Benelux Green Deal for Carbon Neutrality with focus on CCSU and Hydrogen

May 2020

Benelux Business
Roundtable

Executive summary

Benelux Green Deal for Carbon Neutrality with focus on CCSU & Hydrogen

The European Commission has recently presented its **Green Deal with the ambition to increase emissions reduction levels to reach 50-55% by 2030** and carbon-neutrality by 2050 vs. 1990 levels. To make this transition happen, the EC is envisioning **EUR 1,000 billion financing of which EUR 10 billion subsidies will be granted through the ETS Innovation Fund**[1].

Benelux is expected to play a pivotal role in Europe's decarbonization given the region's high emissions target (1.2x EU average) and high emissions density (3.7x EU average) combined with a high Innovation Score (1.3x EU average).

Whilst the Benelux area has made **significant progress** with next-generation low-carbon technologies such as **CCU/S and H2**, there remains a significant **gap between the required carbon abatement and technological capacity** coming online between now and 2050 – a **systematic approach to involve as many industrial players as possible in these technologies** is required.

Within this context, and based on initial conversations with industrial players and relevant political stakeholders, **BBR and its working members would like to play a facilitating role in stimulating cross-industry and cross-border decarbonization progress on 3 fronts:**

1. **Harmonization of cross-border regulation** with initial focus on the cross-border transport of CO2 and H2 and the set-up of an open access pipeline infrastructure;
2. **Acceleration of project impact by stimulating collaboration** through knowledge sharing, both between ETS projects (e.g., Project Porthos, Athos, CCUS Antwerp, CCUS Smart Delta Resources) and ETS and non-ETS projects – thus increasing the number of large-scale, cross-border, cross-sector projects and thereby potentially increasing eligibility for European funding;
3. **Development of a holistic industry decarbonization plan and perspective on associated energy system needs** that clearly outlines the path to carbon-neutrality across multiple time horizons, incl. an assessment of potential symbiosis between ETS non-ETS sectors.

Concrete next steps:

1. Write a **position paper on cross-border regulation harmonization** (key focus on CO2 and H2) consolidating inputs from all stakeholders – the intention is to finalize a **first version of this paper by end of May** to facilitate further stakeholder engagement ahead of the *Vlaams-Nederlandse top* on November 4, 2020;
2. On the basis of the current project landscape, **identify potential areas for collaboration** that could in the short-term provide operational benefits for all parties involved and which may in the mid-term improve eligibility for European funding;
3. **Confirm the need for a holistic industry decarbonization plan** with key actors from different industries and scientific partners

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1. Total subsidies depending on evolution of CO2 prices

Benelux industry climate action plan

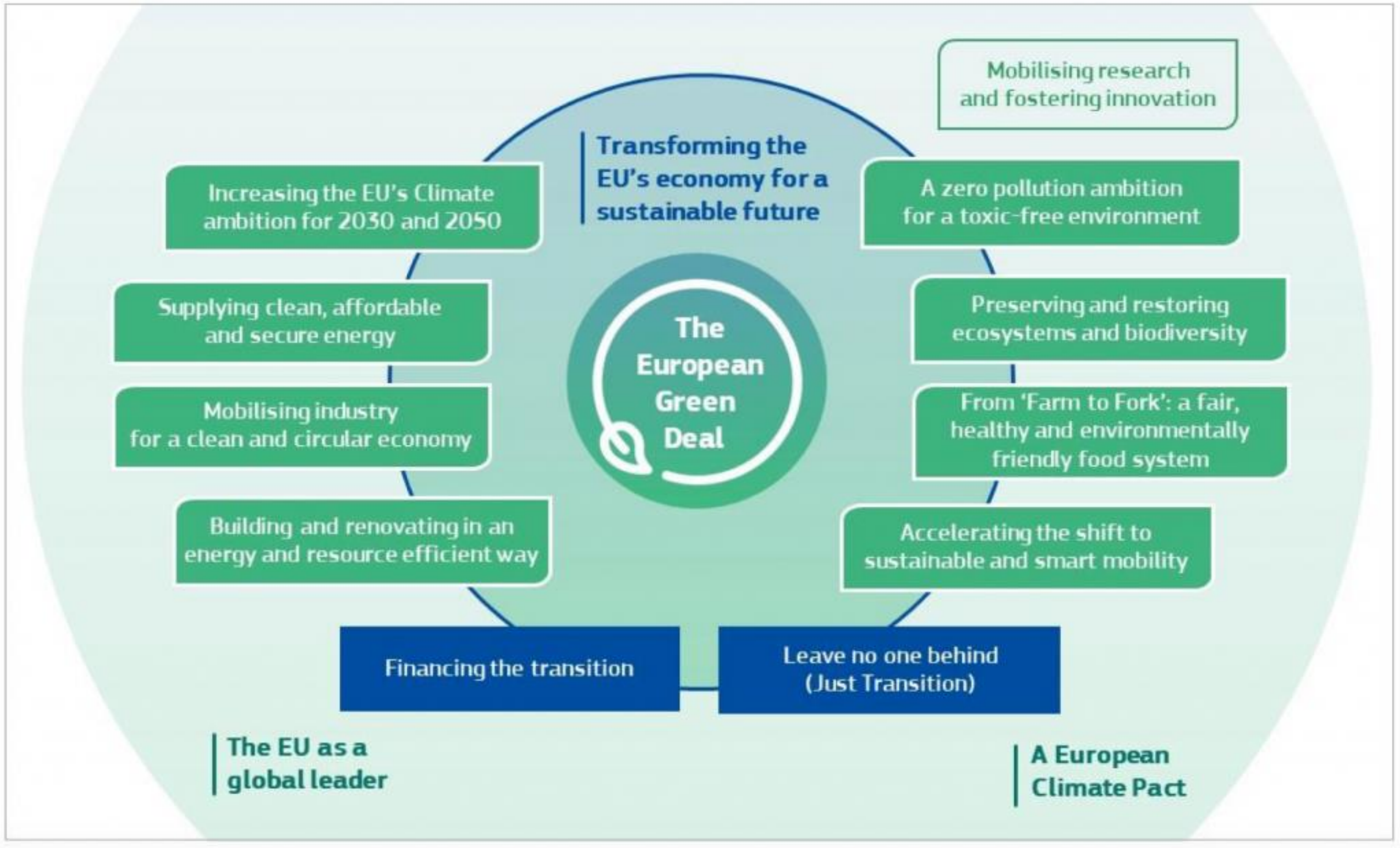
The bigger picture – European Green Deal

Benelux industry plan – Current status and partnership opportunities

Next steps

The Green Deal aims to transform EU's economy for a sustainable future

GREEN DEAL STILL TO BE APPROVED BY EUROPEAN PARLIAMENT AND MEMBER STATES



Key policies under consideration

Decarbonization: Carbon neutrality by 2050, -50 to 55% decarbonization by 2030

ETS[1] evolution: Reduction in ETS cap to increase from -2.2% p.a. to almost double

Changes to the ETS system: Buildings, marine and road transport to be added

Border Carbon Adjustment: Ensuring competitiveness of domestic producers ("level-playing field") as e.g. ETS prices go up in coming decade

Financing: 1tln EUR climate-related investment in the next decade

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1. Emissions Trading Scheme

Source: EC 2020 The European Green Deal communication

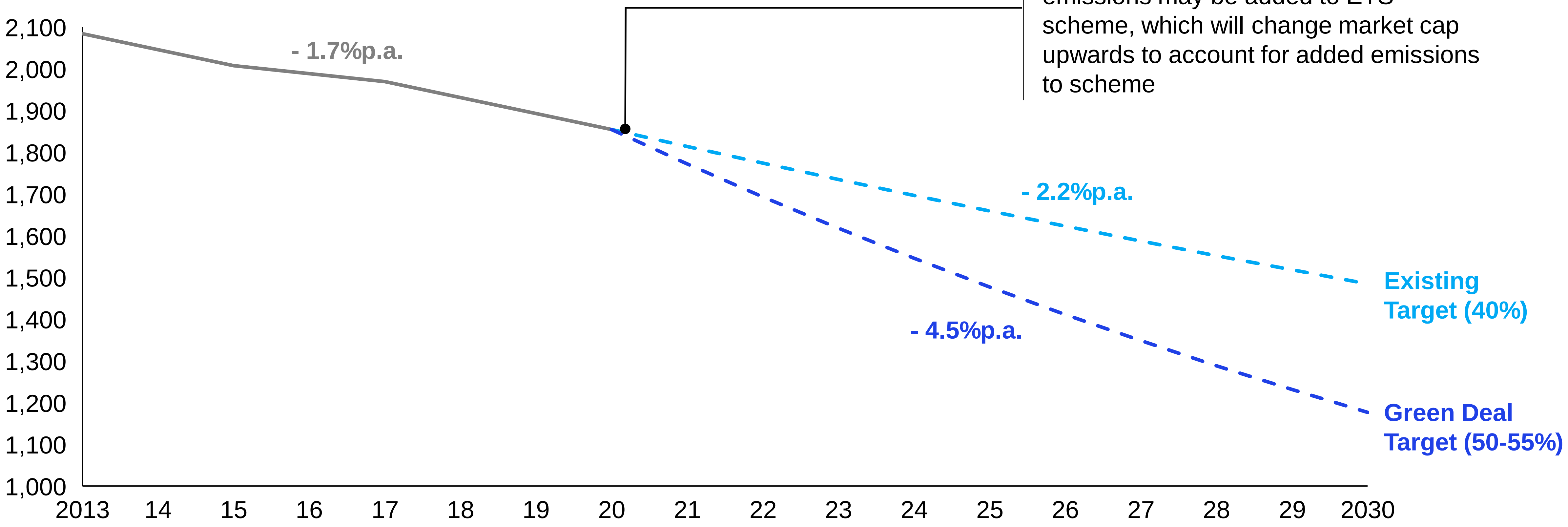
Under the EU Green Deal, the ETS cap would need to come down almost twice as fast by 2030 than under existing policy

MtCO2

GREEN DEAL STILL TO BE APPROVED BY EUROPEAN PARLIAMENT AND MEMBER STATES

ETS market cap

mln EUA (=MtCO2e)



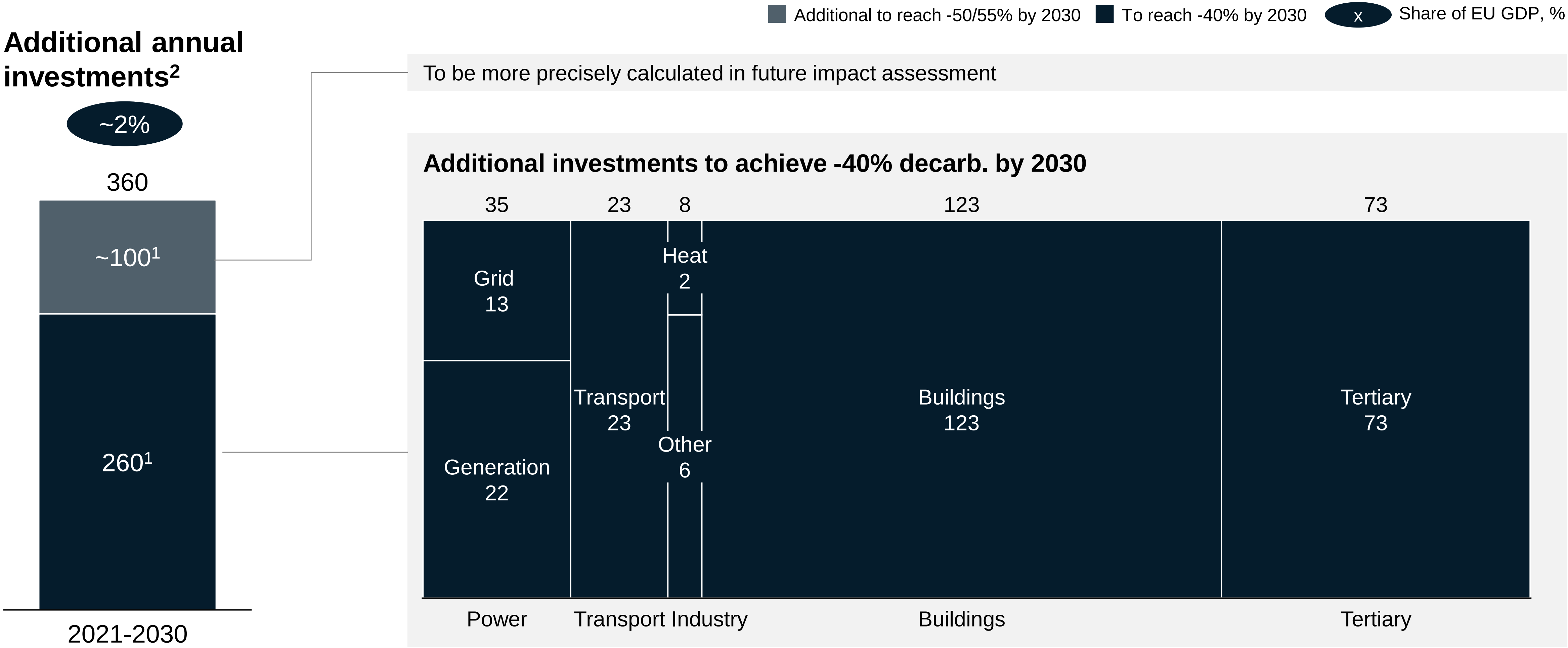
Policies under consideration

Buildings, marine and road transport emissions may be added to ETS scheme, which will change market cap upwards to account for added emissions to scheme

Source: EC 2020 The European Green Deal communication

Over 360 bln EUR of additional annual investments will be needed to reach the 2030 target

bln EUR, average 2021-2030



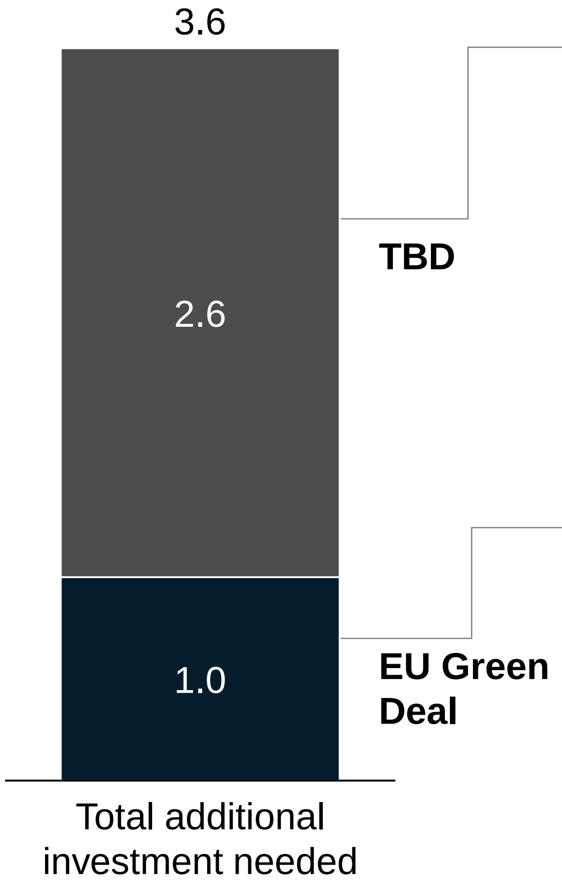
1. 260 bln EUR figure comes from extensive impact assessment on meeting -40% target by 2030, additional 100 bln EUR is assumed by commission as additional investment to meet -50/55% by 2030 (exact impact assessment on this will follow by summer 2020)
2. Versus baseline, where GHG -30% in 2030, -60% in 2050

Source: EC 2020 The European Green Deal communication; A Clean Planet for all, EC COM(2018) 773

