Identification of suitable carbon as feedstock for PtX products to be exported to Europe

Perspectives from EU regulation and beyond

This document serves to support in the identification of suitable carbon sources as feedstock for PtX products, facilitating compliance with EU regulations, particularly regarding GHG emission thresholds.

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Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

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IMPRINT

As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

Published by:
Deutsche Gesellschaft fur
Internationale Zusammenarbeit (GIZ) GmbH

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The International PtX Hub is implemented by the Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Affairs and Climate Action (BMWK). Financed by the International Climate Initiative (Internationale Klimaschutzinitiative, IKI), the International PtX Hub is a contribution to the German National Hydrogen Strategy of 2020 and represents one of the four pillars of the BMUV's PtX action programme initiated in 2019.

Berlin, 26th July 2024

CONTENT

Within this text, direct and indirect references are made to already existing publications of the PtX Hub. Below, find a list of publications that support understanding the legal and technical background of this text. Especially the first publication mentioned are summarises varies concepts and rules that are relevant for this text.

- EU Requirements for Renewable Hydrogen and its Derivatives:
  https://ptx-hub.org/publication/policy-brief-on-eu-requirements-for-renewable-hydrogen-and-its-derivatives/
- Certification for Green Hydrogen and Power-to-X
  https://ptx-hub.org/publication/briefing-on-certification-for-green-hydrogen-and-power-to-x/
- Industry targets in European legislation for hydrogen and PtX products
  Industry targets in European legislation for hydrogen and PtX products - PtX Hub (ptx-hub.org)
- Carbon for Power-to-X
  Carbon for Power-to-X: suitable CO2 sources and integration in PtX value chains - PtX Hub (ptx-hub.org)
- Development of a Sustainable Carbon Carrier for PtX Use in Namibia
  https://ptx-hub.org/publication/study-bush-biomass-as-sustainable-carbon-carrier-for-ptx-from-namibia-to-a-global-market/
- Carbon Sources in the Context of Power-to-X
  https://ptx-hub.org/publication/sustainability-briefing-1-carbon-sources-in-the-context-of-ptx/
- Carbon Capture in South Africa
  An overview on Carbon Capture and Storage or Utilisation in South Africa - PtX Hub (ptx-hub.org)
- Analysis of CO2 Availability for the Production of Green Hydrogen Derivatives in Uruguay (Spanish only)
  https://ptx-hub.org/publication/analysis-of-co2-availability-ptx-in-uruguay/

Within this text, references are made to specific legal texts and other relevant sources. Below, find the respective links to those resources:

- **Short Name: RED II**
  Official Name: Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources
  URL: **Richtlinie - 2018/2001 - EN - EUR-Lex (europa.eu)**
- **Short Name: RED III**
  Official Name: Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652
  URL: **Directive - EU - 2023/2413 - EN - Renewable Energy Directive - EUR-Lex (europa.eu)**
- **Short Name: CDR 2023/1184, also known as delegated act (DA) pursuant to Art 27(3) RED II**
  Official Name: Commission Delegated Regulation (EU) 2023/1184 of 10 February 2023 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by establishing a Union methodology setting out detailed rules for the production of renewable liquid and gaseous transport fuels of non-biological origin.
  URL: **https://eur-lex.europa.eu/eli/reg_del/2023/1184/oj**
- **Short Name: CDR 2023/1185, also known as delegated act (DA) pursuant to Art 25(2) and 28(5) RED II**
  Official Name: Commission Delegated Regulation (EU) 2023/1185 of 10 February 2023 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by establishing a minimum threshold for greenhouse gas emissions savings of recycled carbon fuels and by specifying a methodology for assessing greenhouse gas emissions savings from renewable liquid and gaseous transport fuels of non-biological origin and from recycled carbon fuels.
  URL: **https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023R1185**
- Official Name: Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a system for greenhouse gas emission allowance trading within the Union and amending Council Directive 96/61/EC
  URL: **EUR-Lex - 02003L0087-20240301 - EN - EUR-Lex (europa.eu)**
- **Q&A implementation of hydrogen delegated acts - Version of 14/03/2024**
  URL: **Q&A implementation of hydrogen delegated acts (europa.eu)**
- **List of voluntary schemes**
  URL: **Voluntary schemes (europa.eu)**
- **Sustainability principles of voluntary schemes (examples)**
  ISCC: **ISCC Principles – ISCC System (iscc-system.org)**
  RSB: **Framework – RSB**
  REDcert: **Information for the biofuels sector (redcert.org)**

1 Introduction

In persuing industrial sustainability and reduced dependence on fossil resources, attention has increasingly turned towards alternative and innovative technologies. Among these, Power-to-X (PtX) technologies have emerged as pivotal solutions, particularly in sectors characterised as hard to electrify or hard-to-abate. PtX technologies provide a means to synthesise traditionally fossil feedstock-dependent commodities, such as fuels and chemicals, using renewable electricity and carbon. These climate-neutral e-fuels and chemicals hold promise for defossilise – or better defossilise – high-emission industries, spanning chemicals, fertilizers, steel, cement, aviation, and maritime transport. Synthetically produced hydrocarbons (syngas) notably contribute to global defossilisation initiatives. Electrification is the primary driver of defossilisation. Some processes can also utilise pure hydrogen or ammonia, which is a carbon-free platform chemical. However, since most PtX end products are derived from hydrocarbons, this publication will focus on them.

While much focus has been directed toward developing a green or renewable hydrogen molecule and its value chain, an equally significant yet often overlooked challenge lies in identifying suitable carbon sources. Carbon emerges as a critical resource in PtX-driven fossil-free transitions. However, the focus shifts from mere carbon availability to the identification of sustainable carbon feedstocks. This quest for suitable carbon feedstock is foundational for synthesising e-fuels and PtX products, particularly in sectors such as aviation, shipping, and the chemical industry, where green hydrogen alone falls short of this objective. This shift towards sustainable carbon sourcing underscores the concept of defossilisation, emphasising the need for sustainable carbon alongside decarbonisation efforts.

The current spectrum of carbon sourcing methods includes Direct Air Capture (DAC), biogenic sources, and Carbon Capture and Utilisation (CCU), each presenting distinct advantages and challenges. This diversity underscores the necessity for a robust regulatory framework, ensuring the sustainable production of both hydrogen and carbon. Moreover, tailored assessments, specific to individual country contexts, are essential for navigating the practical complexities of PtX implementation.

As traditional production routes, predominantly reliant on syngas, transition towards sustainable hydrogen and carbon sources, the landscape of industrial transformation undergoes significant evolution. This introductory chapter sets the stage for a comprehensive exploration into the identification of suitable carbon feedstock, vital for facilitating the export of PtX products to Europe.

