SCOT Project

Smart CO_2 Transformation

Carbon Dioxide Utilization in Europe

Using CO_2 as a resource

Enabling European industry to become more resource-efficient, sustainable and competitive

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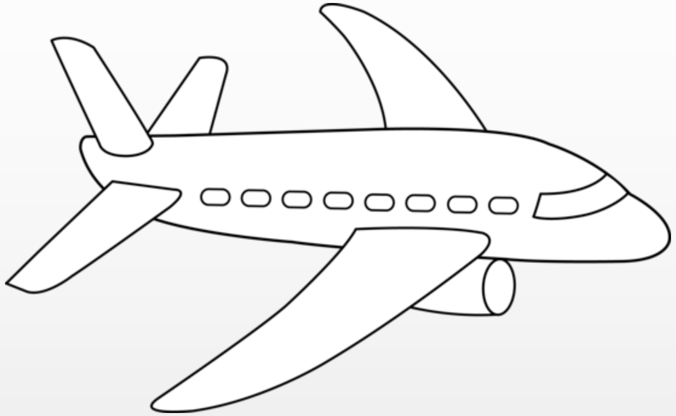
SCOT
Smart CO_2 Transformation

Imagine a future in which, you will be able to …

Buy a mattress made with CO_2 derived polyols from major European retailers

Live on an island that has a self-sufficient sustainable …



Travel on a plane powered by a percentage of CO_2 derived aviation fuel

Construct a truly carbon-negative house from mineralised wastes and CO_2 capturing cements

Fill a car with synthetic fuels

A Vision for CO_2 utilisation in Europe

- CDU can be one of the major growth areas in EU's future low-carbon circular economy
- CDU can help to facilitate Europe's energy transition
- CDU can contribute to achieving EU's aims for decreasing carbon emissions

