
PARIS REINFORCE

Delivering on the Paris Agreement in a fragmenting world

PARIS REINFORCE final event, Sorbonne, Paris, November 15, 2022

# Bottlenecks to sectoral decarbonisation in Europe: national insights

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www.paris-reinforce.eu

# Motivation: Limits of Techno-Economic Models

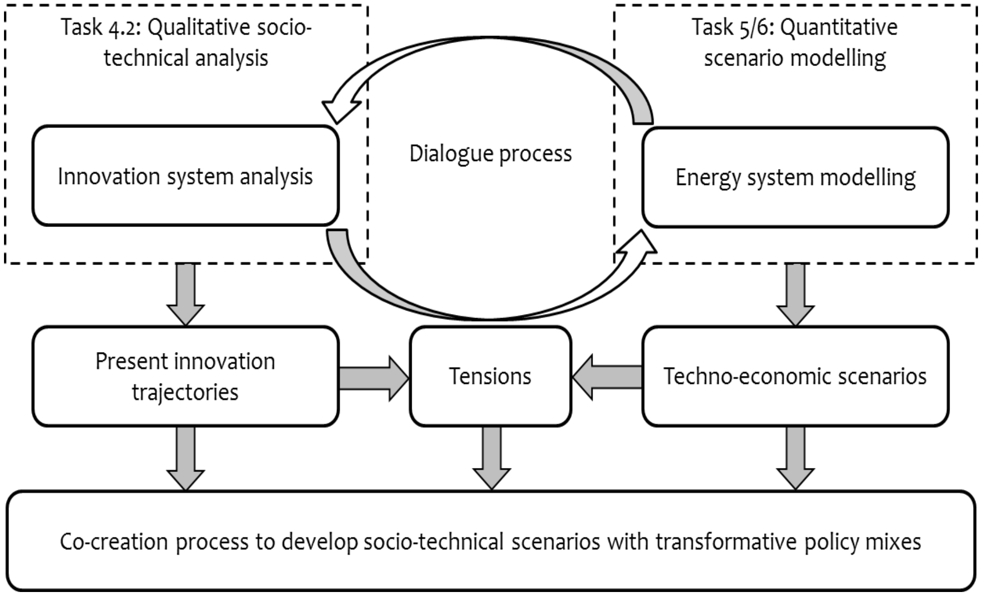
- **Techno-economic models** commonly used to inform climate policy
- **High relevance** of model-based techno-economic scenarios is uncontested

- Limited coverage of **transitions beyond diffusion** of innovations
- **Depicting only parts** of the complex empirical reality **of the manifestation of innovations**
- Ineffective **inclusion of policymakers** in the heart of modelling activities

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

**One objective within PARIS REINFORCE:**

**Extend quantitative techno-economic scenarios** in line with the Paris targets to socio-technical narratives **based on innovation system analyses.**




*Source: own representation of Fraunhofer ISI*

**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 narratives by describing transformative policy mix to overcome these over time

**5 case studies**

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

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# Net-zero emissions in the industry sector requires profound change

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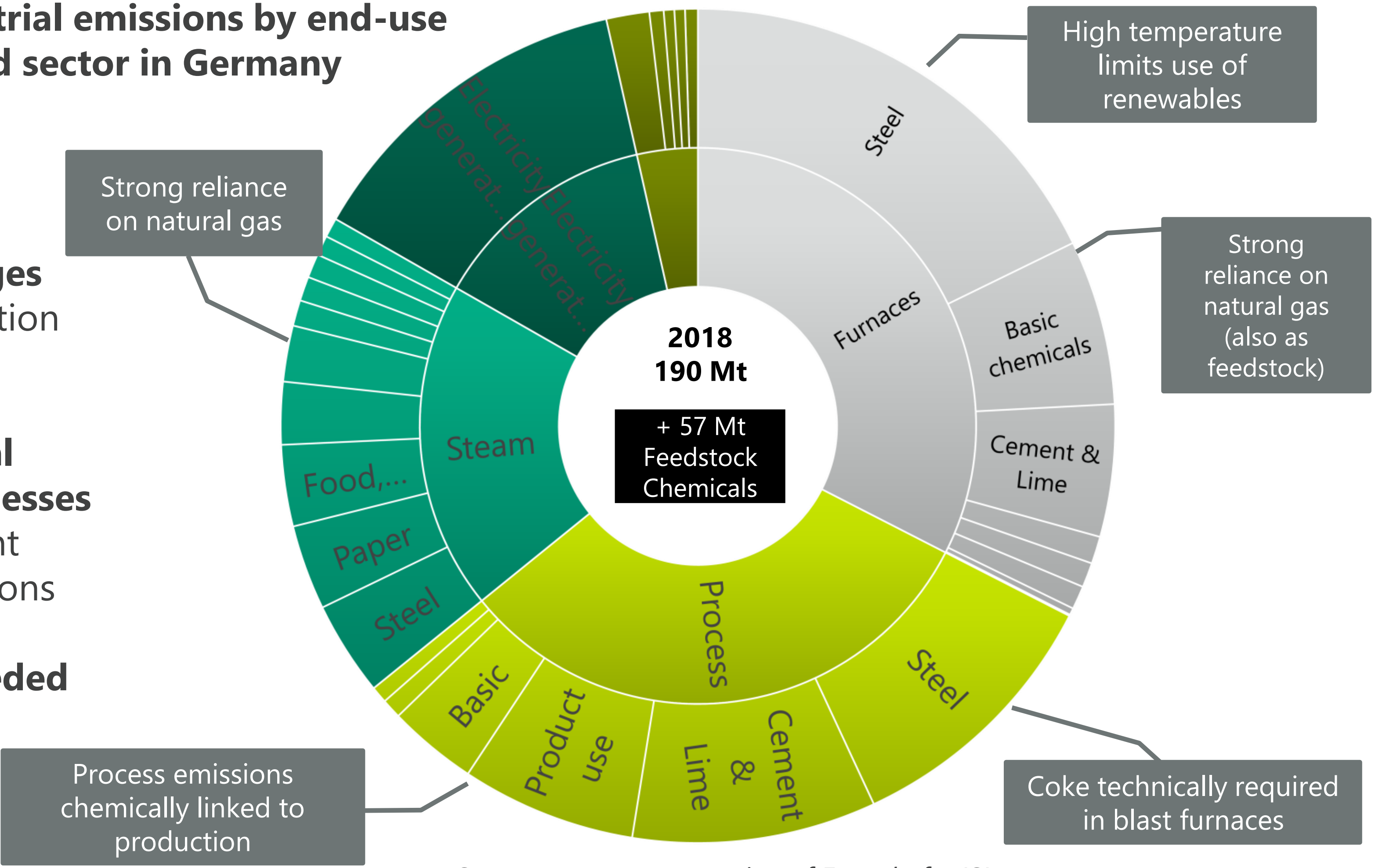
## Direct industrial emissions by end-use category and sector in Germany

- **Diverse challenges** across all application areas
- **New $CO_2$-neutral production processes** address important sources of emissions
- But **action is needed in all areas**

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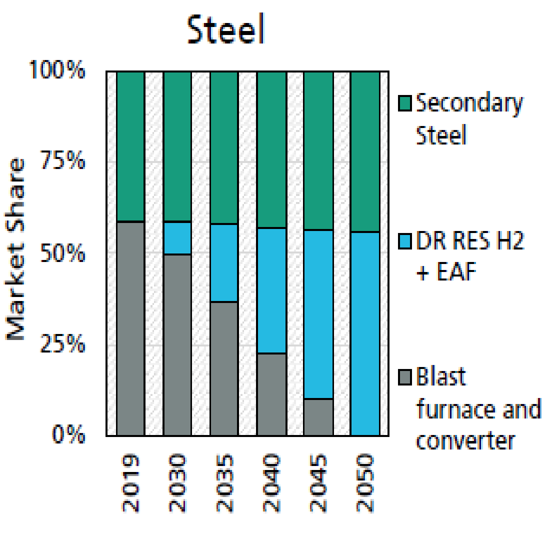
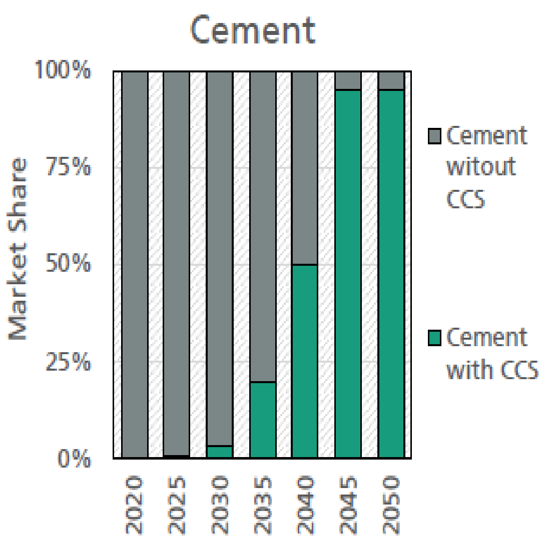
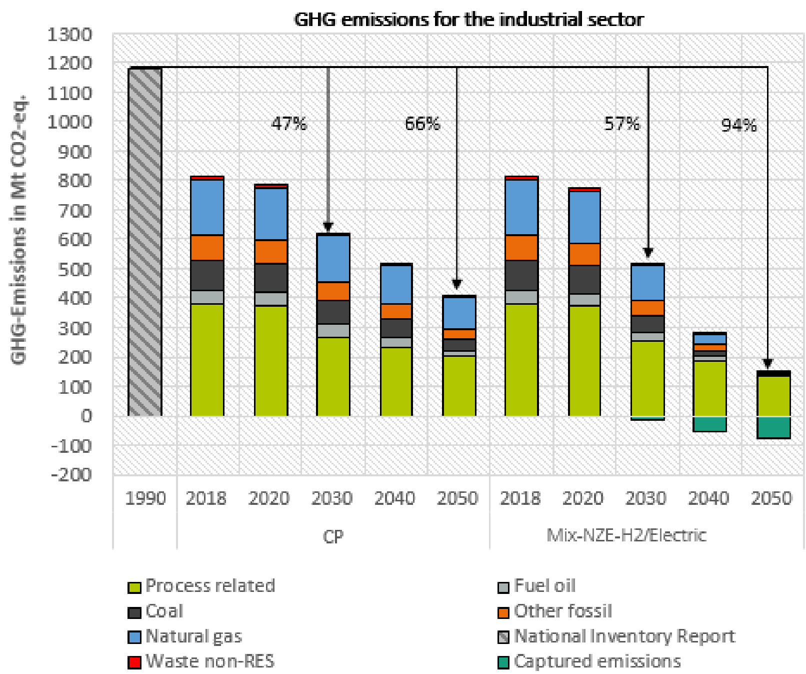
# Characteristics of net-zero pathways for energy-intensive industries in Germany and the EU

