CARBONDIRECT

Market Criteria for Carbon Farming Pathways

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OUR MISSION

Carbon Direct leverages scientific expertise, proprietary data, and commercial experience to scale carbon management solutions.

Our team includes the world's foremost carbon management scientists, who have expertise in all leading carbon removal & utilization technologies.

We synthesize our expertise and superior data to identify and help scale the best solutions across all domains of carbon management.

We leverage our leading investment business to understand the true opportunities, risks, limitations, and applications of various carbon management solutions.

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Outline

Carbon offsets

- Fundamentals
- Principles for high-quality removal

Biochar

- Project structure
- Durability
- Supply
- Protocols
- Risks & Interventions

Soils

- Protocols
- Measurement

Carbon offsets

Fundamentals of carbon offsets

- Carbon offsets have the potential to deliver climate benefits by **avoiding, reducing, and/or removing greenhouse gas emissions** through a variety of project types.

- Project types can include **agricultural activities** (e.g., manure methane digesters), **carbon capture and storage** from an emitting facility, **chemical processes** (e.g., destruction of ozone-depleting substances), **forestry and land use** (e.g., planting new forests), **household and community** (e.g., clean cookstoves), **industrial manufacturing** (e.g., waste heat recovery), **renewable energy projects** (e.g., solar), **transportation** (e.g., clean fueling infrastructure), and **waste management** (e.g., landfill methane capture).

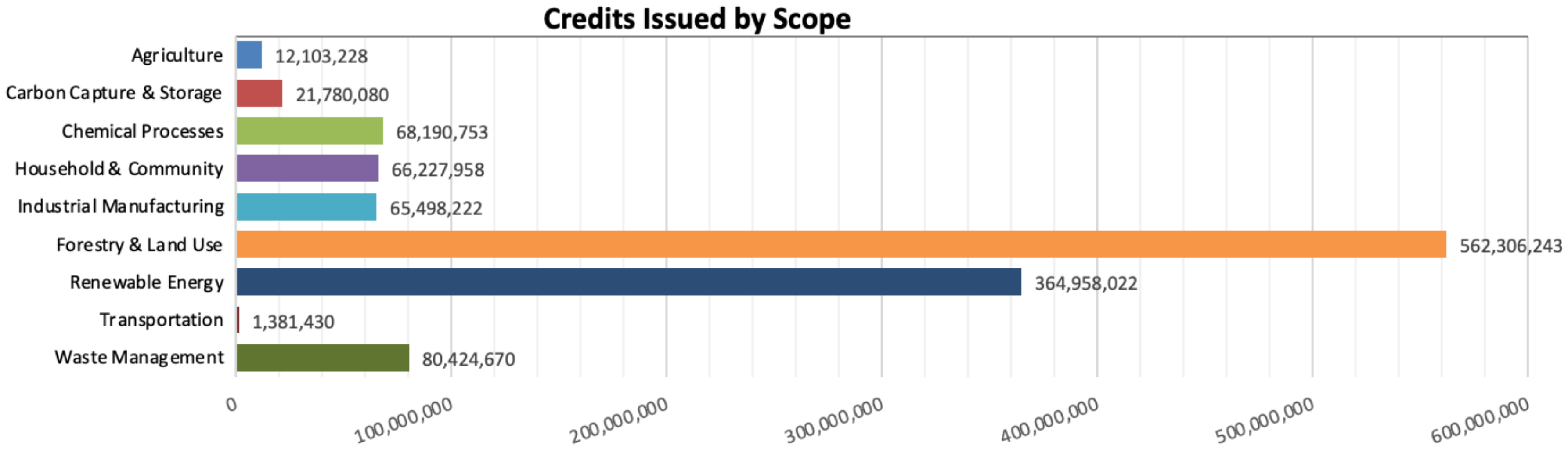
- Credits generated from carbon offset projects can be **bought, sold, and traded** in the voluntary carbon market.

- Entities purchase credits to **"offset" emissions** from their own emitting activities.

- Carbon credits on the voluntary market are issued and transacted as **metric tonnes of CO_2e,** a unit of measurement that translates the warming impact of all GHGs associated with a project to an equivalent amount of CO_2 emissions. **1 offset credit = 1 metric tonne of CO_2e**.

- **Over 240 million credits transacted in 2022 (YTD)**. Market has been growing substantially since 2017.

Offsets credits issued by project category



Source: Barbara Haya, Ivy So, Micah Elias. (2021, September). Voluntary Registry Offsets Database, Berkeley Carbon Trading Project, University of California, Berkeley. Retrieved from: https://gspp.berkeley.edu/faculty-and-impact/centers/cepp/projects/berkeley-carbon-trading-project/offsets-database

Motivations and characteristics of offsets

- Corporate **motivations for offsetting are multifaceted**.

