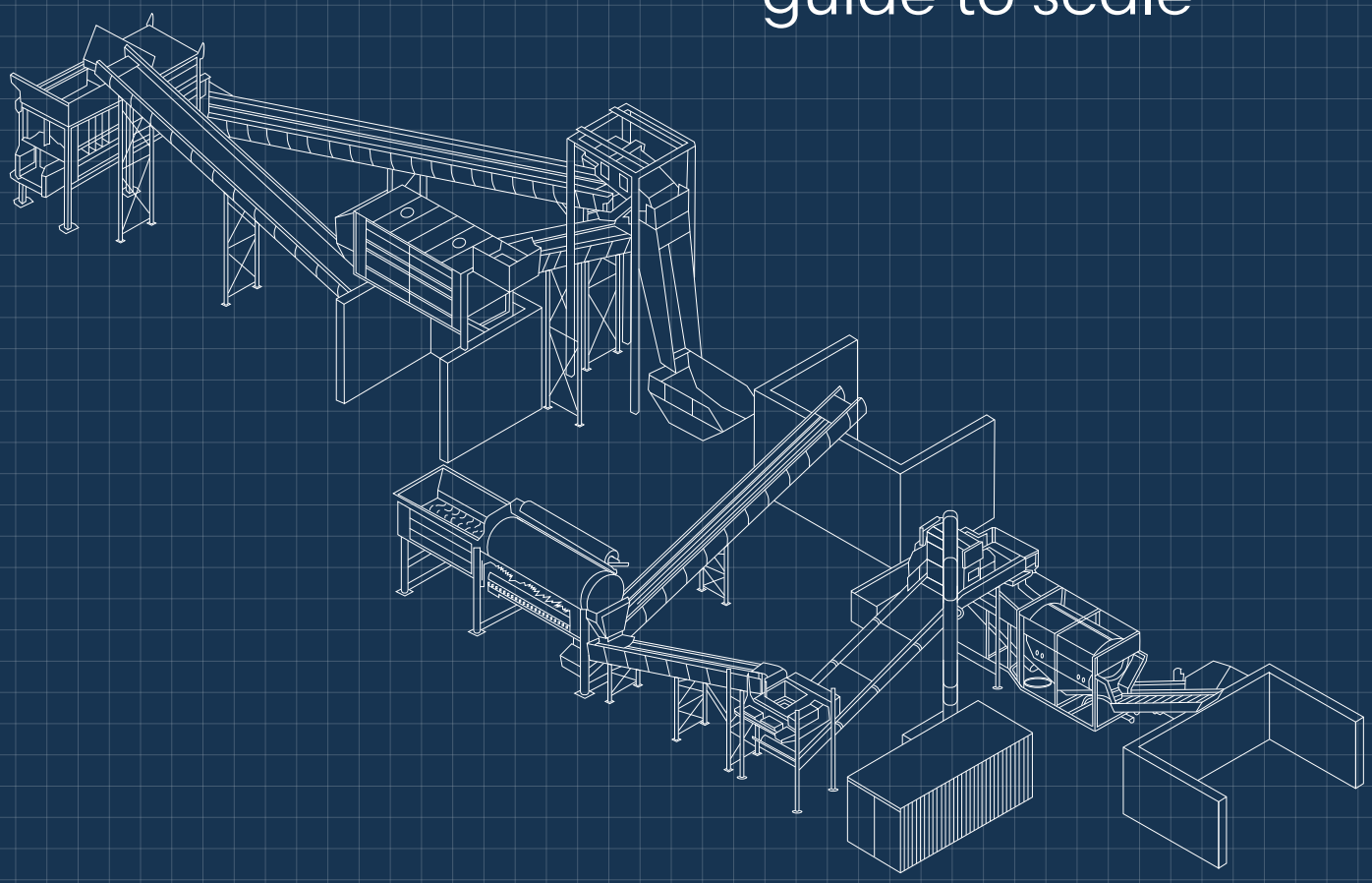
A Healthier Earth

The Biochar Blueprint

A developer's guide to scale



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Contents

Foreword

Collaboration – it's at the heart of how humanity has achieved anything of consequence. It's what makes us extraordinary: our ability to act together, to align our interests while maintaining our individuality. It's also what makes us vulnerable. We depend on collaboration to do great things, and yet our collective actions can have unintended consequences, even when driven by the best of intentions.

Our changing climate is one of those consequences. It stems from the incredible industrial progress of the past two centuries; progress that has lifted billions out of poverty, extended lifespans, and connected our world in ways once unimaginable. But it has also come at a cost: the depletion of finite resources and the transformation of our atmosphere, creating warming effects with potentially devastating, and still not fully understood, outcomes.

I believe we can continue to progress as a species and preserve a habitable planet. To do that, we must once again collaborate. This time, to create a healthier Earth for humans to thrive on. One powerful way to start is by addressing the carbon already in our atmosphere while restoring the biosphere that sustains us. Biochar, though often working quietly under the radar, does both.

Its dual ability to decarbonise our atmosphere and re-carbonise our biosphere makes it uniquely suited to the challenge. The problem isn't whether biochar works, it's that we don't yet have enough of it. That's why I commissioned this report. I wanted to share what we've learned so far: the opportunities, the obstacles, and the insights that might help others accelerate their own projects.

This white paper is itself a product of collaboration. It draws on conversations with financiers, developers, users, and researchers. It's written for those who want to build, scale, and improve, faster and together. At A Healthier Earth, we believe partnership is the key to scale. The Biochar Blueprint is part our contribution, a reflection of what we've learned so far, and an open invitation to those who share our vision of a healthier, more resilient planet.

Alastair Collier
Chief R&D Officer, A Healthier Earth

Introduction

Our planet is warming. And it's no secret why.

For all the world's collective efforts to drive up energy efficiency, boost renewables, and slash fossil fuel consumption, greenhouse gas (GHG) emissions keep inching upwards.

Ten years ago, at the signing of the landmark Paris Agreement, the concentration of carbon dioxide (CO_2) in the world's atmosphere measured 399.4 parts per million (ppm);[1] today, it's hovering at closer to 425 ppm.[2]

All the evidence suggests the figure will keep creeping up. But even if present-day GHG emissions were to stabilise or decrease, the problem of our warming planet remains. Why? Because the long life of GHGs mean that the emissions of yesteryear still linger in our atmosphere. Hence, the surging interest in carbon dioxide removal (CDR) in recent years. CDR technologies are now widely seen as the world's only hope of actually bringing down levels of atmospheric carbon; so reversing global heating, not just holding it in abeyance.

But CDR has a problem of its own. Many of the technological solutions currently on the table are heavily engineered, eye-wateringly expensive, and, in large part, commercially unviable.[3] The notable exception on all these counts is biochar, which stands out as a credible, affordable, and ready-to-go climate solution.

As awareness about biochar's benefits has risen, so too has market demand. According to current projections, the global biochar industry is expected to almost triple in value over the next seven years, to over US$2 billion.[4] Such a prospect is causing considerable excitement, with some commentators already brandishing biochar with the "gold rush" label.[5]

We are more cautious. For all its unquestionable merits, the biochar sector is in a delicate transition stage. While the industry can boast a handful of successful industrial-scale investments, the vast bulk of projects remain either artisanal or small-to-medium scale. To hit market projections and meet expanding demand, a step change is therefore required. Not only must current projects scale up quickly, but we also need multiple new industrial-level projects coming on stream in short order.