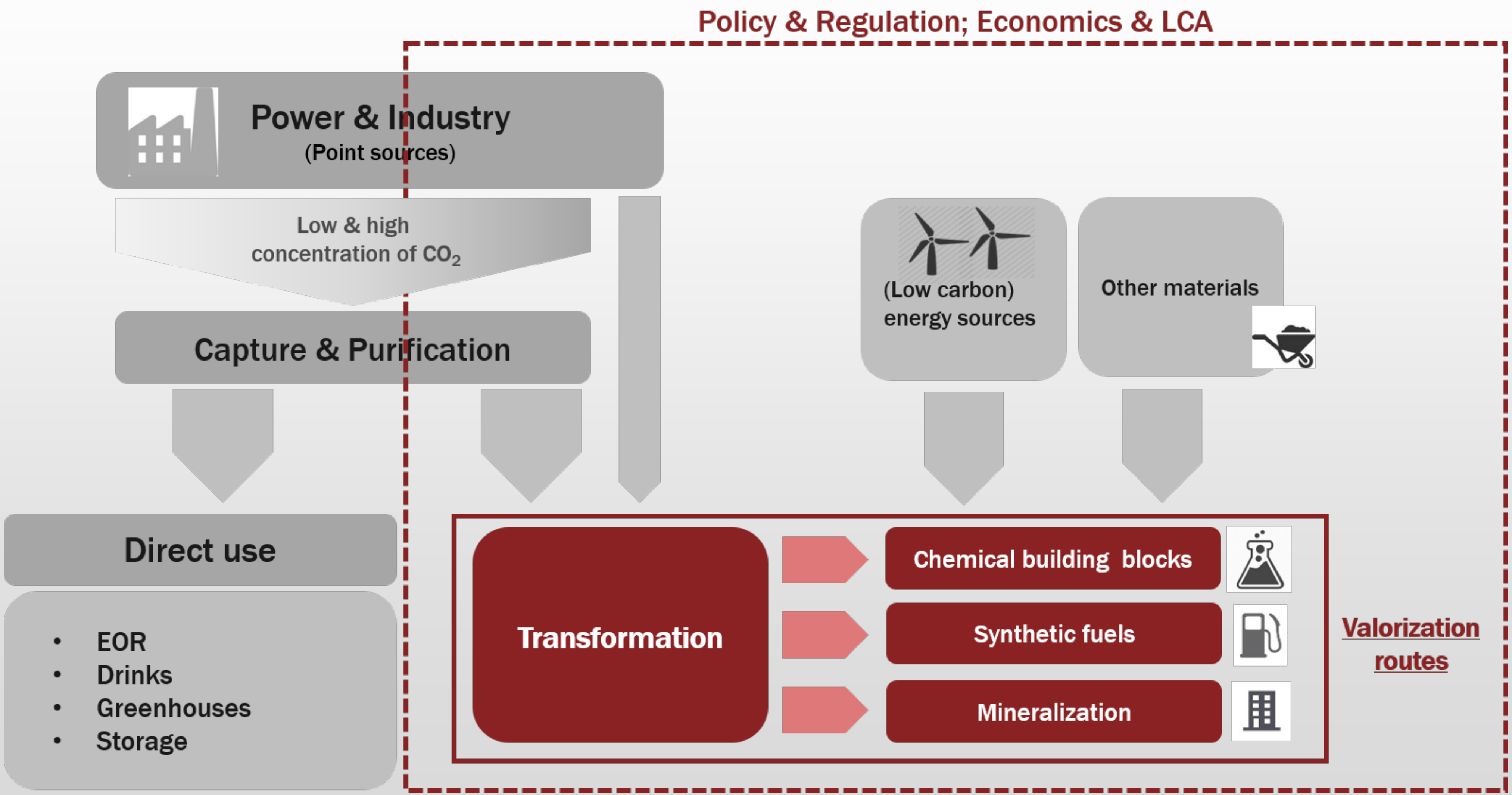
Content

1. **What is Carbon Dioxide Utilization?**
2. How to bring CDU products from Lab to market
3. Key Learnings from existing Cases
4. Concluding remarks

What is Carbon Dioxide Utilization (CDU)?

- CDU is a range of novel carbon **pathways**
  - Each pathway includes a process that uses **CO_2-as a source of Carbon**
    - … to then **transform** it into value added **products**

The CO_2 value chain is a mutliple value creation paths



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How to bring CDU Products from Lab to market?
What are the non-technical levers?

Policy Incentives	Economic Barriers	The Global Value Chain	Social Uptake
▪ CO_2 Price ▪ Transport/Fuel directives ▪ Waste directives ▪ Circular economy packages ▪ Standardisation ▪ Labelling	▪ Reducing costs ▪ Bridging the finance to support demonstration and pilot initiatives	▪ Network of actors ▪ Strategic partnerships	▪ Create demand ▪ Reduce risk perception ▪ Improve industrial understanding ▪ Capacity building

