BIOMETHANE INDUSTRIAL PARTNERSHIP

BIOGENIC CO_2: THE ROLE OF THE BIOMETHANE INDUSTRY IN SATISFYING A GROWING DEMAND

APRIL 2024 // TASK FORCE 4.1

BIP Europe
Biomethane Industrial Partnership

Table of **Contents**

Glossary & Colofon

bcm	Billion cubic meters
BECCS	Bioenergy with Carbon Capture and Storage
BioCO_2	Biogenic CO_2 (CO_2 from biological sources)
BIP	Biomethane Industrial Partnership
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilisation
CCU+S	Carbon Capture and long-term Utilisation, resulting in long-term Storage
CCUS	Carbon Capture Utilisation and Storage (umbrella term for CCU, CCS and CCU+S)
CDR	Carbon Dioxide Removal
DAC	Direct Air Capture
EBA	European Biogas Association
EC	European Commission
E-fuel	Electrofuel
EOR	Enhanced Oil Recovery
ETS	Emission Trading System
EU	European Union
Gt	Gigatonne
ISCC	International Sustainability and Carbon Certification
kt	Kilotonne
Mt	Megatonne
RFNBO	Renewable Fuel of Non Biologic Origin
TF	Task Force
TRL	Technology Readiness Level

This is a report by Task Force 4 of the Biomethane Industrial Partnership.

Contributors
This report is prepared based on contributions from: BioForce, Biokraft, Circe, EBA, ENGIE, ERGaR, Future Biogas, Gasum, Nippon Gases, Nova Q, ReFuels, Snam, STX Group, and VINCI Energies.

Authors: Leo Gray, Kees van der Leun, Evelien Smit (Common Futures, rapporteur)

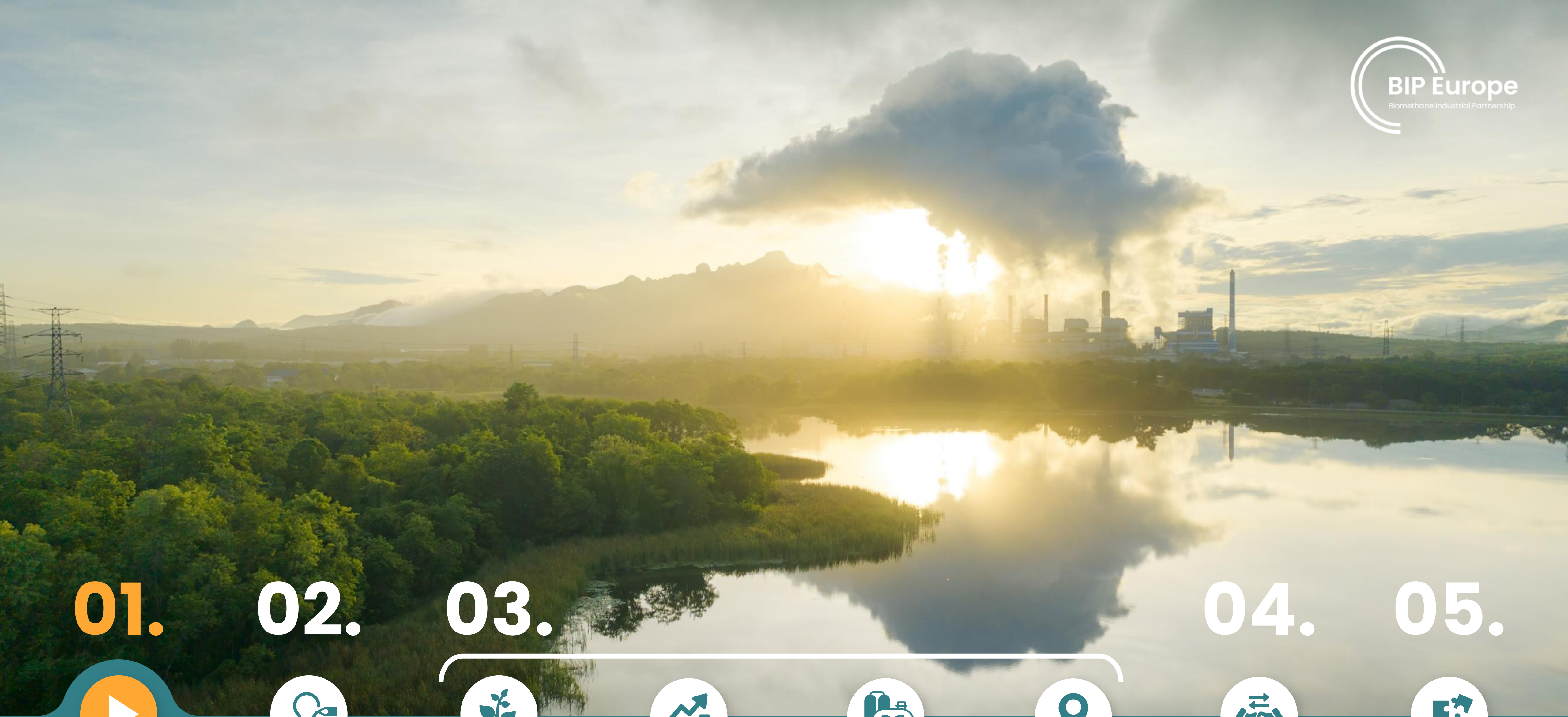
Imprint

Date
April 2024

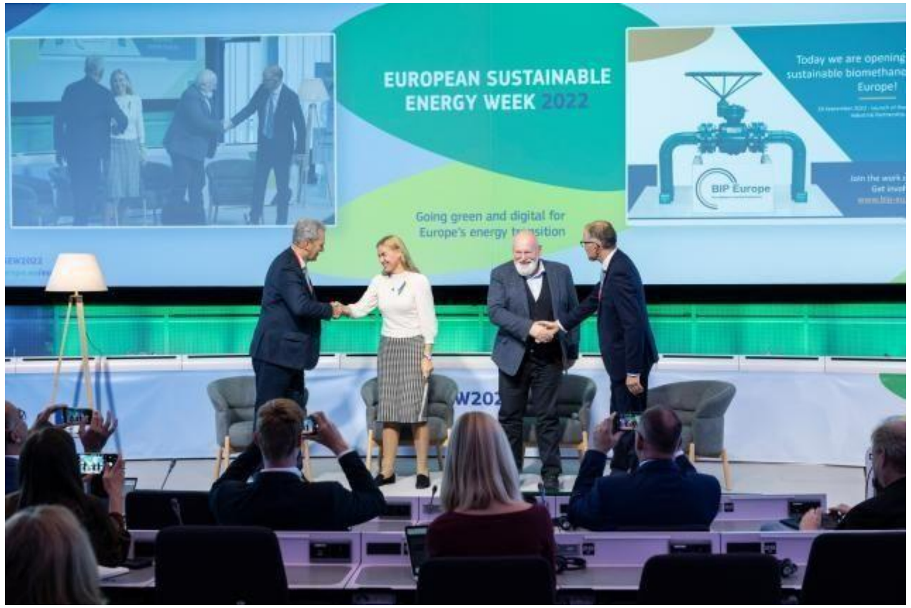
Contact
Renewable Energy House
Rue d'Arlon 63/67, 1040 Brussels
Belgium

www.bip-europe.eu

secretariat@bip-europe.eu



The Biomethane Industrial Partnership



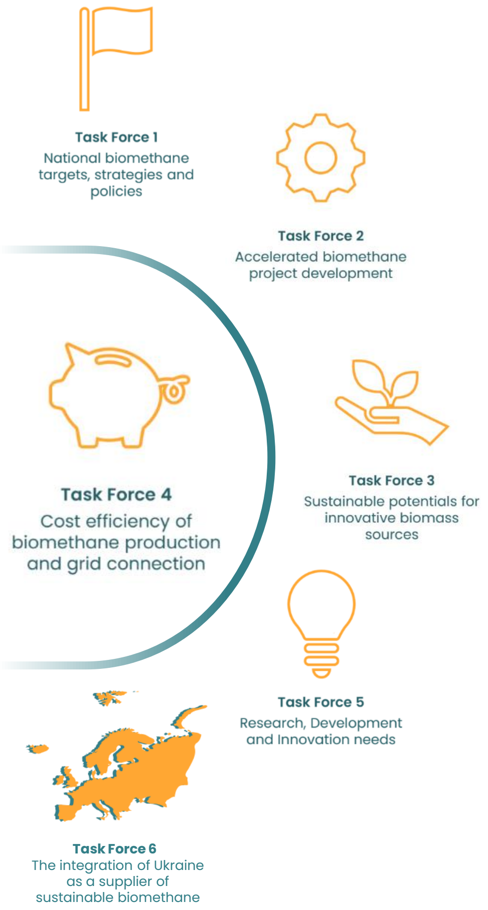
Launch of the BIP by EVP Timmermans and Commissioner Simson on 28 September 2022 during the European Sustainable Energy Week

- The Biomethane Industrial Partnership (BIP) is a collaboration between 20 EU member states, the European Commission, and biomethane industry. The BIP was created with the aim to **help to achieve the REPowerEU target of 35 bcm of annual biomethane production by 2030**.
- The European Commission introduced the 35 bcm target as it recognises the important benefits of biomethane in enhancing Europe's **energy security** and **reducing greenhouse gas emissions** (including the ability to generate **negative emissions**).
- Biomethane also has other benefits as an enabler of more **environmentally friendly, circular agriculture,** plus important **energy system benefits** as a source of storable, energy-dense renewable energy which can be transported through existing gas infrastructure.

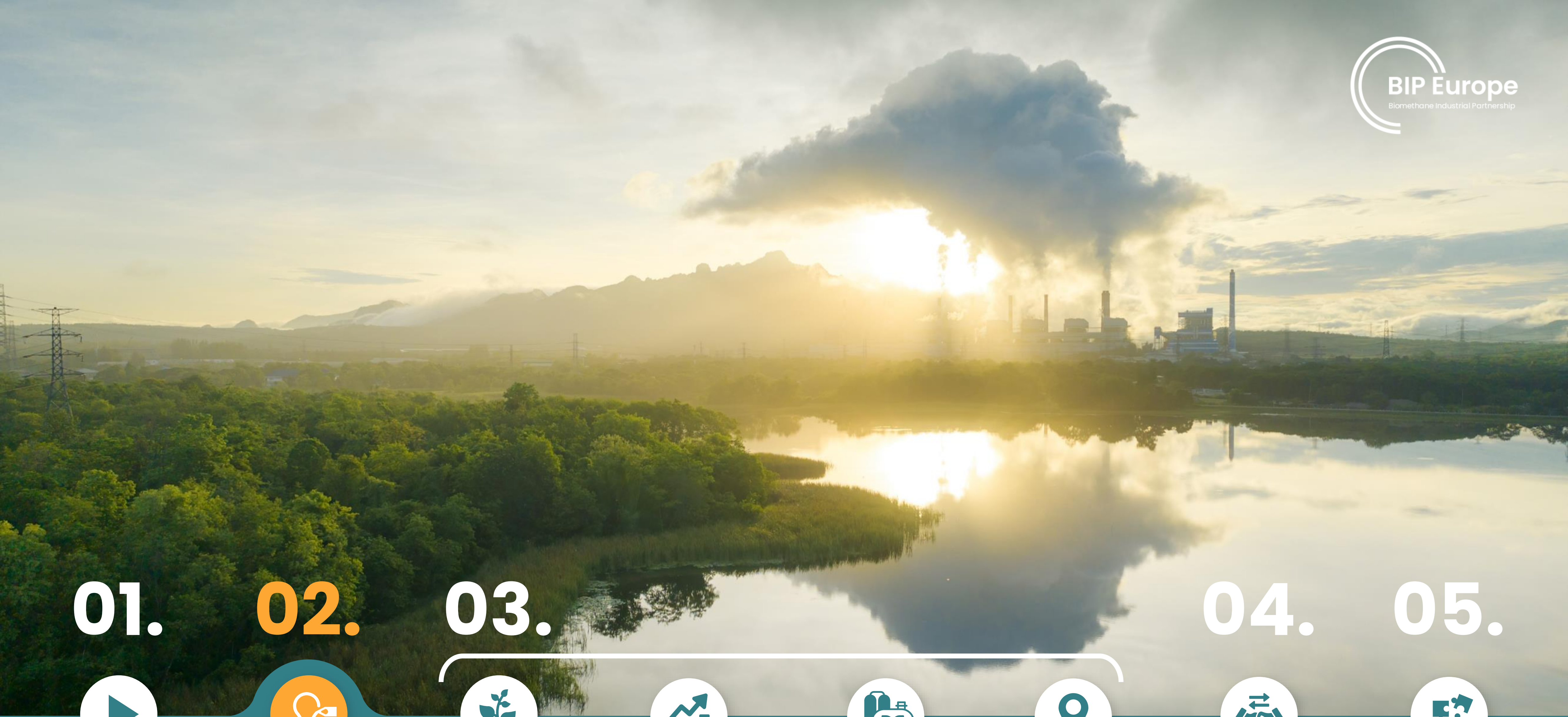
BIP Task Force 4.1's initial work focuses on bioCO_2 from biomethane production

Introduction

- Work of the BIP takes place in six Task Forces, each with their own focus
- Task Force 4 aims to provide insights into best practices for efficient and low-cost biomethane production and grid injection.
- **Task Force 4 has three subgroups:**
  - **Task Force 4.1 – Valorisation of by-products of biomethane production e.g. digestate and biogenic CO_2**
  - Task Force 4.2 – The cost of biomethane production and how this can be reduced
  - Task Force 4.4 – Optimise grid connections and grid reinforcements to allow low cost biomethane injection
- **The present memo captures the initial work of Task Force 4.1 on bioCO_2**
  - This work focuses on the valorisation of biogenic CO_2 (shortened here to bioCO_2) from biomethane production. The memo builds on insights from the EBA report on biogenic CO_2.[1]
  - This work is also linked to the work of other Task Forces, e.g. the work of BIP Task Forces 2, 3, & 5, where work is done on evaluating the business case, innovative feedstocks, and research and innovation in biomethane respectively.



