Biochar come strumento di sequestro del carbonio

David Chiaramonti

Politecnico di Torino

RE-CORD

Soil Carbon Accumulation and Policies *Biofuels vs Carbon Removals*

Two main streamlines to Carbon accounting

- **REDII – IR** (and **REDIII**): relevant for Sustainable Biofuels. In place.
- **CRCF**: Carbon offsetting, under development by DG Clima initiative. Relevant to voluntary and mandated (revised ETS, 2026) Carbon markets.

Soil Carbon Accumulation and Sustainable Biofuels

SCA (SOC) & Biofuels

REDII (2018)

Implementing Regulation (2022)

Official Journal of the European Union — L 328

English edition — Legislation — Volume 61 — 21 December 2018

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DIRECTIVES

(1) Text with EEA relevance.

EN

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Official Journal of the European Union — L 168

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II

(*Non-legislative acts*)

REGULATIONS

COMMISSION IMPLEMENTING REGULATION (EU) 2022/996 of 14 June 2022 on rules to verify sustainability and greenhouse gas emissions saving criteria and low indirect land- use change-risk criteria

Having regard to the Treaty on the Functioning of the European Union,

Having regard to 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 (1), and in particular Article 30(8) thereof,

Whereas:

(1) Directive (EU) 2018/2001 expands the role of voluntary schemes to include the certification of the compliance of biomass fuels with sustainability and greenhouse gas (GHG) emissions saving criteria and the compliance of renewable liquid and gaseous transport fuels of non-biological origin and recycled carbon fuels with the respective GHG emissions saving criteria. Furthermore, the voluntary schemes can be used to certify biofuels, bioliquids and biomass fuels with low indirect land-use change-risk.

(2) In order to establish whether biofuels, bioliquids, biomass fuels, renewable gaseous and liquid transport fuels of non-biological origin and recycled carbon fuels comply with the requirements of Directive (EU) 2018/2001, the correct and harmonised functioning of voluntary schemes is essential. Harmonised rules should therefore be established, to apply across the certification system, bringing about the necessary legal certainty on the rules applicable to economic operators and voluntary schemes.

(3) With a view to minimising the administrative burden, the implementing rules should be proportionate and limited to what is required to ensure that compliance with the sustainability and GHG emissions saving criteria and other requirements is verified in an adequate and harmonised manner that minimises the risk of fraud to the greatest extent possible. The implementing rules should therefore not be considered as a comprehensive standard but rather as minimum requirements. The voluntary schemes may accordingly complement these rules as appropriate.

(4) Economic operators may decide at any time to participate in a different voluntary scheme. However, in order to prevent an economic operator that has failed an audit under one scheme from immediately applying for certification under another scheme, all schemes receiving an application from an economic operator should require that operator to supply information about whether it failed an audit in the previous 5 years. This should also apply to situations where the economic operator has a new legal personality but remains the same in substance, so that minor or purely formal changes, for instance, in the governance structure or the scope of activities, do not exempt the new economic operator from such a rule.

(1) OJ L 328, 21.12.2018, p. 82.

Carbon and Sust.Fuels: REDII

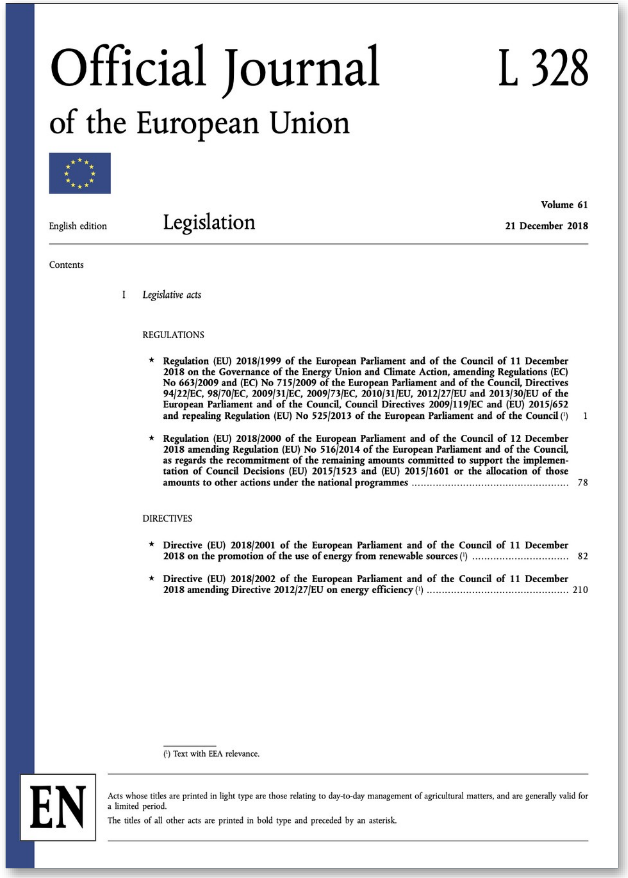
(a) greenhouse gas emissions from the production and use of biofuels shall be calculated as:

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr},$$

where

E	=	total emissions from the use of the fuel;
e_{ec}	=	emissions from the extraction or cultivation of raw materials;
e_l	=	annualised emissions from carbon stock changes caused by land-use change;
e_p	=	emissions from processing;
e_{td}	=	emissions from transport and distribution;
e_u	=	emissions from the fuel in use;
e_{sca}	=	emission savings from soil carbon accumulation via improved agricultural management;
e_{ccs}	=	emission savings from CO_2 capture and geological storage; and
e_{ccr}	=	emission savings from CO_2 capture and replacement.

$$e_{sca} = (CS_A - CS_R) \times 3{,}664 \times 10^6 \times \frac{1}{n} \times \frac{1}{P} - e_f$$


