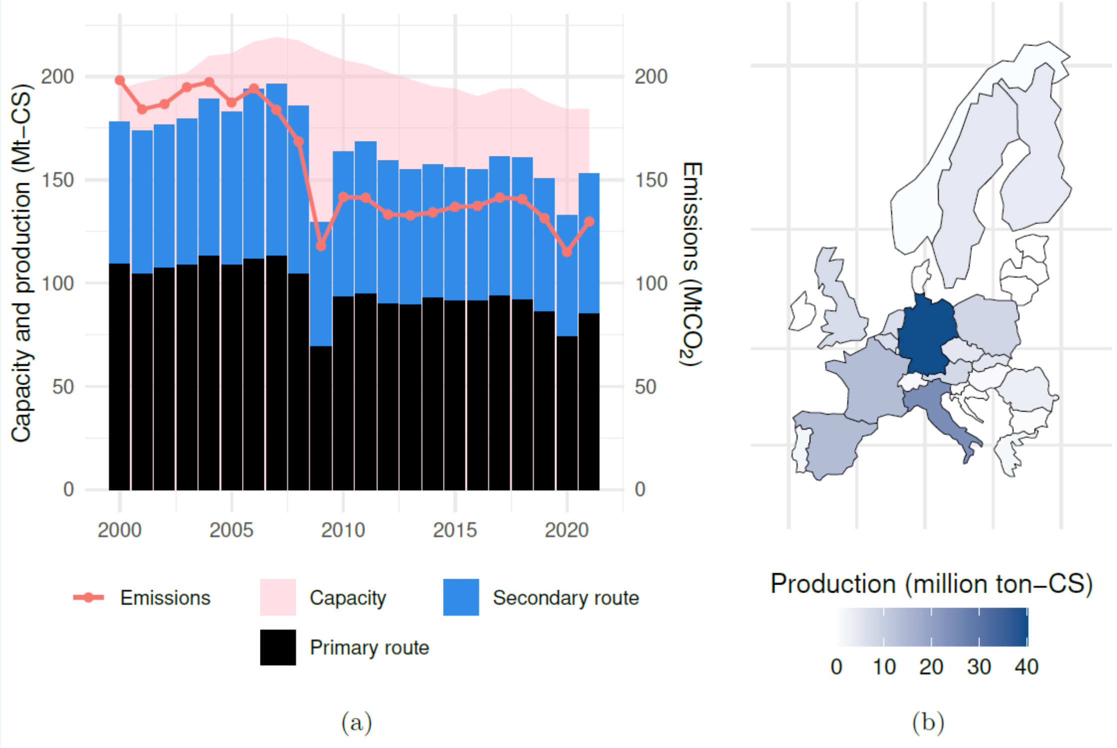
HISTORICALLY, STEEL PRODUCTION HAS FOLLOWED ENERGY & DEMAND.

- Two conventional technologies: BF-BOF (very carbon intensive) and EAF (limited by scrap availability)
- (global) overcapacities exacerbate market situation
- Incremental efficiency improvements, but barely any deep-decarbonising investments at scale



Steel production per technology and total emissions from 2000-2021

Country-level production in 2021

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THREE POLICY CRUNCH POINTS FOR STEEL DECARBONISATION

Research Square

Research Article

Policy crunch points to decarbonising European steel

Sebastian Osorio, Frank Best, Darius Sultani, Michael Pahle

(pre-print)

1. High **costs of low-carbon production**: insufficiently rapid low-carbon project deployment from a societal perspective.
2. Distributional **implications of renewables pull** (here: within the EU).
3. Structural **decline in demand** for European steel: exacerbates distributional concerns and puts pressure on policymakers.

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SCENARIOS IN LIMES-EU: OUR APPROACH IN A NUTSHELL

- Linear EU ETS model LIMES-EU
- Temporal resolution:
  From 2010 to 2070 in 5-year steps (perfect foresight)
- Geographical scope:
  Europe (29 model regions)
- Covers all EU ETS sectors
  - Power sector: detailed representation (35 generation and storage technologies)
  - Energy-intensive industry: **detailed Steel sector module**; rest with MACC
  - Other sectors: MACCs for DH, aviation, maritime
- Detailed MSR operation, banking of EUA

Demand for EU steel	Policy	
	Open market	**Protectionism**
High (+15% in 2050 wrt 2020)	competitive market (Reference)	concentrated prosperity (Protectionism)
Low (-15% in 2050 wrt 2020)	market consolidation (R-LoDem)	Low demand and protectionist policy (P-LoDem)

Proctectionism among „The Big 6”

Germany, Italy, Spain, France, Poland, and the UK keep capacity at least at 2020 level

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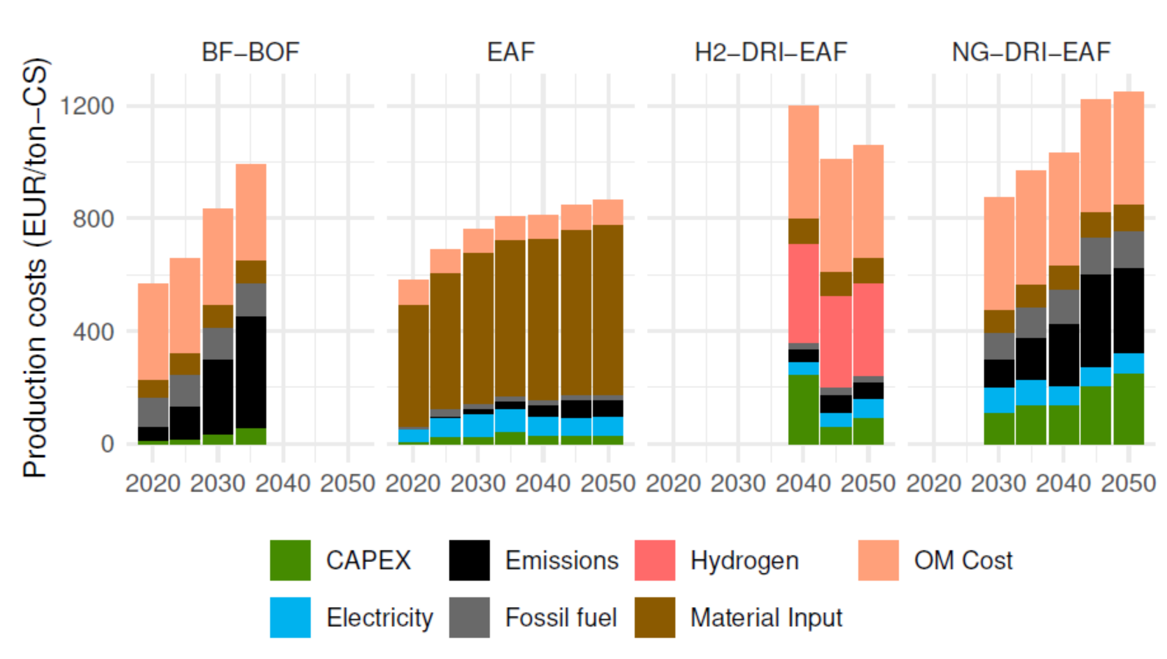
INTERNALISING THE EMISSIONS EXTERNALITY