How to bring CDU Products from Lab to market?
What are the Technical levers?

Upstream Process	CO_2 conversion	Variable inputs	Downstream process	Scaling-up
▪ Electrolysis, co-electrolysis, Carbon capture ▪ Cost of processing V. reaction kinetics ▪ Scale ▪ Process intensification ▪ Technology choice	▪ Chemical catalysis ▪ Biocatalysis ▪ Hybrid chemical-biocatalysis	▪ Renewable energy ▪ Sources of CO_2 ▪ Supply of co-reactants ▪ Variable demand	▪ Products purification ▪ Energy requirements for product purification ▪ Tuning reaction chemistry and process to reduce by-products ▪ Process intensification	▪ Crossing the valley of death ▪ Investment in translational research ▪ Heat & mass transfer ▪ Continuous production ▪ Micro/meso/macro

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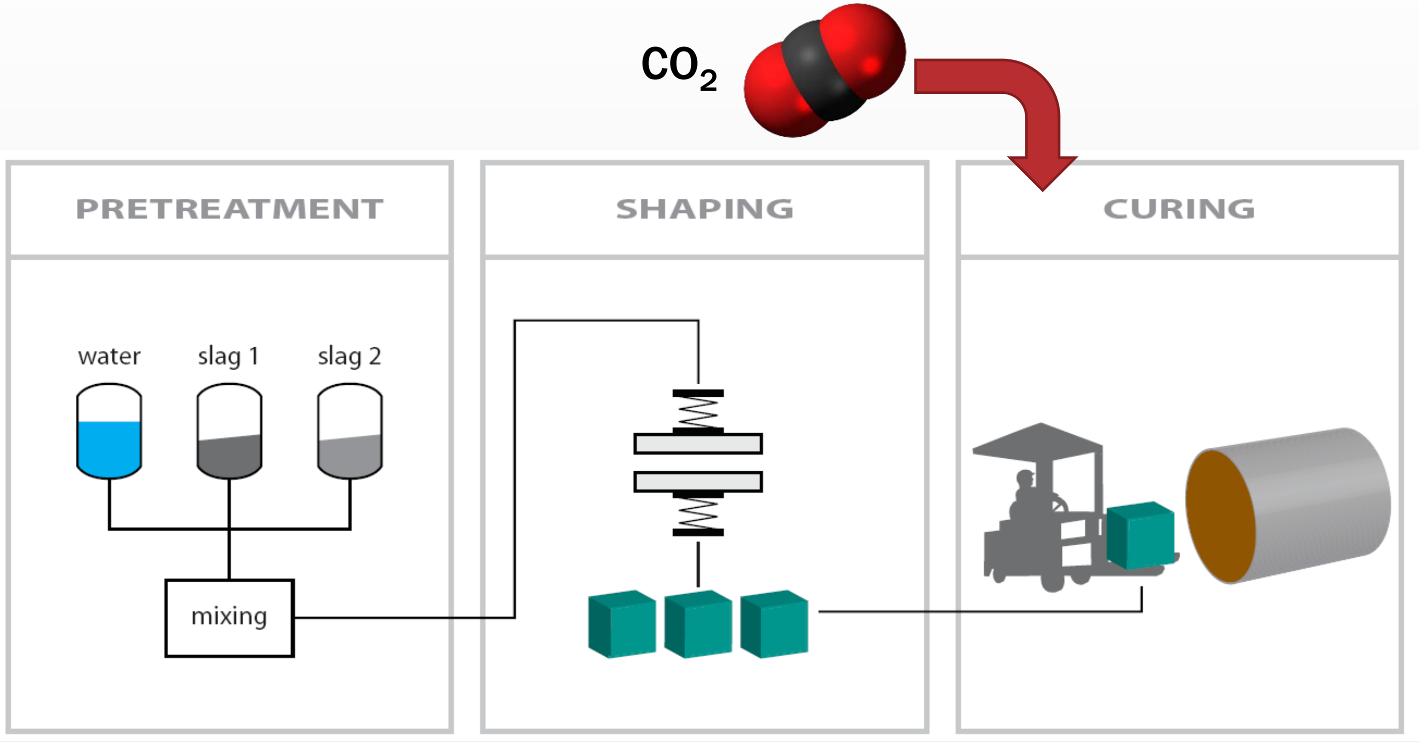
Fine fraction of steel slags recycling into Construction Materials
Recoval, Belgium