| | Reference pathways for energy-intensive industries in the EU | Net-zero pathways for energy-intensive industries in the EU |
|---|---|---|
| **Key characteristics** | • Ambitious energy efficiency measures<br>• Electricity for low-temperature heat<br>• Fuel switch to biomass to a certain extent | • **Ambitious material efficiency + circular economy measures**<br>• Electricity for low- and mid-temperature heat<br>• **Hydrogen + renewable gases as energy carriers** and feedstocks<br>• **Carbon capture + storage (CCS)** for unavoidable process emissions |




*Source: : Al-Dabbas et al. (2022)*

FORECAST
FORecasting Energy Consumption Analysis and Simulation Tool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# Recent emission reductions in German industry very limited

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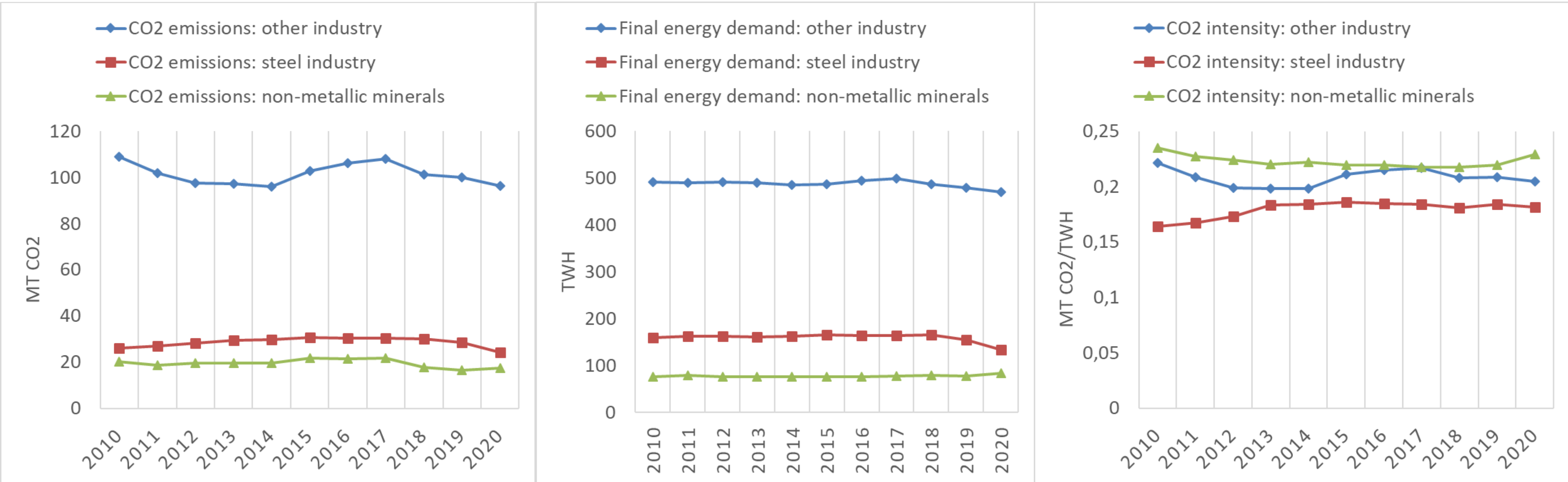
- The $CO_2$ emission intensity of energy-intensive industries has been almost constant since 2010.
- Reduction of absolute $CO_2$ emissions have been driven mainly by reductions in economic output.




*Source: ENERDATA based on official public statistics*

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# Steel: Technology routes for decarbonisation

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## Recycling

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

## Hydrogen

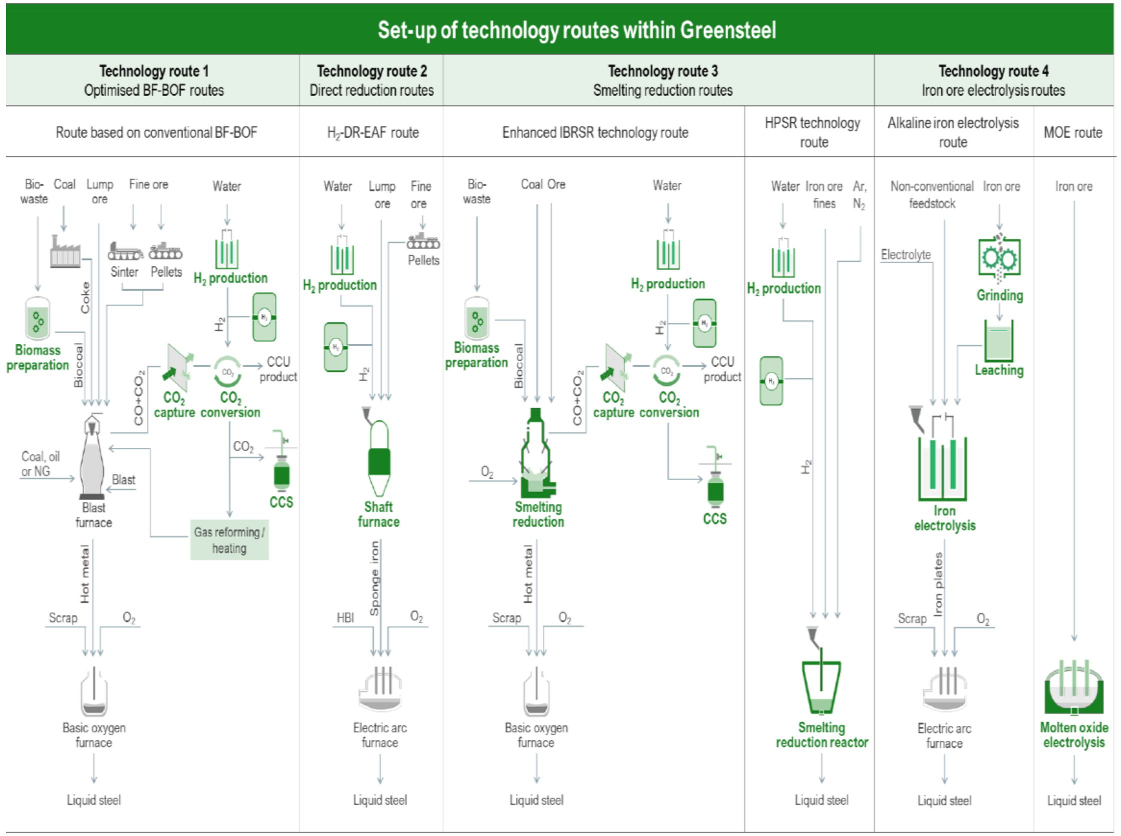
- $H_2$-based direct reduction (TRL 6-8)
- $H_2$ plasma smelting reduction (TRL 5)

