ECO2CELL

Electrochemical Reduction of biogenic CO2 to E-Fuels: ECO2CELL

GIG Karasek's Innovative Solution for CO_2 Utilization

DDI Wolfgang Aichhorn, MBA

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CO_2 UTILIZATION

From problem to opportunity

CO_2 utilization lets us relive the spirit of creativity and reuse from childhood with huge environmental and economic impacts.

HISTORY AND MILESTONES

1933 — **Franz Karasek opens a metal workshop**

1996 — **Acquisition of Grill & Grossmann**

1998 — **Acquisition of Austrian Energy & Environment**, plate type evaporator production plant

1998 — Formation of **Karasek Group**

2004 — **Merger** of GIG and Karasek **to GIG Karasek** and rebranding

2008 — Opening of **Technical Center**

2016 — GIG Karasek becomes **part of Dr. Aichhorn Group**

2022 — New business unit **Environmental Technologies** with focus on CO_2 valorization

SCOPE OF SERVICES

ENGINEERING

MANUFACTURING & PROCUREMENT

SUPERVISION & INSTALLATION

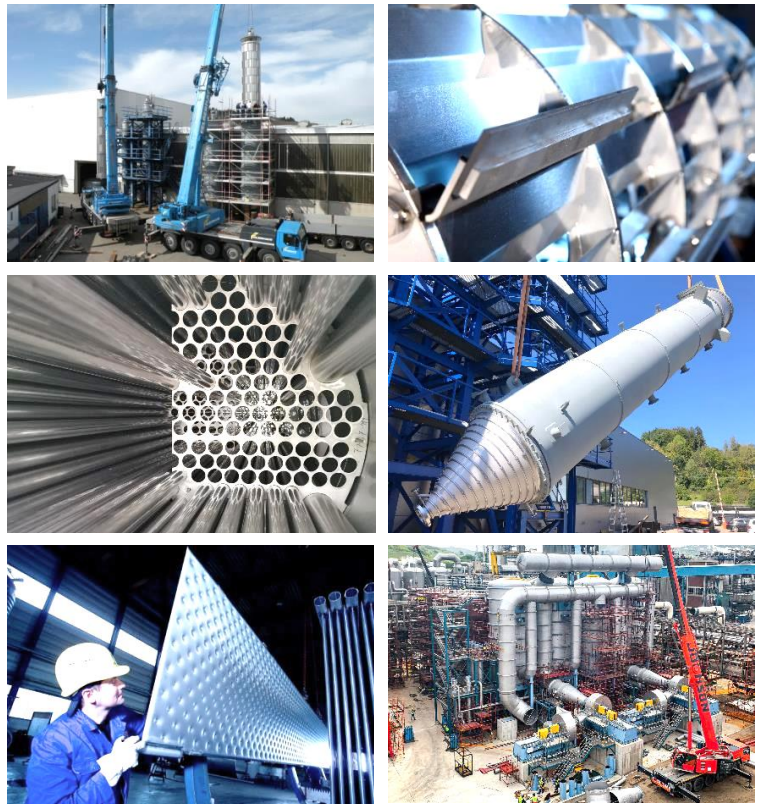
COMMISSIONING, START-UP & TRAINING

ALL PROJECT SIZES (pilot plant, skid unit to turnkey projects)

AFTER SALES SERVICE

PROJECT MANAGEMENT & CONTROLLING

QUALITY, HEALTH & SAFETY

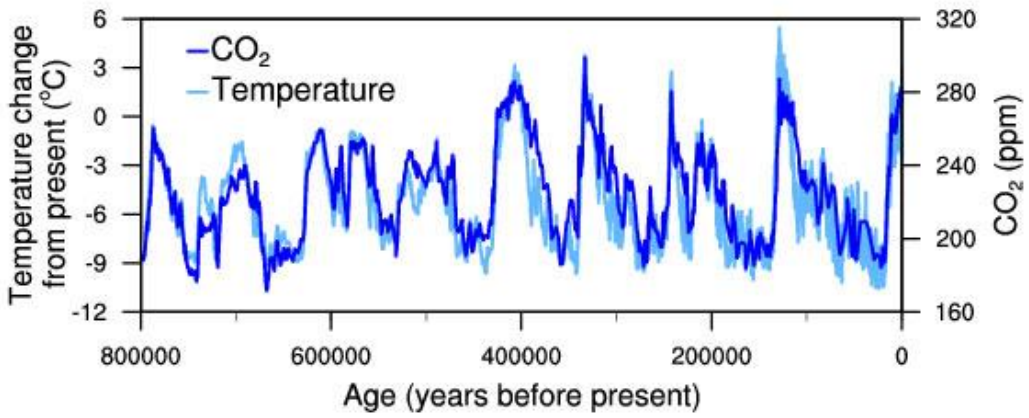


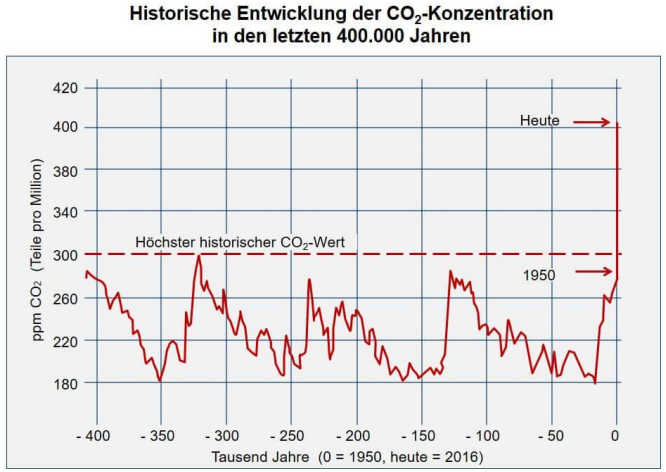
- Optimization & Modernization
  - Revamping
  - Retrofitting
  - Debottlenecking
- Technical Center
  - Laboratory tests,
  - Pilot tests
  - Contract distillation
- Consulting and studies
  - Expansion concepts / energy optimization
  - Cleaning concepts
  - Trouble shooting

