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Implications of European industrial decarbonisation pathways for the EU and UK industry policy mix, London, October 7, 2022

Introduction to the PARIS REINFORCE project

Dr. Alexandros Nikas *(National Technical University of Athens)*

www.paris-reinforce.eu

Title:	Delivering on the Paris Agreement: A demand-driven, integrated assessment modelling approach (PARIS REINFORCE)
Funding:	European Union's Horizon 2020 Research and Innovation Programme (H2020)
Lifetime:	June 2019 - November 2022 (42 months)
Coordination:	NTUA, Energy Policy Unit, National Technical University of Athens
Participants:	13 European partners; 5 international partners
Call/Grant:	H2020-LC-CLA-01-2018/820846

The PARIS REINFORCE project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 820846.

Consortium

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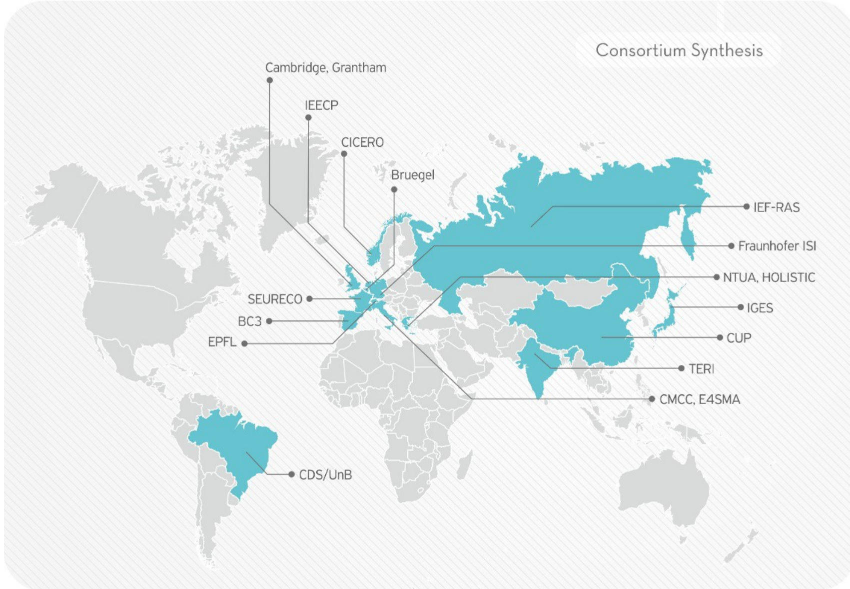
NTUA - National Technical University of Athens	GR
BC3 - Basque Centre for Climate Change	ES
Bruegel - Bruegel AISBL	BE
Cambridge - University of Cambridge	UK
CICERO - Cicero Senter Klimaforskning Stiftelse	NO
CMCC - Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici	IT
E4SMA - Energy, Engineering, Economic and Environment Systems Modelling Analysis	IT
EPFL - École polytechnique fédérale de Lausanne	CH
Fraunhofer ISI - Fraunhofer Institute for Systems and Innovation Research	DE
Grantham - Imperial College of Science Technology and Medicine - Grantham Institute	UK
HOLISTIC - Holistic P. C.	GR
IEECP - Institute for European Energy and Climate Policy Stichting	NL
SEURECO - Société Européenne d'Economie SARL	FR



CDS/UnB - Centre for Sustainable Development of the University of Brasilia	BR
CUP - China University of Petroleum-Beijing	CN
IEF-RAS - Institute of Economic Forecasting – Russian Academy of Sciences	RU
IGES - Institute for Global Environmental Strategies	JP
TERI - The Energy and Resources Institute	IN

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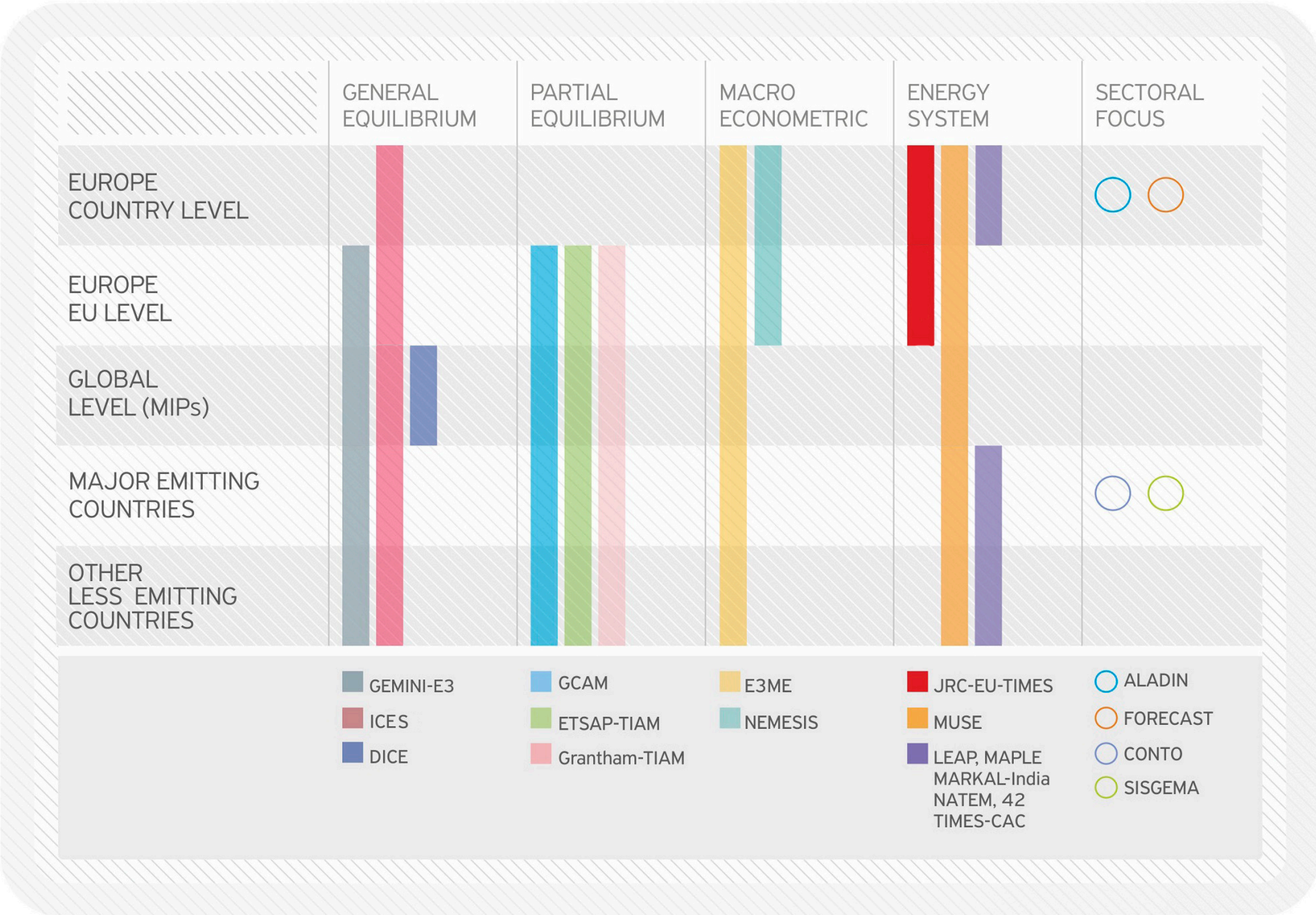
Modelling Ensemble



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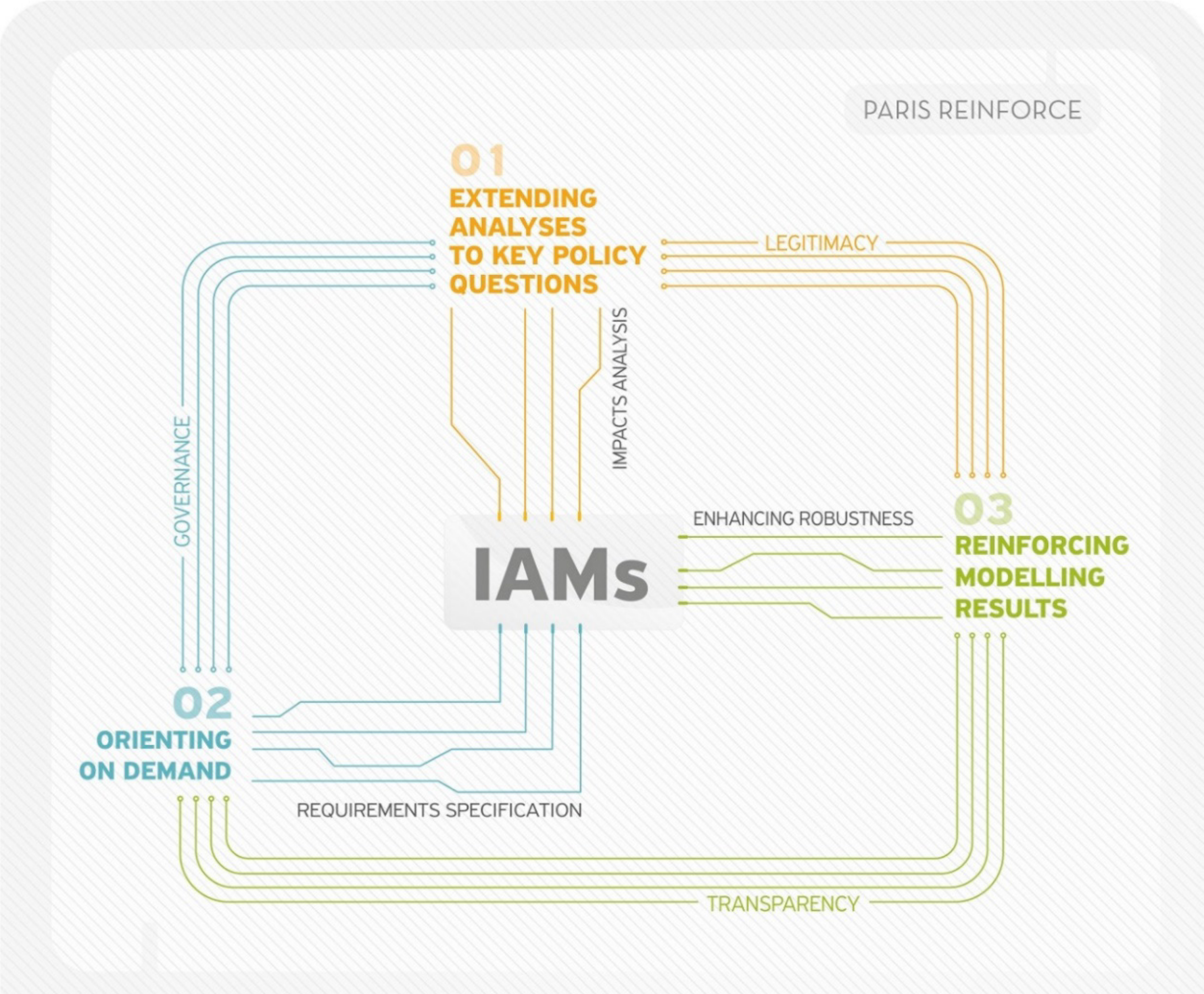

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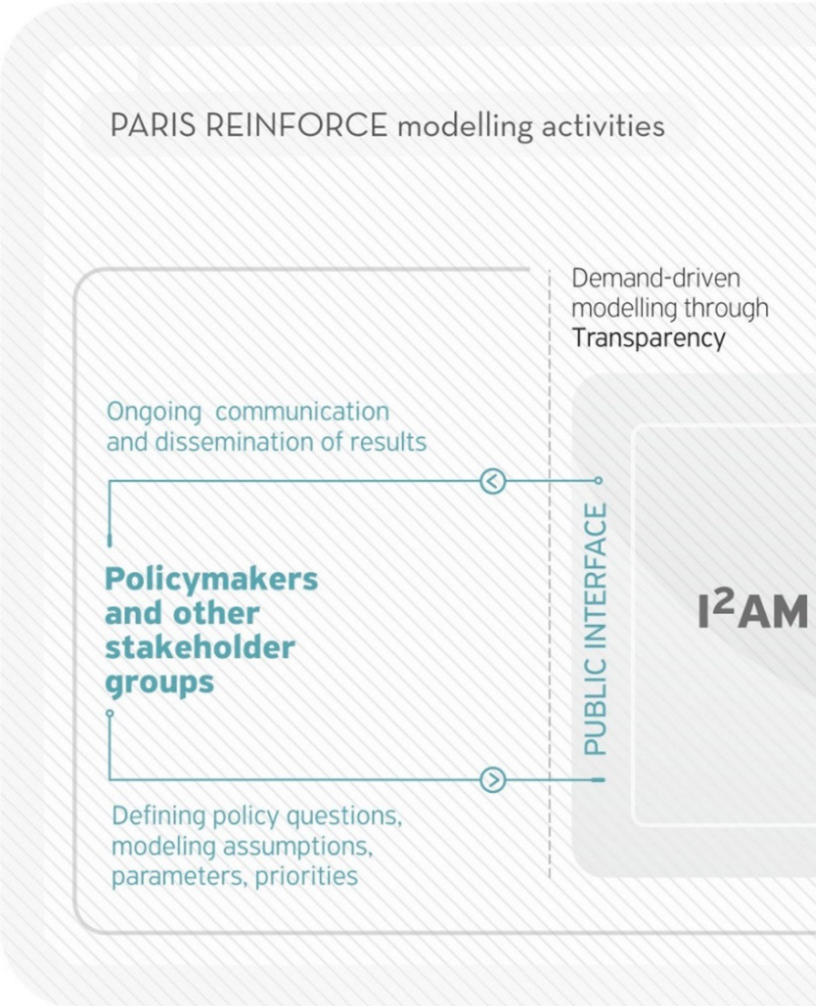
The I²AM PARIS public interface



- You may find a detailed, dynamic, and comparative documentation of all PR (and non-PR) models & harmonisation heatmaps across models, including a policy brief on modelling capabilities ('What can our models do?').
- In theme-specific workspaces, you may find a user-friendly presentation and visualisation of policy-relevant results and policy prescriptions, in response to co-created policy/research questions, as well as libraries with relevant papers and policy briefs.

