FEDIL

The Voice of Luxembourg‘s Industry

A hydrogen strategy for Luxembourg based on three principles

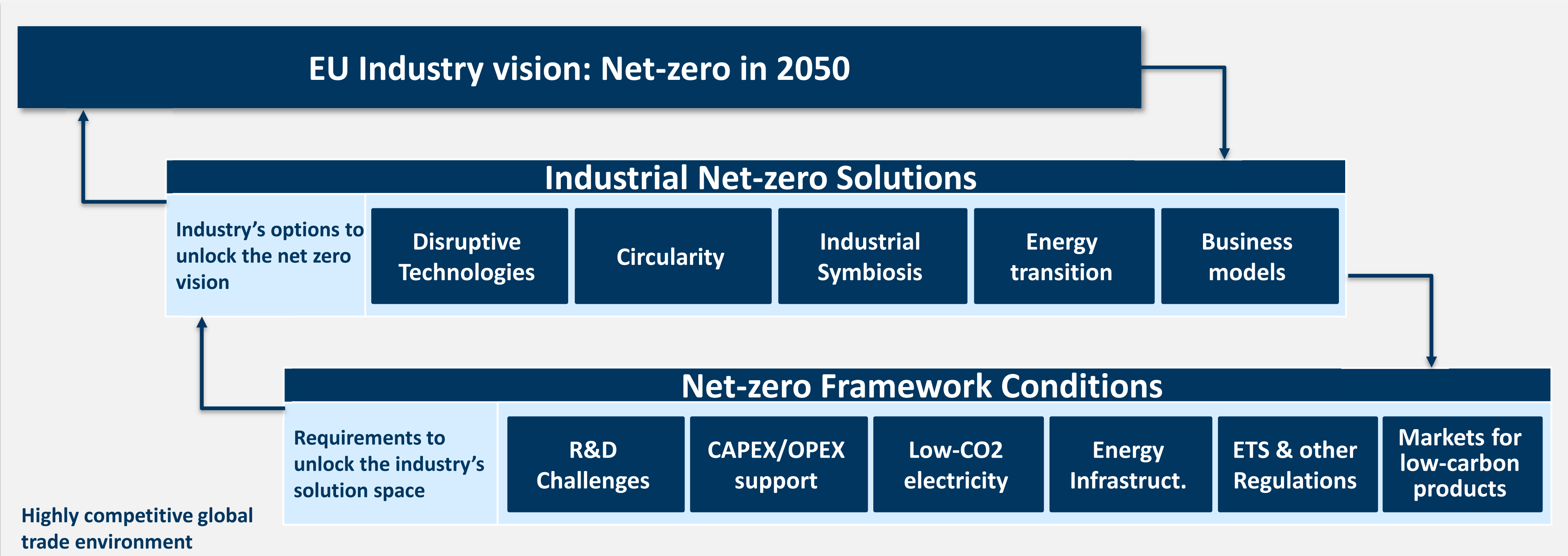
June 30th 2021

@Fedil_Lux

FEDIL - The Voice of Luxembourg's Industry

Industrial vision of Net-zero

What industrial solutions and framework conditions are needed?



Success of the Net-Zero vision depends on whether framework conditions 1.) support the implementation of industrial net-zero solutions and 2.) protect their competitiveness in global trade.

Industrial Net-zero transition challenges

Three types of challenges persist

1. Challenges in solution deployment

a) **The development of disruptive, low carbon breakthrough technologies** is long, expensive, and many of them have not even reached industrial scale demonstration level.

b) **Industrial symbiosis, clustering and synergies** with non-industrial sectors across the entire value chain show potential for significant energy savings & material efficiency but are still little developed.

c) **High levels of final electricity demand** is expected if industrial low-Co2 technologies are deployed, it may create a virtuous cycle with **competitively priced and abundant renewable energy production.**

d) **New business models need to emerge** in the areas of energy transition and circular economy, new low-carbon markets are needed.

2. Challenges in the business environment

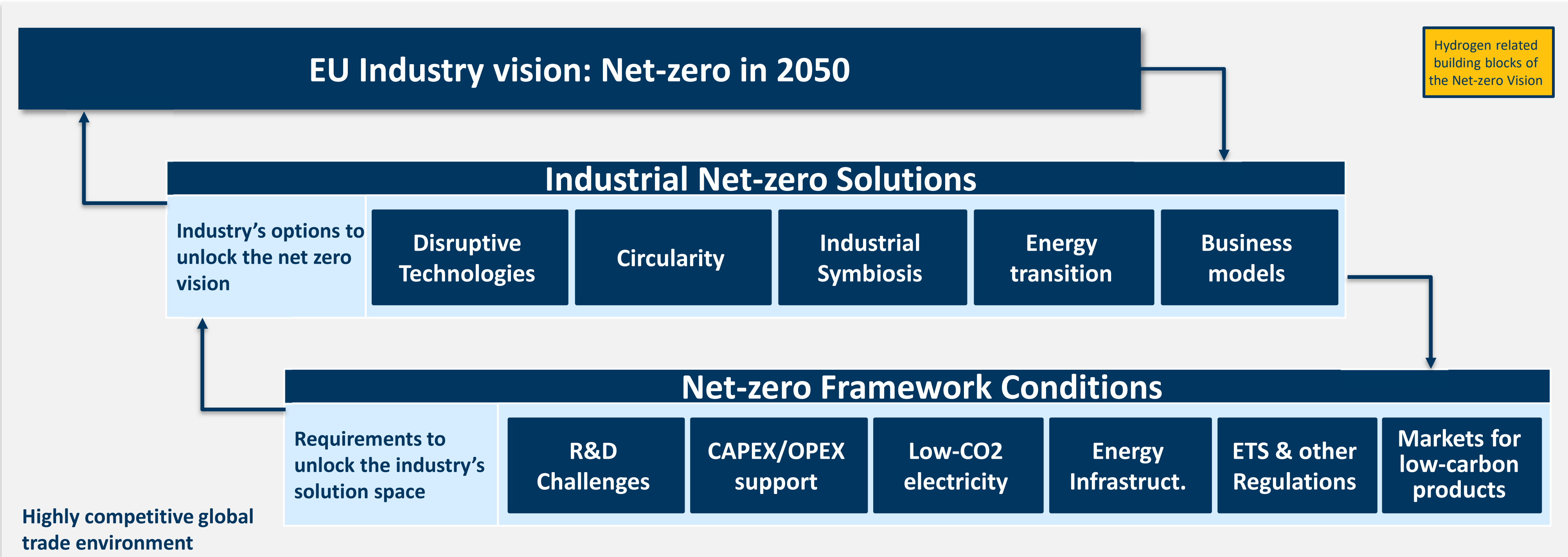
The industrial transition happens in a **highly competitive** and **global** business environment; a **level playing field** is however missing.

