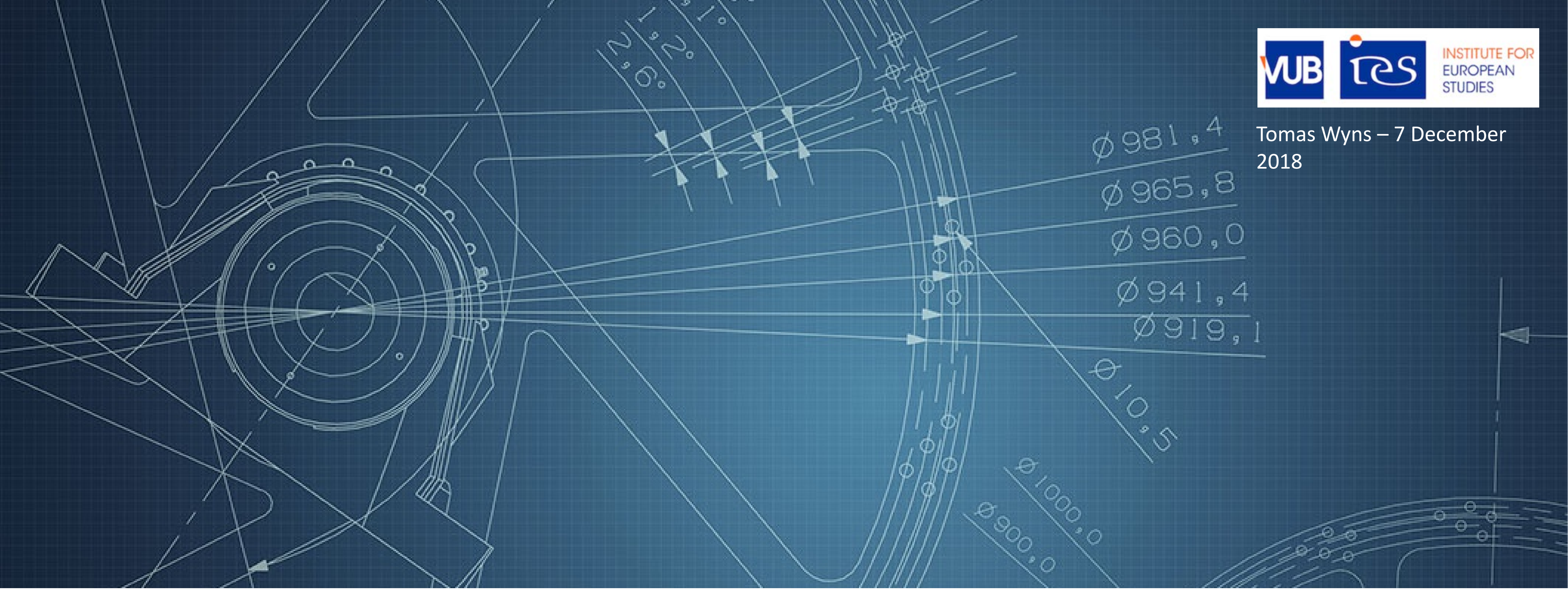


INSTITUTE FOR EUROPEAN STUDIES

Tomas Wyns – 7 December 2018

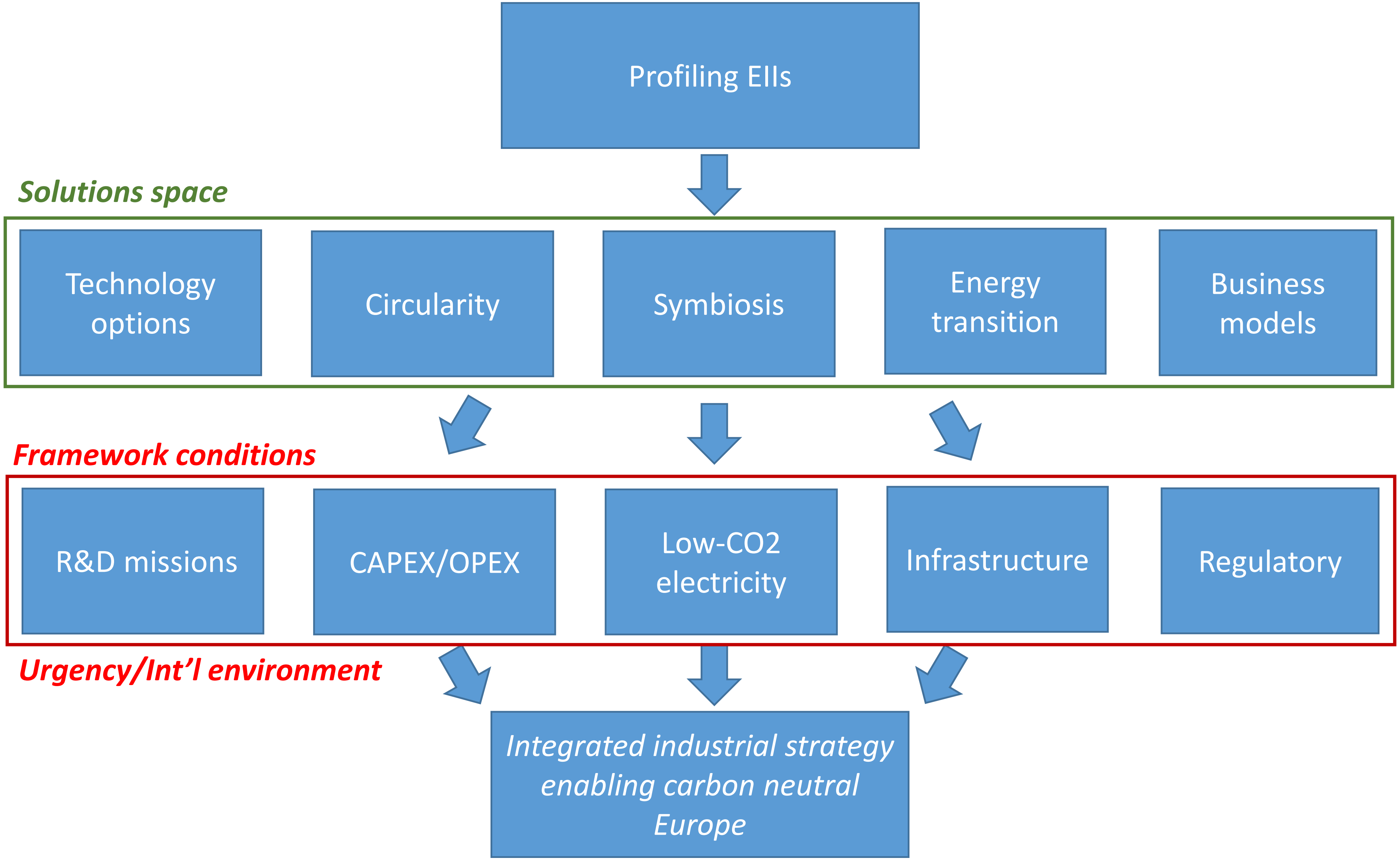
Industrial Value Chain: A Bridge Towards a Carbon Neutral Europe