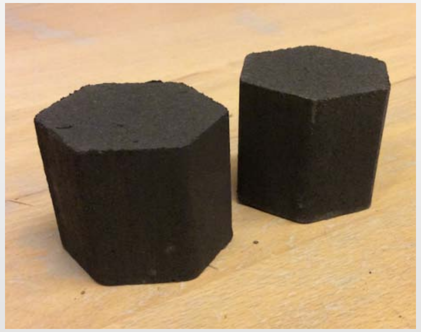
0. Industrial Waste

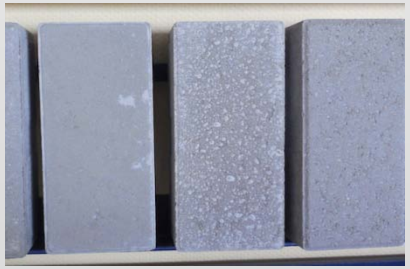


1. Slags pre-treatment:
- Mixing
- Grinding
- Hydration

2. Shaping:
- Rotary drum
- Autoclave

3. Carbonation:
- Curing chamber



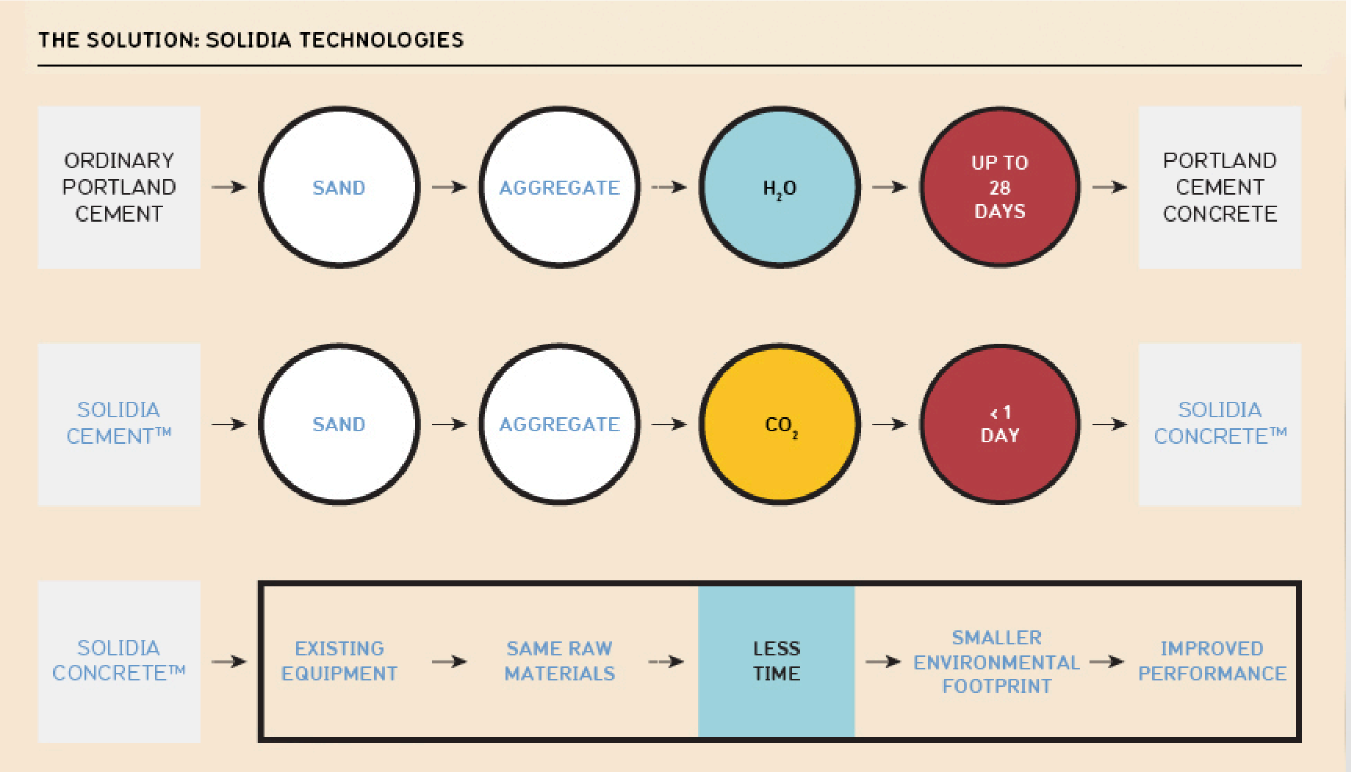


Products meet The Netherlands & Belgium standards

Demonstrated at Pilot-scale level

Sustainable Cement & CO_2-cured Concrete

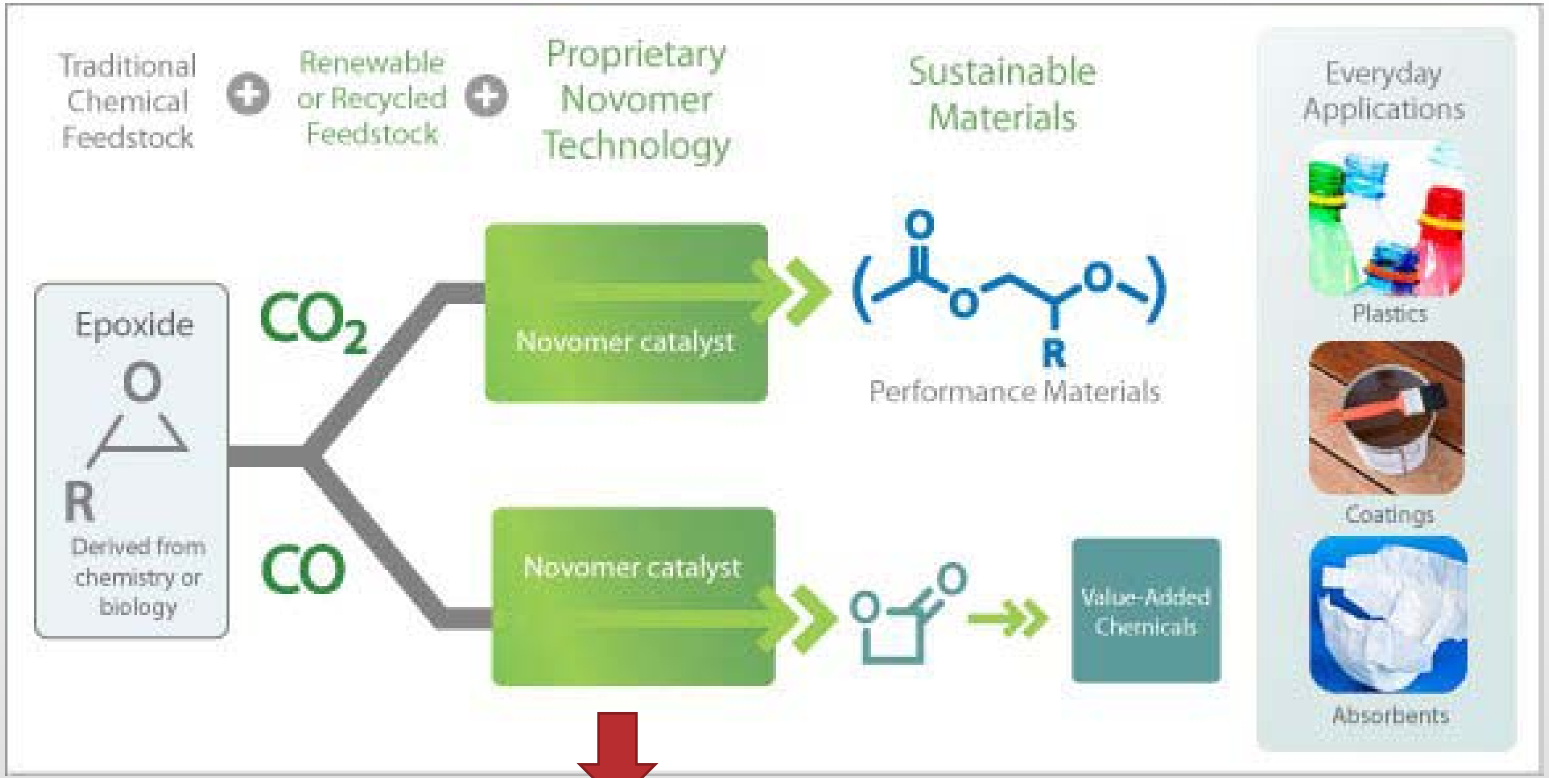
Rutgers State University of NJ, US start-up Solidia & Lafarge



- Produced at traditional precast concrete manufacturing facilities
- Hardening through carbonation, in curing process with overall carbon footprint reduction by up to 70%.
- Full strength is reached in less than 24 hours vs. 28 days for precast concrete made using Ordinary Portland Cement
- Considerable energy savings and cost reductions to precast concrete manufacturers.