The science is there to make this happen. The technology is there. What's lacking is investment capital. It's not that financiers don't share the excitement around biochar's potential; they do. What concerns them is biochar's "bankability"; that's to say, its viability as an investable asset class that will reliably deliver attractive financial returns over the short to medium term.

So, what is holding back project investors and the buyers of biochar-based carbon credits? And, more particularly, what can developers do to win them over?

To answer these questions, this paper focuses on five main financing hurdles faced by biochar developers: the design of offtake contracts, voluntary carbon market arrangements, the pricing of carbon credits and other revenue streams, technology selection and risk management, and documentation and regulatory compliance. With the goal of providing developers a practical way forward, each section briefly analyses the problem at hand and makes suggestions as to how these might be overcome.

Barrier 1

01

Financing and Contract Structure

Contract bankability and investor requirements

"Black gold": dynamic demand, but sluggish supply

Biochar's status both as a high-potential climate solution and a multi-revenue opportunity is generating growing interest among the investment community.

On the demand side, much of the early running is being led by a small group of corporate buyers, who see biochar as a prime opportunity to meet their ambitious climate targets. Spearheading this momentum is the Frontier Coalition, made up of Stripe, Alphabet, Shopify, McKinsey and others; and global tech giants like Microsoft, Google and Meta. These first movers are focused on helping stimulate demand not just for biochar, but for the wider engineered CDR market as a whole.

The major challenge for the biochar market at present is to ramp up supply. While a multitude of small, often experimental projects are currently underway, the vast majority lack the characteristics required for mainstream investors to deploy capital to support their growth. The high, upfront capital expenditure (capex) requirements of industrial-scale biochar are often cited as a major barrier. In reality, the truth is more nuanced.

The fact that infrastructure projects are capex-heavy is something that most investors in the infrastructure space are well inured to. Indeed, given the high due diligence and legal costs associated with infrastructure investments, investors typically only start considering projects with a capex above around US$25 million. Instead, the main stumbling block for investors tends to centre on the perceived capacity of a developer to generate an acceptable return on this scale of investment. At issue here is the developer's ability to point to low-risk or (ideally) derisked future revenue streams. Without this, investors are reluctant to invest in a developer or issue it a loan, leaving the latter struggling to ramp up its projects to a scale that is meaningful either for carbon sequestration or for investor returns.

> We model the credit risk of an emerging market and scale-up performance data. Essentially, our goal is to try and price in what is the default risk for these companies. And then on top of that, we layer on the physical risks that a project might face, like fire, machinery breakdowns, or disruptions to feedstock supply.
>
> **James Kench, Managing Director – Insurance, Kita**

Offset agreements – questionable bankability

A major sticking point for investors is the contract that biochar developers strike with end buyers. These contracts (referred to as "offtake agreements") establish an agreed price at which the buyer will purchase the carbon removed (expressed in tons of carbon dioxide equivalent, or "tCO_2e") through the project in question. Typically, such contracts run over a three to five-year period, thus providing the developer with only a relative "short term" stable revenue stream.

In theory, a signed offtake agreement should provide the security that a financial institution such as a bank or investment fund needs to lend a developer the capital that it requires to build or expand its project. The same de-risking strategy has been shown to work for other first-of-a-kind (FOAK) clean-energy technologies. In the early days of solar and wind energy, for example, many large-scale projects obtained finance on the back of similar long term offtake agreement, often referred to as a Power Purchase Agreement (PPA) in the electricity sector.[6]

With biochar, however, there appears to be a disconnect between theory and practice. Why? Simply put: investors are nervous. This is understandable. Firstly, it remains early days for biochar's status as a commercial-scale investible asset. While everything points to the science and technology being sound, developers still need to prove themselves.

As importantly, investors are worried about the maths. Payback periods of most infrastructure projects are a minimum of seven years, so the fact that most biochar offtake agreements run to a much shorter timespan makes them wary. Stringent contract terms compound this narrow pay-back window, allowing little room for delays or cost overruns.

As a result, the offtake agreements that developers secure need to be completely buttoned down. Unfortunately, from a conventional investor's perspective, most existing contracts fall short.

Common complaints include:

- A lack of firm delivery and payment obligations.
- An absence of clear legal recourse in the case of under-delivery or non-delivery.
- An ability for buyers to too easily annul the contract.
- A guaranteed revenue contract period that is too short.

> Insurance is possibly the most problematic aspect of the project development process. The due diligence that insurers insist on is three or four times as rigorous as an investor. These are new kinds of projects after all, and if you are looking for risks, then naturally you'll find them.

Jerom van Roosmaden, Co-Founder, Green Carbon Factory

Support for Developers

1

Bankable contracts: "must haves"

Every contract is, to some extent, an exercise in mutual compromise. Biochar is no exception. As a nascent technology, and with strong competition from other climate solutions, it's a buyers' market right now. That makes it difficult for developers to negotiate commercial terms. At the same time, for an offtake agreement to secure the financing that developers require, it must meet certain "must haves" for investors.

While no financier is the same, the same core requirements feature on every investor's checklist.

These include:

- **Clear obligations:** Fixed delivery volumes, schedules, and payment timelines.
- **Unambiguous language:** No vague "agree to agree" clauses or open-ended liabilities.
- **Project integration:** Links to other project documentation (such as feedstock supply, carbon transport and storage, procurement and construction, and operations).
- **Compliance with standards:** In accord with terms of certification requirement of standard setters (such as Puro.earth, Carbon Institute Standards, Carbon Removals and Carbon Framing (CRCF),[7] UK Greenhouse Gas Removals(GGR Standard[8])).
- **Transparency provisions:** Right to audit a project and receive progress reports.

2

Bankable contracts: predictable cash flows

Investors of all stripes are looking for predictable cashflow, especially so in infrastructure-based investments. Biochar projects fit a similar cash flow model as infrastructure projects, as the capital investment requirements are high during pre-revenue and the revenues are typically flat once full capacity has been achieved. While any new business venture always presents risks and challenges, well-structured offtake agreements can help assure investors that revenue streams are robust and reliable.

Part of providing such assurance includes the anticipation of potential disruptions and clarification of the subsequent steps that the developer (or other relevant parties) will then take. Key components of any contract therefore include:

Securing revenues:

- **Establish fixed delivery schedules:** Delivery volumes and timelines spelled out in details (with floating start dates or other flexibility measures anchored by agreed milestones).
- **Include take-or-pay clauses:** Provisions to obligate the buyer to pay for credits in all circumstances (or, as a minimum, to pay for a fixed proportion).
- **Assess counterparty risks:** Ensure creditworthiness of all key partners (potentially including credit guarantees, letters of credit or buffer credits).

Mitigating disruptions:

- **Define remedies:** Draw up enforceable steps in the event of non-delivery (such as permitted rollovers, procurement of replacement credits, or liquidated damages).
- **Clarify financial exposure:** Establish the maximum downsides should a default scenario occur (e.g. via tools such as liquidated damages, replacement cost clauses, and liability caps).
- **Anticipate requirement changes:** Decide on provisions to address alterations of regulations or methodologies (including allocation of resultant costs).
- **Establish cure periods:** Include timeframes for remedying breaches or delivery failures.
- **Decide on pass-through of liabilities:** Risks such as reversal or delivery failure should be properly allocated and passed through the value chain.
- **Focus on failure:** Define reasonable cause for either the payment of compensation or for a project's termination (such as force majeure), and clarify each party's rights in such circumstances.