[1] EBA (2022) Biogenic CO_2 from the biogas industry. (Link)



The biomethane industry can become an important supplier of bioCO_2

Executive summary

CO_2 is not just a greenhouse gas; it is also an important feedstock for some industries e.g. food & beverages.

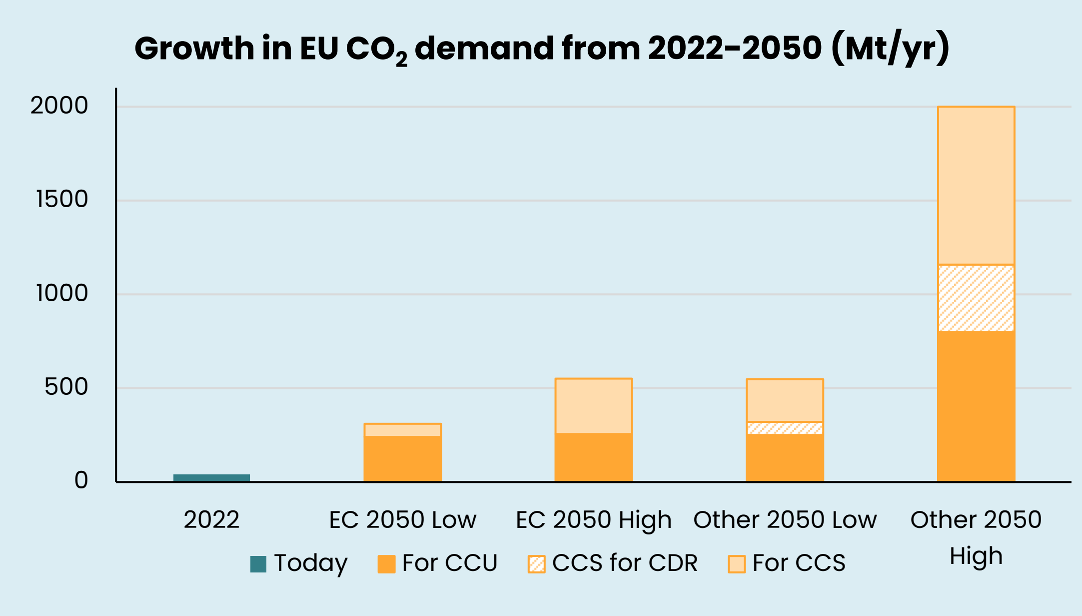
The demand for CO_2 in the EU, is currently 41 Mt/yr, **is estimated to increase to hundreds of Mt/yr by 2050**, mainly driven by the need for it as feedstock for zero-emission synthetic fuels and the need for CO_2 removal from the atmosphere.

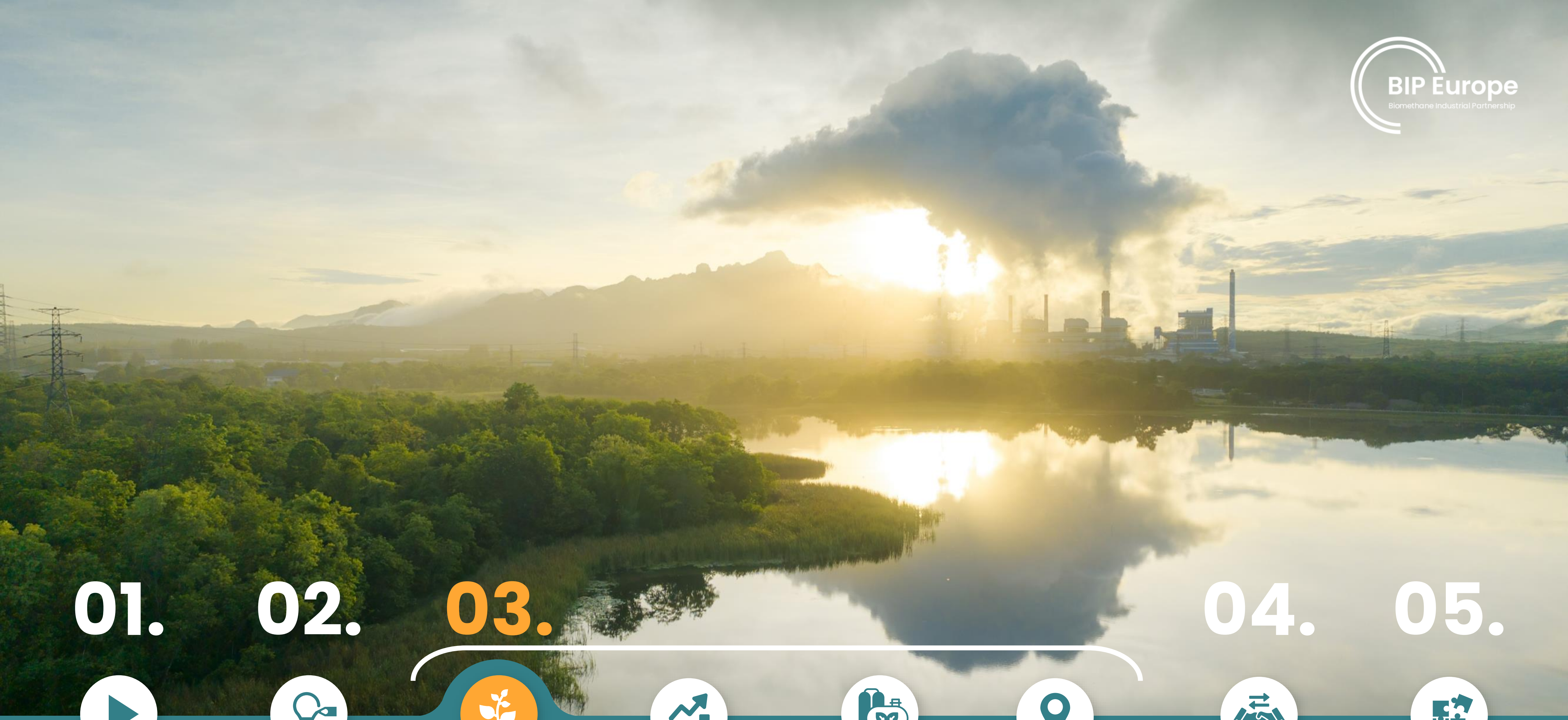
Biogenic CO_2 will be crucial in meeting this new demand with renewable CO_2, its main alternative being Direct Air Capture (DAC).

A key difference: biogenic CO_2 is captured following the production of energy from biomass while **DAC uses currently scarce renewable electricity** to capture atmospheric CO_2.

The biomethane industry provides a growing base of production plants where biogenic CO_2 is separated in highly concentrated streams. This low-cost – but distributed - source of biogenic CO_2 is currently underutilised, while it could become a valuable second product.

With the foreseen growth in biomethane production towards 2050 the theoretical potential for the associated biogenic CO_2 supply can reach ~124 Mt CO_2/yr.





BIP Europe
Biomethane Industrial Partnership

01. Introduction to the BIP

02. Executive Summary

03. Introduction to bioCO_2

Demand for CO_2

BioCO_2 from biomethane

End-uses of bioCO_2

04. Role of markets and certification

05. Conclusions

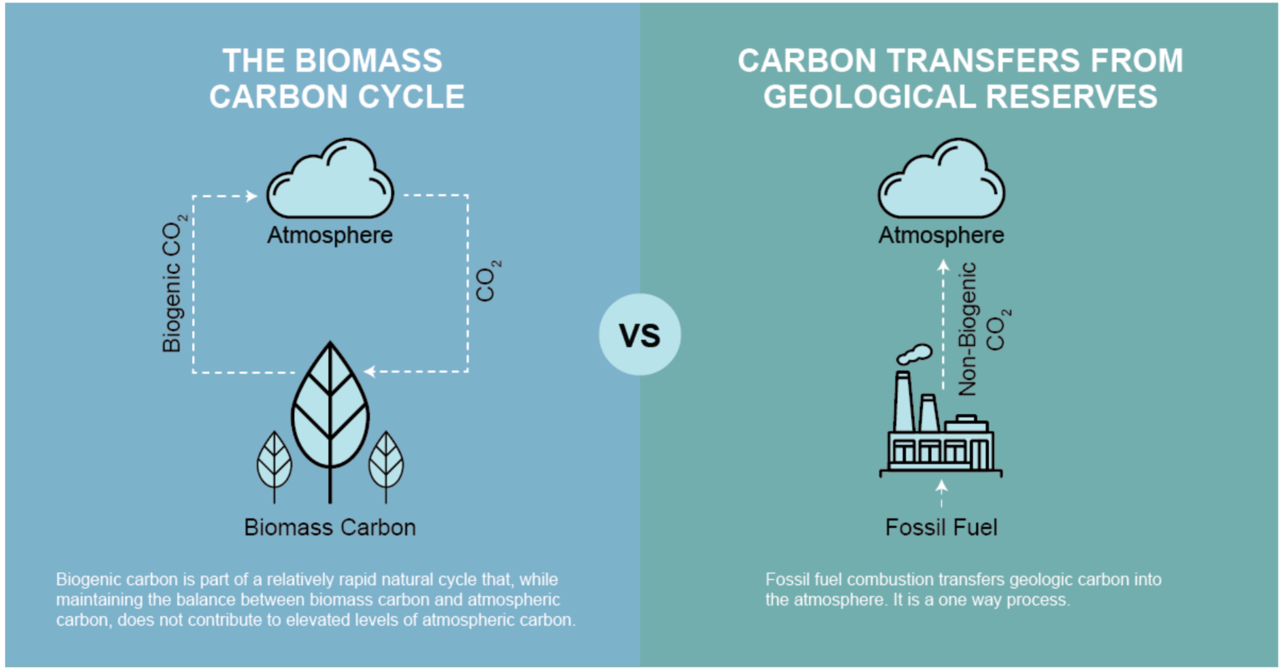
Biogenic CO_2 use avoids the accumulation of fossil carbon in the atmosphere

CO_2 is commonly known as a greenhouse gas, but it is also a molecule that is crucial for life. CO_2 is captured from the atmosphere by plants during photosynthesis and shortly stored in biomass before being released back into the atmosphere, by decomposition, digestion, or combustion, creating a short carbon cycle. We call this CO_2 released from biomass **bioCO_2**.

In contrast, geological carbon is part of an extremely long carbon cycle. Here the carbon is stored underground and would not return to the atmosphere for millions of years without human interference. This carbon is commonly used in the form of fossil fuels and produces CO_2 following combustion – leading to a net accumulation of **fossil CO_2** in the atmosphere.

The difference is illustrated in the diagram on the right from a recent EBA report, which explains the two cycles in more detail.[1]

This work focuses on short cycle biogenic CO_2 and how it can be used as a co-product from biomethane production to avoid the further accumulation of fossil CO_2 in the atmosphere, while providing biomethane producers with a new revenue stream.



[1] EBA (2022) Biogenic CO_2 from the biogas industry. (Link)

What is a tonne of CO_2 and what are the different ways of using captured CO_2?