Official Journal of the European Union L 328

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★ **Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council** (1) 1

★ **Regulation (EU) 2018/2000 of the European Parliament and of the Council of 12 December 2018 amending Regulation (EU) No 516/2014 of the European Parliament and of the Council, as regards the recommitment of the remaining amounts committed to support the implementation of Council Decisions (EU) 2015/1523 and (EU) 2015/1601 or the allocation of those amounts to other actions under the national programmes** 78

DIRECTIVES

★ **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** (1) 82

★ **Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency** (1) 210

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EU on Carbon and Sust.Fuels: REDII - IR

Examples of essential soil management practices to promote soil carbon sequestration (given the absence of residues) and promote soil quality

Requirement	Soil quality parameter
At least a 3-crop rotation, including legumes or green manure in the cropping system, taking into account the agronomic crop succession requirements specific to each crops grown and climatic conditions. A multi-species cover crop between cash crops counts as one.	Promoting soil fertility, soil carbon, limiting soil erosion, soil biodiversity and promoting pathogen control
Sowing of cover/catch/intermediary crops using a locally appropriate species mixture with at least one legume. Crop management practices should ensure minimum soil cover to avoid bare soil in periods that are most sensitive.	Promoting soil fertility, soil carbon retention, avoiding soil erosion, soil biodiversity
Prevent soil compaction (frequency and timing of field operations should be planned to avoid traffic on wet soil; tillage operation should be avoided or greatly reduced on wet soils; controlled traffic planning can be used).	Retention of soil structure, avoiding soil erosion, retaining soil biodiversity
No burning of arable stubble except where the authority has granted an exemption for plant health reasons.	Soil carbon retention, resource efficiency
On acidic soils where liming is applied, where soils are degraded and where acidification impacts crop productivity.	Improved soil structure, soil biodiversity, soil carbon
Reduce tillage/no tillage – Erosion control – addition of organic amendments (biochar, compost, manure, crop residues) – use of cover crops, rewetting Revegetation: planting (species change, protection with straw mulch) – landscape features – agroforestry	Increase soil organic carbon

27.6.2022 EN Official Journal of the European Union L 168/1

II

(Non-legislative acts)

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(1) OJ L 328, 21.12.2018, p. 82.

45 / 25 (biochar/other) gCO2e/MJ threshold

Based on measurements of C stock
MODELS allowed only if validated

CRCF:
Biochar in Soil Carbon Accumulation and CDR

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Carbon Removals and Carbon Farming

Permanent carbon removals +

Carbon farming and soil emission reductions +

Carbon storage in long-lasting products +

Carbon Removals and Carbon Farming in a nutshell

Carbon removals

Innovative approaches to capturing CO_2, directly from the atmosphere and from biogenic emission sources, before storing it in reservoirs such as geological formations, forests, soil or products for the long term.

Carbon farming

Climate-friendly practices implemented by farmers and foresters to enhance carbon sequestration and storage in forests and soils, as well as reduce greenhouse gas emissions from soils.

EU Carbon Removals and Carbon Farming Certification (CRCF) Regulation

On 10 April 2024, the European Parliament adopted the provisional agreement on the Carbon Removals and Carbon Farming (CRCF) Regulation, which created the first EU-wide voluntary framework for certifying carbon removals, carbon farming and carbon storage in products across Europe. By establishing EU quality criteria and laying down monitoring and reporting processes, the CRCF Regulation will facilitate investment in innovative carbon removal technologies, as well as sustainable carbon farming solutions, while addressing greenwashing.

Explore the sections below to learn more about the specific activities covered by the CRCF Regulation.

EU Expert Group on carbon removals

The Expert Group on carbon removals advises the Commission on the development of tailored EU certification methodologies. With around 70 members from different backgrounds, including national authorities, businesses, NGOs, and research institutions, it ensures broad representation of stakeholders. The Expert Group meets biannually in person and remotely, following Commission guidelines.

Role of CRCF Regulation in voluntary and regulated carbon markets

Corporate claims and sustainable finance

- **Corporate Sustainability Reporting Directive**
  - Sustainable Reporting Standards on Climate for non-financial reporting
- **Green Claims**
  - Commission proposal from March 2023 in co-decision

Post-2030 EU climate policy

- **EU ETS review in 2026**
  - Commission to assess the inclusion of permanent removals in EU ETS
- **Review of LULUCF and Effort-Sharing Regulation in 2026**

Biochar in CRC

PROCESSES AND END-USES

- From **pyrolysis** or **gasification**
- In **soil** or **materials** (cement, concrete, asphalt..): no distinction in CRCF

PERMANENCE assessment: two methods

- Decay function **> 200 y**
- **Inertinite** assessment or **IPCC**
- Higher permanence as H/Corg reduces. H/Corg < 0.7 (**<0.4** recommended)

PRODUCT CHARACTERISTICS

- Feedstocks: limited to **wastes** and **residues** (proposed). Sustainability requirement as BioCCS
- EBC Guidelines for product specifications
- Standardised baseline 0 t_{CO2e}/yr

Other specifications

- Allocation of emissions between biochar and other co-products
- Processes with low biochar yield to treat it as residue: no emission allocated (gasification)
- CH4 emission from feedstock decomposition depending on adoption of storage practices

Other specifications

- Allocation of emissions between biochar and other co-products
- Processes with low biochar yield to treat it as residue: no emission allocated

Experimental evidence of Carbon permanence

Biochar and Carbon Permanence

Chiaramonti *et al. Biochar* (2024) 6:81
https://doi.org/10.1007/s42773-024-00366-7

Biochar

PERSPECTIVE **Open Access**

Biochar is a long-lived form of carbon removal, making evidence-based CDR projects possible