Strategic partnership in place for moving to commercialization

Co-polymerization of epoxides to make polycarbonates
Cornell University, Novomer, USA with EU as target market



Highly active and selective catalyst that maximizes CO_2 incorporation (up to 50% by weight CO_2)

Technology Platform 1

Waste CO_2 + commodity epoxide (Propylene Oxide) to form PPC

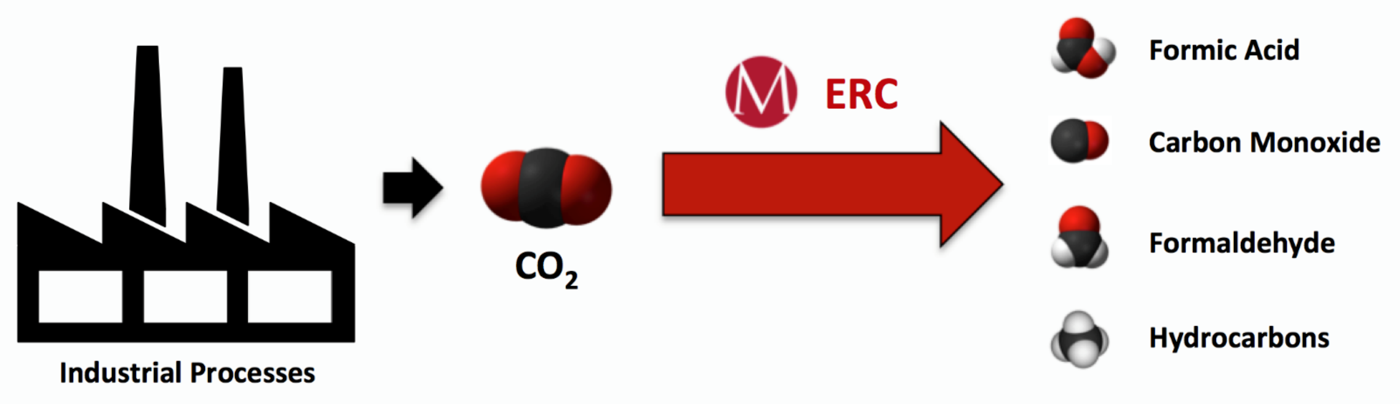
Technology Platform 2

Waste CO + commodity epoxide (Ethylene Oxide) to form PEC

PPC polyol is available at a commercial scale and adopted into a formulation for polyurethane hot-melt adhesives by Jowat AG (Detmold, GE).

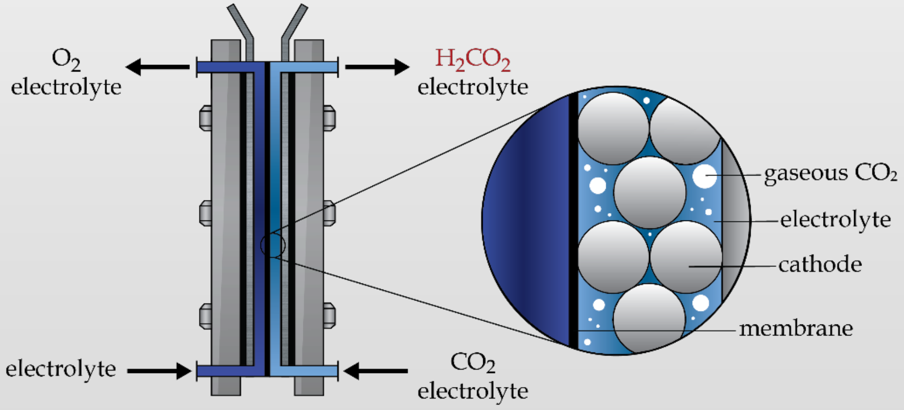
Fomric Acid/Formate, CO/Syngas & Methanol

Mantra Energy, Canada



Applications in industry:

- Agriculture, textiles and leather, pharmaceuticals, oil well drilling, and de-icing.
- CO: methanol, SNG, gasoline and diesel.