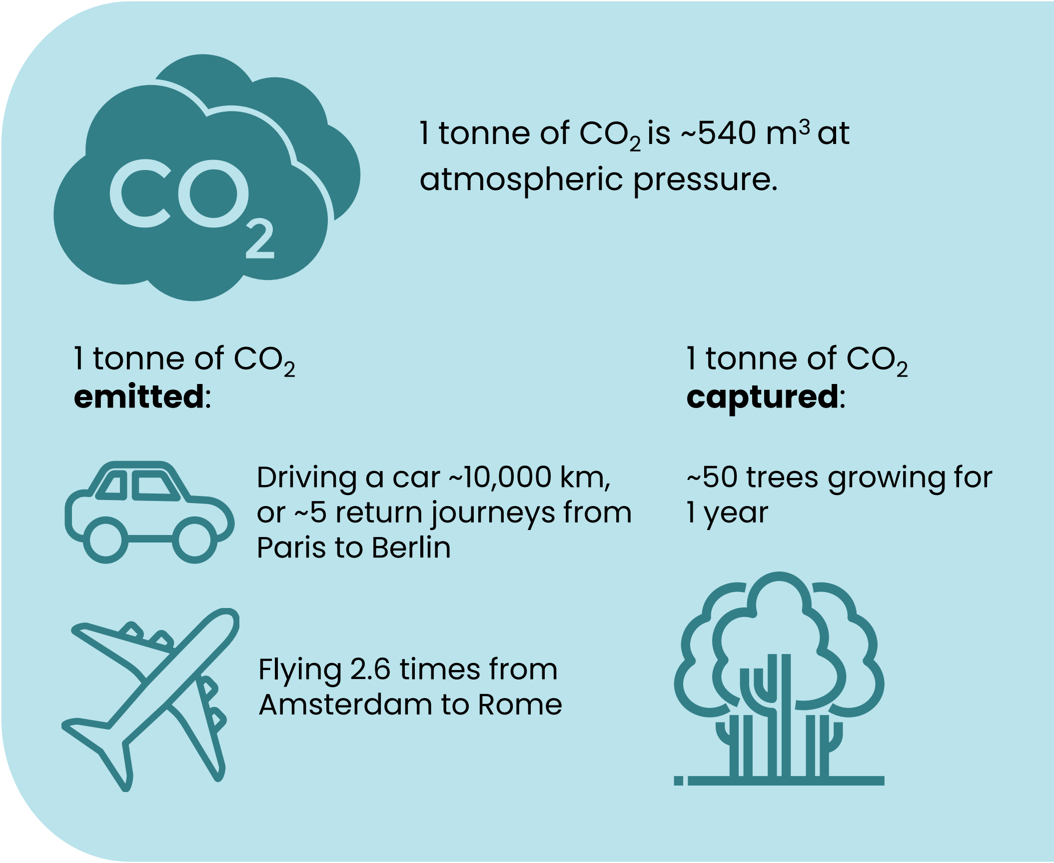
In this report, the amount of CO_2 will be expressed in tonnes. To understand the these values the graphic on the right explains what 1 tonne of CO_2 is in today's world.[1]

Other terminology used throughout this report is to do with categorising what happens to captured CO_2. This can generally be done under the following three headings:

- ***Carbon Capture and Utilisation (CCU):*** Carbon is captured and used as a feedstock or product, reducing the need for a fossil carbon source. The CO_2 still reaches the atmosphere after use, but the reduced need for fossil fuels results in overall GHG emissions savings.
- ***Carbon Capture Utilisation with Storage (CCU+S)*:*** Carbon is captured and used in a product, however the CO_2 is not released from this product for a long period of time, typically >50 years.
- ***Carbon Capture and Storage (CCS):*** Carbon is captured and stored underground for the long-term, typically >100,000's years.

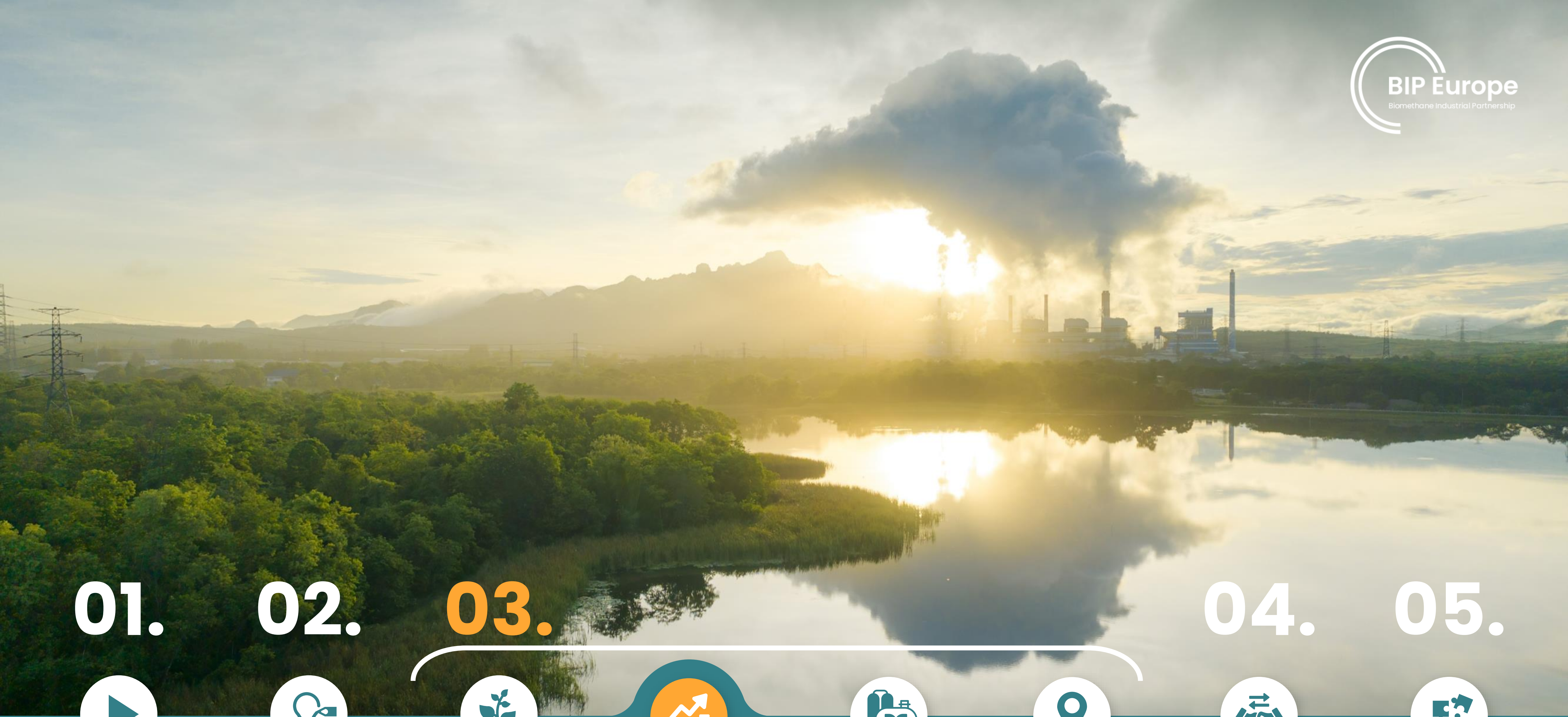
CCS with CO_2 from biogenic sources or from the atmosphere results in negative emissions and is a form of ***Carbon Dioxide Removal (CDR).*** The IPCC defines CDR as 'anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products'.[2]

CCS with fossil CO_2 emissions is not negative emissions but emission avoidance, and thus not a form of CDR.



*) CCUS is widely used as an umbrella term for CCU, CCU+S, and CCS

[1] Climate Neutral Group. What exactly is 1 tonne CO_2. Accessed 5th December 2023. (Link)
[2] IPCC AR6 WGIII. CDR Factsheet. (Link)



BIP Europe
Biomethane Industrial Partnership

01. Introduction to the BIP

02. Executive Summary

03. Introduction to bioCO_2

Demand for CO_2

BioCO_2 from biomethane

End-uses of bioCO_2

04. Role of markets and certification

05. Conclusions

Current CO_2 demand in the EU is dominated by the food & beverages industry

Demand for CO_2

While CO_2 is commonly viewed as a waste, there is also a demand for CO_2 to make products and provide services.

In 2015, global demand for CO_2 was approximately 230 Mt.[1] Fertiliser production and Enhanced Oil Recovery (EOR) were the main end uses.

The EU market for CO_2 was estimated at 41 Mt in 2022,[2] with 4 Mt in liquid form.[3] Pinpointing current CO_2 usage is complex and not crucial for our analysis, as future primary uses may shift. However, the existence of a CO_2 market, partially addressable by bioCO_2, is noteworthy.

In the EU, food and beverages is the largest market, making up ~40% of the demand. This is a large difference to the global average because fertiliser production is less common in the EU, where natural gas prices are historically high, and EOR is not as widespread a practice as in major oil-producing regions.

The CO_2 used to satisfy this demand today is typically provided by capturing high purity CO_2 from industrial processes. These processes traditionally use fossil fuels for production, e.g. natural gas for ammonia production.

EU CO_2 demand in 2022

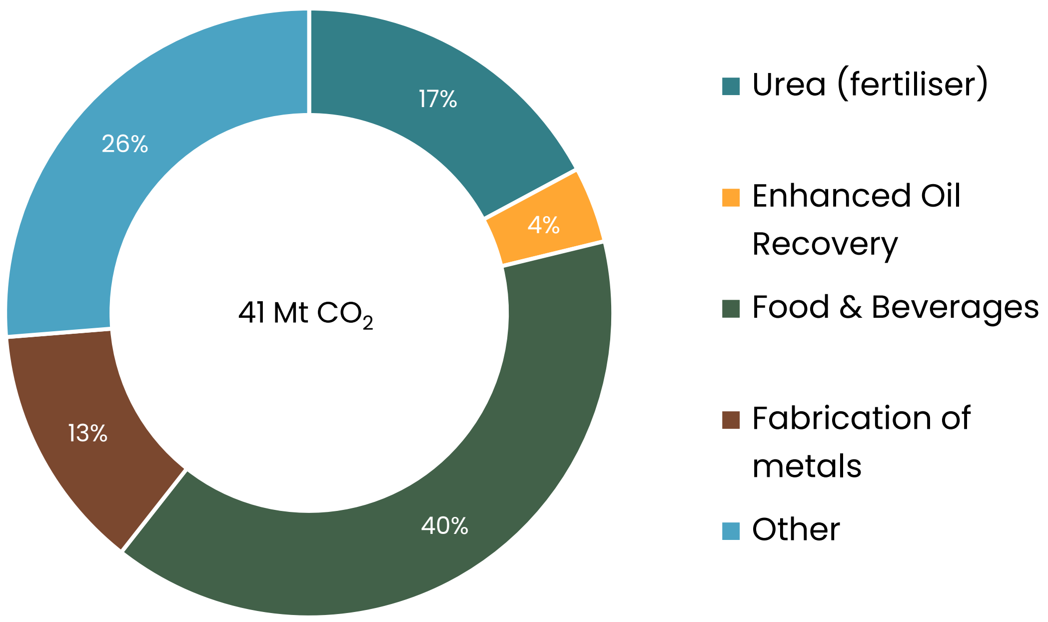


Figure 1. The 2022 demand for CO_2 in the EU by end use. [2]

[1] IEA (2019). Putting CO_2 to Use: Creating Value from Emissions. (Link)
[2] ERM Group (2022). Assessment of European biogenic CO_2 balance for SAF production. (Link)
[3] ChemAnalyst (2023). Europe Liquid Carbon Dioxide (CO2) Market Analysis: Industry Market Size, Plant Capacity, Production, Operation Efficiency, Demand & Supply, End-Use, Sales Channel, Regional Demand, Manufacturing Process, 2015-2035. (Link)

EU renewable CO_2 demand estimated to grow to hundreds of Mt/year

The demand for CO_2 is expected to grow rapidly in the future, under the two general headings, Carbon Capture and Utilisation (CCU) and Carbon Capture and Storage (CCS). In combination with bio-energy the latter is referred to as BECCS, one of the few options to achieve negative emissions.

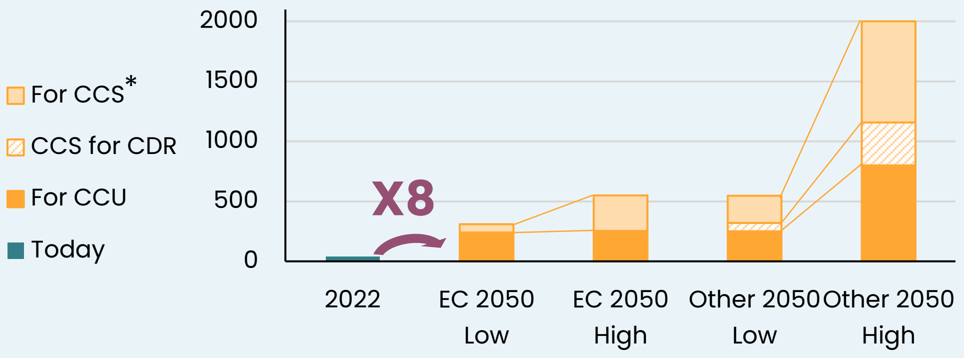
CCU demand in 2050 is expected to be more than 6 times the total current CO_2 demand
Several studies estimating the future demand for CO_2 indicate a large range in the potential EU demand of ~250-800 Mt CO_2/yr for CCU, e.g. for e-fuel production, in 2050.[1 2 3] Modelling for the European Commission (EC) falls in line with the lower end of this range, with a demand range of ~240-255 Mt CO_2/yr.[4] As CCU leads to the eventual release of CO_2 it should be renewable CO_2; either biogenic or atmospheric CO_2, by 2050 to avoid accumulation of fossil CO_2 in the atmosphere. Any fossil CO_2 use would need to be compensated for with negative emissions.