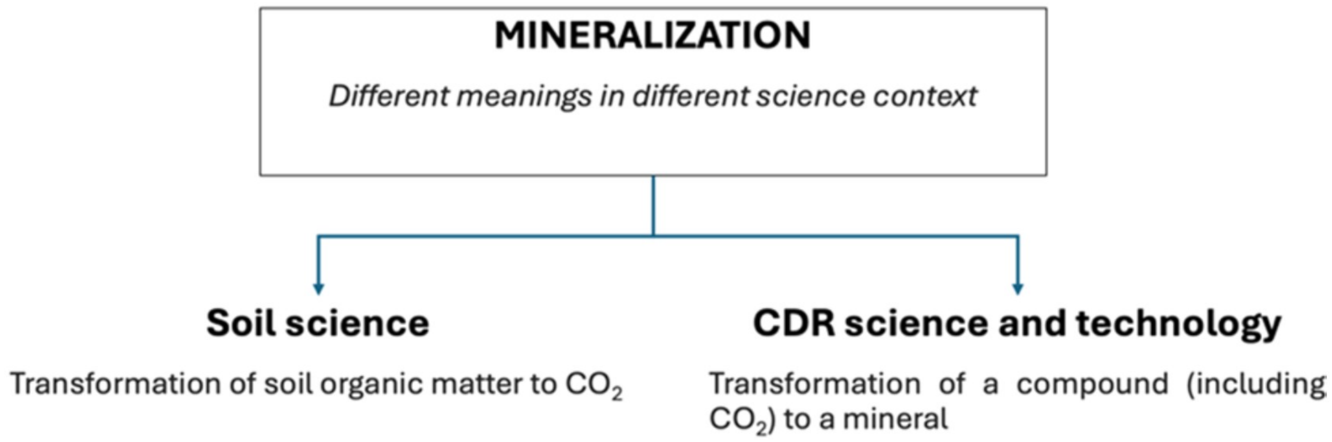
David Chiaramonti[1*], Johannes Lehmann[2], Franco Berruti[3], Paola Giudicianni[4], Hamed Sanei[5] and Ondrej Masek[6]

Abstract
Science should drive policies and regulations to ensure a sustainable (environmentally, socially, and economically) green transition to a Net-Zero / Net-Negative circular economy. Since 2015, which saw COP21 in Paris, Net Zero has been a global target that must be rapidly accompanied by a Net Negative strategy to mitigate climate change. Accordingly, biochar's role as a durable carbon removal method is gaining attention and increasing. In this work, we discuss the durability of the carbon in biochar and the need for analytical techniques to support stakeholders on a project level. The different ecologically relevant groups of carbon forms contained in biochar are presented, and possible project-based methods to assess the quality and durability of the product versus the regulatory requirements for the permanence of carbon removals are summarized. Biochar is today one of the CDR technologies with the highest technology readiness level (TRL 8–9) that can ensure permanent removals for time frames relevant to climate change mitigation projects, combined with co-benefits that are gaining relevance in terms of mitigating climate impacts in agricultural soils.

Abstract Highlights

- Biochar comprises different carbon forms, for which permanence is discussed here.
- Biochar can deliver cost-effective long-term Carbon Dioxide Removal (CDR), which is possible to deploy at large scale.
- Project-level Biochar Carbon Removal (BCR) can be verified by analytical techniques and third-party certification.
- Certified BCR can be accounted towards nation-wide climate targets.
- Site-specific co-benefits can be generated, supporting the shift to more sustainable and climate-resilient agriculture

Keywords Biochar carbon removal, Carbon dioxide removal



Recovery and assessing real-case Carbon Permanence

Biomass and Bioenergy 191 (2024) 107484

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BIOMASS & BIOENERGY

Assessment of long-lived Carbon permanence in agricultural soil: Unearthing 15 years-old biochar from long-term field experiment in vineyard

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A R T I C L E I N F O

Keywords:
Biochar permanence
Biochar long-term field experiments
Carbon dioxide removal
Biochar carbon removal
Sustainable agricultural practices

A B S T R A C T

Carbon persistence in soil is a key issue in the context of Carbon Dioxide Removal (CDR) policies and regulations: Soil Carbon Accumulation (SCA) is also included in the latest EU regulations on sustainable biofuels, and gaining attention at international level within ICAO and IMO. The long-lived nature of the durable carbon share in biochar can meet the most sever criteria set by relevant and ambitious CDR policies: however, the possibility to quantitatively assess the persistent carbon fraction in biochar has been highly debated in recent years. While lab-scale incubation experiments are intrinsically limited in providing information on long-term permanence, they do not address actual farm-scale persistence under real cultivation management practices. The deployment and combined use of recent analytical techniques allows instead to identify and quantitatively assess the persistence of the durable carbon fractions in biochar, and thus compliance of this carbon removal with the targets of CDR policies. The present work builds on one of the longest, almost unique, biochar experiments in the EU, originally developed for assessing the agronomic performances of biochar amended agricultural soil: for the first time, biochar distributed in a vineyard soil at 22 t/ha scale in 2009 was unearthed in 2024 and collected for full characterization. The agricultural soil was subject to conventional agricultural practices over the 15 years of vineyard cultivation. The scope of this research is to assess the permanence of biochar under these conditions. The present work shows the complexity of unearthing biochar from soil, applying a focused method to recover and clean the material before its characterization, without altering its chemical and physical properties. Both unearthed and original (i.e. before deployment) biochars were washed with water under same condition and procedures, and fully characterized. In addition to analytical practices commonly adopted for biochar characterization, FT-IR, SEM EDX, and Random Reflectance (R_o) techniques were used, quantifying the amount of the inertinite carbon component in biochar. Despite the dilution from the inclusion of exogeneous organic and inorganic matter from soil in the original biochar, the ratio of fixed carbon (Cfix) to total carbon (Ctot) showed minor variations (~8 %). Moreover, the inertinite and semi-inertinite fractions in the washed original and unearthed biochars remained almost unchanged over 15 years of active use in agricultural soil, confirming the permanent nature of the inertinite share of carbon in biochar. This result, together with other recent findings in literature, provides scientific evidence supporting Biochar Carbon Removals (BCRs) as permanent removal in Carbon Dioxide Removal (CDR) regulations.