Evolution of production costs in the *Reference* scenario.
Note: Electricity and hydrogen costs are the only components that vary across countries.

- Steep cost increases for conventional and NG-based EU steel production (CBAM needs to work)
- Carbon price bridges cost gap to low-carbon routes from 2035 onwards, no further BF-BOF investments after that
- Side note: Limited share of electricity costs (7-11%) across countries

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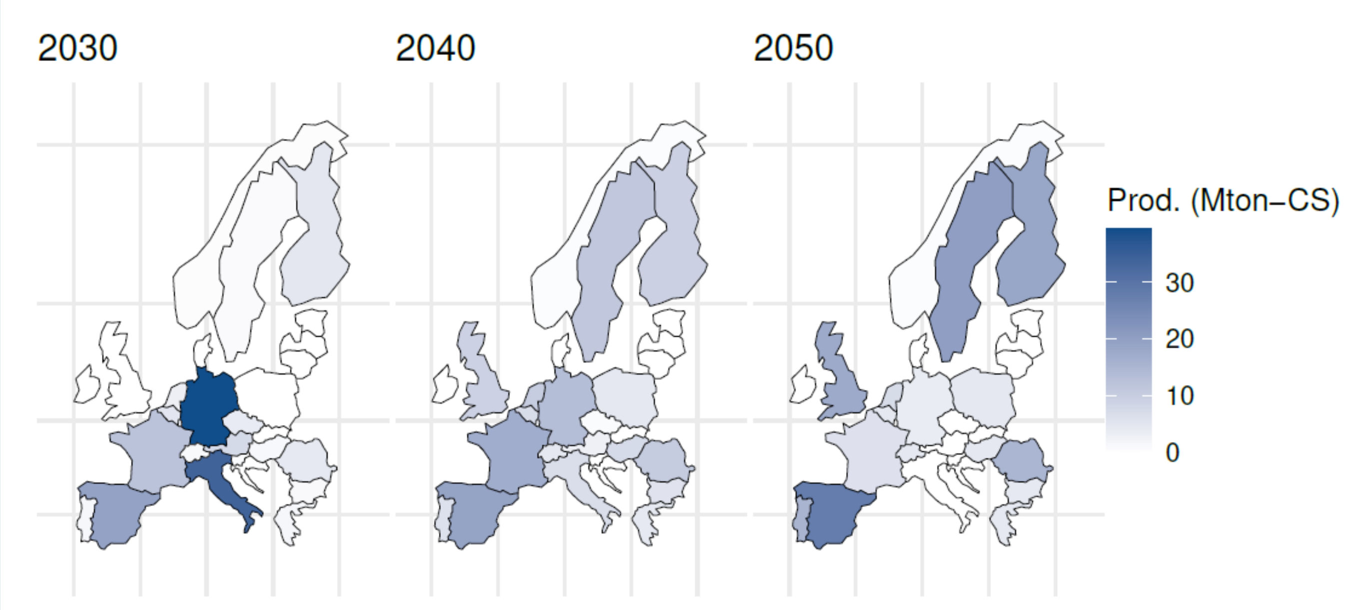
REGIONAL ELECTRICITY AND HYDROGEN COST DIFFERENCES DRIVE A „RENEWABLES PULL“ WITHIN EUROPE.



LIMES-EU total steel production volumes across Europe over time.

- Production (again) follows the energy
- Shift away from EU’s industrial “heart” (DE/IT) towards Spain and the Nordics
- Two (major) caveats:
  - Simplified representation of international trade effects (demand assumptions)
  - Supply chains assumed to be rigid, esp. no HBI trade