CCS demand in 2050 could be an order of magnitude greater than the total CO_2 demand today, with a substantial demand for bioCO_2 and atmospheric CO_2
The EU demand for CCS in 2050 is estimated in several studies to be between 298 – 1,200 Mt CO_2/year for various scenarios, while the EC's own modelling indicates a range of ~70-295 Mt CO_2/year for a net-zero 2050.[1 2 3 4]
A substantial part of this will be for creating the negative emissions needed to compensate for remaining hard-to-abate emissions. These negative emissions will require BECCS and direct air capture (DAC) with CCS as forms of carbon dioxide removal (CDR).[5] The demand for CDR in 2050 was recently estimated to require 70 – 358 Mt CO_2/yr of BECCS, and 0 - 22 Mt CO_2/yr DAC when CCS was limited to 425 Mt CO_2/yr due to technical limitations.[6]

These estimates indicate an extreme growth in demand. When taking the lower estimate for both CCU and CDR the demand for biogenic and atmospheric CO_2 in 2050 will be at least 8 times larger than the total current market for CO_2.

The EU may have to move on to net-negative emissions, which can dramatically increase this future demand for CCS
Paris Agreement-compatible climate scenarios indicate the need to move on to net-negative emissions, which would lead to an even higher demand for biogenic and atmospheric CO_2. In IPCC scenarios, ~9 Gt CO_2/yr CDR is required on average globally in 2050 to keep warming below 1.5°C.[7]
If the EU were to take a responsibility for 10% of this global CDR need, that would already see this demand double from the minimum CDR expected in 2050 mentioned above.

Growth in EU CO_2 demand from 2022-2050 (Mt/yr)



*CCS is not a demand for CO_2 if not for CDR. However, because the EC modelling does not specify the share of CCS for CDR, CCS values are incorporated in the graph for comparative clarity.

Figure 2. The potential demand for CO_2 in the EU in 2050 split between CCU, CDR, and CCS, and between the modelling for the European Commission[4] and other studies[1 2 3 6]

[1] Butnar et al., (2020). Review of Carbon Capture Utilisation and Carbon Capture and Storage in future EU decarbonisation scenarios. (Link). The median levels across the scenarios limiting warming to 1.5°C were considered.
[2] Ricardo Energy (2022). European CO_2 availability from point-sources and direct air capture. (Link)
[3] ERM Group (2022). Assessment of European biogenic CO_2 balance for SAF production. (Link)
[4] European Commission (2021) Working document on Sustainable carbon cycles for a 2050 climate-neutral EU Technical Assessment. (Link)
[5] The IPCC defines CDR as 'anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products' (Link)
[6] European Scientific Advisory Board on Climate Change (2023). Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050 (Link)
[7] IPCC, (2018) Section C3.2 (Link)

Future demand by end-use: e-fuel production and CCS likely to be largest

Large ranges for end-use demands of CO_2 in 2050

The split of the future demand for CO_2 by end use is not clear, with various publications giving widely different ranges, as shown in Table 1. The most extreme ends of these ranges come from modelling work where some of the abatement alternatives are not permitted, e.g. no CCS use, which leads to a larger demand for CO_2 in other sectors such as e-fuels.

Future end-use demands for CO_2 will be new, with most of the growth in demand expected to come from e-fuel production and CCS

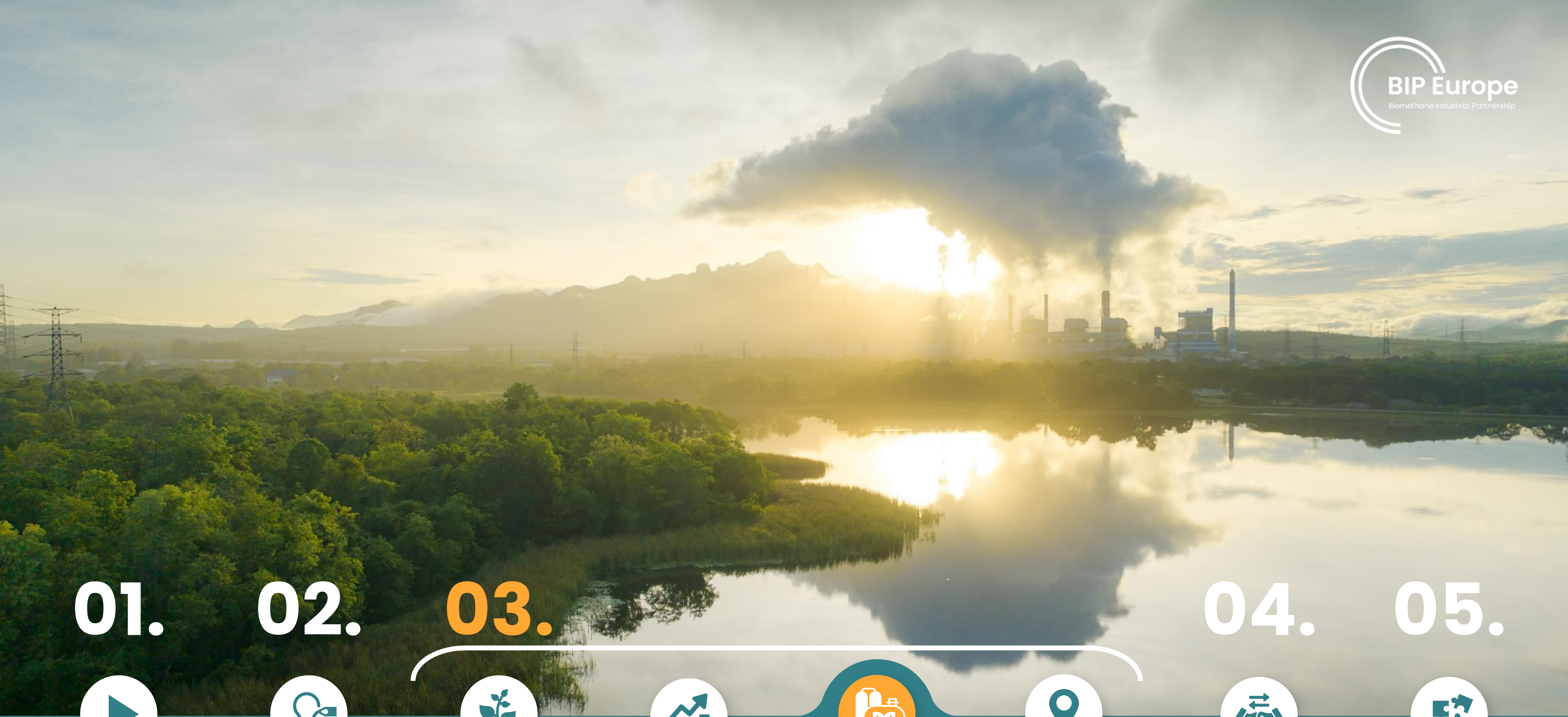
Despite the wide ranges and the discrepancy between estimates, what is clear is that current end uses will not be the main market for CO_2 in the future. Instead, future demand growth will be driven by sustainability focused applications such as e-fuel production, sustainable chemical production, and CCS. In its recent Industrial Carbon Management Strategy,[3] the European Commission has indicated that specific objectives for carbon removals could be considered. For industrial removals, there would likely be a connection to the EU-ETS.

Here the availability of renewable CO_2 is crucial to ensure the creation of e-fuels that can be classified as renewable fuels of non-biological origin (RFNBOs)[4] or to provide CDR if coupled with CCS.

Table 1. Breakdown of demand between end-uses from considered 2050 estimates.

CO_2 demand type	Estimated demand in 2050 (Mt CO_2/yr)			
	Butnar et al. 2020	*Ricardo Energy 2022*	*ERM Group 2022*	*EU Commission 2021*
Carbon Capture and Utilisation (CCU)				
Use in e-fuel production	150-800	363-523	161-296	185-195
Use in chemicals (e.g. biopolymers, and biochemicals)	0-300	28	50-102	N/A
Use in existing demands (e.g. fertilisers, and food & beverages)	N/A	96	40	N/A
Carbon Capture and Utilisation with Storage (CCU+S)				
Use in materials	47-80	46	N/A	55-65
Carbon Capture and Storage (CCS)				
Underground Storage	930-1200[2]	298	N/A	70-295[1]

[1] Recent modelling work by the EU Commission and the IPCC indicates that at least 150 Mt of CDR will be required in 2050, likely increasing the lower end of this range (Link)
[2] The median range of CCS needed. The full range for CCS requirements in the considered model runs leading to 1.5 C warming is 324-2230 MtCO_2/yr
[3] EC (2024). Towards an ambitious Industiral Carbon Management Strategy for the EU. (Link)
[4] RFNBO classification is important for e-fuel production, as it allows the use of the e-fuel count towards EU sub targets for renewable transport fuels, for road, maritime, and aviation fuels, (see Link, Link, Link respectively). This will allow for a higher price on the market. RFNBOs will be able to use fossil CO2 up until 2041 at the latest if significant emission reductions are proven, but after this the CO2 source must be biogenic or atmospheric. (Link).



BIP Europe
Biomethane Industrial Partnership

01. Introduction to the BIP

02. Executive Summary

03. Introduction to $bioCO_2$

Demand for CO_2

$BioCO_2$ from biomethane

End-uses of $bioCO_2$

04. Role of markets and certification

05. Conclusions

CO_2 is mostly captured from fossil fuels today, but a switch to biogenic CO_2 and DAC is needed

Today, CO_2 is mainly captured from industrial processes using fossil fuels…
Certain fossil fuel processes currently offer most of the lowest cost options for CO_2 capture, as shown in Table 2, as the costs of capture generally go down with increased CO_2 concentration in the relevant gas stream, and increased volumes being captured.[1 2]

…yet to reach a net zero EU in 2050 a shift to capturing biogenic and atmospheric CO_2 is needed
In the future, using fossil CO_2 for CCU and CCS will be limited due to the requirements for net-zero emissions. This means that both existing and future CO_2 demands must increasingly use renewable CO_2 sources. When comparing the potential sources of renewable CO_2 there are two general categories; bioCO_2 and Direct Air Capture (DAC).[3]

DAC can capture atmospheric CO_2, but the costs high
Due to the very low concentration of CO_2 in the air and the high energy requirements of DAC technologies, the cost of capture are high. The costs are ~€250-600/tCO_2 today, and expected to remain high towards 2050, with a capture cost of approximately €120-540 /tCO_2.[6 7 8 9 10 13]

DAC can be deployed anywhere; it does not rely on a point source of emissions. As such in the long run, the potential of DAC is limited by the availability of the technology itself and the demand for DAC. In the short run however, the need for plentiful, renewable energy (both electric and heat) to power DAC can be a limit on its potential, as large amounts of renewable energy are needed for other uses too.

Table 2. Characteristics of different fossil and renewable **CO_2 sources.**

CO_2 source	Concentration (% CO_2)	Capture cost (€/t CO_2)
Natural gas processing	96-100	15-25
Coal to chemicals	98-100	15-25
Ammonia	98-100	25-35
Bioethanol*	98-100	25-35
Ethylene oxide	98-100	25-35
Hydrogen (SMR)	30-100	50-80
Iron & steel production	21-27	40-100
Cement	15-30	60-100
Paper and pulp*	14-30	40-92[10]
Waste to energy*	6-12	60-80
Power generation	3-15[11]	50-100

*Existing sources of bioCO_2.

Sources: [1, 7, 8, 9, 10, 11]

Large volume renewable CO_2 alternatives and their cost ***in 2050***

Biomass for power & heat*	10-12	100-200
Biomethane*	96-100	25-90[14]
Direct Air Capture	0.04	120-540

Sources: [5, 6, 7, 13]

[1] Global CCS Institute (2021). Technology readiness and the cost of CCS. (Link)
[2] Some locations e.g. Italy, have geological CO_2 seeps that can be high purity and very low cost to capture.
[3] In its recent communication on an Industrial Carbon Management Strategy, the European Commission writes: "After 2040, industrial carbon management should be an integral part of the EU's economic system, and biogenic or atmospheric carbon should become the main source for carbon-based industrial processes or transport fuels" (Link, p. 7)
[7] IPCC (2018). Chapter 4. (Link)
[8] IEA (2019), Putting CO_2 to use. (Link)
[9] IEA (2021), Is carbon capture too expensive?, Accessed on 11/12/2023: (Link)
[10] Eurelectric (2023). Decarbonsiation Speedways (Link)
[11] IEAGHG (2016). Techno-economic evaluation of retrofitting CCS in a market pulp mill and an integrated pulp and board mill (Link)
[12] NETL, Carbon Dioxide Capture Approaches. Accessed on 14/12/2023: (Link)
[13] EC (2024). Towards an ambitious Industrial Carbon Management Strategy for the EU. (Link)
[14] Insights from Task Force 4.1 members.