Evaluating the Two-Pool Decay Model for Biochar Carbon Permanence

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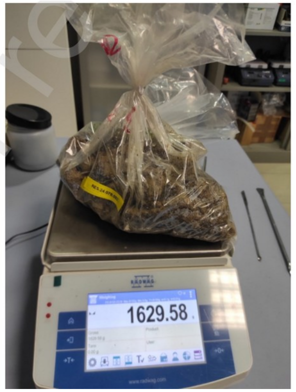
Accepted for publication on Biochar J. Proof under preparation

Recovery and assessing real-case Carbon Permanence

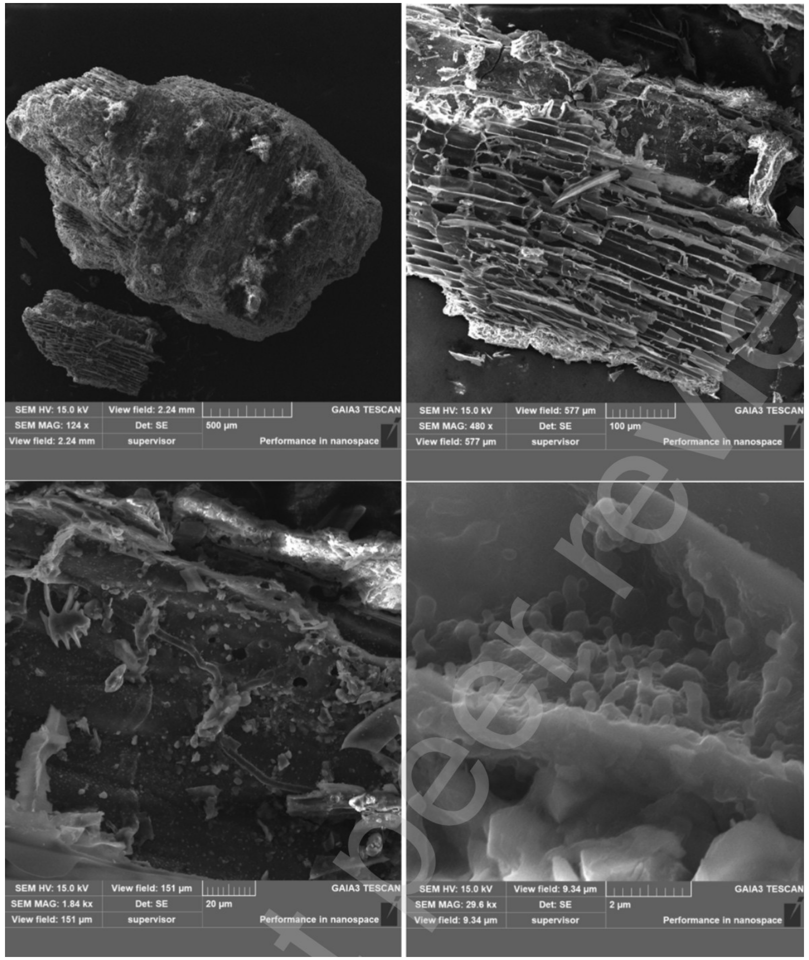
Crushed < 5 mm before deployment

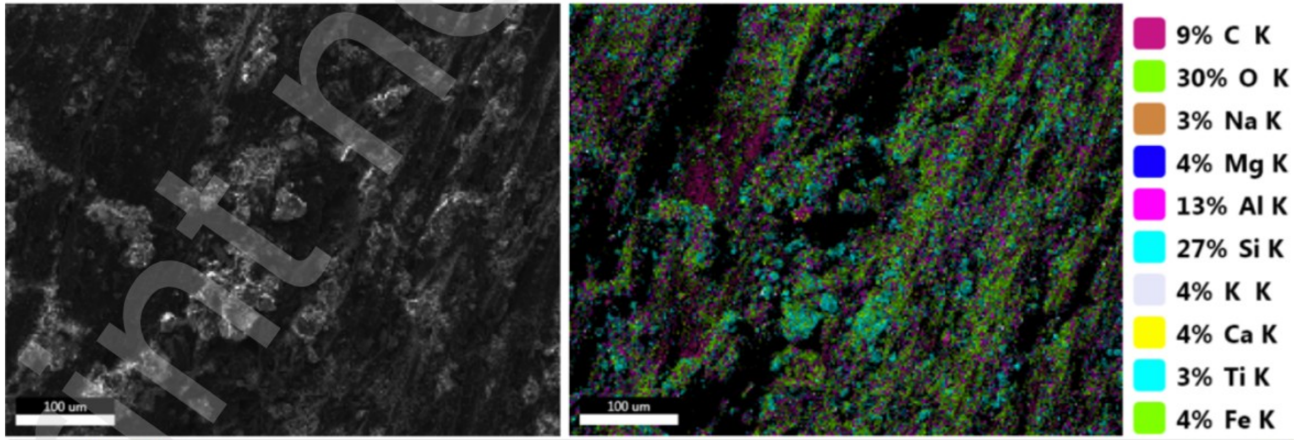


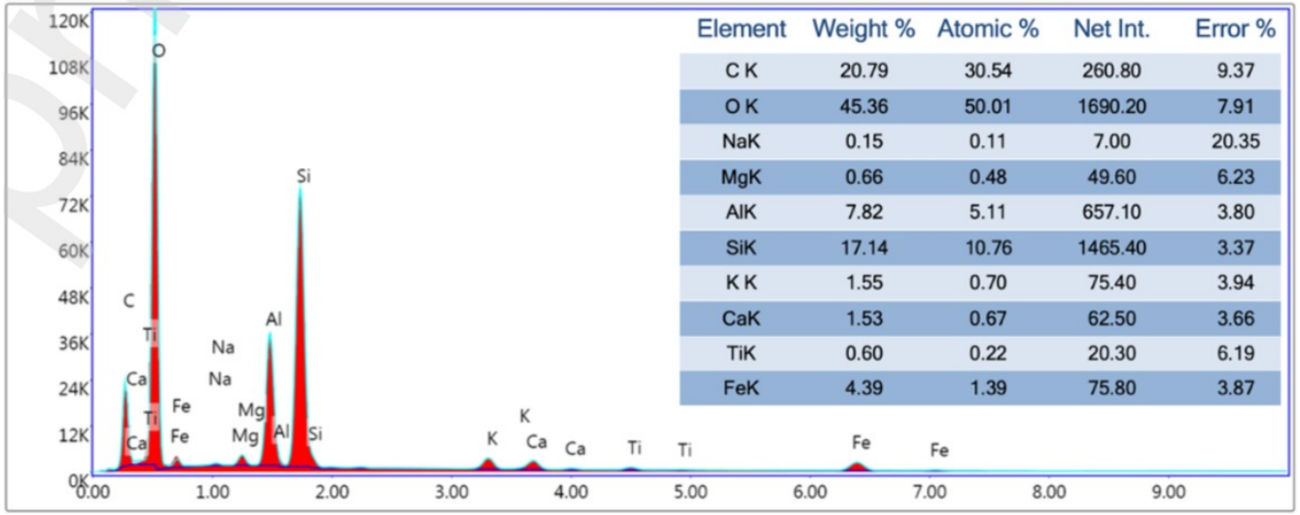
<u>REMARK</u>: Crucible: **80 mg**, Soil Sample: **1,63 kg** → 0,0000491 = **0. 00491 %**
Biochar (a concentrated form of Carbon) is unevenly distributed in soil (solid-solid mixture)
→ **<u>Soil sampling is not a suitable verification method for certification</u> of biochar amount in soil**

Recovery and assessing real-case Carbon Permanence

- **FT-IR, SEM-EDX, CHNSO, TGA, ...**







Element	Weight %	Atomic %	Net Int.	Error %