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Results already available in I²AM PARIS

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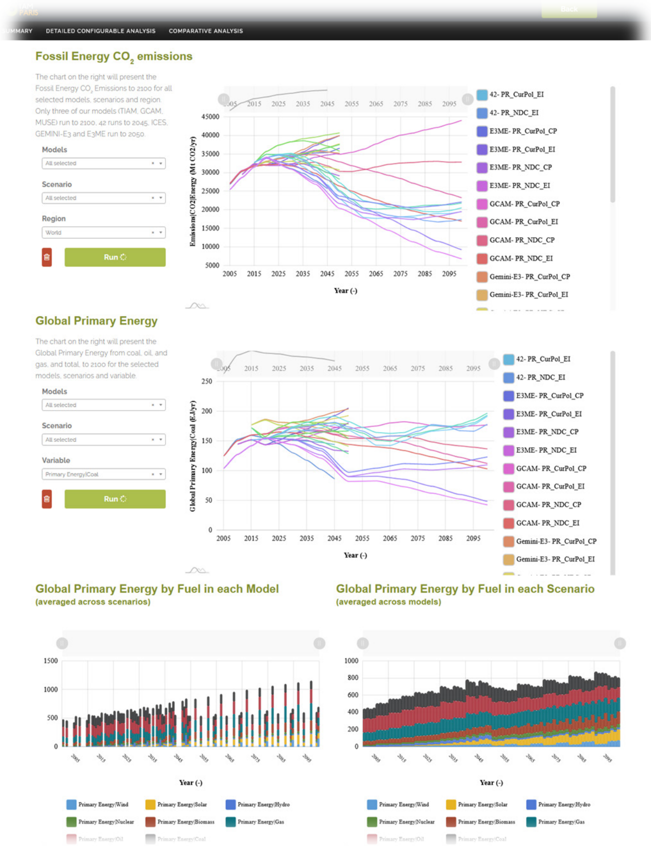
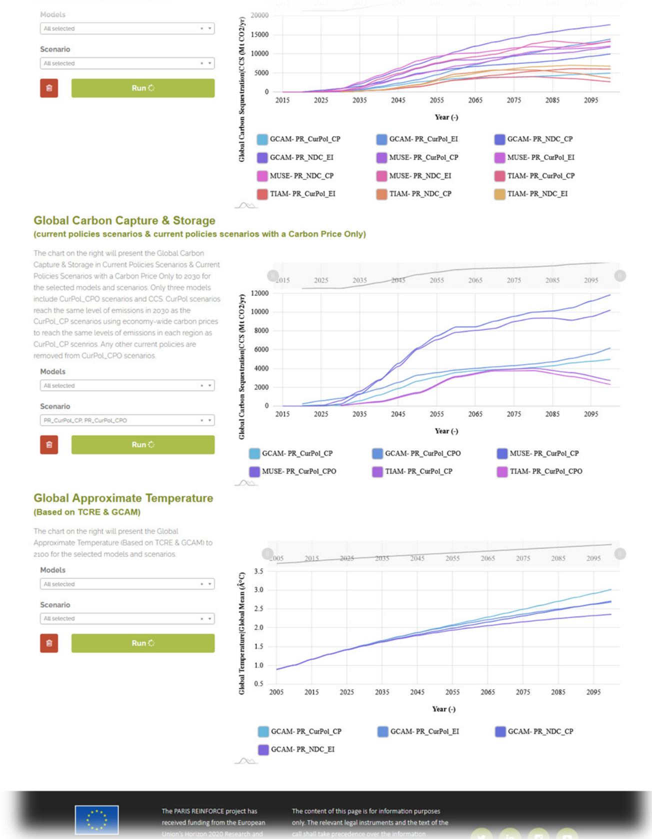
http://i2am-paris.eu





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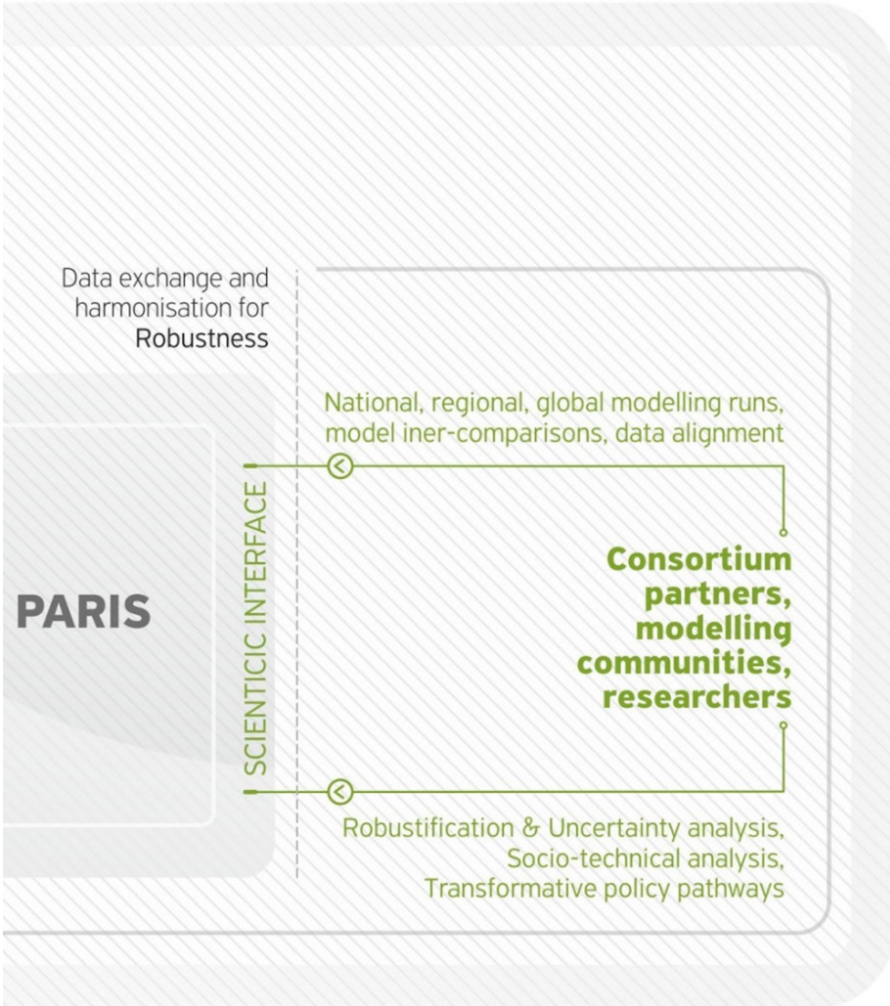
- All modelling teams can provide a detailed documentation of their model(s), so that we can include it in our database and documentation.
- Like the public interface, experts can also view the advanced scientific presentation of modelling results, databases, etc.; as well as access similar templates to provide us with the topics (research questions) they have addressed, as well as their modelling inputs and results to host in I²AM PARIS.



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Policy

- EU-level: next **NDC**; national level: **NECPs**
- Sectoral analyses for **detailed EU 2050 roadmap**
- All ten **major emitters**; other **less emitting** countries
- Forum for discussing **game-changing** topics

Society

- **Co-creation**: needs scenarios, assumptions
- Enhanced **transparency** & legitimacy
- Improved **understanding of models**

Research

- **I^2AM PARIS**: open access, multi-modelling, data exchange platform
- New **paradigm**: modelling **ensembles**, **robustness** analysis, systems of innovation
- IPCC **AR6** & other assessments: **reviews**, **global** analyses & **inter-comparisons**

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UK industry among project national/sectoral case studies

Koasidis, K., Nikas, A., Neofytou, H., Karamaneas, A., Gambhir, A., Wachsmuth, J., & Doukas, H. (2020). The UK and German low-carbon industry transitions from a sectoral innovation and system failures perspective. Energies, 13(19), 4994.

Workshop objectives:

- Present implications of EU net-zero for key fuel demands in UK industry
- Discuss challenges for sector in net-zero context
- Co-create transformative policy mixes to overcome bottlenecks

In light of:

- COVID-19/recovery (GVA drop by 35% in manufacturing/heavy, changes in product lines, automotive & aerospace industry hits, limited access to raw materials due to supply chain shocks & CN export)
- Ukraine/energy crisis (energy bills up, operational hours down, job cuts, reduced demand due to inflation, power cuts, potential for own power generation, insolvencies due to energy costs)

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Thank you!

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UK Workshop - 7th October 2022 - London

Overview of key industrial energy system transitions in the UK and EU

Ajay Gambhir (Imperial) & Baptiste Boitier (SEURECO)

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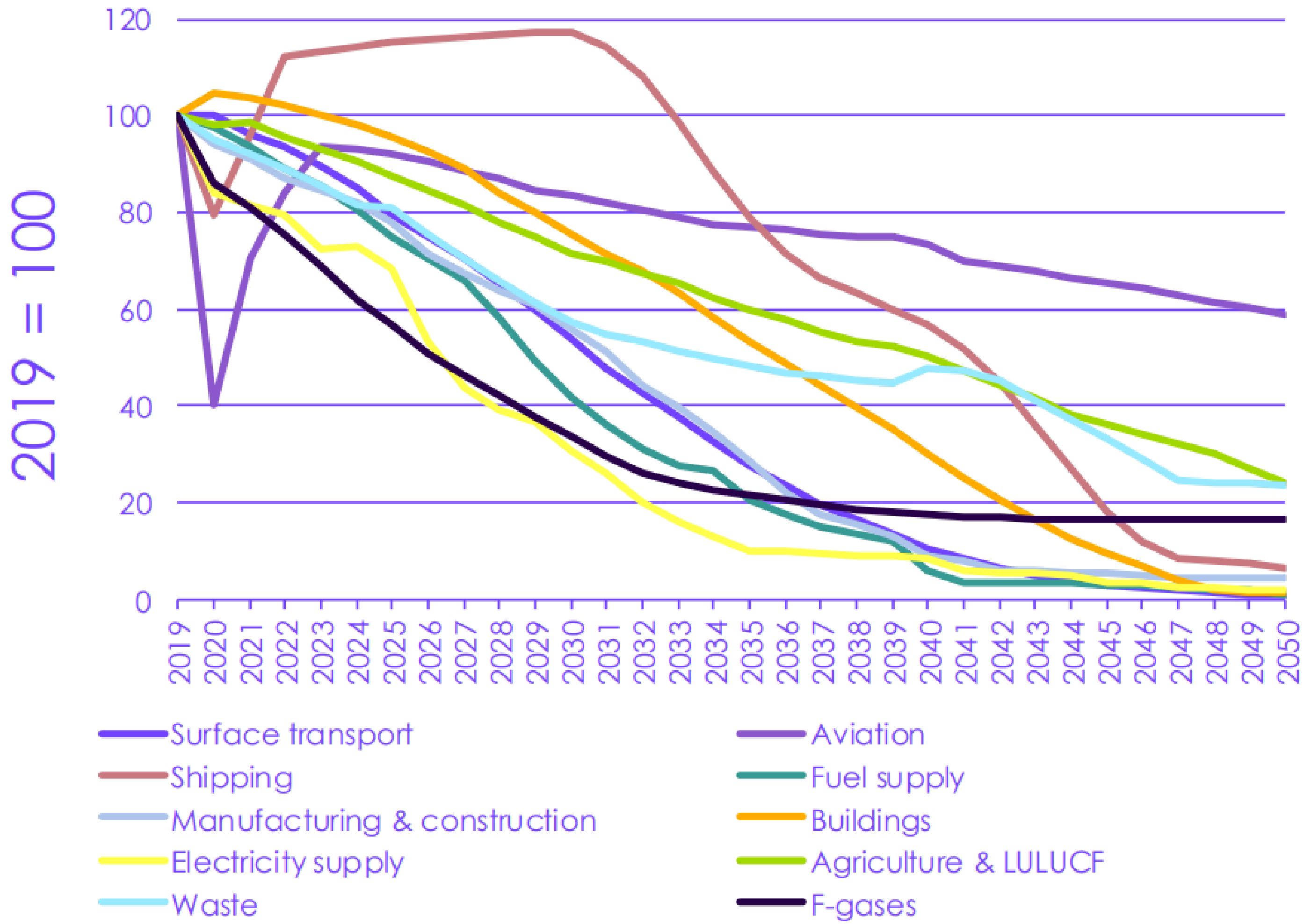
UK Energy and Climate Transition
CCC Balanced Net Zero Pathway