The 1 tln EUR investment budget presented as part of thee EU Green Deal will account for ~30% of the additional investment need

tln EUR, cumulative between 2021 and 2030

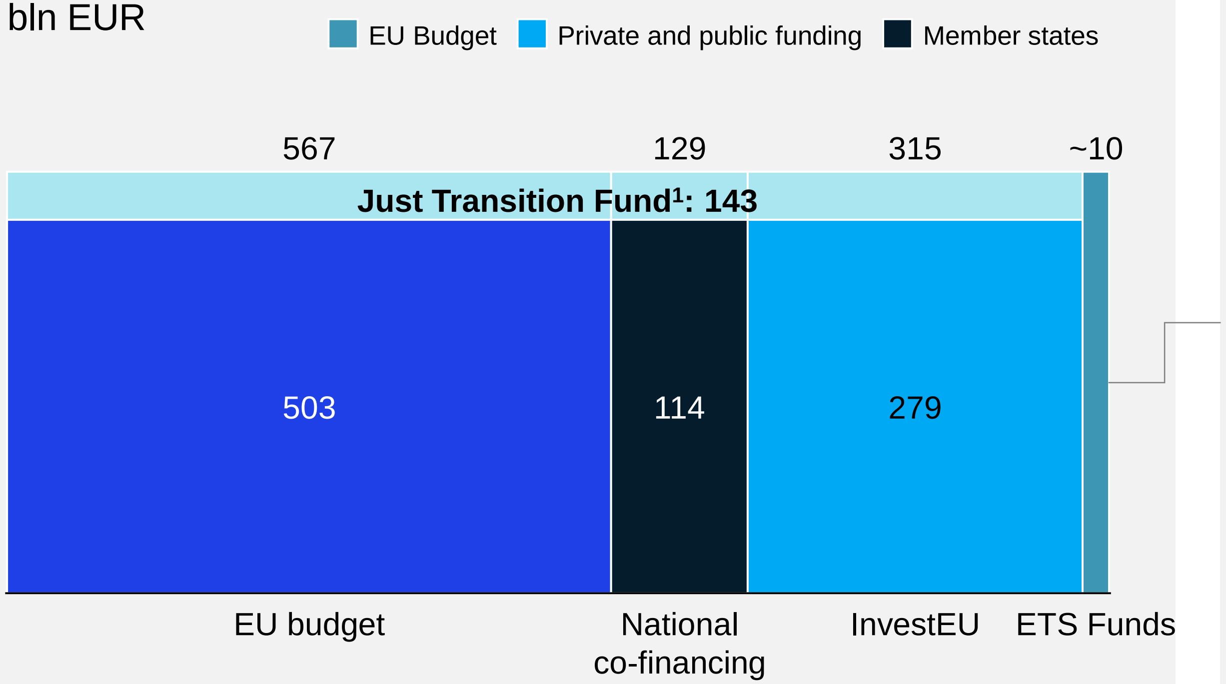
GREEN DEAL STILL TO BE APPROVED BY EUROPEAN PARLIAMENT AND MEMBER STATES



As of yet unclear where funding will come from

EU funding for EUR Green Deal

bln EUR



Key features of ETS funds

Project selection criteria

- GHG emissions avoidance
- Innovation level
- Project maturity
- Scalability
- Cost efficiency

Application milestones

- 09/20 Round 1 Application deadline
- 01/21 Round 1 Results
- 04/21 Round 2 Application Deadlines
- 10/21 Round 2 Results

+ **Further info in appendix**

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1. At least 80 bln EUR addtional funding required for the Just Transition Fund, in total at least 143 bln will go in Just Transition Fund (with potentially up to 63bln EUR overlap with other funding programs

Source: EC 2020 The European Green Deal communication; A Clean Planet for all, EC COM(2018) 773

Numbers not explicitly from EU Green Deal communications, but based on EC “Clean Planet for all” work that informed policy making

Moreover, large private investments that under BAU would go to conventional tech would need to be redirected to low carbon tech

tln EUR, cumulative between 2021 and 2030

Relative Sizes of Splits in Bar Charts Illustrative

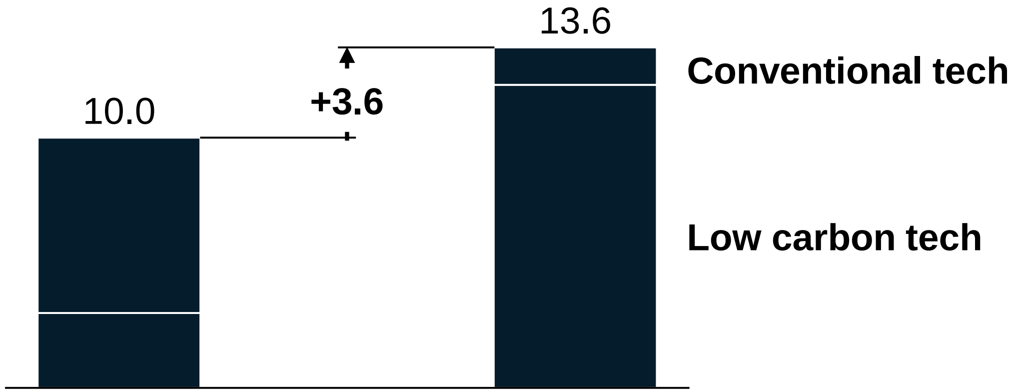
GREEN DEAL STILL TO BE APPROVED BY EUROPEAN PARLIAMENT AND MEMBER STATES

BAU

EU Green Deal targets[1]

Key insights

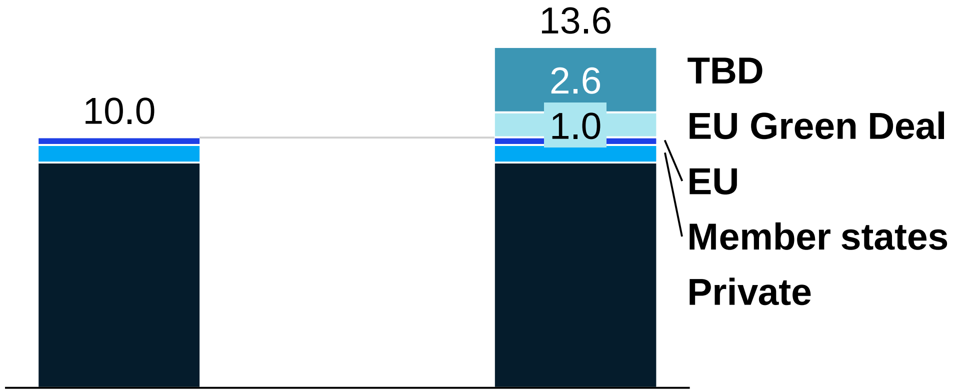
Investment need



To meet the EU Green Deal targets, total investments will need to go up by ~3.6 tln EUR over the 2021-2030 period

Most of BAU investments in conventional technologies needs to be redirected to low carbon technologies

Source of investments



The EU Green Deal plans to fill in 1 out of the 3.6 tln EUR additional investment need to 2030

The residual 2.6 tln EUR investment will need to come from member states or private parties – which collectively will need to increase their investments by 26% vs BAU

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1. -50% GHG reduction by 2030 vs 1990

Source: EC 2020 The European Green Deal communication; A Clean Planet for all, EC COM(2018) 773

Numbers not explicitly from EU Green Deal communications, but based on EC “Clean Planet for all” work that informed policy making

Post-2030, additional investments to reach carbon neutrality are twice as high as those required to reach the existing -80% target

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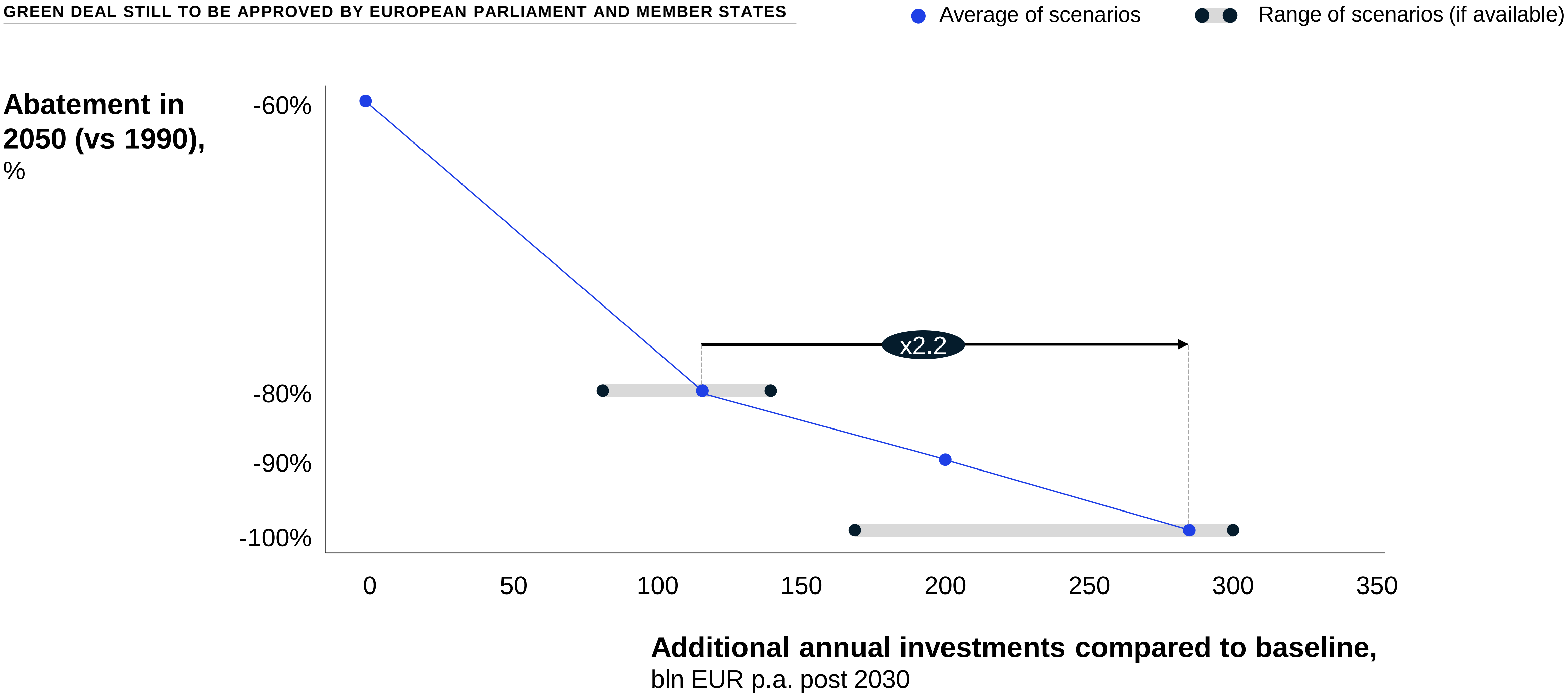


Source: A Clean Planet for all, EC COM(2018) 773

The EU Green Deal’s Roadmap has several critical milestones with direct relevance to Benelux industry

- ● The EU as a global leader
- ● Sustainable and Smart Mobility
- ● ‘Farm to Fork’
- ● Preserving and protecting Biodiversity
- ● Clean, affordable and secure energy
- ● Industrial Strategy for a clean and circular economy
- ● The European Climate Pact
- ● Climate Ambition
- ● Zero-pollution ambition
- ● Mainstreaming Sustainability
- ☐ Esp. relevant for Benelux

From 2020

- ● Initiatives stimulating lead markets for climate neutral & circular products for energy intensive
- ● Initiatives screen & benchmark green budgeting practices

From 2020

- ● Proposal on legislative waste reforms
- ● Measures for deforestation-free value chains
- ● Green Deal Agenda for Western Balkans
- ● Integration of SDG in European Semester

March 2020

- ● European Climate Law Proposal
- ● European Climate Pact Launch
- ● Biodiversity Strategy 2030
- ● Farm to Fork Strategy

June 2020

- ● National Energy and Climate Plans Assessment

Autumn 2020

- ● Renewed Sustainable Finance Strategy

By Q4 2020

- ● Building Sector ‘Renovation wave’ initiative
- ● Trans-European Network – Energy Regulation Evaluation & Review
- ● Strategy on off shore wind
- ● Review of the Non-Financial Reporting Directive
- ● 8th Environmental Action Programme Proposal
- ● Smart sector integration Strategy

From 2021

- ● Measures addressing biodiversity loss
- ● Initiatives increasing capacity of railways & inland waterways

By Q4 2021

- ● Examination of draft national strategic plans – F2F, Green Deal
- ● Review of State aid guidelines

By Q4 2021

- ● Revised proposal for a Directive on Combined Transport
- ● Review of Alternative Fuels Infrastructure Directive and the Trans European Network – Transport Regulation
- ● Proposal for carbon border adjustment mechanism
- ● Proposal on air pollutant emission standards for combustion-engine vehicles

From 2020

- ● Funding call for public recharging and refueling points
- ● Legislative options assessment to boost sustainable alternative fuels production and supply
- ● Remedy incoherent legislation
- ● Strengthen EU Green Deal Diplomacy
- ● Bilateral efforts on action & policies comparability

January 2020

- ● Just Transition Mechanism Proposal
- ● Sustainable Europe Investment Plan

March 2020

- ● Circular Economy Action Plan: sustainable products initiative focusing on energy intensive sectors
- ● EU Industrial Strategy

Summer 2020

- ● Chemicals strategy for sustainability
- ● Plan to increase EU 2030 climate target (50%-55%)

October 2020

- ● Legislation on batteries supporting Strategic Action Plan on Batteries and circular economy

By Q4 2020

- ● Sustainable and smart mobility strategy
- ● Proposal to support zero-carbon steel-making processes by 2030
- ● New EU Forest Strategy

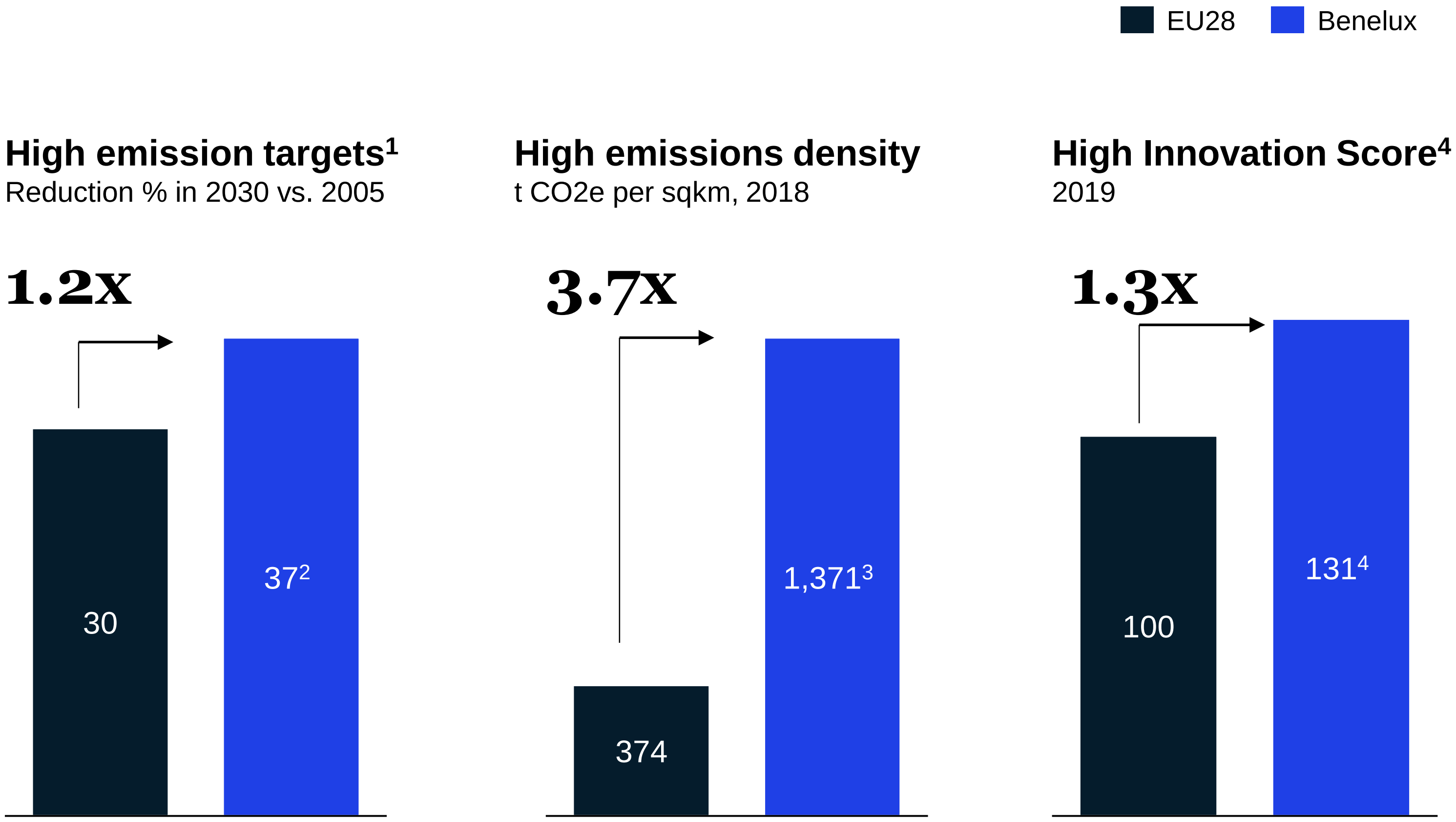
June 2021

- ● Revision of relevant legislation to support increased 2030 target
- ● Revision Proposal Energy Taxation Directive