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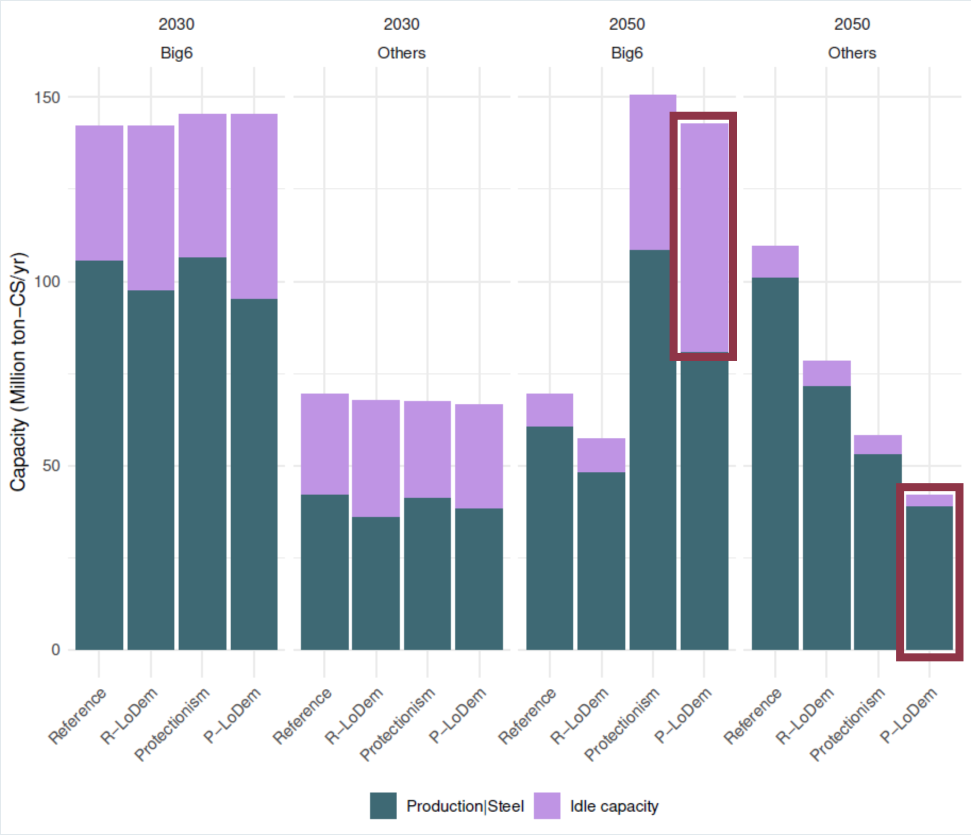
PROTECTIONIST POLICIES RUN THE RISK OF SUBSIDISING IDLE CAPACITY.

- Protectionist policy re-distributes capacities across EU
- Non-protecting countries lose capacity particularly when they have to absorb a demand shock
- Risk of subsidising idle capacity is largest when MS take protectionist approach while demand drops



Production and idle capacity in all four scenarios considered.

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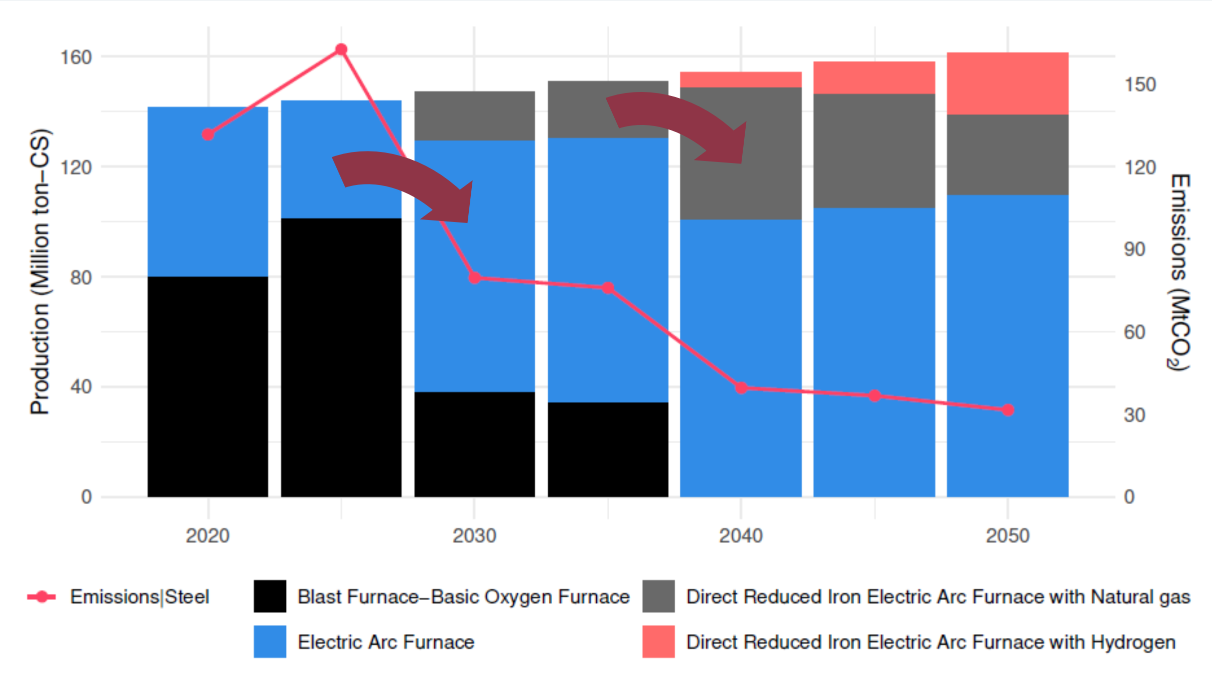
CAPACITY EXPANSION: HOW FAST CAN WE GO?



Resulting steel production per technology route and average carbon emissions in LIMES-EU *Reference* scenario.

Potential bottlenecks:

- Labour
- Equipment manufacturers
- Infrastructure
- …

Challenge 1:
Identify and address bottlenecks for low-carbon capacity expansion.