3. Challenges in timing

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

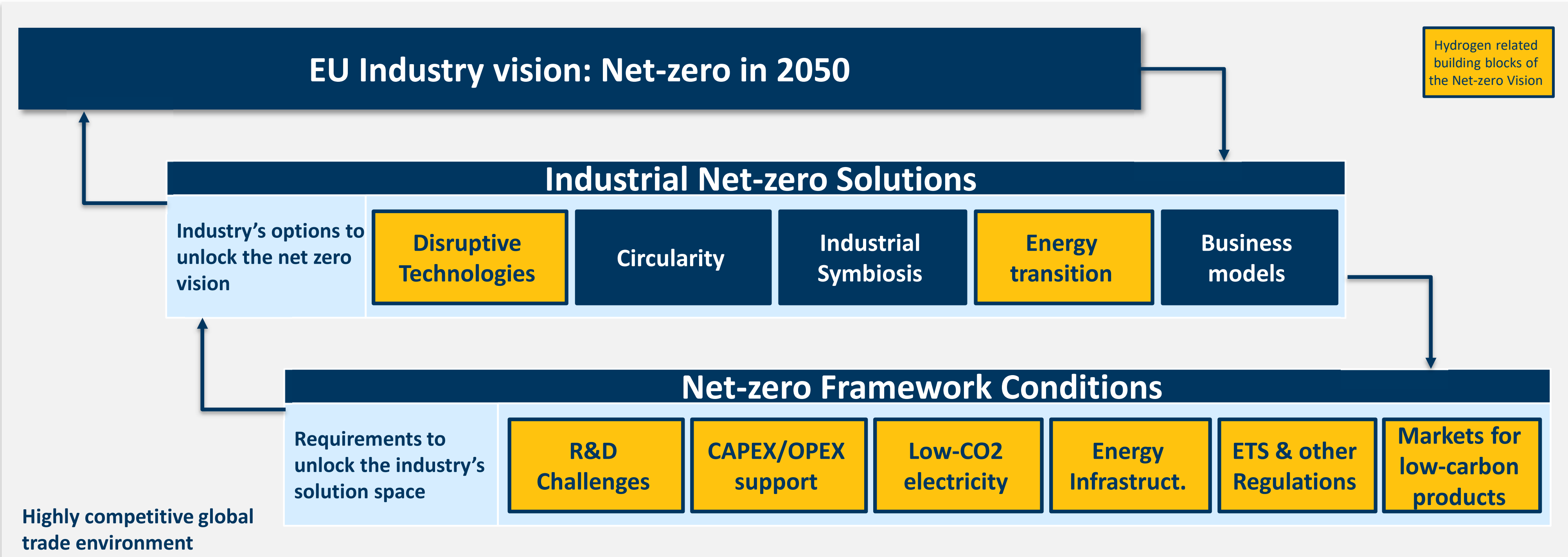
Industrial vision of Net-zero

Hydrogen is part of the energy transition



Industrial vision of Net-zero

Hydrogen is part of the energy transition



The challenge is huge: Making hydrogen a low carbon fuel affects the majority of the industrial net-zero vision's building blocks

FEDIL

The Industry’s carbon neutral ambition 2050

The top three potential are in electrification, hydrogen and CCU/S

	Key levers	Potential contribution for industrial CO2 reduction by 2050, %	Example applications
1	Electrification of heat	~35-40%	Electric furnaces, boilers, and heat pumps (e.g., use high-temperature heat pumps in the drying process of ceramics producer)
2	Hydrogen as fuel or feedstock	~25-30%	Used as a feedstock or a source of high-temperature heat (e.g., Yara Clean Ammonia unit)
3	CCU/S	~20-25%	Mainly in industries with high- to median- CO2 concentration streams (e.g. chemicals, steel, cement)
4	Biomass as fuel or feedstock	~10-15%	Solid biomass, biogas and biomethane used as a substitute to fossil feedstocks and fuels (e.g., bio-coal for steelmaking at Arcelor Mittal’s Ghent plant)
5	Energy efficiency	~5-10%	Upgrades to best available technology (BAT) and use of waste heat (e.g., upgrades at CF Fertilizers to provide high-efficiency steam)
6	Demand circularity	~1-5%	Recycling of plastics and other chemical products, glass and metals (e.g., Total’s recycled polypropylene plants)
7	Other innovations	~1-5%	Other technologies such as waste as fuel, inert anode technology in smelting, geothermal heat

Source: BBR membership and industry interviews

Constrains of ambitious industrial decarbonisation

Decarbonisation strategies need to preserve industrial competitiveness

- Electrification of heat
- Hydrogen as fuel or feedstock
- CCU/S
- Biomass as fuel or feedstock
- Energy efficiency
- Demand circularity
- Other innovations

- Despite the hype, hydrogen is one of many possible decarbonisation technologies
- Two of the top three decarbonisation technologies (H2 & CCU/S) are new for many industrial applications
- All technologies, and in particular hydrogen and CCU/CCS come with unknown economic and technical constrains and require enormous upfront investments*

Industrial decarbonisation strategies need to strike the right balance between environmental ambitions and industrial competitiveness

FEDIL

*The energy transition is less than 10% complete, measured by the share of cumulative energy-investment needed by 2050, source: The Economist June 12th 2021, page 9

Industrial decarbonisation strategies

Call for technology neutrality

Three Technology Neutral Principles:

1. Protect against carbon leakage and maintain industry's competitiveness in global trade

2. Support low-carbon investment (R&D & CAPEX, OPEX) into industrial scale technologies

3. Achieve the climate targets cost-effectively without high additional costs

Scope: EU Emissions Trading Scheme (ETS) Industry

Luxembourg’s CO2 emissions 2017 per sector

ETS sectors have different CO2 reduction targets than other national sectors

Data of 2017, source: PNEC

Three Technology Neutral Principles

For industrial decarbonisation strategies

Scope: Industrial ETS Sector

1. Protect against carbon leakage and maintain industry's competitiveness in global trade
2. Support low-carbon investment (R&D & CAPEX, OPEX) into industrial scale technologies
3. Achieve the climate targets cost-effectively without high additional costs

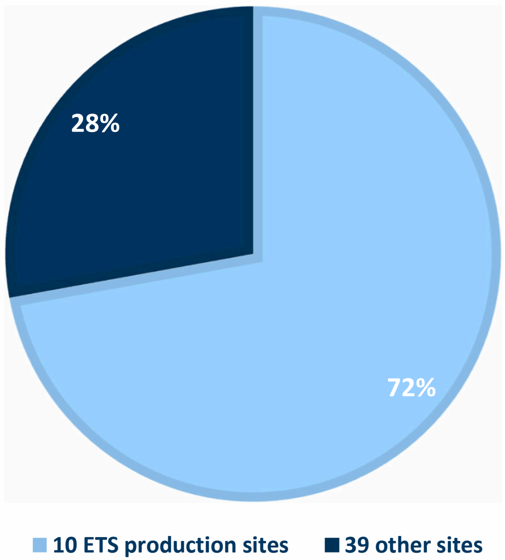
Luxembourg's main ETS companies (I/II)

Nearly 10 thousand jobs

GOODYEAR
ArcelorMittal
GUARDIAN GLASS
Cimalux Ciments & Matériaux
DUPONT
LIBERTY

Total employment of all six companies in 2021: 9.634

5 from 6 companies are exposed to risk of carbon leakage (6.000+ employment = 16% of all industry jobs)



6 companies

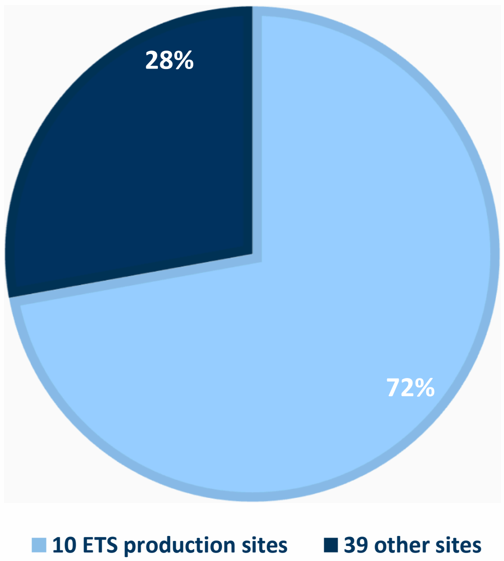
10 ETS production sites

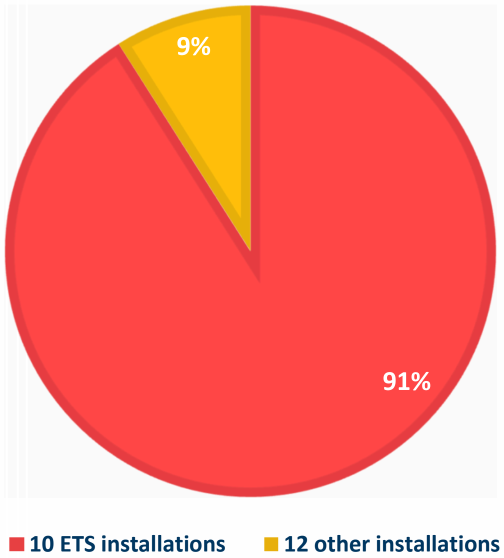
72% of energy in VA*

*Voluntary Agreement, data: 2017-2019 average consumptions of all forms of energy

Luxembourg's main ETS companies (II/II)

What does the delegation represent?