By Q4 2021

- ● New EU Climate Change Adaptation Strategy
- ● Zero Pollution action plan for water, air, soil
- ● Revision of measures addressing pollution from large industrial installations

Benelux is expected to significantly contribute to reach EU emissions targets



High emission targets[1]
Reduction % in 2030 vs. 2005

High emissions density
t CO2e per sqkm, 2018

High Innovation Score[4]
2019

1. Under EU Effort Sharing Legislation; country-specific targets for non-ETS sectors to achieve EU wide -30% target vs. 2005 levels by 2030. EU Effort Sharing Legislation is one of the key pillars of 2030 Climate and Energy Framework (along with ETS Directive and LULUCF Regulation).
2. Benelux average is not weighted across 3 countries: Belgium: 35%; Netherlands: 36%; Luxembourg: 40%
3. Benelux average not weighted across 3 countries. Belgium: 1,440 tCO2e/sqkm, Netherlands: 2,104 tCO2e/sqkm, Luxembourg: 568 tCO2e/sqkm
4. Based on European Commission Innovation Score based across 27 key metrics. Benelux average not weighted across 3 countries. Belgium: 128; Netherlands: 135; Luxembourg: 129. All 3 are in Top 6 of EU's most innovative countries

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Source: European Commission Effort Sharing Legislation, European Commission Emissions Database for Global Atmospheric Research 2018, European Commission Innovation Scoreboard 2019

Benelux is optimally positioned to play a key role in Europe's decarbonization given its…

…**regional emissions targets** set by the European Commission are meaningfully above European average

…high industrial density per sqkm enables **large-scale efficient decarbonization** in clusters

…already established above average innovation levels **facilitate next-gen low-carbon tech**

… direct access to the North Sea and **large offshore wind potential**

On top of that, Benelux can…

…**leverage its geographic position** (3 important ports, access to offshore carbon sinks) for rapid and cost-efficient scale-up of CCUS projects

…utilize its large network of **existing gas infrastructure**

…apply **existing knowledge/capabilities** for further large-scale CCUS/H2 projects

… deploy short-term connecting possibilities for NRW to **accelerate development of a European network**

Benelux industry climate action plan

The bigger picture – European Green Deal

Benelux industry plan – Current status and partnership opportunities

Next steps

There is an impressive number of ongoing CCU/S and H2 projects in the Benelux area

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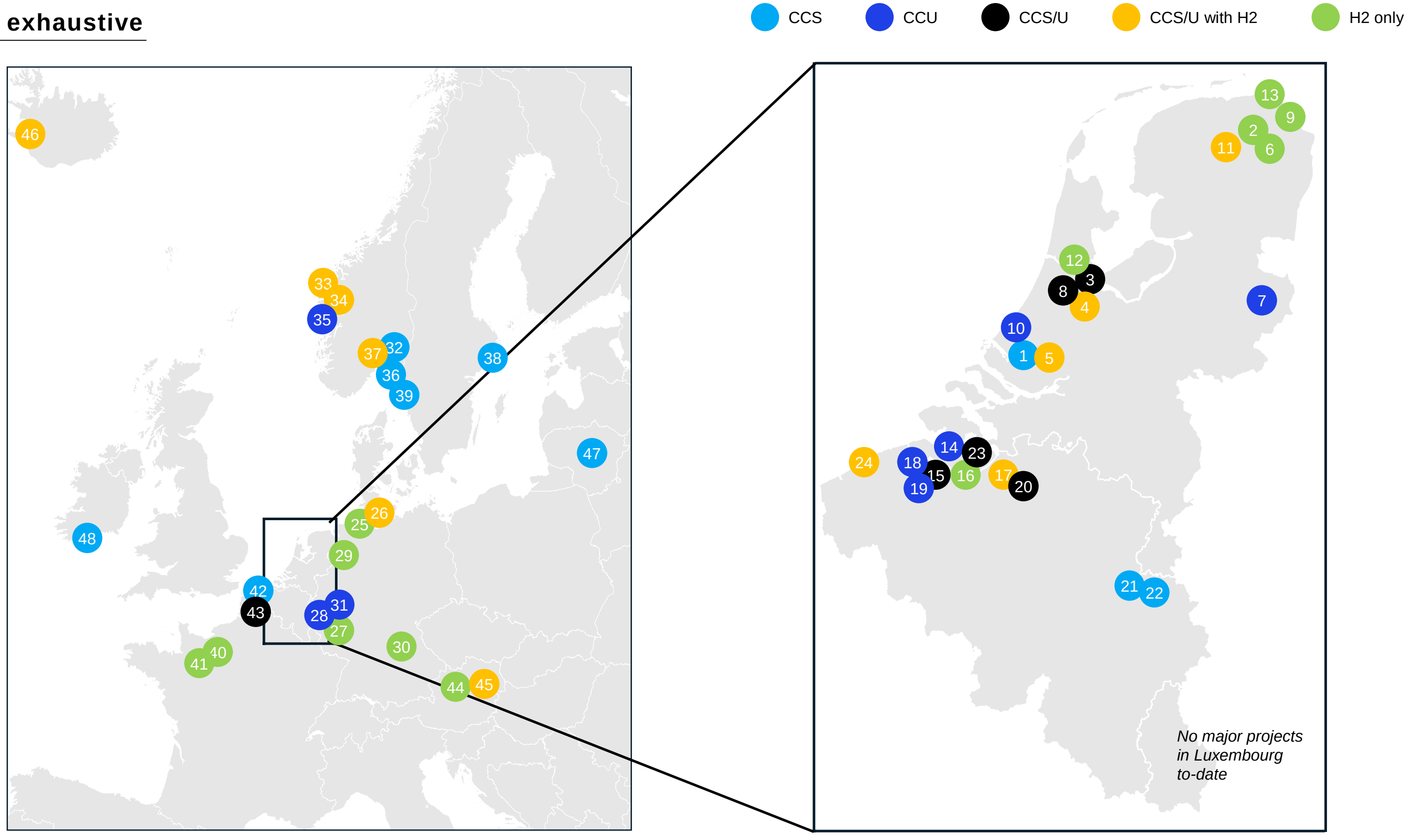
Not exhaustive



Mapped projects focus on European Innovation Fund and, in more detail, Benelux area

Significant progress in Benelux region

24 initiatives

Large-scale CCS/U and/or H2 consortium-led undertakings[1] in Belgian or Dutch clusters

>4 bn EUR

Required investment in CO2/H2 infrastructure – likely underestimated[2]

18 million tons CO2

Estimated **emission avoidance** by 2030[3]

-13%

Potential reduction of Benelux ETS volume by 2030 vs. 2018[4]

1. 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)
2. Significant underestimation likely due to (i) technology maturity (early-stage projects) and (ii) lack of public information
3. Simplified tech deployment and CO2 abatement estimations in analysis (see p.14 for details); potential overlaps of initiatives not accounted for
4. Based on simplifying assumptions in analysis (see p.14 for details); Based on 2018 Verified Emissions in ETS of 137.6 MtCO2

Source: Press research, Company statements, European Commission Emissions Database for Global Atmospheric Research 2018

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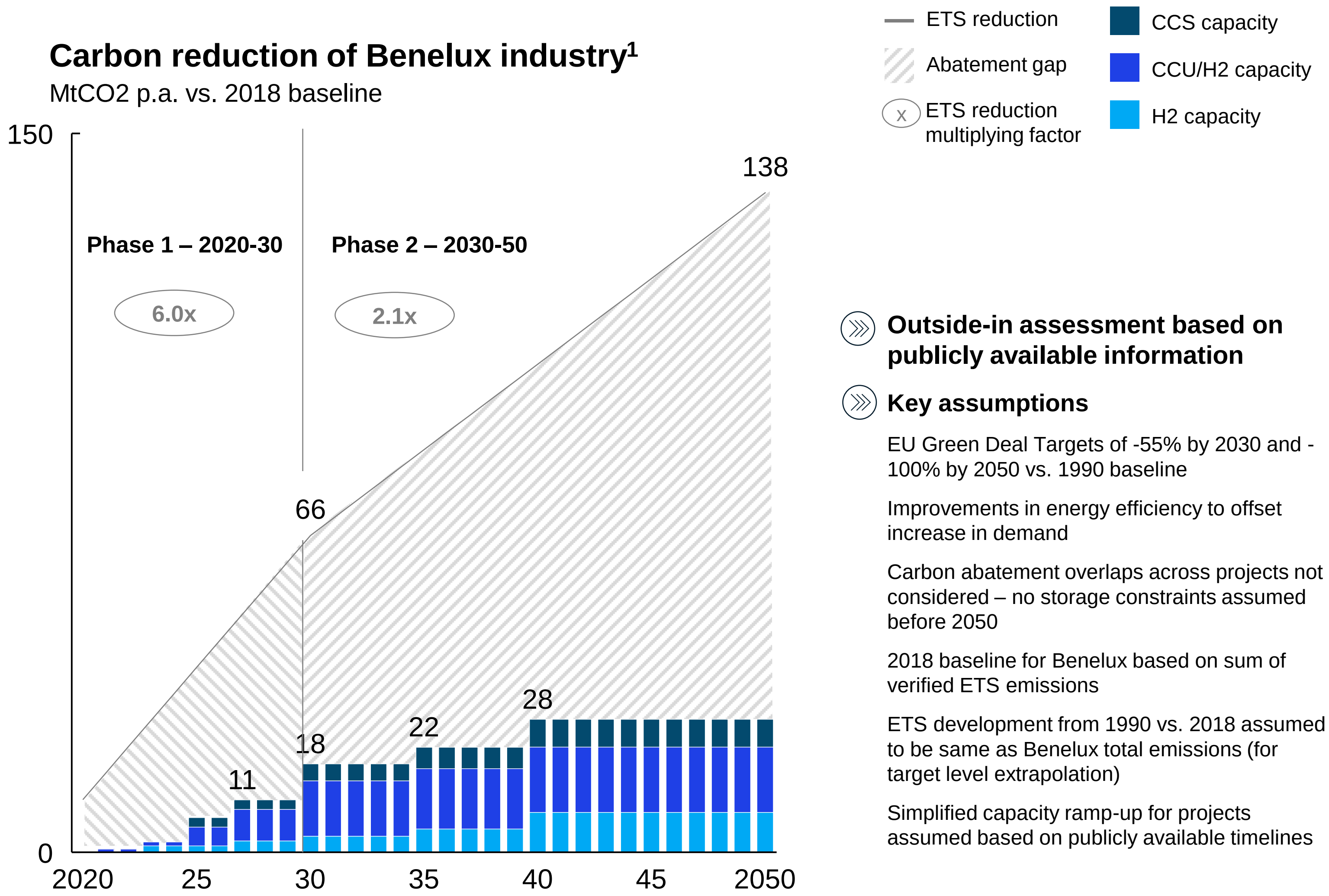
Yet, first estimations show substantial gap between existing projects and EU target

Carbon reduction of Benelux industry[1]

MtCO2 p.a. vs. 2018 baseline



Outside-in assessment based on publicly available information

Key assumptions

EU Green Deal Targets of -55% by 2030 and -100% by 2050 vs. 1990 baseline

Improvements in energy efficiency to offset increase in demand

Carbon abatement overlaps across projects not considered – no storage constraints assumed before 2050

2018 baseline for Benelux based on sum of verified ETS emissions

ETS development from 1990 vs. 2018 assumed to be same as Benelux total emissions (for target level extrapolation)

Simplified capacity ramp-up for projects assumed based on publicly available timelines

28 Mtpa capacity by 2040

Significant CCU/S and H2 capacity expected to come online **by 2030 and beyond**

20% of CO2 abatement

Yet, CCU/S and H2 capacity can cover **only 20% of required CO2 abatement in 2050 – insufficient** to comply with **EU Green Deal**

110 Mt CO2 gap in 2050

Substantial gap between required and planned carbon abatement – 38 MtCO2 in 2030 and ~110 MtCO2 in 2050 will need to be addressed via a range of **other decarbonization technologies**

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1. Projected CCU/S and/or H2 capacity ramp-up based on simplifying assumptions stated above and limited public data

Source: European Commission ETS Transactions Log – 2018 data, Press releases on CCU/S and/or H2 projects (see backup for selected projects),

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Additional efforts will be needed for systemic decarbonization

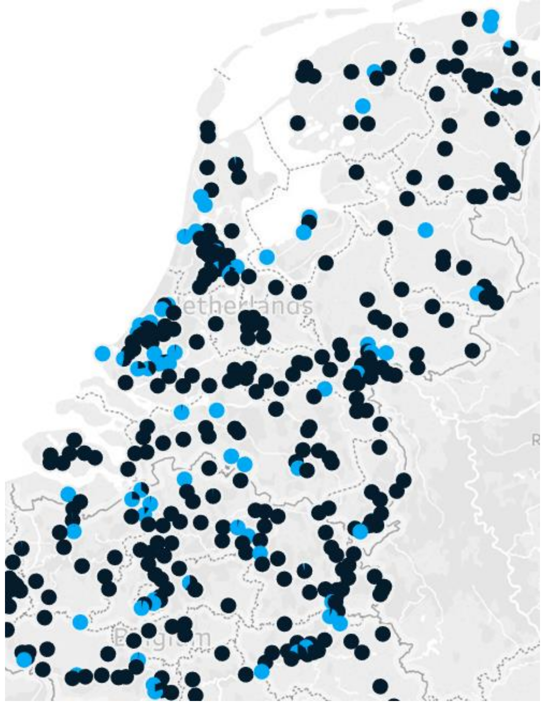
Overview of CO2-emitters in Benelux that are subject to the ETS system[1-3]

Only showing industrial companies subject to ETS, tCO2e

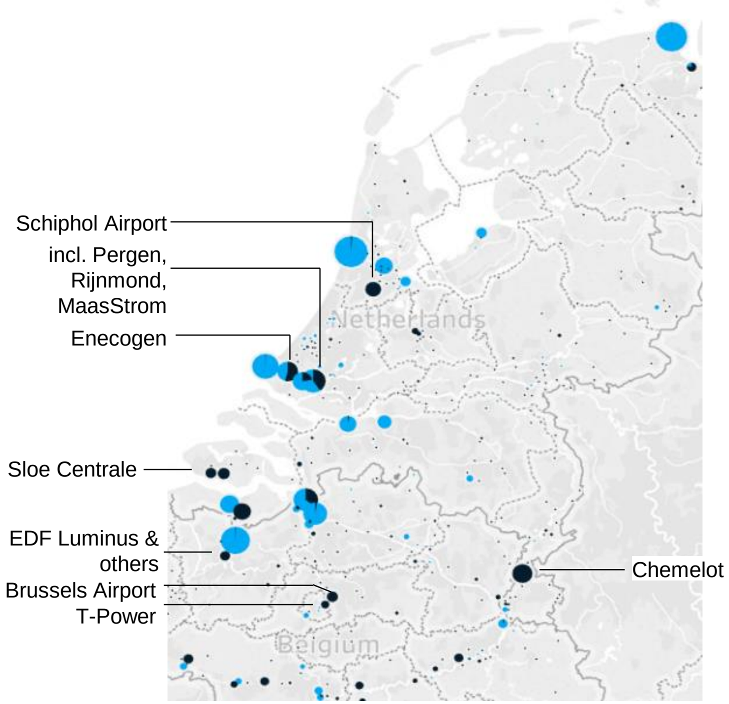
● Industrial companies that have not yet communicated efforts on CCS/U and/or H2[2]

● Industrial companies that have launched one or multiple CCUS and/or H2 projects (based on project list in Appendix)[3]

○ **Size not proportional to CO2-emissions**



○ **Size proportional to CO2-emissions**



Additional information on individual emitters in appendix

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1. Based on 2018 Verified Emissions from ETS: # of plant locations n=776, sum of emissions = 137,6 MtCO2 once data anomalies were removed
2. Emitters represent any plant participating in the ETS (i.e., one company can have multiple plants as emitters)
3. For simplification, all emitters (i.e., plant locations) of any company active in a large-scale CCU/S and/or H2 technology are marked as light blue. Analysis focuses on large-scale and heavy industry applications (i.e., not FCEVs)

Source: European Commission ETS Transactions Log – 2018 data,

20% Only one fifth of Benelux players **are actively advancing CCU/S or H2 technology** (i.e., Map A: # of plants by players with no CCU/S or H2 projects as % of total)

63% Yet, more than half of Benelux **emissions are being addressed** by large-scale CCU/S or H2 efforts (i.e., Map B: plant emissions by players with CCU/S or H2 projects as % of total)

Largest emitters seem to be on the forefront of CCU/S and H2 efforts – yet, participation of more companies will be needed for systemic decarbonization

Meaningful progress on CO2 abatement projects in recent years - however**, large number of initiatives running in parallel** may lead to

- **Limited exchange of knowledge**
- **Dispersed focus,** potentially limited impact
- **Sub-optimal leveraging of scale**
- **Inefficient geographical coverage**

How to accelerate the path to carbon-neutrality?