Standardised contracts for offtake deals would save considerable legwork for developers. However, no such resource yet exists. This leaves project sponsors needing to make sure they have access to sound legal advice. Developers should seek out a law firm with a strong background in the infrastructure sector. Obviously, if they have first-hand experiences of helping structure purchase agreements in the carbon market, then this can prove of great advantage.

Useful resources

Philip Lee (2025). Bankability of Offtake Agreements (see: Appendix 9)

Supercritical (2025). How to structure a good biochar offtake

Case Study

Insurance-enabled models

Insurance can prove a valuable tool to reduce regulatory, operational, or other project-related risks. Knowing a project is insured reduces balance sheet risks, while providing investors with confidence that strong due diligence and risk management are in place. The cost of insurance is an important consideration for developers, with many opting to internalise the risk(s) (or "self-insure") in question rather than pay for cover. That said, the decision by developers to invest in comprehensive insurance is usually rewarded by a perception in the market of greater bankability.

Yet, obtaining insurance for biochar projects is notoriously difficult. Although the science of pyrolysis is well-established, biochar developers are applying the technology in a wide variety of ways (depending on feedstock, site conditions, machinery, etc.). This requires insurers to adopt an almost project-by-project approach to their risk assessment, which, for now, can introduce additional cost to the process.

For developers that actively pursue this route, there can be a few additional hoops to jump through in terms of risk management-related data requests. As the insurance industry becomes more familiar with biochar methodologies and as historic project data become more available, these hurdles should reduce, making insurance more streamlined and accessible for developers.

Early signs suggest this process is already unfolding, with new insurance products tailored specifically to the biochar market beginning to emerge. The carbon insurance specialist Kita, for example, has designed a bespoke product for the non-delivery of credits. The product insures against three main eventualities: unavoidable events, such as wildfires or other natural disasters; counterparty risk, such as negligence or fraud by the developer (for offtakers or investors); and carbon market risks, such as methodology changes during the life of the project. More recently, Kita has added a non-payment (or credit) insurance to its portfolio to help unlock more much-needed bank project financing.

Drawing on its extensive internal expertise on biochar technologies and carbon markets more generally, Kita is already one step ahead of conventional insurers when it comes to identifying material project risks, says James Kench, Managing Director – Insurance. To circumvent the problem of lack of historic data, meanwhile, Kita turns to similar technologies as proxies.

See Appendix 6: Main Types of Insurance

"In an ideal world, we'd have five or ten years' worth of performance and market data to map what is likely to go wrong and what the cost of that would be," he says. "So, we build models based on proxy datasets and information from parallel industries. There's a conservative factor built into that, of course, but, as the market continues to develop, we can chisel down that conservatism.

James Kench, Managing Director – Insurance, Kita

Barrier 2

02

Voluntary Carbon Market (VCM) Contracts

In the absence of a single public registry, obtaining precise tallies of tradeable biochar credits is difficult. But the overriding consensus is that there are too few to satisfy demand.[9] As a result, the ability of buyers to secure attractive, long term biochar credits is limited. According to one recent research paper, by August of this year, only 11% of all industrial biochar credits for 2025 were not already committed.[10] So, why the shortfall?

The voluntary option

In large part, the answer comes down to the structure of the market. At present, carbon credits issued for verified biochar projects are only available through voluntary markets, as engineered carbon projects are currently barred from the world's compliance carbon markets by existing rules. This affects corporate engagement with the market for biochar-linked credits, as they are at liberty to choose whether to participate or not (unlike in compliance markets, where their participation is mandatory). As a result, the voluntary market is far less capitalised than its compliance-based equivalent; recent estimates put the value of the two markets at US$1billion (voluntary) vs US$800 billion (compliance), respectively.[11]

The exclusion of biochar from compliance markets could feasibly change in the future, albeit not immediately and most probably not across all regulated markets at once (see Box 6, page 37).[12]

Market dynamics

Other market factors also affect the supply of long term biochar credits. For one, the voluntary market has historically been skewed heavily towards avoidance-linked credits (80%) rather than removal-based credits (20%) (the category for biochar). Within the removal market, furthermore, biochar is but one of a variety of different technologies vying for the attention of offtake buyers.[13] Finally, buyers of biochar credits in the voluntary market are highly concentrated. A group of eight large corporations, led principally by a trio of large US-based technology companies: Microsoft, Google, and Meta, is responsible for the vast bulk (~90%) of the overall tons of carbon currently removed through biochar offtake agreements (see Box 1, page 11). It is difficult for small- and medium-scale developers to attract these "super buyers" as their production volumes are too small. At the same time, the effective monopoly that these large buyers have created leaves slim pickings for other buyers looking to enter the market as most biochar credits have already been contracted.

Box 1: Biochar major offtake deals

Google & Varaha (India): 100,000 tons by 2030

Microsoft & Exomad Green (Bolivia): 100,000 tons, over ten years

Exomad Green & Supercritical: 130,000 tons, multi-year exclusive

Project profiles... too few, too small

The supply problem for credible biochar offtakes is further complicated by the absence of industrial-scale projects. Most biochar developers are start-ups or scale-ups, many of which are operating at a sub-scale level (e.g. <10,000 tCO_2 per year). At such volumes, entering the carbon credit market makes challenging business sense. Not only are the administrative burden and required expertise to qualify for credits high, but the potential sales revenues are also low (due to the limited amount of credits generated). By the same token, the relatively small size of most projects limits revenues from biochar sales and related byproducts. Both factors significantly reduce the attractiveness of the biochar market as an investment proposition for large-scale funders.

Biochar producers by scale (tonnes of biochar/yr)

0-1,000	Artisanal
1,000 - 10,000	Sub-scale
10,000 - 50,000	Viable industrial scale
50,000 - 100,000	Profitable industrial scale
100,000 +	Regionally relevant scale

Buyer behaviours

Finally, the behaviour of buyers themselves reduces the supply of long term, attractive credits. At present, buyers hold almost all the cards. As stated above, the offtake agreements that biochar developers are typically offered tend to be short term and include high optionality for the buying party (e.g. easy exit clauses and flexible projects). This optionality means even supposedly secure agreements are prone to demand uncertainty and consequently inflated financial risk. The ability of a handful of buyers to effectively set the price for biochar credits adds to this volatility further, as decisions by just one or two major buyers could disproportionately affect the market price. The fate for those without offtake agreements is arguably worse, as they are reliant on spot or future prices, which are one-off and hard to predict.

> The issue is buyers want operational projects with a track record that show developers can deliver. Those kinds of projects are in really, really high demand. What we're not seeing enough of from the buy side is investment in the early-stage projects. So, we've seen a lot of projects really struggle to get going. It's a classic chicken-and-egg problem we have; developers need an offtake to get going and secure finance, but most buyers want to see the finance in place before they sign an offtake.
>
> **Sandy Doran, Supply Lead, Supercritical**

Discounts on Forward Payments

High capex costs up front are standard for all infrastructure projects. Non-artisanal biochar projects are no different in this respect. Sites need to be acquired, industrial facilities need to be built, and machinery and expertise need to be acquired. The trade-off is that operating expenditure is fairly flat once projects are up and running. Another feature is that revenues start flowing almost immediately post build, especially for certified projects with offtake agreements in place.