C K	20.79	30.54	260.80	9.37
O K	45.36	50.01	1690.20	7.91
NaK	0.15	0.11	7.00	20.35
MgK	0.66	0.48	49.60	6.23
AlK	7.82	5.11	657.10	3.80
SiK	17.14	10.76	1465.40	3.37
K K	1.55	0.70	75.40	3.94
CaK	1.53	0.67	62.50	3.66
TiK	0.60	0.22	20.30	6.19
FeK	4.39	1.39	75.80	3.87

Recovery and assessing real-case Carbon Permanence

Parameter	Unit	Original biochar (washed)	Unearthed biochar (washed)	Unwashed Braccesca soil	Undernatant Braccesca soil after washing
Moisture	*wt%wb*	7.73	9.10	1.54	2
Volatile matter	*wt%db*	15.52	27.03	4.75	6.05
Ash content 550°C	*wt%db*	12.60	22.05	95.45	94.15
C	*wt%db*	82.85	63.81	1.40	1.40
H	*wt%db*	1.15	1.46	-	-
N	*wt%db*	0.94	0.67	0.12	0.13
S	*wt%db*	0.11	-	0.02	0.10
O	*wt%db*	2.36	12.02	3.01	4.22
Inorganic C	*wt%db*	0.79	0.02	-	0.04
Corg	*wt%db*	82.05	63.79	-	1.36
BET area	*$m^2 g^{-1}$*	276	91	-	-
C fix	*wt%db*	71.88	50.92	-	-
(C fix/Ctot) ratio	-	0.87	0.80	-	-