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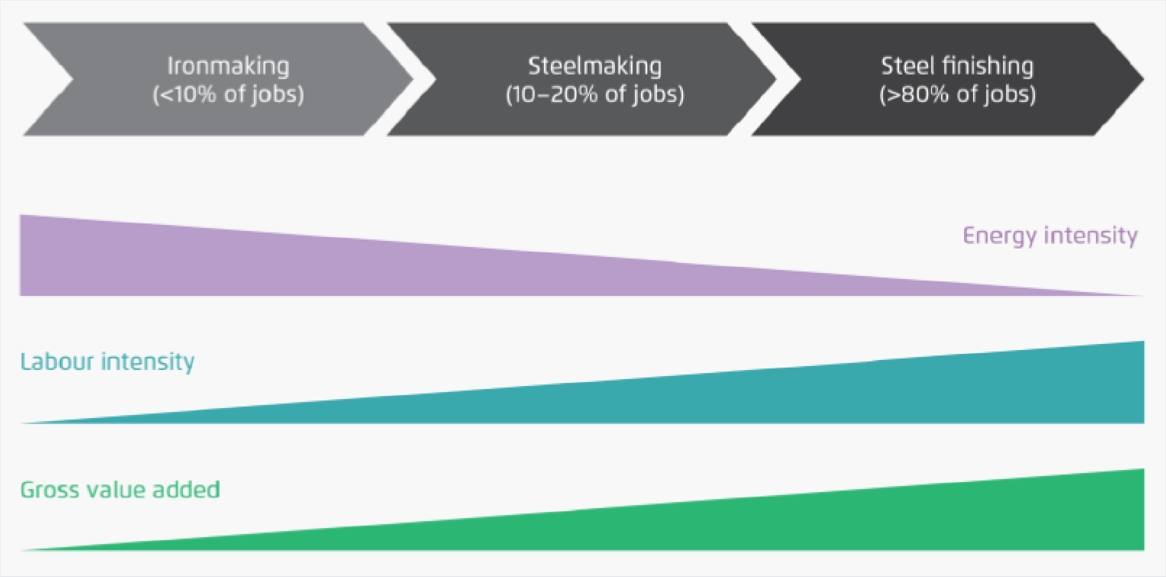
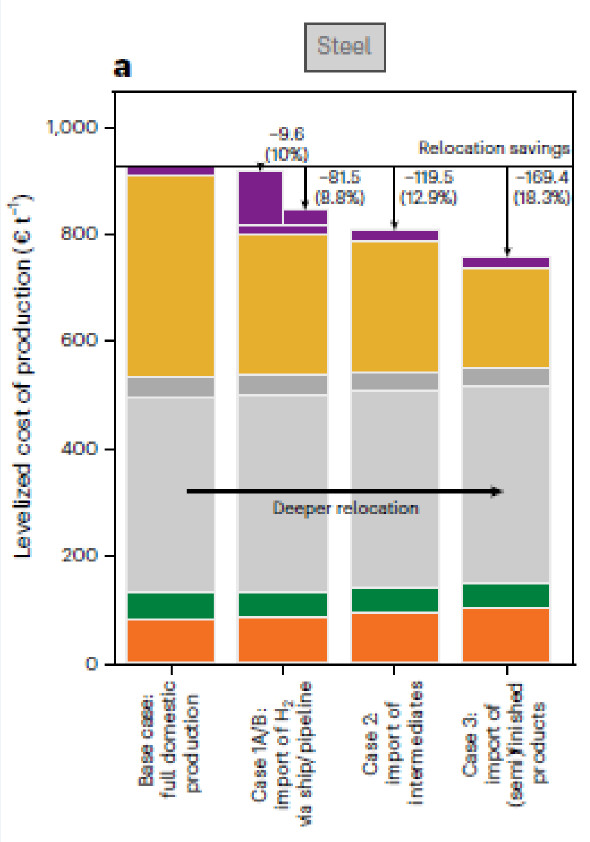
RENEWABLES PULL: ENERGY INTENSITY LIES UPSTREAM, LABOUR INTENSITY DOWNSTREAM THE STEEL VALUE CHAIN.



Energy intensity, labour intensity and gross value added along the steel value chain.
Source: Agora Industry (2025)



Levelised cost of steel production with increasing relocation depth. Source: Verpoort et al. (2024)

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EMBRACING THE LOW-CARBON TRANSITION REQUIRES AN HONEST DISCUSSION ABOUT FUTURE VALUE CHAINS.

Industrial geography of today:

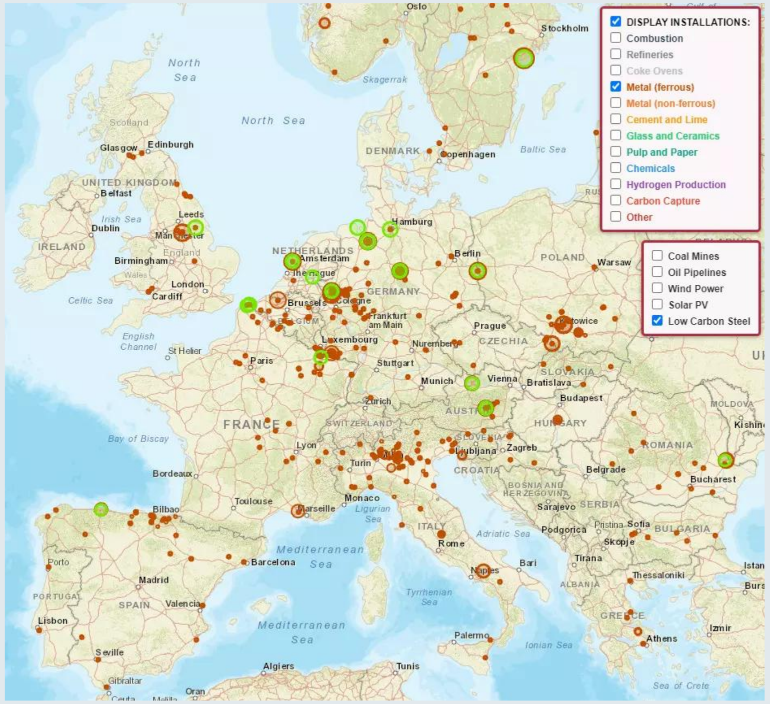
- Existing infrastructure
- Knowledge and labour
- Key customers

… and tomorrow:

- Renewables pull
- CO_2 and H_2 transport
- Geopolitics

Challenge 2:

Identify “sweet spots” in value chains that balance cost-effectiveness and (economic/social) resilience.