High temperature processes:

- Glass oven: 1700 °C
- Steel melting furnace: 1600 °C
- Steel rolling mills: 1200 °C
- Clinker rotary kiln: 1450 °C
- Tires and plastics: 150 – 250 °C

Main emission sources:

- Natural gas combustion
- Primary and alternative fuels
- Limestone decarbonation

72% of energy in VA

91% of ETS* emissions

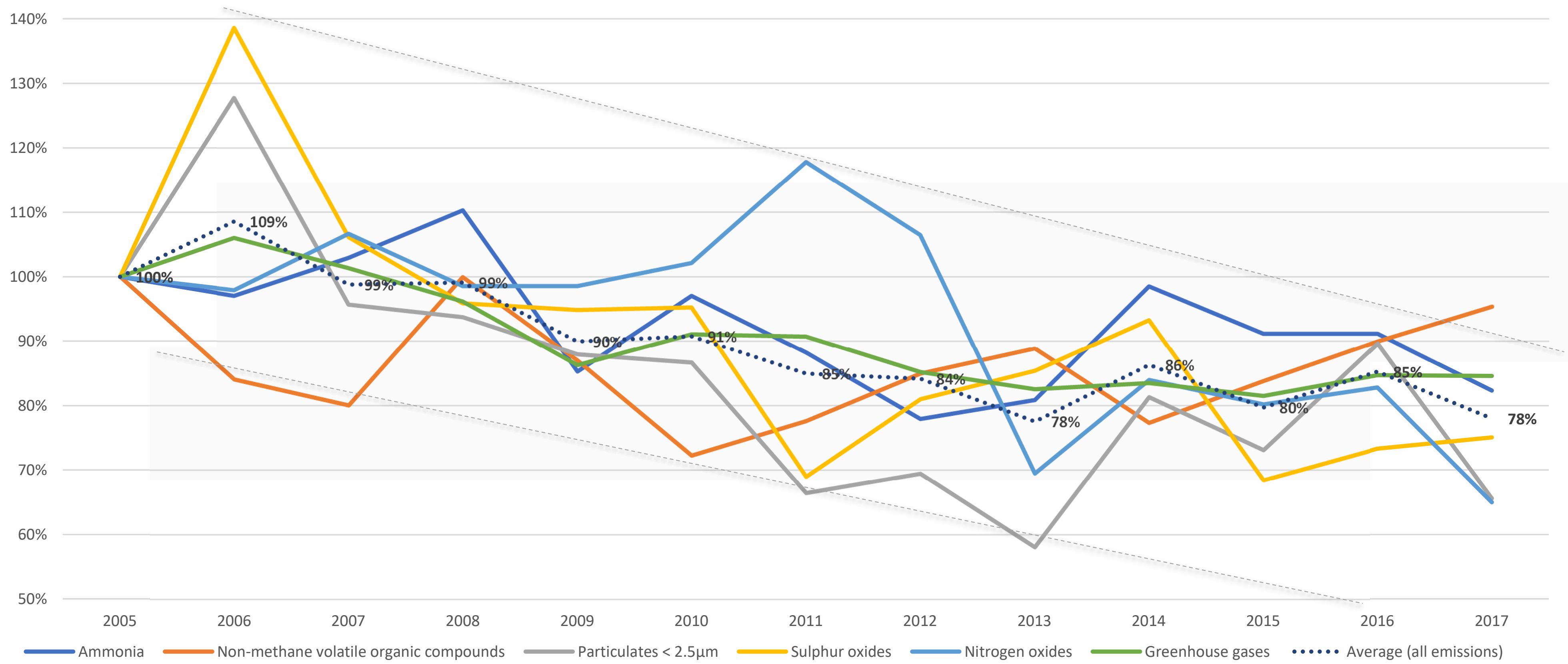
Energy consumption & emission sources

FEDIL

* National ETS emissions in 2020; source: Admin. de l'Environnement

Luxembourg's manufacturing industry

Emissions decreased by -22% on average (2005 - 2017)



Emissions measured in Luxembourg's manufacturing industry are steadily decreasing

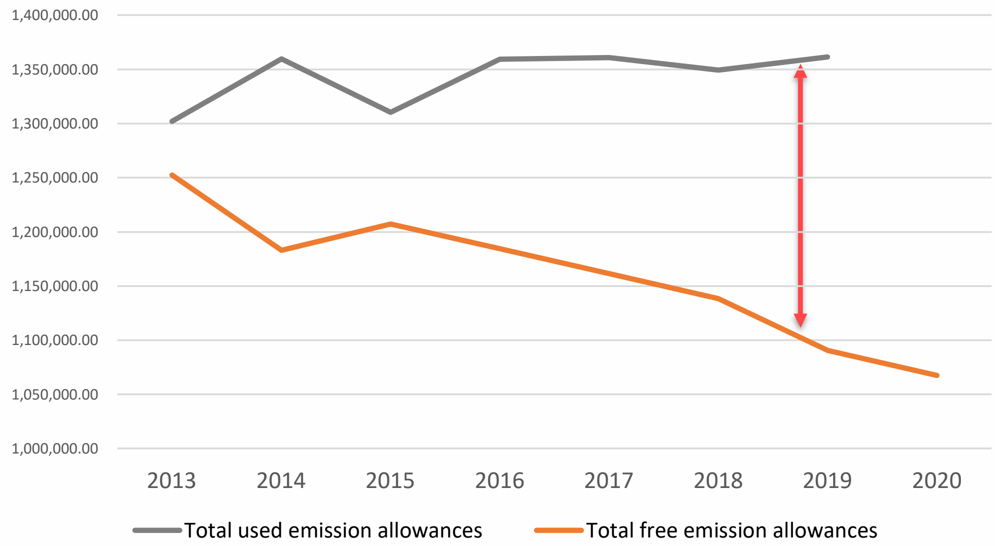
FEDIL

Source: STATEC 2020

Impact of the ETS system

What direct emission costs does the ETS system entail for Luxembourg's ETS sector?

The number of non-free allowances needed by the six companies is sharply rising [tonnes CO2]



The EUA price has quadrupled in three years [€/tonne]

The EU ETS system is expected to cost at least €15Mio. to the six companies in 2021*. With continuously rising EUA prices the EU EII is increasingly exposed to the risk of carbon leakage

FEDIL

* In 2021, estimated 300.000 non-free allowances are needed @ 50€/tonne

EU Energy Intensive Industry's contribution

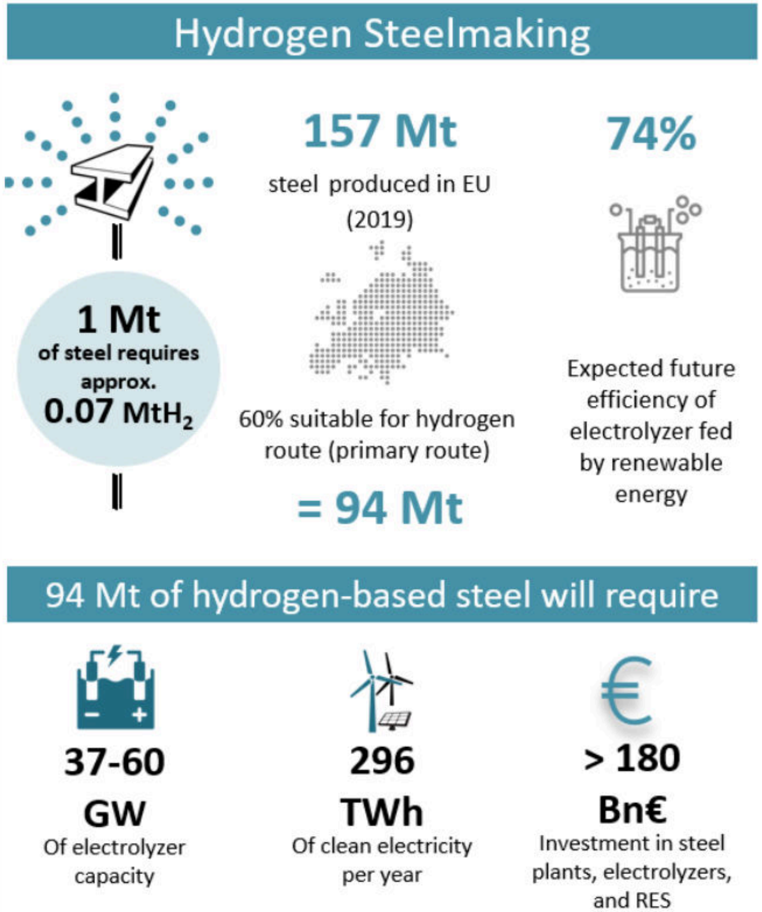
Greenhouse gas emissions reduced by -36% (1990 - 2015)