Energy Intensive Industries' contribution to Europe's long-term climate strategy

Content

- **General approach of contribution**
- **Profiling EIIs**
- **Solutions space**
- **Framework conditions**
- **Towards an Industrial strategy**

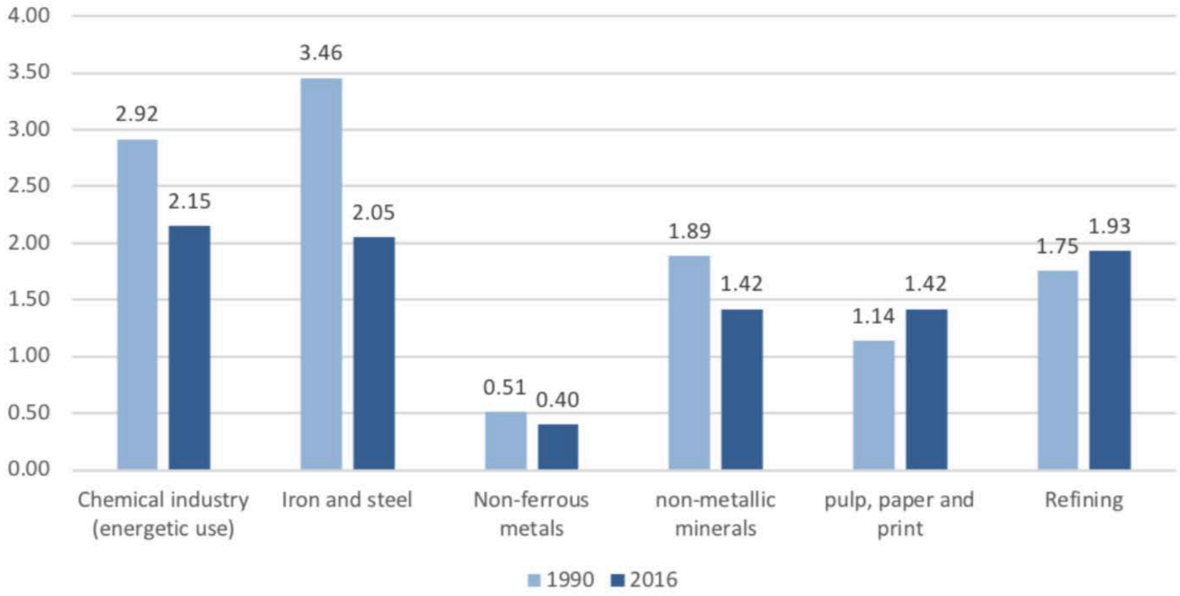
General Approach

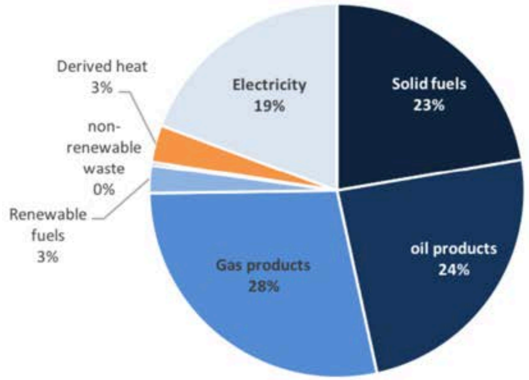


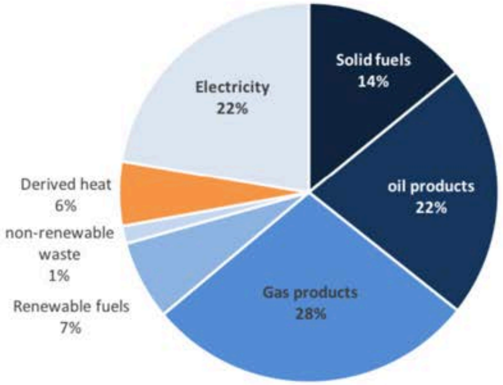
Profiling Ells

EIIs reduced greenhouse gas emissions by 36% between 1990 and 2015 and contributed significantly to the EU's overall emission reductions in same period (-24% in 2015 ref. 1990).

Direct CO_2-eq emissions	**1990**	**2005**	**2015**	**% change 1990-2015**	**Absolute change (Mt) 1990-2015**
Chemicals[3]	325.1	212	128.4	-61%	-196.7
Fertilizers4 [ammonia+nitric acid] (included in chemicals)	*76*	*66*	*28*	*-63%*	*-48*
Steel[5]	258	232	190	-26%	-68
Cement[6]	163	157	105	-36%	-58
Refining[7, 8]	122	143	137	+12%	+15
Pulp and paper[9]	39.9	43.2	32.7	-18%	-7.2
Ceramics[10]	26	26	17	-35%	-9
Non-ferrous metals and ferro-alloys[11]	52.3	31	17.8	-66%	-34.5
Lime[12]	25.9	23	19.4	-25%	-6.5
Glass[13]	*28*	*20*	*18.1*	*-35%*	*-9.9*
Total	**1,040**	**887**	**665**	**-36%**	**-375**
EU28 (excl. LULUCF)[14]	**5,650**	**5,220**	**4,319**	**-24%**	**-1,331**