Low-carbon steel plants planned next to existing capacity.
Source: Zachmann and McWilliams (2021)

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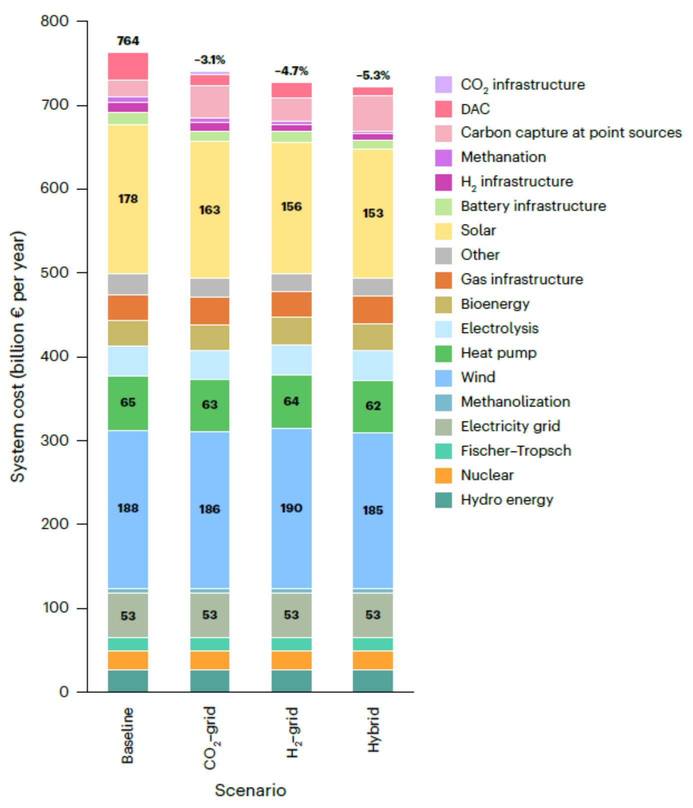
INFRASTRUCTURE'S CHICKEN-AND-EGG PROBLEM: WHERE TO START?

H2 and CO2 backbones, electricity infrastructure define future value chains and vice versa, e.g.

- H2: transport as gas or embedded in product (HBI)
- Synthetic fuels: hydrogen to carbon point sources vs. carbon to low-cost hydrogen

Challenge 3:

Address coordination problem in the EU's ramp-up of low-carbon infrastructure.



Total annual cost for the European energy system under different molecule infrastructure scenarios. Source: Hofmann et al. (2025)

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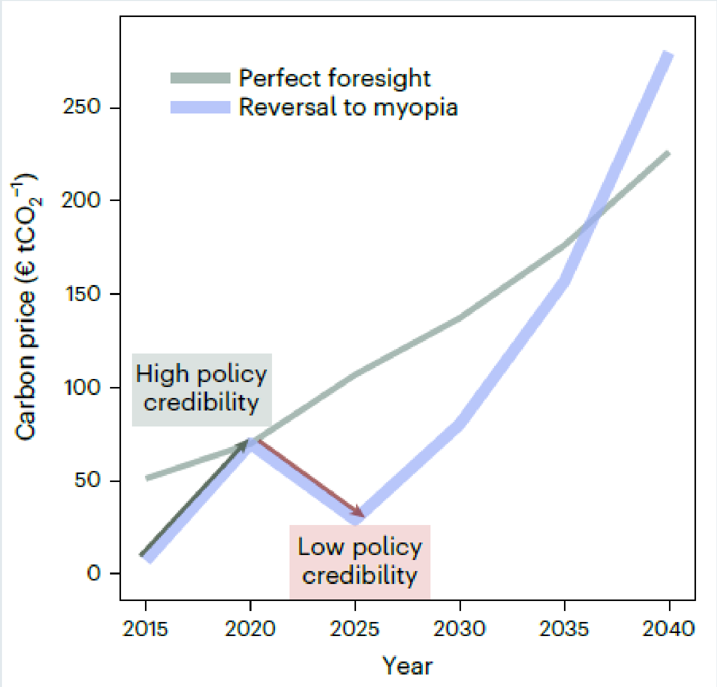
ACTORS' BELIEF IN POLICY COMMITMENT DRIVES CARBON PRICES (HENCE ABATEMENT).

- Policy credibility has two components: signaling and perception
- Timing of investment: wait and see vs. potentially higher carbon prices later

Challenge 4:
Give industry "breathing room" to transform without compromising policy credibility.



Carbon prices assuming perfect foresight and reversal to myopia. Actors are first fully myopic, become farsighted around 2020 and then back fully into myopia until 2025. Source: Sitarz et al. (2024)

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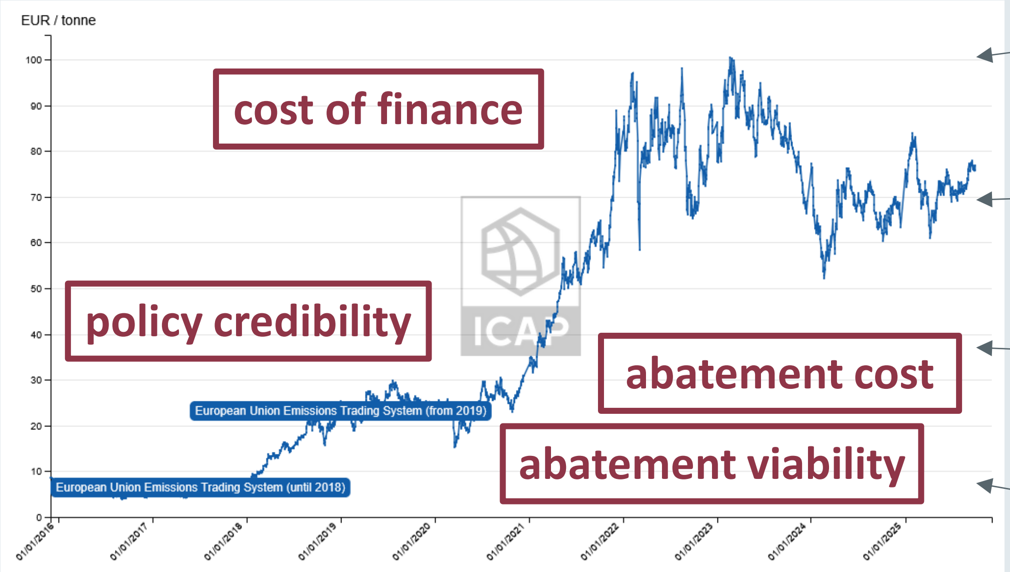
THE IDENTIFIED CHALLENGES CRYSTALLISE IN THE UPCOMING EU ETS REVISION.