1

Harmonization of cross-border regulation

Initial focus on the cross-border transport of CO2 and H2 and the set-up of an “open access” pipeline infrastructure

2

Acceleration of project impact by stimulating collaboration

Identification of potential areas for (cross-border) collaboration across projects and industrial sectors

Depending on the identified synergies (e.g. in terms of investment needs, knowledge, and CO2-reduction potential), consideration of joint application to ETS Innovation Fund to increase likelihood of success

Investigation of CCS/U opportunities that are not yet addressed through existing projects in Benelux

3

Development of a holistic industry decarbonization plan and perspective on energy system needs[1]

Clear outline of path to carbon neutrality by 2050 across multiple time horizons, incl. an assessment of potential symbiosis between ETS and non-ETS sectors (from an industry perspective)

Potential “clean team” with key actors from industrial companies to drive the development of this plan

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[1] Benelux: An energy transition Hub for Europe

2. The different port clusters in the Benelux could benefit from enhanced knowledge sharing

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Not exhaustive

Port cluster	Key project	Objective	Maturity
Rotterdam	**Project Porthos**	**Open access CCUS infrastructure** between Rotterdam Port and depleted gas fields in North Sea Air Liquide AIR PRODUCTS ExxonMobil	**3 –** Permit/ Construction
	H-Vision	**Blue hydrogen production** infrastructure complemented by CO2 storage in North Sea. bp Air Liquide Deltalinqs GasTerra ENGIE TNO Linde Port of Rotterdam equinor uniper OCI NITROGEN gasunie crossing borders in energy TAQA Vopak ebn	**2 –** Feasibility study
North Sea Port	**North-C-Methanol**	**North-C-Methanol** in North Sea Port area, incl. CO2 capture/purification and H2, methanol, ammonia production North Sea Port ENGIE ANGLO BELGIAN CORPORATION We power your future Oiltanking flux50 FLUXYS ALCOBIOFUEL power of nature TERRANOVA SOLAR ArcelorMittal GHENT UNIVERSITY POM Oost-Vlaanderen Bio Base Europe Pilot Plant Cleantech Flanders	**2 –** Exploratory studies
	CCU/S Smart Delta Resources	ArcelorMittal DOW YARA Zeeland Refinery PZEM gasunie crossing borders in energy FLUXYS SDR North Sea Port	**1 –** Concept (start feasibility study in April 2020)
Antwerp	**CCUS Antwerp**	**Open access CCUS infrastructure** for cross-border distribution and storage, linking to Rotterdam & Norway Port of Antwerp BASF The Chemical Company TOTAL INEOS FLUXYS Air Liquide BOREALIS ExxonMobil	**1 –** Concept
Amsterdam	**Project Athos**	**Open-access CCUS infrastructure** with transportation from Europe / Ireland to storage in Dutch North Sea section TATA STEEL Port of Amsterdam gasunie crossing borders in energy ebn	**1 –** Concept
North Netherlands	**Industry Forum**	**Green hydrogen and green biomass-based CO2 production** to support decarbonization of chemical industry Nouryon ENGIE BioMCN OCI NITROGEN NUON BASF The Chemical Company gasunie crossing borders in energy DOW RWE	**1 –** Concept

All major port cluster in the Benelux are **pursuing similar CCUS objectives based on the same technologies**

Almost all projects are still in early stages with focus on conceptual development and demonstration

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2. Overview of CCS/U use cases

OUTSIDE-IN ASSESSMENT

● Not relevant ◐ Semi-relevant 🔵 Relevant ▨ Deep dive next

CO2 demand categories	CO2 use cases	Description	Potential relevance for Benelux
Enhanced oil recovery (EOR)	Conventional CO2 EOR	Use CO2 as a miscible gas to increase the sweep efficiency of oil in conventional reservoirs that have reached the end of primary and secondary recovery phases	●
	ROZ CO2 EOR	CO2 can be injected into the residual oil zone (ROZ) fairways of conventional oil basins to produce oil outside of primary pay zones, typically storing more CO2 than the carbon content of the recovered oil	●
	Unconventional CO2 EOR	Unconventional CO2 EOR techniques such as ‘huff-and-puff’ where CO2 is used to pressurize and ‘swell’ oil such that additional oil gets produced when the pressure is released	●
Construction materials	CO2-cured Cement	Carbon curing of concrete as an alternative to the steam curing process that permanently converts CO2 to stable calcium carbonates, resulting in a significantly faster curing time than conventional methods	◐
	CO2-derived Aggregate	CO2 is used as a raw material for making aggregates, typically using recycled concrete to create carbonate rocks which are then be substituted for traditional concrete aggregates such as limestone	◐
Fuel	Synfuel	Chemical processes can be used to convert CO2 and hydrogen into synfuels that can be substituted into combustion engines using traditional fossil fuel derived products such as gasoline, jet, and diesel	🔵
	Macro- and micro algae	Algae can ‘eat’ CO2 to create fuels which can directly substitute traditional fossil derived fuels	◕
Plastics, chemicals, & new materials	PE, PP, MeOH-based plastics	Methanol synthesized from CO2 can be converted into polyethylene and polypropylene through traditional processes by using heterogenous catalysts to bypass ethane and naphtha steam cracking routes	🔵
	Polycarbonate & Polyurethane	CO2-derived polycarbonate and polyurethane can displace the PC and PU produced by conventional, more CO2 intensive methods	🔵
	Carbon Fiber	Carbon fiber (CF) can by produced by incorporating CO2 into the CF material manufacturing process, subsequently used for aerospace, automotive, wind turbine, sporting good applications, etc.	◐
Food & agriculture	Biochar	Pyrolysis of biomass generates biochar, a stable, solid material that stores carbon over long time periods (>100 years), and can be used as a fertilizer to increase crop yields or as a water filtration material	🔵
	Food & beverage CO2 use	Ultra-high-purity CO2 is used by the food and beverage industry to carbonate beverages and preserve food	◐
	Greenhouse fertilization	CO2 can be used to enrich air in greenhouses beyond atm. concentrations (>400 ppm) and increase primary productivity	🔵
Geologic CO2 Storage	Underground land/ocean	CO2 can be stored in a variety of geological formations, incl. saline formations, depleted O&G reservoirs, unmineable coal seams, basalt formations, organic-rich shales, etc.	◐

Source: Expert interviews

2. Many potential applications with relevance for the Benelux have not yet been addressed by current initiatives

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OUTSIDE-IN ASSESSMENT

⬜ Expected limited impact of CCS/U

🟦 Suitable application, with projects planned/in place in Benelux[1]

▨ Suitable CO2 applications, no projects planned/in place in Benelux[1]

CO2 demand categories		Cost *$/tCO2*	Global CO2 reduction potential *Mtpa*	Cement & Construction	Steel	Plastics & Chemicals	Land & air transport	Food & Beverage	Power	Storage
Construction materials	CO2-cured Cement	25-40	1,060	🟦	⬜	⬜	⬜	⬜	⬜	⬜
	CO2-derived Aggregate	10-15	1,760	▨	⬜	⬜	⬜	⬜	⬜	⬜
Fuel	Synfuel	(110-245)	12,000	⬜	🟦	⬜	🟦	⬜	🟦	⬜
Plastics, chemicals, & new materials	PE, PP, MeOH-based plastics	(40-230)	185	⬜	🟦	⬜	⬜	▨	⬜	⬜
	Polycarbonate & Polyurethane	580-1990	13	▨	⬜	▨	▨	⬜	⬜	⬜
	Carbon Fiber	150-250	0.4	⬜	⬜	▨	▨	⬜	▨	⬜
Food & agriculture	Biochar	270-400	900	⬜	⬜	⬜	⬜	▨	⬜	▨
	Food & beverage CO2 use	75-100	8	⬜	⬜	⬜	⬜	▨	⬜	⬜
	Greenhouse fertilization	75-125	7	⬜	⬜	⬜	⬜	🟦	⬜	⬜
Geologic CO2 Storage	Underground land/ocean	(5-10)	36,000 (all yearly emissions)	⬜	⬜	⬜	⬜	⬜	⬜	🟦

1. Based on outside-in assessment (project list in Appendix)

Source: Expert interviews

2. Especially applications not yet being addressed are the ones that could be most cost competitive

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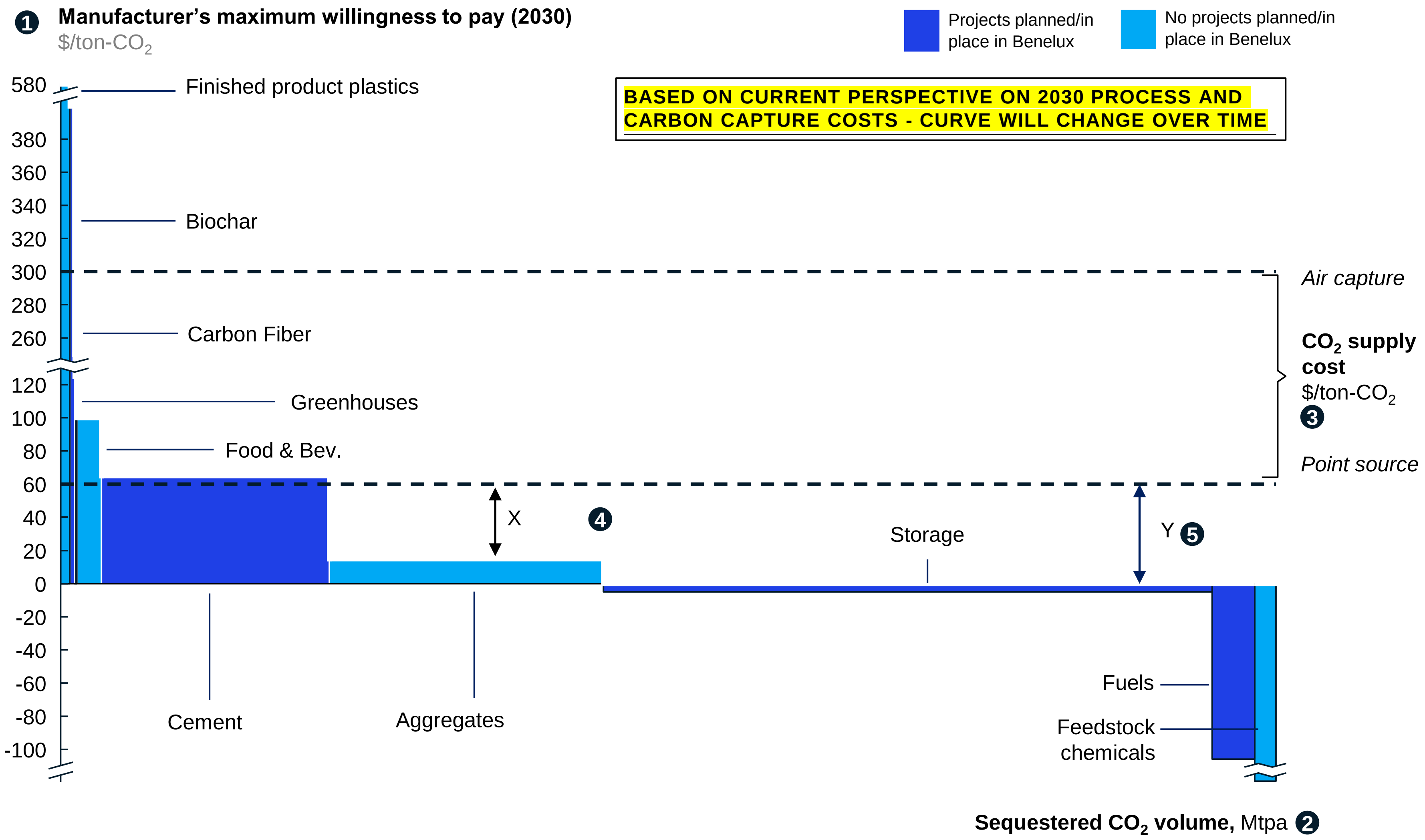

① **Manufacturer's maximum willingness to pay (2030)**
$/ton-$CO_2$

BASED ON CURRENT PERSPECTIVE ON 2030 PROCESS AND CARBON CAPTURE COSTS - CURVE WILL CHANGE OVER TIME

Sequestered CO_2 volume, Mtpa ②

Definitions and assumptions

① **Willingness to pay for CO2** is defined as the maximum amount a manufacturer is willing to pay for CO2 as in input to make their CO2-based product cost competitive with traditional products

② **Sequestered CO2 volume** is defined as the amount of CO2 stored in the product through manufacture (ignores avoided emissions or emissions created through use of the product)

③ **CO2 supply cost** is the range of cost of capture and transport of anthropogenic CO2 for capture from different CO2 sources

④ **Aggregates example:** Application is not economical unless the cost of capture and transport of CO2 reduces by "X". To make it economic in the interim, a carbon price of "X" is required

⑤ **Storage example:** This application will not be economic with current process costs, no matter what the cost of capture and transport of CO2 is. Either process costs need to reduce or a carbon price of "Y" is required to make the application economically feasible

Source: Expert interviews

Benelux industry climate action plan

The bigger picture – European Green Deal

Benelux industry plan – Current status and partnership opportunities

Next steps

Next steps

1. Write a **position paper on cross-border regulation harmonization** (key focus on CO2 and H2) consolidating inputs from all stakeholders – the intention is to finalize a **first version of this paper by end of May** to facilitate further stakeholder engagement ahead of the Vlaams-Nederlandse top on November 4, 2020
2. On the basis of the current project landscape, **identify potential areas for collaboration** that could in the short-term provide operational benefits for all parties involved and which may in the mid-term improve eligibility for European funding
3. **Confirm the need for a holistic industry decarbonization plan** with key actors from different industries and scientific partners