A TOP-URGENT GLOBAL CHALLENGE

CO_2 emissions released by burning of fossil fuels contribute significantly to greenhouse effect and global climate change

Global temperature





Source 1

NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION. (2021). Temperature Change and Carbon Dioxide Change. In *NOAA NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION*. https://www.ncei.noaa.gov/sites/default/files/2021-11/8%20-%20Temperature%20Change%20and%20Carbon%20Dioxide%20Change%20-%20FINAL%20OCT%202021.pdf

A TOP-URGENT GLOBAL CHALLENGE

Opportunities and necessities

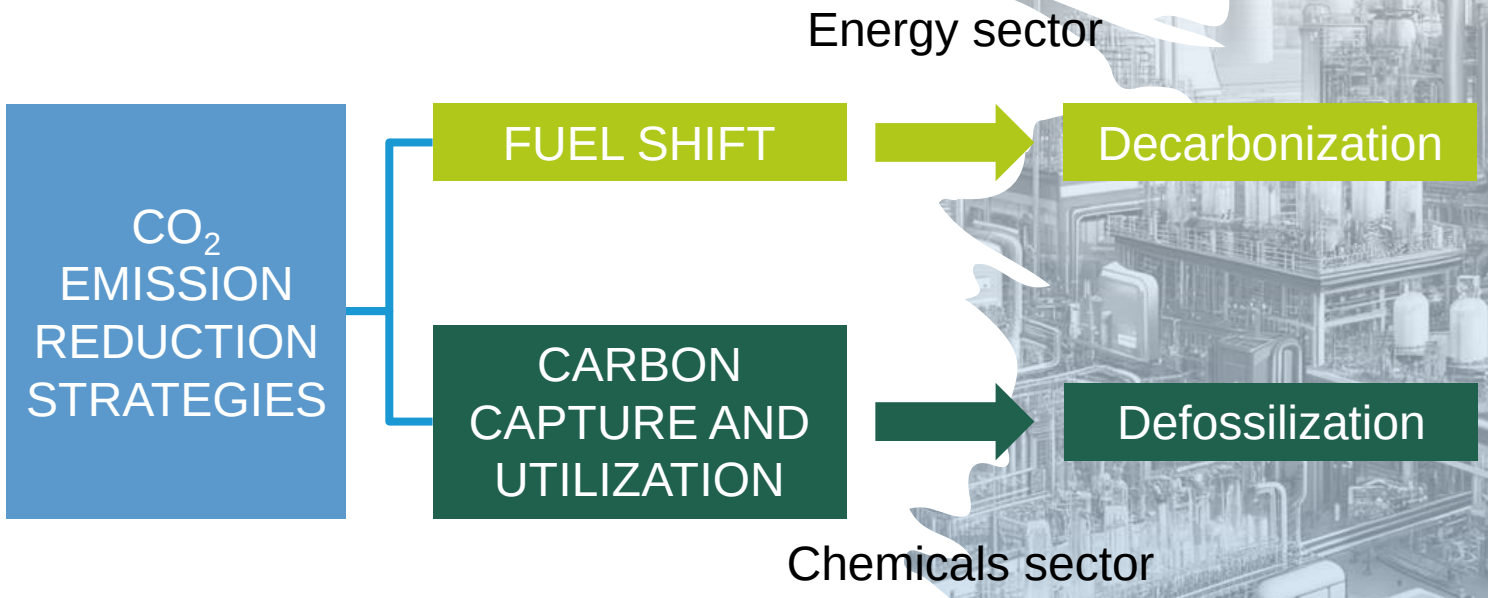
CO(2) Utilization Will Be a $550 Billion Market by 2040

Carbon capture utilization remains a pivotal technology to remove and recycle CO(2) emissions, according to Lux Research

CO_2 emission prices of up to 450 euros per metric ton still too low?

CO2 Emissionsrechte EUR | Euro Co2 Emissionsrechtepreis aktuell | Euro Co2 Emissionsrechtekurs heute - boerse.de. (o. D.). boerse.de. https://www.boerse.de/rohstoffe/Co2-Emissionsrechtepreis/XC000A0C4KJ2
Luxadmin. (2024, 27. März). *The Leading Technology, Innovation & Consumer Research Firm*. Lux Research. https://luxresearchinc.com/

THE SOLUTION: RENEWABLE CARBON



Required carbon for producing chemicals and derived materials must come from **renewable carbon** (i.e., biomass, CO_2 and recycling of carbon containing waste streams) instead of fossil-based sources.

