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.
### Status of developments

<table>
<thead>
<tr>
<th>CCU category</th>
<th>CCU-technology</th>
<th>Product</th>
<th>Research</th>
<th>Demonstration</th>
<th>Economic feasible*</th>
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<tr>
<td>Organic products</td>
<td>Catalysis</td>
<td>Methanol</td>
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<td>Polyols → polyurethanes</td>
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<td>Plasma reforming</td>
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<td>C1-C5 oxygenated products</td>
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<td>Photosynthesis algae</td>
<td>Biosilica, others</td>
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<td>Photo-electrochemistry</td>
<td>Methane, methanol, formic acid</td>
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<td>Fermentation (from CO)</td>
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<td>Fermentation</td>
<td>Single Cell Proteins</td>
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<td>Inorganic products</td>
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<td>Carbonatation</td>
<td>Powders</td>
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</table>

*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)
### 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)

*Source: LNE (2016)*
Exploratory assessment based on 5 criteria (climate and economic aspect)

- Actual contribution to emission mitigation, taking into account (in)direct CO₂ 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 CO₂-emissions = fixed CO₂ (negative value) + ∑ (in)direct CO₂-emissions
- Difference in CO₂-emissions = Net CO₂-emission (reference – CCU-scenario)
- Use of 3 emission factors:
  - 0 ton CO₂/MWhₘₑ (100% renewable electricity)
  - 0.285 ton CO₂/MWhₘₑ (standard emission factor Belgian electricity production)
  - 0.4 ton CO₂/MWhₘₑ (LCA emission factor Belgian electricity production)

Source: LNE (2016)
CCU case: Power-to-methanol (Port of Antwerp)
Reference case: Production of methanol from natural gas

Source: LNE (2016)
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SUMMARY FOR THE SELECTED 4 CASES BASED ON 4 CRITERIA

<table>
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<tr>
<th>Criteria</th>
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<th>Case 2</th>
<th>Case 3</th>
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<td>Potential scale of application in Flanders</td>
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<tr>
<td>Technology readiness level</td>
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</tbody>
</table>

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

- **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 CO₂ 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)

*Source: LNE (2016)*
Flemish authorities consider CCU as promising option to realize emission reductions in energy-intensive industry because

- Flanders has large CO₂ point sources (a.o. in ports) potentially suited for CCU projects
- Sufficient expertise is present at knowledge institutes for reuse of CO₂

Measures can be taken towards reuse of CO₂, 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 CO₂-reduction
- High costs of CO₂ capture

Report available on-line

- Executive summary (in English): CCU in Flanders – Summary

Source: LNE (2016)
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
- ...
Several technical and economic barriers for CO₂ 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
Work program BIOTEC-5-2017: Microbial platforms for CO₂-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 CO₂ 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 CO₂ 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 CO₂ reuse.

Proposals can be considered complementary to those dealing with CO₂ 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.”
“An industrial biotechnology route for CO₂ re-use is fermentation, where CO₂ 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 CO₂ into chemicals. Moreover, the final yield of the products is low and the process needs optimisation. Ultimately, the success of CO₂ 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 CO₂ (low concentrations, presence of impurities, etc.). Therefore, substantial research is required to achieve the goal of a CO₂ 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 CO₂ emissions in the medium to long term;
- Supporting the EU in becoming a global leader in CO₂ re-use technologies through the utilisation of microbial platforms.”

### GENERAL INFORMATION OF 1 WINNING PROPOSAL

<table>
<thead>
<tr>
<th>Title</th>
<th>Biological routes for CO₂ conversion into chemical building blocks</th>
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<td>VITO</td>
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<td>Consortium</td>
<td>Well-balanced and experienced group of 2 Research and Technology Organizations, 2 universities, 4 SMEs and 4 large industries (value chain approach)</td>
</tr>
</tbody>
</table>

- 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