Appendix

Industry in Benelux – Status Quo

ETS Innovation Fund - Characteristics

Selective CCS/U and H2 projects

Overview of 2018 greenhouse gas emissions by company

Top 20 companies in Benelux account for ~70% of industrial emissions

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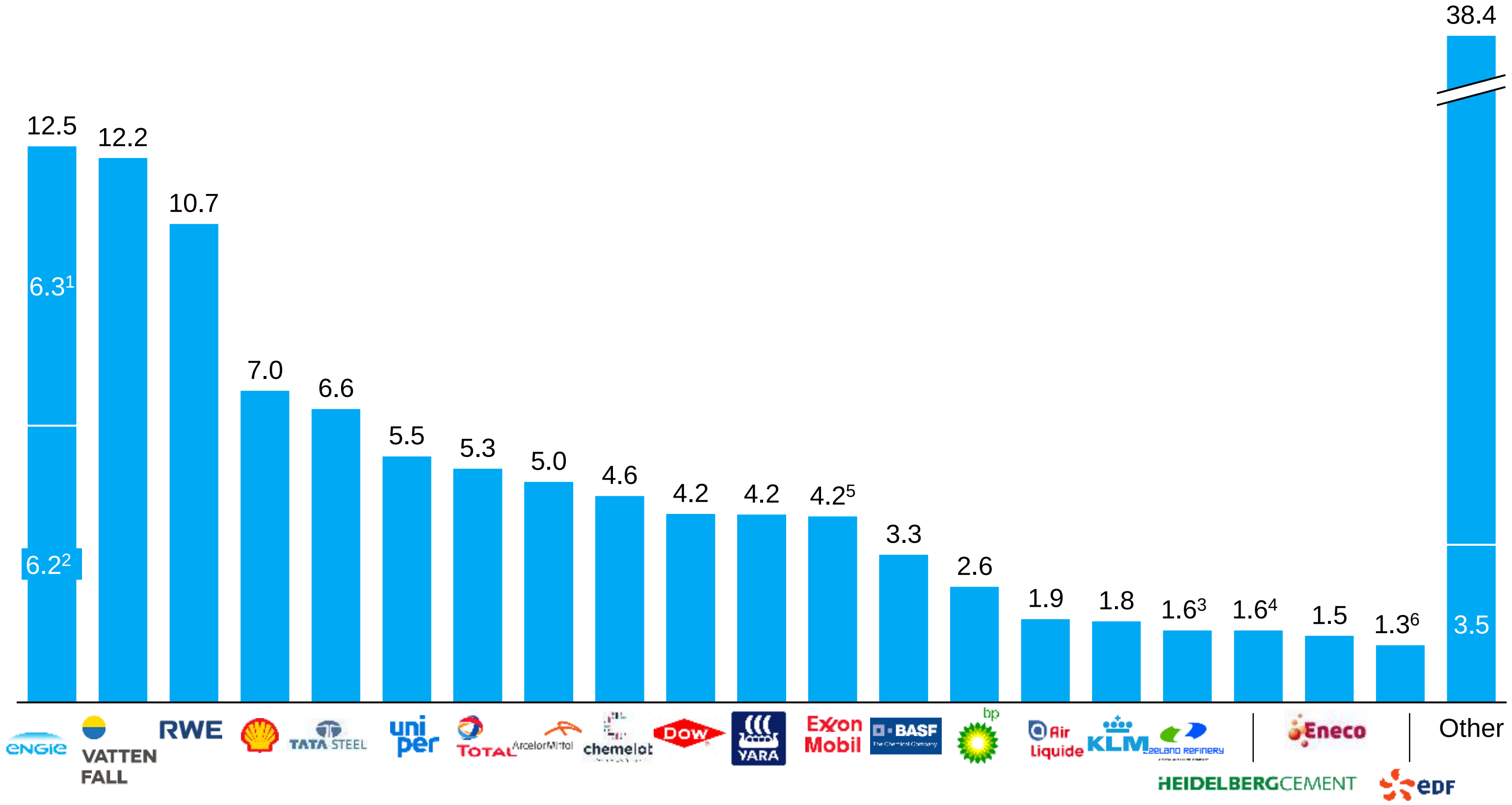
Highest emitting companies in Benelux (based on ETS reporting)

2018 ETS, MtCO2e



1. Belgian portion of Engie emissions 2. Dutch portion of Engie emissions, incl. ~3.3 MtCO2e emissions from the Rotterdam plant which is no longer part of Engie's portfolio 3. Zeeland Refinery is a Total and Lukoil company 4. subsidiary of HeidelbergCement 5. incl. Esso plants in Benelux 6. SloeCentrale plant owned by French EDF and Dutch energy company PZEM

Source: European Commission ETS Transactions Log – 2018 data,

138 Mt CO2e

per year from industrial activities in Benelux (as per 2018 ETS), of which ~70% are emitted by Benelux's Top 20 emitters

Appendix

Industry in Benelux – Status Quo

ETS Innovation Fund - Characteristics

Selective CCS/U and H2 projects

The ETS Innovation fund is empowering businesses to contribute to achieving the 2030 GHG reduction targets

The ETS Innovation Fund will provide about EUR 10 billion of grants to private sector projects aimed at reducing greenhouse gas (GHG) emissions between 2021 and 2030

Main focus on projects regarding:

Innovative low-carbon technologies and processes in energy intensive industries

Carbon capture and storage/ utilisation (CCS/U)

Innovative renewable energy generation

Energy storage

Objectives

Create the **right financial incentives** for investing into projects supporting the EU's low-carbon transition

Boost growth and competitiveness of EU companies

Support innovative low-carbon technologies in taking off and reaching the market in **all Member States**

Source: https://ec.europa.eu/clima/policies/innovation-fund_en

The deadline for the first round of Applications will be in September 2020

➡ Preparation time

Preparation time for first application

June 2020

Expression of interest ("first call")

September 2020

Confirmation of interest and filing of complete application file

January 2021

Communication of results of the first assessment

April 2021

Application deadline for the second round of assessment

October 2021

Communication of results of the second assessment

Coaching and preparation time for second application

To date, 200 projects have been discussed during working sessions of the Innovation Fund, of which ~80% are driven by consortia

Mitigation/ sector option	Energy storage	Renewable energy[1]	Cement & lime	Refineries	Iron & steel	Chemicals	Glass & ceramics	Pulp & paper	Hydrogen production	Power generation	Other sectors[3]
Efficient improvement	5	21	4	1	10	6	3	7	12		2
Fuel switch[2]			4	14	8	6	2	4	2		1
CCU			9	8	5	9					
CCS			1	3	1	2			1	4	
Circular			2	1	3	6			1		6
Other	1	6		3	2	2			2		1

---

1. Wind, solar, ocean, hydro, geothermal, bio
2. To renewable energy source (incl. RES H2, electricity, biogas)
3. Non-ferrous metals, mineral wool, gypsum

Projects will be selected based on their performance against 5 criteria

	Description
① **Greenhouse gas emissions avoidance**	Compare the greenhouse gasses emissions against the ETS benchmark installation ("additionality check") during the first 10 years of operations
② **Degree of innovation**	Focus on break-through technologies that are not yet widely commercially available
③ **Project maturity**	In terms of planning, business model and financial and legal structure, where 1=concept, 2= feasibility study, 3= pilot, 4= running small scale & 5= running full scale
④ **Scalability**	Defined as the market potential by 2050
⑤ **Cost efficiency**	Measured as requested grant versus expected emissions avoidance

Appendix

NOT EXHAUSTIVE

Overview of European CCS/U and hydrogen projects (1/4)

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

- Information not publicly disclosed ▨ Further detail in this document

	Name	Technology	Leading company	Project type	CO_2 impact	Cost, EUR M	Funding	Maturity[1]
Netherlands	1. Project Porthos	S	Shell	C →	37Mt max.	400-500	⊖ PCI status	3
	2. NorthH2	H	Gasunie	C →	7 Mtpa	-		1
	3. Project Athos	U S	Port of Amsterdam	C	3-7.5 Mtpa	-	⊖ PCI status	1
	4. Project Everest	U H	Tata Steel	C	4-5 Mtpa	-		3
	5. H-Vision	(U) S H	Deltalinq	C	2.2-4.3 Mtpa	839-2,769		2
	6. H2 Magnum	H	Vattenfall	C →	1.3 Mtpa	-		1
	7. CCU at Twence	U	Twence	C	0.1 Mt[2]	-	✓	2
	8. Basic Oxygen Furnace 2 Urea	U (S)	TNO	C	0.1 Mtpa	120	✓	1
	9. BioMCN	H	Nouryon	C	0.03 Mtpa	-	✓	1
	10. Renewable Jet Fuel from air	U	Climeworks	C	-	-		1
	11. North Netherlands Industry Forum	U (S) H	Chemport Europe	C	0.03 Mtpa	-		1
	12. H2ermes	H	Tata Steel	C	-	-		1
	13. Eemshydrogen[2]	H	RWE		-	-		2
	14. CCU/S Smart Delta Resources	U S H	Consortium	C →	-	-	⊖ PCI status	1
	15. The Hydrogen Delta	H	Consortium	C →	-	-		1

Note: Not including projects that are already operational ; overview based on publicly available information unless otherwise indicated

---

1. Scale of 1 to 5, with 1 being conceptual and 5 operational at large-scale
2. Development of electrolyzer in Eemshaven, directly connected to the Westereems wind park and deliver of green hydrogen to Delfzijl industrial area

NOT EXHAUSTIVE

Overview of European CCS/U and hydrogen projects (2/4)

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

- Information not publicly disclosed ▨ Further detail in this document

	Name	Technology	Leading company	Project type	CO_2 impact	Cost, EUR M	Funding	Maturity[1]
Belgium	16. North-C-Methanol	U H	CCU Hub Ghent consortium	C →	0.6 Mtpa	500		2
	17. Power-to-methanol	U H	Port of Antwerp	C	-	-		3
	18. Steelanol	U	ArcelorMital	C	0.2 Mtpa	150	✓	5
	19. Carbon2Value	U	ArcelorMital	C →	-	10.5	✓	3
	20. CCUS infrastructure Antwerp	U S	Port of Antwerp	C →	-	-		1
	21. Leilac Project	S	HeidelbergCement	C →	-	21		4
	22. CEMCAP	S	HeidelbergCement	C	-	10		4
	23. Steel2Chemicals	U S	Consortium	C →	-	-	✓	3
	24. HyPort Ostend	U H	DEME	C	-	-		1

Note: Not including projects that are already operational ; overview based on publicly available information unless otherwise indicated

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1. Scale of 1 to 5, with 1 being conceptual and 5 operational at large-scale

NOT EXHAUSTIVE

Overview of European CCS/U and hydrogen projects (3/4)

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

- Information not publicly disclosed ▨ Further detail in this document

	Name	Technology	Leading company	Project type	CO_2 impact	Cost, EUR M	Funding	Maturity[1]
Germany	25. HySynGas	H	Vattenfall	C	0.04 Mtpa	130	✓	1-2
	26. Westküste100	U H	LafargeHolcim	C	-	100	⊖	1
	27. REFHYNE	H	Concawe		-	16	✓	3-4
	28. CO2Min	U	HeidelbergCement	C	-	3	✓	2
	29. GetH2	H	RWE	C	-	-	✓	3
	30. LOHC Industry Transformation	H	Hydrogenious		-	-		varies
	31. Post-combustion CO2 scrubbing	U	Linde	C	-	-		3
Norway	32. Northern Lights	S	HeidelbergCement & Equinor	C	100 Mt max.	1,600	⊖ PCI status	2
	33. Commercial scale CO2-to methanol	U H	Carbon Recycling International	C	0.03 Mtpa	150		2
	34. Norsk E-Fuel Alpha	U H	Sunfire	C	0.03 Mtpa	150		2
	35. CCU Solvay	U	Solvay	C	0.1 Mtpa[3]	-		1-2
	36. CCS Norcem	S	HeidelbergCement (Norcem)	C	-	-		-
	37. E-Fuel 1	U H	Nordic Blue Crude	C	0.03 Mtpa	150		2
Sweden	38. Bio CHP in Stockholm	S	Stockholm Exergi		0.8 Mtpa	55-72 EUR/tCO2		3
	39. Preem CCS	S	Preem		0.5 Mtpa	-		2
France	40. H2V NORMANDY	H	H2V Industry		-	230 - 250[2]	✓	2-3
	41. H2V 59	H	H2V Industry		-	230 - 250[2]	✓	2-3
	42. 3D Dunkirk	S	ArcelorMittal		-	-		2
	43. IGAR	U S	ArcelorMittal	C	-	-		2

Note: Not including projects that are already operational ; overview based on publicly available information unless otherwise indicated

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1. Scale of 1 to 5, with 1 being conceptual and 5 operational at large-scale; 2.as part of larger H2 infrastructure investment in the region; 3. by CCU and other initiatives

NOT EXHAUSTIVE

Overview of European CCS/U and hydrogen projects (4/4)

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

- Information not publicly disclosed ▨ Further detail in this document

	Name	Technology	Leading company	Project type	CO_2 impact	Cost, EUR M	Funding	Maturity[1]
Austria	44. UpHy	H	OMV		0.01 Mtpa	-		3
	45. CCU – Green Methanol	U H	OMV	C	-	-		-
Iceland	46. CirclEnergy	U H	Carbon Recycling International		-	-	✓	3
Lithuania	47. Clean Energy Project	S	Minijos Nafta	C →	200 Mt max.	-		2
UK & Ireland	48. Cork CCS	S	Ervia	C	2.5 Mtpa	-	✓	2
European Projects	49. ICO2CHEM	U	VTT	C	-	-	✓	2
	50. RECODE	U	Titan Cement	C	20%	-	✓	3

Note: Not including projects that are already operational ; overview based on publicly available information unless otherwise indicated

---

1. Scale of 1 to 5, with 1 being conceptual and 5 operational at large-scale

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

1: Project Porthos

Key characteristics: S C →

Context

Project Porthos is a CO_2 transport and storage infrastructure set to be built between the Port of Rotterdam and depleted gas fields beneath the North Sea.

It was initiated by three parties:

- **Port of Rotterdam Authority**: knowledge of the local situation and market
- **Energie Beheer Nederland B.V. (EBN)**: expertise of the deep subsurface
- **N.V. Nederlandse Gasunie**: gas infrastructure and transport expert

ExxonMobil, Shell, Air Liquide and Air Products have signed (non-binding) agreements to use the infrastructure

Description

Porthos is a transport and storage system that comprises a pipeline on land, the compressor station, a pipeline at sea and the storage of CO_2 deep below the North Sea. CO_2 will be captured from various companies and supplied to the pipeline and its platform. There it is pumped into an empty gas field 3-4 km below the North Sea.

Porthos uses an "open access" approach, meaning it can be used by various companies, achieving substantial cost advantages.

Timeline

In 2020, Porthos will focus on four main issues:

- Technical development of the transport and storage infrastructure
- Environmental Impact Assessment and permits
- Agreements with companies to supply CO2
- Agreement with the government to enable CCUS

It is expected that Porthos will be functional and running in the second half of 2023.

Overzicht onderdelen Porthos.

Key Metrics

CO_2 Impact: max. 37 Mton, 2 – 2.5Mtons per year in early years of operations

Maturity: 3 – Permitting / construction

Cost: estimated €400M - €500M total cost (EUR 13.5 / tCO2)

Funding: granted Project of Common Interest (PCI) status by the European Commission, making it eligible for funding from the Connecting Europe Facility (CEF)

Note: Phase 2 (2026) considers a cross-border CO2 pipeline between Antwerp, Rotterdam and North Sea Port – CO2Transports program

Key documents

Project Porthos brochure

Milieu-effectenrapport

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
- U CCU
- S CCS
- S H H2 enabled CCU/S
- H H2 only

Project Type
- C Consortium
- → Cross-border

2: NortH2

Key characteristics: H C →

Context

The objective is to **produce green hydrogen based on wind energy from new mega wind parks in the North sea**. NortH2 aims to turn Groningen province into Europe's first European Hydrogen Valley and to contribute to the European "Green Deal" and Dutch Climate Accord.

Consortium coordinated by **Gasunie, Groningen Seaports and Shell Nederland**

GRONINGEN SEAPORTS

gasunie crossing borders in energy

provincie groningen

Description

Vision of the project is to develop Europe's largest green hydrogen project in Groningen (Netherlands), from production to customer.

The envisaged production of green H2 is based on renewable wind energy in the North Sea with planned generation of 3-4 GW by 2030 and ~10 GW by 2040. Initial production via an electrolyser located in Eemshaven may possibly be extended by offshore electrolysers later.

The green H2 is planned to be transported via Gasunie (current gas) infrastructure to industrial customers in Netherlands and NW Europe.

Once fully operational in 2040, NortH2 is set to produce 800,000 tonnes of green hydrogen and to offset 7Mt CO2 p.a.

Timeline

2020: Feasibility study

2027: First wind turbines and first hydrogen produced

2030: 3-4 GW of wind energy for green H2 production

2040: ~10 GW of wind energy for 800,000 tonnes of green H2 production

Key Metrics

CO_2 Impact: 7Mt p.a. once fully operational by 2040

Maturity: 1 - Concept

Cost: N/A

Funding: N/A

Key documents:

[Gasunie press release]

Source: Company press releases

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

3: Project Athos

Key characteristics: U S C

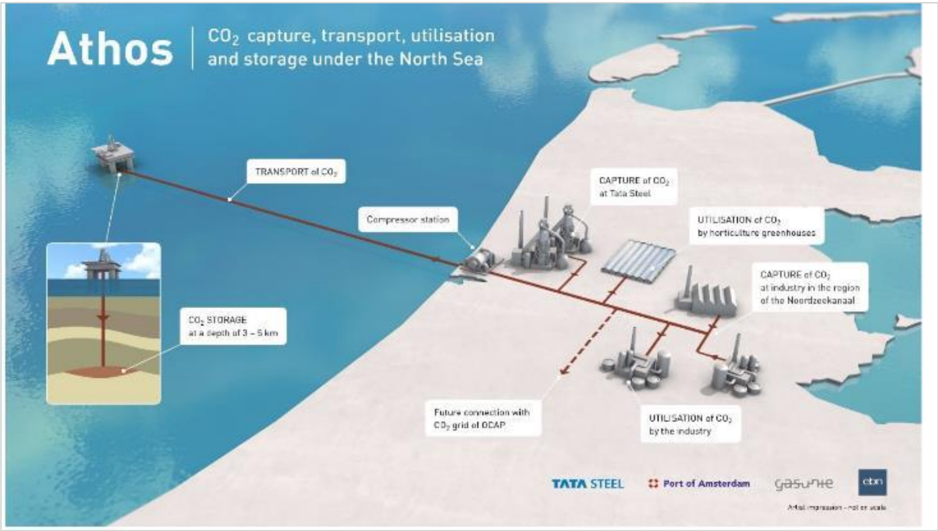
Context

Development of **open-access** interoperable high-volume **CO2 transportation infrastructure** from Europe / Ireland to storage locations in Dutch North Sea section

Consortium between TATA Steel, Port of Amsterdam, Gasunie and EBN

Description

CO2 would be captured from Tata steel operations in Ijmuiden and stored in empty gas fields under the North Sea. The planned network could comprise an onshore CO2-transport pipeline, offshore storage facilities, and exit-/feed-in points for other companies directly connected to this network or other CO2 transport networks.