wb=wet basis; db=dry basis

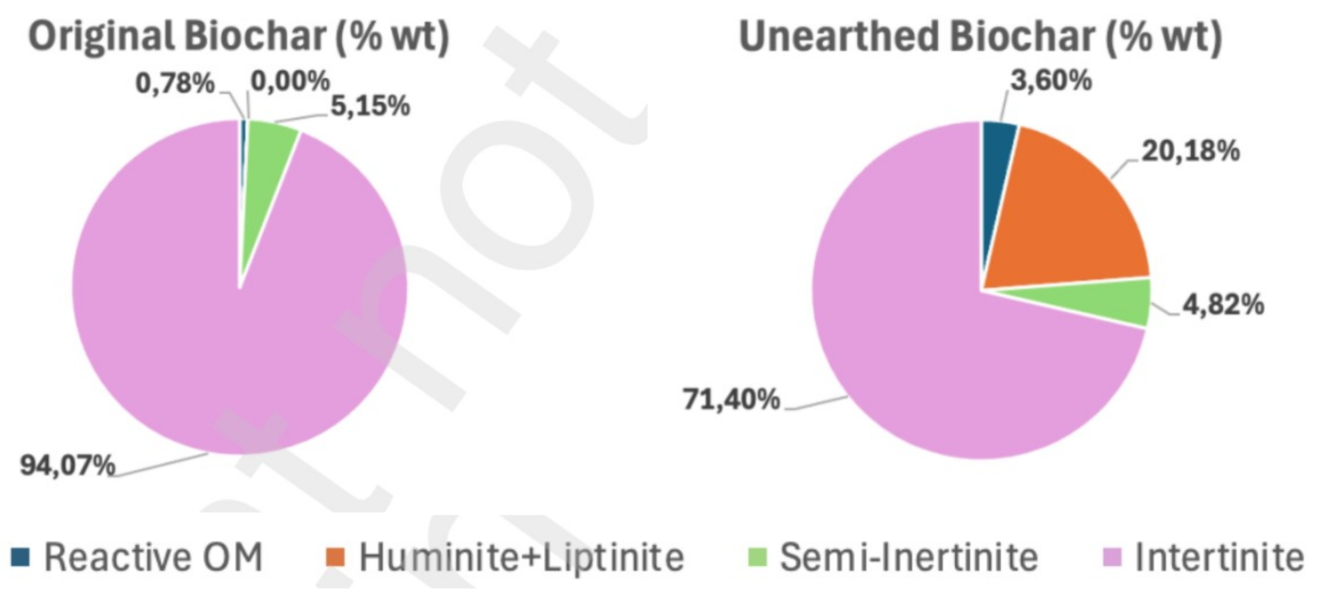
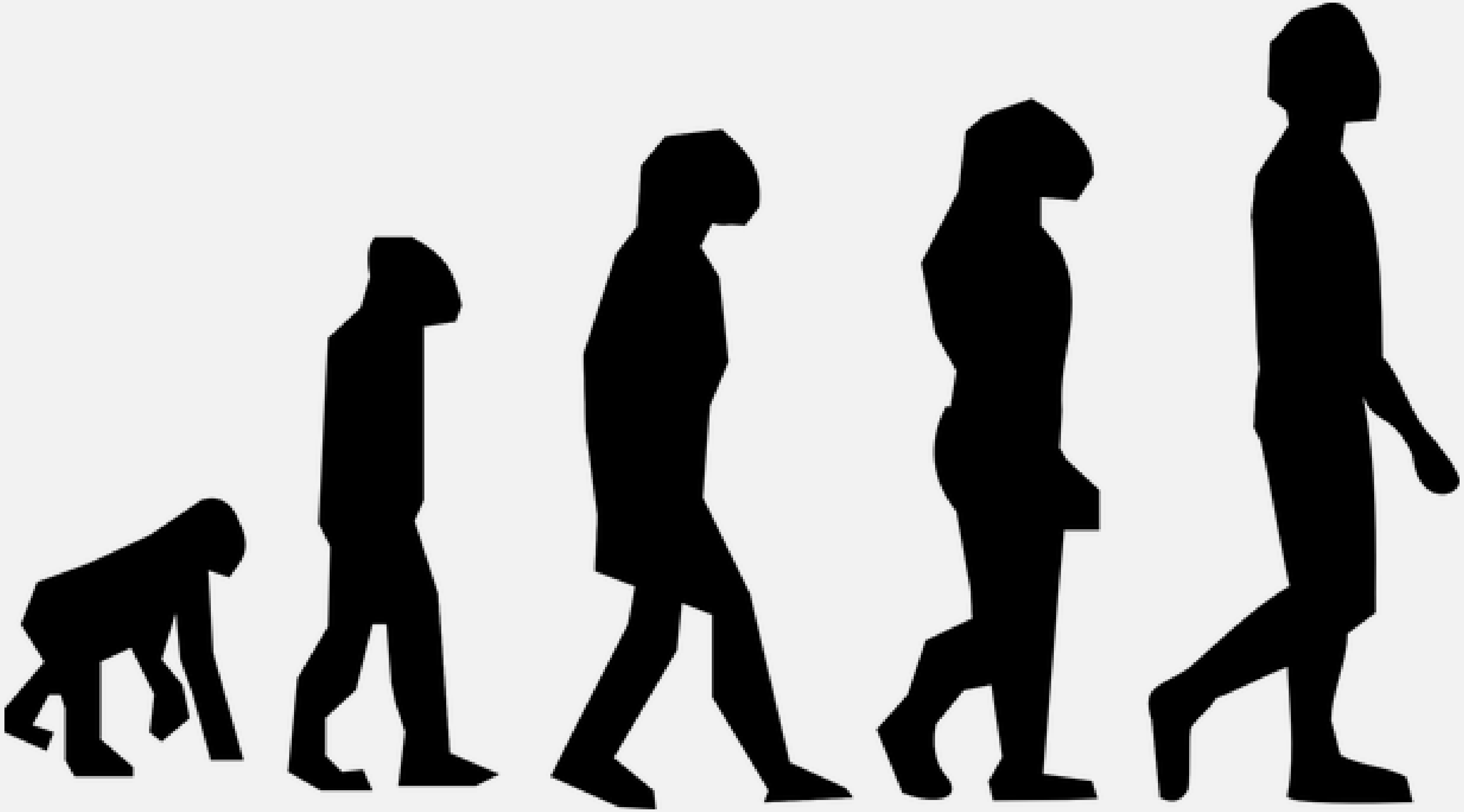


Table 3 Semi-Inertinite vs Inertinite % fractions on Original and Unearthed biochar

Sample	Semi-inertinite% vs Inertinite % fractions (Corrected by removing reactive OM and Huminite/Liptinite fractions)
Original biochar (2009)	5.5% : 94.8%
Unearthed biochar (2024)	6.8% : 93.7%

Biochar Value Chain is mature



- **ICAO, 2017 → 142** Mt CAF at 2010 → 570-**860** Mt at 2050 (Intern. Aviation) + 400-600 % !!
- **100% CAF substitution (MAX scenario)** – **170 new biorefineries each year** from **2020 to 2050** (15-60 $B/y) –
- **MAX** would **reduce CO_2 emission by 63%**

LTAG Scenarios *(ICAO, March 2022)*

Key messages from ICAO

None of the scenarios reach zero CO_2 emissions (Net Zero) using in-sector measures only.