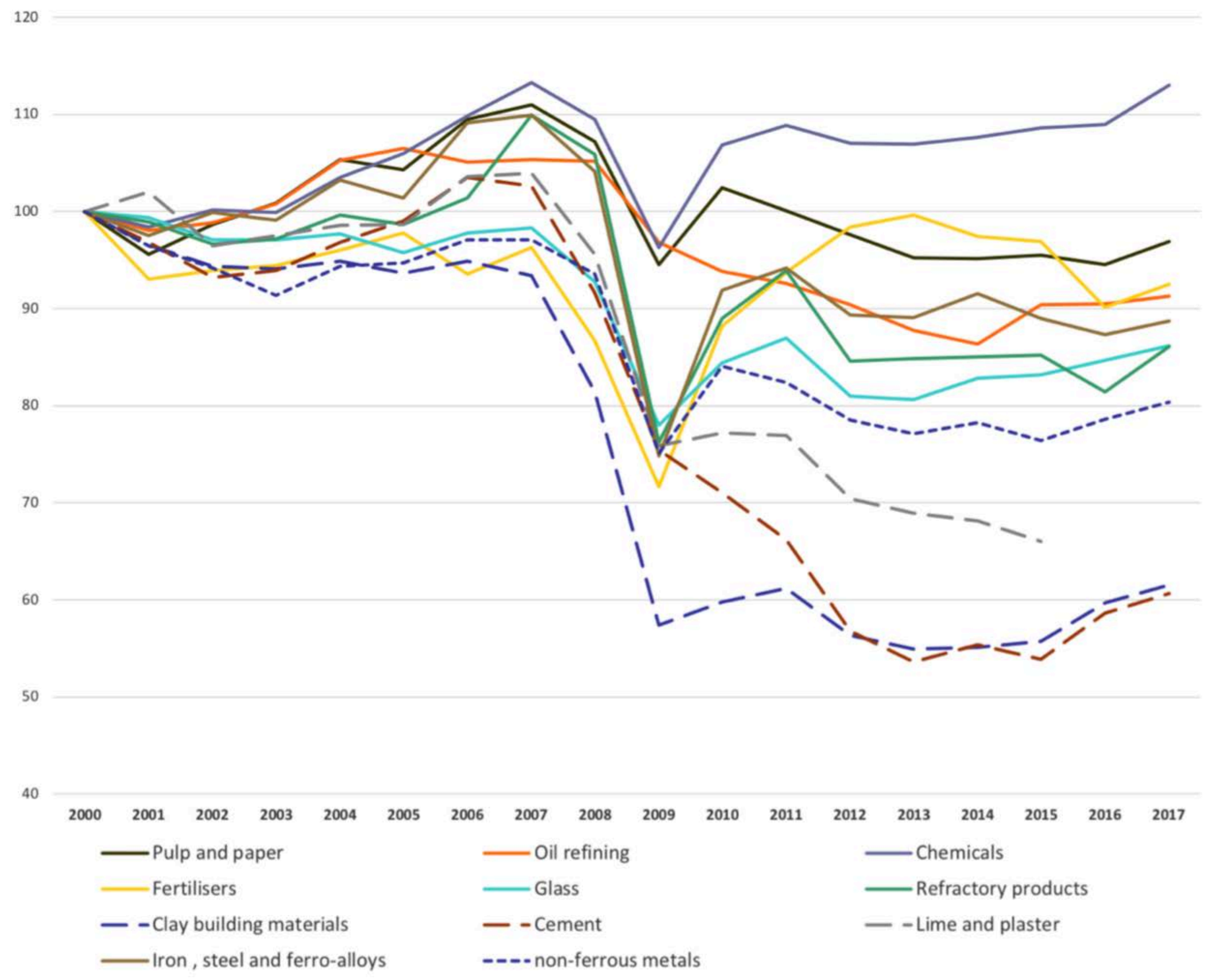






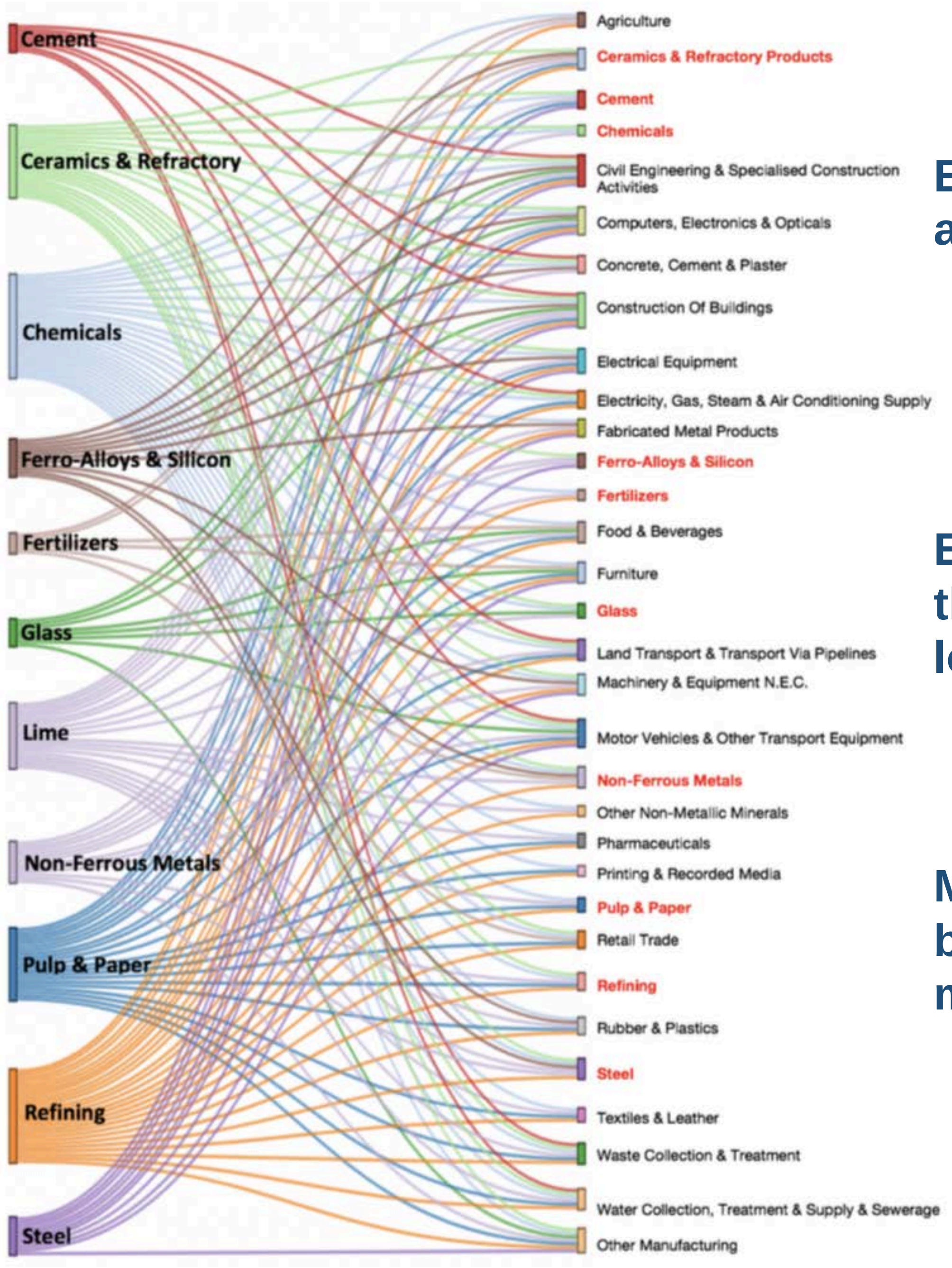
- **Final energy use by EIIs was reduced by 20% between 1990 and 2016.**
- **Most sectors showed significant efficiency improvements over this period.**

A major fuel shift occurred away from solid fuels towards biomass, waste and electricity in same period.



EIIs production was seriously affected through the economic crisis. Only chemicals production was above pre-crisis levels in 2017.

Most EIIs have a high trade intensity and are exposed to a high-level of international competition.



EIIs are the lifeblood of key value chains in EU but also their supply chains are linked to other EIIs.

EIIs products are and will be needed more to enable the energy transition and will be at the forefront of low-carbon solutions.

Most EIIs already see recycled materials, waste and by-products of other industries as important raw material inputs.

Solutions Space

- Important progress has been made in the development of **low-CO2 breakthrough technologies** for EII processes.

- Continued European R&D support under different programmes together with private R&D initiatives played an enabling role in this progress.

- The **gestation time of these breakthroughs is long** and many of them have not reached industrial scale demonstration level.

- Much **higher levels of final electricity demand are expected** if industrial low-CO_2 technologies are deployed across the EU.

- Transition to higher levels of electrification can create a **virtuous cycle between the EU's renewable energy and industrial transition**, under the right conditions.

- **EIIs play an important role in the circular economy and this role will increase in the future** in a conducive regulatory environment.