## 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)




*Source: https://www.estep.eu/green-steel-for-europe/publications/*

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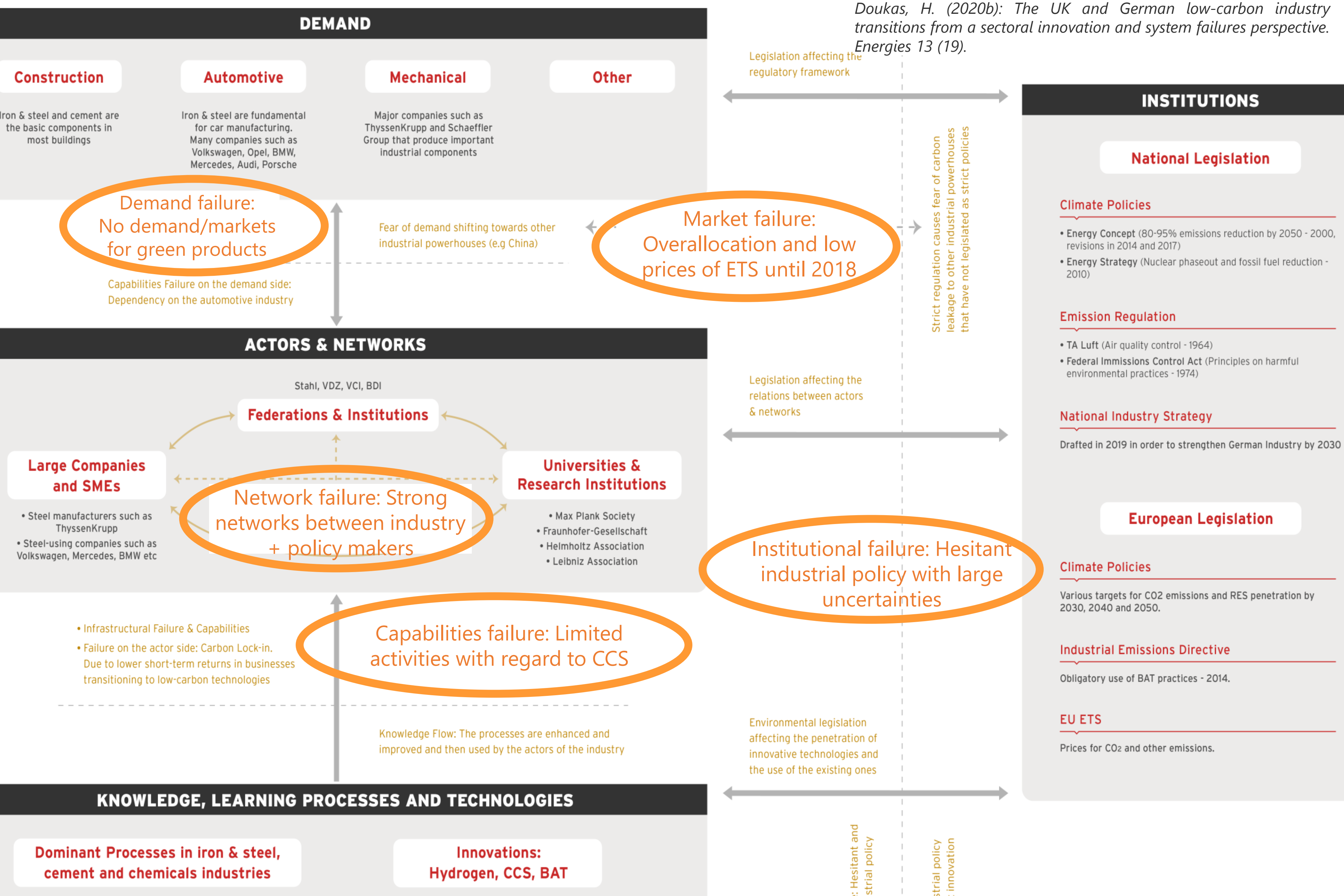
# The German Low-Carbon Industry Transition from a Sectoral Innovation and System Failures Perspective

*Source: 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).*



# Conceptual approach to co-creating transformative policy mixes

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## Pre-workshop processes

### Model-based transformation pathways

- Where we are heading
- Paris-compatible pathways (optional: several variants)

### Innovation system analysis and policy mix delineation

- Stage of transformation
- Actor constellations and power structures
- Infrastructures: physical, knowledge, financial
- Role of regulation and socio-cultural factors

## Workshop preparation

### Workshop inputs

- Geographically and sectorally focused overview of modelled pathways
- Input on innovation system, including an indicative list of potential bottlenecks
- Input on present policy mix and its delineation

### Stakeholder involvement

- Stakeholder mapping
- Stakeholder selection for workshop

## Workshop implementation

### 1st block: bottlenecks

Tensions between model-based pathways & current trajectories:

- social + political feasibility
- techno-economic feasibility
- socio-ecological and socio-economic impacts

### 2nd block: transformative policy mix elements

1. Agree on a policy strategy
2. Combine policy instruments
3. Reflect on actor & governance structure

**Wrap up:** policy mix signposts

## Workshop evaluation

### Result: STEEP narrative

- Comparison of **current and desired transformation** pathway
- Social, technical, economic, ecological, political **bottlenecks** along the way
- **Signposts for a transformative policy mix:** how to
  - … overcome bottlenecks
  - … destabilize non-sustainable practices
  - … foster the realization of sustainable pathways
- **Implications for implementation** of policy mix

*Source:* *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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# Transition bottlenecks for the German industry sector

| Bottlenecks energy-intensive industries in Germany | |
|---|---|
| **Social feasibility** | • Fossil industry seen as guarantor for economic growth + labor<br>• Low acceptance of CCUS and no established framework yet |
| **Political feasibility** | • International and EU state aid regulations limit subsidies<br>• Strong networks btw. industry and policy makers<br>• Uncertainty political framework conditions<br>• Certification green steel/cement |
| **Technological feasibility** | • CCS + hydrogen technologies are not fully mature yet<br>• upscaling of technologies in an unprecedented way<br>• Potential lack of high-quality resources |
| **Economic feasibility** | • Price impacts and value chain disruptions due to Covid and Russia-related sanctions<br>• Investment cycle requiring invest in process not yet competitive<br>• No infrastructures for transport of hydrogen ($H_2$) + $CO_2$<br>• No established markets for green $H_2$ + cement yet |
| **Socio-economic impacts** | • Uncertainty about CBAM impacts<br>• Price impacts for downstream industries<br>• Risk of carbon leakage and associated job losses |
| **Socio-ecolo-gical impacts** | • Land use conflicts related to infrastructure + RES expansion |


*Source: own representation based on Koasidis, K. et al. (2020b) and Wachsmuth, J.; Aydemir, A.; Döscher, H.; Eckstein, J.; Poganietz, W.-R.; François, D.-E. et al. (2021): The potential of hydrogen for decarbonising EU industry. Brussels: European Parliament.*


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| **Economic feasibility** | • Price impacts and value chain disruptions due to Covid and Russia-related sanctions<br>• Investment cycle requiring invest in process not yet competitive<br>• **No infrastructures for transport of hydrogen ($H_2$) + $CO_2$**<br>• **No established markets for green $H_2$ + cement yet**<br>• **Uncertainty w.r.t. availability of $H_2$ + renewable electricity** |
| **Socio-economic impacts** | • Uncertainty about CBAM impacts<br>• Price impacts for downstream industries<br>• Risk of carbon leakage and associated job losses<br>• **Customer-related barriers (norms, competences)** |
| **Socio-ecolo-gical impacts** | • Land use conflicts related to infrastructure + RES expansion |


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# Narrative: How major bottlenecks to the industry decarbonisation in Germany will have been overcome

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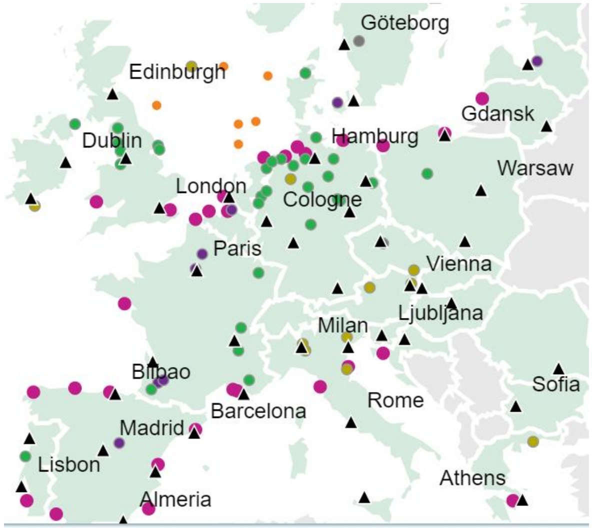


**2020s**

?