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2 Carbon feedstock for PtX production

In PtX production, the selection of carbon feedstock is an important determinant of sustainability and efficiency. This chapter delves into two primary forms of carbon feedstock: Carbon dioxide (CO_2) and solid carbon. Each form presents distinct acquisition technologies and utilisation potentials, offering diverse production pathways for carbon-neutral PtX processes.

2.1 CO_2 as feedstock

CO_2 plays a crucial role as a feedstock in PtX synthesis, serving as a key component for carbon recycling and emission reduction efforts. Widely recognised as the primary feedstock in PtX processes, CO_2 is preferred due to its abundant availability. PtX processes utilising CO_2 encompass various production routes, including reverse-water-gas-shift or (co-)electrolysis, and then on to methanol synthesis, Fischer-Tropsch synthesis, or carbonylation processes, among others. However, despite its prevalence and importance, CO_2 poses logistical challenges due to its gaseous state, necessitating the development of complex transportation infrastructure, such as pipelines, to facilitate its efficient utilisation in PtX synthesis. Despite these challenges, the utilisation of CO_2 as a feedstock holds significant promise for advancing carbon-neutral PtX production methodologies and contributing to sustainable energy and chemical industries. There are different ways to source for CO_2, which will be explained in the following section.

Industrial Point Sources from the energy and industry sectors play a significant role in contributing to CO_2 emissions, thereby presenting opportunities for carbon capture and utilisation initiatives. It needs to be differentiated between two processes where those emissions occur.

1. The energy sector emits 43% of global CO_2 emissions, mainly from the combustion of fossil fuels for heat and electricity generation.
2. The industry sector is highly energy intensive, but besides energy emissions, industrial processes also produce CO_2 as a byproduct in some chemical reactions. These process emissions account for 4% of global CO_2 emissions and are originated in the production of cement, iron and steel, chemicals and petrochemicals, pulp and paper, and aluminium, among others (see publication: Carbon for Power-to-X)

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While these point sources offer ample CO_2 availability, their sustainability and long-term viability are contingent upon environmental and regulatory considerations. Additionally, various capture technologies, including post-combustion, pre-combustion, and oxyfuel combustion approaches, are employed to capture CO_2 from industrial processes, each presenting unique advantages and challenges in implementation and effectiveness.

Direct Air Capture (DAC) presents a promising avenue for sourcing CO_2 directly from the atmosphere, thereby contributing to carbon reduction efforts and enhancing PtX feedstock availability. However, despite its potential, DAC today is characterised by its energy-intensive nature and high associated costs, which pose challenges to its widespread adoption. However, as the learning curve progresses, DAC will become cheaper in the future and there is potential for this technology to become mainstream in the long term.

Biogenic Carbon sourced from biomass (gaseous, liquid, or solid) processing or combustion, emerges as an alternative feedstock option for PtX production, offering unique benefits and challenges. To ensure sustainability, only residues should be taken into consideration. Utilising biogenic carbon entails addressing sustainability challenges by adhering to sustainable biomass harvesting practices to maintain environmental integrity and optimise resource efficiency (e.g., by using residues). In addition, it must be ensured that deforestation and competition for food crops are counteracted. However, incorporating biogenic carbon into PtX processes poses logistical complexities, including transportation and infrastructure challenges. Innovative solutions are needed to overcome these obstacles and ensure the cost-effectiveness and environmental soundness of PtX processes utilising biogenic carbon.

2.2 Special case of biogenic carbon: Solid carbon carrier as a feedstock

Solid carbon in the form of wood residues, shells, straw, and husk in pure form or as (torrefied) pellets serve as a promising alternative feedstock for PtX production, leveraging innovative approaches to harness carbon from biomass sources directly and efficiently. This innovative approach combined with green hydrogen leads to more efficient and cost-effective fuel production and carbon sourcing infrastructure. Maximising biogenic carbon potential involves utilising gasification, pyrolysis, and torrefaction technologies to convert biomass into useful intermediates like syngas, bio-oil, or biochar, thereby optimising carbon utilisation efficiency. However, regional considerations are crucial, as solid carbon pathways rely on regional biomass availability. Careful consideration of bio-residue sources is necessary to mitigate environmental impacts and ensure sustainability.

In conclusion, the selection of carbon feedstock in PtX processes is a multifaceted decision, influenced by technological feasibility, environmental and regulatory considerations and regional biomass availability. Understanding the nuances of CO_2 and solid carbon pathways is essential for advancing sustainable and efficient PtX production methodologies.

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Perspectives of carbon

Each carbon source comes with its own set of pros and cons, emphasising the need from a European (import market) perspective to create a regulatory framework. This framework should facilitate the import of necessary hydrocarbon products ensuring that both hydrogen and carbon are provided sustainably. It is important to note that determining the path forward in sourcing carbon for synthetic fuel production goes beyond European legislation, as the carbon will likely be sourced in the countries where these fuels are produced. This highlights the need to also assess practical possibilities on the ground, considering factors such as available carbon sources, existing infrastructure, the economic viability of each source, and the local/ regional demand landscape.

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3

Export of PtX products to the EU –

Requirements and the role of carbon

In the context of exporting green PtX products to the EU market, certification is essential to ensure that a product can be counted under EU policies and quotas. Key to assessing this possibility is the selection of an appropriate carbon source as a feedstock.

To meet EU requirements and qualify for premium pricing, it is crucial to consider key factors outlined in the EU regulatory framework, particularly outlined in the Renewable Energy Directive II (RED II) and its Hydrogen Delegated Acts (DA). A comprehensive understanding of these requirements is imperative to navigate the complexities of the EU market successfully.

Key requirements include:

a) Renewable electricity sourcing: PtX products must be produced using renewable electricity, ensuring adherence to sustainable sourcing practices.

b) GHG emission accounting: The greenhouse gas (GHG) emissions associated with PtX production must be accurately accounted for and kept below specified thresholds outlined in the RED II framework.

The key requirements are explained in detail here:
EU Requirements for Renewable Hydrogen and its Derivates
https://ptx-hub.org/publication/policy-brief-on-eu-requirements-for-renewable-hydrogen-and-its-derivatives/

Failure to meet these key requirements jeopardises the eligibility of PtX products under EU regulations, potentially resulting in exclusion from EU quotas and premium pricing incentives.

While there is no legal prohibition against importing uncertified products, adherence to EU requirements is paramount for accessing premium markets and maximising profitability.