- **Industrial symbiosis, clustering and synergies** with non-industrial sectors show potential for significant energy savings and materials efficiency.

- In the areas of energy transition and circular economy **new business models are being explored.**

Chemicals & Fertilizers

Thermochemical processes	**H2**	Can be used for splitting of water (through high-temperature heat) and of CO2. Direct water splitting requires more than 2000°C, and the process therefore requires catalytic thermochemical cycles to reduce the temperature. The thermochemical processes allow generation of syngas (synthesis gas).	TRL 4	n.a.	n.a.	n.a.	n.a.	DECHEMA, p.53-54
Photocatalytical processes	**H2**	Splits water at the surface of a catalyst by using solar light energy.	TRL 2-3	n.a.	n.a.	n.a.	n.a.	DECHEMA, p.54
Low Carbon Ammonia (H2 based)	**H2**	Low-carbon ammonia synthesis is therefore limited to an alternative, low-carbon hydrogen production, where hydrogen is produced through electrolysis. No CO2 is formed as co-product in this synthesis route.	TRL 7	Up to -100% (Provided full decarbonisation of the power sector; compared to 1.83 tCO2/tNH3 for CH4 based ammonia production)	The low-carbon route has 2 times higher CAPEX than conventional production [p.127]	3 times higher OPEX than conventional production [p.127]	130% (including feedstock)	DECHEMA p.56-57
Hybrid Ammonia production (H2 and CH4)	**H2**	In a hybrid plant for ammonia production, natural gas is used as second feedstock and in addition to the previously described hydrogen-based ammonia production.	n.a.	Higher CO2-emissions than low-carbon ammonia, due to use of fossil fuels.	Lower CAPEX than electrolysis-based low-carbon ammonia production, since no Air Separation Unit is needed.	n.a.	n.a.	DECHEMA, p.59-60
Low-carbon methanol production (CO2 + H2)	**CCU/H2**	Low-carbon methanol can be produced using hydrogen (e.g. produced by water electrolysis with low-carbon electricity), in combination with hydrogenation of CO2 as carbon source. Hydrogenation of CO2 is used also in conventional methanol production by adding small amounts of CO2 to adjust the CO/H2 ratio of the syngas. Synthesis of methanol from CO and CO2 are tied through the water gas shift reaction.	TRL 7	-145% (Compared to natural gas based methanol production; negative number due to utilisation of CO2)	CAPEX and OPEX similar to production from natural gas.	CAPEX and OPEX similar to production from natural gas.	105 to 111%; or 5-11% higher if feedstock (GJ) is included in natural gas based methanol production (37.5 GJ/t	DECHEMA, p.63-64
Low-carbon ethylene and propylene via MTO (Methanol to Olefins) and methanol is made using H2 and CO2	**CCU/H2**	Low-carbon ethylene and propylene can be produced via MTO (Methanol to Olefins), if methanol is made using H2 and CO2 as previously described. The MTO reaction is strongly exothermic and the process follows a two-step dehydration of methanol to dimethyl ether and water, to control the heat of reaction and the adiabatic temperature increase, followed by the conversion to olefins.	TRL 7 (Although MTO technology is well known, the TRL is limited by the TRL of methanol production from CO2 and low-carbon H2)	Approx -249% (in the MTO process -1.13 t CO2/t olefin , compared to the naphtha route 0.76 tCO2/t olefin)	Major economic constraints: new investments needed in both hydrogen-based methanol plants and MTO plants.	n.a.	500% (In comparison to the naphtha route 16.9 GJ/t)	DECHEMA, p.68-69
Olefins out of H2 and CO2 in single system	**CCU/H2**	Olefins can be created from H2 and CO2 in a single system, for example in a single-stage electro-catalytic process, which omits the need for intermediate products (e.g. methane and methanol as feedstock for olefin synthesis).	TRL 3-4	n.a.	n.a.	n.a.	n.a.	DECHEMA, p.68
Benzene, toluene and xylenes (BTX) via H2 based methanol	**CCU/H2**	BTX can be produced from hydrogen based methanol, which requires a lower temperature and requires a higher catalyst acidity.	TRL 7	-416% (Compared to Naphtha based process)	n.a.	n.a.	1000% (176 GJ/t compared to naphtha based process 16.9 GJ/t)	DECHEMA, p.70-72
Poly(propylene)carbonate and polycarbonate etherols using CO2	**CCU**	Poly(propylene)carbonate is a polymer that can be produced using CO2 as building block. It is mainly used for packaging foils/sheets. Polycarbonate etherols can also be produced from CO2, and is mainly used in polyurethane foams.	TRL 7-9	n.a.	n.a.	n.a.	n.a.	DECHEMA, p.83
Formic acid (using electrochemical CO2 reduction)	**CCU**	Formic acid can be produced through electrochemical CO2 reduction, and is mainly used for example as a preservative, adhesive, precursor or as fuel in fuel cells.	TRL 7	n.a.	n.a.	n.a.	n.a.	DECHEMA, p.83
Mineral carbonation	**CCU**	Mineral carbonation can be used for treatment of industrial waste, metallurgy slag, production of cementitious construction materials etc.	TRL 7-9	n.a.	n.a.	n.a.	n.a.	DECHEMA, p.83
Dimethylether DME (direct synthesis from CO2)	**CCU**	Dimethylether (DME) can be produced through direct synthesis from CO2, and used as a fuel additive or a LPG substitute.	TRL 1-3	-30%	n.a.	n.a.	n.a.	DECHEMA, p.83
Sodium acrylate from ethylene and CO2	**CCU**	Sodium acrylate from ethylene and CO2 is currently investigated in lab scale.	TRL 1-3	n.a.	n.a.	n.a.	n.a.	DECHEMA, p.83
Electrocatalytic processes to convert CO2 to ethylene	**CCU**	Conversion of CO2 to ethylene through an electro-catalytic process is currently investigated in lab scale.	TRL 1-3	n.a.	n.a.	n.a.	n.a.	DECHEMA, p.83
Biomethanol	**Biomass**	Biomethanol is produced via gasification of bio-based feedstock, in the same way as coal-based methanol production. A large variety of biomass feedstock can be used (e.g. wood compared to sugar and starched crops), which generate different yields, costs etc.	TRL 6-7	-24% without sequestered carbon and -187% including carbon sequestered in biomass (compared to gas-based route; ref. 0.84 t CO2/tons of methanol via CH4)	CAPEX (per unit of capacity) around 3.4 times higher for the biomass route. Notably, biomethanol plants are around 1.8 times more expensive (based on the same energy output) compared to bioethanol facilities	200-500 €/ton of product. OPEX around 1.5 times higher	117% (Compared to gas-based route; 14.6 GJ/ton of methanol compared to 12.5 GJ/t for CH4 based methanol production excl. feedstock)	DECHEMA, p.85-96

Low-carbon technology database with over 80 technological options as addendum to EII contribution

For each sector multiple technology options are being developed towards significant GHG reductions.