Offsetting needed.

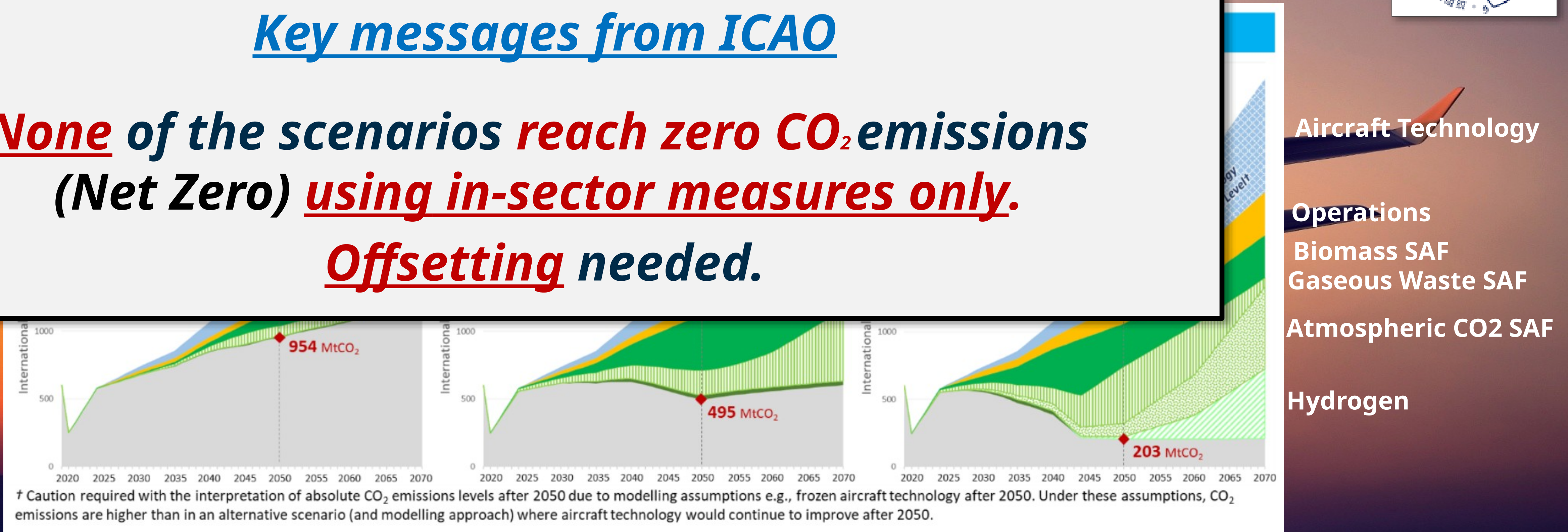


Figure 1. CO_2 emissions from international aviation associated with LTAG Integrated Scenarios

- ***Aircraft Techn:*** *Advanced tube and wing, unconventional airframe/propulsion concept aircraft, non-drop-in fuels such as battery electric etc*
- ***Operations****: improvements in the performance of flights across all phases*

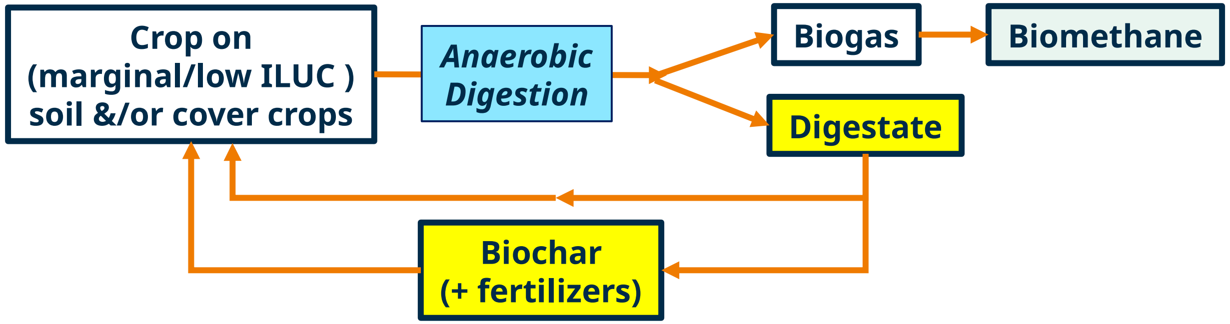
CARBON NEGATIVE: Offset (Compensate)

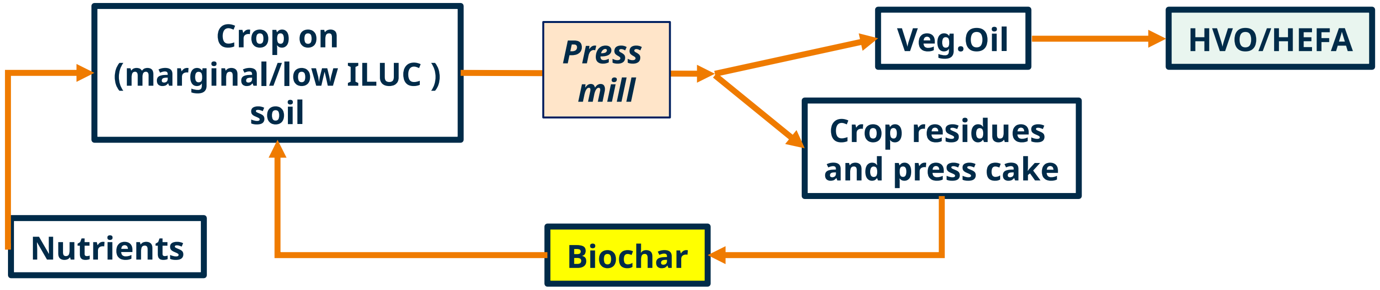
- ✓ **Low-ILUC** : Camelina&Barley in recovered land under marginalization (**BIO4A, BIKE**)
- ✓ **Offsetting CO2** at EU airport land, landside and/or airside + Circular Airports (**TULIPS**)
- ✓ **Nature-based offsetting** next to **SAF** production, or in combination with it (**BIO4A, BIKE**)