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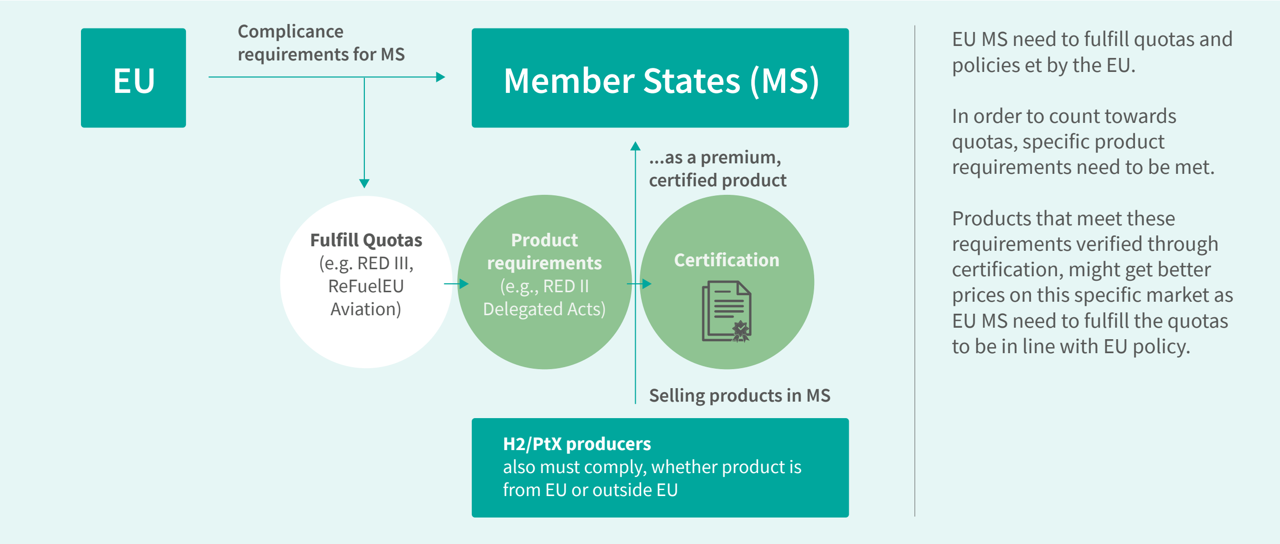

Figure 1: The 'premium' EU market is shaped by the regulatory framework

In the context of PtX production, the choice of carbon sources is not a matter of eligibility but rather revolves around the methodology for calculating GHG emissions. Every carbon source is permissible as long as the PtX product achieves a minimum of 70% GHG emission savings, as stipulated by RED II.

The methodology for GHG emissions calculation is outlined in regulatory documents such as the DA pursuant to Art 25(2) and 28(5) of RED II. The key formula element of interest is "$e_{ex\text{-}use}$", which denotes emissions from inputs' existing use or fate. These emissions can be deducted from the overall GHG emissions of the PtX product if certain conditions are met.

Failure to receive a deduction for "$e_{ex\text{-}use}$" results in the full inclusion of the carbon source's emissions in the GHG accounting, potentially jeopardising the ability to reach the 70% savings threshold. Therefore, it is advisable to select a carbon source that qualifies for deductions under "$e_{ex\text{-}use}$" (for more information on this and other formula elements, see the publication on the EU requirements).

This approach regulates the choice of carbon sources through emissions accounting of the final product. Rather than designating allowed or prohibited carbon sources, the emphasis is on the emission footprint of the final product. Certain carbon sources may receive deductions, influencing the overall GHG accounting.

Extreme potential cases illustrate the importance of considering the entire value chain in GHG accounting:

a) Carbon source without deduction: In this scenario, a carbon source is utilised that does not qualify for deductions under "$e_{ex\text{-}use}$". However, other production processes in the value chain do not have many emissions, resulting in an overall GHG emission savings of at least 70% so that the final product qualifies under the EU requirements (renewable electricity souring + emission threshold) and thus will be eligible to be counted towards the targets and incentives in the Renewable Energy Directive.

b) Carbon source with deduction: Conversely, a carbon source qualifies for deductions under "$e_{ex\text{-}use}$" However, emissions-intensive processes elsewhere in the value chain prevent the overall GHG emission savings from reaching the 70% threshold so the final product does not qualify under the EU requirements (renewable electricity souring + emission threshold) and thus will not be eligible to be counted towards the targets and incentives in the Renewable Energy Directive.

In conclusion, while the choice of carbon source is crucial, GHG accounting must consider the entire value chain. The carbon source can significantly impact whether the PtX product meets the 70% threshold for GHG emission savings. Therefore, careful consideration of carbon sources and their implications is essential in PtX production.

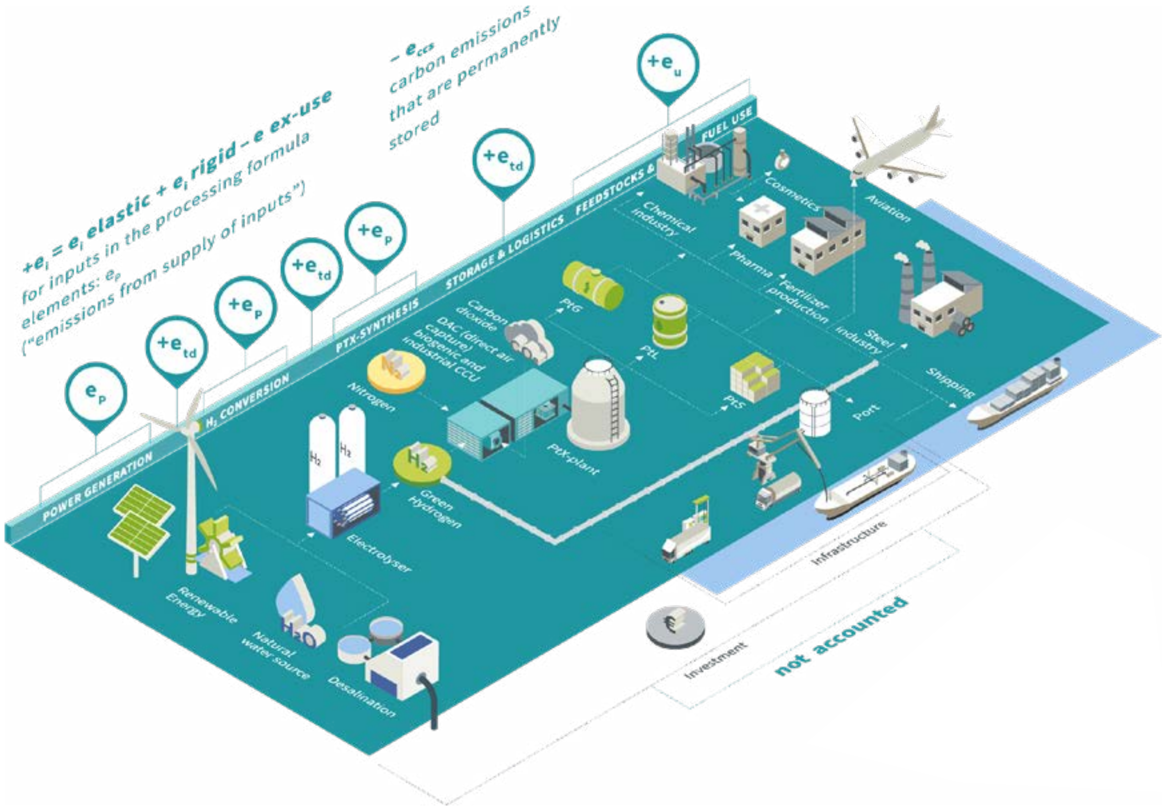

Figure 2: Illustration of the EU GHG methodology for calculating the emissions of renewable hydrogen and RFNBOs