Source: ICAP Allowance Price Explorer

Identify and address bottlenecks for low-carbon capacity expansion.

Identify "sweet spots" in value chains that balance cost-effectiveness and (economic/social) resilience.

Address coordination problem in the EU's ramp-up of low-carbon infrastructure.

Give industry "breathing room" to transform without compromising policy credibility.

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REACTIONS

Francesca Payne (Salzgitter AG)
Ysanne Choksey (Agora Industry)
Ben McWilliams (Bruegel)

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BACKUP

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Steel module (I)

Assumptions

- Demand increase 15% between 2020 and 2050 (i.e., ~0.5%/yr)
- Max 46% (later: 60%) production from EAF (maximum historic share between 2000 and 2021 [JRC-IDEES 2021])
- Max capacity factor of 90%
- Fix capacities and production 2010-2020

Technology (new / relined or refurbished)	Investment costs (Eur/ ton-CS-cap)	Fixed O&M costs (% inv. costs)	Var. O&M costs (Eur/ton-CS)
BF-BOF	159 / 80	0.3%	239
EAF	169 / 84		58
NG-DRI-EAF	698 / 349		279
H2-DRI-EAF	698 / 349		279

Technology (unit per ton-CS)	Gas (GJ/t)	Coal (GJ/t)	Coke (GJ/t)	Electricity (GJ/t)	H2 (GJ/t)	Scrap (GJ/t)	CO2 intensity (tCO2/t)
BF-BOF	0.6	4.4	11.7	0.0	0.0	0.2	1.6
EAF	1.6	0.2	0.0	2.5	0.0	1.1	0.1
NG-DRI-EAF	10.6	0.0	0.0	2.5	0.0	0.2	0.6
H2-DRI-EAF	2.0	0.0	0.0	2.5	6.9	0.2	0.1

Source: Agora Industrie et al (2022b), Cappel (2021) and Material Economics (2019)

Steel module (II)

Capacity expansion assumptions:

- Capacity additions in 2025 fixed to announced to start operations; upper bound in 2030
- Decommissioning capacity not fixed / bound to announcements
- Possibility to reline BF-BOF / Refurbish EAF and DRI-EAF indefinitely at 50% of CAPEX
- Max capacity addition every 5 years per country: 5 million ton-CS
- Net increases in capacity incur further costs
- Constrained capacity additions in small producing countries

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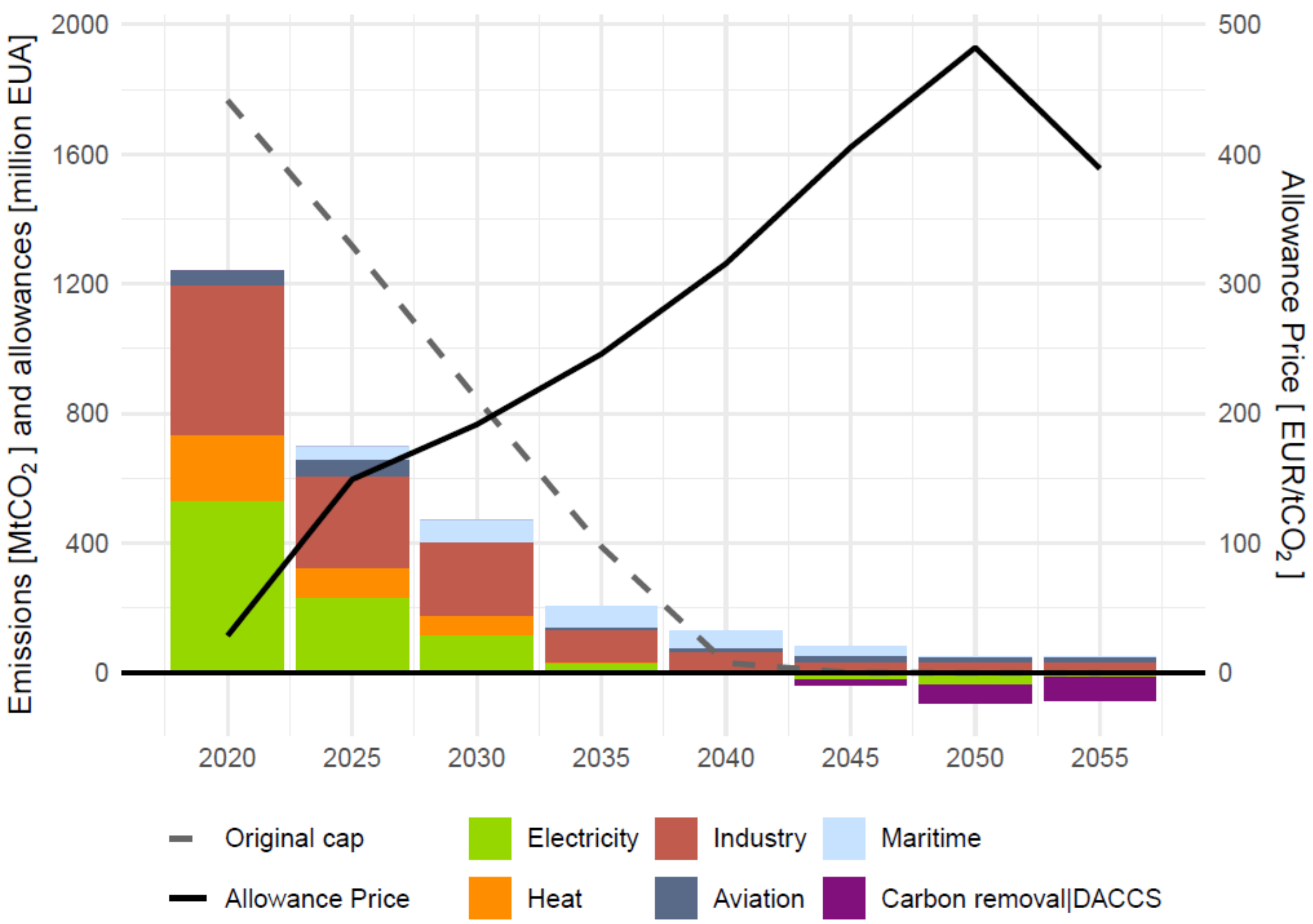
From Power to Industry: the next wave of decarbonisation