→ **Energy** can **support more sustainable agriculture** through **Biofuels Done Right models**

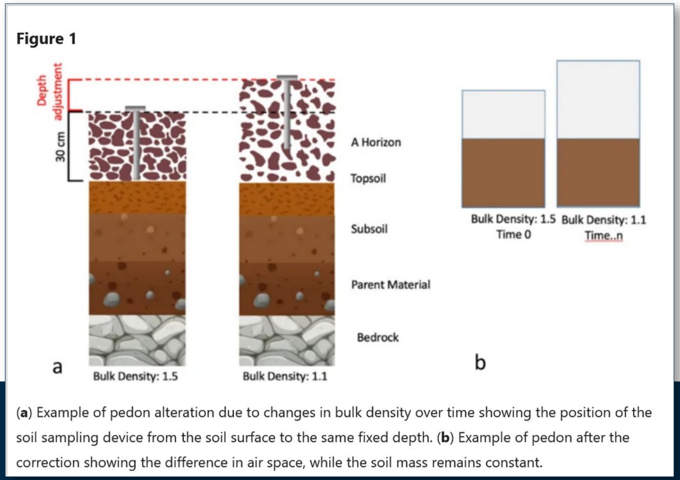
“Biofuels Done Right” can be Carbon Negative and support farming in EU

- **Carbon NEUTRAL vs Carbon NEGATIVE: renewable BIOfuels can be C-Negative**
- **Biogas Done Right and Digestate, or Pyrolysis of residues to Biochar are some examples**
- **Fully deploying REDII-IR (Esca factor → C in soil in GHG assessment)**





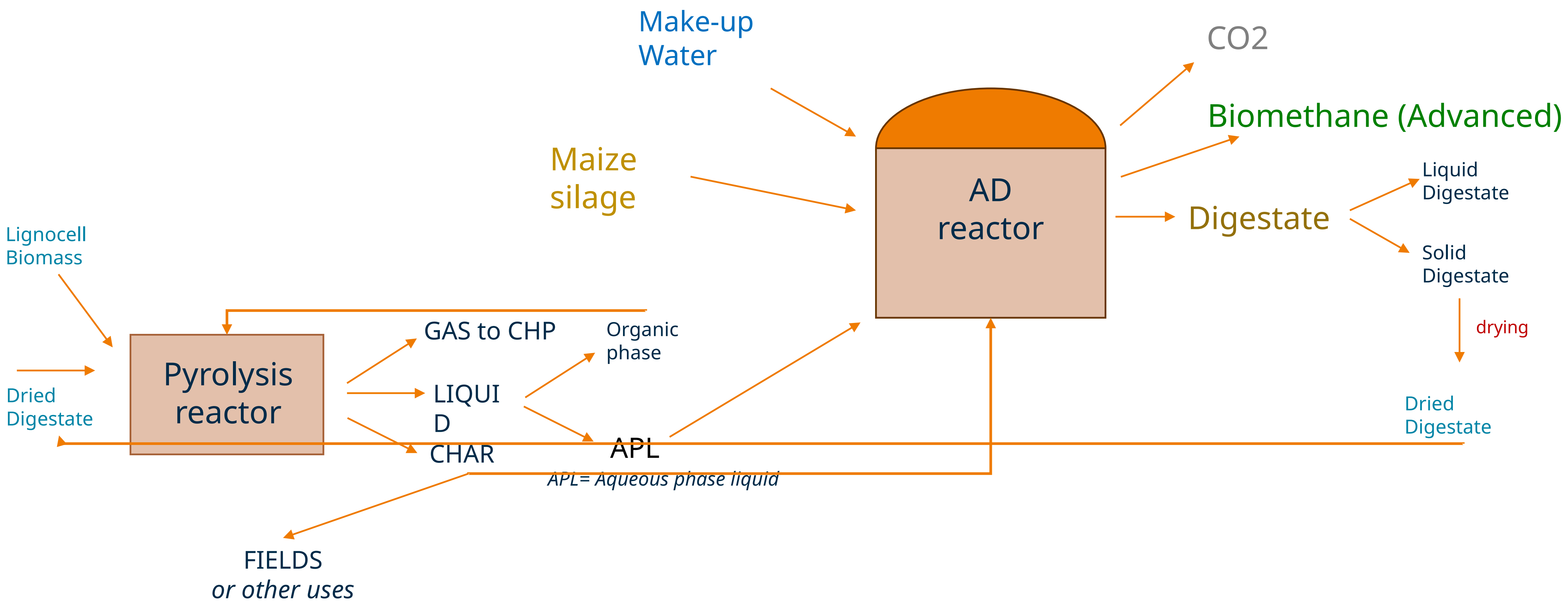
No fertilization | **Mineral fertilization** | **100% Compost** | **100% Biochar** | **Biochar+ Compost 10%**



Bulk density very relevant in SOC accounting

Slow Pyrolysis and Anaerobic Digestion

Zero waste – C negative



Conclusions

- Regulation is rapidly evolving to incorporate biochar as a key CDR NET
- This will pave the way to large scale uses, bringing additional environmental benefits beyond CDR
- Costs and technologies will have to meet these growing C markets
- Integration of Slow Pyrolysis and other processes (as AD) hides large environmental and economic opportunities (and challenges, both technical and non-technical)
- New integrated processes are under development (demo, FOAK). Industrial symbiosis is the keyword

Thanks for your attention

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