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4 The carbon feedstock identification process

In this chapter, the deduction possibilities for various carbon sources are explored, and key considerations associated with each source are clarified. Drawing from guidelines outlined in EU regulations, a structured examination is provided while also emphasising additional identification processes necessary for comprehensive evaluation.

4.1 The "fossil option"

This option is explained in the respective Delegated Act as follows:

> *"the CO_2 has been captured from an activity listed under Annex I of Directive 2003/87/EC and has been taken into account upstream in an effective carbon pricing system and is incorporated in the chemical composition of the fuel before 2036. This date shall be extended to 2041 in other cases than CO_2 stemming from the combustion of fuels for electricity generation."*

A deduction is only possible, if all three conditions listed below are met:

1. **The CO_2 must stem from an activity** listed under **Directive** 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a system for greenhouse gas emission allowance trading within the Union and amending Council Directive 96/61/EC

In its latest version, Annex I lists the following activities. Note that not only fossil sources are listed here but the relevance of this option mainly adheres to fossil sources.

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Table 1: List of activities in Annex I of Directive 2003/87/EC

Combustion of fuels in installations with a total rated thermal input exceeding 20 MW
Refining of oil, where combustion units with a total rated thermal input exceeding 20 MW are operated
Production of coke
Metal ore (including sulphide ore) roasting or sintering, including pelletisation
Production of iron or steel (primary or secondary fusion) including continuous casting, with a capacity exceeding 2,5 tonnes per hour
Production or processing of ferrous metals (including ferro-alloys) where combustion units with a total rated thermal input exceeding 20 MW are operated. Processing includes, inter alia, rolling mills, re-heaters, annealing furnaces, smitheries, foundries, coating and pickling
Production of primary aluminium or alumina
Production of secondary aluminium where combustion units with a total rated thermal input exceeding 20 MW are operated
Production or processing of non-ferrous metals, including production of alloys, refining, foundry casting, etc., where combustion units with a total rated thermal input (including fuels used as reducing agents) exceeding 20 MW are operated
Production of cement clinker in rotary kilns with a production capacity exceeding 500 tonnes per day or in other furnaces with a production capacity exceeding 50 tonnes per day
Production of lime or calcination of dolomite or magnesite in rotary kilns or in other furnaces with a production capacity exceeding 50 tonnes per day
Manufacture of glass including glass fibre with a melting capacity exceeding 20 tonnes per day
Manufacture of ceramic products by firing, in particular roofing tiles, bricks, refractory bricks, tiles, stoneware or porcelain, with a production capacity exceeding 75 tonnes per day
Manufacture of mineral wool insulation material using glass, rock or slag with a melting capacity exceeding 20 tonnes per day

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Drying or calcination of gypsum or production of plaster boards and other gypsum products, with a production capacity of calcined gypsum or dried secondary gypsum exceeding a total of 20 tonnes per day
Production of pulp from timber or other fibrous materials
Production of paper or cardboard with a production capacity exceeding 20 tonnes per day
Production of carbon black involving the carbonisation of organic substances such as oils, tars, cracker and distillation residues with a production capacity exceeding 50 tonnes per day
Production of nitric acid
Production of adipic acid
Production of glyoxal and glyoxylic acid
Production of ammonia
Production of bulk organic chemicals by cracking, reforming, partial or full oxidation or by similar processes, with a production capacity exceeding 100 tonnes per day
Production of hydrogen (H2) and synthesis gas with a production capacity exceeding 5 tonnes per day
Production of soda ash (Na2CO3) and sodium bicarbonate (NaHCO3)
Capture of greenhouse gases from installations covered by this Directive for the purpose of transport and geological storage in a storage site permitted under Directive 2009/31/EC
Transport of greenhouse gases for geological storage in a storage site permitted under Directive 2009/31/EC, with the exclusion of those emissions covered by another activity under this Directive
Geological storage of greenhouse gases in a storage site permitted under Directive 2009/31/EC

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2. **The CO_2 must have been taken into account upstream in an effective carbon pricing mechanism.** More details of what this entails is explained in the official Q&A of the EU COM on the mentioned Delegated Acts:

> *"Accounting upstream in an effective carbon pricing system means that the emissions are subject to a carbon price when the renewable fuels of non-biological origin (RFNBO) or recycled carbon fuel (RCF) is first produced. For example, when emissions from an industrial process are subject to carbon pricing when captured and used to produce an RFNBO (e.g., e-kerosene). By contrast, downstream accounting means carbon pricing is only applied where the emissions are finally released into the atmosphere from the RFNBO (e.g. when the e-kerosene is used in aviation).*
>
> *As concerns what is an effective carbon pricing system in this context, the system must meet minimum criteria ensuring effective enforcement, so each tonne emitted is paid for:*
>
> 1. *have a robust monitoring, reporting and verification (MRV) process;*
> 2. *be binding on its participants;*
> 3. *be stable;*
> 4. *apply the carbon price at least on the whole sector producing the RFNBOs or RCFs;*
> 5. *ensure stringent enforcement;*
> 6. *be government-led.*
>
> *In addition, the design features of the system need to ensure that the carbon price is effective in achieving its purpose of leading to emission reductions in line with climate neutrality:*
>
> 1. *in the case of an emissions trading system (ETS): with an absolute and ultimately declining cap aligned with the climate neutrality target of the country for achieving the country's Paris-aligned nationally determined (NDC).*
> 2. *in the case of a tax: with an increasing trajectory aligned with the climate neutrality target of the country for achieving the country's Paris-aligned NDC.*
> 3. *for both an ETS and a tax: without design features which render the cap or tax ineffective.*
>
> *The following systems can be considered to fulfil the requirement of upstream accounting in an effective carbon pricing system:*

> 1. *EU ETS which applies in the 30 States of the European Economic Area: the EU-27 Member States and in three EFTA States Iceland, Liechtenstein and Norway*
> 2. *Swiss ETS*
> 3. *UK ETS*
>
> *This list is not exhaustive. Other systems within which RFNBOs and RCFs are expected to be produced may request to be assessed.*
>
> *The criteria applied in this context to assess what is an effective carbon pricing system do not prejudge the recognition of a carbon price paid under the Carbon Border Adjustment Mechanism (CBAM).”*

This condition creates an opportunity for non-EU countries to further assess whether an existing carbon pricing mechanism is in line with these rules or whether developing a carbon pricing system, not only against the background of this regulation but also against the background of the Carbon Border Adjustment Mechanism (CBAM), is a valuable option to more effectively partake in the opportunity of exporting PtX products.