GIG KARASEK TECHNOLOGY

We have set ourselves the task to contribute to the worldwide efforts of **Carbon Capture, Utilization and Storage (CCUS)**

- New business unit for **carbon utilization** formed in 2022
- Focus: **Electrochemical transformation of CO_2 in valuable chemicals and fuels**
- Perfectly suited for carbon-intensive industries

SEE VIDEO

ECO2CELL

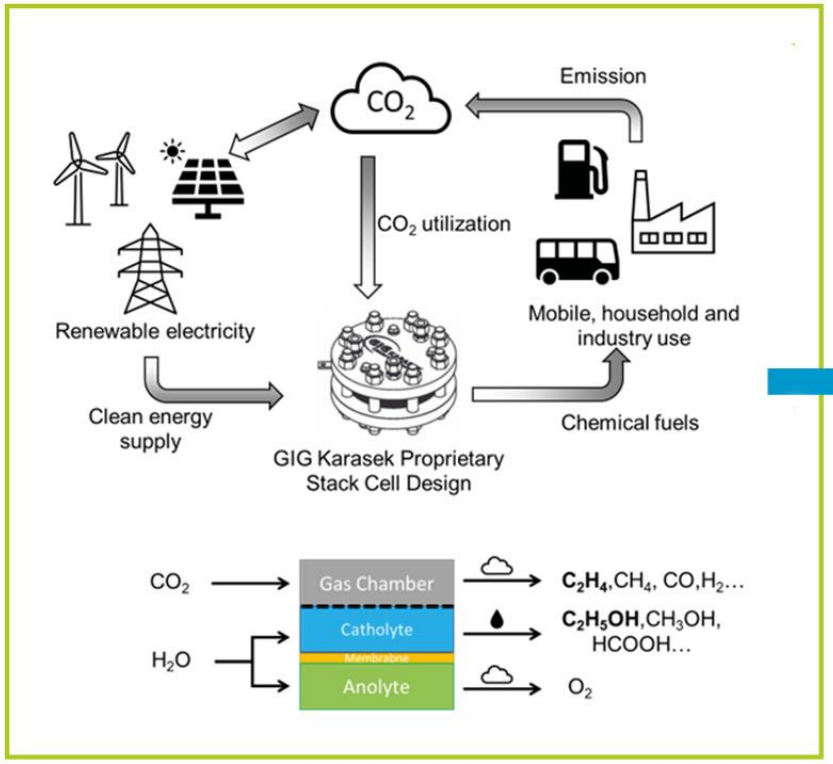
GIG KARASEK ECO2CELL TECHNOLOGY

ECO2CELL

FUNCTIONAL PRINCIPLE

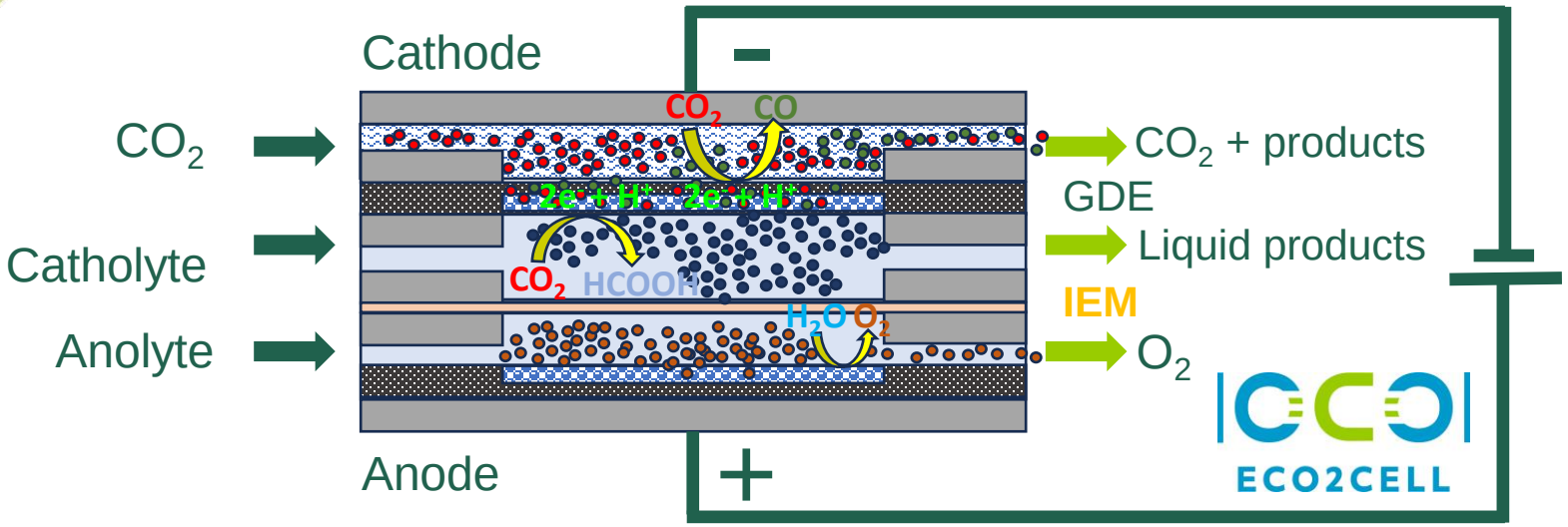
System uses **CO_2**, **water** and **electricity** for production of different carbon compounds

Our solution: electrochemical reduction of CO_2



GIG Karasek downstream separation

ELECTROCHEMICAL REDUCTION OF CO_2



ADVANTAGES

- Product diversity: production of a wide range of valuable products
- Zero-emissions thanks to combination of water and electricity from renewable sources
- Scalable to customer demand
- Mild process conditions
- No hydrogen for process needed

Our special stack electrolyzer and the optimized electrochemical process enable the **simultaneous production of fuels (synthesis gas) and chemicals (formic acid / formate)**