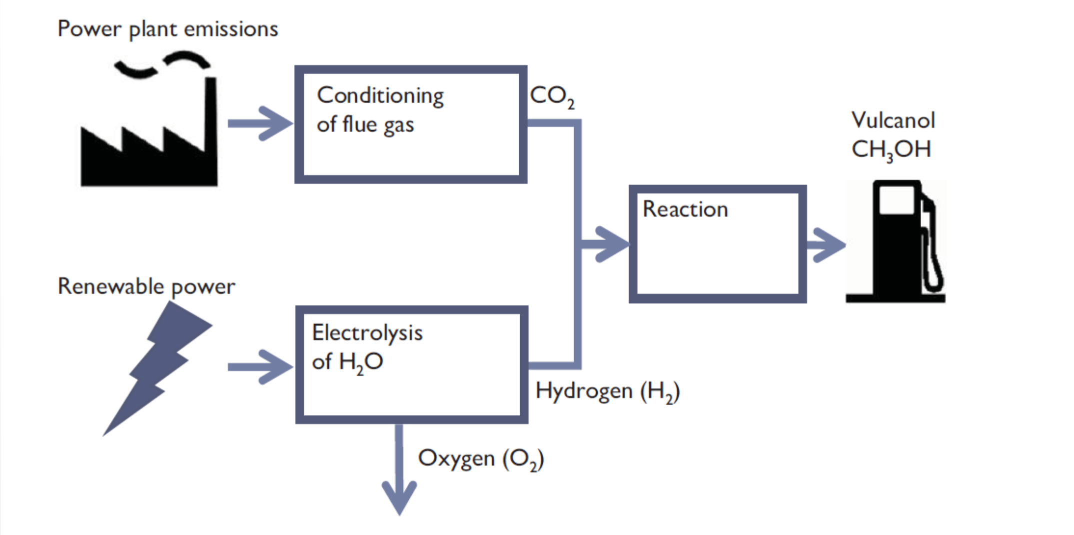


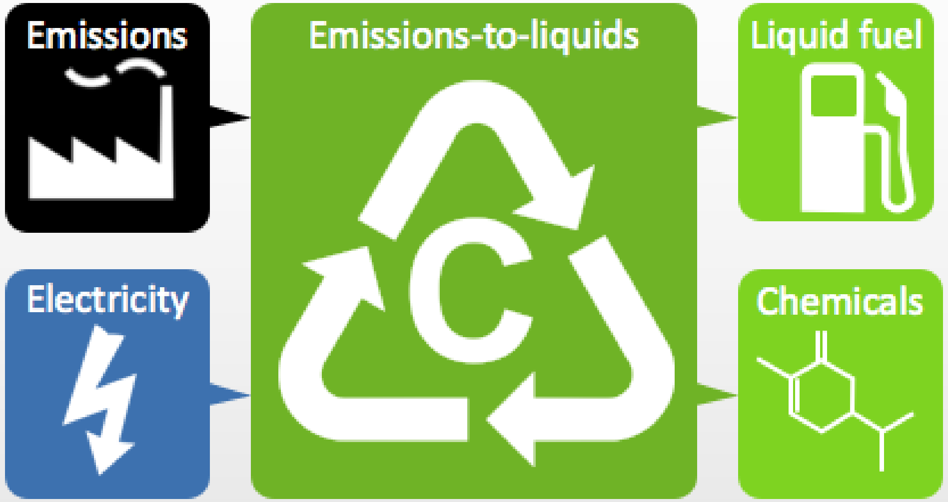
$$CO_2 + H_2O \longrightarrow \tfrac{1}{2}O_2 + H_2CO_2$$

- Subsidiary in the US, in order to access large-scale funding opportunities, and improve the visibility of the technology to investors and industry
- Pilot plant to be built for converting CO_2emissions from the Lafarge cement plant in Richmond, BC, into formic acid and its salts

The Electrochemical Reduction Chemistry (ERC) process can be "dropped-in" to any industrial CO_2 emission source, with no retrofitting necessary