Timeline

2019 – Feasibility study finished by Sept 2019; start of concept selection phase

Key Metrics

CO_2 Impact: 3-7.5 Mtpa

Maturity: 1 - Concept

Cost: N/A

Funding: granted Project of Common Interest (PCI) status by the European Commission, making it eligible for funding from the Connecting Europe Facility (CEF)

Key documents:

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

4: Project Everest

Key characteristics: U H C

Context

The Everest project will utilise carbon monoxide and hydrogen by-products from steel production for conversion into chemicals and also capture waste CO2 for storage in North Sea gas fields

Collaboration between **Tata Steel** (Ijmuiden), **Arcelor Mittal** (Ghent) **and DOW Chemicals** (Terneuzen)

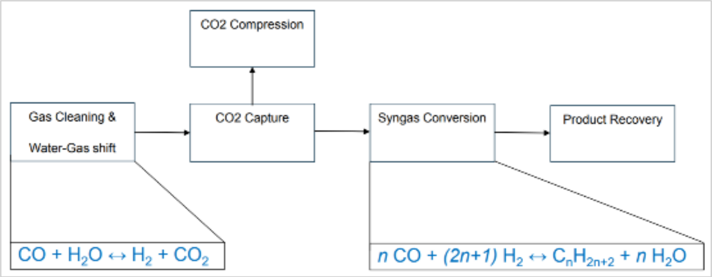
TATA STEEL

DOW

ArcelorMittal

Description

CO from Tata Steel blast furnace gas in this pilot in Ijmuiden is converted into synthetic naphtha (Fischer-Tropsch). Dow Chemical subsequently uses this naphtha as a raw material for making plastics that can in turn be used as feedstock for the blast furnace process.



$CO + H_2O \leftrightarrow H_2 + CO_2$

$n\,CO + (2n+1)\,H_2 \leftrightarrow C_nH_{2n+2} + n\,H_2O$

Timeline

2019-2020: Basic Engineering carbon capture

2020-2021: Approvals and pilot version in Ghent (Steel2Chemicals)

2022: Pilot operation IJM and basic engineering syngas conversion

2022-2027: Detail design, procurement, construction & commissioning

2027: Commercial operation

Key Metrics

CO_2 Impact: 4 Mtpa

Maturity: 3 – Permitting / Construction

Cost: N/A

Funding: N/A

Dependencies: CO2 transport to be provided by project Athos

Key documents:

[Project Everest overview]

Source: Company website, Annual sustainability report, Expert interviews

5: H-Vision

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

Key characteristics: U S H C

Context

Blue hydrogen[1] (hydrogen produced from natural gas, usually via steam-reforming, with CCS) as accelerator and pioneer for energy transition in the industry

Partners include **Deltalinqs, Air Liquide, BP, Gasunie, the Port of Rotterdam Authority, Power Plant Rotterdam, Shell, Uniper** and **Royal Vopak**

Description

Construction and operation of large-scale blue hydrogen production facilities in Rotterdam. The CO2 that is released during production will be captured and stored in depleted gas fields under the North Sea or used for other purposes, such as crops fertilizer.

Timeline

Final investment decision in 2021

Start operating H-vision facility late 2025

Increase production capacity towards 2030

Key Metrics

CO_2 Impact: 2.2Mtons p.a. by 2026 up to 4.3Mtons p.a. in 2030

Maturity: 2 – Feasibility study

Cost: €839 - €2,769M CAPEX investment depending on scope (EUR 86-146 / tCO2 depending on the macroeconomic scenario)

Funding: *Initial analysis indicates need for EUR 700 M subsidies*

Dependencies: Intention to collaborate with the CCUS Porthos project in the port of Rotterdam. Option for collaboration with the H2M project, which aims to use hydrogen as a fuel for the Magnum power plant in Eemshaven in Groningen. The Chemelot industrial site in South Limburg could be an additional collaborator and become a user of the hydrogen from Rotterdam.

Key documents:

H-vision position paper

Feasibility study report

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1. Feasibility studies have shown that the CO2 footprint of blue hydrogen (0.82-1.12 kgCO2-eq./kg H2) is comparable with hydrogen produced via electrolysis with renewable electricity sources (0.92-1.13 kg CO2 eq./kg H2) now and towards 2030

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

6: H2 Magnum

Key characteristics: H C →

Context

The objective is to **convert one natural-gas unit of Nuon's Magnum gas power plant to hydrogen** by 2023.

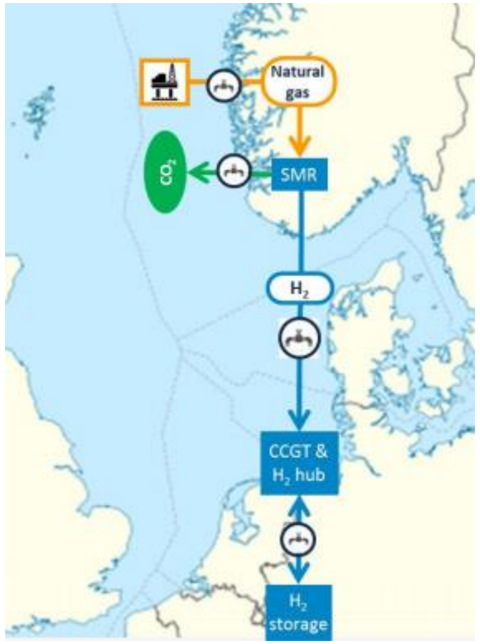
Consortium led by **Vattenfall, its subsidiary Nuon, Gasunie, Equinor and MitsubishiHitachi.**

VATTENFALL
NUON
equinor
gasunie
MHPS

Description

Vattenfall and its Dutch subsidiary are aiming to convert one of their gas power units in Eemshaven to hydrogen, away from natural gas.

Equinor will produce the hydrogen by converting Norwegian natural gas and Dutch gas infrastructure company Gasunie plays important role in distributing the H2 to the Magnum station. The CO2 resulting from Equinor's conversion activities is set to be stored in the Sleipner field.



Timeline

2017: Project start and conceptualization

2019/20: investment decision

2023: Conversion of first CCGT[1] to H2 instead of natural gas

2026: Conversion 2nd and 3rd CCGT units

2030+: local H2 production

Key Metrics

CO_2 Impact: 1.3 Mt p.a. once 1st CCGT[1] unit is operational by 2023

Maturity: 1 - Concept

Cost: N/A

Funding: N/A

Key documents:

Vattenfall announcement

Nuon Company presentation

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1. Combined Cycle Gas Turbine

Source: Company press releases

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

8: Basic Oxygen Furnace Gas to Urea (BOF2UREA)

Key characteristics: U S C

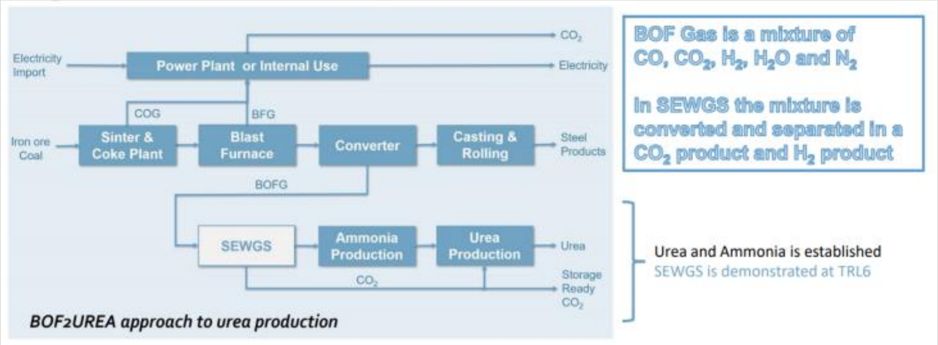
Context

Targets emission and energy reduction for the production of urea based products

Lead by consortium consisting of **ArcelorMittal, TNO, Kisuma, Processi Innovativi, Stamicarbon, OCI Nitrogen,** and **Radboud University**

Description

The project sets out to (1) optimise the process to produce urea from basic oxygen furnace gas at a cost level lower than that based on natural gas, (2) determine the CO2 footprint reduction potential of the optimised process, and (3) form a lasting value chain to enable implementation of the process in a timeframe of 5 years



Timeline

Kick-off in late-2018

Implementation of the process planned within 5 years

Key Metrics

CO_2 Impact: 0.1 Mtpa for every 1 Mtpa steel production (scalable)

Maturity: 1 - Concept

Cost: EUR 120 M

Funding: received 170k funding from TKI Energie of the Toeslag voor Topconsortia voor Kennis en Innovatie (TKI's) by the ministry of Economic Affairs of the Netherlands

Key documents:

Concept presentation

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

9: BioMCN

Key characteristics: H C

Context

The objective is to **produce low-carbon renewable methanol based on green hydrogen** from renewable energy. The plans play into the partners' wider efforts regarding circular economy.

Consortium led by **Nouryon, BioMCN (by OCI) and Gasunie**; further partners include McPhy, DeNora and Hinicio.

Description

BioMCN is one of Europe's largest methanol producers with a strong focus on bio-methanol.

The vision for the three key partners Nouryon, BioMCn and Gasunie is to convert renewable electricity to green hydrogen and, thus, produce renewable methanol from CO2 at BioMCN.

Nouryon and Gasunie will supply green H2 produced by a 20MW water electrolysis unit in Delfzil (Netherlands) to BioMCN. There, the hydrogen will be combined with CO2 from various processes to produce renewable methanol, which avoids 27,000 tons of CO2 p.a. versus conventional methanol.

The feasibility of the ambition is being investigated by the partners – final decision expected in H2 2020.

Timeline

H2 2020: final decision on feasibility and go-ahead expected

Key Metrics

CO_2 Impact: 27kt p.a.

Maturity: 1 - Concept

Cost: N/A

Funding: N/A

Key documents:

Nouryon press release

EU Funding

Source: Company press releases

10: Renewable jet fuel from air

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

Key characteristics: U C

Context

The objective is to build a plant capable of producing **1,000 liters of renewable jet fuel** per day through **Direct Air Capture (DAC)**

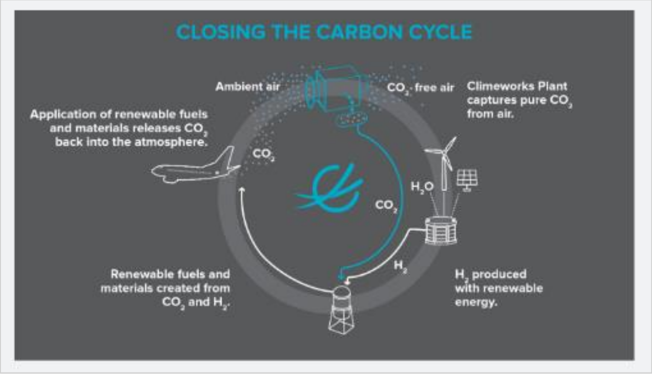
Consortium coordinated by **EDL Anlagenbau Gesellschaft GmbH, Sunfire GmbH** with **Climeworks, Interatec GmbH** and **Rotterdam The Hague airport Airport**

CLIMEWORKS Capturing CO₂ from air · sunfire · EDL PÖRNER GRUPPE · Rotterdam The Hague Airport · INERATEC · SkyNRG · URBAN CROSSOVERS RESILIENT SOLUTIONS · Schiphol Group

Description

Goal of the study is to define the concept & basic engineering of onsite production of renewable fuels. Further, it will enable a cost estimate for both the actual construction of the plant and the fuel itself, which will be decisive for further project development.

CO2 is captured (DAC) and transformed to syngas with electrolyser cells (Sunfire). By means of the Fischer-Tropsch process, syngas is turned into synthetic hydrocarbons (Interatec) and finally into jet fuels (EDL).



Timeline

N/A

Key Metrics

CO_2 Impact: N/A

Maturity: 1 - Concept

Cost: N/A

Funding: N/A

Key documents:

Press release

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

12: H2ermes

Key characteristics: H C

Context

The objective is to advance **carbon-neutral steel production with use of green hydrogen.**

Consortium coordinated by **Tata Steel, Nouryon and Port of Amsterdam.**

TATA STEEL

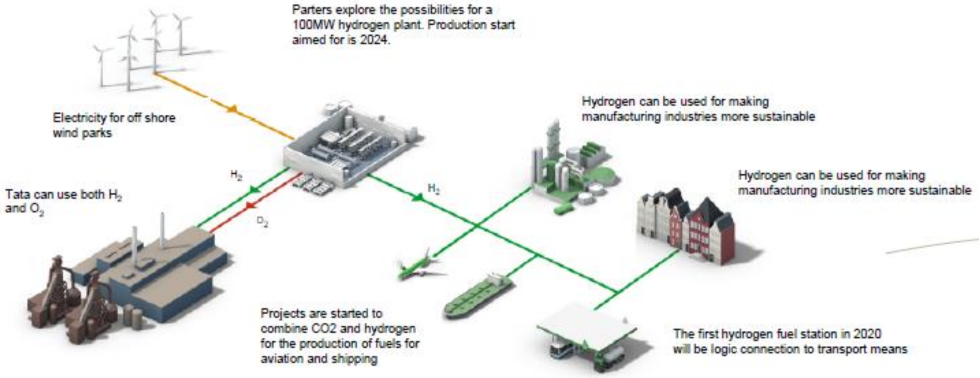
Nouryon

Port of Amsterdam

Description

The aim of the project is to investigate a H2 production facility on the Tata Steel Ijmuiden site with up to 15,000 tons of green H2 p.a.

The green H2 shall be based on renewable electricity from windpark power connection to Tennet and a large-scale 100 MW electrolyzer. The Port of Amsterdam is focused on linking up the H2 network from this project with other CO2 and H2 transport networks in the Dutch region (e.g., Project Athos).



Timeline

2018: Start of H2ermes project

Key Metrics

CO_2 Impact: N/A

Maturity: 1 - Concept

Cost: N/A

Funding: N/A

Key documents:

Nouryon press release

Tata Steel press release

Source: Company website, press release

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

14: CCU/S Smart Delta Resources

Key characteristics: U S H C →

Context

Most cost effective CC(U)S routing for the region based on the highest CO2 reduction and lowest costs base for the whole CCS value chain.

Consortium of Zeeland Refinery, Dow, Yara, ArcelorMittal, PZEM, Gasunie, Fluxys, Smart Delta Resources and North Sea Port.