	Electrification (heat and mechanical)	Electrification (processes: electrolysis/ Electrochemistry excl. H2)	Hydrogen (heat and/or process)	CCU	Biomass (heat and feedstock)/ biofuels	CCS	Other (including process integration)
Steel	**xxx**	xx	xxx	xxx	x	xxx	Avoidance of intermediate process steps and recycling of process gases: xxx Recycling high quality steel: xxx
Chemicals fertilizers	xxx	xxx	xxx	xxx	xxx	xxx(*)	Use of waste streams (chemical recycling): xxx
Cement Lime	xx (cement) x (lime)	o (cement) o (lime)	x (cement) x (lime)	xxx (cement and lime)	**xxx** (cement) x (lime)	xxx (cement and lime)	Alternative binders (cement): xxx Efficient use of cement in concrete by improving concrete mix design: xxx Use of waste streams (cement): **xxx**
Refining	xx	o	xxx	xxx	xxx	xxx	Efficiency: **xxx**
Ceramics	xxx	o	xx	x	x	o	Efficiency: **xxx**
Paper	xx	o	o	o	**xxx**	o	Efficiency: **xxx**
Glass	xxx	o	x	o	xxx	o	Higher glass recycling: xx
Non-ferrous metals/alloys	**xxx**	**xxx**	x	x	xxx	x	Efficiency: **xxx** Recycling high quality non-ferrous: xxx Inert anodes: xxx

o: Limited or no significant application foreseen
x: Possible application but not main route or wide scale application
xx: medium potential
xxx: high potential
xxx: *Sector already applies technology on large scale (can be expanded in some cases)*
(*) in particular for ammonia and ethylene oxide[116]

Synergies between the EU's energy transition and the EIIs' low-CO_2 transition

- *Reducing indirect emissions*
- *Industrial Low-CO_2 Power Purchase Agreements (PPAs)*
- *Industrial Demand Response*
- *Storage options*
- *New value chains in Europe: can become very important (size)*

→ *The virtuous cycle:* Energy Transition powers Industrial Transition powers Energy Transition

Nine Emerging Business Models related to the green economy

- *Industrial symbiosis*
- *Product Management Service*
- *Cradle to Cradle* (C2C)
- *Green Supply Chain Management* (GSCM)
- *Circular Supplies business model*
- *Product Life Extension*
- *Lean manufacturing*
- *Closed loop production*
- *Take Back Management* (TBM)

→ *Digital Economy/Digitisation as facilitator/enabler*

Framework conditions

Two Horizontal Challenges

SPACE

The industrial transition will have to happen in highly competitive and dynamic international environment.

TIME

For most energy intensive companies, 2050 is just one (large) investment cycle away from today.