3. **The CO_2 is incorporated in the chemical composition of the fuel before 2036. This date shall be extended to 2041 in other cases than CO_2 stemming from the combustion of fuels for electricity generation.** This condition gives a time limit under which the listed activities can be used in order to receive a deduction.

4.2 The “direct air capture option”

This option is explained in the respective Delegated Act as follows:

> *“the CO_2 has been captured from the air”*

Although rather straightforward, it is important to note that under this option, and under every other option as well, the emissions of the capturing process need to be accounted for. So, if, for example, the direct air capture plant runs on fossil-based electricity, this contributes to the GHG accounting of the final product.

4.3 The “biogenic option”

Here the text of the Delegated Act does not differentiate between biogenic CO_2 that is separated from a process (e.g., from fermentation in ethanol production) and carbon sources where no direct CO_2 capturing process has taken place, for example solid carbon (e.g., from torrefaction processes or for gasification, pyrolysis, etc.). For a full examination, the latter case is added here under 4.3.2.

4.3.1 CO_2 as captured emissions

This option is explained in the respective Delegated Act as follows:

> *"the captured CO_2 stems from the production or the combustion of biofuels, bioliquids or biomass fuels complying with the sustainability and greenhouse gas saving criteria and the CO_2 capture did not receive credits for emission savings from CO_2 capture and replacement, set out in Annex V and VI of Directive (EU) 2018/2001 [RED II]"*

This results in two interlinked conditions:

1. **The fuels from which CO_2 is derived must comply with sustainability and GHG saving criteria.** These criteria are explained in the RED II in Article 29. The criteria include the following main topics: land use change, biodiversity, land with high carbon stocks (e.g., wetlands), sustainable forest biomass, and the GHG accounting of biofuels. In other words, it becomes relevant that the biomass was sustainably sourced and that the fuels derived from the biomass meet respective GHG emission saving criteria. So any biogenic CO_2 that is used must stem from a sustainable source. If the CO_2 source is not sustainable, it cannot receive the deduction.

   This means that although the biofuels used to derive the carbon from were not originally intended for any usage in the European market under the RED II criteria, now for using the carbon, this becomes relevant. Proving that the mentioned criteria are met may eventually necessitate certification of the biofuel process to demonstrate alignment with the RED II criteria. For biofuel certification, many certification schemes are already recognised. They can be found here: **Voluntary schemes (europa.eu)**. Every scheme that is recognised has its own criteria and principles of the certification process that can be found on their respective websites.
2. **The CO_2 capture did not receive emissions credits from CO_2 capture and replacement under the RED II framework.** This mainly addresses one aspect of double accounting, also relevant in chapter 4.6. Here it refers to the RED II definition of CO_2 capture and replacement:
   "Emission savings from CO_2 capture and replacement, e_{ccr}, shall be related directly to the production of biomass fuel they are attributed to, and shall be limited to emissions avoided through the capture of CO_2 of which the carbon originates from biomass and which is used to replace fossil-derived CO_2 in production of commercial products and services."
   It means that the biofuel producer cannot receive an emission credit (in this case under e_{ccr}), while at the same time, the PtX producer receives an emission credit under $e_{ex\text{-}use}$.

4.3.2 Carbon sources with no capturing process

The regulatory framework mentioned above does not explicitly include cases where carbon is not captured in the form of CO_2, for example the utilisation of solid carbon (distinct from CO_2 as the biomass can be gasified to an extent where no CO_2 but only CO is produced). This case is shortly mentioned in the Q&A of the EU COM:

"How is carbon monoxide considered under the methodology?"

Reply: "Carbon monoxide is treated as any other input that has an energy content. It would need to be established whether the carbon monoxide is an elastic or rigid input. The factor e_i is determined by subtracting the factor $e_{ex\text{-}use}$ (the carbon embedded in the fuel) from the factor e_i elastic/e_i rigid. In case the carbon monoxide qualifies as an elastic input, the CO_2 equivalent of the carbon incorporated carbon monoxide is not considered under $e_{ex\text{-}use}$ given that the emissions are not avoided (there is no relevant existing use). The only exceptions are cases where CO is an intermediate product and $e_{ex\text{-}use}$ has already been determined in a previous production step. In this case the previously established values are maintained and only the additional inputs are considered. Further, the origin of the input (RFNBO, RCF or fossil fuel) must be considered when determining the share of RFNBOs and RCF in the output."

Nonetheless, solid carbon in the form of wood, shells, straw, or husks in pure form or as (torrefied) pellets represent a crucial option for carbon sourcing. Essentially, biogenic carbon carriers are directly employed as feedstock for PtX processes aimed at synthesising fuels or chemicals. The distinguishing factor from other sourcing options elucidated in this context lies in the utilisation of carbon within an energetic feedstock, rather than solely as CO_2. This is exemplified in the following process setup from Namibia, where torrefied biomass pellets could be employed:

Maximization of carbon use process

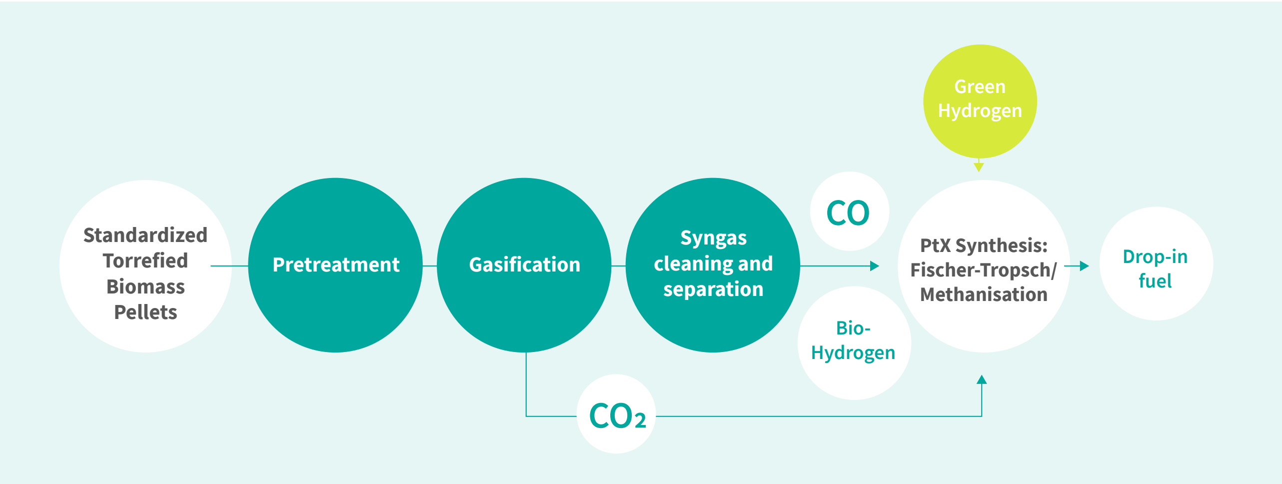

Figure 3: Illustration torrefied biomass pellets set-up

More traditional processes where biogenic end products are produced using only the carbon and energy contained in the biomass feedstock, emit CO_2 (Biomass-to-X). By adding green hydrogen an innovative pathway is created to maximise the carbon utilisation efficiency. This is because green hydrogen is added to the extent where almost all carbon contained in the feedstock is transformed into a product, leaving almost no CO_2 emissions in this production process. At the core of this system, there is gasification and a supplementary green hydrogen feed that drastically alters the traditional Biomass-to-X approach (see publication: **Development of a sustainable carbon carrier for PtX use: from Namibia to a global market**)

From a regulatory perspective, one key aspect to consider in processes where not-captured carbon is used is the topic of energetic allocation. The key criterion for a product to qualify as an RFNBO is that "the energy content of which is derived from renewable sources other than biomass" (RED II). In such set-ups, however, also the energy content of the biomass is used, for example in the form of H_2 or CO. So, the biomass contributes to the final product as a source of carbon but at the same time also contributes with energy content to the final product. In this case, the product is an RFNBO and a biofuel simultaneously, the shares determined by energetic allocation meaning that there are from a regulatory perspective two different shares of end-product – one share that qualifies as RFNBO and one that qualifies as biofuel. The relevant output share of RFNBO would of course still need to match the renewable electricity sourcing criteria and the GHG emission threshold to qualify as RFNBO. Furthermore, it can be questioned whether this regulatory interpretation is in general target oriented as maximising the usage of unutilised biomass is from a climate perspective highly desirable while the production of mixed shares of RFNBO and biofuel simultaneously creates additional obstacles for developers regarding accounting, certification and marketing of the products.

See also this text from the Q&A of the EU COM:

> "Does co-processing of syngas from biomass gasification and hydrogen from renewable electricity result in co-production of biofuel and RFNBO (although the biogenic CO in the syngas contributes to the energy content of all the product)?"
>
> *Reply: "Yes"*

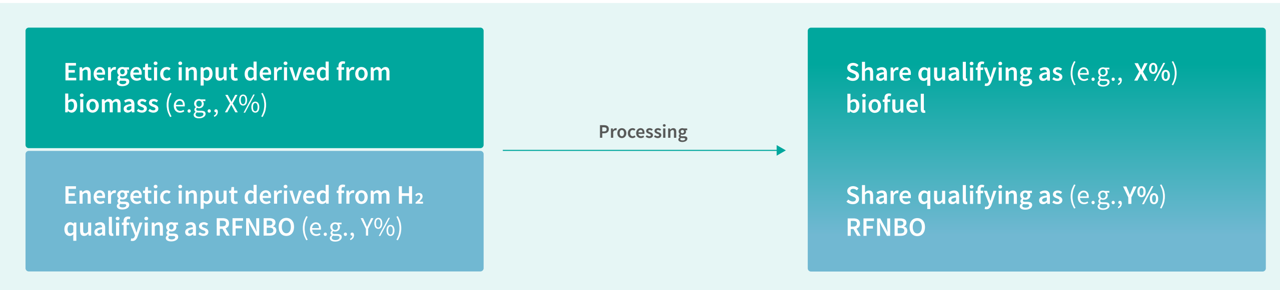

Figure 4: Exemplary illustration of the accounting processes with energetic allocation

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From a GHG accounting perspective, the deduction under $e_{ex\text{-}use}$ is only possible if the carbon does not qualify as an elastic input meaning that its supply cannot be increased to meet extra demand.

Although not specifically mentioned in the regulatory texts, the sustainability criteria for biofuels are likely to be relevant also for the RFNBO share in this example. This is because there is biogenic carbon involved. More general, sustainability criteria for biomass is one key narrative in the relevant EU regulatory texts, for example in RED II Article 29, similar to the case described in 4.3.1. Proving that the mentioned criteria are met can eventually lead to the need to a certification of the biofuel process to demonstrate the alignment with the RED II criteria. The exact implementation and calculation of the described case would need further research, concrete example calculations, and assessments from certification schemes and auditors.

The fact that this sourcing option includes two critical questions (energetic allocation and deduction under $e_{ex\text{-}use}$) demonstrates that here uncertainties for project developers exist. Against the background of existing scenarios where this sourcing option may be applied (e.g., bush biomass in Namibia or wooden residues in Uruguay), clarifications from a regulatory perspective would be beneficial.

4.4 The "RFNBO option"

This option is explained in the respective Delegated Act as follows:

> *"the captured CO_2 stems from the combustion of renewable liquid and gaseous transport fuels of non-biological origin or recycled carbon fuels complying with the greenhouse gas saving criteria, set out in Article 25(2) and Article 28(5) of Directive (EU) 2018/2001 and this Regulation"*

Here the text is essentially self-referencing. The carbon **can also stem from an RFNBO (or RCF) process but in order to qualify for that in the first place, one of the other options should have been used initially.**

4.5 The "geological option"

This option is explained in the respective Delegated Act as follows:

> *"the captured CO_2 stems from a geological source of CO_2 and the CO_2 was previously released naturally"*

Regarding geological sources, it is important to note that **CO_2 capture can be accompanied by other processes** (e.g., heat extraction), however, there must have been a natural release process in the first place. Otherwise it is not eligble CO_2 for the deduction.

4.6 Deliberate CO_2 production and double accounting

There are two aspects that under no circumstance can lead to a deduction of the carbon source in the GHG accounting.

1. **“Captured CO_2 stemming from a fuel that is deliberately combusted for the specific purpose of producing the CO_2” cannot receive a deduction.** Here processes are meant that are specifically designed or initiated to create the carbon source for the PtX process. Usually, combusting a fuel does have purposes other than releasing CO_2 but as it is not further defined what “deliberate” means, it can be assumed that if the main purpose of combusting a fuel does not have any concrete usage or outcome, it may not be possible to receive a deduction for the released CO_2 in that process. The aim of this limitation is clearly to avoid any unviable combustion processes.