Description

To be announced

Timeline

To be announced

Key Metrics

CO_2 Impact: N/A

Maturity: 1

Cost: N/A

Funding: granted Project of Common Interest (PCI) status by the European Commission, making it eligible for funding from the Connecting Europe Facility (CEF)

Key documents:

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

15: The Hydrogen Delta

Key characteristics: H C →

Context

1GW green hydrogen project in Delta region (incl. hydrogen infrastructure)

Consortium of ArcelorMittal, Dow Benelux, ENGIE, Fluxys, Gasunie, ICL-IP, Impuls Zeeland, North Sea Port, Orsted, Smart Delta Resources, Yara Sluiskil and Zeeland Refinery with support from Nederlands Ministerie van Economische Zaken, Provincie Oost-Vlaanderen and Provincie Zeeland

Description

Ambition to become largest hydrogen cluster in Netherlands and Flanders and lead the transition to the hydrogen economy

Timeline

2025: large-scale pilot (~100 MW electrolyzer)

2030: large-scale “hydrogen factory” (~1 GW) as well as hydrogen infrastructure

Key Metrics

CO_2 Impact: N/A

Maturity: 1

Cost: N/A

Funding: N/A

Key documents:

[Press announcement]

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

16: North-C-Methanol

Key characteristics: U H C →

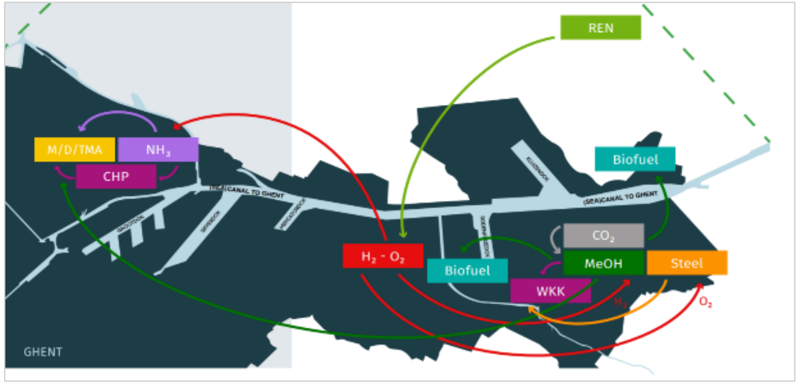
Context

Fifteen public and industrial partners have the ambition to realize a Carbon Capture and Utilization Hub (CCU hub) in the North Sea Port area

Consortium of City of Ghent, North Sea Port, Ghent University (CAPTURE), Bio Base Europe Pilot Plant, Cleantech Flanders, POM East Flanders, ENGIE, ArcelorMittal, Anglo Belgian Corporation, Alco Bio Fuel, Oiltanking, Terranova Solar and Fluxys and the spearhead clusters Catalisti (chemistry and plastics) and Flux50 (energy)

Description

The CCU Hub strategy consists of four processes to be integrated into a circular value chain: (1) the production of hydrogen / oxygen (Rodenhuize, 63MW electrolysis plant), (2) the capture and purification of CO2 (Knippegroen), (3) the production of **methanol** and (4) the production of **ammonia**.



Timeline

2023: Construction of the North-C-Methanol project (63MWe production of green methanol)

2027: Scaling up to about 300MWe production of green methanol, ammonia, methylamines, formic acid,…

2030: Preparing large scale infrastructure

Key Metrics

CO_2 Impact: 647 ktpa

Maturity: 2

Cost: estimated investment of €500M for 4 units

Funding: By valorizing the O2 by-product and heat recovery for industrial processes and by regulation in REDII the unprofitable top is estimated at 20%

Key documents:

[Exploratory study]

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

17: Power-to-methanol demonstration project

Key characteristics: U H C

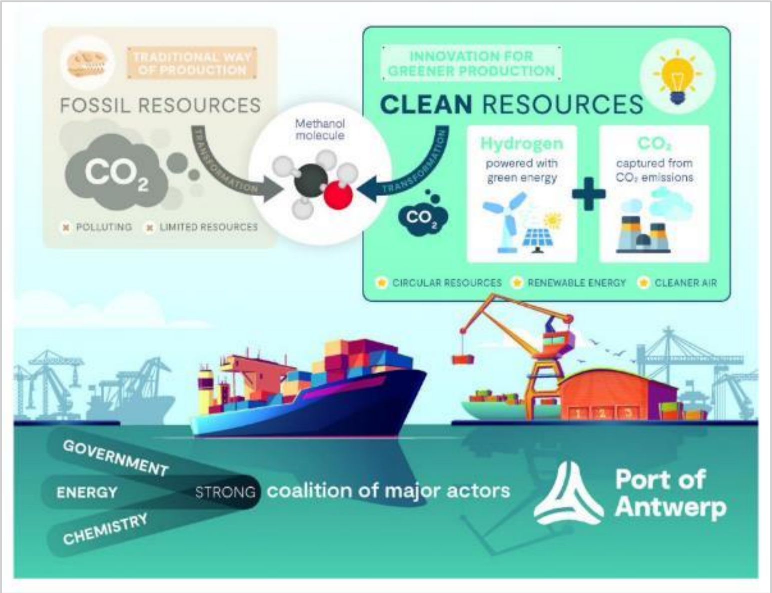
Context

Production of sustainable methanol being an important raw material in the Port of Antwerp area (~300,000 tonnes p.a.)

Cooperation between **Port of Antwerpen, ENGIE, Oiltanking, Indaver, Vlaamse Milieuholding (VMH)** and **Helm-Proman**

Description

Methanol will be produced from waste CO2 and green hydrogen which will be generated in a new electrolysis plant



Timeline

N/A

Key Metrics

CO_2 Impact: 4-8k tonnes of sustainable methanol (~2% of annual demand in Antwerp cluster)

Maturity: 3

Cost: N/A

Funding: N/A

Key documents:

Press release

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

18: Steelanol

Key characteristics: U C

Context

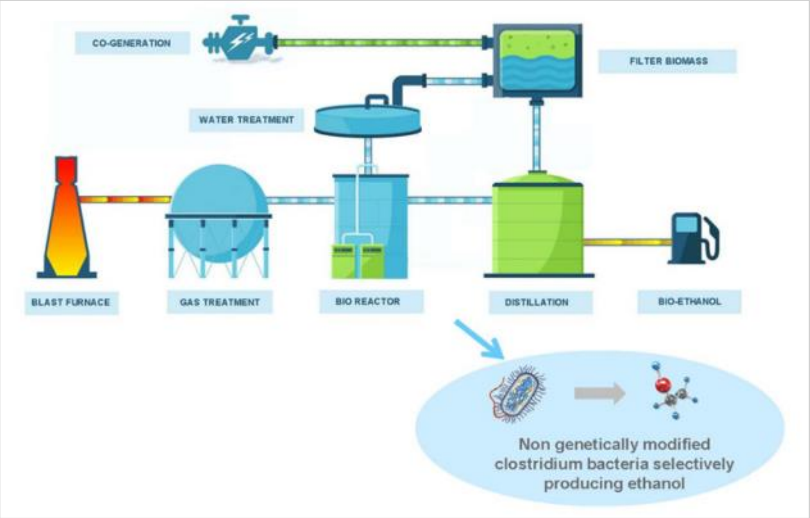
Transforming industrial waste gases into advanced bio-ethanol for use in the transport sector by way of a novel **gas fermentation technology**

Develped by **ArcelorMittal**, in cooperation with **Primetals Technologies, LanzaTech** and **E4Tech**

Several key players in the transport sector, **Boeing, Virgin Atlantic** and **Mitsui**, have expressed strong interest and support for the project

Description

The technology developed by Lanzatech uses **microbes that feed on (ferment) carbon monoxide** to produce bioethanol



Timeline

Construction of facility has started mid-2019

First production expected end-2020

Key Metrics

CO_2 Impact: 184.000t of CO_2 (equal to 80M liters of gasoline)

Maturity: 5

Cost: estimated at €150M

Funding: received €10.2M funding from EU Horizon 2020 research and innovation program (No. 656437)

Key documents:

[Presentation Vlaamse Klimaattop (2015)]

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

19: Carbon2Value

Key characteristics: U C →

Context

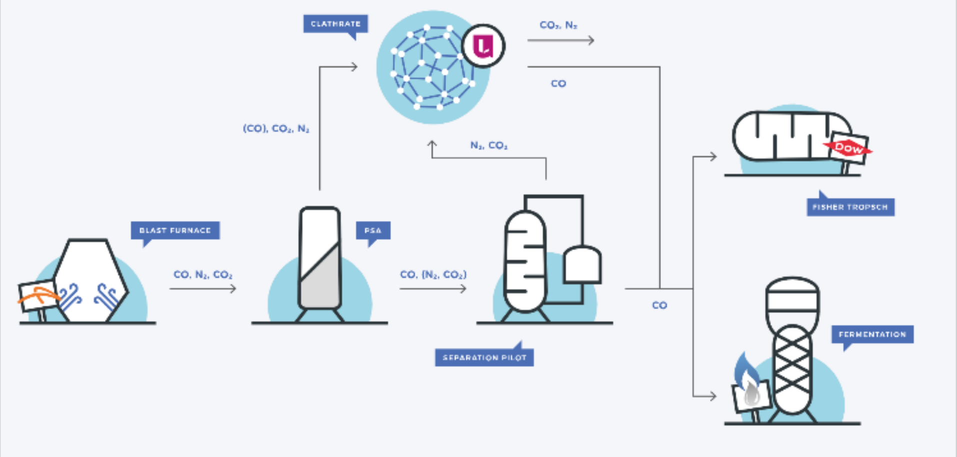
Transformation of CO2 and CO streams from the steel industry into new value chains (ethanol and synthetic naphtha)

Develped by **ArcelorMittal**, in cooperation with **Dow Benelux, LanzaTech, University of Lille, ISTP and POM EF**

Description

Blast furnace gas is directed to a Pressure Swing Adsorption (PSA) installation to separate CO from other gases. The CO gas stream can be valorized via two routes: (i) Fischer-Tropsch catalytical conversion to ethylene and (ii) biofermentation to ethanol.

CO-poor tail gases will be separated from nitrogen and other gas components using Clathrate technology.



Timeline

Pilot was launched mid-2019 and is expected to be finished mid-2021

Key Metrics

CO_2 Impact: 30-45% reduction of GHG emissions from blast furnace gases

Maturity: 3

Cost: €10.5M

Funding: received support from the Interreg 2 Seas program and €4.4M ERDF[1] subsidies

Key documents:

Carbon2Value website

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1. European Regional Development Fund

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only
Project Type
C Consortium
→ Cross-border

20: CCUS infrastructure Antwerp

Key characteristics: U S C →

Context

Economic and technical feasibility study into the development of **"open access" CCUS infrastructure**

Consortium between Air Liquide, BASF, Borealis, INEOS, ExxonMobil, Fluxys, Port of Antwerp and Total **– Announced December 2019**

Description

The feasibility study will also investigate the possibilities for CO2 storage. Belgium does not have suitable geological formations for storing CO2 underground, and so **international collaboration will be necessary**. To support this international collaboration, Port of Antwerp and a number of other partners submitted two applications to the European Commission earlier this year for recognition as **'Projects of Common Interest'.**

Both projects offer possibilities for investigating the development of cross-border CO2 transport infrastructure, **linking up respectively with Rotterdam (CO2TransPorts project) and Norway (Northern Lights project).**

Timeline

Feasibility study completed towards the end of 2020

Key Metrics

CO_2 Impact: N/A

Maturity: 1

Cost: N/A

Funding: N/A

Key documents:

Press release

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

21: Leilac Project

Key characteristics: S C →

Context

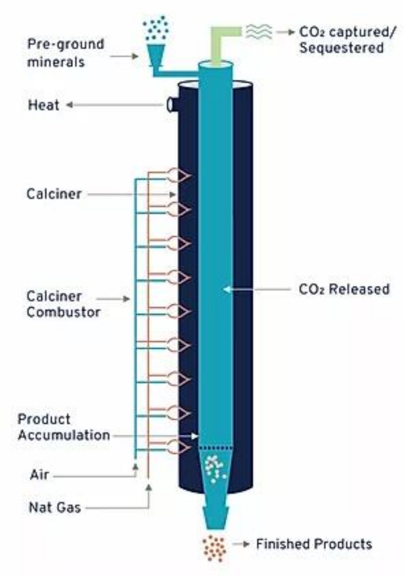
Aim of the project is to demonstrate ability of Direct Separation technology to **reduce CO2 from lime and cement production**.

Consortium is led by **Heidelberg Cement, Cemex, Calix, Tarmac, Lhoist** and others.

Description

LEILAC (Low Emissions Intensity Lime and Cement) is a pilot project situated in Lixhe, Belgium, to employ that Direct Separation technology in the cement and lime production process.

The demonstration project aims to enable the capture of the unavoidable CO2 emissions (about 60 % of total CO2 emissions) from both industries without significant energy or capital penalty other than compressing the CO2.



Timeline

2016: project passed pre-FEED study

2017: Final investment decision made

2019: Completion of pilot, on time and under budget

2020: Final completion of Leilac

Key Metrics

CO_2 Impact: N/A

Maturity: 4

Cost: €21m

Funding: €12m by EU Horizon 2020, €9m from key partners

Key documents:

Leilac Project Webiste

Source: Project website, company press releases

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

22: CEMCAP Project

Key characteristics: S C

Context

Objective is to capture CO2 from cement production facilities directly.

The project is led by **Heidelberg Cement and its subsidiaries with technology and academic partners.**

Description

Overarching aim of CEMCAP is to prepare the industry for large-scale implementation of CO2 capture from cement plants. Hence, the project evaluates different technologies with a targeted capture rate of 90% to identify greatest potential for retrofitting.

Based on findings, CEMCAP will describe routes for large scale deployment and follow-up potential innovations.

Timeline
N/A

Key Metrics

CO_2 Impact: N/A

Maturity: 4

Cost: €10m

Funding: €9m funding by EU Horizon 2020

Key documents:

Cemcap Project Website

Source: Project website, company press releases

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

23: Steel2Chemicals

Key characteristics: U S C →

Context

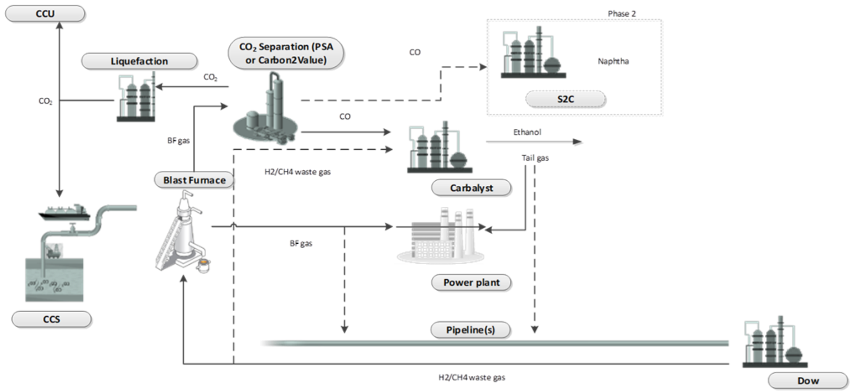
The objective of the Steel2Chemicals project is to demonstrate a cost-effective solution for cutting carbon emissions by establishing a **new value chain between the steel and the chemical industry**

Collaboration between **Arcelor Mittal** (Ghent), **DOW Chemicals** (Terneuzen), **Tata Steel** (Ijmuiden), **ISPT**, **TNO-ECN**, and **University of Ghent**

Description

The S2C project first of all aims to explore the performance for a new catalyst under industrial conditions – **converting CO together with H2 into high quality naphtha**. An additional study was launched to liquefy the remaining CO2 (for instance using cryogenic technology) to be able to transport, reuse or store the CO2 via Northern Light or Porthos network.

As a **parallel but separate track the valorisation of waste H2/CH4 gas from the chemical industry as a sustainable reductant for the steel industry** will be investigated. H2/CH4 waste gas from Dow (Terneuzen) will be transported in a future pipeline to ArcelorMittal Gent. The gas will be injected in a blast furnace as reductant to replace fossil coal. From the hydrogen enriched BF top gas the CO2 will be separated, shipped and stored. The rich CO2/H2 gas stream will in an initial stage be converted into ethanol using the Carbalyst technology (see other project) and in a second stage into naphtha via Fischer-Tropsch (S2C) in combination with additional hydrogen rich industrial gases.



Timeline

2020: Pilot at Arcelor Mittal plant operational

Key Metrics

CO_2 Impact: 2.3 tCO2 per ton of naphtha captured in chemical products, plus additional 4.5 tCO2 per ton of naphtha storage (+85 ktCO2 p.a. from H2/CH4 pipeline)

Maturity: 3 – Permitting / Construction

Cost: N/A

Funding: RVO (Rijksdienst Voor Ondernemend Nederland)

Key documents:

[Project description]

Source: Arcelor Mittal

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

24: HyPort Ostend

Key characteristics: U H C

Context

The project goal is to have a **plant operational in the port area of Ostend by 2025** that produces green hydrogen. This end product, green hydrogen, will both serve as an energy source for electricity, transport, heat and fuel purposes and as a raw material for industrial purposes.

Collaboration between DEME, Port of Ostend and PMV.

Description

In the **first phase** of the process, the **general feasibility** will be further investigated and a development plan will be worked out. An innovative demonstration project with mobile shore-based power will then be started.

A **demonstration project with an innovative electrolyser of around 50 MW** is also scheduled.

By 2022, the roll-out of a **large-scale shore-based power project**, running on green hydrogen, will start.

The **finish line will be crossed in 2025** with the completion of a commercial green hydrogen plant in the context of the planned new offshore wind concessions.