ECO2CELL

REACTIONS & POTENTIAL APPLICATIONS IN P&P

$CO_{2(g)} + 2H^+ + 2e^- \rightarrow CO_{(g)} + H_2O_{(l)}$

$CO_{2(g)} + 2H^+ + 2e^- \rightarrow HCOOH_{(l)}$

$CO_{2(g)} + 6H^+ + 6e^- \rightarrow CH3OH_{(l)} + H_2O_{(l)}$

$CO_{2(g)} + 8H^+ + 8e^- \rightarrow CH_{4(g)} + 2H_2O_{(l)}$

$2CO_{2(g)} + 12H^+ + 12e^- \rightarrow C_2H_{4(g)} + 4H_2O_{(l)}$

$2CO_{2(g)} + 12H^+ + 12e^- \rightarrow C_2H_5OH_{(l)} + 3H_2O_{(l)}$

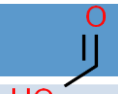
$3CO_{2(g)} + 18H^+ + 18e^- \rightarrow C_3H_7OH_{(l)} + 7H_2O_{(l)}$

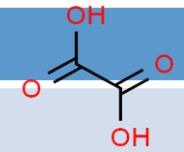
Product	Phase	Potential Use in the Pulp & Paper Industry
Carbon Monoxide (CO)	Gas	Used in the synthesis of various chemicals used in the P&P industry such as acetic acid
Methane (CH_4)	Gas	Can be used to power boilers and other equipment, reducing reliance on fossil fuels
Ethylene (C_2H_4)	Gas	Key raw material in the production of ethyl cellulose, a common paper-coating material
Formic Acid (HCOOH)	Liquid	Can be used as a pulping agent and in the bleaching process to brighten paper and remove residual lignin
Methanol (CH_3OH	Liquid	Can serve as a solvent, is used as a raw material in the production of formaldehyde, is sold as an "industrial chemical" or is used as a fuel in recovery boilers.
Ethanol (C_2H_5OH)	Liquid	Is mainly sold as fuel, which is then added to gasoline.
Oxalic Acid ($C_2H_2O_4$)	Liquid	Used in bleaching of pulp to remove impurities, especially for high-grade white paper
Formaldehyde (CH_2O)	Gas	Used in resin production for bonding fibers and adhesives industry (e.g., urea resin, melamine resin).
Acetic Acid (CH_3COOH)	Liquid	Used in the production of modified cellulose, a component of many paper products

GIG KARASEK TECHNOLOGY PLATFORM

Product suite and state-of-the-art selectivity

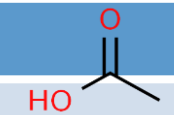
+2e	**Carbon monoxide**	$C^{-}\equiv O^{+}$
Faradaic efficiency >>90%		
Catalysts: Au, Ag, Zn, Pd		
Energy requirement* ~4.3 kWh/kg		

+2e	**Formic acid**	
Faradaic efficiency >>90%		
Catalysts: Pb, Hg, In, Sn		
Energy requirement* ~2.9 kWh/kg		

+2e	**Oxalic acid**	
Faradaic efficiency >70%		
Catalysts: Pt, Pb in PC/AcN		
Energy requirement* ~1.7 kWh/kg		

+4e	**Formaldehyde**	$=O$
Faradaic efficiency ~75%		
Catalysts: B-doped diamond		
Energy requirement* ~7.7 kWh/kg		

+6e	**Methanol**	$-OH$
Faradaic efficiency ~80%		
Catalysts: Cu,-Pd in ionic liq.		
Energy requirement* ~10.1 kWh/kg		

+8e	**Acetic acid**	
Faradaic efficiency ~92%		
Catalysts: N-doped diamond/Si		
Energy requirement* ~6.7 kWh/kg		

+8e	**Methane**	CH_4
Faradaic efficiency ~94%		
Catalysts: N-doped graphene		
Energy requirement* ~23.6 kWh/kg		

+12e	**Ethylene**	$=$
Faradaic efficiency ~60-70%		
Catalysts: Cu, Cu-'X'		
Energy requirement* ~22.4 kWh/kg		