- Most offsets are used as a means of mitigating climate damage or making **corporate claims** as to carbon neutrality or net-zero emissions. **Community co-benefits** and non-environmental factors are often important along with **verification** from a standards body.

- Offsets come in many flavors. A useful high-level distinction is between **“avoided/reduced” vs. “removed”** emissions.

- Most offsets historically are for avoided/reduced emissions; **not carbon removal**.

- **Nature-based projects dominate** the industry for offsets that are removal. Carbon removal offsets tend to be from forests, soils, and changes in land management projects.

- **Not all offsets are created equal in terms of quality**. Those projects that are of high quality can span many methods and technologies, each with distinct advantages and disadvantages.

Principles for high-quality carbon removal

Carbon Direct Inc.'s aim is to create a virtuous cycle where demand for high-quality carbon removal encourages increased supply, driving greater climate impact. We partnered with Microsoft to develop criteria for what "good" looks like. See the full report here.

Additionality & Baselines

Credited removals are not mandated or a geographically common practice, and would not have occurred without carbon removal payments. Baselines should be set conservatively to minimize the risk of over-crediting.

Carbon Accounting Method

Quantify and monitor net carbon removal using repeatable and verifiable methods, and estimate project-specific uncertainty in removal estimates in a conservative manner.

Do No Harm & Pursue Co-Benefits

Low risk of any material negative impacts on the surrounding ecosystems and local communities. Potential for improving local communities, environmental quality, and climate resilience beyond carbon removals.

Environmental Justice

Fosters community involvement in the project. Generates wealth for and/or economically empowers local historically disadvantaged communities.

Durability

Low risk of stored carbon being re-released into the atmosphere through voluntary or involuntary reversal events. Projects should have measures in place to minimize risk and account for it in carbon estimates.

Leakage

Minimal risk of activities that cause displacement of emissions from the project site to another site. Projects should account for any displacement.

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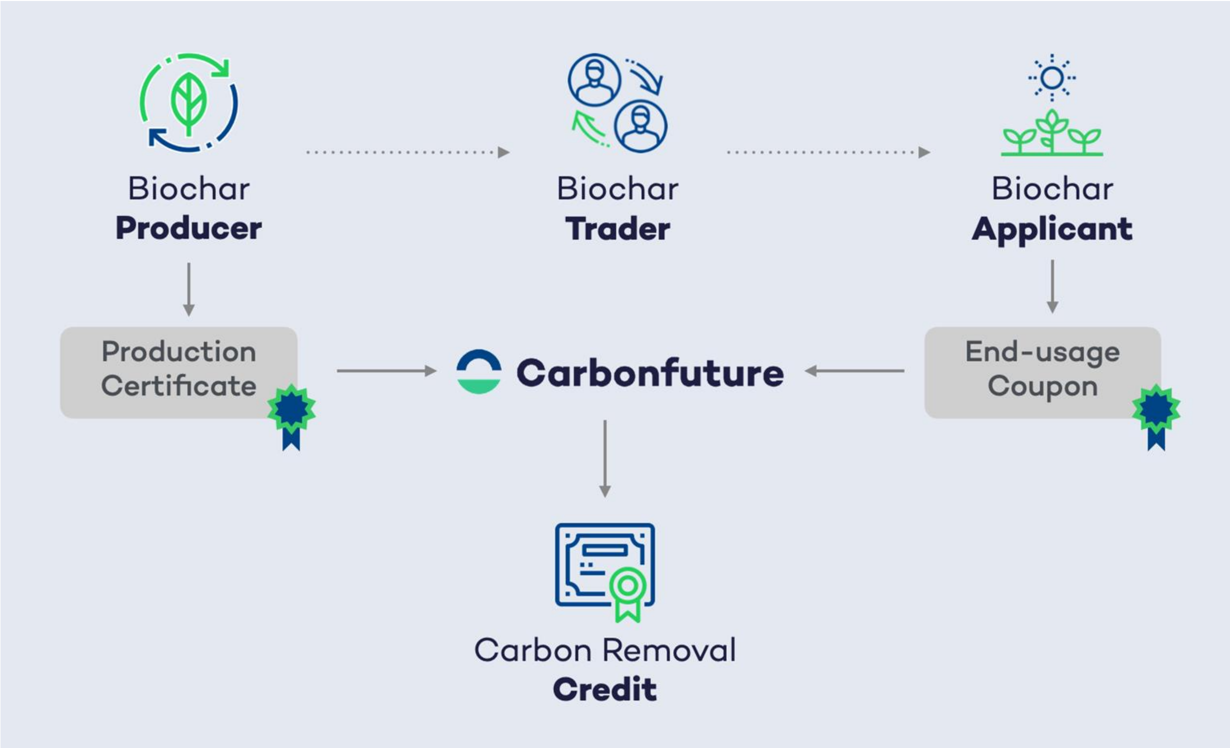
Biochar