Methanol Production
Carbon Recycling International, Iceland

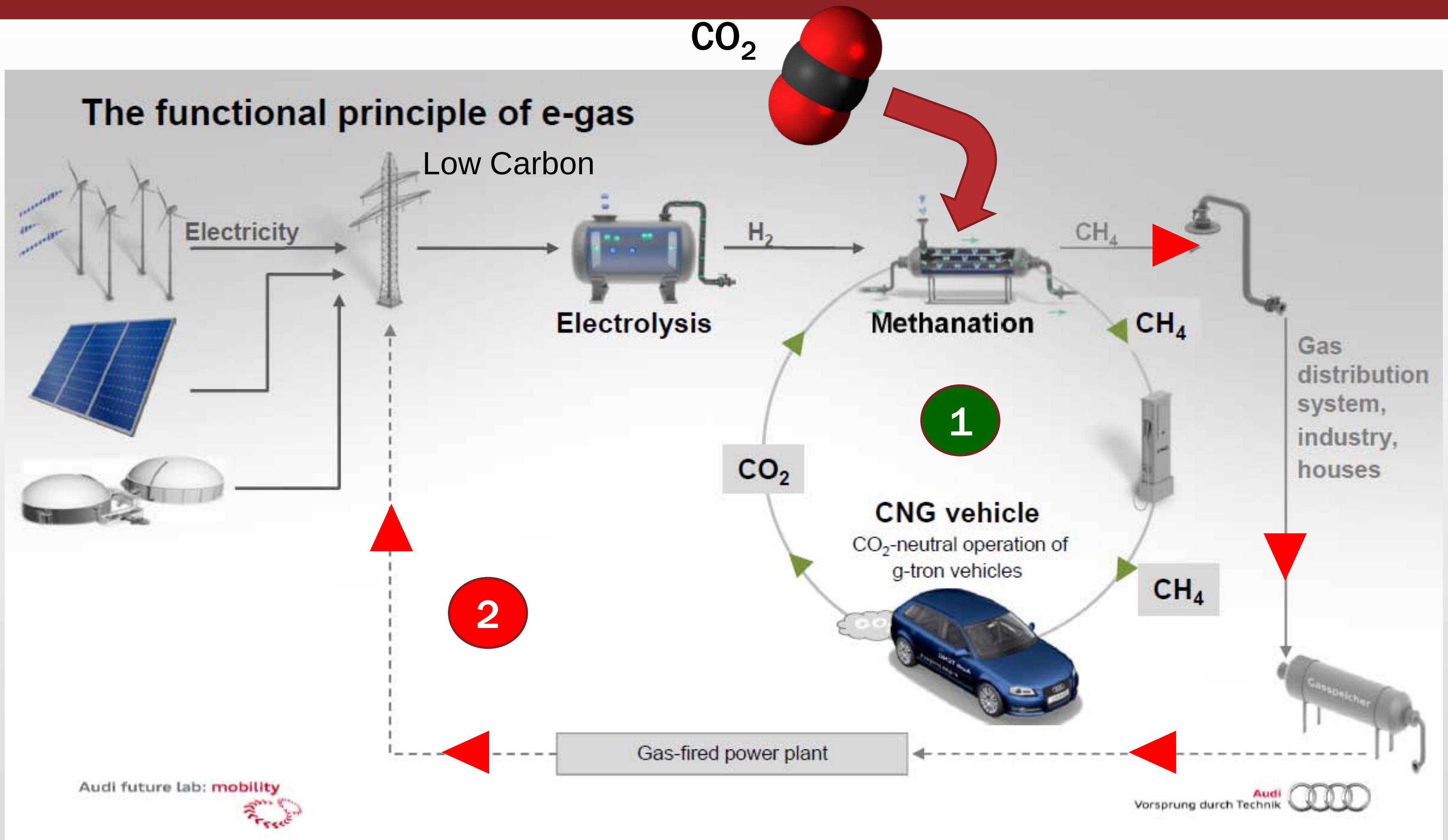




Methanol can be used as a transport fuel and as a chemical feedstock for many common building blocks for basic materials

- Commercial scale plant CO_2 from by processing of gas emissions from a geothermal power plant
- H_2 by electrolysis of H_2O using renewable sources of energy from the Icelandic power grid (from hydro, geothermal and wind sources).
- Currently we have a 4000 metric ton/year production capacity.