Biomethane production can be a cost-effective source of bioCO$_2$ today and in the future

Solid biomass for centralised power & heat production has the largest bioCO$_2$ potential, but at a high cost because of relatively low concentrations

The production of bioCO$_2$ from power and heat production and DAC are seen as the two largest scale options to provide this renewable CO$_2$ in the EU.

The potential volume available from BECCS on power & heat production facilities is estimated to be 5-382 Mt CO$_2$/year.[1 2] Despite large point sources of CO$_2$ here, low CO$_2$ concentration in the flue gas means that the capture costs here will likely be high. Also importantly, the likelihood of low running hours for thermal generation units in 2050 will increase as the penetration of solar and wind increases. This will lead to high costs of capture, of approximately €100-200/tCO$_2$,[3] and irregular production of bioCO$_2$, which is undesirable for offtakers.

High concentration bioCO$_2$ sources exist, and can be competitive

Carbon capture is typically most cost-effective for point source emissions exceeding 300 ktCO$_2$/yr. The economics of bioCO$_2$ capture vary case-by-case, hinging on volume and concentration, along with specific process characteristics. For instance, substantial volume sources such as paper and pulp mills have the advantage of waste heat availability, which facilitates carbon capture, making it economically feasible despite lower CO$_2$ concentrations. Other biogenic sources offer high CO$_2$ concentration, leading to capture costs on par with those for fossil CO$_2$, detailed in Table 2 on the previous slide. These high-concentration bioCO$_2$ streams are most associated with fermentation, like in bioethanol production, and digestion processes in biogas and biomethane production.

Biomethane production has a low carbon capture cost, as CO$_2$ separation is part of the existing process

For biomethane production, biogas - with typical contents of 45-70% CH$_4$ and 25-50% CO$_2$ - is separated into a concentrated biomethane stream and a secondary gas stream with a high concentration of CO$_2$ (usually ~96-100%).[4] Depending on the size of production and the CO$_2$ concentration in the gas stream, the cost of capture can be €25-90/tCO$_2$, the equivalent to €3-12/MWh biomethane.[5 6] This cost can be low because the biomethane production process essentially has a CO$_2$ separation step already, meaning CO$_2$ capture costs in Table 2. are mainly associated with the cost of liquefaction.

The ease of carbon capture is important as an average biomethane facility of ~500Nm^3/h capacity produces approximately ~ 5ktCO$_2$/yr bioCO$_2$, significantly less than the 300 ktCO$_2$/year scale typically seen as the minimum for current commercial CO$_2$ capture projects.[7 8]

[1] Ricardo Energy (2022). European CO$_2$ availability from point-sources and direct air capture. (Link). p.50-52
[2] Concito (2023). The potential and risks of carbon dioxide removal based on carbon capture and storage in the EU. (Link)
[3] Lebling et al., (2022). 6 Things to Know About Direct Air Capture. World Resources institute. Accessed on 22/12/2021. (Link)
[4] The CO$_2$-concentration in off-gas-streams of biogas upgrading plants depends mainly on the use of stripping air (physical absorptions such as water scrubbers) and the use of air (N$_2$/O$_2$) for the in-situ biological desulphurization in the digester. Less prevalent separation processes exist with lower resulting CO$_2$ concentrations behind complete desorption.
[5] Insights from Task Force 4.1 members.
[6] Assuming 0.13 t CO2/MWh biomethane following upgrading
[7] Global CCS Institute (2021). Technology readiness and the cost of CCS. (Link)
[8] Assumption for average plant in EU of 500Nm^3/h capacity. CO$_2$ is taken as 40% of the biogas input, with an assumed 8,000 running hours with a 95% capture rate.

Biomethane has a high potential for growth compared to other concentrated $bioCO_2$ sources

Bioethanol production is expected to decrease towards 2050, reducing its potential as a source for $bioCO_2$
Of the high CO_2 concentration sources of $bioCO_2$ from Table 3, biomethane production is the process showing the highest potential for growth towards 2050. Bioethanol production is expected to decrease towards 2050 as biofuel demand in road transport decreases with the rise of electric vehicles.[1] Additionally, fermentation in the food & drink industry is not expected to increase dramatically from its relatively small volumes of CO_2 production today. Increases in production will likely offset by the need for CO_2 in the food and beverage industry. Today fossil CO_2 is often used despite the production of $bioCO_2$ onsite in many circumstances, so any growth in $bioCO_2$ in the future could be used directly to replace that.[2]

The potential of biomethane indicates it can become a relatively large source of low cost $bioCO_2$ both today and in 2050
Today, if all biogas and biomethane plants captured their $bioCO_2$ there would be a supply of ~27 Mt CO_2/yr.[3] Additionally, biomethane production is indicating the potential for rapid growth. By 2030 it is the goal of the EU's RePowerEU to reach 35 bcm annual biomethane production in the EU, producing ~46 Mt CO_2/yr.[4] This growth is expected to continue towards 2050, with the European Biogas Association (EBA) estimating that biomethane production can possibly reach 95 bcm/yr in 2050, giving a total potential bioCO2 supply of 124 Mt CO_2/yr in 2050.[5] This is the equivalent of 6-38% of the mentioned estimates of CO_2 demand in 2050, which would be a substantial contribution.

This potential production in 2050 is lower than recent estimates where the sustainable potential of biomethane in the EU is found to be ~165 bcm/yr.[6] Additionally, this does not include the potential to capture $bioCO_2$ from biomethane after its combustion, where the end use allows it.
With consideration for both these factors the potential for $bioCO_2$ from biomethane production in 2050 could be notably higher.

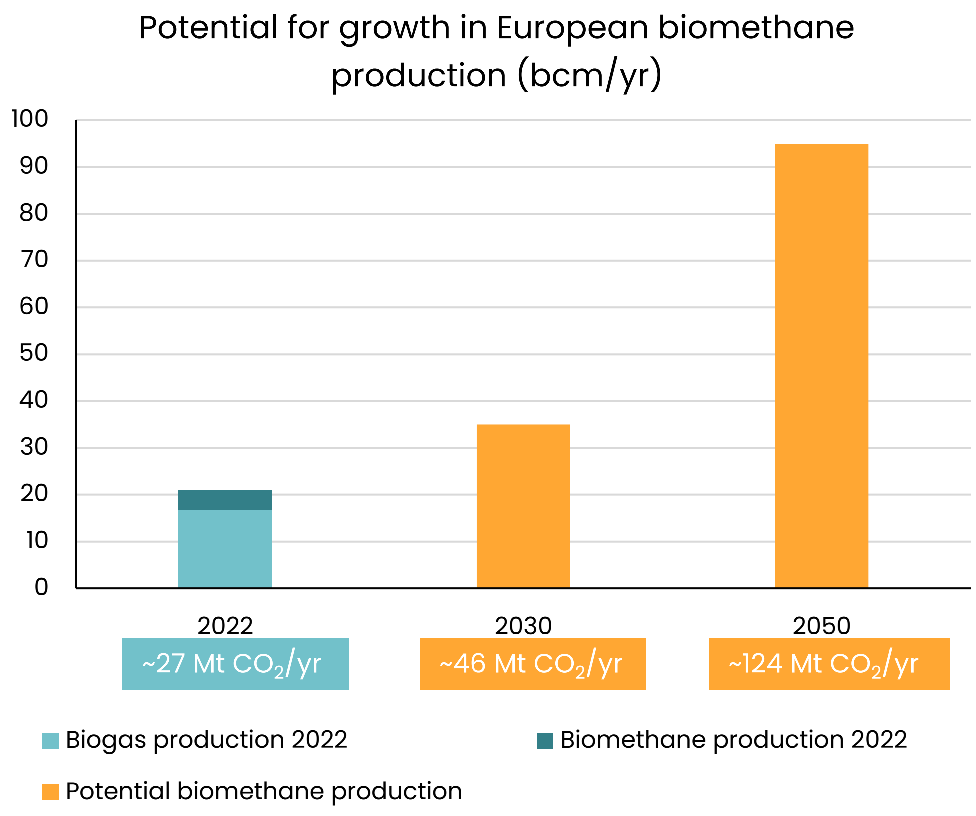


Figure 3. The current production of biogas and biomethane and the potential growth of biomethane production in Europe towards 2030 and 2050, with the equivalent CO_2 available in the box below.

[1] Concawe (2021). Transition towards Low Carbon Fuels by 2050: Scenario analysis for the European refining sector. (Link)
[2] ERM Group (2022). Assessment of European biogenic CO_2 balance for SAF production. (Link)
[3] EBA (2023). Statistical report. Assuming that all biogas is upgraded to biomethane and an average CO_2 production from this process of 0.13 tonne/MWh biomethane (1.3 Mt/bcm)
[4] European Commission (2022). REPowerEU Plan (Link)
[5] EBA (2022). Biogenic CO2 from the biogas industry. (Link)
[6] Guidehouse (2022). Biomethane production potentials in the EU. (Link)

BioCO_2 from biomethane production requires reliable, low-cost transport

The logistics associated with bioCO_2 from biomethane production can drive up cost
Although bioCO_2 is cheap to capture from biomethane production, it can come with logistical challenges. Biomethane plants are typically located in the countryside and are not spatially clustered. This brings increased cost and difficulty of transport and storage as a result of smaller scale facilities and potentially longer transport distances. If the bioCO_2 is valorised onsite, or a local offtaker can be found, these issues can be avoided, and biomethane's already large role in stimulating local rural economies can be further enhanced.

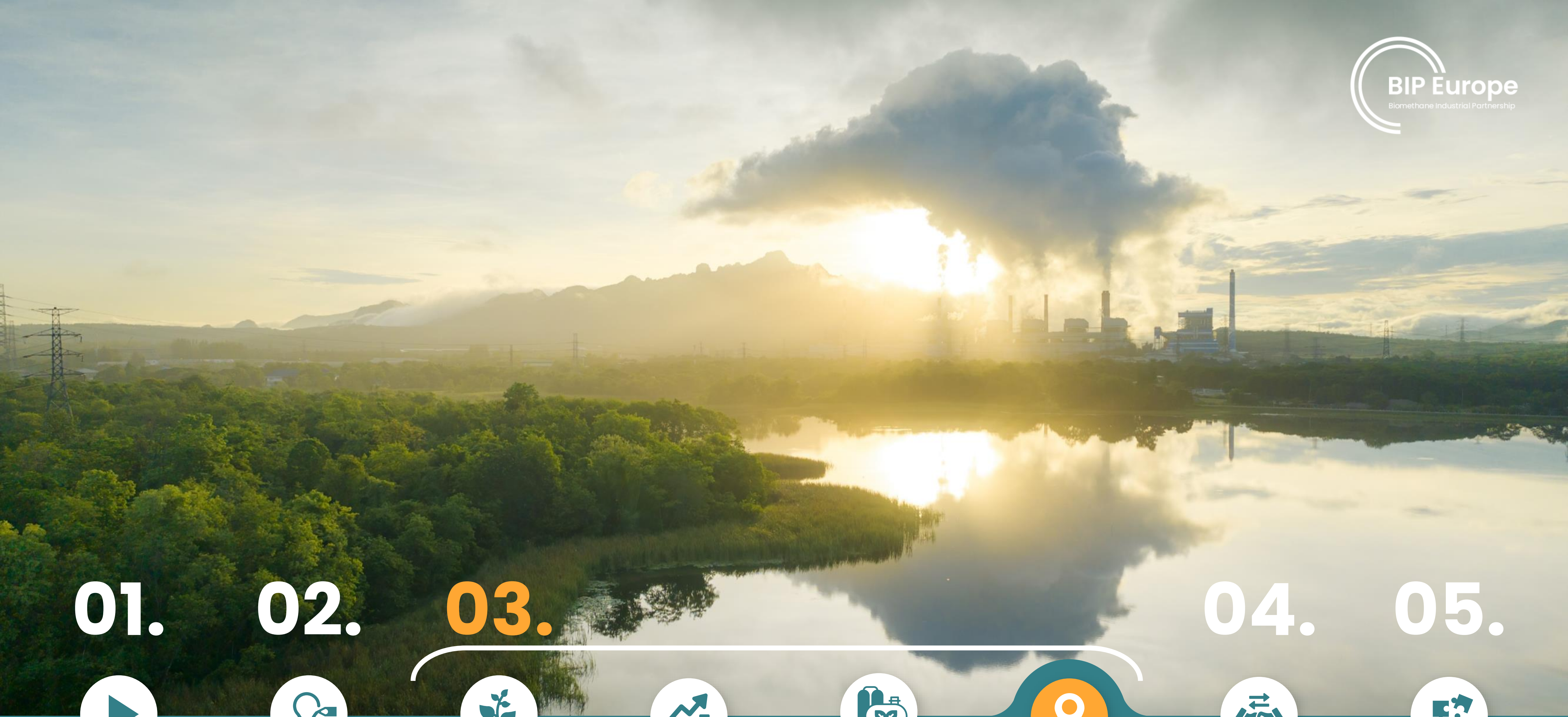
Truck transport the likely transport method for biomethane installations
Truck transport of liquid bioCO_2 is the most likely option for biomethane plants, as it is competitive with other transport methods such as pipelines or ships for smaller volumes and shorter distances. This cost competitiveness depends on many factors but tuck transport is generally considered viable for transport volumes below 300 ktCO_2/year. [3] This is equal to the bioCO_2 production of between 15-60 biomethane plants,[4] indicating that truck transport will be done by almost all biomethane plants unless alternative infrastructure is available nearby, e.g. CO_2 pipelines/ port locations.