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**

Source: Tomas Wyns et al, Industrial Value Chains, 2019

Climate constrains vs low carbon solutions

Example of green steel making

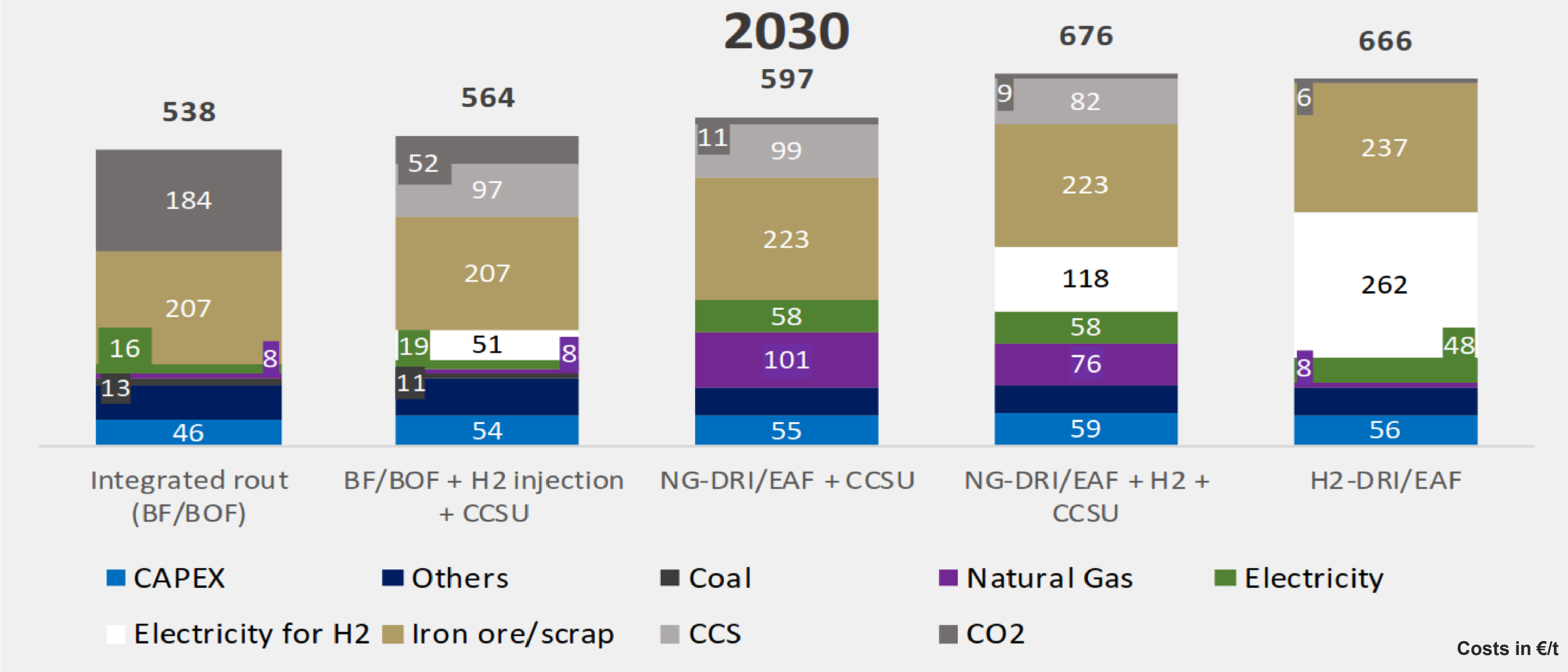


- **94 Mt of steel produced in Europe originates from blast furnace (BF) / basic oxygen furnaces (BOF) is suitable for H2 reduction (DRI) instead of coal**
- **It would require approx. 37-60GW of electrolyser capacity producing 6.6Mt H2 /year**
- **In 2030 the EU Hydrogen Strategy aims to have 40GW of electrolyser capacity installed requiring 296TWh of green electricity**
- **Reference: in 2020 Germany produced a total of 176TWh of green electricity**
- **The DRI technology is expected to reach commercialisation at large capacities only by 2035**

Source: Carbon-free steel production, EPRS, April 2021

Steel production cost breakdown by production route

Green steel has a huge impact on international competitiveness of EU Steel makers



Innovative steel making routes will increase the end-product costs by up to 24% for EU manufacturers in 2030

FEDIL

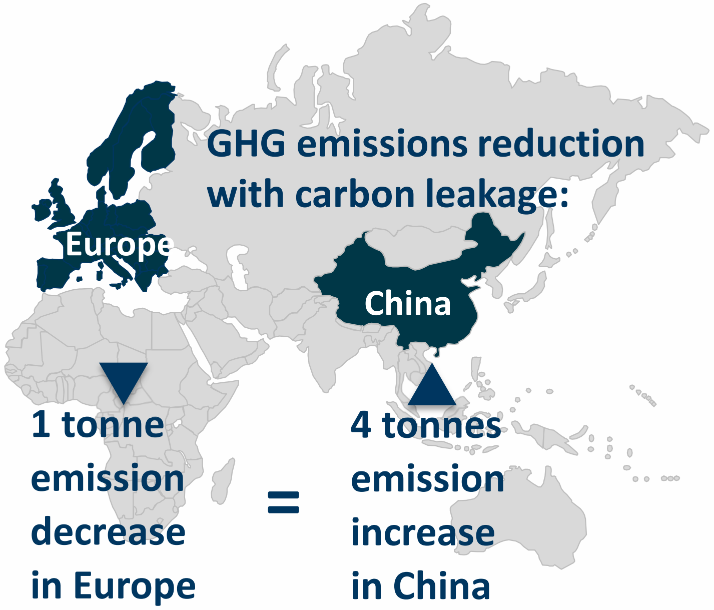
The calculation assumes an EU ETS of €84 /ton of CO_2 in 2030 for all production routes
Source: Carbon-free steel production, EPRS, April 2021

Principle 1 (recap)

Avoid carbon leakage by safeguarding the competitiveness of sectors exposed to global competition while they invest in low carbon technologies

Carbon leakage is real: example Aluminium production

- The EU lost a third of its total primary aluminium output between 2002 and 2016
- In 14 years, more than 10 smelters have closed up shop
- EU's primary aluminium production of 3 million tonnes in 2002 is down to 2.1 million in 2017
- During the same time (2002-2017), world aluminium demand increased by 32,2%
- Domestic production only satisfies around 30% of total consumption, making the EU reliant on 70% imports
- In aluminium production, greenhouse Gas (GHG) emissions in China are 4x greater than in Europe



Sources: Aluminium Insider (2019); Euractive.com, Stopping the demise of Europe's aluminium industry, 2019

Three Technology Neutral Principles

For industrial decarbonisation strategies

Scope: Industrial ETS Sector

1. Protect against carbon leakage and maintain industry's competitiveness in global trade
2. Support low-carbon investment (R&D & CAPEX, OPEX) into industrial scale technologies
3. Achieve the climate targets cost-effectively without high additional costs

Life cycle thinking (I/III)

A virtuous cycle of decarbonisation lead by constant innovation

Flat Glass:

A climate neutral EU by 2050 will demand more glass

*In buildings, the CO2 emitted to produce an energy efficient double glazing window is offset within 6 to 20 months by its energy savings**

Energy efficient buildings and renovation: 80% of EU's flat glass is used in buildings

Clean vehicles: 15% of EU's flat glass is used in the automotive sector

Solar power & energy efficient appliances : 5% of EU's flat glass is used in solar panel & other appliances

- **Circularity**: Glass is an endlessly recyclable material
- **Resilience**: The EU glass processing and transforming industry provides jobs to 110.000 Europeans
- **Local sourcing:** 90% of EU's glass industry's raw material come from Europe

** Windows stay on buildings for an average of 40-50 years; source Glass Europe*

Life cycle thinking (II/III)

A virtuous cycle of decarbonisation lead by constant innovation

Steel:

Clean energy infrastructures & mobility will rely on low emission steel

Europe’s steel industry is the most advanced of its kind in the world, it is leading in environmental and climate performance.