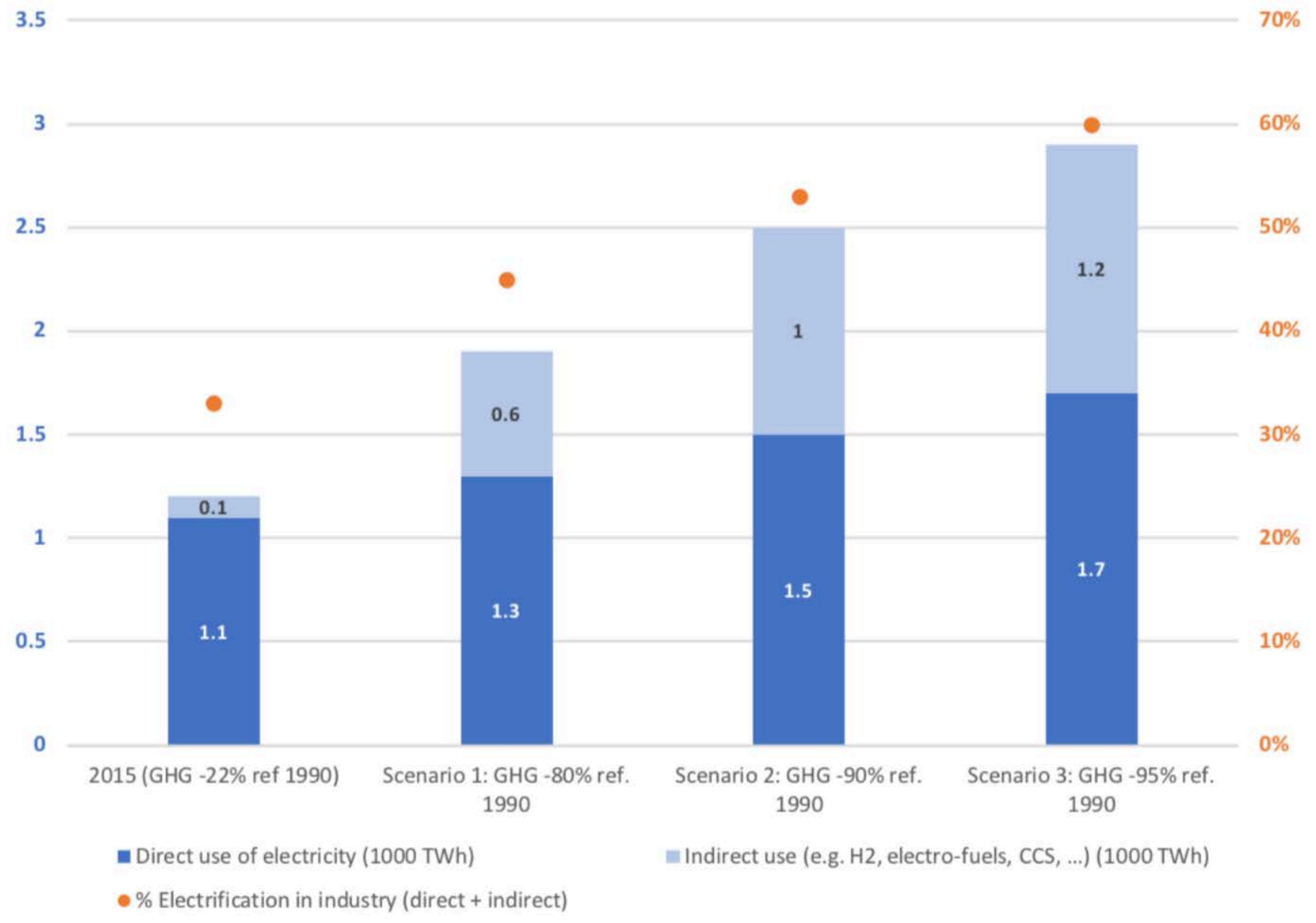
Three main R&D challenges

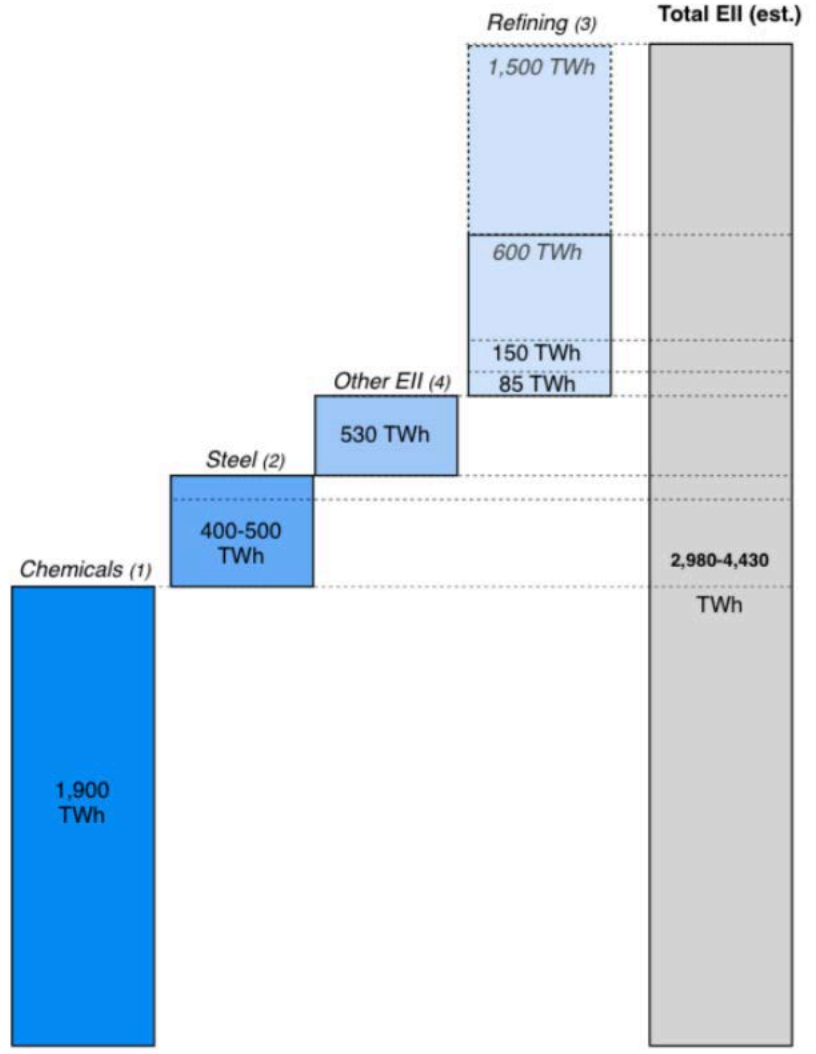
1. The need to scale up breakthrough technologies towards demonstration and commercialisation.
2. Optimal combination and integration of technologies (incl. breakthrough technologies)
3. An increased focus on cost reduction (OPEX).

Examples

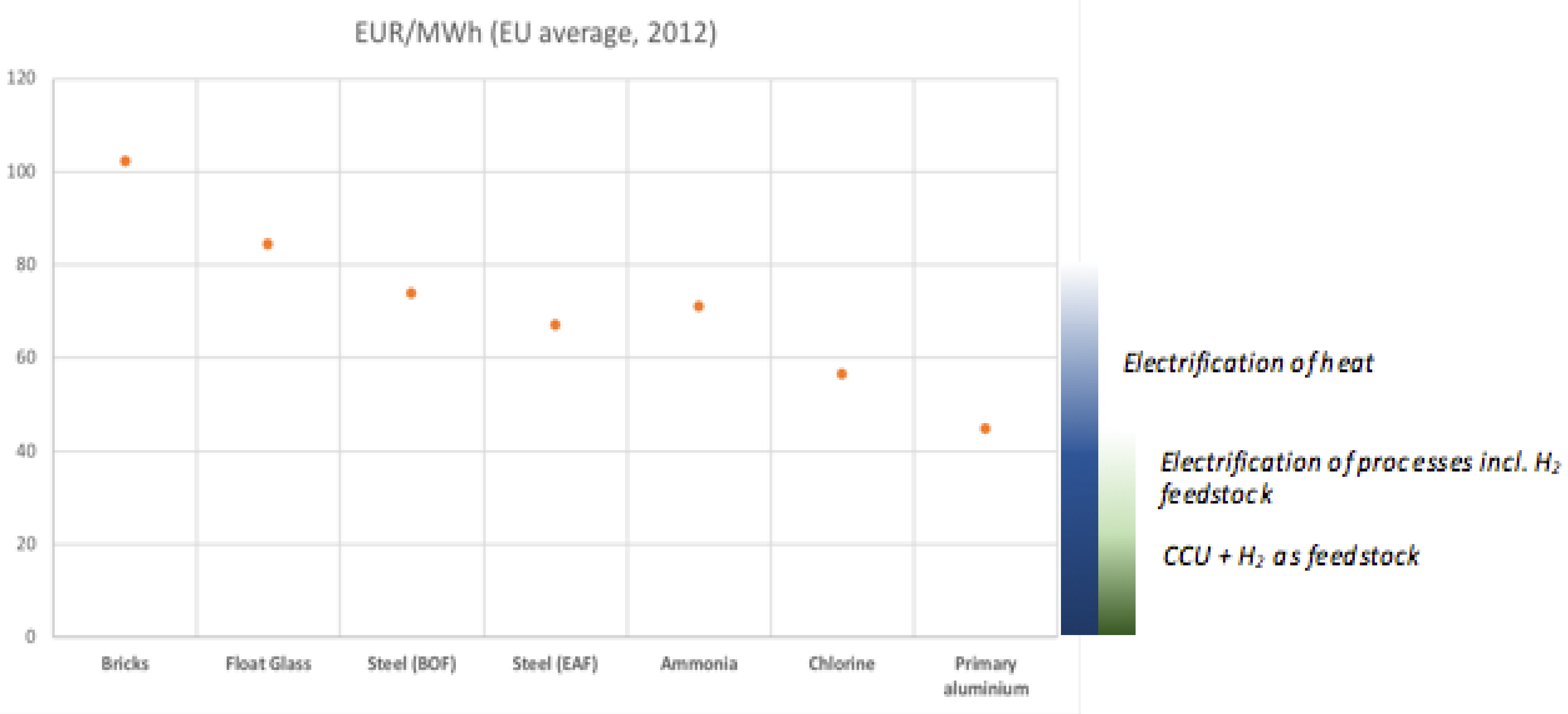
•Reducing the cost of low-CO_2 H_2 production and development of alternative production of low-carbon H_2 such as methane pyrolysis and water photolysis;
•Reducing the cost of biomass (waste) transformation to fuels or basic chemicals
•Optimisation of technologies needed for the electrification of high temperature furnaces (comparable to commercial sizes of current glass, cement and ceramic furnaces) and other electricity based processes (including electrochemistry, intensified processes with alternative energy forms such as plasma and microwave technologies, and pyrolysis technologies) at industrial scale.
•Reducing cost of capturing and purifying CO_2.