Project structure

- Biochar producer produces two products:
  - Biochar
  - Carbon removal certificates / offsets
- Biochar is designated for non-combustive use
- Products are typically sold separately



Source: Carbonfuture

Durability

Biomass is susceptible to degradation and C loss by multiple mechanisms:

- Biochemical (biotic)
- Physicochemical (abiotic)

Degradation rates estimated by relatively short term incubation studies of < 1 year to ~10 years, results are extrapolated to estimate:

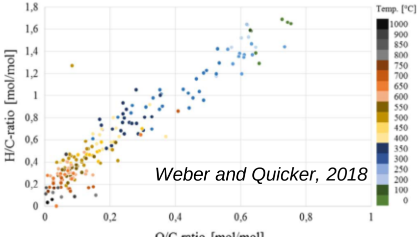
- Half-lives
- Mean residence times
- BC+100 **(% of biochar C remaining in soil for > 100 yr)**

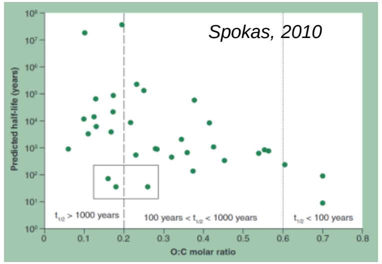
Increased resistance to biotic and abiotic degradation achieved through increased pyrolysis severity (temperature, residence time):

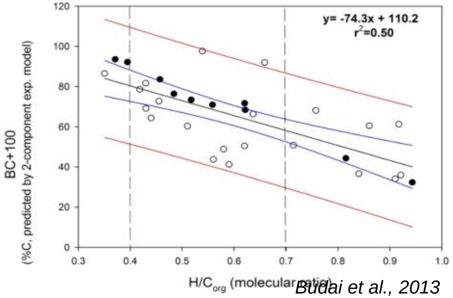
- Increases the aromatic content of biochar
- Increases C fraction, reduces O and H content

Various methods proposed to assess durability of biochar, derived from correlation of CHO to degradation rates:

- O/C molar ratio (Spokas, 2010)
  - > 0.6 : half-life <100 yr
  - 0.2 - 0.6 : half-life 100-1000 yr
  - < 0.2 : half-life >1000 yr
- H/C molar ratio (International Biochar Initiative)
  - < 0.4 : 70% @ 100+ yr
  - 0.4 - 0.7 : 50% @ 100+ yr
- O/C and H/C (European Biochar Certificate)
  - O/C < 0.4 and H/C < 0.7





