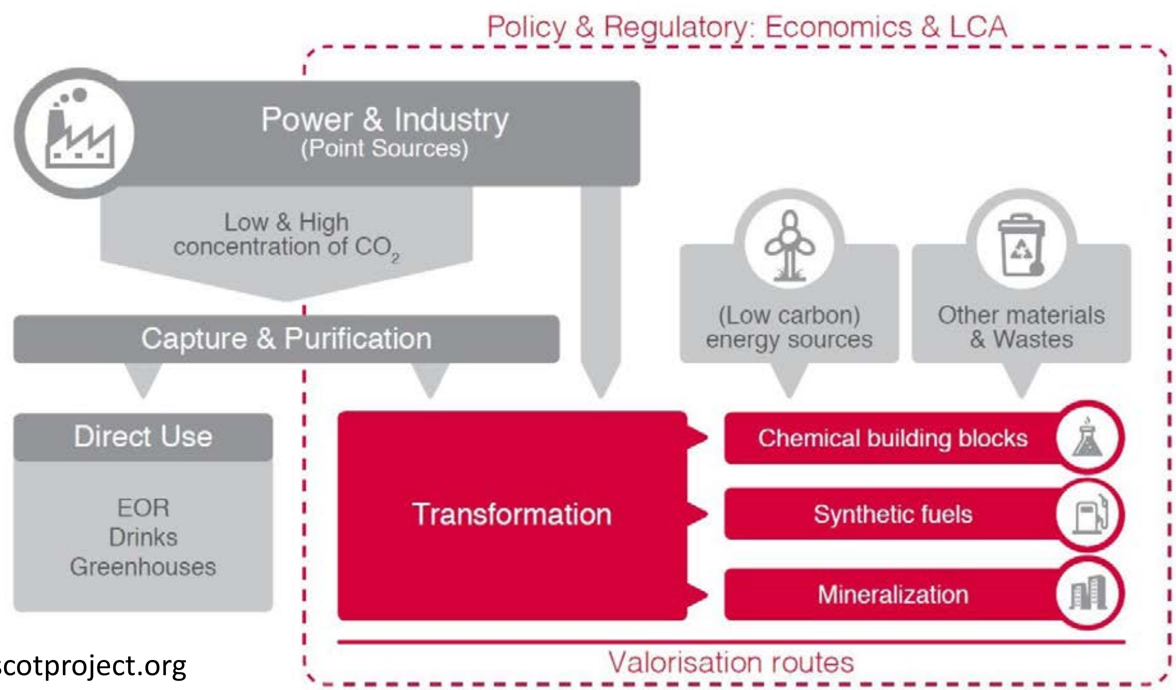
NATIONAL ACADEMIES CARBON UTILIZATION COMMITTEE

Heleen De Wever, 28 March 2018

CCU STUDY TENDERED BY FLEMISH AUTHORITIES

- To map valorization pathways for CO_2 as raw material/feedstock with a view to their application in Flanders and assess which contribution they could make to emission reductions in the Flemish Region
- To formulate concrete policy recommendations to encourage application of CO_2 in Flemish Region, taking into account the EU ETS (Emissions Trading System) framework in Europe



www.scotproject.org

INVENTORY OF CCU ACTIVITIES IN FLANDERS

- Status of developments

CCU category	CCU-technology	Product	Research	Demonstration	Economic feasible*
Organic products	Catalysis	Methanol			
	Catalysis	Fuels, chemicals			
	Catalysis	Carbonates, carbamates			
	Catalysis	Polyols → polyurethanes			
	Chemical looping reforming	Syngas			
	Plasma reforming	Syngas			
	Plasmacatalysis	C1-C5 oxygenated products			
	Electrocatalysis	Carboxylates			
	Photosynthesis algae	Biomass			
	Photosynthesis algae	Biosilica, others			
	Photo-electrochemistry	Methane, methanol, formic acid			
	Fermentation (from CO)	Ethanol			
	Fermentation	Acetate			
	Fermentation	Methane			
	Fermentation	Polyhydroxyalkanoates			
	Fermentation	Single Cell Proteins			
	Bioelectrosynthesis	Acetate, ethyl acetate, caproate			
Inorganic products	Carbonatation	Building materials			
	Carbonatation	Powders			