Clearly, however, getting over this initial capex hump requires an injection of capital up front. For biochar developers, one popular strategy to help achieve this is to sell their anticipated credits by pre-purchase or advance payment. While this may work well in the immediate term for the developer, it leaves the offtaker potentially exposed. What if the project fails to deliver? Reasonably enough, offtakers tend to request a discount on the final credit price to cover the additional risk. Such a measure also reflects the opportunity cost for the buyer of tying up capital that could be invested elsewhere.

In principle, discounts on forward payments present a workable solution for both sides. The only question is one of size. Too great a discount and a project's future economic viability may be compromised; too little and offtakers may simply opt to walk away. At present, the discount rate (when paid up front) typically lands at somewhere between 19-31% below spot prices, which is far more than what infrastructure projects should be paying.[14] For developers, such rates are crippling. The stronger a developer's risk management and the more locked-in its future revenue streams, the more leverage it has to negotiate down the discount that it pays.

Support for Developers

Assuming that biochar projects are not going to qualify for compliance schemes any time soon, developers need to consider how they can strike the best offtake agreement possible, both for themselves and for buyers, within the parameters and dynamics of the voluntary market.

1

Smart structuring: win-win offtake contracts

A good starting point for any developer entering an offtake agreement is to put themselves in the shoes of their counterparty. What do offtakers and investors really want? The answer is relatively simple: green-minded or not, security and predictability top their priority list. They want to know that projects will deliver the volumes stated (the higher, the better), within the timeframe stated, at the quality stated.

No project developer, whatever the industry, can offer 100% guarantees. What they can offer, however, is the assurance that concrete steps are in place to make their guarantees as firm as possible; so, evidence that revenues are shored up, risks are mitigated, and liabilities are assigned. The strongest offtake contracts do just that, helping to assuage buyer concerns and thus improve the developer's negotiating position.

General tips for making offtake agreements more attractive for both the buyer and seller include:

Look to the long term

Most contractual terms are no more than three or four years; in contrast, project lifespans run to 20 years or more. As a minimum, contracts should cover the investment payback period (i.e., around seven years). Ideally, they would run longer, extending to ten years or more and thus covering a sizeable proportion of project's lifespan. **Note:** this is typically the case with power purchase agreements (PPAs) in the renewable energy sector.

Build in a break clause

While both parties typically desire long term security, providing a means for either the buyer or seller to step away should the need arise offers a welcome degree of flexibility. Ensuring clear terms by which a break clause can be actioned is essential to striking the desired balance between security and flexibility. That said, developers should be very wary about terminational clauses that enable buyers to walk away on unfair or subjective grounds.

Fix on a fair discount

Given the capex needs of developers, buyers are in a strong negotiating position to demand discounts in return for prepayment of future credits; yet, overplaying their hand can ultimately prove counterproductive, as excessive discounts can jeopardise a project's long term viability and thus acerbate buyers' counterparty risk.

Centre on certification

Independently certified verification underpins the credibility of any carbon credit; selecting an exacting standard-setter (e.g. Puro.earth, Isometric, Carbon Standards International (CSI)), plus a credible third-party auditor, increases the credibility of a project's resulting credits.

2

Strategies for managing risk in VCM contracts

Risk management is an ongoing imperative for developers throughout the lifecycle of a project. But the contract stage can help to reduce the load and smooth the road ahead. How? By enabling developers to spell out what the main risks comprise, how these will be mitigated, and who must do what should any materialise.

Turn to a template

Every biochar project is different, so off-the-peg contracts will never suffice; but starting with a standardised template and then modifying it appropriately helps ensure common risks are not missed and that investor expectations are accounted for.

Open the books

Every project has its hiccups; what undermines investor confidence is being kept in the dark when problems happen. Allowing investors and buyers to audit how projects are performing and committing to provide regular progress report avoids surprises and cements trust.

Diversify the project pool

Aggregating multiple projects under a single platform or intermediary can spread risk and provide buyers with more predictable supply..

Also see: 'Mitigating Disruptions', Barrier 1, page 8

"From the financier's perspective, there just isn't that much familiarity with biochar yet or with carbon removal more generally. At the end of the day, what they care about most is that at some point in the future a project is going to generate enough revenues to repay their loan. Those revenues could come from carbon credits or from purchasers of biochar. Whatever it may be, they just want to see there's certainty of revenue in the future.

Michael Byrd, Partner in Climate Project, Philip Lee

3

Mechanisms to increase credit pricing and stability in VCM contracts

Credit pricing and stability rely heavily on project quality and market positioning, but contractual assurances can also play an important role in improving long term predictability.

Eschew exclusivity

It serves both parties for the contract not to be completely tied into a single approach to selling/buying credits. By settling on a percentage of the total volume of credits available (e.g. 80-90%), buyers have the flexibility to obtain credits from the spot market (at a potentially lower price), while developers avoid the risk of being totally reliant on a single buyer.

Offer price protections

Advanced pricing structures such as most favoured nation (MFN) clauses and price adjustment clauses reduce buyers' exposure to future price declines; non-delivery or credit insurance can have a similar effect.

Select by solvency

To date, the biochar sector has benefited from a pool of buyers with strong financials (e.g. Microsoft and Google). As the market grows and less reputable buyers potentially enter the market, developers should undertake a robust examination to check the creditworthiness of all potential offtakers.

Give guarantees

Developers that can demonstrate contractual assurances such as enforceable delivery terms, high-integrity certification, robust insurance cover, and comprehensive monitoring, reporting, and verification (MRV) measures are better placed to gain buyers' confidence and negotiate a premium price.

Big up (co-)benefits

Some buyers are willing to pay a higher price if they know that the credits are generating additional social or environmental benefits, such as yield increases, water retention or pollution remediation.

Couple up

Pooling projects with other developers spreads delivery and quality risks, as well as increasing the volume of credits, all of which support a less volatile investment proposition, providing developers with grounds for a price premium.

Useful resources

Johnstone, I., Fuss, S., Walsh, N. and Höglund, R. (2025). 'Carbon Markets for Carbon Dioxide Removal,' Climate Policy, May, 1–8. doi:10.1080/14693062.2025.2478288.

IATA (2025). A guide to the Carbon Dioxide Removals (CDR) market.

Case Study

Multi-year biochar offtake: Exomad Green and Microsoft

In December 2023, the Bolivia-based biochar producer Exomad Green signed a landmark offtake agreement with Microsoft. This initial deal saw the biochar producer, an offshoot of Exomad, a high-quality wood products manufacturer, agree to deliver over 32,000 tons of carbon removal credits by 2024. Revenues from this initial agreement helped Exomad Green scale its production, persuading Microsoft to enter a much larger offtake agreement in May 2025. This more recent deal commits Exomad Green to deliver credits for the removal of at least 1.24 million tons of CO_2e over the next then years.

The largest biochar deal of its kind (by volume) at this report's publication date, the 2025 Exomad-Microsoft offshoot agreement provides a useful reference point for how developers should approach the structuring of a successful voluntary market offtake contract. Among its most notable components are:

Contract length

The agreement stretches over a ten-year period, offering Exomad Green a fixed income over the long term.

Certification

The credits will be issued under the Puro.earth Biochar Standard,[15] widely recognised as one of the most rigorous standards for engineered carbon removal.

MRV

Monitoring, reporting, and verification for the credits is conducted by a reputable third party, Carbonfuture, whose digital MRV system (dMRV+)[16] will track every ton of CO_2 from the point of capture to the issuance of credits throughout the contract's lifespan.

Feedstock security

The agreement includes financing for a state-of-the-art Forest Monitoring Centre at Exomad's main production facility in Bolivia, ensuring that the waste wood used as feedstock in the biochar meets high environmental and ethical standards.