Energy efficient buildings and infrastructures: 35% of EU’s steel consumption is used in buildings

Clean vehicles: 19% of EU’s steel consumption is used in the automotive sector

Renewable energy engineering: 15% of EU’s steel is used in mechanical engineering applications

- **Circularity:** Steel is 100% and infinitely recyclable
- **Resilience:** The EU steel industry provides directs jobs to 330.000 Europeans (+1.6Mio indirect jobs)

Life cycle thinking (III/III)

Industrial symbiosis, innovation and smart life cycle management for decarbonisation

Cement:

A pivotal material for constructing climate neutrality

Foundations of wind turbines, hydro-electric dams, passive housing, tidal power installations and new transport infrastructure all rely on the unique qualities of concrete and cement.

Tyres:

Tyres account for 20-30% of vehicle's energy consumption

The European tire industry is leading innovation in its industry.

Plastics:

The focus on end of life issues fall short of plastic's benefit across its entire life cycle

Lightweight, versatile and durable plastics can help save key natural resources, energy and water in strategic sectors.

Industrial symbiosis:

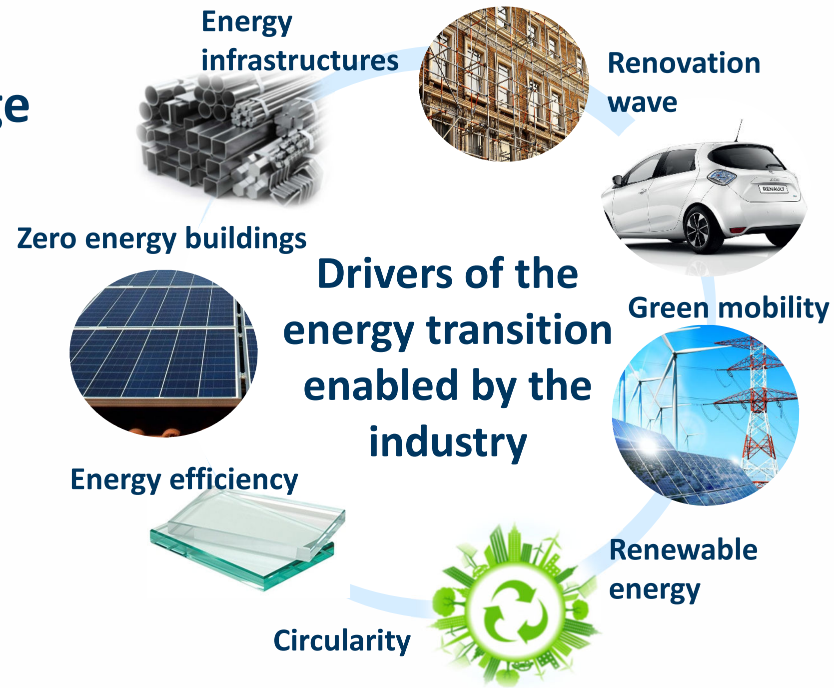
End of life tires and non-recyclable plastics used as alternative fuels for the cement industry

Principle 2 (recap)

Support low-carbon investment (R&D & CAPEX, OPEX) into industrial scale technologies

The EU Energy intensive industry is pivotal to reach carbon neutrality and to fight against climate change

- The introduction of low carbon fuels is dependent on novel breakthrough technologies at an industrial scale*
- The industry has to carry the burden of the transition:
    1. Developing green technologies to an industrial scale;
    2. Investing the upgrading of installations;
    3. Operating them at higher costs than conventional technologies
- State aid rules and subsidies need to be adapted to match the magnitude of the energy transition's challenge
- Create markets for low carbon products by including green public procurement criteria



* For net-zero 2050, almost half the reductions come from technologies that are currently only at the demonstration or prototype phase, source: IEA: Net Zero by 2050, May 2021

Three Technology Neutral Principles

For industrial decarbonisation strategies

Scope: Industrial ETS Sector

1. Protect against carbon leakage and maintain industry's competitiveness in global trade
2. Support low-carbon investment (R&D & CAPEX, OPEX) into industrial scale technologies
3. Achieve the climate targets cost-effectively without high additional costs

Gradually develop energy transition options

Technology neutrally promote most time and cost-effective options as available

Prioritisations is necessary to develop sourcing and transport options time- and cost-effectively <u>during a transition phase</u>

Prioritisation of sourcing options

1. EU imported low carbon hydrogen with and without CCU(S)
2. National hydrogen production from grid electricity with and without guarantees of origin (Pilots)
3. Consider alternative national hydrogen production f. ex. from local waste
4. Additionality must be introduced gradually and not as a precondition
5. Engage in energetically efficient and cost effective sourcing projects with third counties

Prioritisation of transport options

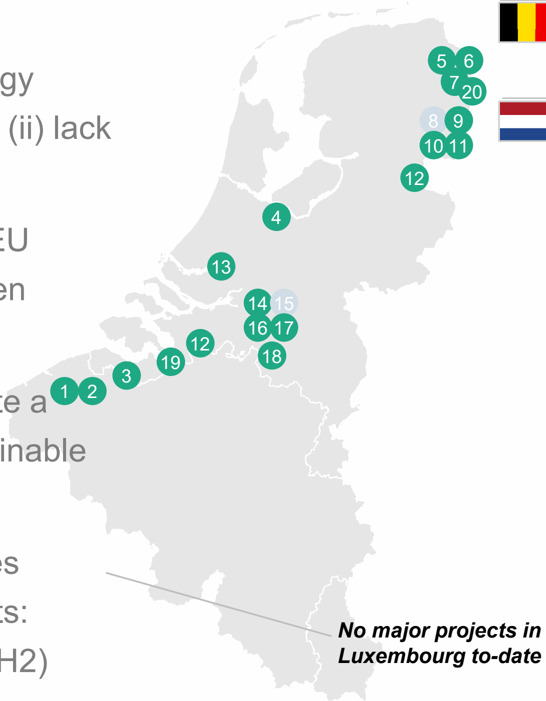
1. Participate in transnational hydrogen grid projects to rapidly gain access to interconnection opportunities
2. Support transport of all types of hydrogen in the national grid
3. Engage in low carbon hydrogen transport infrastructure projects – do not restrict to renewables only
4. Injection of hydrogen into the gas grid must be considered during the transition phase

→ **Gradual "greening" of options until international market dynamics establishes**

Large scale Hydrogen projects in Benelux

Accumulating decarbonisation knowledge gap in Luxbg: Risk of carbon leakage

- Existing projects are significantly underestimated due to (i) technology maturity (early-stage projects) and (ii) lack of public information
- Compared to other Benelux and EU Member States: No major Hydrogen projects in Luxembourg;
- Luxembourg is about to accumulate a huge knowledge gap in both sustainable molecules and CCU technologies
- Merely two Luxembourg companies participating in all identified projects: Arcelor Mittal (CCU), Paul Wurth (H2)