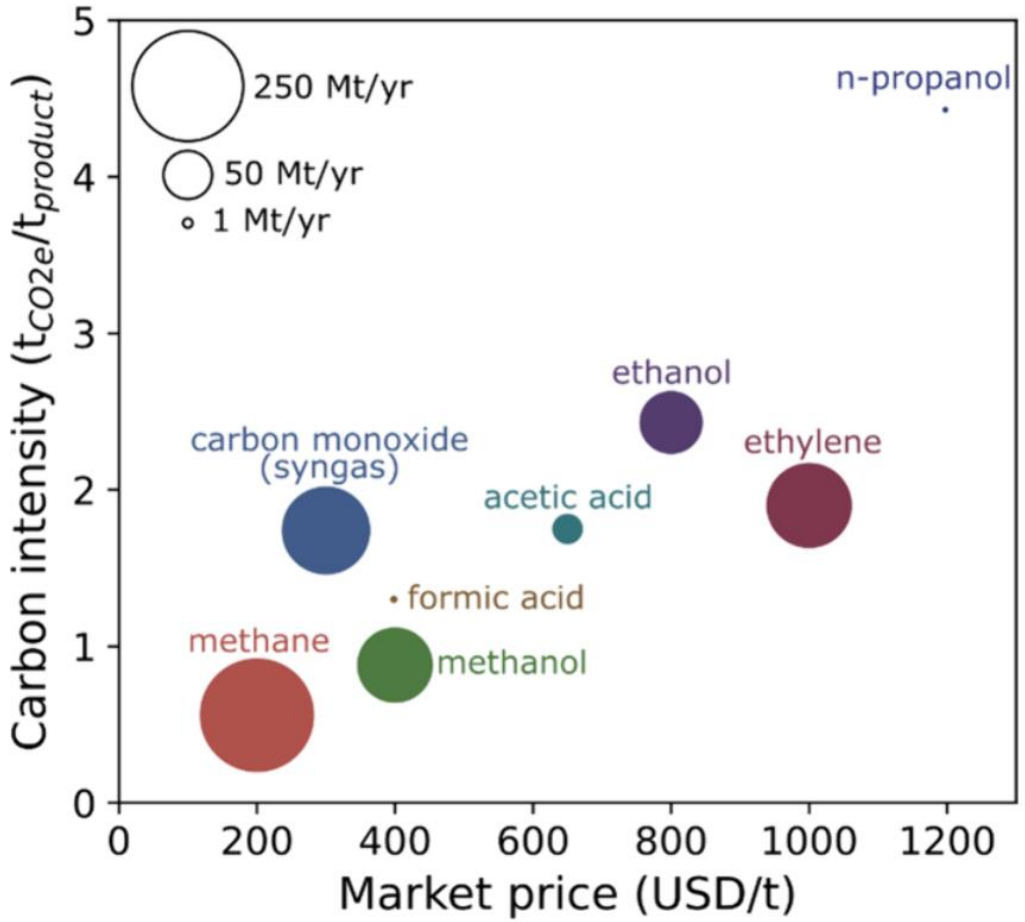
+12e	**Ethanol**	
Faradaic efficiency ~93%		
Catalysts: B-N-doped diamond		
Energy requirement* ~13.4 kWh/kg		

* @ 60% efficiency

MARKET SIZE, MARKET PRICE

The market size, market price, and carbon intensity of the most common CO_2R and COR products.

In the pursuit of CO_2 impacts on the Gt scale, ethylene (140 Mt/yr) and ethanol (77 Mt/yr) are more attractive targets, presenting a combination of high product value and large carbon intensity.



https://pubs.acs.org/doi/10.1021/acs.chemrev.3c00206

MODULAR AND SCALABLE DESIGN

GIG KARASEK
A Member of Dr. Aichhorn Group

ECO2CELL

00 Lab scale

- Proof of concept

0.01 kt/a CO_2
0.001 MW
00

01 Prototype scale

- Validation of a technology for a given flue gas/application
- Mobile turnkey solution (40’ container)
- Construction: 1 year
- Validation: 1 – 1 ½ years

0.1 kt/a CO_2
0.01 MW
01

02 Commercial scale I

- For first step utilization implementation
- Construction: 1 year
- Start-up: ½ years

0.7 kt/a CO_2
0.1 MW
02

03 Commercial scale II

- For small scale emitters, bio-incineration,…
- Standard container-built turnkey solution
- Construction: 1 ½ years
- Start-up: ½ years

1.5 kt/a CO_2
1 MW
03

04 Commercial scale III

- For medium-scale emitters and applications such as biogas, etc.
- Construction: 1 ½ years
- Start-up: ½ years

20-40 kt/a CO_2
10-20 MW
04

05 Commercial scale IV

- For large-scale emitters & applications (e.g. cement-, metal industry, power plants)
- Construction: 2 years
- Start-up: ½ year

50-200 kt/a CO_2
25-100 MW
05

Key benefits: efficiency, modularity, scalability, sustainability, and cost-effectiveness