Companies   Most activities   Few activities

Source: LNE (2016)

IDENTIFIED BARRIERS FOR INTRODUCTION OF CCU TECHNOLOGIES

- Technological barriers
  - Characterization and optimization of processes at low Technology Readiness Level (TRL) for proper assessment of their potential
  - Expansion of product range to accelerate market introduction
  - More interaction between companies and research centers to better determine which combination technology - product has the most potential
- Regulatory barriers
  - Compliance with complex legislation (for example food) or standards (for example construction materials) for CCU-based product
  - Limited incentives for CCU technologies by current climate policy framework
- Need for upscaling and demonstration projects under real conditions

Source: LNE (2016)

FURTHER EVALUATION OF INVENTORIZED CCU TECHNOLOGIES

- Selection criteria
  - Technologies developed in Flanders (innovation aspect)
  - Processes that produce fuels (legislation aspect)
  - Diversity of used technologies
  - Processes that generate products with high added value (economics)

- Selected cases
  - Production of ethanol from waste gases of the steel industry (ArcelorMittal)
  - Power-to-methanol, *i.e.* production of methanol using green electricity (Port of Antwerp)
  - Production of algal biomass for use as larval feed (Proviron)
  - Production of construction materials from steel slags/other residues (Carbstone Innovation)


Algae biomass


Power-to-methanol


Steel waste gas to ethanol


Carbstone

Source: LNE (2016)

FURTHER EVALUATION OF INVENTORIZED CCU TECHNOLOGIES

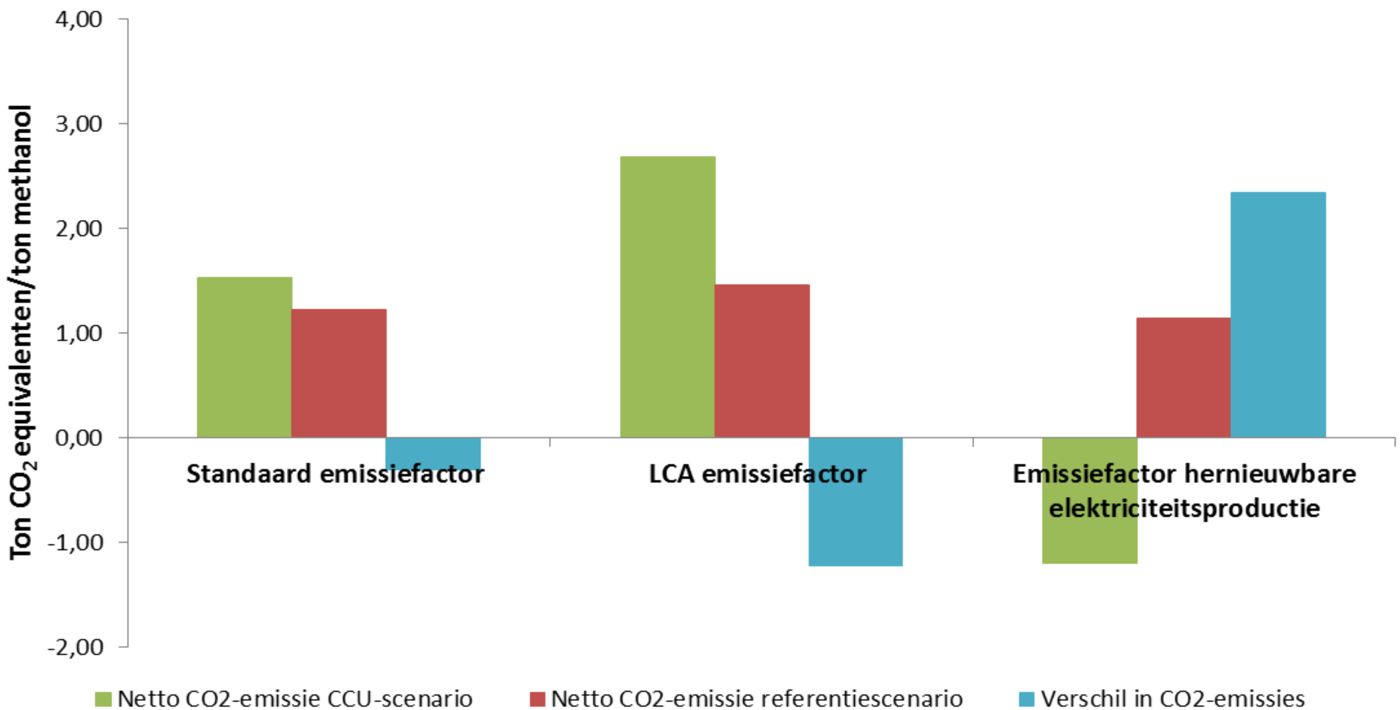
- Exploratory assessment based on 5 criteria (climate and economic aspect)
  - Actual contribution to emission mitigation, taking into account (in)direct CO_2 emissions
  - Economic feasibility and sensitivity analysis
  - Potential scale of application in Flanders
  - Technology Readiness Level (TRL)
  - System analysis