Product quality

Regular quality testing ensures that the biochar consistently meets high international standards, both in respect to carbon sequestration and soil enhancement.

Co-benefits

As well as avoiding the incineration (and associated emissions) of waste wood from Exomad's manufacturing business, the resulting biochar is used to improve soil fertility for farmers in Bolivia.

> By embedding dMRV [digital monitoring, reporting, and verification] into the contract, this deal delivers the transparency and traceability the market needs as it scales toward megatons of impact.*
>
> **Hannes Junginger-Gestrich, CEO, Carbonfuture**

*This quote was taken from a public source, Hannes Junginger-Gestrich was not interviewed for the development of this white paper. Data Centre Dynamics (2025). 'Microsoft to purchase 1.24m tons of carbon removal credits from biochar firm Exomad Green'.

Barrier 3

03

Biochar Offtake and Pricing

On the face of it, biochar looks like it should be a profitable business, with multiple revenue streams that allow it to mitigate concentration risks. However, the multi-revenue based approach to biochar also leads to some of the biggest challenges for developers. First, a developer must balance these revenues with each having their own specific market dynamics and potentially correlated risks with a variable cost base in feedstock.

Pulling this off successfully actually requires quite sophisticated revenue and financial management skills. This can lead to an undervaluing of biochar as a market proposition. At issue here is biochar's multi-pronged revenue streams. While new market opportunities are cropping up all the time, developers tend to focus on three primary sources of income:[17]

- **Carbon credits:** Generated by producing and applying biochar, which are purchased through the voluntary carbon market by organisations to offset their emissions.
- **Physical biochar:** Created through the sale of the biochar itself for use primarily as a building material or as a soil amendment in agriculture or horticulture.
- **Energy products or fuel:** Resulting from energy byproducts generated during the pyrolysis process, such as syngas, bio-oil, or heat, which can be used for power generation, heating, or further refined into fuels.

As a rule of thumb, most projects require at least two of these three revenues streams to be commercially viable. This is certainly the case if they wish to succeed at scale. On paper, the maths is attractive. Every one ton of physical biochar sequesters the equivalent of around 2 to 2.4 tons of carbon dioxide from the atmosphere. This translates to the same proportion of credits (i.e., 2 to 2.4). Importantly, these are issued only at the point that the physical biochar is actually utilised by the biochar's final user. This places an onus on developers to find a recipient for their physical product.

Carbon credits

Biochar carbon credits struggle with a supply-demand mismatch. At the crux of the issue are two misalignments. The first is between supply (which is low) and demand (which is high, albeit skewed heavily towards large premium buyers at present). Without the advantages of scale, developers need to sell at a high price to make their projects economically viable. On the flip side, high price levels dissuade new buyers from entering the biochar market. This limits the ability of developers to access the capital to expand, thus denying them the ability to achieve economies of scale and bring down prices in line with higher production volumes. In short, a classic Catch 22.

One specific area of contention is the need for developers to prove to carbon credit buyers that carbon finance is "catalytic". The problem habitually arises if a project is already profitable from physical biochar or energy sales; in such cases, the project may not qualify for carbon credits or may receive fewer credits. This leads to a tension for a developer between maximising revenue from co-products and maintaining eligibility for carbon finance.

Box 2: CDR credit prices

The price point for biochar credits bought through offtake agreements is typically private. However, information collated by market analysts indicate an average price range in mid-2025 of between **US$130-$200 per ton of CO_2** removed. The spot price for biochar-linked CDR credits at this same time was at the middle of this range. Biochar offsets and spot prices both compares favourably with credits issued through other CDR technologies.

Biochar	US$177/tonne CO_2
Direct Air Capture (DAC)	>US$500/tonne CO_2
Bioenergy with Carbon Capture and storage (BECCS)	US$389/tonne CO_2
Enhanced Rock Weathering	>US$200/tonne CO_2

Source: Biochar Today[18]

> Some people have a criticism of the biochar industry that, 'Oh, these companies say they're going to be able to operate these facilities, but it never works out.' But actually, biochar facilities are already working, plus they are quick to build at scale. And, at the same time, companies are taking enormous bets on BECCS [bioenergy with carbon capture and storage] at very high credit prices, with very little evidence that it's going to work without high CDR prices plus government incentives. Beyond price, right now, there are no BECCS facilities that are operational at scale except those attached to ethanal production facilities.

Myles Gray, Executive Director, US Biochar Initiative

Biochar Sales

To increase project competitiveness and long term viability, every certified biochar project should have a fixed and well-priced market for its physical biochar and other services, alongside the sale of credits.

In nascent markets, this may require business development strategies to initiate and develop demand (see Case Study, page 21). Two basic strategies to improve the price and security of non-credit revenue streams that are valid for all project types include:

1. Fit supply to demand

Too many developers start with project design (technology, feedstock, site location, etc.) and only then seek out a market for their project's byproducts. Instead, focusing on a strong demand case first and then designing the project accordingly makes for a much stronger business proposition.

2. Pursue value-based pricing

Byproducts from biochar such as improvements to soil health, increases in water retention, and better nutrient management all represent significant added value for end users. Pricing should reflect this value, recognising that specific consumer groups differ in the value they ascribe to biochar's varied suite of outputs.

Developers are also advised to adopt measures to help broadly align their biochar prices with market expectations (see Box 3, page 20). However, where market conditions are known to be volatile, it makes sense for developers to put in place anticipatory measures that allow them to share or pass on the consequent increase in prices. The seasonal and unpredictable purchasing practices of agricultural buyers of biochar is a prime example of how market trends might affect prices. Likewise, the outbreak of geopolitical tensions can have dramatic knock-on effects on the price of energy (and thus heating and cooling prices), as the global spike in energy prices following Russia's 2022 invasion of Ukraine illustrated.

Biochar developers are not unique in facing volatile prices and can take lessons from other sectors in how best to share these fluctuations with customers and other business partners.

Contract and pricing structures:

- **Index-linked pricing:** Unit prices move with a published index, such as for electricity.
- **Surcharges:** Separate line items that float with a driver, such as feedstock price.
- **Cost plus pricing:** Customer pays actual cost (sometimes verified) plus a fixed margin.
- **Dual part tariffs:** Fixed capacity/availability fee plus a variable, index linked usage fee.
- **Periodic repricing clauses:** Prices are firm for a short validity window (e.g., 30–90 days).
- **Volume-linked pricing:** Discounts contingent on firm volume forecasts.

Commercial terms:

- **Shorter quote validity:** Quotes expire quickly; repricing reflects live markets.
- **Minimum order quantities:** Reduces exposure to sudden price moves.
- **Payment-term adjustments:** Early pay discounts or supply chain finance to offset working capital impact of rising costs.
- **Prioritisation rules:** During spikes, priority goes to customers who accept pass through terms.

Risk-transfer and hedging:

- **Back to back hedging:** Supplier hedges inputs and embeds hedge cost in price.
- **Collar/band sharing:** Prices adjust only if an index moves beyond a band (e.g., ±5%) movements inside the band are absorbed by the supplier, outside are shared.
- **Fixed for floating swaps:** Customer agrees to a fixed price while supplier takes floating exposure and hedges in financial markets.

Common pitfalls to avoid:

- Using obscure or supplier-controlled indices (erodes trust).
- Omitting lags, bands, or caps (creates invoice shock).
- Over-frequent repricing without admin capability (billing disputes).
- Not aligning pass through with service levels and allocation during shortages.