- EUA prices increasing from 200 to 500 EUR/t between 2030 and 2050
- Bulk of reductions occur already in the 2020s (emissions in 2030 66% lower than in 2020)
  - Industry decarbonising slower (52% less in 2030) than in electricity sector
- Abatement in the 2030s will mainly come from the industry sector

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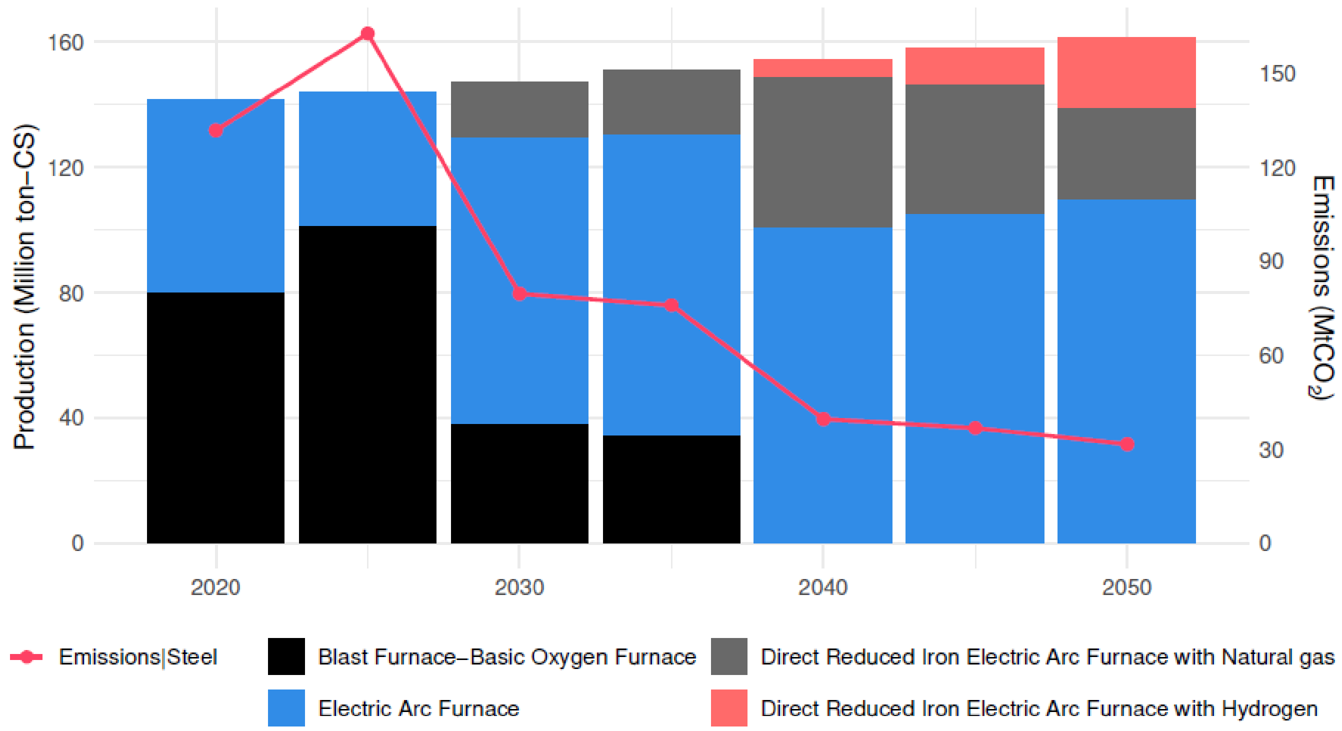
Steel decarbonization goes through three phases



- Three phases:
  - First, BF-BOF and EAF stay the dominant production technologies until 2030;
  - BF-BOF is phased out completely after 2030, replaced mainly by NG-DRI-EAF (bridging-technology)
  - Natural gas is progressively replaced by H2-DRI-EAF
- Evolution of emissions
  - From coal- and coke-dominated to gas- and electricity-dominated
  - Green steel ≠ zero-carbon steel: need to balance residual emissions