**Demand for $CO_2$-neutral hydrogen increases substantially**

- 2030: 68-144 TWh
- 2050: 825 – 1289 TWh

Hydrogen production **increases the electricity demand by up to 1700 TWh**, i.e. +200%


**2040s**

*Sources: European Hydrogen Backbone (2022), A-Dabbas et al. (2022)*

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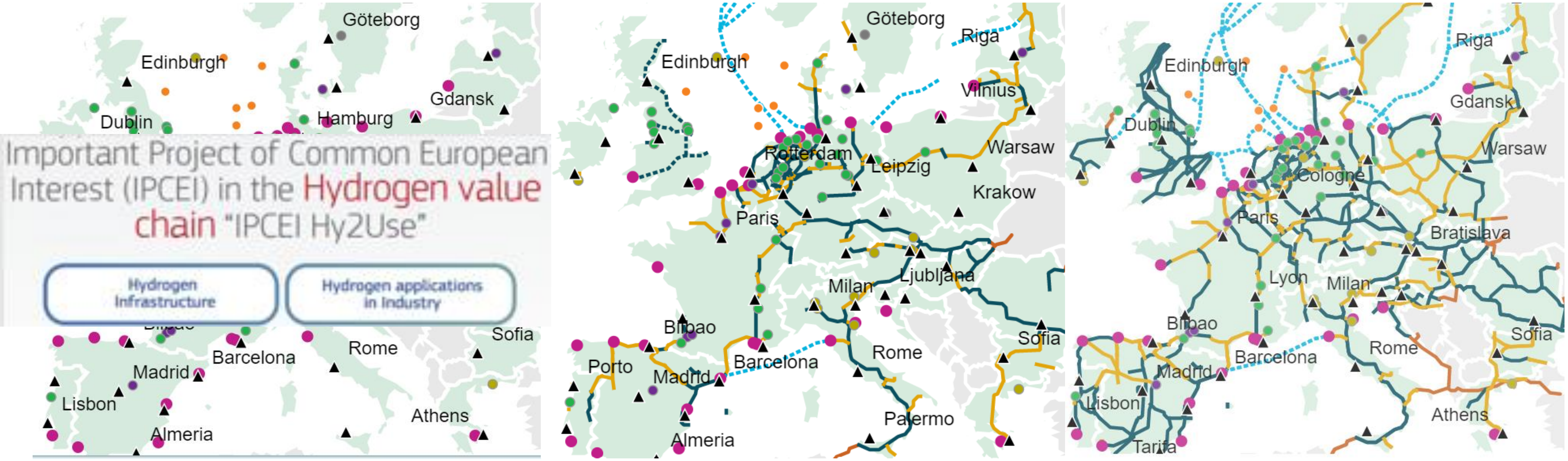


## 2020s

- Developing an **overarching system development strategy**
- **Certification of green and blue H2** based on RED III and Gas Package
- **Support schemes for infrastructure and electrolyser build up**
- Carbon **contracts for difference**

## 2030s

- **Green public procurement initiative** in the building sector
- Establishing **labels and green lead markets**

*Sources: European Hydrogen Backbone (2022), A-Dabbas et al. (2022)*

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# Sectoral bottlenecks considered most relevant by stakeholders

| Country | Sector | Bottlenecks considered most relevant by the stakeholders |
|---|---|---|
| **Germany** | **Energy-intensive industries** | (1) Infrastructure-related bottlenecks: Uncertainty around availability of hydrogen and renewable electricity & political framework conditions<br>(2) Demand-side-related bottlenecks: Certification & markets for green steel/cement, customer related barriers (norms, competences) |
| **UK** | **Energy-intensive industries** | (1) Financing, investment cycles, and energy prices<br>(2) Unprecedented upscaling of technologies and required skilling<br>(3) Infrastructure expansion |
| **Brazil** | **Transportation** | (1) Issues around resistance of powerful actors<br>(2) price of batteries, access to credits and<br>(3) cost of mobility, Diesel sensitivity. |
| **Canada** | **Transportation** | (1) uncertainties around CCS technologies<br>(2) decarbonisation of freight transport<br>(3) urban planning not suitable for mobility shift<br>Crosscutting: governance issues resulting from multi-scalar structures |
| **Greece** | **Electricity sector** | (1) High costs of grid adaption to RES requirements & Access to finance<br>(2) Issues with RES (esp. wind power) expansion: opposition, ecosystem impact & land use constraints<br>(3) Potential lock-in due to high investment into (L)NG infrastructure<br>(4) Storage maturity |

*Source: Wachsmuth, J.; Warnke, P.; Gambhir, A.; Giarola, S.; Koasidis, K.; Nikas, A.; Pied, M.; Vaillancourt, K. (2022): D4.7 – Transformative Policy Mixes: Comparing National Case Studies. To be published on the PARIS REINFORCE website soon*

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## Conclusions

- The workshops made clear that substantial **tensions exist btw. modeled pathways and the real world → Realisibility of the narratives remains open!**
- **Some challenges and solutions stand out in all countries** in spite of the strong diversity of contexts:
  - **Allocation of capital** towards massive investments into low-carbon solutions
  - **Infrastructure development** for hydrogen, capture and use of $CO_2$ and electricity grids and storage adapted to renewable energy solutions
  - **Stakeholder and citizen dialogues** where agreement is reached on cornerstones of long-term decarbonisation trajectories
  - **Demand-side measures** complementing investments into low-carbon processes

## Outlook

- In order to facilitate change in the respective countries, **the narratives need to be validated, enriched and amended by the stakeholders** themselves.
- This process reaches beyond PARIS REINFORCE but can and **should be initiated by the project partners** in their respective countries or in further cooperations.

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# Thank you!

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# Narrative: How major bottlenecks to the industry decarbonisation in Germany will have been overcome

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| | Relevant policy mix elements |
|---|---|
| **Social feasibility**<br>**Political feasibility** | • **Inclusive policy making:** processes that foster dialogue, new ways of interaction modes, societal experimentation<br>• **Flexible governance:** adaptive mechanisms that coordinate governments, market actors + civil society<br>• **Systemic instruments:** linking different stakeholders and activities of innovation systems |
| **Technological feasibility**<br>**Economic feasibility** | • **Technology push:** Instruments that pay attention to innovative technology options<br>• **Demand pull:** Mechanisms that stimulate the demand side (economic or regulatory)<br>• **Systemic instruments:** mecha-nisms that foster provision of required infrastructures |
| **Socio-economic impacts**<br>**Socio-ecological impacts** | • **Systemic instruments:** mecha-nisms that tackle structural change, social inequalities and socio-ecological impacts<br>• **Inclusive policy making:** processes that foster partici-pation of 'dormant' stakeholder |


*Source: Wachsmuth, J.; Warnke, P.; Gambhir, A.; Giarola, S.; Koasidis, K.; Nikas, A.; Pied, M.; Vaillancourt, K. (2022): D4.7 – Transformative Policy Mixes: Comparing National Case Studies. To be published on the PARIS REINFORCE website soon*

# Narrative: How major bottlenecks to the industry decarbonisation in Germany will have been overcome

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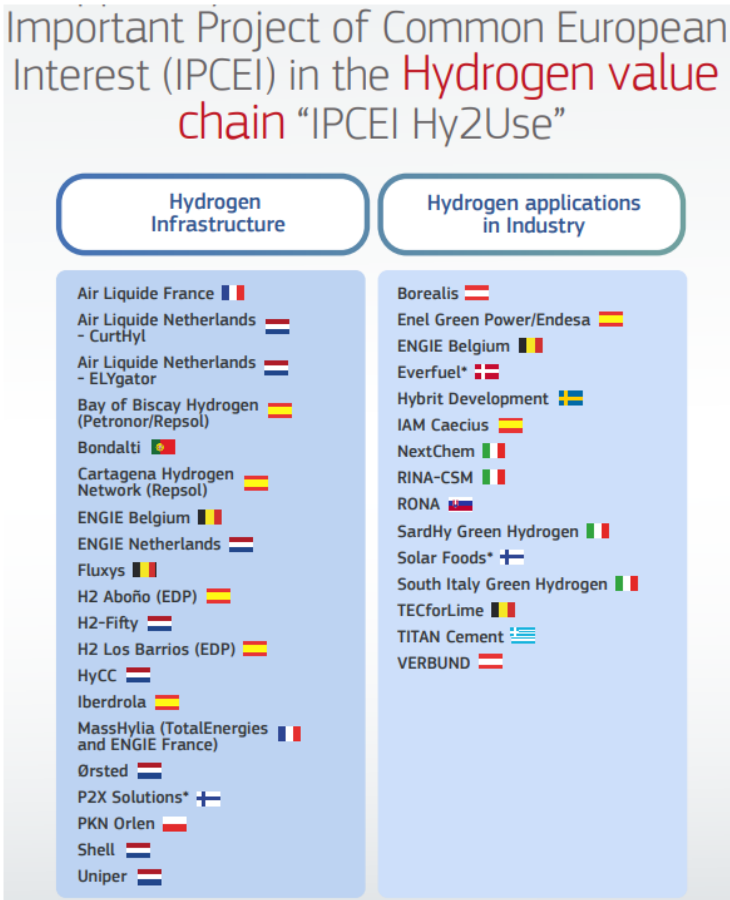
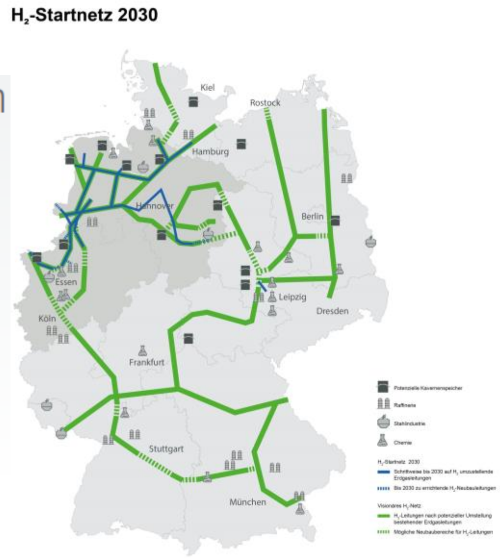
| | Relevant policy mix elements | Elements of a transformative policy mix in addition to current policies |
|---|---|---|
| **Social feasibility**<br>**Political feasibility** | • **Inclusive policy making:** processes that foster dialogue, new ways of interaction modes, societal experimentation<br>• **Flexible governance:** adaptive mechanisms that coordinate governments, market actors + civil society<br>• **Systemic instruments:** linking different stakeholders and activities of innovation systems | • **Visioning process on CCUS** with broad societal participation<br>• **Green building communication campaign**<br>• Sites for **testing innovative building solutions** (Reallabore)<br>• **High-level roundtable** with NGOs, policy and industry<br>• Developing an **overarching system development strategy** |
| **Technological feasibility**<br>**Economic feasibility** | • **Technology push:** Instruments that pay attention to innovative technology options<br>• **Demand pull:** Mechanisms that stimulate the demand side (economic or regulatory)<br>• **Systemic instruments:** mecha-nisms that foster provision of required infrastructures | • Stronger **R&D in recycling + alternative building materials**<br>• Strengthening **secondary steel route**<br>• Carbon **contracts for difference**<br>• **Certification of green and blue H2** based on RED III and Gas Package<br>• **Support schemes for infrastructure and electrolyser build up** |
| **Socio-economic impacts**<br>**Socio-ecological impacts** | • **Systemic instruments:** mecha-nisms that tackle structural change, social inequalities and socio-ecological impacts<br>• **Inclusive policy making:** processes that foster partici-pation of 'dormant' stakeholder | • Establishing **labels and green lead markets**<br>• **Green public procurement initiative** in the building sector<br>• Strategy for **improving decarbonisation skills + competences** |