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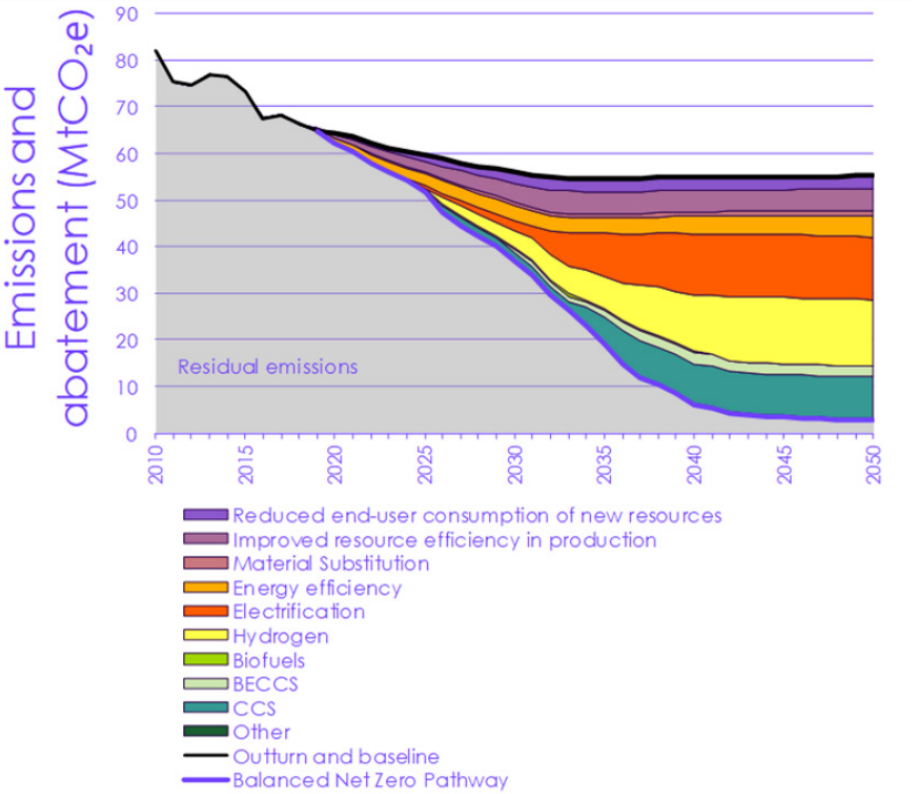
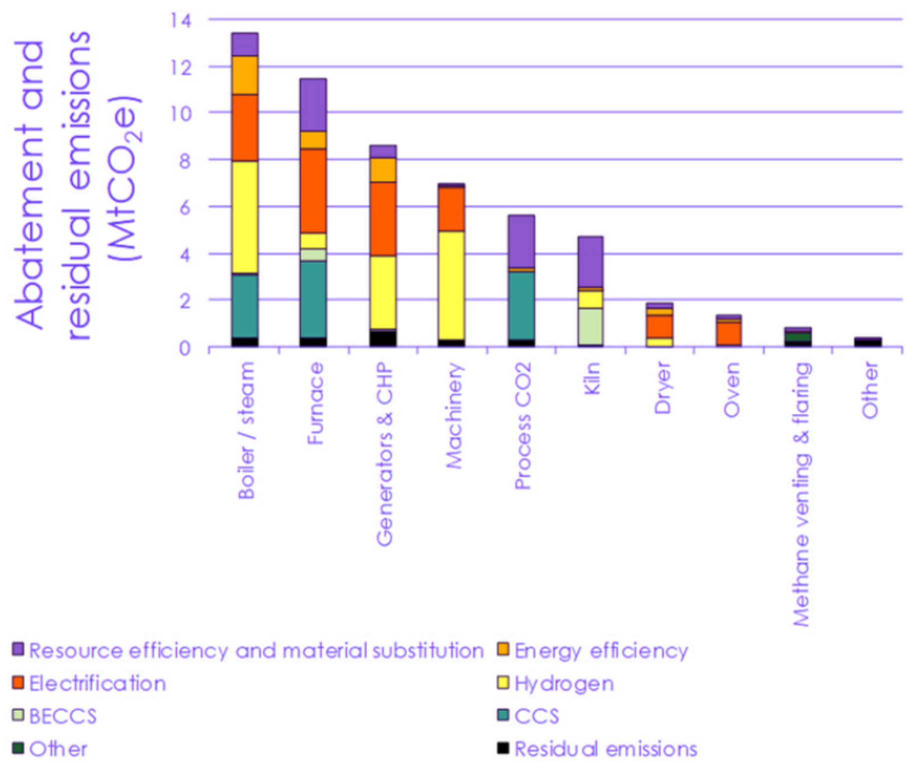
Mitigation options for industry





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- Emerging set of policies to:
  - cap emissions via the UK emissions trading scheme (UK ETS)
  - upgrade the least-efficient operations
  - support innovation and early deployment

- However, there are several policy gaps including on:
  - resource efficiency
  - electrification
  - off-road mobile machinery
  - decarbonisation of the 40% of emissions from smaller operations that are outside the UK ETS
  - energy efficiency policy

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CCUS (6 $MtCO_2$ by 2030, 9 $MtCO_2$ by 2035)

Switch to 50 TWh of low-carbon fuels by 2035

Energy efficiency saving 11 $MtCO_2$ by 2035

Initiatives to shift to low-carbon products

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- Seven different models

	Type	Institute	Geographical coverage
ALADIN	Bottom-up sector perspective (Transport)	Fraunhofer ISI	All EU-27 individualised + UK + NO + CH
E4SMA-EU-TIMES	Energy system model	E4SMA	All EU-27 individualised + UK + NO + CH + IS
FORECAST	Bottom-up sector perspective (Industry and Buildings)	Fraunhofer ISI	All EU-27 individualised+ UK + NO + CH
GCAM	Global Partial Equilibrium	BC3	EU15 (including UK) + EU13
GEMINI-E3	Global General equilibrium model	EPFL	EU28 (including UK)
ICES	Global General equilibrium model	CMCC	9 MS individualised + Benelux + Rest-of-EU + UK
NEMESIS	Macroeconometric model	SEURECO	All EU-27 individualised + UK + NO + CH + IS

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The scenario design

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Core scenarios

- **Where are we heading?**
  - **WWH21**: forecasting medium to long term impacts of current climate policy in EU
- **Paris Agreement Compliant**
  - **NZE Benchmark**: backcasting least-cost scenario with GHG trajectory as from "Fit for 55" and revised "Long-term strategy 2050"
  - **NZE EU Policy Standard**: as NZE Benchmark + burden sharing between ETS and ESR sectors

	WWH21	NZE Benchmark	NZE EU Policy Standard
ALADIN	X		X
EU-TIMES	X	X	X
FORECAST	X		X
GCAM	X	X	X
GEMINI-E3	X	X	X
ICES	X	X	X
NEMESIS	X	X	X

EU-27

	WWH21*		NZE Benchmark**		NZE EU Policy standard**	
	2030	2050	2030	2050	2030	2050
GHG emissions reduction (w.r.t 1990)	-40%	carbon price equivalent	-55%	Net Zero Emission	-55%	Net Zero Emissions
EU-ETS GHG emissions reduction (w.r.t. 2005)	-43%				-61%	Adjusted to reach NZE EU-level target
ESR GHG emissions reduction (w.r.t. 2005)	-30% (w. national targets)				-40% (wo. national targets)	-80%

UK

	WWH21		NZE			
	2030	2050	2025	2030	2035	2050
GHG emissions reduction (w.r.t 1990)	-58% (wo LULUCF & in't transports)	carbon price equivalent	-55% (w LULUCF & wo in't transports)	-68% (w LULUCF & wo in't transports)	-78% (w LULUCF & w in't transports)	NZE
EU-ETS GHG emissions	2021-2025: 736 $MtCO_2eq$. 2026-2030: 630 $MtCO_2eq$.					
ESR GHG emissions reduction	-37% (w.r.t. 2005)					

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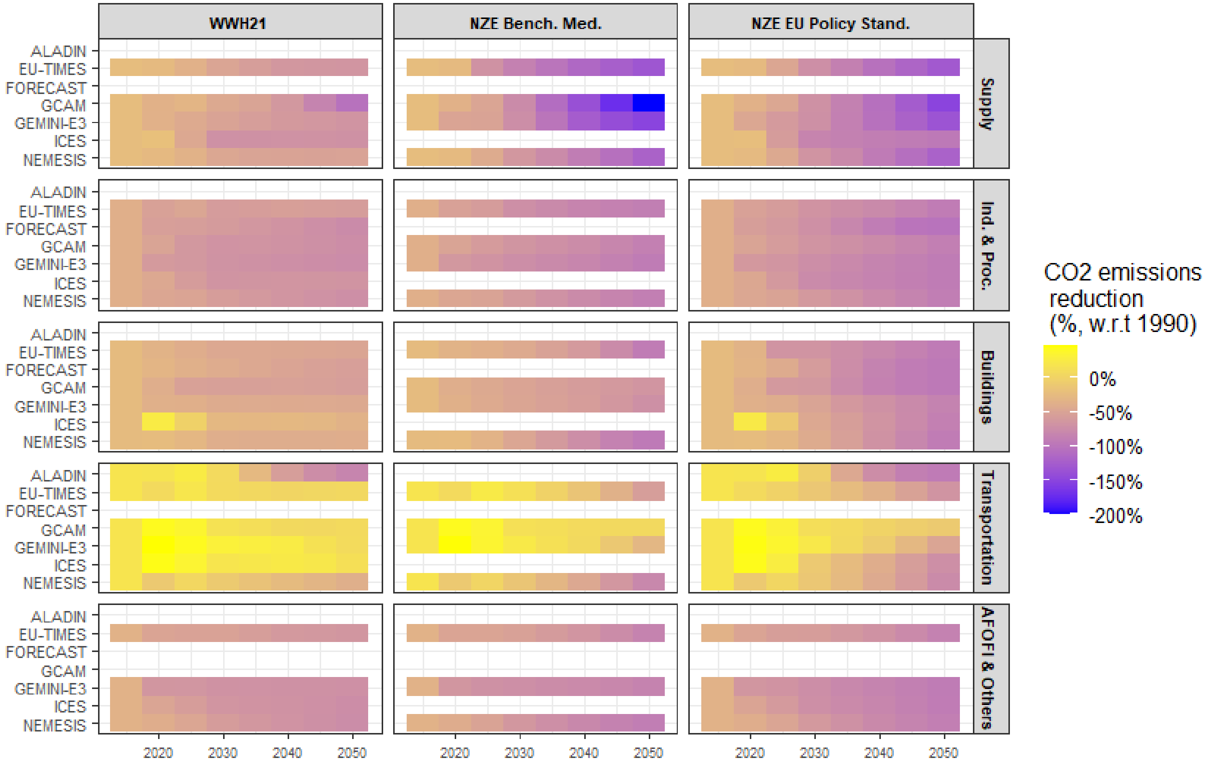
CO_2 emissions reduction per sector:

- NZE is reached rapidly in the supply sector with NZE between 2035 and 2045, but, it means a rapid and lar deployment of BECCS
- Decarbonisation is slower in other sectors and particularly in the transport sector
- Industry CO_2 emissions reduce between 60% and 77% in NZE scenarios in 2030 and 85% and 100% in 2050 (w.r.t 1990).
- In UK, similar results, with more homogeneous mitigation efforts across sectors

CO_2 emissions reduction by sector in EU

(w.r.t 1990 emissions level)



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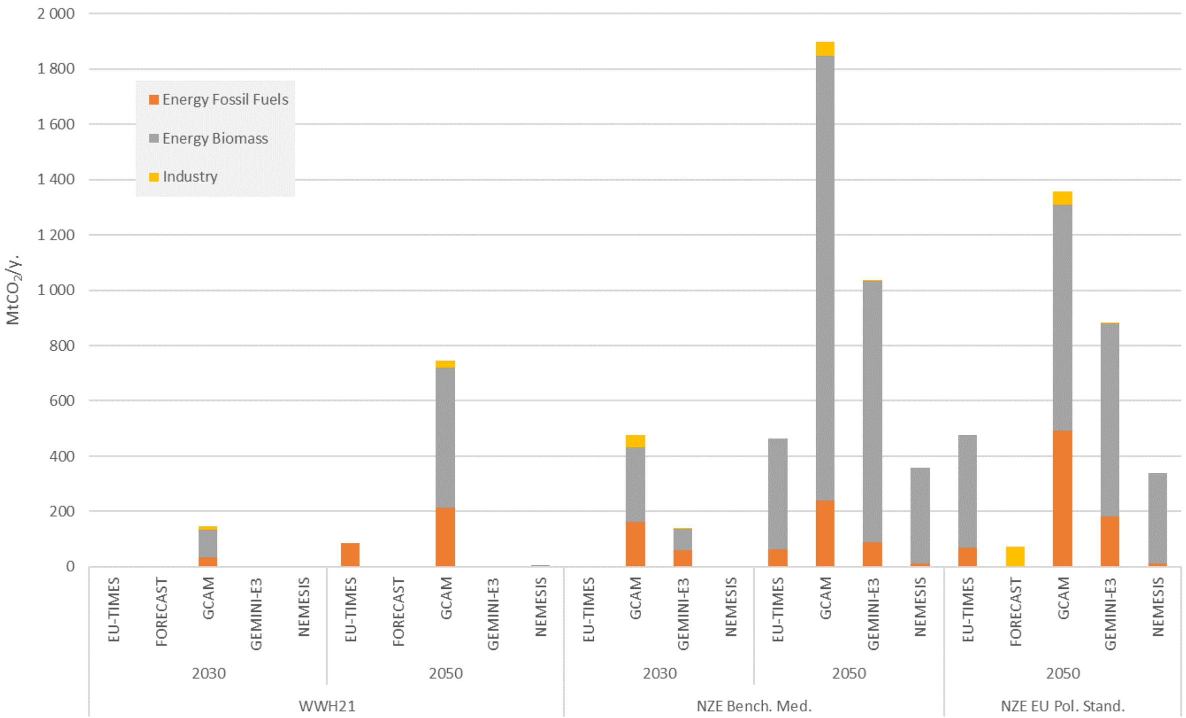
EU carbon sinks ($MtCO_2$/y.)