- Criterion 1: Actual contribution to emission mitigation (→ *simplified approach*)
  - Determine mass and energy balances for reference and CCU case
  - Calculated CO_2-emissions = fixed CO_2 (negative value) + ∑ (in)direct CO_2-emissions
  - Difference in CO_2-emissions = Net CO_2-emission (reference – CCU-scenario)
  - Use of 3 emission factors:
    - 0 ton CO_2/MWh_{el} (100% renewable electricity)
    - 0.285 ton CO_2/MWh_{el} (standard emission factor Belgian electricity production)
    - 0.4 ton CO_2/MWh_{el} (LCA emission factor Belgian electricity production)

Source: LNE (2016)

ACTUAL CONTRIBUTION TO EMISSION MITIGATION: DEPENDENCE ON EMISSION FACTOR

- CCU case: Power-to-methanol (Port of Antwerp)
- Reference case: Production of methanol from natural gas

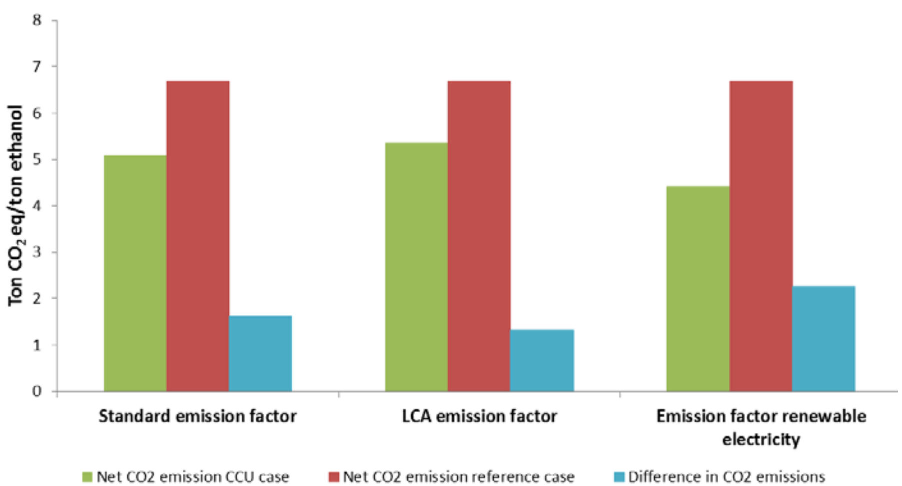


Source: LNE (2016)