CASE STUDY

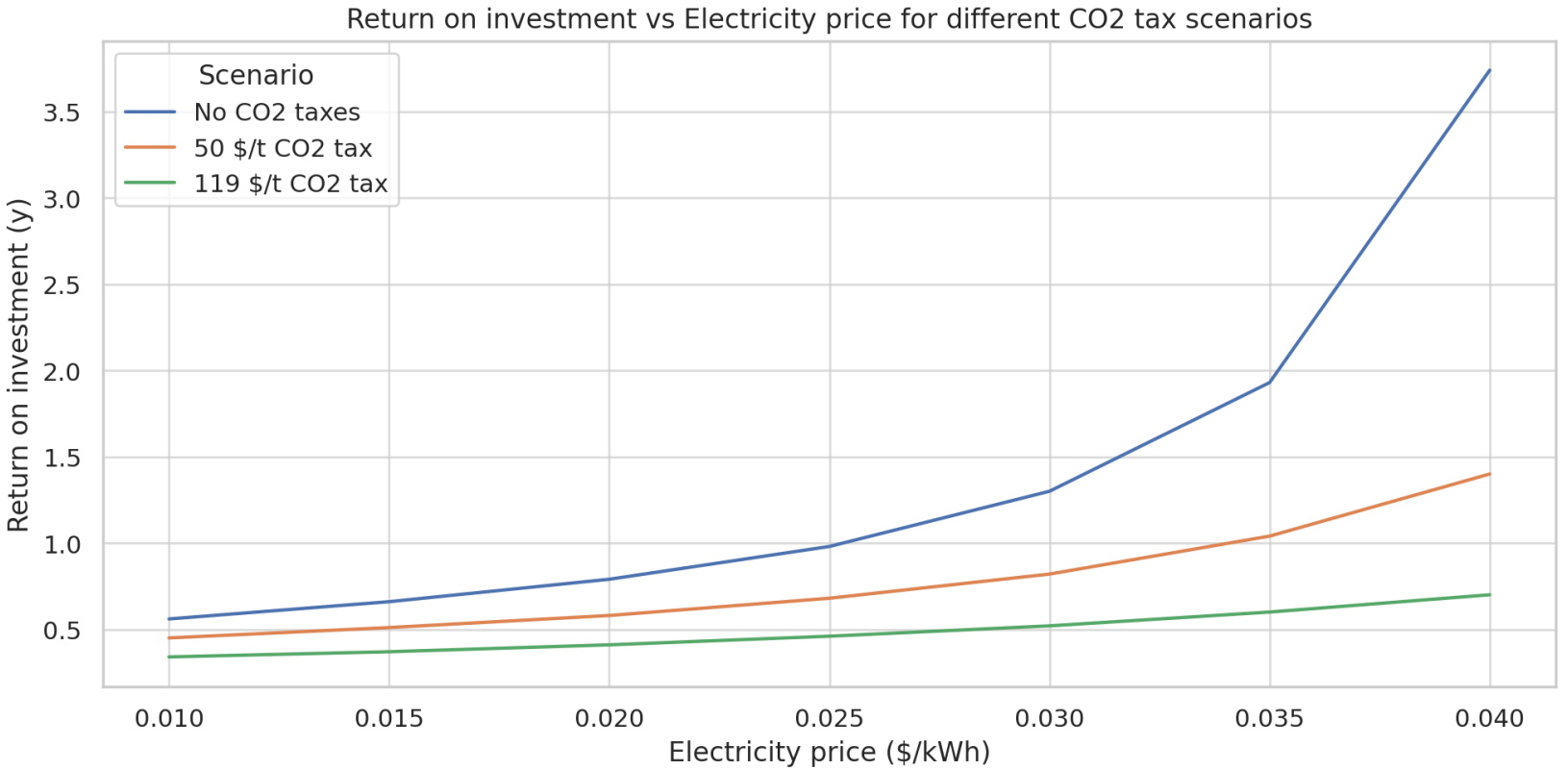
- Producing methanol in a 400 kta pulp and paper plant
- Based on an available CO_2 stream of 79 mol/s or 100 kt/a
- Assumptions
  - 50% CO_2 conversion
  - 1.7 V cell voltage,
  - 0.3 A/cm^2 current density
- With a methanol production of 28.7 mol/s or 38 kt/a
- Electricity cost of $0.02/kWh
- Methanol price of $0.4/kg

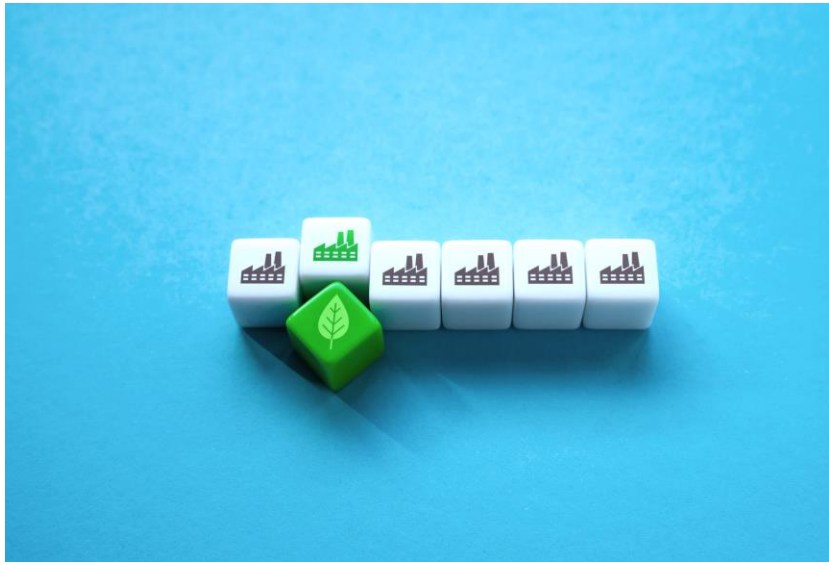
Electrochemical reduction of CO_2 into methanol

Electrolyzer size (cm^2) = (Available CO_2 (mol/s) x CO_2 conversion) / (CO_2 converted per cm^2 (mol/s))

Cost reduction = - (OPEX + Product value + CO_2 tax) x (CO_2 conversion) x (Emissions density) / Product price

RETURN ON INVESTMENT



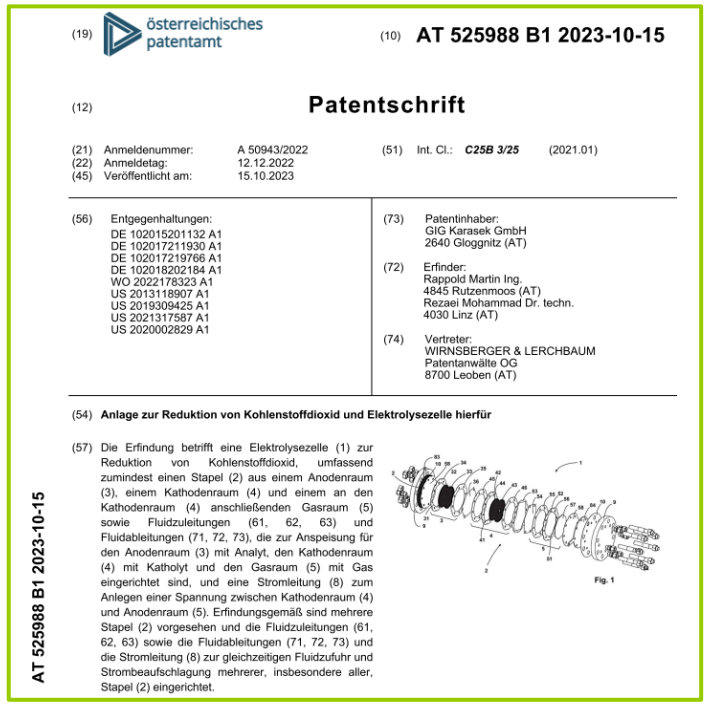


Across Different CO_2 Tax Scenarios

PATENT RECEIVED

GIG Karasek received patent for pioneering CO_2 electroreduction

ECO2CELL



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(12) **Patentschrift**

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DE 102018202184 A1
WO 2022178323 A1
US 2013118907 A1
US 2019309425 A1
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US 2020002829 A1