Low-CO2 electricity challenges: access + cost



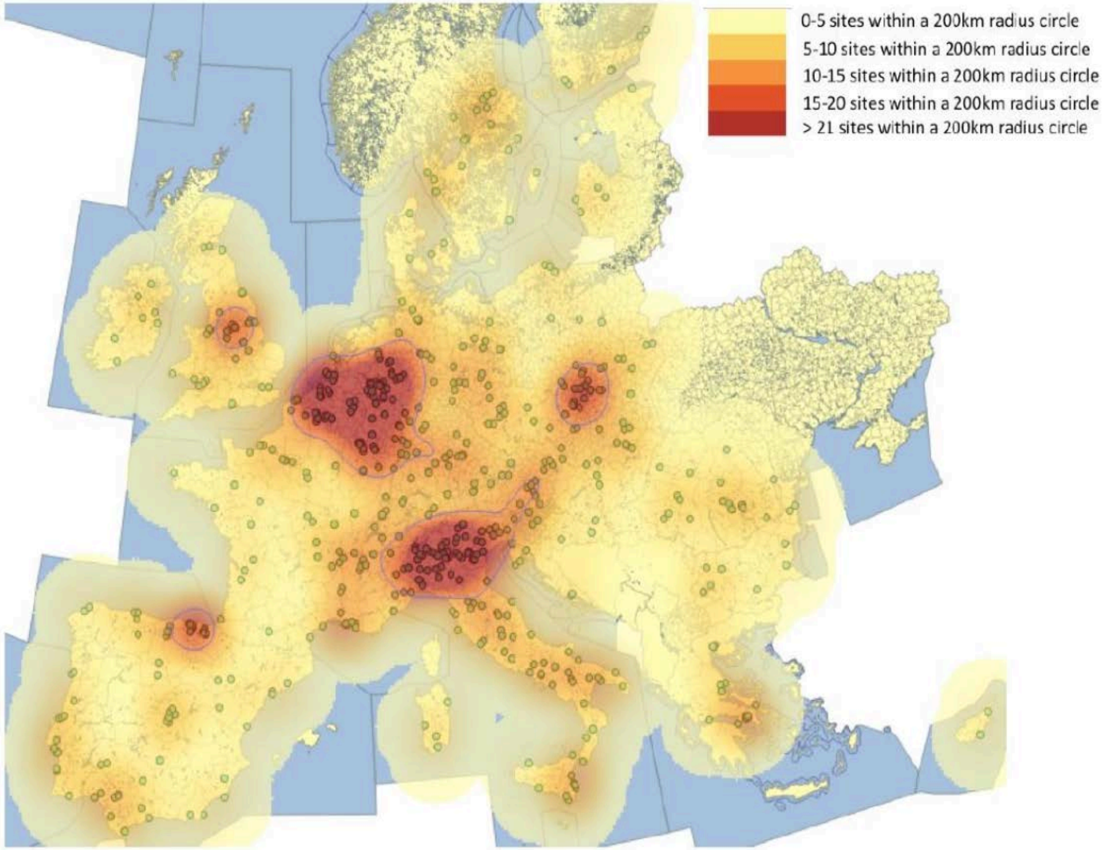


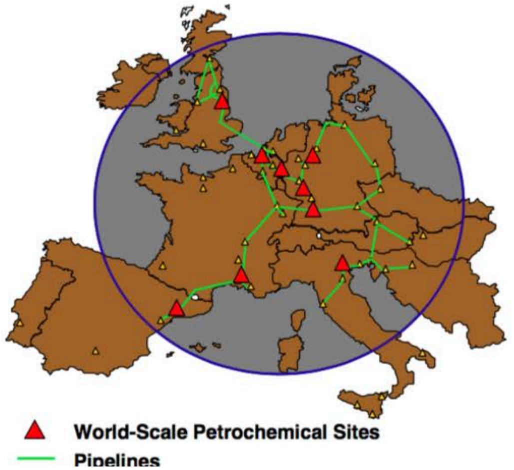
Estimates on future electricity demand by industry (left: Eurelectric, right: aggregation of EII sectoral inputs/roadmaps)

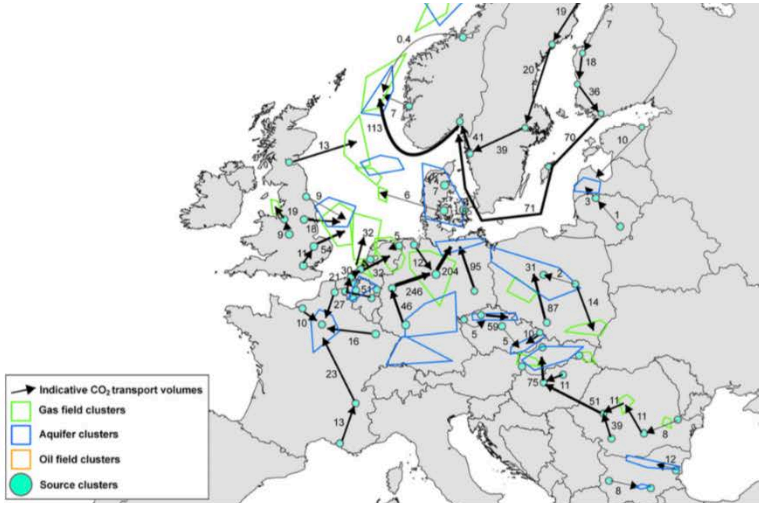


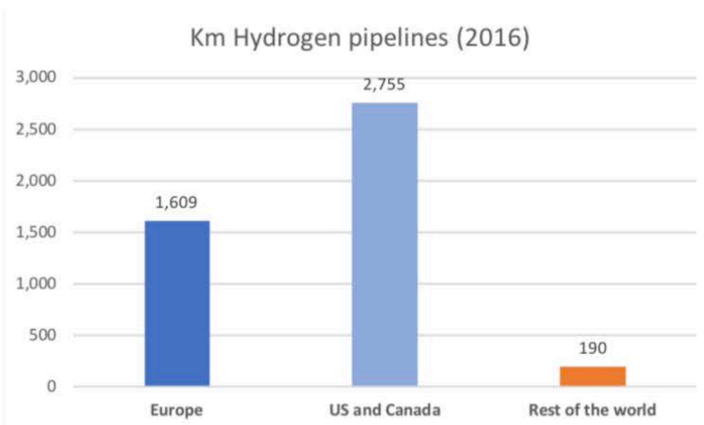
(Left) Average electricity prices for selection of energy/electro intensive producers (Source: CEPS) and (right) price ranges where types of electrified industrial heat and processes could be able to compete with existing processes.

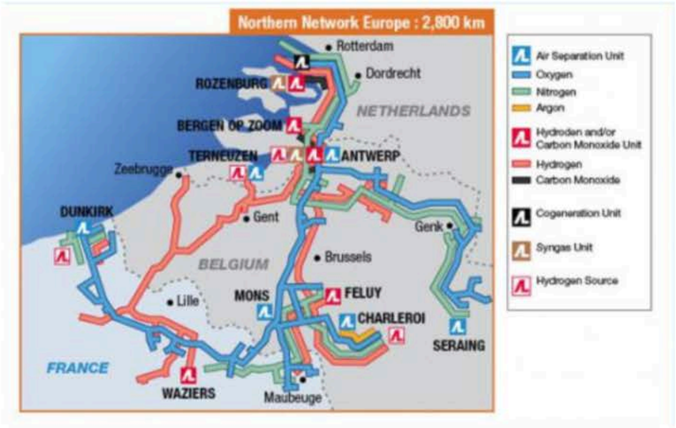
Infrastructure challenges











Urgent need for (future) infstrastructure mapping: start bottom up (clusters), identify EU industrial projects of common interest