*Source: Wachsmuth, J.; Warnke, P.; Gambhir, A.; Giarola, S.; Koasidis, K.; Nikas, A.; Pied, M.; Vaillancourt, K. (2022): D4.7 – Transformative Policy Mixes: Comparing National Case Studies. To be published on the PARIS REINFORCE website soon*

# First steps towards a hydrogen economy

- **IPCEI Hydrogen** is starting to pave the way for uptake of hydrogen supply + infrastructure, but delays in notification
- **Hydrogen valleys** for regional experimentation are established all over Europe
- ENTSO-G and German TSOs are pushing for a EU **Hydrogen Backbone**
- No comparable activities on CCUS yet!




isclaimer: Bei der Karte handelt es sich um eine schematische Darstellung, die hinsichtlich der eingezeichneten Speicher
d Abnehmer keinen Anspruch auf Vollständigkeit erhebt.


*Sources: European Commission 2022;*
*FNB Gas (2022), Clean Hydrogen Partnership (2022)*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# Bottom-up modelling of energy demand & GHG emissions

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

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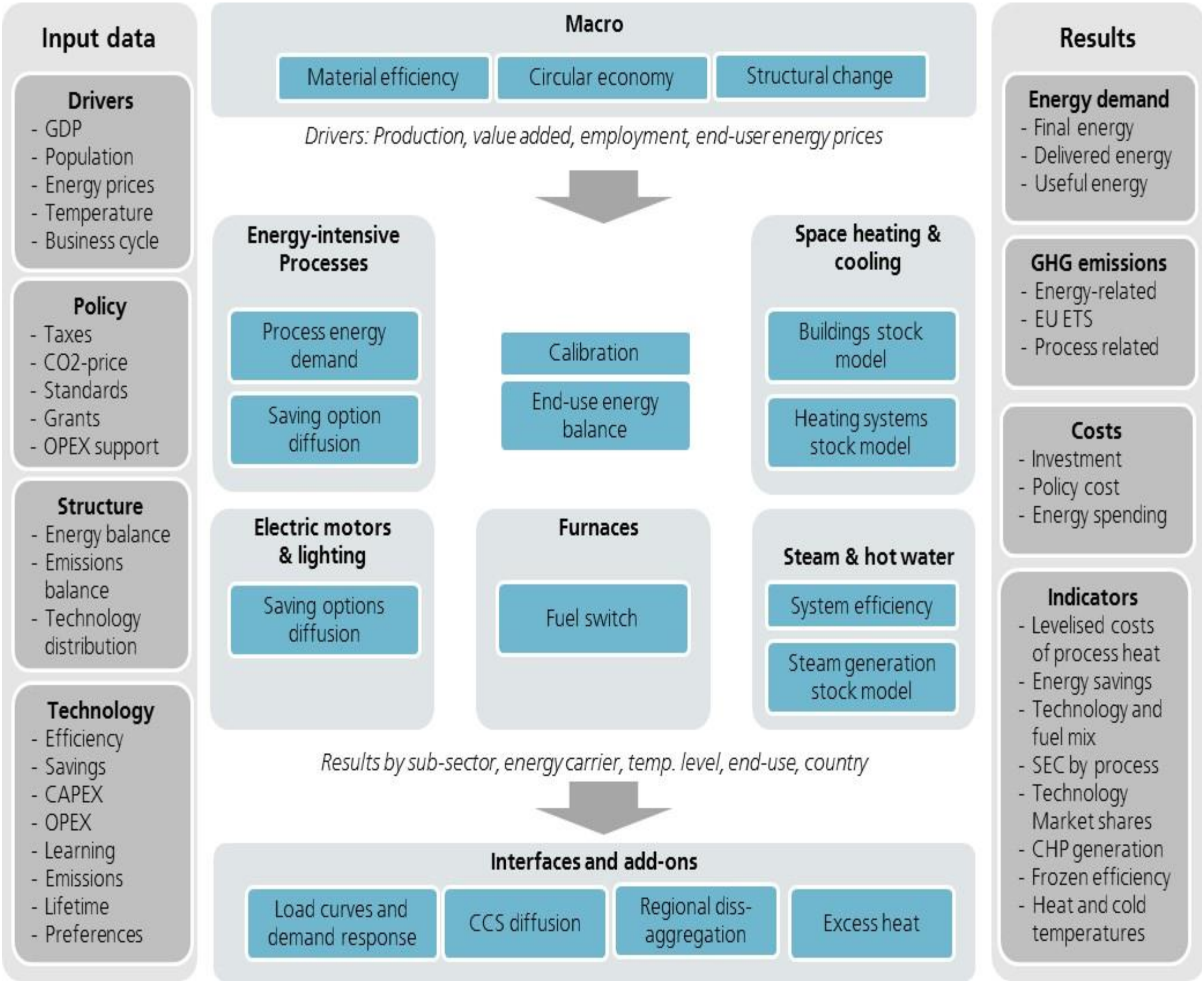
https://www.forecast-model.eu

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## Overview of key scenario assumptions for EU industry

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| | WWH21<br>Current Policy | Focus electrification<br>NZE-Mix-Electric | Focus hydrogen<br>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%,<br><br>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 | |
| **$CO_2$ price** | Low EU ETS prices in line with Ref2020 50€/tCO2-eq in 2030<br><br>200€/tCO2-eq in 2050 | Higher $CO_2$ price for the EU ETS<br><br>110€/t$CO_2$-eq in 2030<br><br>490€/t$CO_2$-eq in 2050 | |