- ✓ Carbon sinks play a **fundamental** role in delivering net-zero in the EU
- ✓ **Biomass CCS** (with net-negative emissions) balances hard-to-abate sectors
- ✓ Sinks are primarily related to electricity generation

The UK case

- ✓ Up to 75 Mt/y. in NEMESIS
- ✓ No in EU-TIMES

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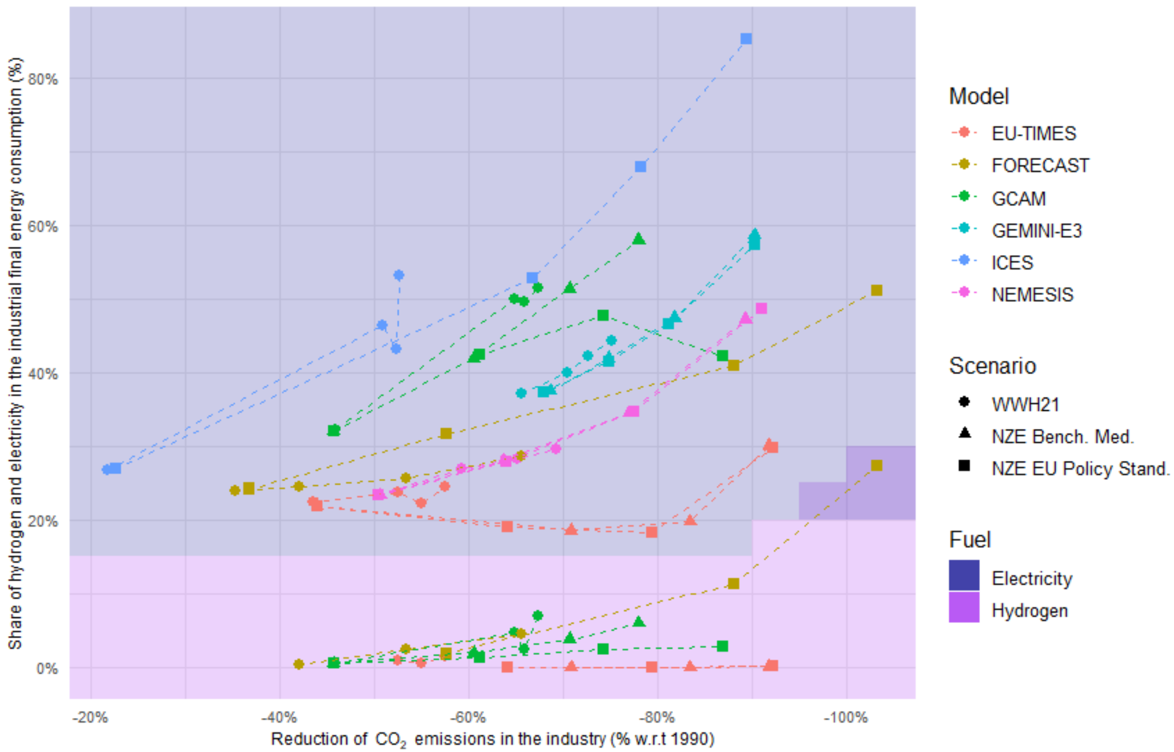
NZE in EU: Electricity and H_2 in industry

- Electricity and H_2 penetration in the EU industry
  - ✓ Electricity and H_2 shares grow with the decarbonisation of the industry sector
  - ✓ Electricity share reaches between 30%-89% in 2050 (median value around 50%)
  - ✓ H_2 share between 3%-25%



- In UK:
  - ✓ From 25% in 2020, electricity share in industry final energy grows to 33%-60% in NZE scenarios
  - ✓ And hydrogen share is marginal in EU-TIMES (0-4%) and significant in FORECAST with 24% and even 37% in the hydrogen-oriented scenario

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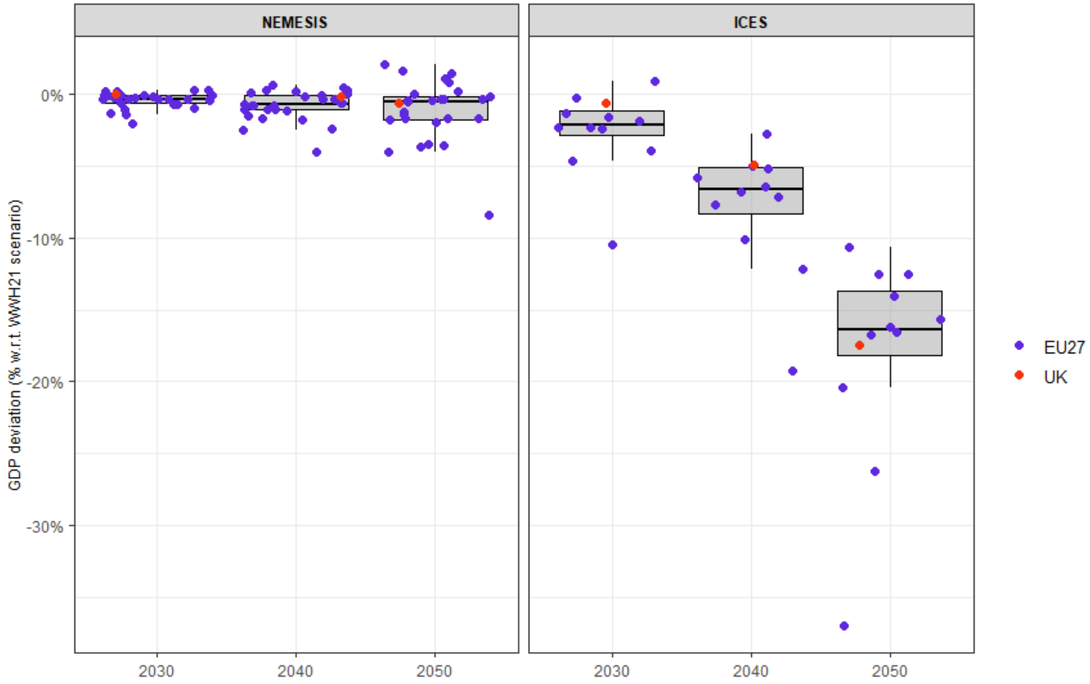
GDP deviation by Member States

- In NEMESIS, the economic burden of GHG emissions mitigation to reach NZE is limited with EU GDP deviation between 2020 and 2050 about 0,5%
- GEMINI-E3 delivers slightly higher GDP loss over the period 2020 to 2050, with up to -1,5% in the worst case
- When mitigation options are limited (no CCS and H_2 and few technological details), reaching NZE can drastically impact GDP, as in ICES, up to -20% in 2050 (with respect to WWH21)



Illustrative figure on GDP deviation in Members States + UK
(w.r.t. the WWH21 scenario – NZE EU Policy Standard scenario)

GDP deviation (% w.r.t. WWH21 scenario)

	2020-2030			2030-2050			2020-2050		
	GEMINI-E3	ICES	NEMESIS	GEMINI-E3	ICES	NEMESIS	GEMINI-E3	ICES	NEMESIS
NZE Bench. Low	-0.24%	--	0.01%	-1.30%	--	-0.75%	-1.02%	--	-0.55%
NZE Bench. Med.	-0.22%	--	0.01%	-1.20%	--	-0.56%	-0.94%	--	-0.41%
NZE Bench. High	-0.20%	-0.30%	0.03%	-1.01%	-7.07%	-0.46%	-0.80%	-5.35%	-0.32%
NZE EU Policy Stand.	-0.24%	-0.84%	-0.08%	-1.97%	-7.83%	-0.58%	-1.53%	-5.97%	-0.44%

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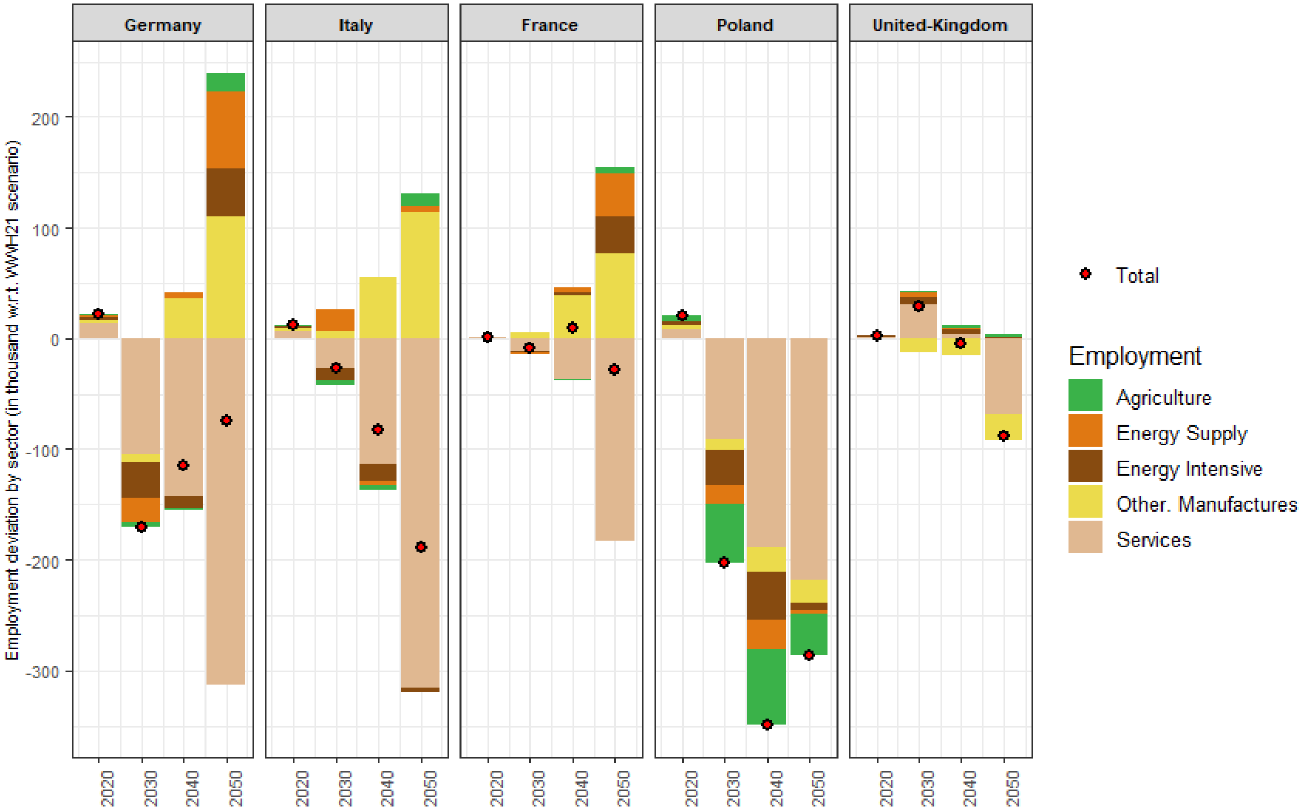

Employment deviation by sector in some MS and UK

(in NZE EU Policy Standard scenario, thousand w.r.t. WWH21 scenario)

(Source: NEMESIS)

- Employment deviation by sector in some MS:
- ✓ Total employment is declining in almost all MS, in 2050:
  - -75,000 in Germany
  - -190,000 in Italy
  - -290,000 in Poland
  - -89,000 in UK
- ✓ Employment in industry (energy supply, energy intensive and other manufacturing sectors) is positively impacted thanks to investments needs for the climate transition
- ✓ Except in countries with higher abatement costs such as Poland that lose in relative competitiveness

Industrial employment deviation by sector in 2030: -115,000 in EU and -23,000 in UK and (in NZE EU Standard Policy scenario, w.r.t WWH21 scenario)

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Thank You

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Focus on Mitigation Pathways for Energy-Intensive Industries and Transition Bottlenecks

Khaled Al-Dabbas, Jakob Wachsmuth, Philine Warnke
(Fraunhofer ISI)

UK workshop, 7th September 2022, London

Climate neutrality in 2050 requires profound change

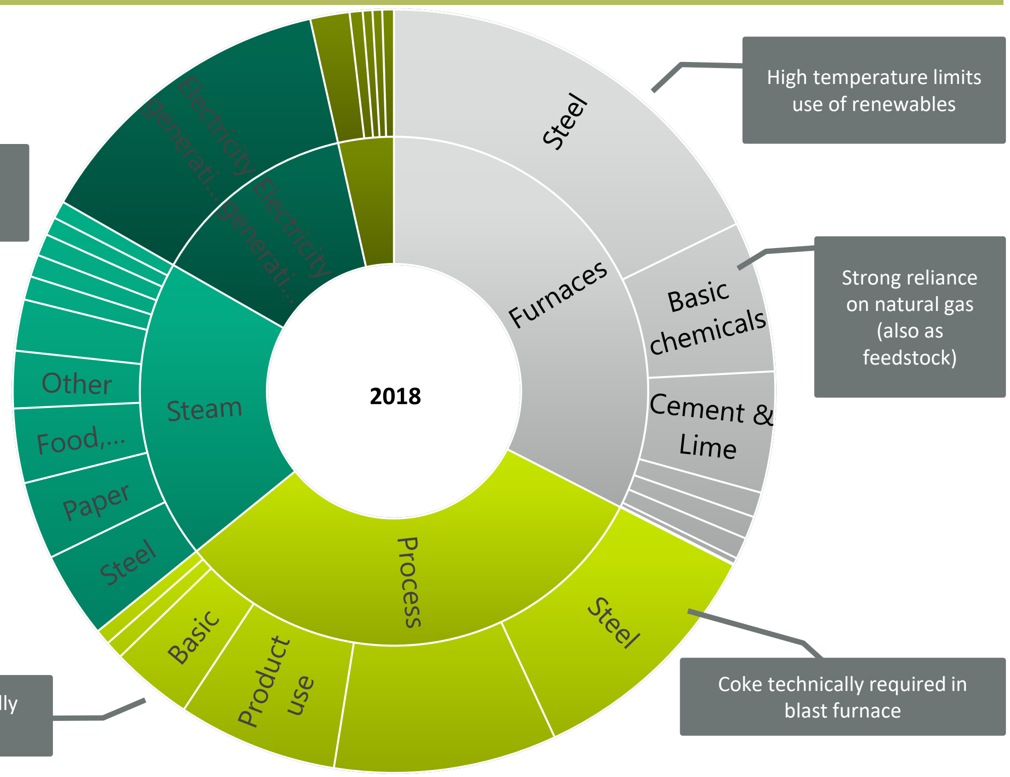
› **Diverse challenges** across all application areas

› **New CO2-neutral production processes** address important sources of emissions

› **In 2018, the Iron and Steel and Chemical industries were responsible for 28% of the UK's industrial emissions**