Country	Project* Name	Company Name
	1 Hyport - Phase 1	DEME, Port of Oostende, PMV
	2 Hyport - Phase 2	DEME, Port of Oostende, PMV
	3 Hyoffwind	Eoly (Colruyt), Parkwind, Fluxys
	4 Ijmuiden	Tata Steel, Nouryon, Port of Amsterdam
	5 Delfzjil Project Phase 1	Nouryon, Gasunie
	6 Delfzjil Project Phase 2	Nouryon, Gasunie
	7 DSL-1 (H2 supplied by Delfzjil Phase 2)	SkyNRG, KLM Royal Dutch Airlines, SHV Energy and Amsterdam Airport Schiphol
	8 Magnum (H2M)	Vattenfall, Equinor, Gasunie
	9 NorthH2	Shell, Gasunie, Groningen Seaports, Equinor, RWE
	10 RWE Eemshaven power station	RWE, innogy
	11 HyNetherlands	Engie, Gasunie
	12 SinneWetterstof Hydrogen Pilot Project	Alliander, BayWa re
	13 PosHYdon pilot	Gasunie, Poseidon Energy, TAQA, EBN B.V., NAM, NOGAT B.V., Noordgastransport B.V, Nextstep, TNO
	14 H2 backbone Port of Rotterdam	Port of Rotterdam, Gasunie
	15 H-Vision Phase 1	Deltalinqs, TNO, Air Liquide, BP, EBN, Engie, Equinor, Gasunie, GasTerra, Linde, OCI Nitrogen, Port of Rotterdam, Shell, TAQA, Uniper and Koninklijke Vopak
	16 Multiphly	CEA, Neste, Paul Wurth, Engie
	17 Tweede Maasvlakte at port of Rotterdam	Shell, Eneco
	18 H2-Fifty	BP, Nouryon, Port of Rotterdam
	19 Sluiskil Ammonia plant	Orsted, Yara
	20 Hystock	Gasunie

Creating no viable decarbonisation options via Hydrogen or CCU (next slide) techn. for sectors as prominent in Luxembourg as cement, glass and steel exposes them to the risks of investment- and carbon leakage

FEDIL

*Including large-scale projects with focus on infrastructure for heavy industry, but excl. smaller-scale research initiatives (e.g., lab R&D by individual players) or non-industrial end-uses (e.g, fuel cell-based mobility)

Diagram source: Benelux Business Roundtable, April 2021: How Benelux's industry and power sector could become carbon neutral by 2050

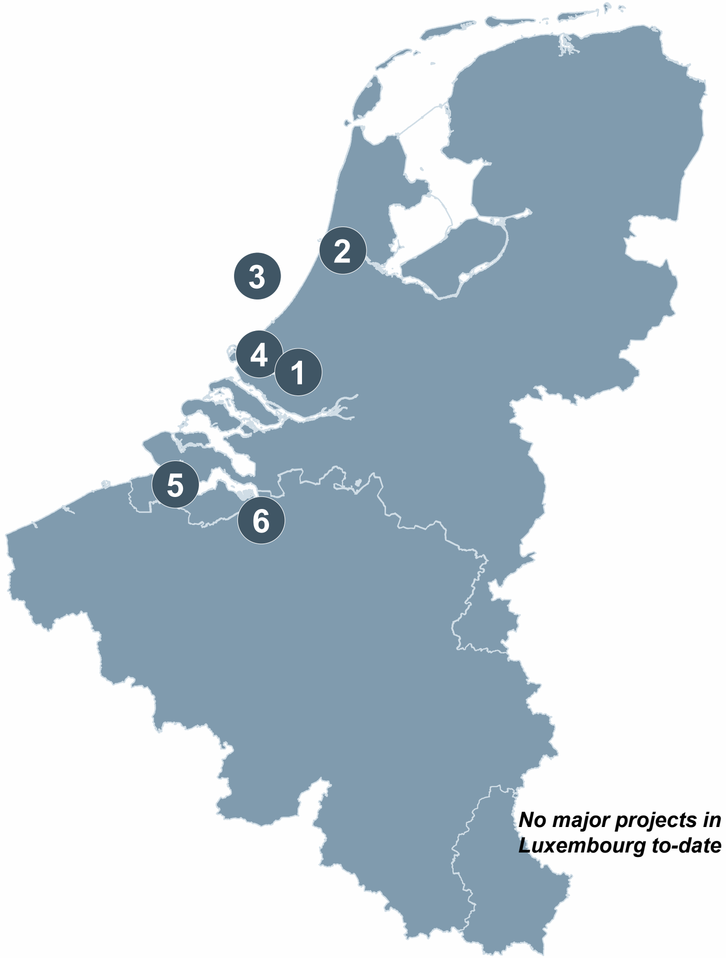
Overview of large-scale CCS projects in the Benelux

Currently ongoing large-scale projects

Carbon capture | Transport (pipeline) | Transport (ship) | Use | Offshore storage

Project	Scope	Capture Capacity	# CO2 suppliers	Source of supply
1 Porthos	Carbon capture, Transport (pipeline), Offshore storage	2.5 Mtpa (2023) 10 Mtpa (optional phase 2)	4	Air Liquide, Air Products, Shell and ExxonMobil
2 Athos[1]	Carbon capture, Transport (pipeline), Offshore storage, Use	4-5 Mtpa (2030)	1	Tata Steel
3 Aramis	Offshore storage	N.A.	N.A.	N.A.
4 H-Vision	Carbon capture, Transport (pipeline), Offshore storage, Use	2.2 Mtpa (2026) 4.3 Mtpa (2031)	5	Shell, ExxonMobil, BP, Equinor, Air Liquide
5 Carbon Connect Delta	Carbon capture, Transport (pipeline), Transport (ship)	1 Mtpa (2023) 6.5 Mtpa (2030)	5	Arcelor Mittal, Dow, Yara, Zeeland Refinery and PZEM
6 Antwerp@C	Carbon capture, Transport (pipeline), Transport (ship)	~9 Mtpa (2030)	6	Air Liquide, BASF, Borealis, ExxonMobil, Ineos and Total)

Total capacity >20Mtpa[2] by 2030



1. Includes the Everest project from Tata Steel which is the carbon capture segment of the Athos project
2. Assuming all projects will come online

FEDIL

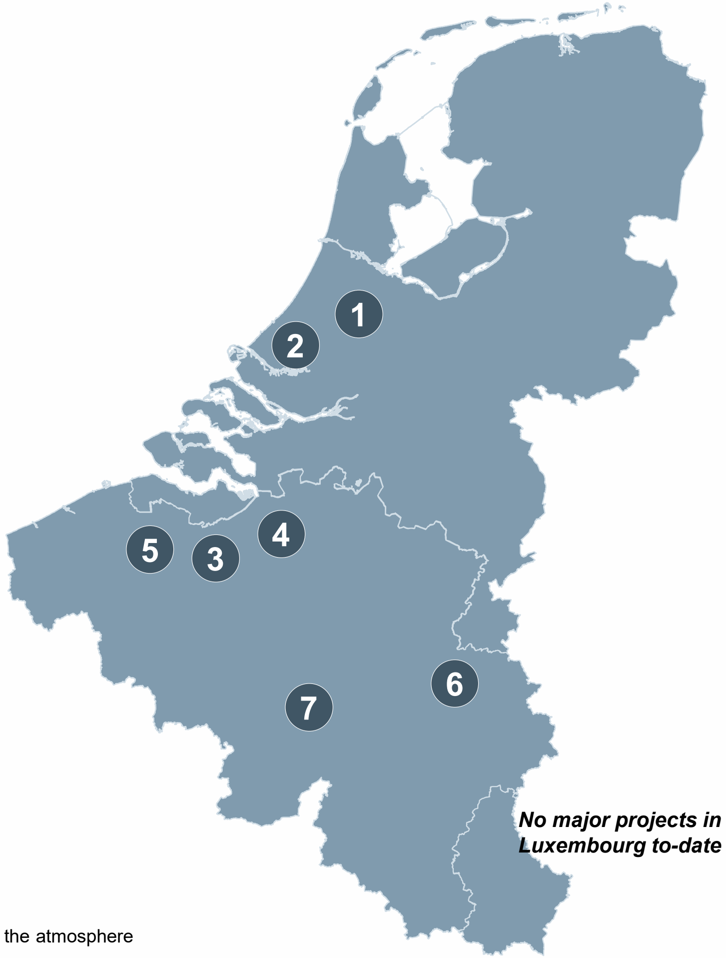
Source: Benelux Business Roundtable, April 2021: How Benelux's industry and power sector could become carbon neutral by 2050

Pilot & industrial scale CCU/S projects in the Benelux

Currently ongoing pilots and industrial-scale demonstrators

Carbon capture | Transport (pipeline) | Transport (ship) | Use | Offshore storage