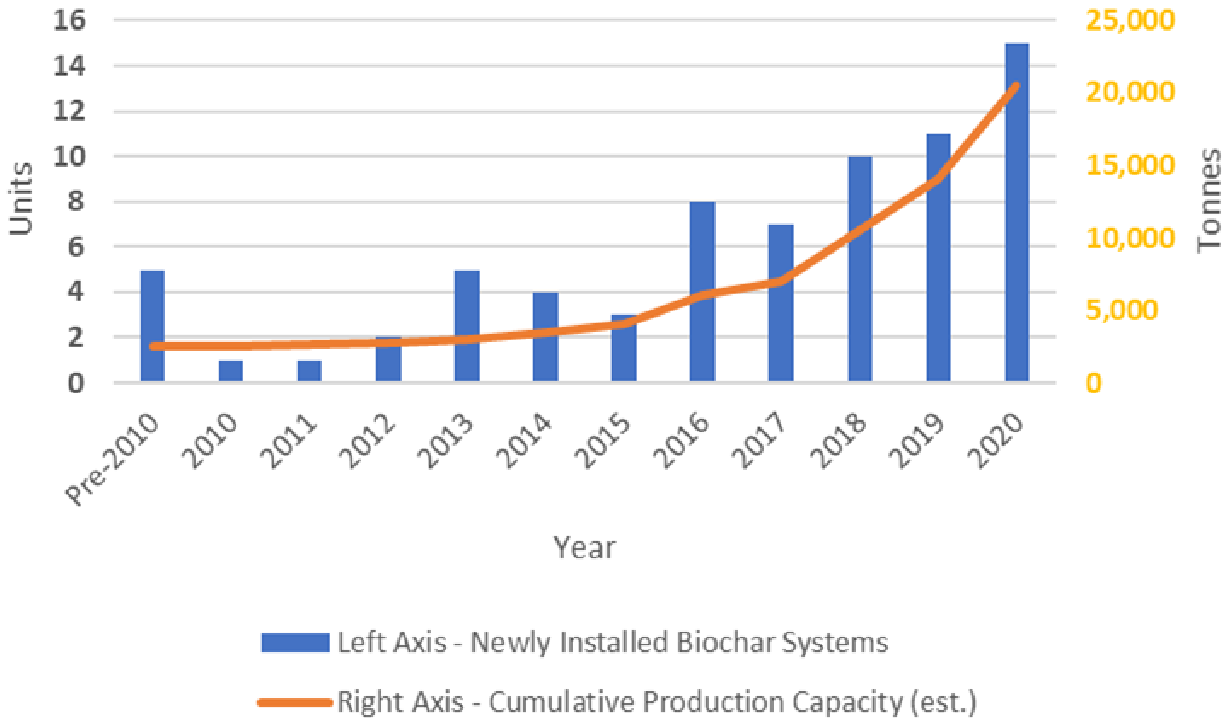


Budai et al., 2013

Do No Harm (Ecosystem and Public Health Impacts)

Risks	*Safeguards*
Contaminated feedstocks (pesticides, heavy metals, PAH, dioxins) can yield chars, gases, and oils that may pose risks to human and ecosystem health.	Production conditions should be specified. Biochar should be lab-tested for composition and contaminants prior to deposition in soil. Laboratory analysis of feedstocks and biochars can mitigate these risks and better inform soil health impacts.
While underutilized waste residues offer a low-cost input that can reduce demand for land and water resources, determining what is 'waste' is difficult.	Accordingly, biochar producers should be responsible for 1) specifying the source of their feedstock and 2) documenting the proposed counterfactual (e.g., what is the alternative use).
Biochar is the not the only product of pyrolysis, and and co-products with no/low value may be irresponsibly discarded or present in char.	Biochar proposals should reflect a cradle-to-grave accounting of materials including oils and gases produced during the pyrolysis process.
Historically, biomass power facilities have been located in low-income socially disadvantaged regions of the US, causing cumulative harm.	Biochar proposals should outline any air, water and/or other hazards as well as demographic information surrounding the facility, as well as wage/compensation information.