› But **action is needed in all areas**

Direct industrial emissions by end-use category and sector*



* Excluding refineries; Source: Fraunhofer ISI

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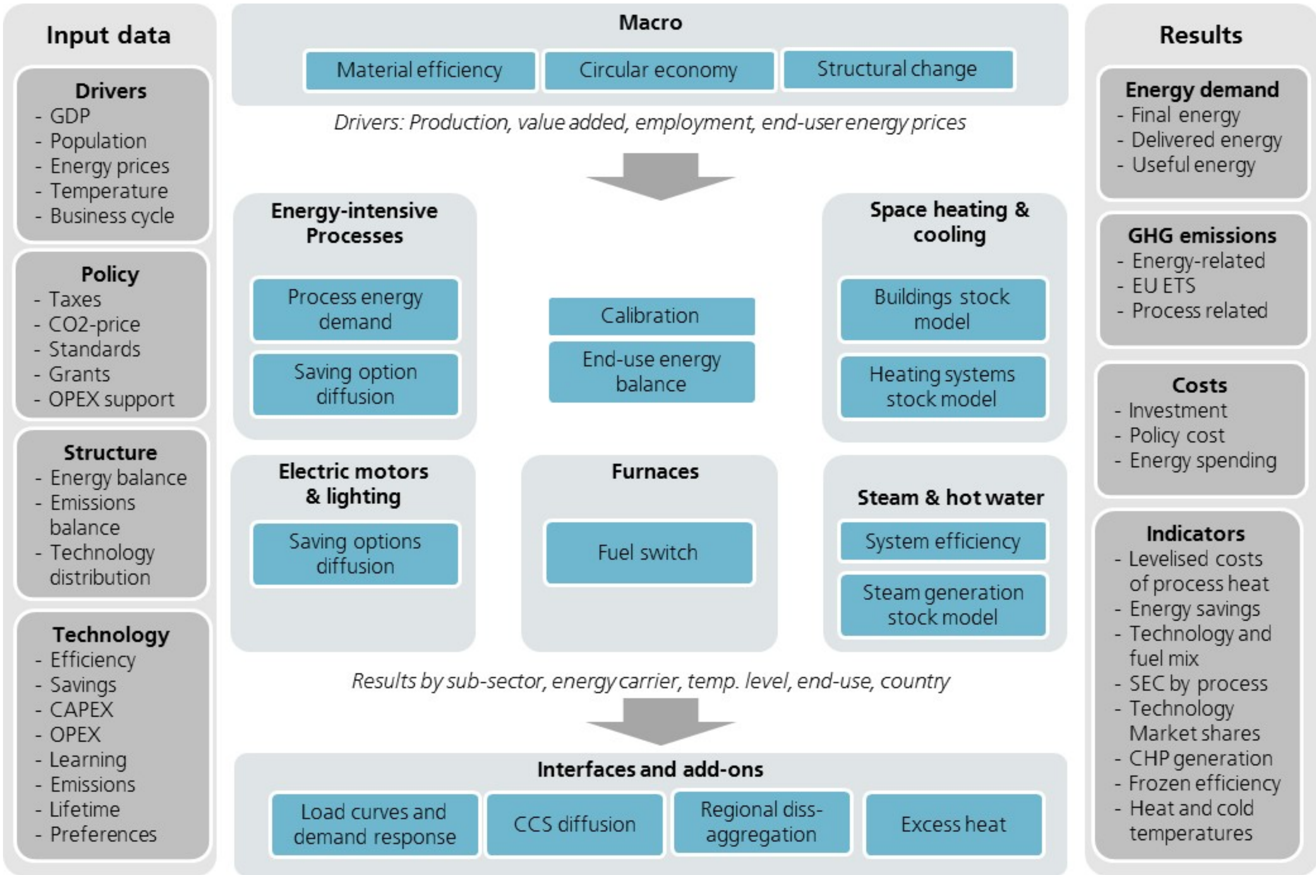
Bottom-up modelling of energy demand & GHG emissions

- **High technology resolution**
- Consideration of all **important abatement options**
- Energy and greenhouse gas balance
- **Annual results** until 2050



FORECAST
FORecasting Energy Consumption Analysis and Simulation Tool
https://www.forecast-model.eu

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Overview of key scenario assumptions for industry

	WWH21 Current Policy	Focus electrification NZE-Mix-Electric	Focus hydrogen NZE-Mix-H2
GHG reduction 2050	80% GHG reduction	At least 95% GHG reduction compared to 1990 for industry (in line with overall GHG neutrality)	
GHG reduction 2030	40% GHG reduction	Reduction in line with FF 55 meeting overall 55% GHG reduction target	
Economic growth	Continued long-term growth of industry GVA ~0.8%, recovery of Covid-crisis with higher growth before 2030		
Process switch	Diffusion of Best Available Technologies (BAT) with (8-9 TRL)	Diffusion of innovative technologies with Technology Readiness Level (TRL) above 4	
Energy and material efficiency and circular economy	Ambitious energy efficiency measure and continuation of current trends in recycling	Ambitious progress	
fuel and feedstock switch	-	Priority electrification	Priority hydrogen
CCS and CCU	-	Included for cement and lime plants only	
CO2 price	Low EU ETS prices in line with Ref2020 50€/tCO2-eq in 2030 200€/tCO2-eq in 2050	Higher CO2 price for the EU ETS 110€/tCO2-eq in 2030 490€/tCO2-eq in 2050	

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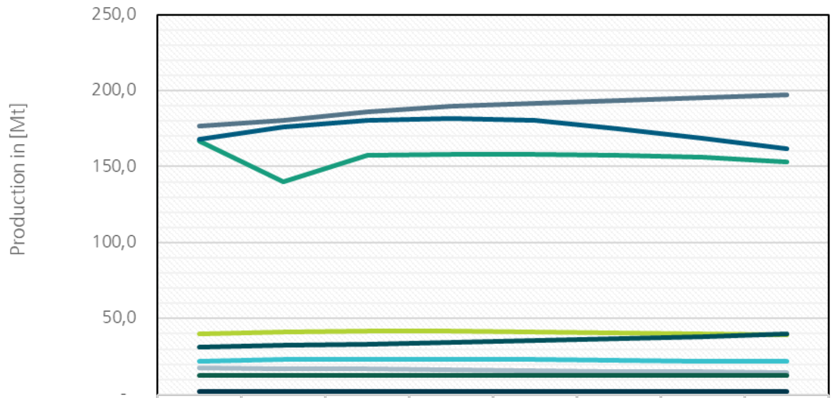
Material efficiency reduces demand for **energy-intensive products in the NZE scenarios but No Carbon Leakage**

Product	Material efficiency assumption
Steel	More efficient steel use and substitution result in decreasing the production by about 9%
Cement and lime	Efficient concrete use and substitution, concrete recycling and re-use result in 7% decrease in production. 20% decrease in the clinker share Reduced demand for lime from blast furnace and power plants
Chemicals	Plastics substitution, reduced fertilizer demand and more efficient material use.
Glass	13% decrease in container glass as result to more efficient use
Paper	Structural change: Reductions in graphic paper are overcompensated by packaging demands

Assumptions on production outputs of selected basic materials



	2015	2020	2025	2030	2035	2040	2045	2050
Crude steel	166,8	139,8	157,5	158,3	158,2	157,5	155,9	153,3
Cement	167,8	176,0	180,5	181,6	180,6	174,7	168,5	162,1
Ammonia	17,7	17,2	16,8	16,3	15,8	15,4	14,9	14,4
Ethylene	21,7	23,2	23,1	23,0	22,9	22,5	22,2	21,8
Glass	40,2	41,0	41,8	42,0	41,2	40,6	40,0	39,4
Aluminum	12,5	12,5	12,6	12,6	12,6	12,6	12,7	12,7
Zinc	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3
Paper products	176,6	180,6	185,7	189,8	191,8	193,7	195,4	197,0
Plastics	31,1	32,2	33,4	34,6	35,8	37,1	38,4	39,7

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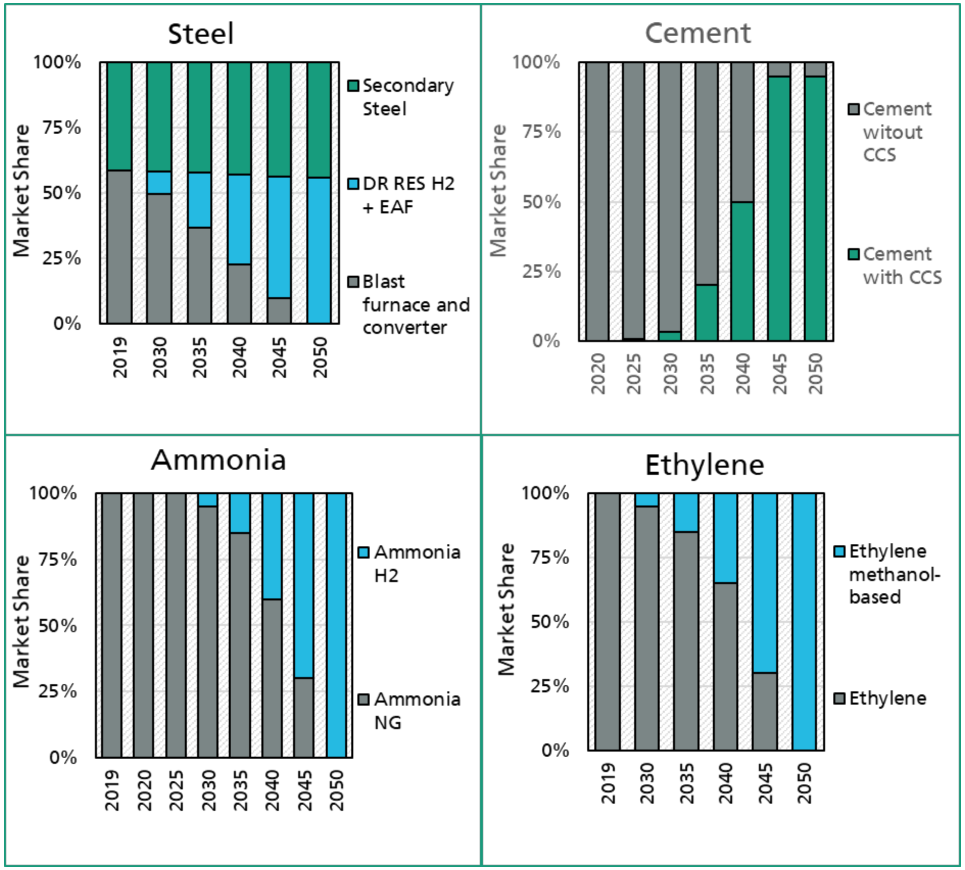
Diffusion of new low-CO2 production Routes

Product	Focus-EL	Focus H2
Steel	100% H-DR share by 2050	
Cement and lime	Strong diffusion of CCS reaching ~80% of production capacity by 2050 Slow increase in low-carbon cements to ~15% market share by 2050 (new binders)	
Chemical feedstocks	100% Feedstock H2 for Methanol, ethylene, ammonia and other feedstocks	
Glass	70% Electric furnaces by 2050	Higher share of hybrid furnaces
Steam generation	Electric boilers and heat pumps, limited biomass	H2 boilers, hybrid boilers, electric heat pumps, limited biomass



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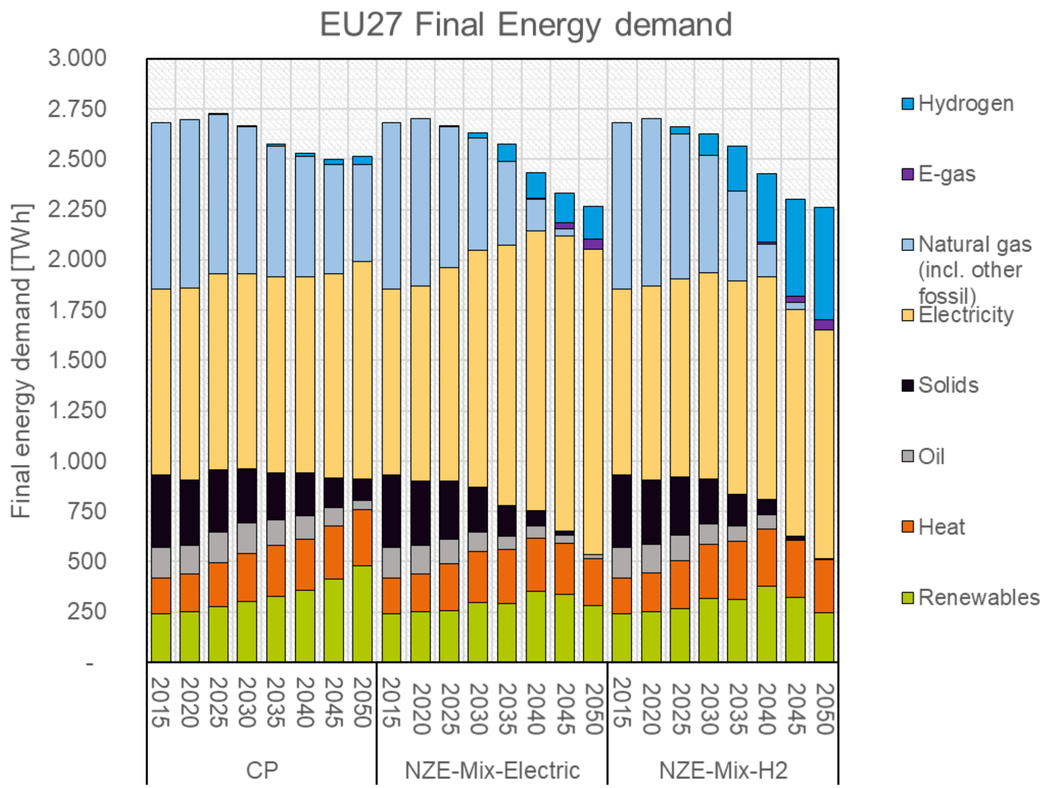
Industrial transformation requires high quantities of CO2-neutral energy carriers

- Reduction in FED compared to 2015 (14% in CP and 24% in NZE scenarios)
- The direct and indirect electrification of FED is a persisting trend in both scenarios:
  - 1519 TWh electricity demand in the NZE-Mix-Electric (UK: 144 TWh)
- 559 TWh Hydrogen demand in the NZE-Mix-H2 (UK: 41 TWh)
- In the WWH21 scenario (CP), the demand for natural gas decreases significantly, however, it remains an important energy carrier.