Project	Scope	Key companies	CO2 source	CO2-based product	Start-up date
1 Basic Oxygen Furnace 2 Urea	Carbon capture, Transport (pipeline), Use	Arcelor Mittal, TNO	Steel (0.1 mtpa)	Urea	
2 Renewable Jet Fuel from air	Carbon capture, Transport (pipeline), Use	EDL	Direct air capture	E-kerosene (~300t p.a.)	
3 North -C-Methanol	Carbon capture, Transport (pipeline), Use	Arcelor Mittal, Engie, Fluxys	Steel (0.07 mtpa)	E-methanol (~45,000t p.a.)	2024
4 Power-to-Methanol	Carbon capture, Transport (pipeline), Use	Engie, Fluxys, INOVYN		E-methanol (~8,000t p.a.)	2022
5 Steelanol	Carbon capture, Transport (pipeline), Use	Arcelor, Primetals, Lanzatech	Steel (0.2 mtpa)	Bio-ethanol (~65,000t p.a.)	2022
6 Leilac project[1]	Carbon capture	Heidelberg Cement	Lime (0.02 mtpa)		2019
7 Colombus	Carbon capture, Transport (pipeline), Use	Engie, John Cockerill, Carmeuse	Lime (0.02 mtpa)	E-methane	2025



1. The Leilac project focuses on improving capture technology for CO2 produced during the lime & cement production process. Captured CO2 is released into the atmosphere

Source: Benelux Business Roundtable, April 2021: How Benelux's industry and power sector could become carbon neutral by 2050

Principle 3 (recap)

Achieve the climate targets cost-effectively without high additional costs

- **Gradually transit towards green hydrogen**
- **Avoid the creation of a decarbonization knowledge gaps**
- **Intensify cooperation with Benelux partners:**
  - Develop an open-access cross border infrastructure for the import of green energy of sufficient scale and scope
  - Develop options for the transport of CO_2
  - Deepen regulatory convergence
  - Improve access to public and private funding to support realistic business cases
  - Increase of social acceptance for projects related the energy transition

Sources: Aluminium Insider (2019); Euractive.com, Stopping the demise of Europe's aluminium industry, 2019

Industry's net-zero 2050 vision

How do the principles contribute?

Scope: Industrial ETS Sector

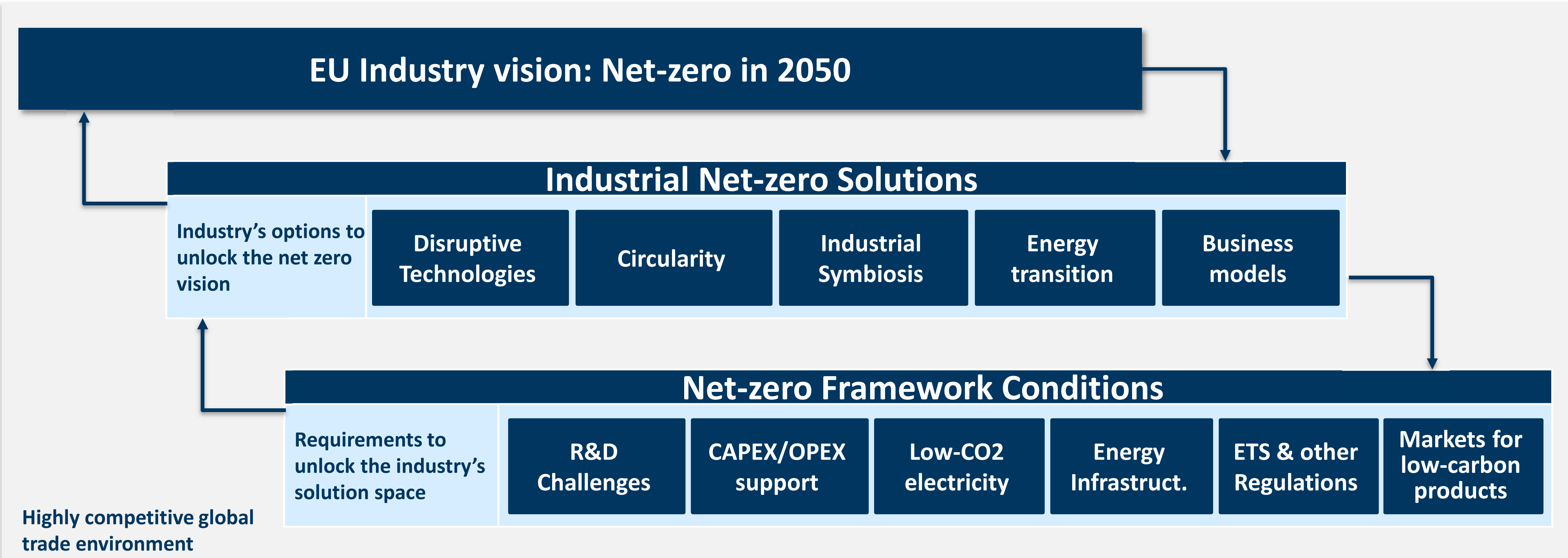
1. Protect against carbon leakage and maintain industry's competitiveness in global trade

2. Support low-carbon investment (R&D & CAPEX, OPEX) into industrial scale technologies

3. Achieve the climate targets cost-effectively without high additional costs

How do the principles contribute?

Principles each tackle different framework conditions opening options for the Industry



How do the principles contribute?

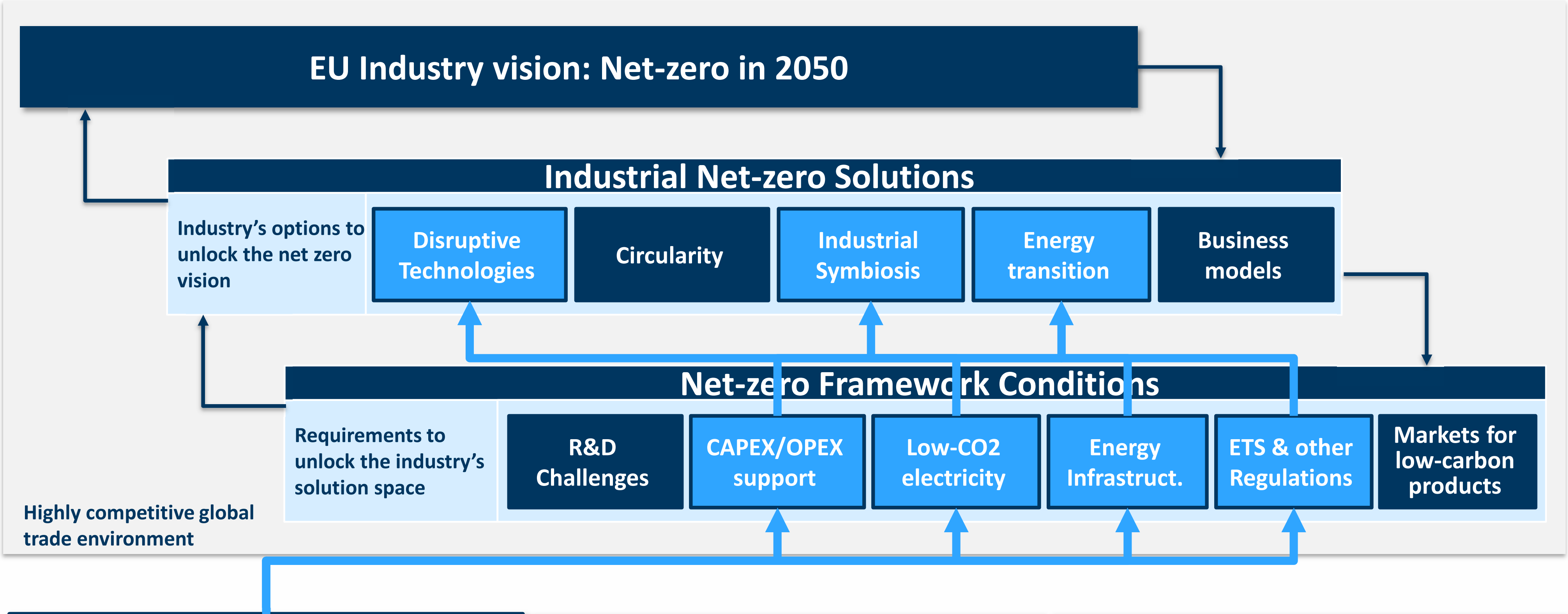
a) **Achieve the climate targets cost-effectively** without high additional costs

b) **Protect against carbon leakage** to maintain the competitiveness in a global trade

c) **Support low-carbon investment** (R&D, CAPEX, OPEX) into industrial scale technologies

Industrial vision of Net-zero

How do our proposals contribute (I/III) ?