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

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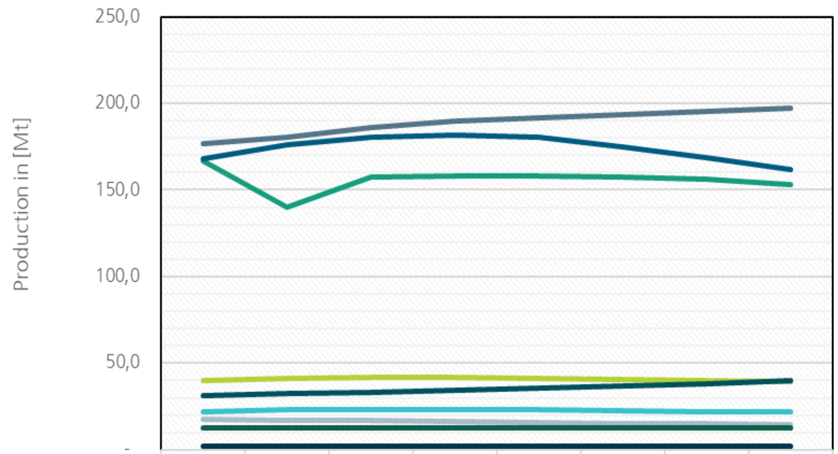
| Product | WWH21<br><br>Current Policy |
|---|---|
| **Steel** | More efficient steel use and substitution result in decreasing the production by about 9% |
| **Cement and lime** | Efficient concrete use and substitution, concrete recycling and re-use result in 7% decrease in production. 20% decrease in the clinker share<br><br>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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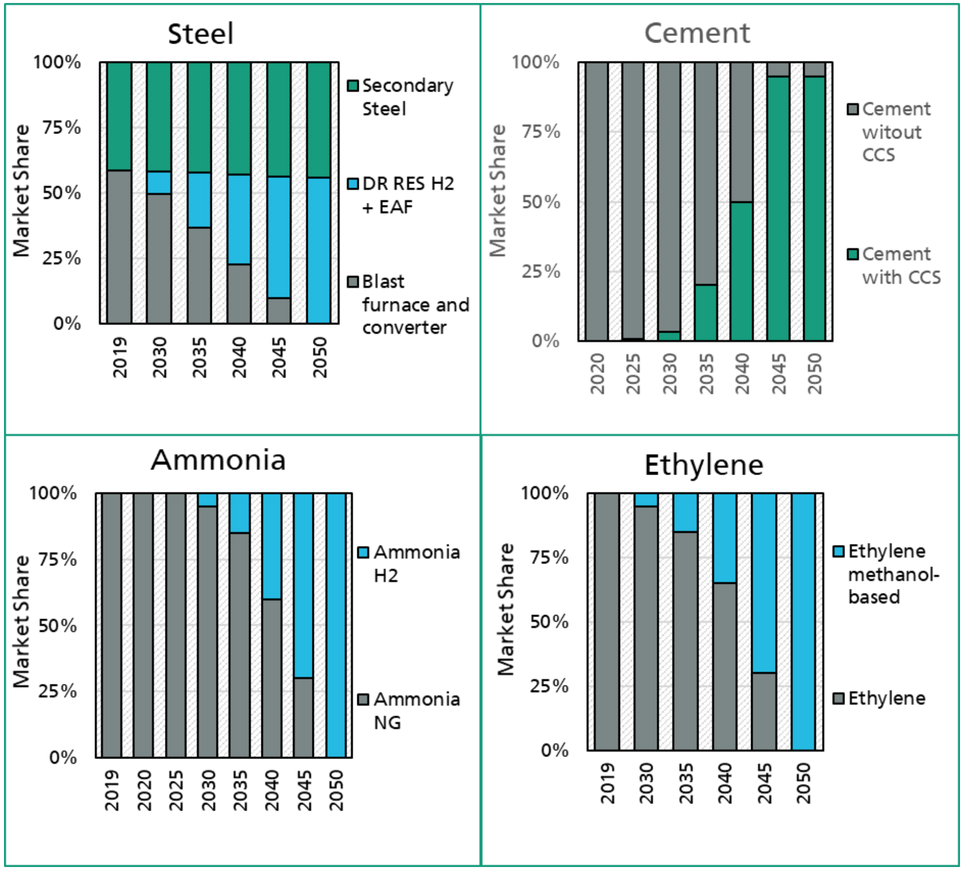
# Diffusion of new low-$CO_2$ production Routes

| 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<br><br>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 $CO_2$-neutral energy carriers

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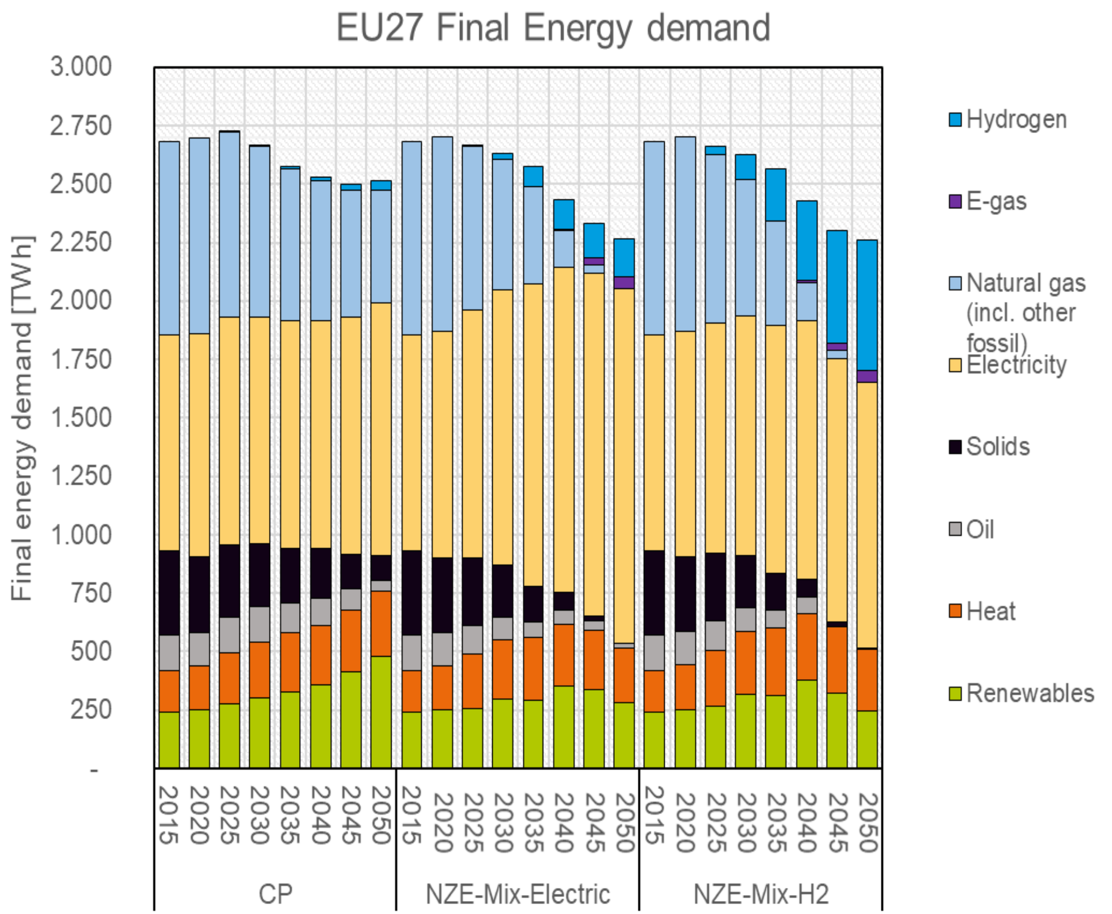
- Reduction in FED compared to 2015 (14% in CP and 24% in MIX95)
- The direct and indirect electrification of FED is a persisting trend in both scenarios:
  - 1519 TWh electricity demand in the NZE-Mix-Electric (DE: 278 TWh)
- 559 TWh Hydrogen demand in the NZE-Mix-H2 (DE: 210 TWh)
- In the WWH21 (CP) the demand for natural gas decreases significantly however, it remains a significant energy

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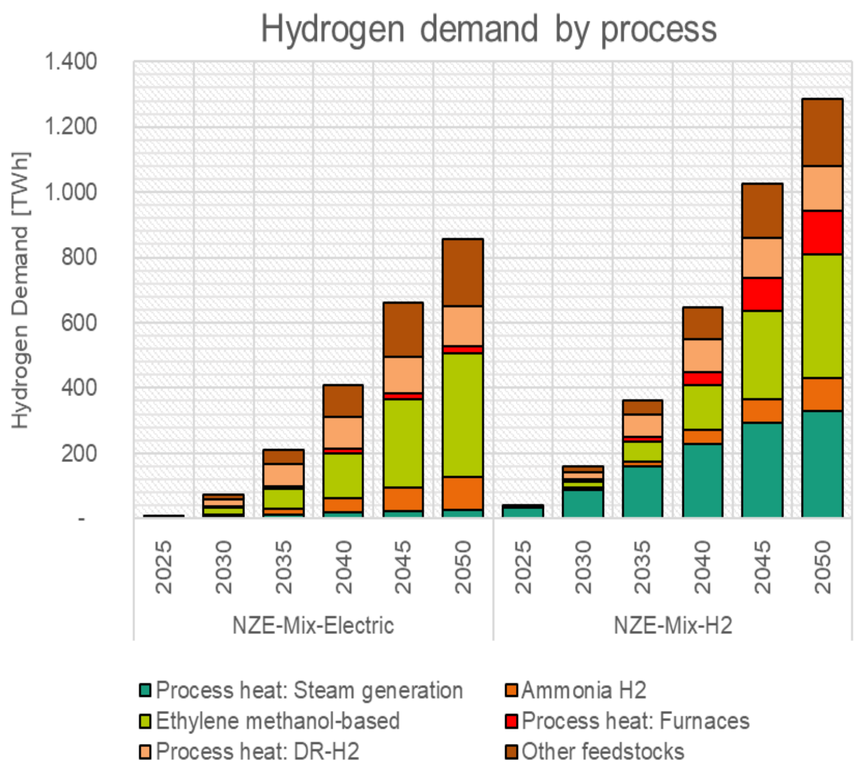
# Feedstock demand is strong driver for hydrogen

- Demand for $CO_2$-neutral hydrogen increases substantially
  - 2030: 68-144 TWh
  - 2050: 825 – 1289 TWh
- The primary sources of $H_2$ demand in NZE-Mix-Electric are feedstock use and steel manufacturing.
- NZE-Mix-$H_2$ extends $H_2$-demands in furnaces and steam generation