2. **CO_2 that has “received an emissions credit under other provisions of the law” can also not receive a deduction.** This corresponds to the issue of double counting meaning that the deduction is not only used in the PtX process but also in any other upstream process, so the benefit would be awarded twice. This in turn means that PtX producers have to have a guarantee that the CO_2 provider did not receive any benefit or credit for capturing the CO_2 in the first place.

OPTION	Option 1: »Fossil option«	Option 2: »Direct Air Capture option«	Option 3: »Biogenic option«	Option 4: »RFNBO option«	Option 5: »Geological option«
THINGS TO CONSIDER	• must stem from an activity listed under this Directive 2003/87/EC Annex I • must have been taken into account upstream in an effective carbon pricing mechanism • only a viable option for receiving the deduction until 2041 (2036)	• no relevant additional criteria other than the accounting of emissions related to electricity and other processes used for the capturing process	• must comply with sustainability and GHG saving criteria (RED II Article 29) • did not receive emissions credits from CO_2 capture and replacement under the RED II framework	• fuel from which the CO2 is derived, must be regonised as RFNBO	• must have been previously released naturally

Relevant for all activities:
- Emissions from capturing, transportation and storage processes must be added in any case
- CO_2 must not stem from a fuel that is deliberately combusted for the specific purpose of producing the CO_2
- CO_2 must not have received an emissions credit under other provisions of the law

Figure 5: Potential CO_2 sources under RED II DA on Art. 28 that can receive a deduction in the GHG calculation

Summary

1. **The “fossil option”**

a. The CO_2 must stem from an activity listed under Annex I of Directive 2003/87/EC.

b. The CO_2 must have been taken into account upstream in an effective carbon pricing mechanism.

c. The CO_2 is incorporated in the chemical composition of the fuel before 2036. This date shall be extended to 2041 in other cases than CO_2 stemming from the combustion of fuels for electricity generation.

Note that even if points a. and b. are fulfilled, this option can only be used until 2041.
For cases where the CO_2 is captured from processes regarding electricity production, even only until 2036.

2. **The “direct air capture option”**

a. The CO_2 is captured from the air.

3. **The “biogenic” option**

<u>CO_2 as captured emissions</u>

a. The fuels from which CO_2 is derived must comply with the biomass sustainability and GHG saving criteria of RED II.

b. The CO_2 capture did not receive emissions credits from CO_2 capture and replacement under the RED II framework.

<u>Carbon sources with no capturing process</u>

c. Although this option is not covered in detail in the legal text, it is likely that sustainability criteria for biomass (RED II Article 29) and GHG saving criteria apply as well which might create the need for certification processes of the biomass itself. Additionally, receiving the deduction is only possible if the supply of the carbon source “cannot be increased to meet extra demand”

4. **The “RFNBO option”**

a. CO_2 can also stem from an RFNBO (or RCF) process but in order to qualify for that in the first place, one of the other options should have been used initially.

5. **The “geological option”**

a. CO_2 stems from a geological source of CO_2 and the CO_2 was previously released naturally.

6. **Overall aspects: deliberate CO_2 production, double-accounting, and emissions of the capturing process**

a. Captured CO_2 stemming from a fuel that is deliberately combusted for the specific purpose of producing the CO_2 cannot receive a deduction.

b. CO_2 that has "received an emissions credit under other provisions of the law" can also not receive a deduction.

c. The emissions of the capturing process need to be accounted in any case. If, for example, the capturing process runs on fossil-based electricity, this contributes to the GHG accounting of the final product.

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5 Exemplary scenarios
(contextualisation)

Yet, what exactly does this entail now? The subsequent sections of this document delineate a selection of representative scenarios to offer a more concrete analysis.

In the foundational scenario, a corporation seeks to undertake PtX production within a particular jurisdiction and subsequently export the final product to the EU market, positioning it as a product that should successfully undergo the EU certification process.

It is assumed that the requirements relating to the Delegated Act on Article 27 (renewable energy sourcing) are met and that it is now solely a matter of the choice of carbon sources which means that it is to some extent a matter of GHG accounting (see chapter 3).

However, it should be noted that not every possible scenario is described but only a few examples are given. How the actual implementation process will constitute itself, depends on the specific context in the respective country and of the project itself.

5.1 Fossil CO_2

You are an entrepreneur with a vision to produce RFNBOs. These fuels are seen as a crucial element in the transition to a sustainable energy future and your business aims to leverage PtX technologies. However, you are operating in a high-emitting country, Country X, which faces significant challenges in meeting its emission reduction targets under international climate agreements.

Country X is heavily reliant on fossil fuels, resulting in substantial CO_2 emissions. However, it also has significant renewable energy potential, particularly in solar and wind power. Recognising the dual challenge of reducing emissions while maintaining energy security and economic growth, you identify a unique win-win potential: using the country's CO_2 emissions as a feedstock for producing RFNBOs via PtX technology. This CCU approach can help mitigate emissions while creating a sustainable fuel source.

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Things you need to consider:

- Check whether you will be reliant on the deduction from "$e_{ex\text{-}use}$" for your carbon source to reach the overall GHG emission threshold for RFNBOs. For this, you need to assess the GHG footprint of your RFNBO according to the rules set up in the Delegated Act on Article 28 of the RED II.
- If not, you can use any carbon source.
- If yes, check whether the carbon stems from a process that is listed under the activities chapter 4.1.
- Also check, whether in your country X there is according to the description in chapter 4.1 an effective carbon pricing mechanism in place and whether the process from which you use the carbon is covered there.
- Be aware that you might get the deduction only until 2041 (for cases where the CO_2 is captured from processes regarding electricity production, even only until 2036). You might want to start looking for alternative commercialisation options after this date.
- Check whether no fuel is deliberately combusted for your CO_2 in the PtX process and make sure that no double-accounting is taking place (chapter 4.6).

5.2 DAC

You are an entrepreneur with a vision to produce RFNBOs. With vast land availability and substantial financial resources at your disposal, you aim to implement DAC technology to remove CO_2 directly from the atmosphere. By combining this captured CO_2 with renewable hydrogen, you can create high-value, sustainable fuels. Your location, blessed with abundant renewable energy resources, offers an ideal setting for this ambitious project.

After extensive research and consultation with experts, you determine that DAC, coupled with PtX technology, is the best option for producing RFNBOs. This approach not only provides a reliable and sustainable source of CO_2 but also contributes significantly to atmospheric CO_2 reduction.

Note that depending on local conditions, the DAC may also render water which would be an additional benefit.