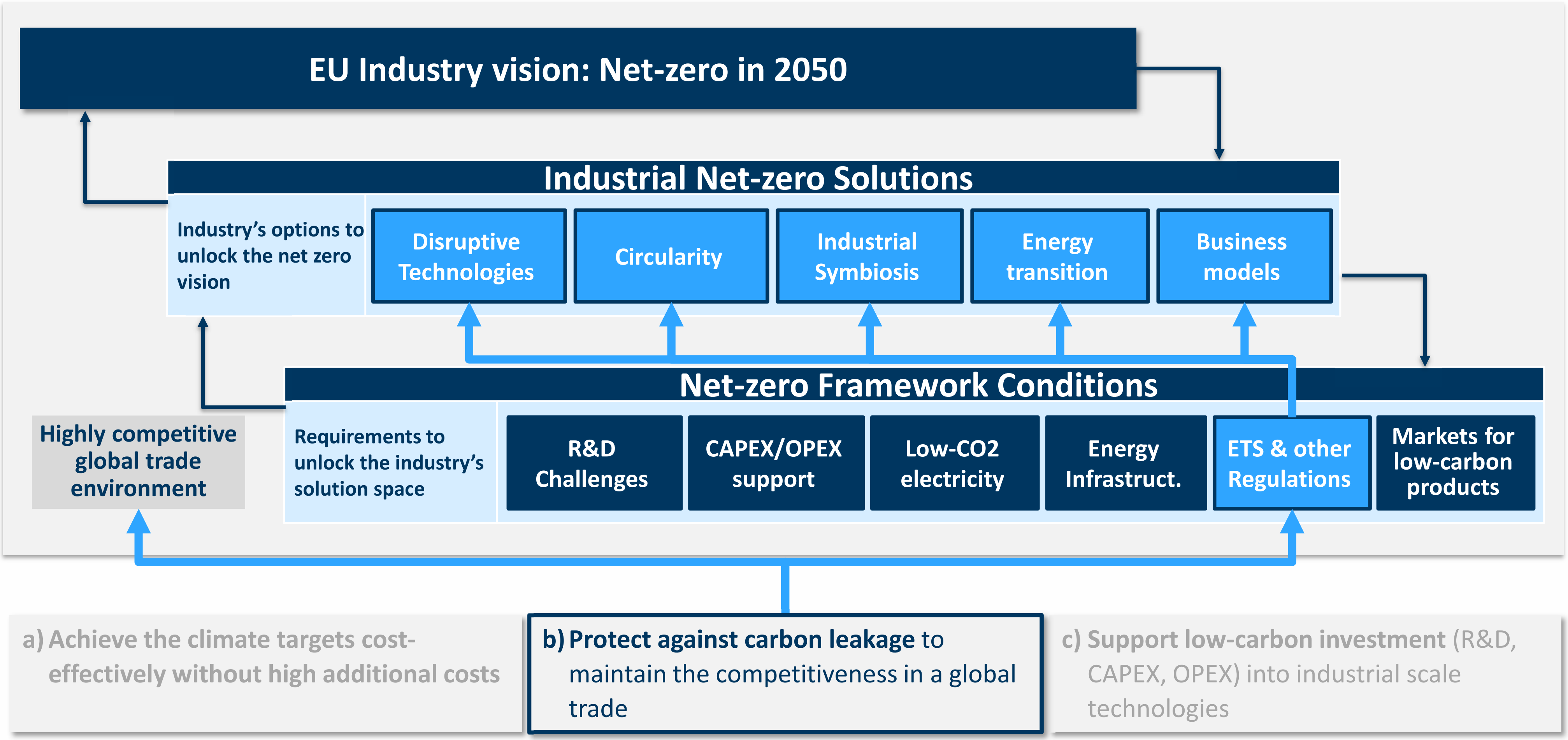
a) **Achieve the climate targets cost-effectively** without high additional costs

b) **Protect against carbon leakage** to maintain the competitiveness in a global trade

c) **Support low-carbon investment** (R&D, CAPEX, OPEX) into industrial scale technologies

Industrial vision of Net-zero

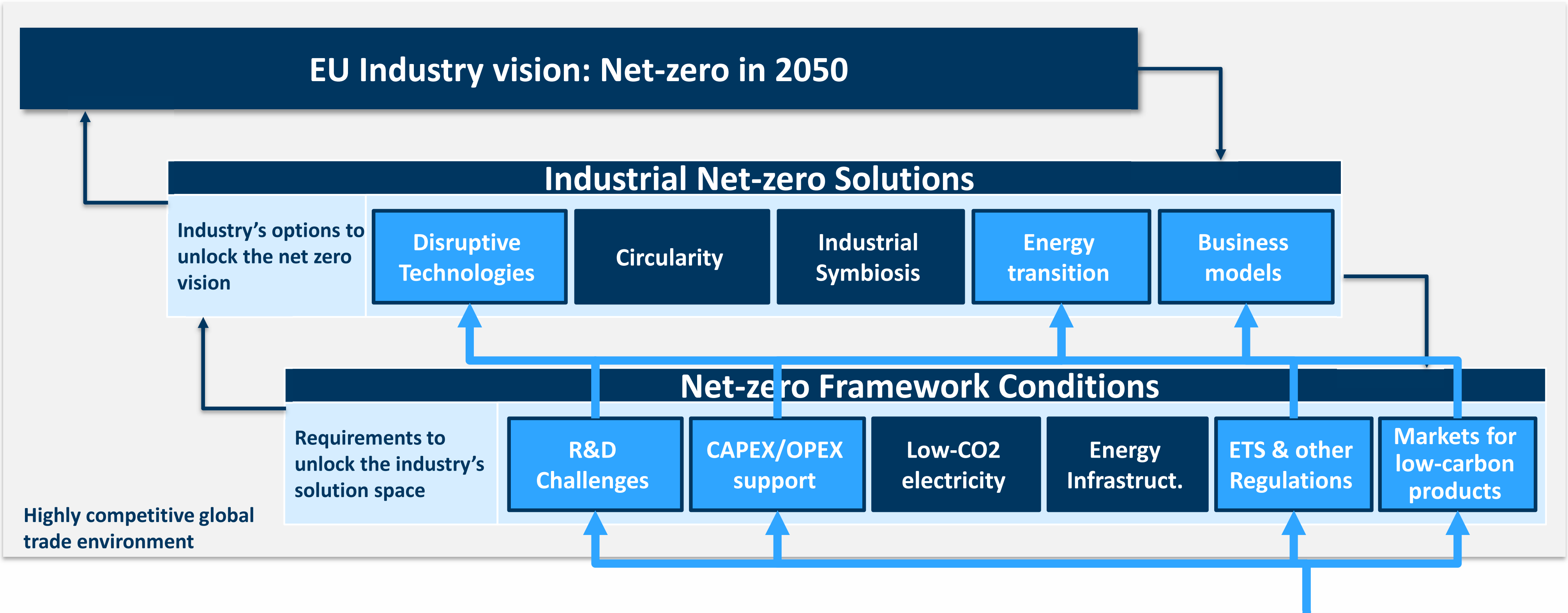
How do our proposals contribute (II/III) ?



FEDIL

Industrial vision of Net-zero

How do our proposals contribute (III/III) ?



a) Achieve the climate targets cost-effectively without high additional costs

b) Protect against carbon leakage to maintain the competitiveness in a global trade

c) **Support low-carbon investment** (R&D, CAPEX, OPEX) into industrial scale technologies

FEDIL

The Voice of Luxembourg's Industry

7, rue Alcide de Gasperi
Luxembourg-Kirchberg
Boîte postale 1304
L-1013 Luxembourg

fedil@fedil.lu
tel: +352 43 53 66-1
fax: +352 43 23 28
www.fedil.lu