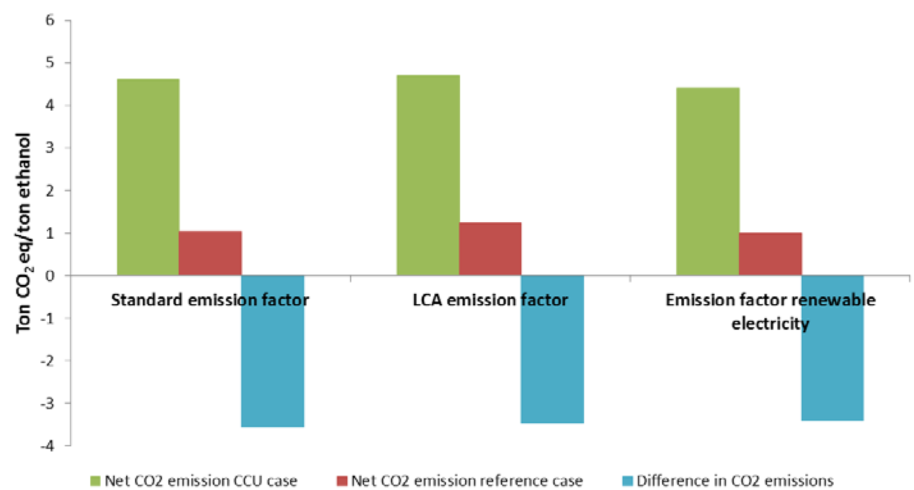
ACTUAL CONTRIBUTION TO EMISSION MITIGATION: DEPENDENCE ON REFERENCE CASE

- CCU case: production of ethanol from waste gases of the steel industry (ArcelorMittal)
- Reference case 1: Combustion of waste gases of steel industry towards electricity
- Reference case 2: Production of ethanol from naphta

CCU *versus* Reference case 1



CCU *versus* Reference case 2



Source: LNE (2016)

SUMMARY FOR THE SELECTED 4 CASES BASED ON 4 CRITERIA

	M	E	M	C als
Emission reduction				
Economically feasible				
Potential scale of application in Flanders				
Technology readiness level				

Note: summary and outcome cannot be used as general and final assessment of technologies because

- Case and location specific
- Strongly dependent on:
  system boundaries - reliable data
- Exploratory study: to be refined

Source: LNE (2016)

POLICY RECOMMENDATIONS – WAY FORWARD

Source: LNE (2016)

- Short-term strategy
  - Stimulating LCA of CCU technologies
  - Facilitating demonstration projects
  - Supporting investments
  - Promoting CCU products (fuels and materials) and CCU services
  - Supporting cluster development

- Long-term strategy
  - Recommending amendments to the EU ETS and RED addressing NER400 funding
  - Contributing to an EU action plan for the circular economy where CO_2 utilization is recognized for its merits
  - Inclusion of CCU in long term climate policy

- To be continued:
  Integrated climate & energy plan 2021-2030 (end of 2018)

CONCLUSIONS

- Flemish authorities consider CCU as promising option to realize emission reductions in energy-intensive industry because
  - Flanders has large CO_2 point sources (a.o. in ports) potentially suited for CCU projects
  - Sufficient expertise is present at knowledge institutes for reuse of CO_2
- Measures can be taken towards reuse of CO_2, but important challenges remain
  - Most applications are still in research phase, only few techniques are already at commercial scale
  - More clarity is needed on impact of CCU-techniques on CO_2-reduction
  - High costs of CO_2 capture

Report available on-line

- Full report (in Dutch): www.lne.be/co2-als-grondstof-afvang-en-gebruik-van-co2-ccu
- Executive summary (in English): CCU in Flanders – Summary

Vlaanderen is omgeving

Source: LNE (2016)