Box 3: Aligning biochar prices with market expectations

The fastest way to resolve price discrepancies is to identify current causes of misalignment and, where possible, provide alternative solutions.

Take account of geography

Make buyers aware of the huge variation in project costs between the Global North and Global South, and build these into price negotiations.

Segment the market

Recognise the varied motivations and budgets of buyers in the market, determine which buyer is the best fit for your project, and tailor the price (and contract) accordingly.

Provide price stability

Many buyers value a stable fixed price, both as a means of making their costs more predictable and a hedge against market volatility; for this reason, the offer of a structured, long term offtake agreement may assuage a buyer's concerns over a higher-than-desire price.

Offer flexibility

Attractive as fixed-price contracts are, buyers are reluctant to have their hands completely tied in case of changes in circumstances; including provisions for steps such as volume adjustments, price reviews, or gain-share clauses can help provide such flexibility.

Keep track of trends

As the biochar market matures, so will demand and supply dynamics alter, with inevitable effects on prices; developers need to be sensitive to the ups and downs of the market and be ready to alter their pricing accordingly.

Be transparent

While secrecy around pricing may appear commercially sensible for one or both parties to an offtake deal, lack of price data undermines market confidence, complicates price benchmarking, and ultimately strengthens the hand of the dominant party in a price-setting negotiation.

Case Study

A Healthier Earth and Viritopia: creating demand

Developers face a classic chicken-and-egg dilemma on pricing. At the heart of the problem lie current supply levels. With very few developers yet having achieved industrial scale, supply is limited and disperse. To balance high set-up costs with low supply, developers are obliged to charge a high price, thus limiting potential buyers. Dropping the price makes biochar more attractive to more buyers, but the economics for the developer only work if supply can be increased accordingly (as this drives sales revenues). Most large buyers also desire high production volumes as it enables them to meet their sizeable demand.

So, how can developers square the troubling circle presented by low supply, high demand, and a current price point that effectively disbars investing in rapid industrialisation?

A Healthier Earth believes it has a solution. The UK-based climate tech subsidiary of Pure DC and biochar producer is betting on the creation of long term commercialisation partnerships with aligned organisations. The partnerships see the organisations work together at a trial stage, enabling both parties to test and improve end-use solutions that deliver tangible added value for the partner organisation. Assuming the solutions deliver clear, measurable benefits, A Healthier Earth is well-positioned to convert its partner into a commercial client and thereby developing its own client base. A Healthier Earth's partnership with Viritopia, the world's leading living wall specialist, demonstrates this theory in practice.

The biochar innovator approached Viritopia three years ago after planning was approved for its parent company, Pure Data Centres Group, to build, at the time the world's largest, living wall on a new data centre in North London, UK. The two organisations (A Healthier Earth and Viritopia) agreed to jointly explore the use of biochar in a growing medium for the latter's living walls. The trial proved successful, showing that biochar helped add to the total carbon sequestered by Viritopia's walls as well as significantly reduced their use of water for irrigation.

"The approach required a notable up front investment on the part of the developers, but the long term trade-off in terms of new business makes it worth it", says Alastair Collier, Founder and Chief R&D Officer of A Healthier Earth. As he explains: "We provided the biochar. We provided the thinking. We provided some time. Viritopia provided the facilities and the expertise in living walls. But the agreement was that if the trials worked, then Viritopia would then buy all its biochar from us going forwards."

And that is what has happened. A Healthier Earth is now providing biochar for the new data centre's wall, covering 7,700 square metres. Moreover, Viritopia has instructed its supplier of growing medium that it wants the company's biochar substrate solution integrated into all future orders. The fact that Viritopia was able to provide the specific formulation of biochar substrate streamlined the process for its supplier, a large horticultural firm. The request also served as an introduction to the supplier of biochar's potential, prompting it to contact A Healthier Earth separately and request trials on a variety of additional product lines.

> It all started with us identifying Viritopia as a potential end user and then approaching them to see for themselves if biochar could work for them. For us, it proved a really effective way of managing the scale-up of our supply at a price point that works for us but that is also achievable in the mainstream market at large volumes.

Alastair Collier, Chief R&D Officer, A Healthier Earth

Heat Valorisation

Pyrolysis is an exothermic process, meaning that it is self-sustaining and generates significant excess heat. Biochar producers often use this heat, which is captured on-site via heat exchangers, to dry feedstock or heat their own facilities. Where the heat produced is high in volume and surplus to the producer's requirements, it can be sold to provide an additional revenue stream. The three main markets for this heat are:

1. **Neighbouring businesses or municipalities:** which source the heat directly from a biochar facility.
2. **District heating:** where the heat is used to supply local heating networks, greenhouses or industrial facilities that are not located on a biochar project's immediate site.
3. **Conversions:** into electricity and selling into local grids as carbon neutral electricity.

Industrial users with a high demand for heat energy include sawmills, greenhouses, asphalt plants, and wastewater treatment facilities, among others. In high-cost energy markets, such as Europe, heat sales often represent an important factor in a biochar project's economic viability. Where biochar producers are able to secure long term offtake agreements for their surplus heat, such agreements can be used to support project financing as they represent a guaranteed income.

A problem faced by many developers is convincing the market of the full value of the various benefits that a single project delivers. It is very rare for developers to find a buyer that is willing to pay for the totality of a project's outputs. This is manifest in the case of heat valorisation. While a developer may find a buyer for its credits, it may struggle to find a corresponding buyer for its heat output. Location is an important factor here: Projects near residential or industrial zones are much better placed to find offtakers for their surplus heat than those situated in more remote areas. Even in built-up areas where demand is high, developers sometimes find themselves hindered from supplying their surplus heat due to poor infrastructure connections or regulatory hurdles.

In summary, on the revenue side, the challenge for developers is to lock in as many secure, long term buyers as possible for as many of its potential business lines (i.e., carbon credits, physical biochar, and heat/energy) as it can. Part of this challenge is a production issue: buyers want to know that producers will deliver at the quality and volumes promised. Part also centres on pricing: producers need to land on a viable price for their respective outputs to ensure their project's long term profitability.

Alongside revenue concerns, however, producers also need to concentrate on optimising their cost base. The ability to drive efficiencies and avoid unnecessary or avoidable expenditure is vital to the profitability of any business venture, especially those operating on tight margins. This management of costs includes precautionary measures against inflation (which can impact feedstock costs, in particular) and other external shocks. So, what steps can developers take to best manage project costs?

> Investors are looking for bankability. We believe the key to scaling newer technologies is an infrastructure real assets mindset focusing on sound unit economics created through a well-integrated commercial framework providing resilient margins and sound execution of construction.

Ralf Rank, Co-Founder, Reinova Partners

Support for Developers

Managing variable costs

If developers can bring down costs, projects can feasibly become viable at a lower price point. Certain costs, notably machinery and equipment, are fixed. Yet, other project costs oscillate in accordance with internal organisational factors and external market factors, such as a project's geographical location.[19]

Irrespective of a project's specific circumstances, there are common measures that all developers can adopt to drive down costs. These include:

Securing low-cost feedstock

The purchase and transport of feedstock is not only one of the most significant operating costs for project operators; it is also one of the most volatile. Establishing a long term, strategic partnership with a project's primary feedstock supplier(s), be they a local forestry, agriculture, or waste management company, or others, is the best option for gaining access to a stable supply of feedstock at a manageable price. This approach could be combined with the co-location of pyrolisers at or near the feedstock provider (e.g., sawmills, asphalt plants, wastewater treatment facilities), thereby reducing Capex (as much of the infrastructure is already in place) and logistics expenses.