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(54) **Anlage zur Reduktion von Kohlenstoffdioxid und Elektrolysezelle hierfür**

(57) Die Erfindung betrifft eine Elektrolysezelle (1) zur Reduktion von Kohlenstoffdioxid, umfassend zumindest einen Stapel (2) aus einem Anodenraum (3), einem Kathodenraum (4) und einem an den Kathodenraum (4) anschließenden Gasraum (5) sowie Fluidzuleitungen (61, 62, 63) und Fluidableitungen (71, 72, 73), die zur Anspeisung für den Anodenraum (3) mit Analyt, den Kathodenraum (4) mit Katholyt und den Gasraum (5) mit Gas eingerichtet sind, und eine Stromleitung (8) zum Anlegen einer Spannung zwischen Kathodenraum (4) und Anodenraum (5). Erfindungsgemäß sind mehrere Stapel (2) vorgesehen und die Fluidzuleitungen (61, 62, 63) sowie die Fluidableitungen (71, 72, 73) und die Stromleitung (8) zur gleichzeitigen Fluidzufuhr und Strombeaufschlagung mehrerer, insbesondere aller, Stapel (2) eingerichtet.

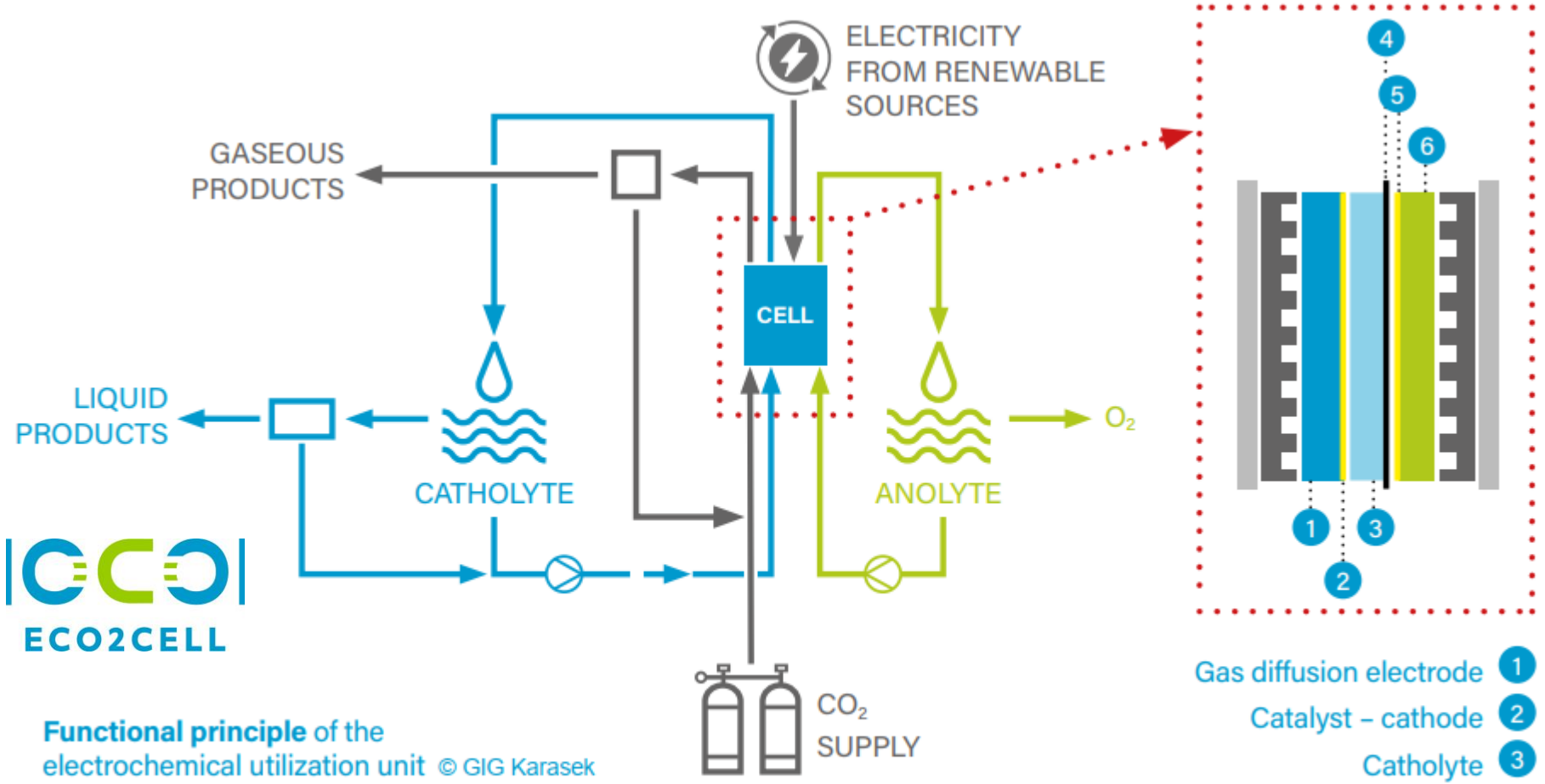
Fig. 1

AT 525988 B1 2023-10-15

INNOVATION AND PATENTS

POSSIBLE END PRODUCTS

- Synthesis gas
- Ethylene
- Formic acid
- Methanol
- Further chemicals and fuels on request