Supply

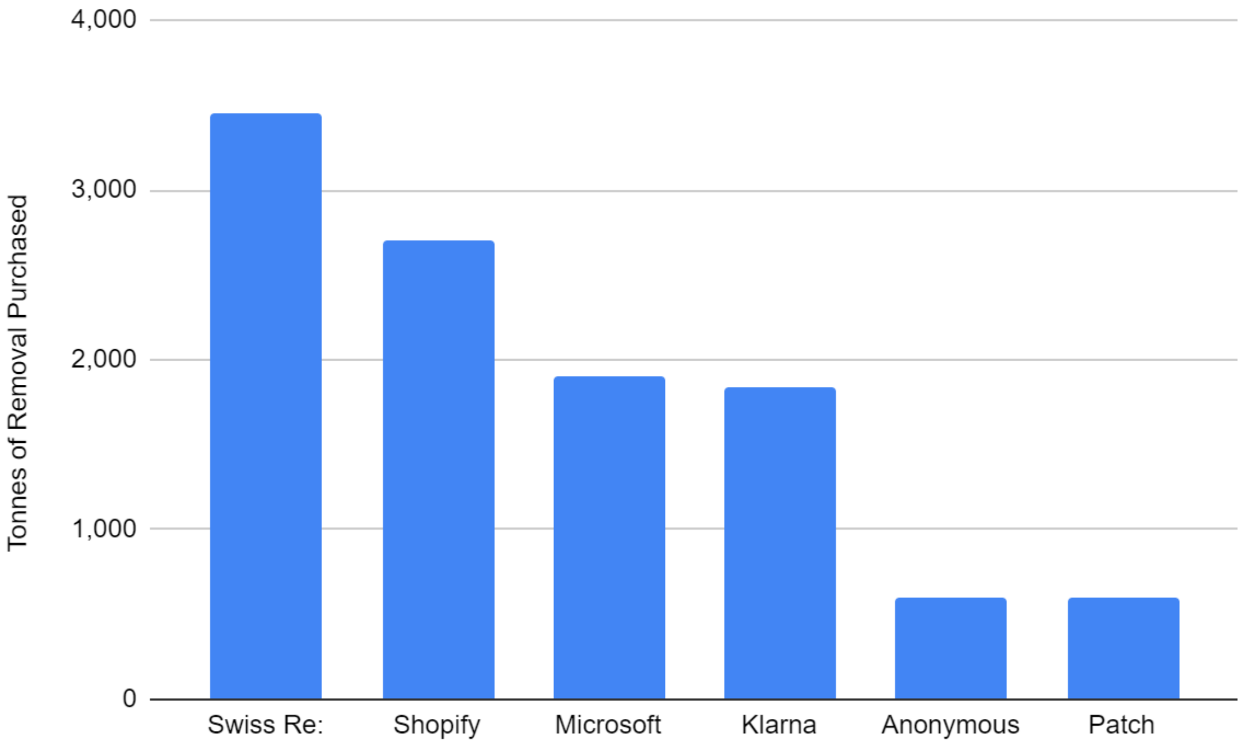


The chart to the left illustrates the previous decade's growth of dedicated biochar production capacity in Europe, both from a cumulative tonnage perspective, as well as counting units added annually.

Europe remains a major production center for biochar globally, along with North America and certain tropical regions.

Source: European Biochar Market Report 2020 - European Biochar Industry Consortium

Major purchases of biochar-based removals



As prices rise in the VCM, buyers are becoming more accepting of biochar as a viable component to their purchasing strategies.

Prices for biochar-based removal credits vary widely, from \$100-500/tCO_2, but many producers are predicting <\$100/tCO_2 as production scales up.

These projections could be challenged by feedstock constraints and demand for the physical biochar.

Note: Puro has reported more than 20,000 tonnes of biochar based removals sold over the past two years.
Source: Marginal Carbon, Carbon Direct

Protocols and their shortcomings

Protocol	LCA allows non-waste biomass	Focus on advanced technology in developed countries	Minimum durability threshold	Sliding-scale durability	Chain of custody certification
Puro.earth	No	Yes	Yes	No	No
Verra (in development)	No	No	No	No	No
Carbonfuture	No	Yes	Yes	No	Yes
Climate Action Reserve (in development)	Likely no	?	?	No	No

Greatest Risks

What we are not testing for
- PAHs, Dioxins (except IBI or EBC standards)

Financial Additionality
- Lack of agreement about methods, particularly with co-production

Durability in soils
- Biotic and abiotic degradation

Priming effects
- Significant potential upside, with lower durability

Potential Interventions

1. **Raise the bar on protocols**
    - Durability adjustments
    - Traceability and MRV requirements on biochar post-production
    - Consistent consideration of PAH and Dioxins

2. **Forward purchase significant volumes for most carbon-removing operations** by quality-motivated buyers

3. **Monitor and adjust for biochar persistence in soils across portfolio of projects**

Soils

Protocols (n=17)

- No protocols track carbon removal and avoided emissions separately
- Apply to a range of geographies and a wide variety of land management practices
- Only 3 of 14 protocols require direct sampling as the basis for issuing soil carbon credits
- Where sampling is required in today’s protocols, quality requirements are generally poor
- Majority of the protocols apply or replicate the much-criticized Clean Development Mechanism additionality standards

Source: Carbonplan

Recommendations for buyers

STEP 1	Define and screen individual projects aggressively for additionality and safeguards, because the current protocols are woefully inadequate on these dimensions.
STEP 2	Ask projects to adopt one of the most rigorous sampling requirements (such as those found in the BCarbon, FAO, or Australia measurement protocols) for their quantification requirements.
STEP 3	Consider a generous discount on credits to account for uncertainty and durability risk, because many types of soil carbon gains are vulnerable to future land management decisions and the existing protocols manage these issues poorly.

Conclusions from Carbonplan:

“Robust soil carbon crediting requires empirical measurements. But we repeatedly found protocols relying partially or completely on modeling to quantify and credit soil carbon gains”

“Buyers cannot rely on any of the protocols to ensure additionality”

“We did not find any protocols that achieved a high bar for durability, which requires both a long permanence period and robust risk management provisions.”

Source: Carbonplan

Measurement

Fractionation
- Particulate organic matter (POM)
- **vs.**
- Mineral-associated (MOM)
- Inorganic C is not quantified

Stratification
- Practice, soil type, vegetation, climate

Depth
- How do we “measure to impact”?

Processing
- Sieving for roots and rocks
- Combustion vs. C/N analysis (elemental or mass spec)

Market information

Typical prices: \$10 – 25 / tCO_2
Prices up to \$45 / tCO_2

Relatively few projects on registries

Many large agronomics companies developing their own protocols and markets that will use their existing clients as suppliers

Potential for higher prices and longer durability for mineral-associated carbon

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