Selecting reliable equipment:

Low-cost equipment can seem an attractive option at first but it often proves a false economy as breakages are common and maintenance requirements are high; this leads to lengthy downtimes, high production losses, and additional technical expenses. For the same reasons, standardising equipment and processes can be a good cost-saving measure as it increases efficiency and reduces maintenance costs (see Chapter 4).

Automating processes

The rapid advance of digital technologies, such as artificial intelligence and the Internet of Things (IoT), means that many operational aspects of project management (notably MRV) can now be substantially automated, saving on labour costs. The ability to acquire real-time operational data and analyse it with near immediacy also offers opportunities to drive efficiencies, reduce time, and weed out waste.

Pursuing modularity

Modular projects enable projects to be scaled more efficiently, benefiting from economies of scale and spreading fixed costs over more production; likewise, the aggregation of several medium-sized projects ("pooling" or "platforming") can also drive down costs (e.g. through collective certification or shared monitoring).

Investing in training

Increasing the level of competence and professionalism of all project participants improves efficiency and minimises costly errors. Putting robust project management processes in place similarly ensures that projects run more smoothly and efficiently (e.g., hitting budget, delivering on time, ensuring quality control).

Conclusion

For developers to demonstrate the bankability of their project, it is not sufficient to prove that they have either locked in multiple secure revenue streams or that their cost management processes are sound and rigorous. To convince financiers, both these conditions need to be in place. No credible buyer or investor looks at only one side of a project's balance sheet; it's only logical therefore that developers follow suit.

Useful resources

Supercritical (2025). 'Locked in or left behind? 2025 Biochar Offtake Report.'

Barrier 4

04

Technology Selection and Risk Management

Biochar is nothing new. Indeed, widespread discoveries of "terra preta" ("dark earth") in Amazonia have led archaeologists to believe that biochar has been used for agricultural enhancement purposes for at least two millennia.

Evidence even exists of the ancient Egyptians practicing a basic form of pyrolysis in the embalming process. Pyrolysis in its more modern form started a little over a century ago, when chemists began experimenting with a slower version of this thermal decomposition technology with torrefaction becoming commonplace in certain industries.

Complexity meets uncertainty

The chemistry of pyrolysis may not have changed much over the centuries, but its associated technologies are evolving at a blistering pace. Recent years has seen an explosion in the range of equipment available to project developers. In part, this is due to innovations in the wider tech space, particularly the boom in digital capabilities such as automation and the Internet of Things (IoT). In equal measure, it's a response to the product innovation happening within the biochar industry itself. As biochar developers experiment with new feedstocks and explore novel end-uses for biochar, equipment manufacturers have designed machines and technology to match. An important backdrop to these changes is the drive by developers to rapidly scale the sector's production profile; i.e., from the current mix of micro-, small-, and medium-size projects through to industrial-level ventures.

For many developers, especially those relatively new to industrial-scale biochar, the plethora of technological options now on offer can prove somewhat dazzling. Every individual project is a combination of moving parts. Depending on developers' feedstock choices, end-use application(s), regulatory environments, and a wide sweep of other factors, their technology needs will differ. Even with two very similar project proposals, nuances will exist that make a particular technology option apt for one developer but inappropriate for another. Technical attributes aside, the relevance of cost should not be overlooked: of all the considerations going into the decision-making calculus of developers, the price-tag for particular technologies is usually most front-of-mind.

Rapidly Evolving Technological Landscape

On the surface, the technology field for biochar appears disjointed and project specific. That said, it's possible to identify a number of evolving technological and market trends to which equipment providers are responding and of which developers should be aware.

Co-location

Establishing projects on existing industrial sites (such as cement plants, sawmills, and wastewater treatment facilities) has emerged as a popular option as it typically places developers close to feedstock sources and enables them to leverage existing infrastructure. For equipment designers, however, co-location posits important considerations around how best to integrate the pyrolysis process into a site's current operations. An element of modification and tailored design is almost inevitable.

Novel feedstocks

Wood and agricultural residues, such as rice husks and straw, have long provided a staple for biochar production, but developers are increasingly exploring alternative biomass materials to serve as feedstock. Examples include manure, sewage sludge, and invasive species, among others. While this opens up exciting new avenues for commercialisation, it adds to the technological complexity of the biochar market as each feedstock requires its own adaptations. Indeed, some may well require new technological processes altogether. Several sewage-based projects in the United States, for example, have recently introduced biodrying into their pyrolysis process to resolve problems of excessive moisture in their feedstock.

Digitalisation

The capacity of new digital technologies to capture, store, and analyse operational data in real time presents huge opportunities for on-site efficiencies, lower labour costs, and more informed decision-making. Providers of MRV services are among those leading the charge in this regard. Over the last few years, a host of new digital platforms, automated software solutions, geolocation and blockchain tolls, and other MRV solutions have entered the market. Beneficial as many of these may prove for developers, questions of quality, interoperability, and value for money can be difficult for project owners to assess.

Co-benefits

In an attempt to increase the economic viability, and thus the bankability, of their projects, developers are giving growing attention to new revenue streams alongside income from carbon credits. Heat, power, bio-oil, and landfill avoidance feature among this emerging crop of exciting revenue drivers. For most biochar developers, these represent a departure into completely new markets, each of which comes with its own myriads of technological options and potential pitfalls.

Technology Assessment and Evaluation Challenges

Biochar production is an unequivocally natural process, as its sometimes categorisation as a "nature-based solution" indicates. At the same time, it is also profoundly industrial, hence its often "engineered solution" categorisation. As the market grows in size and sophistication, this industrialised character will only become more pronounced.

As with any industrial process, the choice of technology is a business-critical issue. Get it wrong and the chance of failure is high; get it right and huge production and efficiency gains can be accrued. Naturally, any technology option has to be appropriate for the here and now; so, is it reliable, safe, low maintenance, energy efficient, etcetera? But, if biochar stands a chance of increasing supply in line with demand, technologies also need to be suitable for future expansion; so, are they easily replicable and realistically scalable?

Choosing the technology that fits an individual developer's specific strategy and operating conditions is rarely straightforward. This is due to the quantity of uncertainties and, in many cases, unknowables that are common to many nascent industries.

These arise from:

- **Market fragmentation:** Although biochar has an evolving support ecosystem around it (e.g., regional trade associations, sector conferences, specialist press, boutique advisory services, etc.), the market remains diffuse. This hinders the ability of developers to access reliable information, share experiences, and form partnerships.
- **Paucity of performance data:** There is no surer way of assessing a technology's viability than interrogating its performance history. However, the relative infancy of most biochar projects means that such data is in short supply.
- **Lack of standardisation:** As yet, no universal set of international standards exists for technology providers. This introduces significant data inconsistencies and information gaps, making it difficult for developers to assess technological attributes in a like-for-like fashion.

"We're modelled on credit ratings agencies in the capital markets like S&P, Moody's and Fitch. Our aim is to make project-related risks transparent. That way, the buyer or the investor can then understand them and make a decision on the level or risk they are comfortable with. And developers can see where they might have blind spots and take steps to mitigate these.