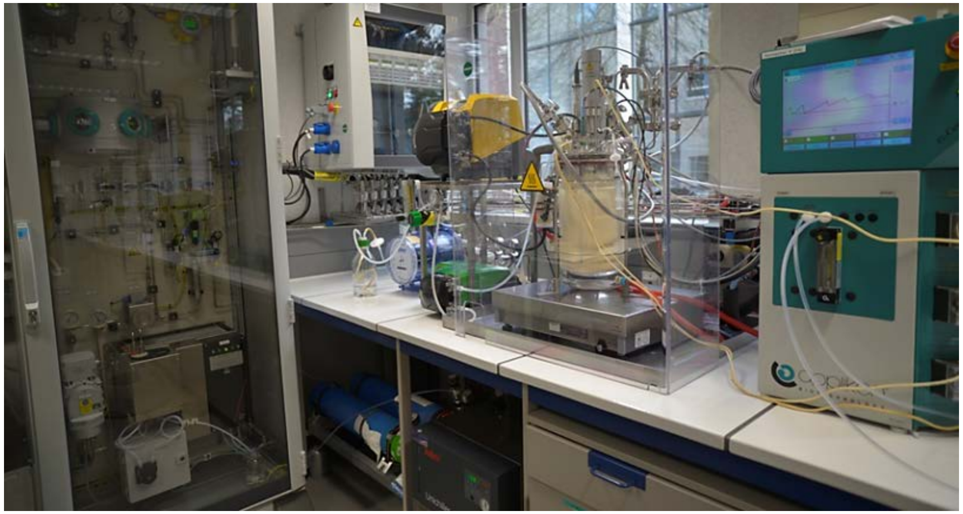
BIOTECHNOLOGY FOR C UTILIZATION

Link to BioRECO$_2$VER project

WHY BIOTECHNOLOGICAL CO_2 CONVERSIONS?

Claimed advantages compared to chemo-catalytic routes

- Milder environmental conditions
- Lower associated energy consumption
- Lower sensitivity to variations in gas composition
- Higher tolerance to impurities that are toxic to chemical catalysts
- Higher product selectivity
- Synthesis of other and complex molecules possible
- …



HURDLES FOR BIOTECHNOLOGICAL CO_2 CONVERSIONS

Several technical and economic barriers for CO_2 conversion, such as but not limited to

- gas pretreatment costs
- gas transfer into liquid phase in bioreactors
- product inhibition
- product recovery costs
- footprint
- scalability
- industrial implementation – economics
- public acceptance
- sustainability assessment

CALL TOPIC DESCRIPTION

- Work program topic: BIOTEC-5-2017: Microbial platforms for CO_2-reuse processes in the low-carbon economy
- Type of action: Research and Innovation Action
- Description: https://cordis.europa.eu/programme/rcn/701809_en.html

"Proposals should address current limitations of CO_2 reuse technologies based on microbial platforms, by developing their full potential, and need to cover one or more of the following issues:

- Microbes with an improved ability to convert CO_2 as a feedstock into chemicals and plastics.
- Discovery of new, more active and robust enzymes for improved bio-catalysis.
- Design of new synthetic microbial systems to produce useful enzymes.
- Improved microbes with resistance to impurities, by-products and target products.
- Exploring the potential application sectors of the products and technologies to be developed.

Proposals should address elements of Social Sciences and Humanities (SSH), exploring the public perception and acceptance of the technology of CO_2 reuse.
Proposals can be considered complementary to those dealing with CO_2 reuse in the SPIRE public-private partnership (….), where the issue is being tackled from a purely chemical perspective.
Activities are expected to focus on Technology Readiness Levels 3 to 5. This topic addresses cross-KET activities."

CALL TOPIC DESCRIPTION (CONTINUED)

"An industrial biotechnology route for CO_2 re-use is fermentation, where CO_2 is fermented into a desired molecule using hydrogen as a source of energy. However, there are technical issues that need to be resolved, because the biochemical reactions involved are not yet self-supporting in terms of energy for the industrial scale conversion of CO_2 into chemicals. Moreover, the final yield of the products is low and the process needs optimisation. Ultimately, the success of CO_2 reuse technologies will depend on developing processes which are less energy and material intensive than the processes they aim to replace and which can be scaled to an industrial level of production. In this context, an important consideration or advantage would be the ability of the microbes to process raw CO_2 (low concentrations, presence of impurities, etc.). Therefore, substantial research is required to achieve the goal of a CO_2 economy.