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# Electricity demand for $H_2$ generation needs to be considered

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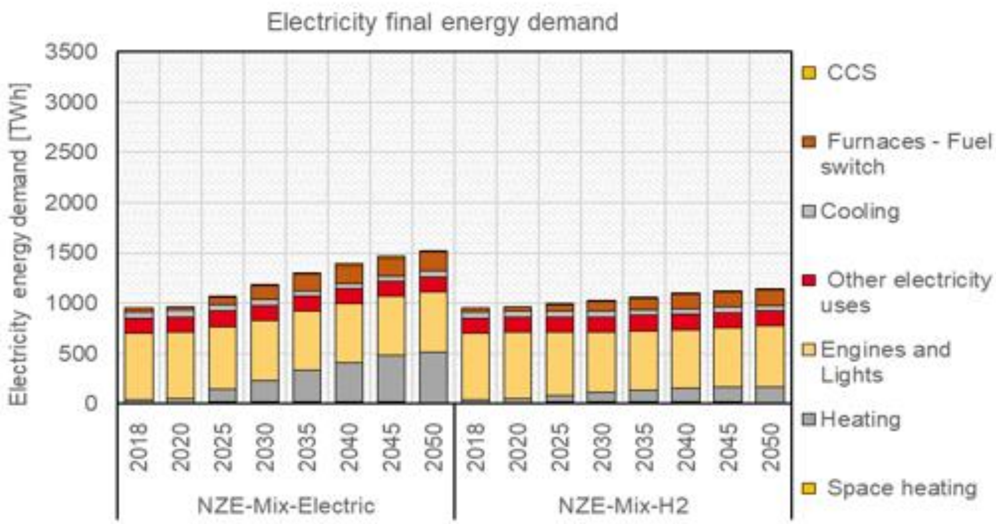
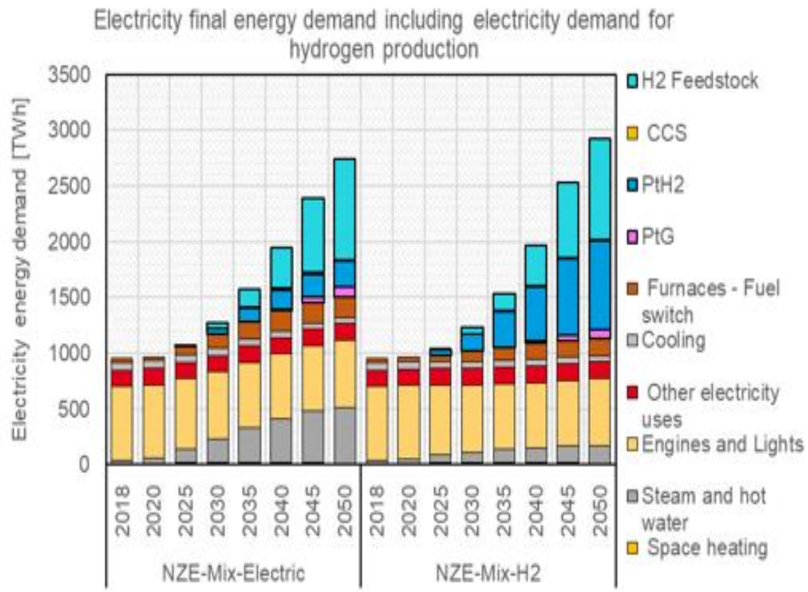
- In NZE-MIX-Electric process heating via steam generation and industrial furnaces increase electricity demand by 614 TWh -> + 50%
- Considering the Electricity equivalents needed for Hydrogen production increases the electricity demand in NZE-MIX-H2 by 1700 TWh, i.e. + 200% (DE: 690 TWh)

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# Transition bottlenecks for the UK industry sector

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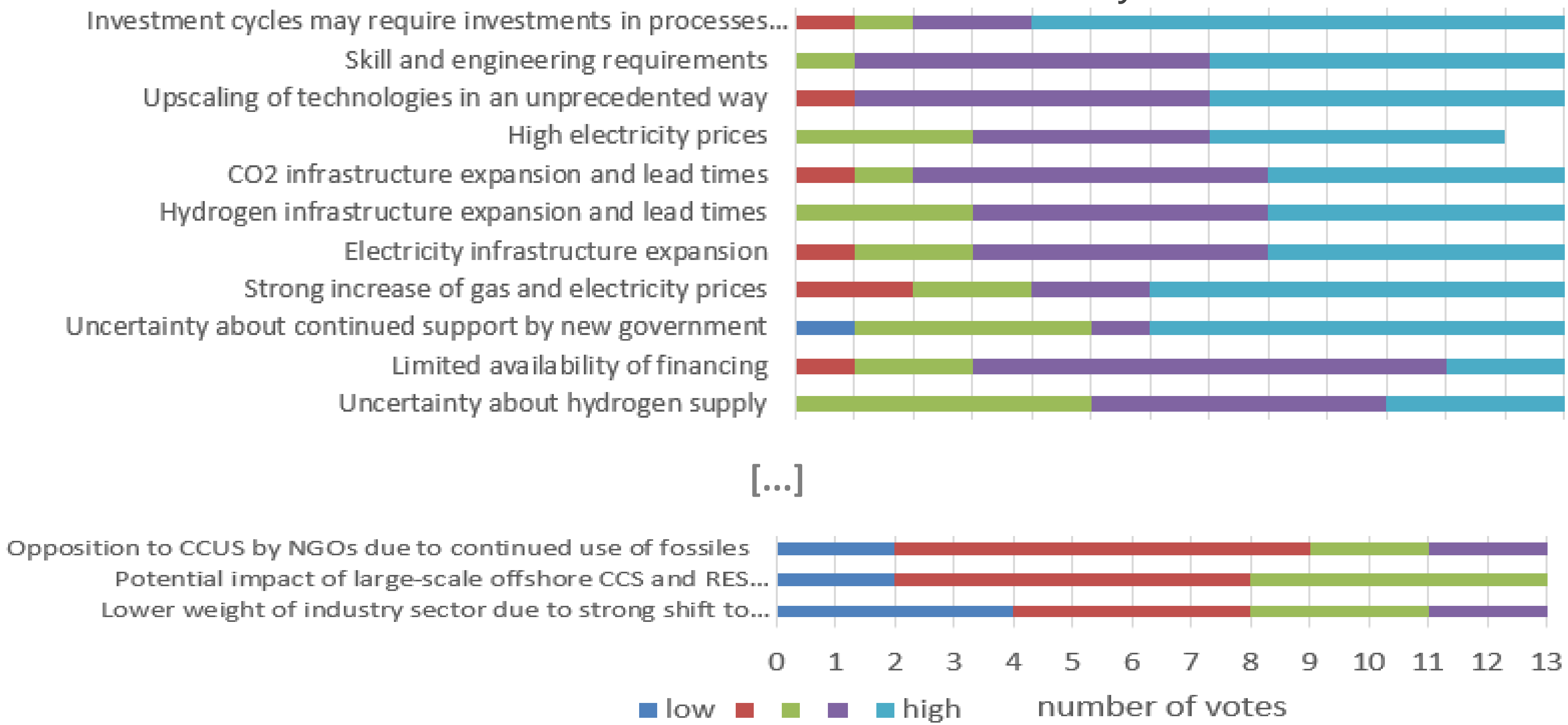


*Source: own representation by Fraunhofer ISI*

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# Greek Power Sector:
# Market liberalization and RES uptake

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Window of opportunity: Liberalisation of the market

Window of opportunity: Historically low RES electricity generation prices

**Second Period (2009-2017)**

| | | 2009 | 2017 |
|---|---|---|---|
| Lignite | This further decrease resulted from the increased penetration of RES and the high emissions prices. 8 lignite plants shut down and no new ones were constructed. | 52% | Further reduced to 34% |
| Oil | This fall was led by the installation of RES power plants and the interconnection of some islands with the mainland grid. Moreover, the few oil plants operating in the mainland grid shut down. | 16% | Further reduced to 10% |
| Hydro & RES | Hydro comprises 10% of Greece's electricity generation in 2017. The remaining 15% results from the significant increase of wind and solar power plants. | 10% | Further increased 25% |
| Natural gas | More natural gas plants were constructed replacing the reduced lingite electricity production. | 22% | Further Increased to 31% |

**Nowadays** (not thoroughly examined in the MLP)

| | | 2017 | 2020 |
|---|---|---|---|
| Lignite | According to the NECP's target for complete delignitisation by 2028, many lignite plants have already been shut down with the rest being shut down by 2022, except the new Ptoleimada V plant that will be converted to a natural gas plant by 2028). | 34% | Significantly decreased to 12% |
| Oil | Still many islands are not interconnected with the mainland grid. | 10% | almost steady at 10%, slightly decreased |
| Hydro & RES | Hydro comprises 7% of total energy generation. RES are accountable for 32% of electricity generation, mainly due to the hisotrically low prices. Moreover, the reduction of lignite usage is also contributing to the rise of RES energy generation. | 25% | Significantly increased to 39% |
| Natural gas | More natural gas plants were constructed substituting for the reduced lingite electricity production. | 31% | Further increased to 39% |