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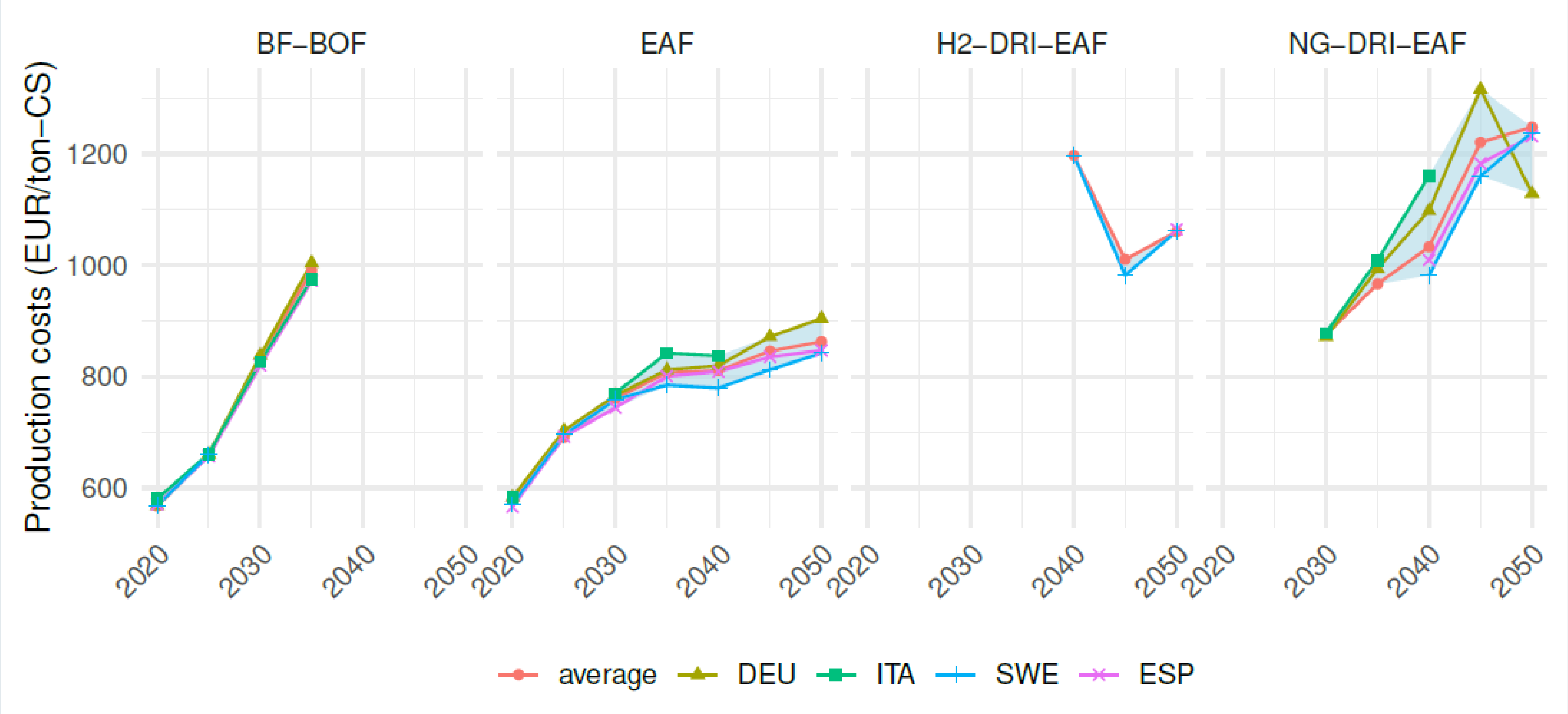
REGIONAL ELECTRICITY AND HYDROGEN COST DIFFERENCES ACROSS ROUTES



Production costs per route for selected countries.
Blue ribbons indicate the range of production costs across Europe.

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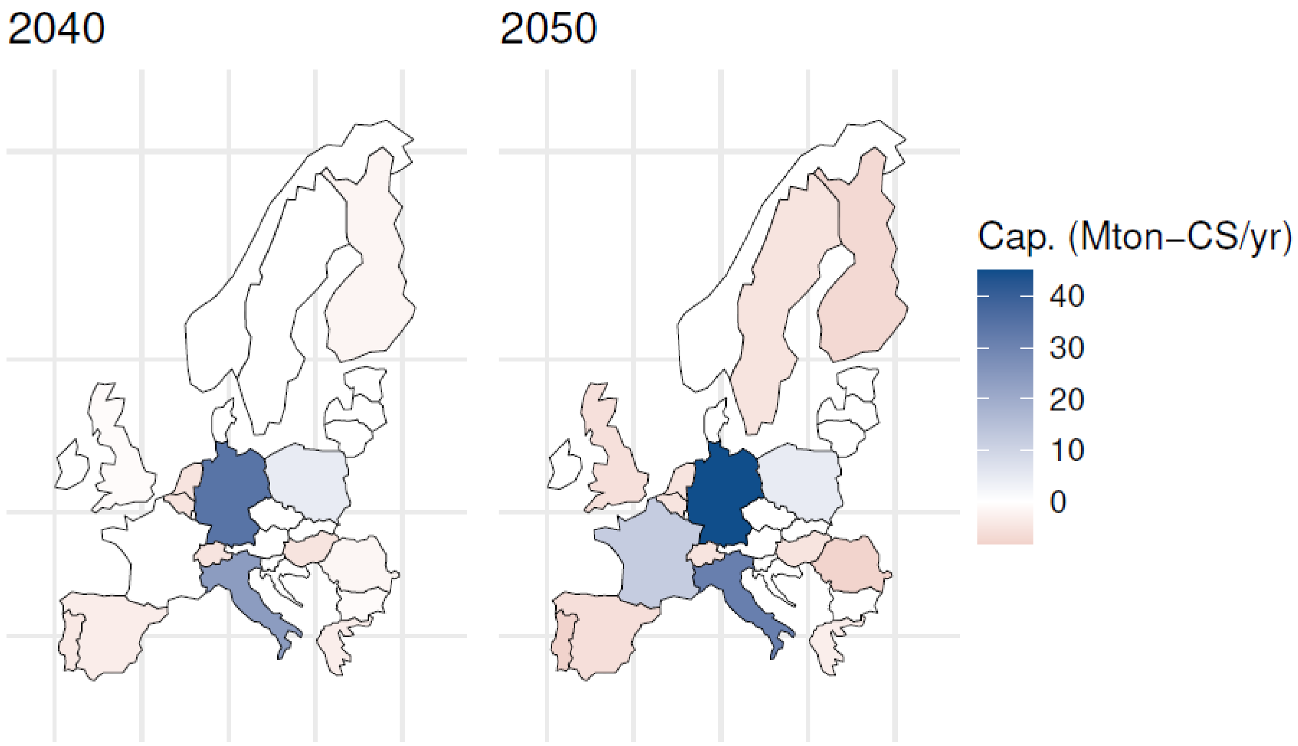
Protectionism: from ‘renewables pull’ to political pull

(Additional constraint: ‘The Big 6’ keeping capacity at least at 2020 levels)



Differences in total capacity between *Protectionism* and *Reference* scenarios.

Effects of protectionism

- Subsidies are effective in countries that would experience a severe capacity drop otherwise (Germany, Italy)
- Spain and Sweden remain relatively competitive even in this scenario

Cost of protectionism

- Up to 75 EUR/ton-CS
- Total cost of protectionism in „Big 6“ producing countries: EUR 2.8 billion (1 billion for DE alone)

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