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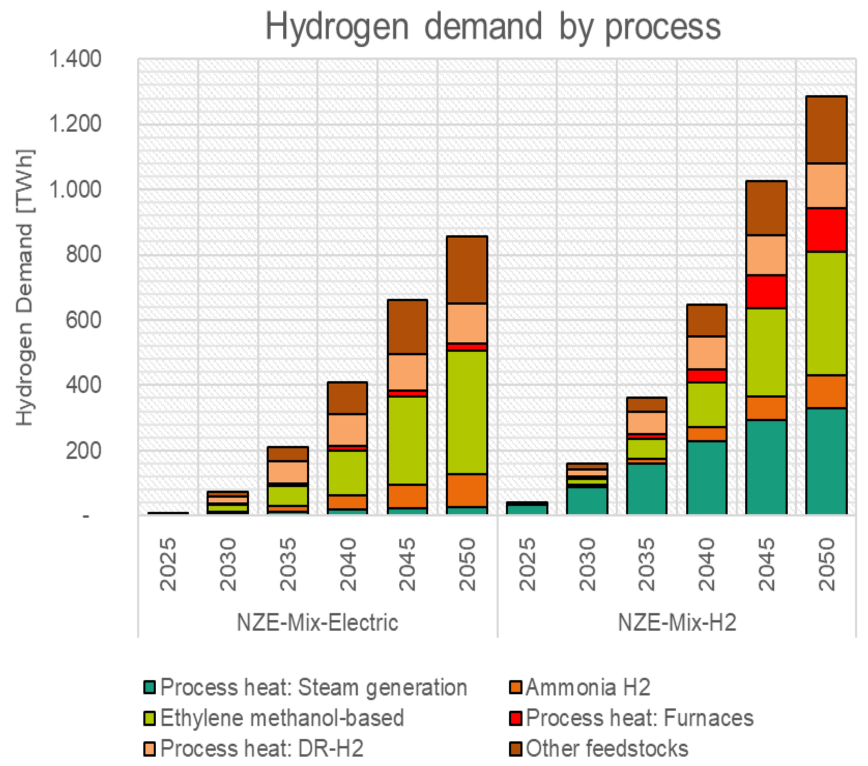
Feedstock demand is strong driver for hydrogen

- Demand for CO2-neutral hydrogen increases substantially
  - 2030: 68-144 TWh
  - 2050: 825 – 1289 TWh
- The primary sources of H2 demand in NZE-Mix-Electric are feedstock use and steel manufacturing.
- NZE-Mix-H2 extends H2-demands in furnaces and steam generation



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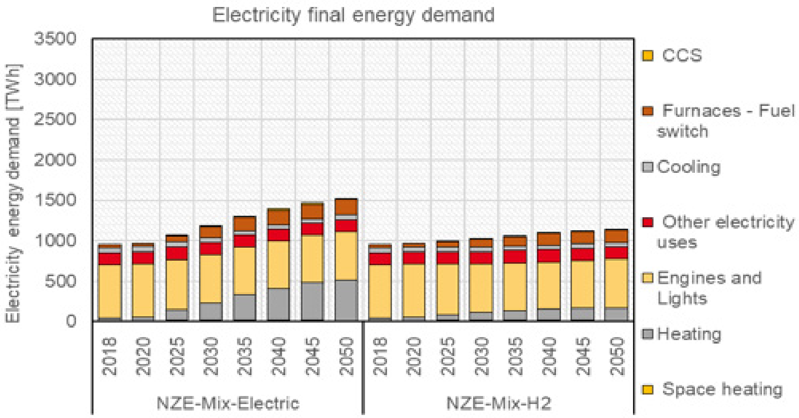
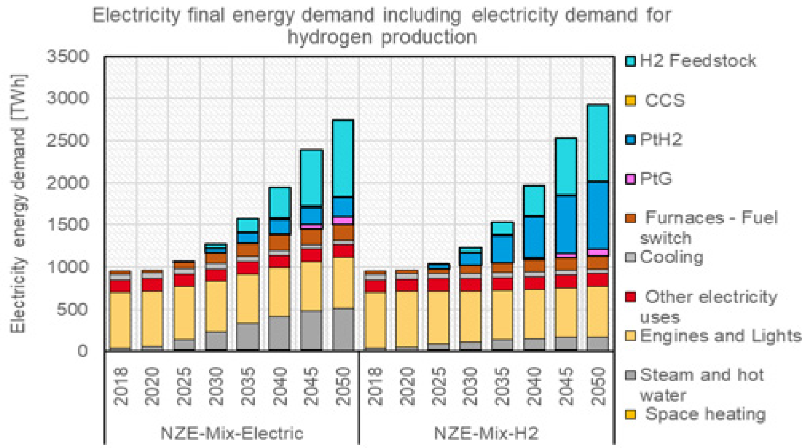
Electricity demand for H2 generation needs to be considered

In NZE-MIX-Electric process heating via steam generation and industrial furnaces increase electricity demand by 614 TWh -> + 50%

Considering the Electricity equivalents needed for Hydrogen production increases the electricity demand in NZE-MIX-H2 by 1700 TWh, i.e. + 200% (UK: 93 TWh (39% of the electricity demand by 2050))





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Only process related emissions at point sources remain in 2050

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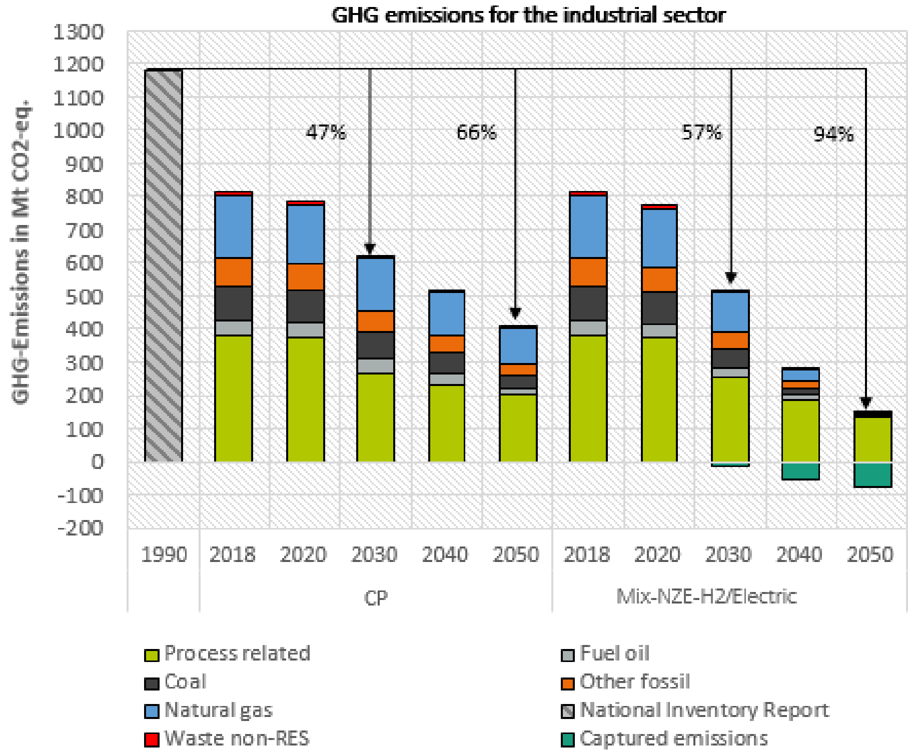
In the CP scenario the industry fails to achieve the GHG emissions target announced in the EU Green Deal.

In the NZE scenarios, the industrial GHG emissions decrease by 57% and 94% by 2030 and 2050 compared to 1990.

With regard to process-related emissions, the use of carbon capture and storage (CCS) in the NZE scenarios is a significant deviation from the CP scenario (75 Mt CO_2-eq. are captured by 2050).



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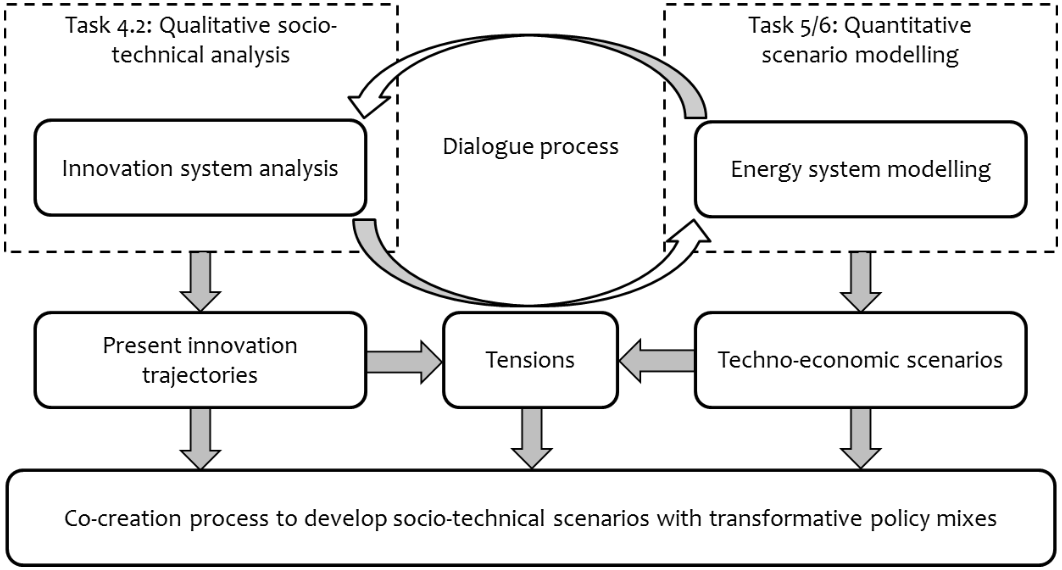
Our objective within PARIS REINFORCE:

To extend quantitative techno-economic scenarios in line with the Paris targets to socio-technical narratives by describing a transformative policy mix based on innovation system analyses



Sources: own representation

Approach: Identify transition bottlenecks and co-create transformative policy mixes

- Bottlenecks are derived from tensions between modeled scenarios and present innovation trajectories.
- Scientists and stakeholders co-create socio-technical narratives exploring how to overcome these.
- A *transformative policy mix* is obtained by describing policy mix guidelines over time

5 case studies

- Energy sector transformation in Greece
- Energy-intensive industries (steel, cement, chemicals) in Germany + the UK
- Transport sector in Brazil and Canada

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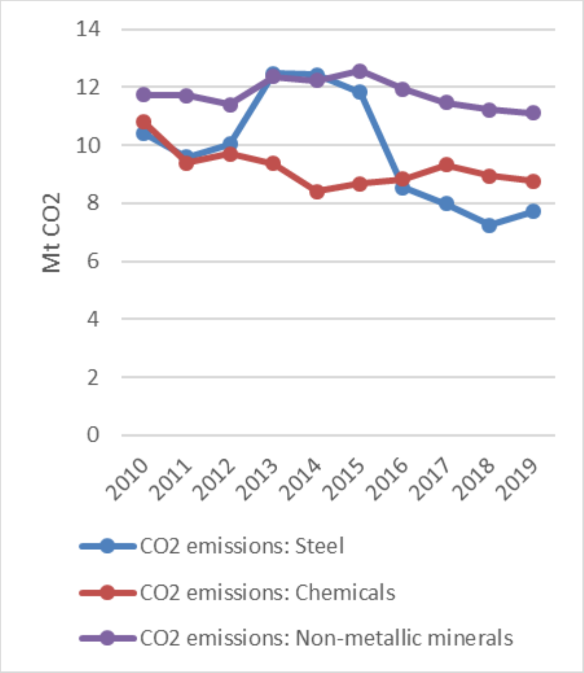
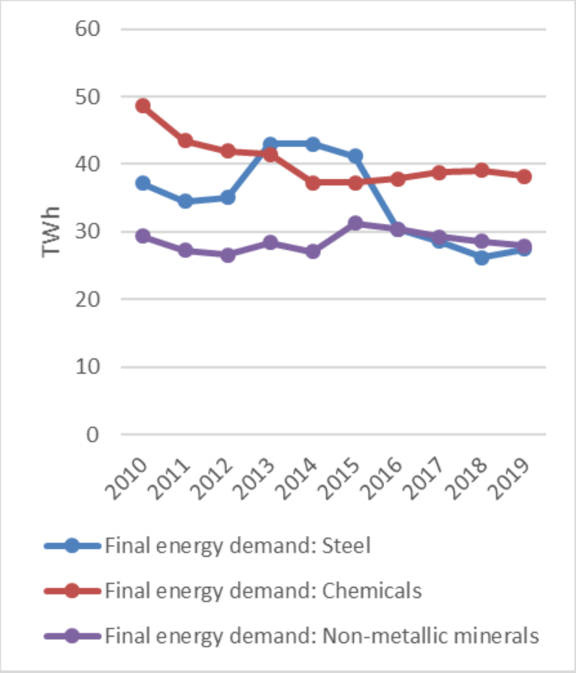
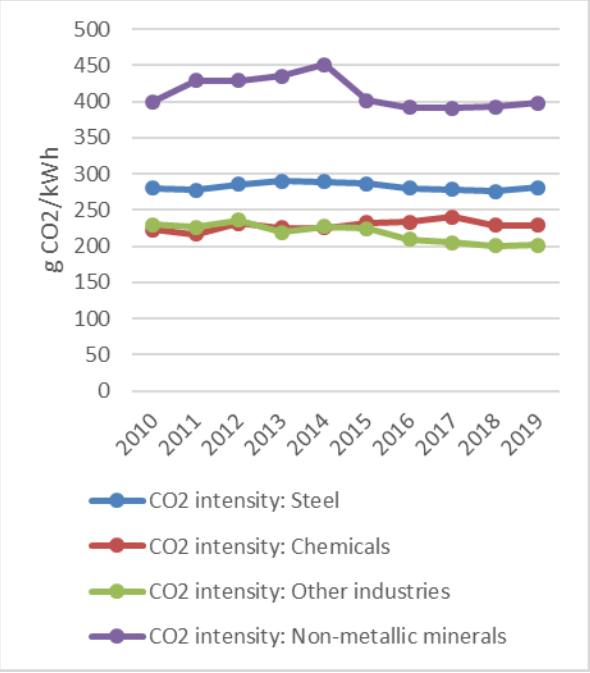
- The CO2 emission intensity of energy-intensive industries has been almost constant since 2010.
- Reductions of absolute CO2 emissions have been driven mainly by reductions in economic output.