Key Metrics

CO_2 Impact: N/A

Maturity: 1 - Concept

Cost: N/A

Funding: -

Key documents:

Press release

Source: Company press releases

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

25: HySynGas

Key characteristics: H C

Context

The aim is to establish a **power-to-gas hub to advance decarbonization in Northern Germany** across sectors.

Consortium led by **Vattenfall, together with ARGE Netz and MAN Energy Solutions.**

Description

The consortium announced a large-scale power-to-gas project in an industrial park in Brunsbüttel (Germany) with a facility to produce green hydrogen and synthetic gases (SNG) from electricity generated by nearby solar and wind plants. A 50 MW electrolyser for H2 as well as production facilities for synthetic methane with a capacity of >40 tonnes per day are planned.

The aim is a cross-sector decarbonization. Hence, envisioned end-user applications include ships, buses, gas power plants and other industrial sectors. First costumers already include Volkswagen, some logistics companies, municipal utilities and more.

The partner companies have also applied for funding from the Federal Ministry for Economic Affairs and Energy to build a related R&D laboratory.

Key Metrics

CO_2 Impact: 0.04 Mtpa

Maturity: 1/2 - Concept

Cost: 130 m EUR

Funding: Yes, but no numbers publicly available

Key documents:

HySynGas Project Website

Source: Company press releases

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

26: Westküste 100

Key characteristics: U H C

Context

Aim is to map and scale a regional hydrogen economy on an industrial scale, activities range from the generation of green electricity to the production of synthetic hydrocarbons

Cooperation between **EDF Germany, Holcim Germany Group, OGE, Orsted, Raffinerie Heide, thyssenkrupp**

Description

Project has a holistic approach, using wind power to generate green hydrogen through electrolysis. CO2 produced in the cement plant is to be used as a raw material together with the green hydrogen in the refinery for the production of synthetic hydrocarbons, which can be used as aviation fuel or chemical raw material

Timeline

Planning scheduled to start early 2020

Scale up to 30MW of electrolysis capacity by 2025

Plant could be up and running by 2030

Key Metrics

CO_2 Impact: N/A (but planned creation of 700MW of hydrogen)

Maturity: 1

Cost: 100 m EUR

Funding: will receive ~100 m EUR funding from German Government

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

28: CO2Min

Key characteristics: U C

Context

Main focus is on environmental assessment of developing processes for mineralization via Life Cycle Assessment

3 year research project at RWTH Aachen in cooperation with **HeidelbergCement**

HEIDELBERGCEMENT

Description

Project explores the absorption of CO2 from flue gas by the minerals olivine and basalt, which are are able to bind CO2 over their entire life-cycle. This process usually takes decades, thus research is focused on speeding up the process. In the future, the carbonised minerals could be used as a value-added additive in the production of building materials.

Timeline

Started in 2017 with investigating different materials

Currently working on marketability and increasing social acceptance

Project finished in May 2020

Key Metrics

CO_2 Impact: N/A

Maturity: 2

Cost: N/A

Funding: funded with €3M by German Federal Ministry of Education and Research (BMBF)

Source: Company website, Annual sustainability report, Expert interviews

Technology Type

- U CCU
- S CCS
- S H H2 enabled CCU/S
- H H2 only

Project Type

- C Consortium
- → Cross-border

29: GetH2

Key characteristics: H C

Context

The vision is to **implement a nationwide H2 infrastructure in Germany** including all elements: production, storage, use and transport on an industrial scale.

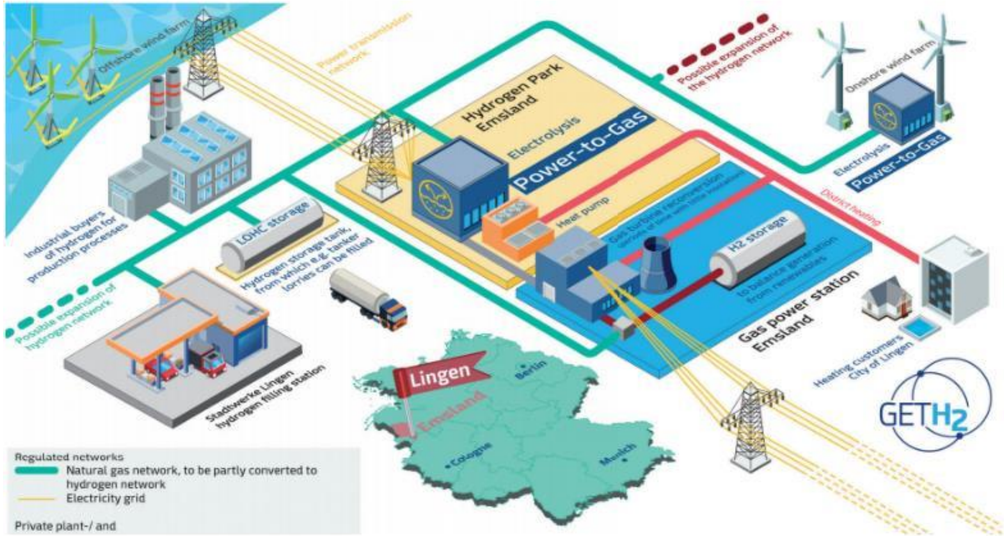
Consortium led by **RWE, Stadtwerk Lingen, Siemens, Hydrogenious, Nowega** and more.

Description

GetH2 aims to connect German regions with high proportions of renewables energies (mainly wind and solar) to produce green H2. The ultimate goal is to establish a nation-wide H2 distribution using existing gas networks, to reach >90% of industry and population (see map). H2 that is not used directly shall be stored.

Initial focus for end-users will be on mobility and large-scale industry.

Project kickoff and project nucleus for GetH2 is in Lingen, Emsland region.



Key Metrics

CO_2 Impact: N/A

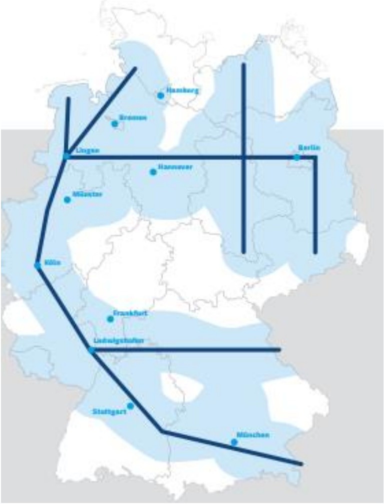
Maturity: 3

Cost: N/A

Funding: N/A

Key documents:

Official GetH2 Brochure



Source: Company press releases

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

31: Post-combustion CO2 scrubbing

Key characteristics: U C

Context

Aim is to recover CO2 generated as a by-product of production processes.

Cooperation between **Linde, RWE** and **BASF**.

Description

CO2 scrubbing involves a scrubbing agent to separate the carbon dioxide emitted by conventional coal-fired power plants following desulphurisation of the flue gas and is the only method suitable for retrofitting existing power plants. CO2 is extracted from flue gas through solutions of amines.

Timeline

2019: First pilot

2020: Commercial readiness expected

Key Metrics

CO_2 Impact: N/A

Maturity: 3

Cost: N/A

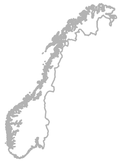
Funding: N/A

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only
Project Type
C Consortium
→ Cross-border

32: Northern Lights Projects

Key characteristics: S C



Context

The Northern Lights project is part of the Norwegian full-scale CCS project.

The project is lead by **Equinor,** who are leading a consortium including **Shell** and **Total**

Memoranda of understanding have been signed with**, Air Liquide, Arcelor Mittal, Ervia, Fortum Oyj, HeidelbergCement AG, Preem, and Stockholm Exergi**

Description

The Northern Lights project includes ship transport, onshore storage, pipeline transport to an offshore injection well, and injection of CO2 for storage in a subsurface storage complex.

CO2 from industrial sources is captured in the Oslo-fjord region and other regions (e.g. Arcelor Mittal) and shipped as liquid CO2 to an onshore terminal on the Norwegian west coast. From there, it will be transported by pipeline to an offshore storage location subsea in the North Sea, for permanent storage

Timeline

Started drilling CCS exploration well in Q4 2019

Current status: awaiting final investment decision for project from partners and government (Q2-Q4 2020)

Scheduled to be operational end of 2023

Key Metrics

CO_2 Impact: 100 Mtons, 1.5 Mtons per year

Maturity: 2

Cost: estimated €1.6B for full-scale CSS including Northern Lights

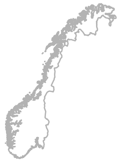
Funding: granted Project of Common Interest (PCI) status by the European Commission, making it eligible for funding from the Connecting Europe Facility (CEF)

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

34: Norks E-Fuel Alpha



Key characteristics: U H C

Context

Aim of project is to promote novel Power-to-Liquid (PtL) technologies in Norway and Europe.

Consortium of **Sunfire, Climeworks** and **Paul Wurth**

sunfire

CLIMEWORKS
Capturing CO_2 from air

PAUL WURTH

Description

Aim is to develop and implement PtL projects using renewable electricity to produce synthetic diesel, jet-fuel and chemicals from water and CO2 (100 % renewable).

CO2 is extracted from atmosphere and chemical site, converted into syngas, refined and then can be used as e-Jetfuel or e-Waxes.

Timeline

Project location identified and available for realization

Financing secured

FEED in progress until mid-2020

Key Metrics

CO_2 Impact: 25k tons per year

Maturity: 2

Cost: estimated at €150M

Funding: N/A

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

38: Bio CHP in Stockholm

Key characteristics: S

Context

Aim is to test carbon capture at Värtan bioenergy plant

Project is led by **Stockholm Exergi.**

stockholm exergi

Description

Overall project aims to install a carbon capture test facility at its biomass-fired KVV8 unit at Värtan combined heat and power (CHP) plant in Stockholm.

Bioenergy Carbon Capture and Storage (BECCS) enables the capture of carbon dioxide (CO2) from the biomass fuel in the post-combustion flue gases.

The CO2 is compressed into liquid form and stored in underground rock formations.

Timeline

Test facility installed in late-2019

Key Metrics

CO_2 Impact: 0.8 Mtons per year

Maturity: 3

Cost: €52 to €77 per tonne of CO2 captured

Funding: N/A

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

39: Preem CCS

Key characteristics: S

Context

Preliminary study on how Preem's refinery in Lysekil could use CCS to capture and store carbon dioxide and define the obstacles and possibilities that exist in Preem's case.

Cooperation between **Prees**, Chalmers University of Technology and SINTEF

Description

Overall aim is to create technology to separate carbon dioxide from the flue gases before being released into the atmosphere.

CO_2 is transported from Sweden to Norway to utilize the infrastructure they are planning to create.

Timeline

Next step: carry out a demonstration project in Lysekil to provide basis for designing a full-scale CCS facility

Study started in 2019 and scheduled to run until 2021

Aiming to build a full-scale facility by 2025.

Key Metrics

CO_2 Impact: 0.5 Mtons per year, around 30% of total emissions

Maturity: 2

Cost: N/A

Funding: N/A

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

40/41: H2V NORMANDY and H2V 59

Key characteristics: H

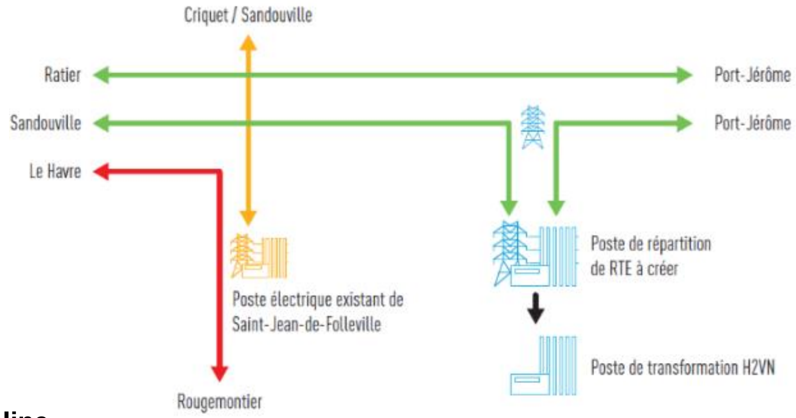
Context

The aim is to provide **green hydrogen to French industrial users** currently using grey hydrogen.

The project is led by **H2V Industry, supported by GE** (e.g., substations).

Description

The project aims to advance the European energy transition by offering green hydrogen to French industrial users in the Normandy region. Many end-users are in port areas such as Le Havre, Dunkirk, etc. Local distribution will leverage the existing H2 network currnelty used for grey H2. Production is planned to reach 28,000 tonnes of H2 annually (3% of total production in France) and create 200 jobs per site by 2022.



Timeline

2016/17: Concept and site selection

2018/19: Feasibility studies and research

2020: Authority approvals

2021-2023: Installation and full operationalization

Key Metrics

CO_2 Impact: N/A

Maturity: 2/3

Cost: 230 - 250 m EUR

Funding: Yes, but no numbers publicly available

Key documents:

H2V Normandy Project Website

Source: Company press releases

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

46: CirclEnergy

Key characteristics: U H

Context

Aim is to reduce society's dependency on fossil fuels by facilitating the expansion of CRI's innovative Emissions-to-Liquids (ETL) technology.

Developed by **Carbon Recycling International**

CARBON
RECYCLING
INTERNATIONAL

Description

Inevitable CO2 industrial emissions are captured, purified and reacted with hydrogen produced through water electrolysis, to generate methanol. Hydrogen may also be processed from by-product streams of industries that produce more than they consume in some cases. The reaction takes place over a well-known copper/zinc oxide catalyst system. The methanol is produced in an aqueous mixture

Timeline

N/A

Key Metrics

CO_2 Impact: N/A

Maturity: 3

Cost: N/A

Funding: Received €1.8M in funding from EU Horizon 2020

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Consortium
→ Cross-border

47: Clean Energy Project

Key characteristics: S C →

Context

Aim is to inject CO2 in oil fields for enhanced oil recovery

Project is led by **Minijos Nafta**

Description

Overall aim is to build an Allam cycle power plant in western Lithuania and capture CO2. CO2 can be used for EOR (Enhanced Oil Recovery), after which it gets recycled and permanently sequestered.

Additionally, it provides a storage site for other major GHG emitters in Lithuania.

Timeline

N/A

Key Metrics

CO_2 Impact: up to 200 Mtons

Maturity: 2 - Feasibility study

Cost: N/A

Funding: N/A

Source: Company website, Annual sustainability report, Expert interviews

Technology Type
U CCU
S CCS
S H H2 enabled CCU/S
H H2 only

Project Type
C Consortium
→ Cross-border

49: ICO2CHEM

Key characteristics: U C

Context

Aims at developing a new production concept for converting waste CO2 to value-added chemicals

Developed by **VTT, INERATEC, Infraserv Höchst, ALTANA, Provadis Hochschule** and **Politecnico di Torino**

VTT
INERATEC
infraserv höchst
provadis Hochschule
ALTANA
POLITECNICO DI TORINO

Description

The technological core of the project consists in the combination of a Reverse Water Gas Shift (RWGS) reactor coupled with an innovative modular Fischer-Tropsch (FT) reactor.

The pilot plant will convert CO2 from a biogas upgrading plant together with industrial H2, a by-product from a chlor-alkali electrolyzer plant, into highly valuable white oils and high molecular weight aliphatic waxes

Timeline

Study results including business plan set to be released by late 2021

Key Metrics

CO_2 Impact: N/A

Maturity: 2

Cost: N/A

Funding: received €6M in funding from EU Horizons 2020

Source: Company website, Annual sustainability report, Expert interviews

50: RECODE

Technology Type

U CCU

S CCS

S H H2 enabled CCU/S

H H2 only

Project Type

C Consortium

→ Cross-border

Key characteristics:

Context

Aim is to use CO_2 from flue gases of cement plant for the production of value-added chemicals and materials to improve cement quality, reduce energy intensity and CO_2

Project is driven by consortium of **Titan Cement,**SMEs and multiple research centers and universities across 7 European countries

Description

The project follows a circular economy approach: CO2 produced by cement manufacturing is purified by ionic liquids and re-used in significant part within the plant itself to produce better cement-related products entailing less energy intensity and related CO2 emissions by a Quadratic effect.

Timeline

Development of key functional materials started in 2017

Project finishes in mid 2021 with assembly of single-process lines and testing at cement manufacturing site

Key Metrics

CO_2 Impact: >20% reduction of emissions

Maturity: 3

Cost: N/A

Funding: received €8M funding from the European Union's Horizon 2020 research and innovation programme

Source: Company website, Annual sustainability report, Expert interviews