Things you need to consider:

- With the implementation of DAC, you found a suitable CO_2 source that does not require much additional checking of criteria and you can continue focusing on other steps in the certification process.
- Be aware that, like for all other carbon sources and scenarios, the processing emissions of the DAC plant and the transport of the CO_2 to your PtX facility contribute to the overall GHG footprint of your RFNBO. So, if your DAC plant operates with fossil electricity, this will negatively impact the emissions of your captured CO_2 and therefore also of your end-product.

5.3 Biogenic CO_2

You are the CEO of a PtX company that aims to produce Power-to-Liquid (PtL) kerosene, a synthetic fuel intended for the EU market. To achieve this, you plan to utilise CO_2 captured from a bioethanol producer in Country Y, which produces ethanol from sugarcane for the local market. By integrating captured CO_2 from the Country Y bioethanol producer into your PtX process, you can produce PtL kerosene with a significantly reduced carbon footprint. This approach not only leverages a sustainable CO_2 source but also opens a new market opportunity for the bioethanol producer, creating a win-win situation.

Things you need to consider:

- Check whether you will be reliant on the deduction from "$e_{ex\text{-}use}$" for your carbon source to reach the overall GHG emission threshold for RFNBOs. For this, you need to assess the GHG footprint of your RFNBO according to the rules set up in the DA on Article 28 of the RED II.
- If not, you can use any carbon source.
- If yes, check whether your fuel (your ethanol) from which you derive the CO_2 is compatible with the sustainability and GHG criteria of RED II Article 29.
  In order to ensure this, you may want to look into certification processes under the RED II criteria for the ethanol to really ensure to have proven that you complied with these criteria.
  In such a scenario, be aware that a) not a full certification of the ethanol may be necessary as the ethanol itself does not leave your Country Y's market and b) that certification criteria for biomass of the recognised voluntary schemes may go beyond the criteria set in RED II Article 29.
  It is recommended to clarify the specific case with the voluntary schemes directly. Examples of their sustainability criteria can be found in their respective system documents. Here are examples from **ISCC**, **RSB** and **REDcert**.
- Check whether no emission credit for the ethanol producer has been allocated in the past for capturing the CO_2 (no matter whether under Country Y or EU legislation, see 4.6). It may be possible that the ethanol producer can no longer claim this credit as you, the PtX producer, are now claiming a credit in the form of a deduction in the GHG calculation for your RFNBO. This may require additional contractual arrangements for the CO_2.
- Be aware that, like for other biogenic carbon sources where no CO_2 capturing process is in place and energy content from the carbon source in the form of, for example, H2 or CO goes into the final fuel, you potentially produce a mix of RFNBO and a biofuel (see 4.3.2).
- Check whether no fuel is deliberately combusted for your CO_2 in the PtX process and make sure that no double-accounting is taking place (chapter 4.6).

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5.4 Solid carbon (no capturing process)

You are an entrepreneur with a vision to produce PtL fuels in Country Z, a nation with abundant bush biomass resources. However, to realise this goal, you require a suitable carbon source for your PtX process. Recognising the potential of the vast biomass availability in your country, you decide to utilise it by transforming it into carbon-dense torrefied biomass pellets. This will serve as the primary carbon feedstock for your PtX process, enabling the production of sustainable synthetic fuels.

Your approach involves a hybrid Biomass-PtX process, combining biomass gasification with green hydrogen to enhance efficiency and maximise fuel output. The torrefied biomass pellets will undergo gasification, a thermochemical process that converts solid biomass into synthesis gas (syngas), consisting of carbon monoxide and hydrogen. To improve the carbon utilisation efficiency, green hydrogen produced from renewable electricity (e.g., solar PV) will be added to the syngas production process.

Things you need to consider:

- Check whether you will be reliant on the deduction from "$e_{ex\text{-}use}$" for your carbon source to reach the overall GHG emission threshold for RFNBOs. For this, you need to assess the GHG footprint of your RFNBO according to the rules set up in the DA on Article 28 of the RED II.
- If not, you can use any carbon.
- If yes, check whether your biogenic feedstock of the carbon source is compatible with the sustainability and GHG criteria of RED II Article 29. This is not explicitly mentioned in the regulatory text but recommended to ensure that the carbon stems from sustainable biomass.
  In order to ensure this, you may want to look into certification processes for the biomass under the RED II criteria to really ensure that you complied with the sustainability criteria.
  In such a scenario, be aware that a) not a full certification of the biomass may be necessary as the biomass itself does not leave your Country Z's market and b) that certification criteria for biomass of the recognised voluntary schemes may go beyond the criteria set in RED II Article 29.
  It is recommended to clarify the specific case with the voluntary schemes directly. Examples of their sustainability criteria can be found in their respective system documents. Here are examples from ISCC, RSB and REDcert.
- Be aware that, like for all other carbon sources and scenarios, for any production set-up where energy content from the carbon source also goes into the final fuel, you potentially produce a mix of an RFNBO and another fuel (see 4.3.2).
- Check whether no fuel is deliberately combusted for your CO_2 in the PtX process and make sure that no double-accounting is taking place (chapter 4.6).

6 Conclusion

This paper demonstrates the relevance of carbon sources for PtX production processes and provides an overview of different types of carbon sources, primarily from the perspective of EU regulations. The consideration of carbon sources in relation to EU requirements for renewable hydrogen and RFNBOs is often overlooked, despite its significance in meeting greenhouse gas emission thresholds. While the EU Delegated Acts on renewable hydrogen and RFNBOs do not prohibit any carbon sources, certain sources are favoured based on their alignment with the deduction logic outlined in the formula element $e_{ex\text{-}use}$. It is crucial to understand this complexity. It can be best understood by reading it through a lens of EU climate, energy and GHG reduction policy.

This paper outlines the potential sources and assesses the associated requirements. Specifically, attention is drawn to fossil sourcing options, which are limited from 2041 (2036) onwards, and the necessity of accounting for carbon sources under a carbon pricing mechanism, requiring further analysis to determine eligibility for deduction. Additionally, the use of biogenic sources entails adherence to sustainability requirements outlined in the RED II. Notably, the utilisation of carbon that is not directly captured in the form of CO_2, although not explicitly mentioned in regulatory texts, can offer multiple benefits for integrating carbon effectively in PtX processes that may go beyond regulatory compliance. In order to provide more clarity from a project developer perspective, it is advised that carbon sources not in the form of captured CO_2 sources should be explicitly integrated in the described sourcing options.

Apart from regulatory considerations, it is crucial to identify and promote the most effective methods for maximising the use of existing carbon, closing the carbon cycle, and contributing to the defossilisation of the industry. The ongoing work of the PtX Hub focuses on exploring carbon sources from various perspectives, including those of PtX producing countries, market availability, and regulatory and sustainability considerations. These efforts aim to identify truly sustainable carbon sources tailored to individual country contexts. Its relevance to a successful ramp-up of sustainable PtX products shall not be underestimated.

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