BioCO_2 from biomethane plants is competitive with renewable CO_2 alternatives when transport costs are low
Capturing bioCO_2 from biomethane plants can come at a cost advantage of €10 – >€150/tCO_2 compared to the renewable CO_2 options with the highest potential. If the cost of transport is lower than this cost advantage then there is a case for the capturing of bioCO_2 from biomethane production. Transport costs will change on a case-by-case basis. One recent paper estimates the cost of truck transport of liquid CO_2 to be ~€0.1/tCO_2/km.[5] This leads to a cost of ~€20/tCO_2 for a distance of 200 km. The cost of onsite storage and 'milk runs' by a truck collecting CO_2 cylinders from multiple locations will need to be added, but indications are that there will be many biomethane plants suitable for bioCO_2 capture and transport. The plants most suitable will likely be larger plants where capture costs can be reduced, and in locations where a local demand can be found, and transport costs minimised.

Transport costs for large sources of renewable CO_2 will likely be lower
Other biogenic CO_2 sources will also have transport costs. If considering large point sources such as CCS on biomass use in heat and power production, transport can be expected to come at a lower cost. This is thanks to economies of scale and the fact that large scale CO_2 sources will have a higher likelihood of having a connection to any eventual CO_2 pipeline network, which can notably decrease transport costs.

Alternatively, the use of DAC can minimise the transport costs and even remove them. Despite the high cost of capture from DAC, it is not spatially tied to a point source of emissions, so the location of DAC could be at the point of demand, avoiding transport costs.

[1] Concawe (2021). Transition towards Low Carbon Fuels by 2050: Scenario analysis for the European refining sector. (Link)
[2] EBA (2022) Biogenic CO_2 from the biogas industry. (Link)
[3] Psarras et al., (2021) Cost Analysis of Carbon Capture and Sequestration from U.S. Natural Gas-Fired Power Plants. (Link)
[4] Assumption for 60 average plant of 500Nm^3/h and 15 large plants of 2000Nm^3/h. CO_2 is taken as 40% of the biogas input, with an assumed 8,000 running hours with a 95% capture rate.
[5] Stolaroff e.a. Transport Cost for Carbon Removal Projects With Biomass and CO2. Front. Energy Res. 9:639943.



BIP Europe
Biomethane Industrial Partnership

01.
Introduction to the BIP

02.
Executive Summary

03.
Introduction to bioCO_2

Demand for CO_2

BioCO_2 from biomethane

End-uses of bioCO_2

04.
Role of markets and certification

05.
Conclusions

Factors influencing the end use of bioCO_2 from biomethane (1/2)

The preferred end use of bioCO_2 from biomethane production depends on many factors such as purity requirements, logistics costs, the cost of alternatives, and the need for CDR.

Purity requirements

There can be many minor impurities in the bioCO_2 from biomethane production depending on the composition of the biogas. Typical impurities in biogas can be water vapour (~6%), nitrogen (0-5%), oxygen (0-1%), and small volumes of ammonia and hydrogen sulphide. Following biogas upgrading some of these impurities can remain in the separated CO_2 stream. There are specific end uses of CO_2 requiring extremely high purity (>99%), which would require this bioCO_2 to be further purified before its use, e.g. food and beverages. This approach incurs additional costs for biomethane producers. Nonetheless, the resulting product can command a premium price from consumers, offsetting the initial investment.

Cost of logistics

Depending on the plant size, location, and available CO_2 transport infrastructure, the cost of CO_2 transport from the biomethane plant to the producer will change. It is acknowledged that bioCO_2 from biomethane producers will likely come with a high cost of logistics, due to factors mentioned above. With high logistics costs the option for onsite methanation of the bioCO_2 may become increasingly attractive, however, this must be weighed up against the logistical costs of this valorisation route, e.g. hydrogen production onsite or hydrogen transport to the biomethane facility.

Cost of electricity

Electricity costs play an important role in the economic feasibility of liquefying bioCO_2 from biomethane production. The electricity required for liquefaction is a significant part of the operational expenses (OPEX), causing the electricity price to impact the overall cost structure of such projects. Sources are found indicating that the electricity consumption for converting bioCO_2 to its liquefied form can be ~0.1 MWh/tCO_2.[1, 2]

[1] Deng, H., Roussanaly, S., and Skeugen, G. (2019). Techno-economic analyses of CO_2 liquefaction: Impact of product pressure and impurities. (Link, table 3 and figure 10)
[2] Li, S., et al. (2013). A feasible energy-saving analysis of a new system for CO2 cryogenic capture. (Link, section 2.2.)

Factors influencing the end use of bioCO_2 from biomethane (2/2)

Cost of alternatives

The use of bioCO_2 in various end uses is also very dependent on the cost of alternatives for emissions reductions of this end-use. While bioCO_2 is expected to have a large and varied role in the future energy system it does not exist in a black box. Alternatives exist to the use of bioCO_2, e.g. the use of green ammonia as an e-fuel for maritime shipping in place of e-methanol. As such, the cost of these alternatives will have a big impact on the end uses where bioCO_2 is deployed in 2050, with some end use demands having more alternatives available than others

Appropriate evaluation of Carbon Dioxide Removals (CDR)

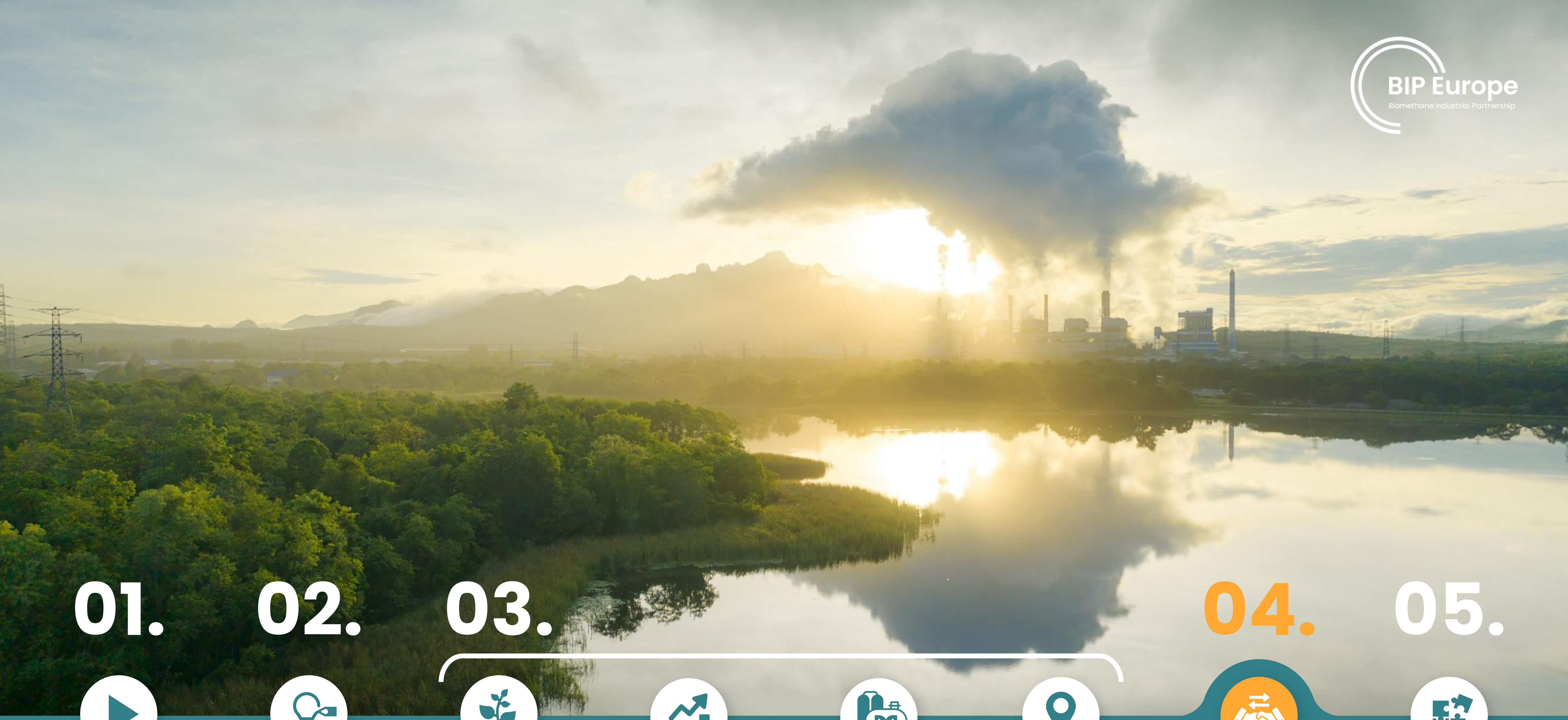
The need for CDRs in the EU is to some extent already taken into account in modelling for policy, however, negative emissions are currently an undervalued and underdeveloped part of the energy transition. CCS is one of the most valuable forms of CDR, so the creation of negative emissions from CCS of bioCO_2 or atmospheric CO_2 will have a high value in the future energy system if the target of limiting warming to 1.5°C is to be realised. While EU modelling is beginning to appreciate the value of these negative emissions more, the role of bioCO_2 in providing the lowest cost technological CDR option is not yet fully appreciated.

The next slide presents a table comparing multiple of the potential end uses of bioCO_2 with a focus on bioCO_2 produced from biomethane. *These end uses are explained in more detail in the background slides.*

Examples of end uses of bioCO_2 from biomethane production

CO_2 end use	End use details				
	Explanation	*What are the bottlenecks*	*Market today & in the future*	*Non-bioCO_2 alternatives*	*TRL*
Onsite methanation (CCU)	Hydrogen assisted biogas upgrading. Can be in the anaerobic digester (*in situ*) or new methanation plant onsite (*ex situ*).	• Getting green hydrogen to the biomethane plant at a competitive price. • Technology currently still at demonstration stage.	• Here bioCO_2 not a product in the market but an input. • RFNBO classification of the e-methane produced would allow for use towards EU RFNBO targets.	• Use of other CO_2 highly unlikely. • Technically DAC is possible.	In-situ: 3-5 Ex-situ: up to 9
E-fuel production (CCU)	Used with green hydrogen to make renewable fuels e.g. e-kerosene.	• Getting green hydrogen at a competitive price • Technology for some fuels still in demonstration stage and earlier. • Demand currently policy driven	• Some mandate driven markets e.g. e-kerosene in aviation. • Other RFNBO sub-targets from EU crucial to creating short term demand. • Large corporation voluntary targets also very influential.	• Up until 2041 certain fossil CO_2 sources can be used for RFNBO status. • DAC.	4-9
Existing demands (CCU)	Replace current fossil CO_2 demand. BioCO_2 use in food & beverages is challenging due to perceived health risk of impurities and the nature of feedstocks used for biomethane.	• Demand already exists. • With additional upgrading and stringent quality control, the use of bioCO_2 could become feasible.	Demand expected to have steady growth in general, with reduced demand for fossil fuel demands e.g. urea production and enhanced oil recovery.	• Fossil fuels in short term. • DAC in the long term.	9
Materials (CCU/CCU+S)	Use in making of building materials e.g. concrete, use for production chemicals and polymers, or use for mineral waste recycling.	• Technology sometimes at demonstration level • No need for high purity CO_2, however, transport and storage only done for high purity, increasing the cost	Currently voluntary, but with implementation of restrictions on emissions from construction this could help reduce the impact of high emission products like cement and concrete.	Most value comes from the carbon storage market, so DAC is only alternative.	8-9
Underground Storage (CCS)	Store the CO_2 underground to create negative emissions, a form of CDR. Can be geological or mineralisation.	• The distribution of storage sites across the EU is not even. • Mineralisation is still in demonstration stage.	CDR from bioCO_2 and CCS is currently not supported by policy within the EU, and is only a voluntary market, though this may change in the future.	If CDR is the goal then DAC is the only alternative. Fossil CO_2 and CCS is only emission avoidance not removal.	7-9

See background information for further details



01. Introduction to the BIP

02. Executive Summary

03. Introduction to bioCO_2 | Demand for CO_2 | BioCO_2 from biomethane | End-uses of bioCO_2

04. Role of markets and certification

05. Conclusions

Deploying valorisation routes for bioCO$_2$ requires certification

There are 4 ways biomethane producers can valorise their bioCO$_2$:

As a part of the biomethane process

1. Use the capture and storage of bioCO$_2$ to lower the carbon intensity of their biomethane production on their Proof of Sustainability – where applicable bringing a price premium on biomethane itself

As its own new product

1. Sell bioCO$_2$ directly to demand that is not required to use renewable CO$_2$ e.g. food & beverage industry – this can bring a premium to help companies reach voluntary targets
2. Sell bioCO$_2$ directly to products that have a bioCO$_2$ demand e.g. renewable fuels – demands a premium, but low demand today means this is not fully realised for bioCO$_2$ sellers today.
3. Sell CDR from bioCO$_2$ with permanent storage in a voluntary market – can demand a large premium

A crucial lever to realising the potential for bioCO$_2$ in the short term in both CCU and CCS is creating certification schemes and trade registries to facilitate this. These will enable producers to get added value for their product.