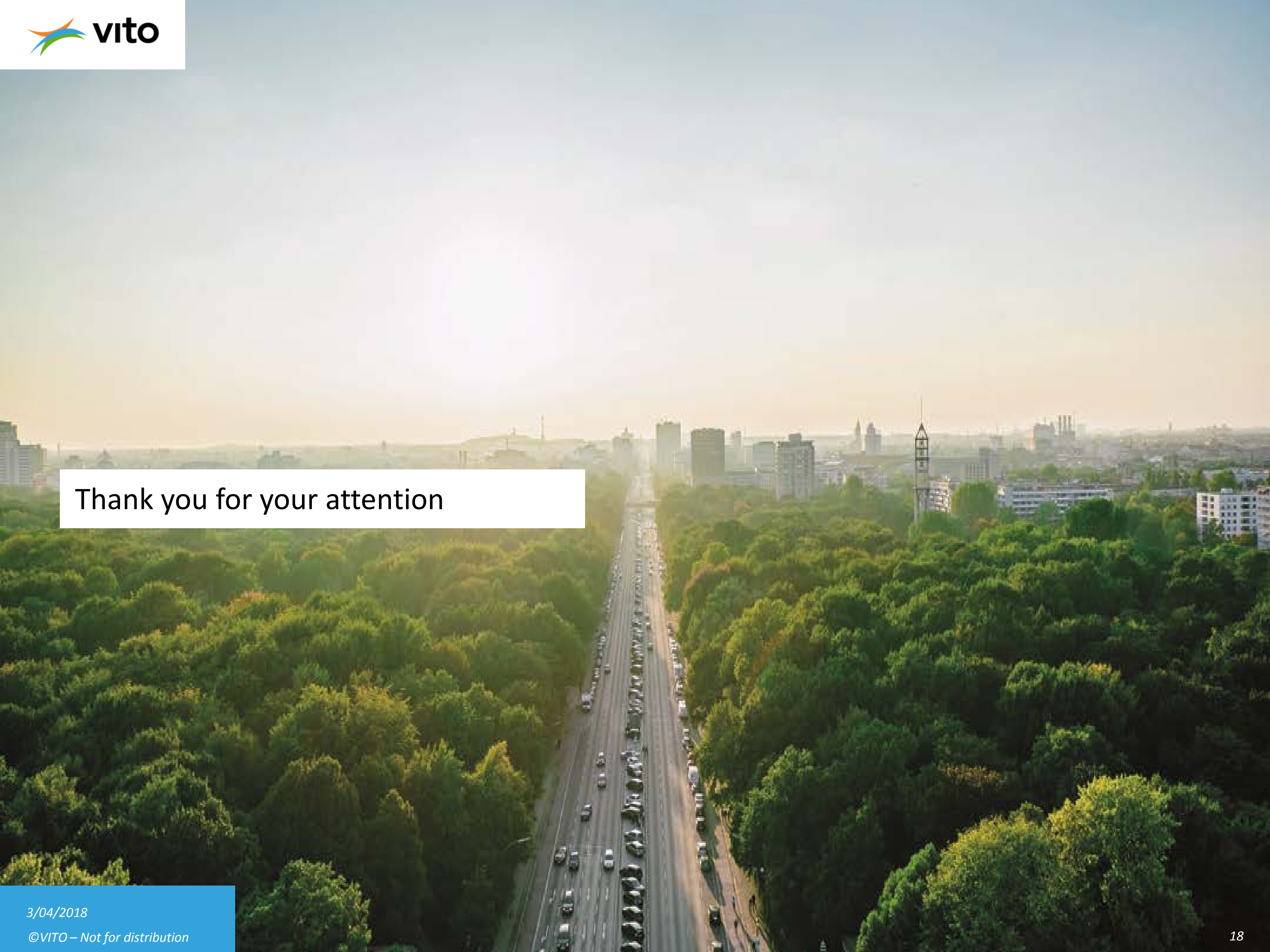
- Development and validation of at least two microbial cell factories;
- Development of concepts for solving challenges expected by an industrial-scale implementation;
- Contribution to the reduction in CO_2 emissions in the medium to long term;
- Supporting the EU in becoming a global leader in CO_2 re-use technologies through the utilisation of microbial platforms."

(source https://cordis.europa.eu/programme/rcn/701809_en.html)

GENERAL INFORMATION OF 1 WINNING PROPOSAL

- Title — Biological routes for CO_2 conversion into chemical building blocks
- Acronym — Bio$RECO_2$VER
- Type of action — Research and Innovation Action
- Start date — 1st January 2018
- End date — 31st December 2021
- Coordinator — VITO
- Consortium — Well-balanced and experienced group of 2 Research and Technology Organizations, 2 universities, 4 SMEs and 4 large industries (value chain approach)

- This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 760431



Thank you for your attention