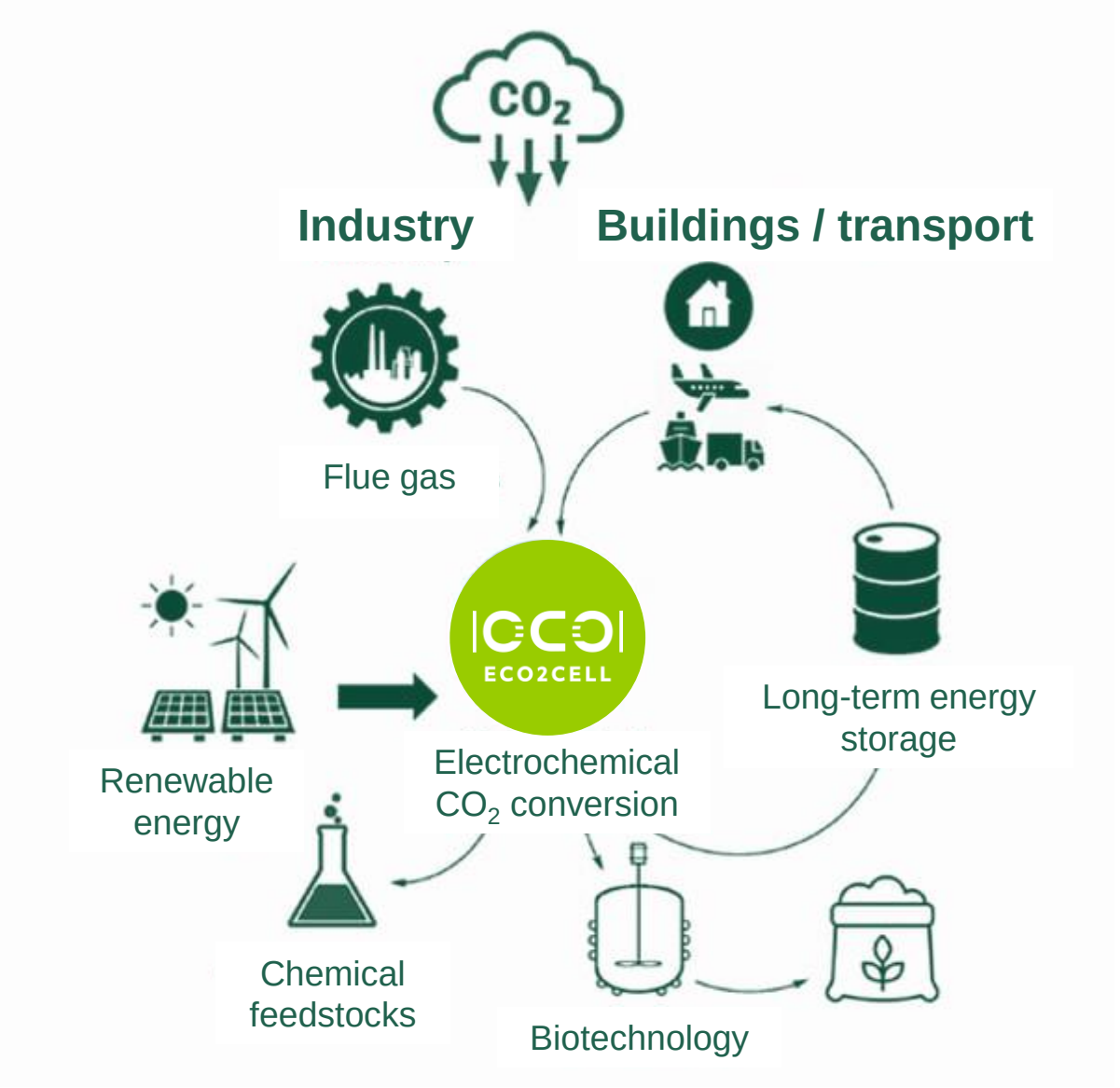
Functional principle of the electrochemical utilization unit © GIG Karasek

SCIENCE AND INDUSTRY PROJECTS

GIG Karasek partners with renowned partners from science and industry

- ZEUS (**Z**ero **E**missions thro**U**gh **S**ector Coupling) Project
- Funded by the Climate and Energy Fund as part of the Energy Research Program 2022. The total cost of the project is EUR 16.8 mio, with EUR 7.7 million in funding.
- 15 kW CO_2 to Syngas Demonstration Scale Plant designed and built by GIG Karasek

SUSTAINABILITY AND CIRCULAR ECONOMY



TRANSFORMING THE ESSENTIALS

Carbon dioxide – from problem to opportunity

Let‘s tap into this enormous potential together!

Opportunity

- Use of CO_2 , H_2O and green energy as feedstock for electrocatalytic synthesis of CO_2-based chemicals or fuels

Advantages

- Zero-emission technology
- Mild operating process with possible attractive energy efficiency
- Scalability to customer demand

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Interested to learn more?

Schedule a meeting!

Important Disclaimer!

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GIG KARASEK
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Concentrating the Essentials