At the moment there are different certification frameworks applicable in other markets. The EU Renewable Energy Directive sets requirements for Guarantee of Origins for electricity and gas such as biomethane or Proofs of Sustainability for liquid and gaseous biofuels. Moreover, new EU legislation is being prepared on the certification of carbon removals. The creation of compliance markets and also the existence of EU wide certification schemes, has promoted increases in renewable electricity production while assisting emission reductions, as such this is a model for the certification of bioCO$_2$.

Today, EU recognised voluntary schemes such as ISCC, REDCert, Better Biomass and 2BS, provide certification for the emissions intensity of biomethane production via the Proof of Sustainability. Furthermore, there is the example of the recent ISCC PLUS which allows for the voluntary certification of bioCO$_2$.[1] This is done by allowing the capture of this bioCO$_2$ to reduce the emission intensity of the biomethane, or to be associated with a new bioCO$_2$ product.

[1] ISCC (2023). ISCC PLUS. (Link, p. 14-15)

Ways to improve the certification of bioCO_2

Three examples of enabling certification schemes to assist in the valorisation of bioCO_2

1. The creation of a biogenic CO_2 Certificate of Origin. If applicable this could allow a more efficient book and claim scheme to be created.
2. The creation of certification of the emission intensity of entire supply chains, where bioCO_2 use can significantly help reduce emissions.
3. The creation of schemes to enable and promote high quality CDRs from negative emissions with bioCO_2. This relevant for both CCS and CCU+S.

In the context of the last example, the proposed Carbon Removal Certification framework[1] introduces a voluntary framework across the EU for certifying carbon removals generated in Europe. Although not a direct incentive, it represents a crucial step towards establishing a common language, quantifying, and certifying CDRs, thereby facilitating the recognition and valuation of high-quality carbon removal efforts.

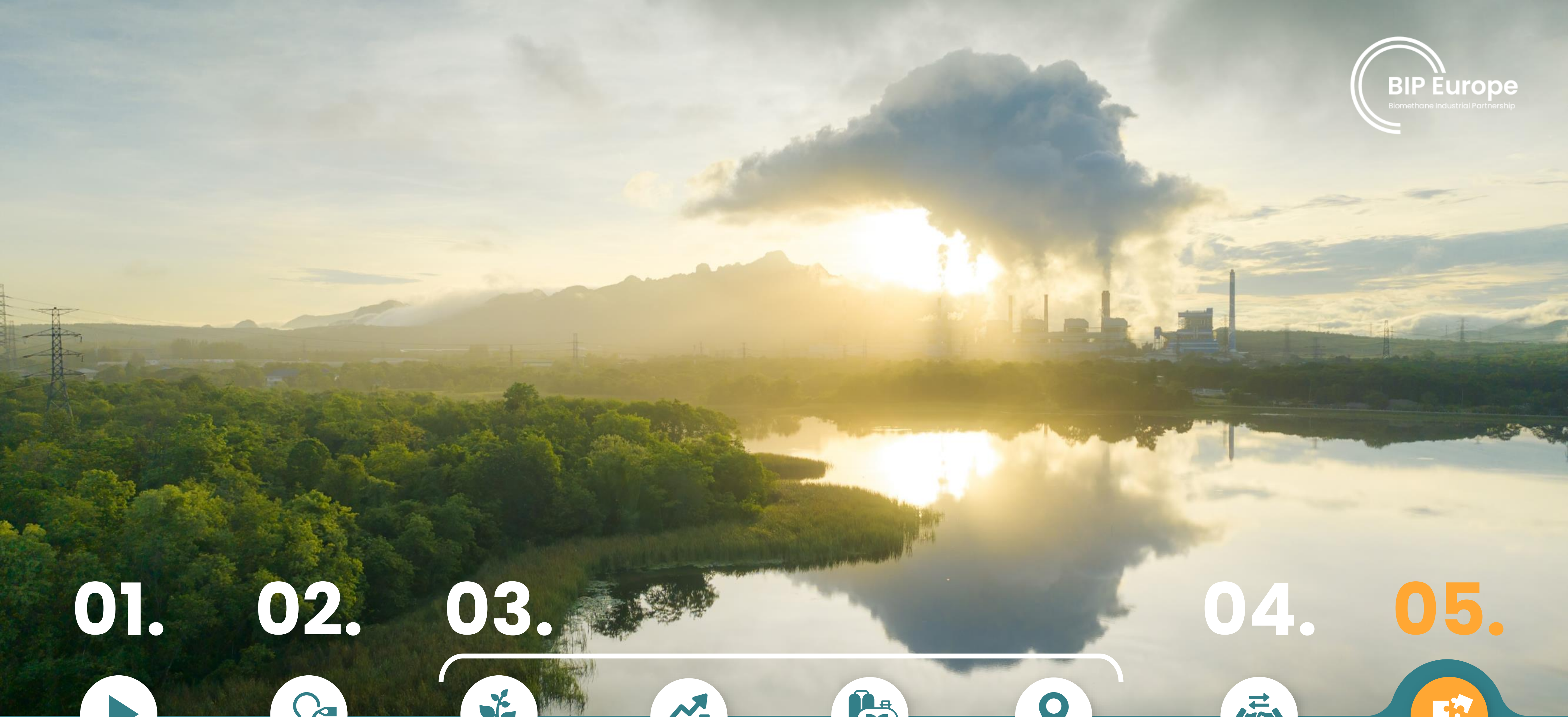
Importance of CDR expected to be conveyed in supporting policy

Important here is the creation of negative emissions using bioCO_2. This is not incentivised with policy currently, and is only supported by voluntary markets. This could change to facilitate the realisation of the EU's share of the ~9 Gt CO_2/year negative emissions required in 2050 to limit warming to 1.5°C outlined by the IPCC.[2]

While doing this, it is important to consider that different quality CDR's exist for different levels of permanence of the CO_2 removal.[3]

Methodologies to treat CDRs are being discussed and defined now at European level, for example in the recent communication of the EC on the Industrial Carbon Management Strategy.[4] There are calls for CDRs to be included in the EU-ETS system, which might e.g. happen in the next review of the ETS in 2026.

[1] European Commission (2022). Proposal for establishing Union certification framework for carbon removals. (Link)
[2] IPCC, (2018) Section C3.2 (Link)
[3] Climeworks. Transparency in the carbon removal market. Accessed on 18/12/2023. (Link)
[4] EC (2024). Towards an ambitious Industrial Carbon Management Strategy for the EU. (Link)



01. Introduction to the BIP

02. Executive Summary

03. Introduction to bioCO_2 | Demand for CO_2 | BioCO_2 from biomethane | End-uses of bioCO_2

04. Role of markets and certification

05. **Conclusions**

Biomethane production provides a source of low-hanging-fruit biogenic CO_2

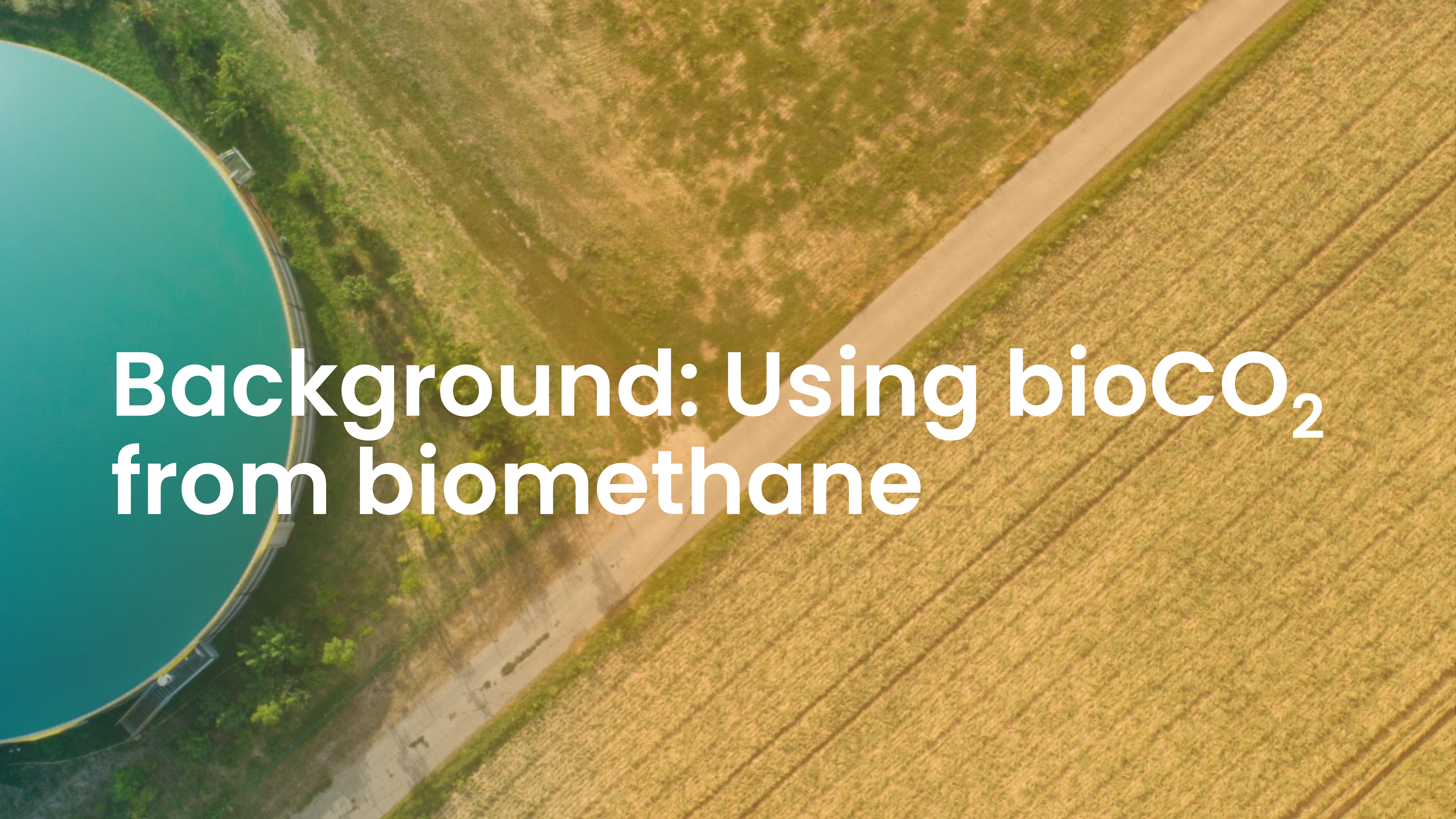
Conclusions

- The demand for zero-emission synthetic fuels and the need for negative emissions will be the main drivers of demand for bioCO_2.
- The **demand for CO_2** in the EU is currently 41 Mt CO_2/yr. This is **expected to rise to between 320 and 2,000 MtCO_2/yr by 2050**. This large growth will also come with a switch in the source of CO_2 from fossil fuel to renewable sources, biogenic CO_2 and Direct Air Capture CO_2.
- **Upgrading biogas to biomethane already involves the separation of bioCO_2 from biomethane in concentrated streams. BioCO_2 capture here is a low-hanging-fruit option.**
- If all biogas were upgraded to biomethane and then all the bioCO_2 from this biomethane were captured today, that would already capture ~27 MtCO_2/yr.
- With a potential large growth in biomethane production towards 2050 the theoretical potential for bioCO_2 supply in 2050 from biomethane can reach ~124 Mt CO_2/yr, supplying 6-38% of the expected CO_2 demand in 2050.
- Regardless of the end use of the biogenic CO_2, from **enabling the hydrogen economy** through **e-fuel production** to facilitating the creation of **high-quality carbon dioxide removals**, biogenic CO_2 is certain to have a growing role in the future energy system.