Source: ENERDATA based on IEA statistics

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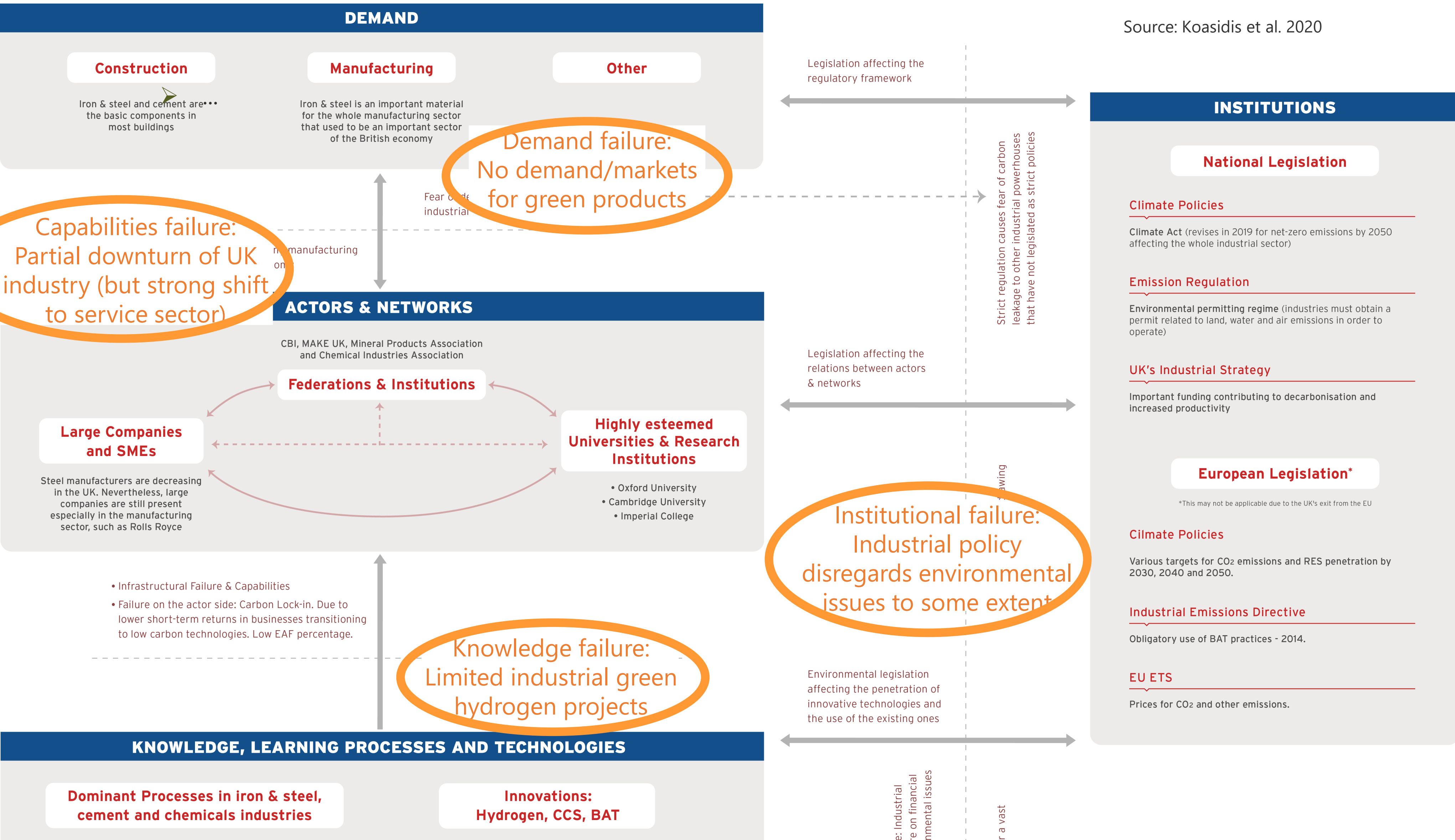
The UK Low-Carbon Industry Transition from a Sectoral Innovation and System Failures Perspective



Steel: Technology routes for decarbonisation

Recycling

- High-quality steel with increased scrap usage (TRL 4-9)

Hydrogen

- H2-based direct reduction (TRL 6-8)
- H2 plasma smelting reduction (TRL 5)

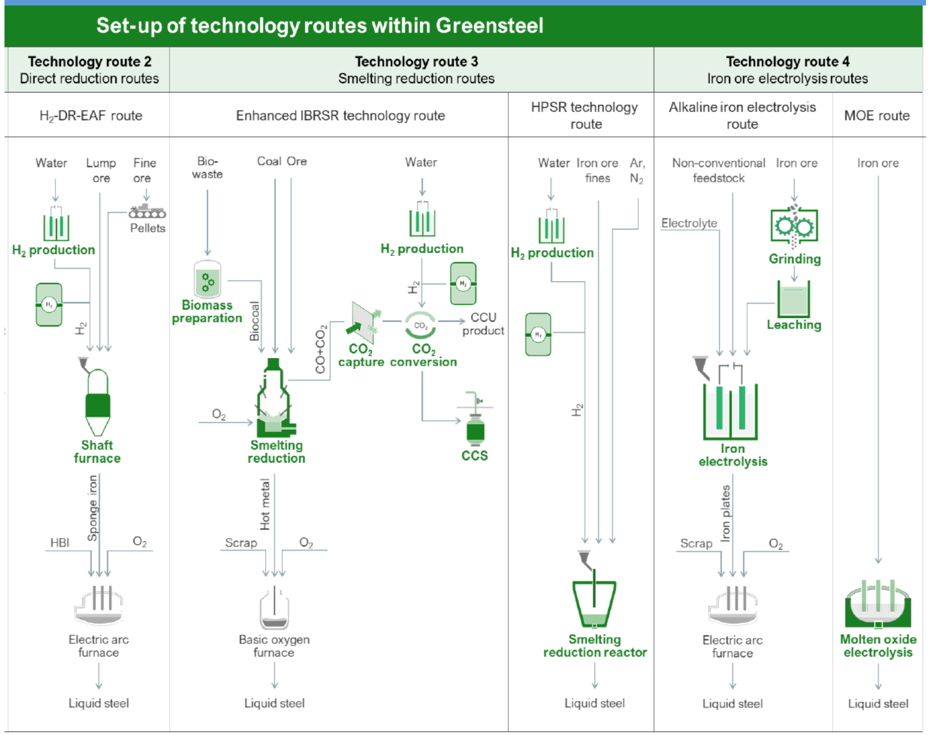
Electricity

- alkaline iron electrolysis (TRL 5-6)
- molten oxide electrolysis (TRL 2)

Carbon based

- Iron based smelting reduction (TRL 6) using „Substitution of fossil energy by biomass (TRL 2-7), carriers by Carbon oxide conversion (TRL 8)
- Optimised BF using „Substitution of fossil energy by biomass (TRL 2-7), carriers by Carbon oxide conversion (TRL 8), Gas injection into the blast furnace (TRL 8)

Further Information https://www.estep.eu/green-steel-for-europe/publications/



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List of bottlenecks to be elaborated in the workshop

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Bottlenecks	Overarching (literature-based, ELABORATED DURING THE WORKSHOP)	Energy-intensive industries (literature-based, ELABORATED DURING THE WORKSHOP)
Social feasibility	• Lower weight of industry sector due to strong shift to services sector • Lack of public engagement strategy • …	• Opposition to CCUS by NGOs due to continued use of fossiles • …
Political feasibility	• International trade regulations limit subsidies • Uncertainty about continued support by new government • …	• Uncertainty about legal framework after Brexit • …
Technological feasibility	• Upscaling of technologies in an unprecedented way • Limited demonstration projects using hydrogen in UK • …	• Hydrogen technologies not fully mature yet • CCUS technologies not fully mature yet • Potential lack of high-quality iron ore • Lack of access to scrap • …

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Source: own representation of Koasidis, K. et al. (2020b), Wachsmuth, J. et al. (2021), CCC progress report 2020

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Technological feasibility	• Upscaling of technologies in an unprecedented way • Limited demonstration projects using hydrogen in UK • ...	• Hydrogen technologies not fully mature yet • CCUS technologies not fully mature yet • Potential lack of high-quality iron ore • Lack of access to scrap • ...
Economic feasibility	• Value chain disruptions due to pandemics • Strong increase of gas and electricity prices due to Russia-related sanctions • Limited availability of financing (due to partial downturn of industry and high inflation) • ...	• Investment cycles may require investments in processes not yet competitive • Uncertainty about hydrogen supply • Hydrogen infrastructure expansion • CO2 infrastructure expansion • Electricity infrastructure expansion • No established business models for CCU yet • ...
Socio-economic impacts	• Risk of carbon leakage and resulting job losses • Risk of lock-in into fossil technologies due to CCUS • ...	• Price impacts for downstream industries • No existing markets for green products • ...
Socio-ecological impacts	• Potential impact of large-scale offshore CCS and RES expansion on marine ecosystems • ...	• ...

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Source: own representation of Koasidis, K. et al. (2020b), Wachsmuth, J. et al. (2021), CCC progress report 2020

Thank you for listening!

PARIS REINFORCE

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Koasidis, K.; Nikas, A.; Neofytou, H., ..., Wachsmuth, J., Doukas, H. (2020b): The UK and German low-carbon industry transitions from a sectoral innovation and system failures perspective. Energies 13 (19).

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Wachsmuth, J.; Jackwerth-Rice, T.; Seus, S.; Warnke, P. (2021): A Methodology for Co-Creating Transformative Policy Mixes as an Approach to Generalise Diffusion-Based Transition Pathways. Submitted to TFSC (based on full paper at the IST 2021 conference)

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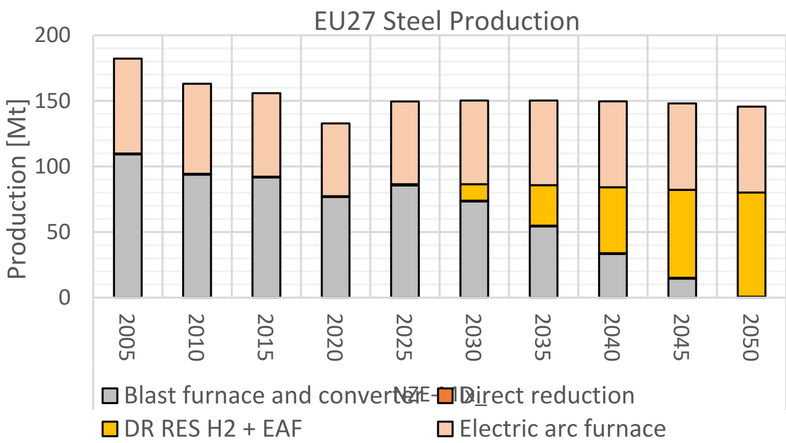
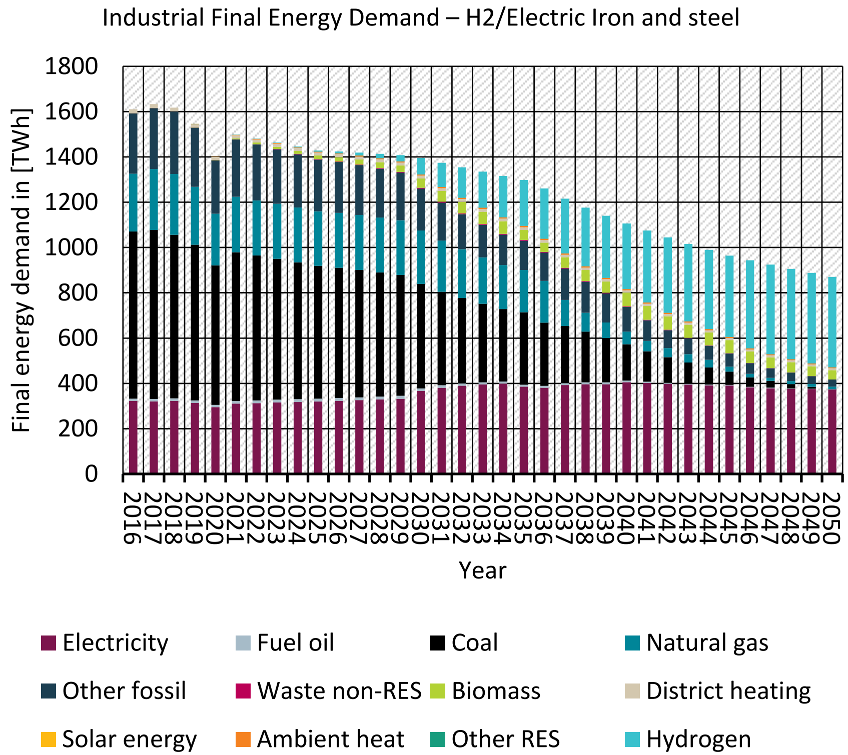
- Final energy decreases by ~45% due to process switch to H2-DRI, material efficiency and more secondary steel
- Main driver: Increase in the DR RES H2 starting before 2030 reaching 100% by 2050