PPC divided into various entities responsible for the production, transmission and distribution of electricity

2020 NECP, aiming on total delignitisation by 2028

*Source: Nikas et al. 2020*

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# Employment effects of fossil and RES power generation

- Employment effects of natural gas are comparably low
- Power generation from lignite coal has high employment effects, in particular in the mining sector and during operation.
- Employment effects of wind and PV power generation can even be higher, but different skills are required.

| **Lignite Coal** | Direct employment (Job-years/TWh) | Indirect employment (Job-years/TWh) | Induced employment (Job-years/TWh) | Total employment (Job-years/TWh) |
|---|---|---|---|---|
| Power Plant Construction | 14.6 | 9.0 | 4.5 | 28.1 |
| Lignite mining, processing & transportation | 119.5 | 39.3 | 84.8 | 243.6 |
| Plant Operation | 104.3 | 19.8 | 54.2 | 178.3 |
| Total | 238.4 | 68.1 | 143.5 | 450.0 |

| **Natural Gas** | Direct (Job-years/ TWh) | Indirect (Job-years/ TWh) | Induced (Job-years/ TWh) | Total (Job-years/ TWh) |
|---|---|---|---|---|
| Construction | 4.0 | 2.5 | 1.2 | 7.7 |
| Operation | 51.3 | 9.7 | 26.0 | 87.0 |
| Fuel extraction and transportation | - | - | - | |
| Total | 55.3 | 12.2 | 27.2 | 94.7 |

| **Wind power plant** | Direct (Job-years/ TWh) | Indirect (Job-years/ TWh) | Induced (Job-years/ TWh) | Total (Job-years/ TWh) |
|---|---|---|---|---|
| Power Plant Construction | 160.3 | 88.2 | 66.3 | 314.8 |
| Operation | 136.9 | 61.6 | 74.7 | 273.2 |
| Total | 297.2 | 149.8 | 141.0 | 588.0 |

| **PV power plant** | Direct (Job-years/ TWh) | Indirect (Job-years/ TWh) | Induced (Job-years/ TWh) | Total (Job-years/ TWh) |
|---|---|---|---|---|
| Power Plant Construction | 612.2 | 333.7 | 255.6 | 1201.5 |
| Operation | 146.8 | 56.4 | 98 | 301.2 |
| Total | 759.0 | 389.4 | 353.6 | 1502.7 |

*Source: Nikas et al. 2020*

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# Transformation bottlenecks for the energy sector in Greece

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| | Bottlenecks for more ambition in the power sector (literature-based, ELABORATED DURING THE WORKSHOP) | Bottlenecks for realization of the high ambition scenario (literature-based, ELABORATED DURING THE WORKSHOP) |
|---|---|---|
| **Social feasibility** | • Lignite sector seen as guarantors for economic growth + labor<br>• Limited acceptance of wind power expansion<br>• … | • Private consumer uptake of e-mobility<br>• … |
| **Political feasibility** | • Target of the coal & NG phase-out not shared by all actors<br>• Current regulation poses hurdles to small-scale renewable electricity generation and inclusion of prosumers<br>• … | • Limited political certainty on future pathway<br>• Strong dependence on natural gas imports from Russia<br>• … |
| **Technological feasibility** | • Upscaling of technologies in an unprecedented way<br>• Balancing of non-interconnected islands<br>• Lack of Green Hydrogen Infrastructure for storage<br>• … | • Infrastructure rollout for e-mobility<br>• … |
| **Economic feasibility** | • High costs of required infrastructure and power storage<br>• Lock-In into LNG due to high Investment … | • High invest requirements for LNG and related infrastructure<br>• … |
| **Socio-economic impacts** | • Expected job losses, in particular in mining sector<br>• Required reskilling of labor forces<br>• … | • High costs of replacing oil and gas boilers with heat pumps<br>• … |
| **Socio-ecological impacts** | • Land use conflicts related to infrastructure + RES expansion<br>• … | • Potential negative impacts of connecting islands on marine ecosystems<br>• … |

*Source: own representation of Nikas et al. 2020, Wachsmuth et al. 2021, expert knowledge*

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


*Source: own representation based on Koasidis, K. et al. (2020b) and Wachsmuth, J.; Aydemir, A.; Döscher, H.; Eckstein, J.; Poganietz, W.-R.; François, D.-E. et al. (2021): The potential of hydrogen for decarbonising EU industry. Brussels: European Parliament.*

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## First Insights Process

- Small number of participants but high quality discussion
- Useful feedback for modelling received in both workshops
- Co-creation approach effective in principle though slot for interactive work rather short
- Several bottlenecks from socio-technical analysis assessed with high importance by stakeholders but in both cases additional ones added

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## First Insights Content

- Modeling Feedback
  - Brazil: specifying contribution of land-use sectors to net emissions
  - Canada: need for a multi-scalar perspective, focus on modal shifts in transport

- Co-creation Key aspects for overcoming bottlenecks
  - Brazil: Recognizing & addressing of inequality/cost of mobility, overcoming resistance of powerful actors, push for science based legislation, fostering sustainable lifestyle choices esp. for wealthy groups
  - Canada: addressing uncertainties around CCS technologies, strategies for decarbonisation of freight transport, urban planning conducive for net zero transport, multi scalar governance

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# Transformation bottlenecks for the transport sector in Canada

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| | Bottlenecks for more ambition in the transport sector (literature-based, ELABORATED DURING THE WORKSHOP) | Bottlenecks for realization of the deep mitigation scenario (literature-based, ELABORATED DURING THE WORKSHOP) |
|---|---|---|
| **Social feasibility** | • Goal of a strong electrification not shared by all actors<br>• Consumer uptake of e-mobility<br>• Uptake of public transportation still limited | • Acceptance of CCS and BECCS<br>• Acceptance of large-scale renewable expansion |
| **Political feasibility** | • Partial resistance by oil and automotive industries<br>• Different energy resources in provinces and strong influence of provinces on transport systems | • Independent provinces may hinder stringent implementation<br>• Integration with US economy |
| **Technological feasibility** | • Maturity of hydrogen-fueled and all-electric HDVs<br>• Limited options for modes other than road transport | • Maturity of CCS technologies |
| **Economic feasibility** | • Growing transport activity<br>• Much lower prices of fossil fuels compared to electricity<br>• Infrastructure rollout (catenary) requires large investment | • Large-scale investments in BECCS needed with uncertain revenue |
| **Socio-economic impacts** | • Increasing costs for mobility<br>• Denser urban living and transport areas | • Potential job losses in oil sector |
| **Socio-ecological impacts** | • Resource use for battery production | • Potential negative impacts of large-scale hydropower expansion<br>• Nuclear waste treatment<br>• Reliance on land use sinks |

*Source: own representation of Koasidis, K. et al. (2020a) and exert knowledge*

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# Conceptual background: Transformation bottlenecks + policy mix elements

| | Transformation bottlenecks (generic examples!!) | Relevant policy mix elements (generic examples!!) |
|---|---|---|
| **Social feasibility** | • lack of acceptance by important groups<br>• deviation from societal trends + norms<br>• required behavioral changes | • **Inclusive policy making:** Processes that foster dialogue,**,** new ways of thinking or interaction modes, societal experimentation, user spaces or demonstration projects, e.g. roundtables, living labs, …<br>• **Flexible governance:** adaptive mechanisms that reflect power structures btw. governments, market actors + civil society, public private partnerships, …<br>• **Systemic instruments:** linking different elements (stakeholder and activities) of innovation systems, , e.g. institutionalized niche markets |
| **Political feasibility** | • established power structures<br>• limitations of current political system.<br>• deviation from political targets + strategies | |
| **Technological feasibility** | • transformation of physical infrastructures<br>• required technological maturity of certain technologies not yet available | • **Technology push:** Instruments that pay attention to innovative technology options, e.g. grants for demonstration projects, investment loans<br>• **Demand pull:** Mechanisms that stimulate the demand side (economic or regulatory): quotas, contracts for difference,<br>• **Systemic instruments:** mechanisms that foster the provision of the required infrastructures, e.g. regulation of discriminatory-free access |
| **Economic feasibility** | • mobilizing needed investments<br>• need of importing certain goods.<br>• deviation from current market trends | |
| **Socio-economic impacts** | • job losses<br>• price increases deemed unacceptable | • **Systemic instruments:** mechanisms that tackle structural change and social inequalities as well as socio-ecological impacts<br>• **Inclusive policy making:** processes that foster participation of 'dormant' stakeholder |
| **Socio-ecological impacts** | • additional uses of land and other natural resources deemed unacceptable | |

*Source: Wachsmuth, J.; Jackwerth-Rice, T.; Seus, S.; Warnke, P. (2021): Outlining a Methodology for Co-Creating Transformative Policy Mixes. Full paper at the IST 2021 conference.*

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