Power-to-Gas
Audi e-gas project, Germany



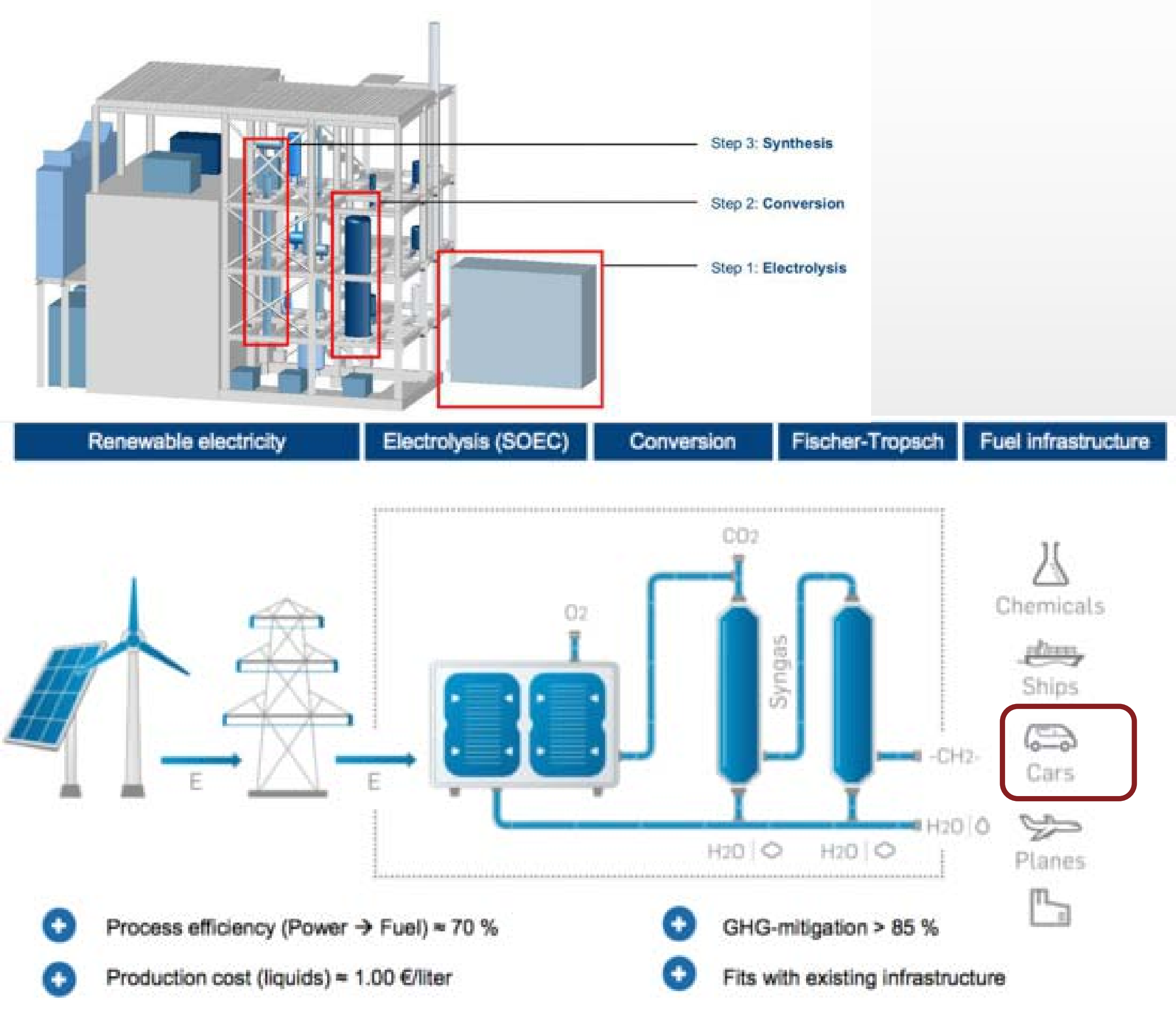
Pilot-scale demonstration of Power-to-Gas technology

❶Linking electricity grid with car mobility

❷Linking electricity grid with the natural gas network

Power-to-Liquid (petrol, diesel, kerosene, methanol)

Sunfire, Germany



Integration of process steps leading to flexible turnkey solutions for different markets

Summary of key learnings from existing case studies

1. Difficult to enter the market with a new product
   ► New materials must have superior properties and serve a specific niche market

2. Introduction of new competitive product takes time and innovative SMEs do not have deep pockets
   ► Partnerships with key industrial players are required

3. The cement and building materials market is already a highly competitive low margins market
   ► The CO_2 recycled products must be available against little or no cost

4. Cement and building materials tend to be virgin materials while CDU products have a history of being a waste
   ► Standards based on the properties of the virgin materials must be relaxed

5. Risk against hazard debate, former waste materials have there hazardous components immobilised
   ► The legislator acts from a hazard perceptive

6. The CO_2 available on the market is of too high a purity
   ►Mineralisation units must be close to a significant CO_2 source without making the carbon dioxide too clean

7. Sustainable labelling might help with the introduction of a new material
   ► Consumers/users must be willing to pay the higher price.

Summary of Key learnings from existing case studies

8. Strategic partnerships involving Universities, SMEs and key industrial players from the consumer side played a major role in boosting Power-to-Liquid and Power-to-Gas technologies

9. Long-term commitment and financial supports from government (Germany, USA) has been essential to support technology development and scaling-up

10. Some SMEs are trying to overcome financial barriers by relocating to countries/regions where financial supports are more accessible

12. Hydrogen electrolysers ► CDU routes are thought to be a strong technical candidate for the use of ‘surplus’ electricity, but overall, its development will be governed by its competitive nature vis-à-vis fossil-fuels and also from the other demands that may make use of ‘surplus’ electricity

13. Some SMEs managed to develop performing and cost-competitive technologies & products

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Concluding Remarks
The Promises of Carbon Dioxide Utilization

1. Make EU more resilient to fluctuations in fossil-fuel resource availability and price
2. Decouple economic growth from greenhouse gas emissions in order to limit the risks of climate change
3. Provide robust and economic solutions to manage the balance between energy supply and demands over varying timescales
4. Reduce the CO_2 footprint of hard to decarbonise parts of the energy system such as aviation, long-haul freight and international shipping
5. Stabilise and increase energy autonomy, and shift resources away from imports to internal low-carbon energy

Thank You

	Axelera	France		Leeds City Council	UK
	Centre for Low Carbon Futures LBG	UK		Service Public de Wallonie	Belgium
	DCMR Milieudienst Rijnmond	The Netherlands		The University of Sheffield	UK
	Dechema	Germany		Trinomics	The Netherlands
	GreenWin (project lead)	Belgium		YCF Limited	UK

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Engage with SCOT

Email us at: info@scotproject.org

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CO_2 as resource
not as waste