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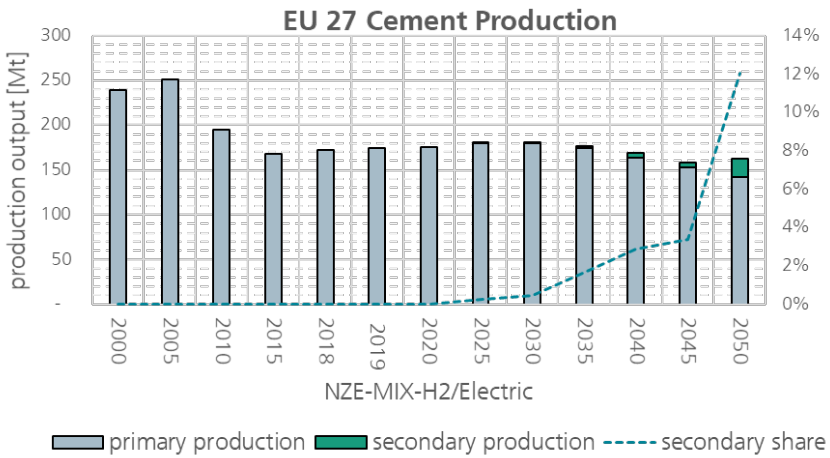
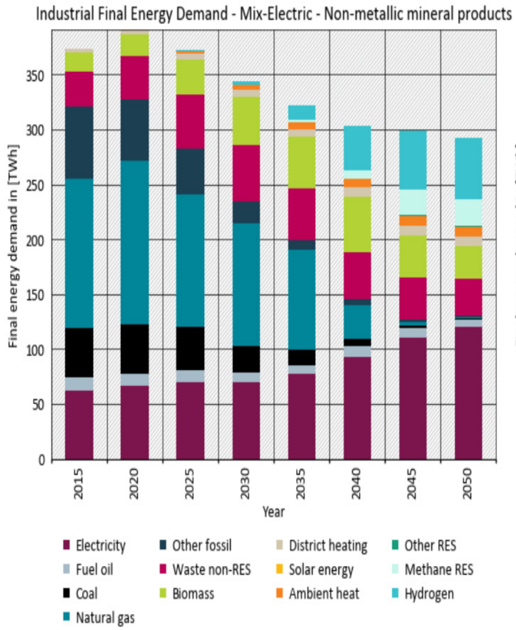
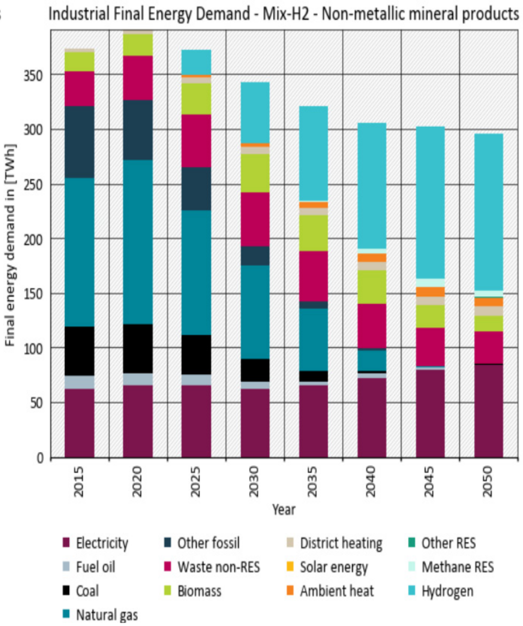
Future energy carrier for the cement production?

- Fuel switch potential in the cement industry is limited as it address only the **energy related emission** ~1/3
- Diffusion of CCS reaching ~80% of production capacity by 2050







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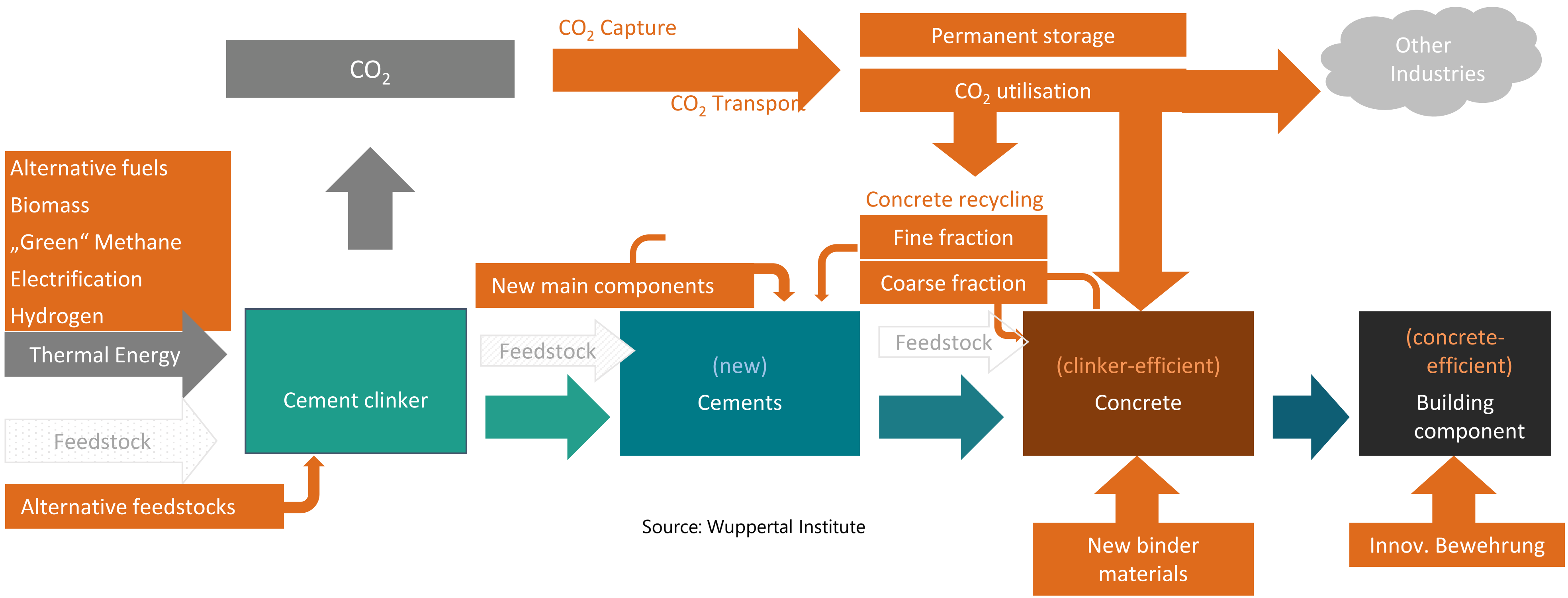
Cement sector:
CO_2 mitigation options along the value chain



Source: Wuppertal Institute

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- CO2-neutral processes must be marketable and economical as early as 2025/2030
  - The higher **operating costs of CO2-neutral** technologies are a major challenge for the rollout of CO2-neutral processes
- **CO2-neutral energy sources must be available**
- CCS is needed to store remaining CO2 emissions from processes in the cement and lime industries
- **Circularity and material efficiency** require effective policy instruments to enable large-scale emission savings. In particular, the switch to secondary steel, and cement have large potential.
- **Expansion of the regulatory framework**

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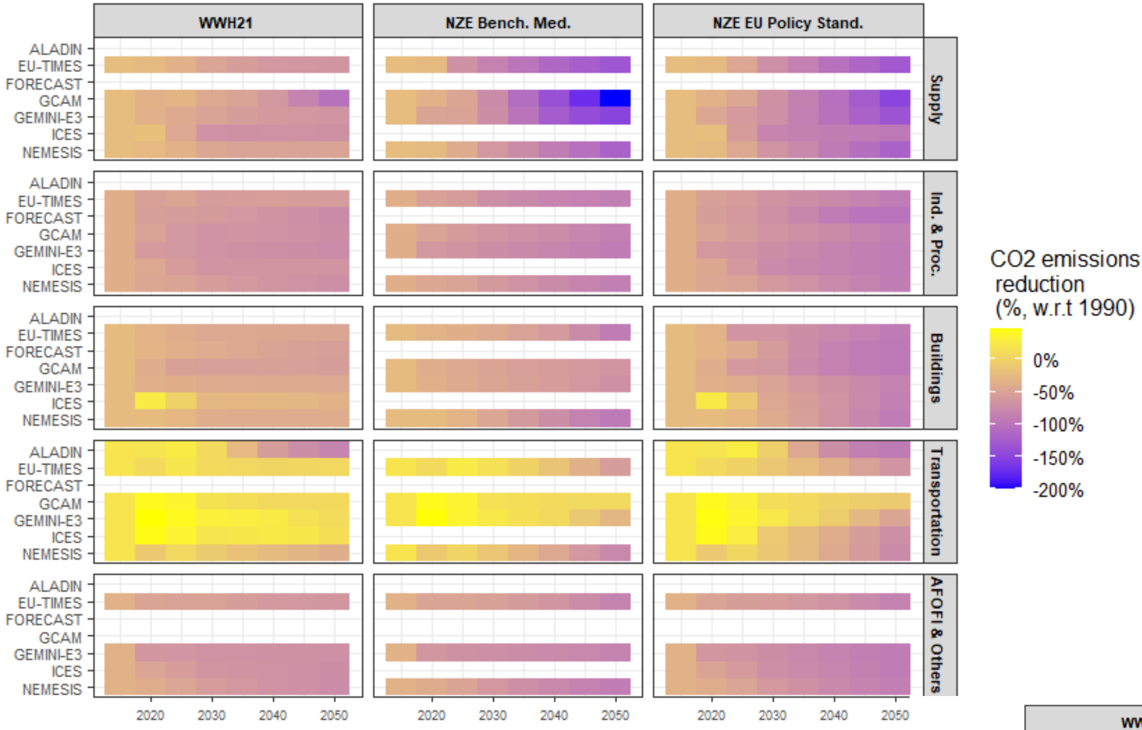
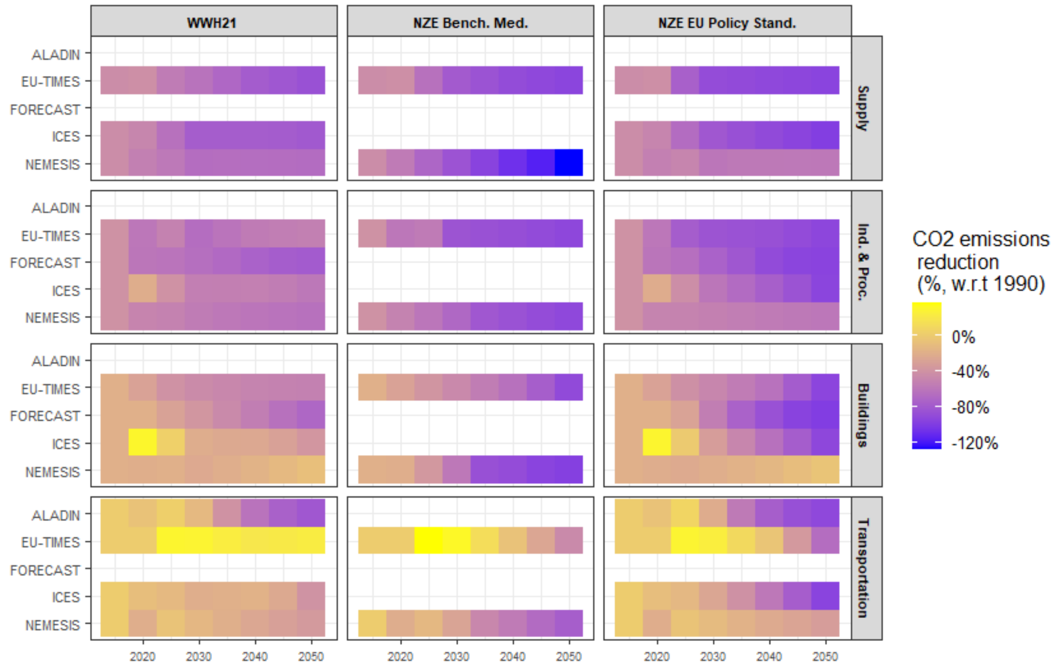
CO_2 emissions reduction by sector in EU

(w.r.t 1990 emissions level)

EU



UK



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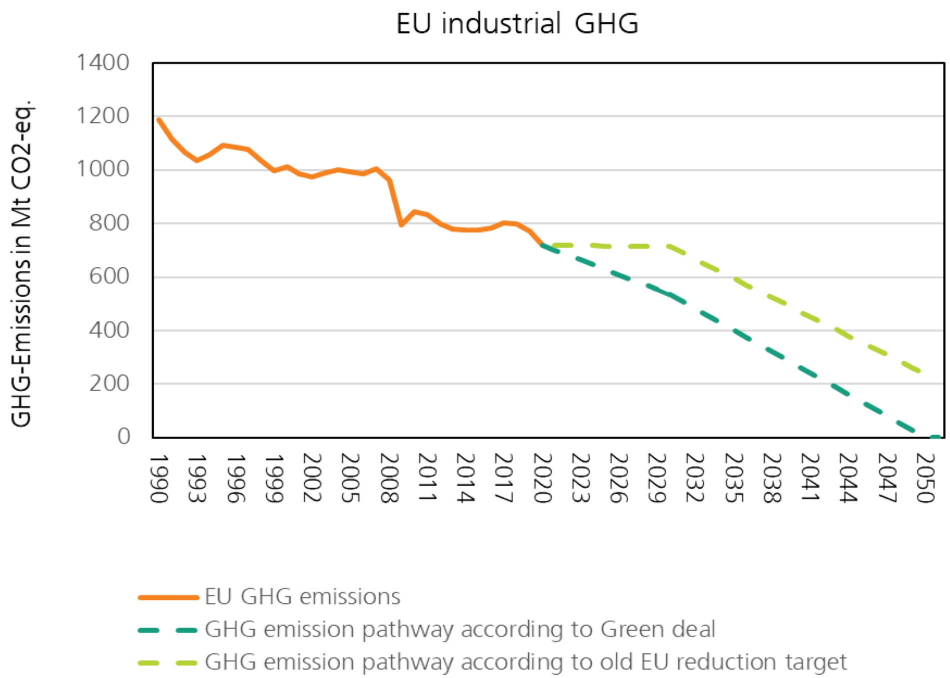
ISI

Industry is responsible for about 21% of the European GHG emissions

- In 2019 the GHG emission **decreased by 35%** compared to 1990
- **Fit for 55:**
  - Reduction of ~55% compared to 1990
  - **535 Mt-CO_2eq.** in **2030 (18- 22 Mt-CO_2eq/year)**
  - **Technology paths** and **political framework** under discussion



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