Effective logistics and supporting policy & certification are crucial for realising this potential

Conclusions

- Given the high expected demand for biogenic CO_2 in the EU it is **important to create a consensus on what biogenic emissions should be targeted for capture**. Biomethane production already having a CO_2 separation step is one of the low-hanging-fruit opportunities for biogenic CO_2 capture. This **role of biomethane beyond just an energy carrier should be communicated**.
- **CCS with biogenic CO_2 is one of the few technological solutions to deliver valuable Carbon Dioxide Removals(CDRs)** which are required for the Paris Agreement to be met. Clarity is needed on the volume of CDR that will be required on national and international level to mitigate the worst impacts of climate change.
- While the capture of biogenic CO_2 from biomethane production is currently starting to be deployed, efforts are still in their early stages. Further research and innovation will be needed to maximise the potential of bioCO_2 from biomethane production.
- Biomethane production is dispersed across the EU today, typically in rural environments. **The organisation of efficient supply chains for the collection and distribution of this biogenic CO_2 is crucial to tapping into the large potential** of this easily accessed biogenic CO_2 resource. Priority needs to be taken to ensure local demands are met with local supply where possible.
- **Certification will be crucial to enabling large-scale use of biogenic CO_2 from biomethane production in the EU.** Today there are several methods of valorising this bioCO_2 as a biomethane producer, however, further work on a biogenic CO_2 guarantee of origins and assigning a higher value to CDR will likely stimulate the capture of bioCO_2 from many biomethane facilities. ERGaR, having actively engaged in the foundational workshop that informed this document, is now actively advancing certification efforts.



Background: Using bioCO_2 from biomethane

Carbon Capture and Utilisation: Existing uses

TRL[2]

Already existing demand

BIP Europe
Biomethane Industrial Partnership

BioCO$_2$ use cases

End use explained

Todays uses for CO_2 in the EU are [1]:

Food & beverages – 16 Mt

Urea – 7 Mt

Enhanced oil recovery (EOR)– 2 Mt

Other (e.g. horticulture) – 11 Mt

Fabrication of metals – 5 Mt

Currently, these demands are met using fossil CO_2, but this is expected to shift in the future. Urea production and Enhanced Oil Recovery (EOR) are closely associated with fossil fuels. However, the demand for CO2 in EOR is anticipated to decrease by 2050, in line with the reduction of oil extraction within the EU. Urea production is closely linked to ammonia production from natural gas today, but this will have to change to achieve emission reduction. Biomethane production can play a role in two ways:

- A separate benefit of biogas and biomethane is the production of digestate which can be used as a bio-fertilizer and thus can displace the demand for urea and other fossil fertilizers. Future BIP TF4.1 work will focus on this topic.
- Alternatively, bioCO_2 can be used with green ammonia to make a sustainable urea product.

Bottlenecks to scaling up

Existing end uses are already at scale. The shift from centralized fossil fuel-based CO2 sources to more dispersed renewable CO_2 sources could introduce supply chain challenges. Additionally, some applications of bioCO_2 from biomethane, like in the food & beverage industry, may come with more challenges due to impurities and the nature of some feedstocks for biomethane production. Advancements in upgrading and quality control are being explored, with promising research underway in France. Given the significant market size, the potential for bioCO_2 in these areas is relevant to remain under consideration at this stage.

Non bioCO_2 alternatives

The non-biogenic CO_2 alternative for these end uses in the future is DAC, as fossil CO_2 is phased out.

The market today & developments

These markets are developed. Steady growth towards 2050 is most likely for most of these existing demands.

[1] ERM Group (2022). Assessment of European biogenic CO_2 balance for SAF production. (Link)
[2] TRL = Technology Readiness Level, on a scale of 1 to 9

Carbon Capture and Utilisation: onsite methanation

***TRL*[2]**

TRL (*in-situ*): 3-5
TRL (*ex-situ*): up to 9

BIP Europe
Biomethane Industrial Partnership

End use explained

Onsite methanation can also be termed "*hydrogen assisted biogas upgrading*". This is done from the methanation of the bioCO_2 with hydrogen either *chemically* or *biologically*. Most chemical routes require a new methanation reactor, and are thus *ex-situ*, while the biological production route can be done from hydrogen injection in to the digester itself, and is *in-situ*.

Hydrogen is crucial to this process, and can either be produced onsite or transported to the biomethane plant by pipeline or truck.

Onsite methanation and injection of the additional methane into the gas grid, is an alternative to liquefaction and transport of bioCO_2.

Non bioCO_2 alternatives

There are no alternatives to the use of bioCO_2 here as this uses bioCO_2 within the existing process and does not use it as its own product.

If onsite use of the bioCO_2 is not possible transport offsite or venting are the alternatives.

Bottlenecks to scaling up

This suite of technologies is still in the demonstration stage. Reaching a higher TRL will allow for production to scale up.

Having hydrogen as an input to the process creates some challenges, as transporting hydrogen to typically remote biomethane production sites necessitates either onsite production or the development of hydrogen supply chains. These options could impose additional costs on biomethane producers and might require plant redesigns for enhanced electrical connectivity or connection to a hydrogen backbone.

For e-methane to attain RFNBO status green hydrogen must be used, which currently comes at high prices.

The market today & developments

The increased methane produced will likely be classified as a RFNBO, if produced with green hydrogen. As such this product will be suitable for RFNBO sub-targets of recent EU targets for transport fuels both on road and at sea.[1]

This valorisation of bioCO_2 in this manner is so that bioCO_2 never becomes a product itself but instead is an internally produced input to allow increased methane output of the plant and RFNBO production.

[1] EU commission 2021 (see Link, Link respectively).
[2] Biomethaverse project database (Link)

Carbon Capture and Utilisation: e-Fuels

TRL[1]

E-Methanol: TRL 8-9
E-Methane: TRL 8-9
E-Kerosene: TRL 4-6

BIP Europe
Biomethane Industrial Partnership

BioCO$_2$ use cases

End use explained

E-fuels are fuels produced from renewable electricity and CO_2. Renewable electricity is not only used in the process, but is also important to produce the green hydrogen input required if the created e-fuel is to be classified as a RFNBO.

Typical examples of e-fuels are e-methanol, e-methane, e-kerosene, and Fischer-Tropsch fuels. These fuels require different volumes of hydrogen and CO_2 to create, e.g. 1.5 t CO_2/t e-methanol or up to 4.5 t CO_2/t e-kerosene. The creation of these fuels can help reduce emissions in many different end uses, with the added benefit of commonly being a drop-in fuel, and suitable for use in existing infrastructure.

Non bioCO$_2$ alternatives

Up until 2041 fossil CO_2 captured from hard-to-abate industry can be used.[2] In this period, this CO_2 can be an alternative for e-fuel production under the RFNBO heading, as long as certain emissions reductions from its use are guaranteed. After 2041 the alternative is only atmospheric CO_2, for the product to remain a RFNBO.

Bottlenecks to scaling up

The demand for e-fuels is relatively new, with the fossil equivalents still mass produced and coming at a lower cost. As new products the production process is often still not applied at large scale to be competitive.

Another important factor here is the need for green hydrogen. Green hydrogen is proving to be more expensive than previously estimated, and as a key input to production, so will e-fuels. The availability of this green hydrogen in the short term is also an issue.

Biogenic or atmospheric CO_2 is also crucial to the sustainable production of e-fuels, with fossil sources of CO_2 not allowed in production past 2041. The availability of this renewable CO_2 is currently not sufficient to facilitate the large demand that is expected in 2041, thus, work needs to be done to scale up production here.

Additionally, despite some targets for RFNBO use in the EU, this is not enough to stimulate large scale e-fuel production, with demand today to a large extent driven by industries voluntary climate goals.

The market today & developments

Market developments are currently mainly driven by major entities pursuing voluntary climate targets.

Regulatory mandates are being introduced for transport fuels. While aviation will exibit a robust demand for CO_2, the maritime sector is still in search for the foremost alternative fuels. Ammonia, bioLNG and E-LNG are some of the options emerging.

[1] Breuer et al., (2022) (Link)
[2] European Commission (2023) Delegated act on hydrogen (Link)
[3] European Commission (2021) (Link, Link, Link respectively).

Carbon Capture and Utilisation with Storage: Long term uses

TRL

Injecting CO_2 into concrete mix: TRL 8 – 9

CO_2 uptake in concrete curing chambers: TRL 8

CO_2 carbonation for mineral waste recycling e.g. into demolished concrete: TRL 8

End use explained

Biogenic CO_2 captured from biogas upgrading is used in products where the CO_2 will be stored for an appreciable amount of time. A good example of the products it is stored in are typically related to the manufacturing of building materials, like cement, concrete and aggregates for building purposes. It is expected that the CO_2 will remain sequestered for at least the lifetime of the constructed structures, and depending on the demolition or reuse methods employed, potentially much longer.

CO_2 is bound permanently into the building material through a chemical carbonation reaction. Adding CO_2 can reduce use of cement, decreasing the manufacturing process carbon footprint + permanently bind added CO_2 to product, thus reducing emissions with two mechanisms.

Non bioCO2 alternatives

Technically, any CO_2 can be used – the value of biogenic CO_2 comes from possible regulation or voluntary markets of CCS – And the fact that the capture cost may be lower than e.g. from flue gases.

Bottlenecks to scaling up

Despite the use of CO_2 in CCU+S already being a commercial process CO_2 use for building materials is still an emerging technology. As an emerging technology it is a large investment to make into CO_2 capture without security on the offtake side. The offtake of CO_2 for CCU+S is also slow to develop, with value chains very immature currently.

Another notable point is that CCU+S applications in building materials does not necessarily require high purity CO_2, however, current CO_2 storage and transport technologies are built to work with very high purity CO_2. This means that even if CO_2 producers can save money by not having to purify the CO_2 for the end user, storage and transport may be tough without some purification steps.

CCU+S applications also rely on carbon markets for their value, thus current erratic carbon markets do not assist the creation of a stable CCU+S market

The market today & developments

Using CO_2 in building materials is voluntary but if mandatory emission limits will be introduced for construction industry - this would likely support CCU+S in manufacturing of building materials. Especially concrete and cement which have a very high carbon footprint.

$BioCO_2$ use cases

Carbon Capture and Storage

TRL

Geological Storage: TRL level 7 - 9.
Mineralisation: TRL 7 - 9.

End use explained

CCS can be done into many ways, but two with promise are *geological storage* and *mineralisation*.

Geological storage involves CO_2 storage in sedimentary basins, especially those already utilised during oil and gas exploration. The CO_2 remains underground for thousands of years as a result of structural trapping, dissolution into underground liquids and its density.

Mineralisation refers to the carbonisation of rocks. This is done by industrialising the natural reaction between CO_2 and mafic rocks to produce carbonate mineral phases that are stable and solid over millions of years.

Bottlenecks to scaling up

For geological storage, the total available capacity is not an issue in the EU, with large storage capacities in specific locations, e.g. the North Sea. The bottleneck is however that these basins are not evenly distributed across the EU, and as such there may be difficulty creating a supply chain to transport the gas to the relative ports. Gas composition requirements for CCS could also be a bottleneck in the short term.

Mineralisation is a more nascent CCS solution currently, with large projects only found in Iceland. Although there are locations in more varied locations across the EU, they are smaller and unproven.

Non bioCO_2 alternatives

Stored CO_2 does not have to be biogenic in nature and can be from any source, biogenic, fossil or atmospheric. If the goal is CDR then the only competitor is atmospheric CO_2.

The market today & developments

CCS can currently be used by companies within the EU ETS to reduce their emissions.

The use of CCS for negative emissions however is not captured in the current EU ETS scheme, and is not supported by any other EU policy. All negative emissions done today are done on a voluntary basis, which may remain the main market for the long term.[1]

It is expected that the EU will come with their industrial carbon management strategy by the end of 2023 which is expected to give clarity on the role of CCS in EU climate policy.[2] Additionally there is pressure for the inclusion of CDR into the EU ETS scheme.

This will be important as more mechanisms supporting CCS are needed to reach the goal of 50 Mt/yr injection capacity for CCS in 2050.[3]

[1] Boston Consulting Group (2023). Climate Needs and Market Demand Drive Future for Durable CDR. (Link)
[2] Concito (2022). The potential and risks of carbon dioxide removal based on carbon capture and storage in the EU. (Link)
[3] European Commission (2023), Net Zero Industry Act. (Link)