Financing/investment challenges

Source	Scope *Region (timeframe)*	*Sector*	Scenario	Mitigation potential	CAPEX (EUR Bn)
Industrial Decarbonisation and Energy Efficiency Roadmaps to 2050[171]	UK (2012-2050)	Iron & Steel	Max tech	-60%	0.8
		Chemicals	Max tech	-88%	5.6
		Oil Refining	Max tech	-64%	0.7
		Pulp & Paper	Max tech (electrification & clustering)	-97.5%	1.4
			Max tech II (biomass)	-98%	1.4
		Cement	Max tech (with CCS)	-62%	0.8
		Glass	Max tech (with CCS/U)	-92%	0.2
		Ceramics	Max tech	-60%	1
		All[172]	Max tech	-73%	22.5
Roadmap for the Dutch Chemical Industry towards 2050[173]	Netherlands (1990-2050)	Chemicals	2030 compliance at least costs	-95%	16[174]
			Direct action and high-value applications	-95%	27[175]
Energy transition: mission (im)possible for industry? A Dutch example for decarbonization[176]	Netherlands (1990-2050)	All industry	Steeper route	-95%	25
Klimapfade für Deutschland[177]	Germany (1990-2050)	All industry	80% climate path	-80%	120
			95% climate path	-95%	230

- CAPEX for industrial low-CO_2 transition will be high & significantly above current investment levels
- Investment decisions in low-CO_2 processes will not happen if OPEX is not competitive.
- Addressing the CAPEX-OPEX challenge will require a mix of instruments
- New low-CO_2 process plants will likely be constructed at same industrial sites leading to additional costs (CAPEX+OPEX) for producers. Allowing accelerated depreciation of new installations and other tax incentives can help address this.
- European environmental state aid guidance will have to be reviewed

Regulatory challenges

1) *Protection against unfair international competition towards a level playing field*

2) *Full carbon leakage protection from both direct and indirect costs of the EU ETS*

3) *A large and ambitious mission oriented RD&I program for industrial low-CO_2 technologies , including funding for industrial demonstration and scale up*

4) *Consistency within the energy and climate policy framework to ensure that energy consumption and low-carbon policies are compatible*

5) *Reconsideration and a better alignment of the environmental state aid guidance*

6) *Industrial symbiosis and a circular economy through the effective combination of energy recovery and recycling*

7) *Streamlining of the permitting procedures allowing a timely and predictable set of infrastructures and interconnections*

8) *Transparent accounting framework for CCU across sectors and value-chains to allow business cases to emerge*

THE WAY FORWARD – A NEW INDUSTRIAL STRATEGY

- Design and implementation of **a EU flagship mission oriented R&D programme** addressing main challenges towards competitive low-CO2 processes in EIIs. Adequate support for demonstration of advanced low- CO2 technologies towards market readiness.

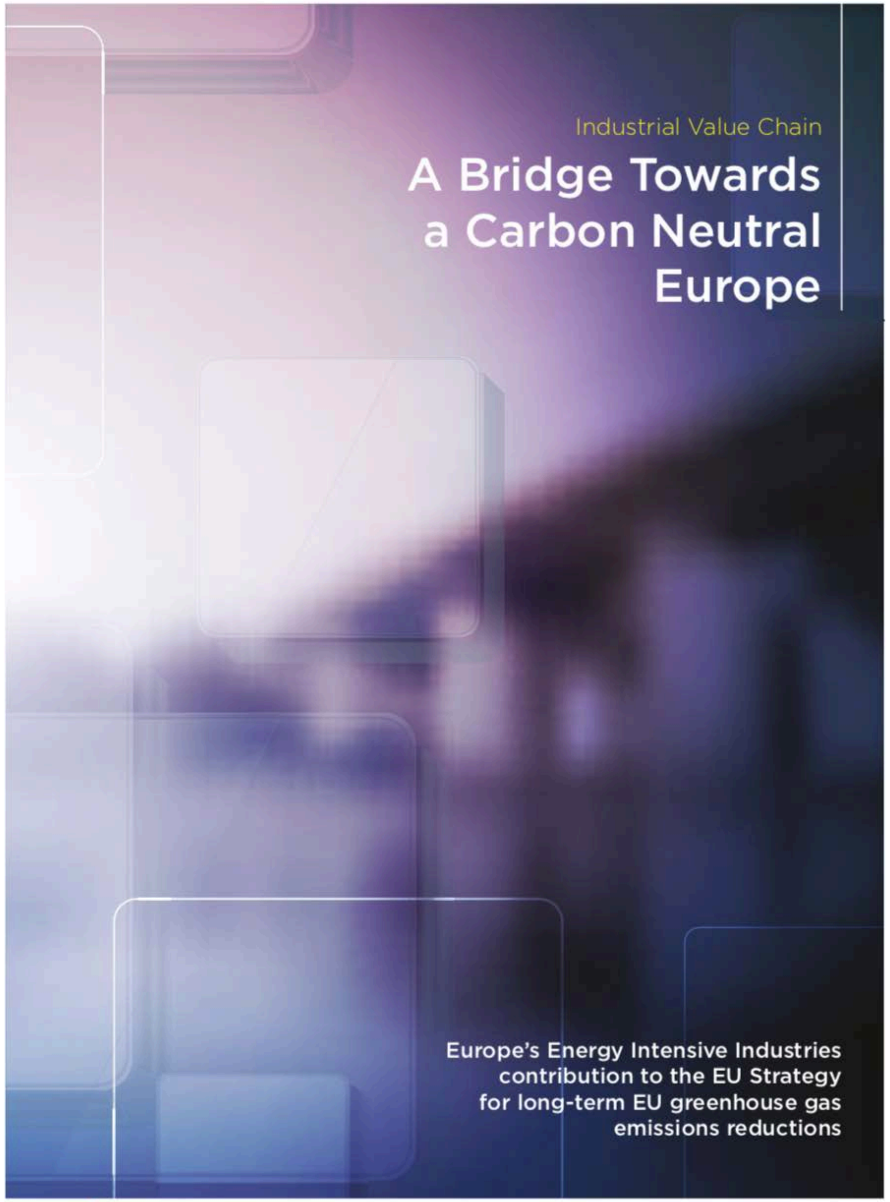
- **Strategic alignment of the EU's energy and industry transitions** in particular (ample and competitive supply of low-CO2 electricity to EIIs).

- Development of **adequate financing mechanisms for high CAPEX (low-CO2) investments** including support for replacement of existing and productive assets. A state aid regime that acknowledges the size and scope of the industrial low-CO2 transition.

- **Strategic industrial low-CO2 infrastructure planning** with a focus on regional and transnational industry clusters and industrial symbiosis & development of EU industrial projects of common interests.

- **Smart regulatory instruments** that can assist with lead market creation for low-CO2 products and processes (e.g. public procurement & development of low-CO2 standards for products).

- During the transition **continued protection** for energy intensive industries to safeguard competitiveness and investments in Europe.



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AN EU STRATEGY FOR LONG-TERM EU GREENHOUSE GAS EMISSION REDUCTIONS WILL ONLY BE SUCCESSFUL
IF IT FULLY EMBEDS SUCH INDUSTRIAL STRATEGY.