Sarah Heard, Senior Director, BeZero Carbon

Technology Pricing and Risk Management

To date, a high percentage of the biochar projects with offtake agreements have missed their delivery obligations. This damages the industry's credibility and reduces investor confidence, both of which negatively affects its long term bankability.

Projects failures typically relate to the quality or quantity of the carbon credits delivered, or to the delayed timing of their delivery, with technology problems frequently featuring among the causes.

Technology pricing:

- **Paying top dollar:** Developers may be tempted to select premium-priced technology in their search for maximum reliability, efficiency, and productivity. High capex costs typically oblige the developer to then set a high price for its subsequent credits and physical biochar, limiting its potential buyer pool.
- **Opting to economise:** A far more typical scenario is for developers to select technology based on affordability. Lower-priced equipment can save on a project's capex, but it often proves a false economy, as maintenance costs are often higher, downtimes are longer, and the technology's total lifetime is shorter.

Technology-related risk management:

- **Operational risks:** Mechanical breakdowns are the most common and most obvious technology-related problem experienced by developers. But biochar facilities can also encounter risks from fire (due to the close proximity of heat and dry feedstock), regulatory changes, or methodologic updates.
- **Poor management:** Lack of resources, management inexperience, or human error can raise the likelihood of technology risks materialising. Where contingencies are not in place or are insufficient, such risks can quickly escalate into expensive delays or serious reputational damage.
- **Access to post installation support:** Many pyrolysis providers are new with limited business experience. Purchasing a system where there are only one or two others in the world can expose you to significant spares, post-production support and ability to expand risks, all things that a funder will be very conscious of.

> There are many skilled engineers, but few have hands-on experience operating pyrolysis systems at an industrial scale –processing 100 to 200 tonnes of biomass per day. That presents a fundamentally different challenge. Building operational capacity and implementing clear production processes are essential to give investors confidence.

Luisa Marín, Executive Director, International Biochar Initiative

Support for Developers

1

Best practices in managing technological and operational risk

Good risk management involves anticipating risks early and taking proactive steps to minimise their likelihood of occurring. A wide range of preventative strategies are available to developers. It's important that these are seen as a collective package, with project operators giving each risk due attention. Naturally, some risks will be higher than others. But the instinct to adopt a 'pick-and-mix' approach to risk management should be avoided. Just one small risk left unattended or overlooked can potentially cause huge operational disruption.

1. Guard against unreliable or unsuitable feedstock supply

Feedstock is the lifeblood of biochar production. Ensuring this crucial link in the chain remains uninterrupted is the first prerogative of any project operator. Long term contracts with feedstock providers, careful technology selection, and extensive scenario-planning all contribute towards avoiding supply-related disruptions.

2. Keep unique project elements to a minimum

Every biochar project inevitably has its idiosyncrasies (based on location, feedstock, site conditions, etc.) and developers need to respond accordingly. By encouraging as much standardisation as possible, however, the potential for mistakes and unanticipated problems is reduced when projects are scaled up or replicated elsewhere. Adopting modular design principles and portfolio-wide standards and protocols are two effective ways of reducing unnecessary complexity.

3. Don't skimp on performance monitoring

Recent advances in sensor technology, data capture, and real-time analysis provide unprecedented visibility of a project's operating status. Investing in a digitised data-management system flags problems as they happen and, in some cases, even before they happen. Ideally, this system will provide end-to-end coverage, ensuring a full picture of a facility's operations. Data management systems comprise software and hardware elements, so ensure these are compatible and speak seamlessly to one another.

4. Put robust health and safety protocols in place

Pyrolysis is a relatively safe industrial process; but, if unexpected problems arise or operational mistakes occur, biochar projects can potentially cause harm to people (e.g., workers and end-users) or to the environment (e.g., fire and feedstock-related damage). Every project should therefore have detailed processes and procedures in place to mitigate such risks; e.g., dust control measures, fire safety drills, pollution prevention steps. It is important for developers to regularly assess and update these measures, as well as train employees and other relevant parties in how to implement them. Regular monitoring of their application is also essential.

5. Establish a maintenance plan – and stick to it

Tempting as it is to run equipment at maximum capacity for the maximum period possible, developers should resist this temptation. Frustrating as it can be to reduce production or stop it altogether for maintenance, doing so represents time and money saved in the long run. Even well-maintained machinery can be prone to failures, however. To prevent costly delays, draw up contingency plans for such scenarios, with a particular focus on operation-critical technologies.

2

Guidance on conducting due diligence for technology

Prevention rather than cure is the maxim for all effective risk management. This is as true for technology as any other aspect of a project. While it's true that an able engineer can resolve most technology-related problems, it's far better from both an operational and cost perspective to avoid the problem arising in the first place. The more effective way to achieve this us to choose the right technology up front.

But how does a developer know what "right" looks like? Box 4 offers some tips on how to whittle down the technology options available. While the criteria for developers may be the same, the answers are likely to vary, as every project is different and there is no such thing as a "one-size-fits-all" technology solution.

What does exist, however, is a set of generic due diligence steps that all developers can take to ensure they land on the right technology for them. Here are five that should be on every developer's list:

1. Be crystal clear on end objectives

Before even considering what specific technologies might be available or desirable, define what the technology needs to deliver. Such clarity immediately narrows the field of choice. Alongside the generation of carbon credits, what are the physical biochar applications that the project is seeking to deliver or the other potential revenue streams that the project is seeking to tap? If a technology doesn't fit, it doesn't matter if it's world class: it won't fly.

2. Do some digging on the manufacturer

The biochar sector may still be a relatively small market, but the number of equipment and technology providers is increasing all the time. Within this growing number, levels of quality and experience vary greatly. Most talk a good game, but it's wise to look beyond the hype and check their credentials. Where real-world performance data is available, ask to see it (where it's not, ask yourself why). If the technology is new and not fully tested at scale, discuss provisos for any teething problems that might occur. Existing clients can be an invaluable source of information; not only about the technology itself, but also about issues like the purchase process and after-sales support. Other practical due diligence steps to consider include an on-site visit to where the technology is in use, third-party evaluation, and peer benchmarking with similar types of technology.

3. Get expert technical advice

Not all developers have the level of in-house expertise necessary to accurately evaluate a particular technology's relevance or reliability. Even when such capacity is on-hand within the company, a second pair of eyes from an external expert is rarely in vain. A priority question for any such evaluation is whether the process of biochar production (e.g., pyrolysis, gasification, hydrothermal carbonisation) is compatible with the project's intended feedstock. If the answer is 'no' or even 'not quite', then it's a non-starter. A technical assessment should also take into account business-critical questions such as energy consumption, maintenance requirements, biochar yields and quality, permanence of carbon sequestration, and so forth.

4. Check for non-compliance

Be sure to check if the technology in question meets all the necessary regulatory requirements and has sign-off from a reputable certification body: anything but a firm seal of approval from all relevant bodies should be treated as a major red flag. However, compliance also depends on feedstock characteristics (type, moisture, pre-processing) and on-site operation. Therefore, provider documentation offers only limited assurance that the equipment will meet local standards, such as emissions. Note that regulations differ from country to country; so, while a piece of technology might tick all the boxes in the technology provider's home market, it could potentially fall foul of regulations in other jurisdictions. Likewise, be mindful that laws and standards are liable to change. Assess the likelihood of this happening for the technology under assessment; if so, consider the risk of the technology becoming redundant or leading to licensing or permitting problems.

5. Use a scorecard to compare

The developer who lands on the one perfect technology first time round is either extremely lucky or, perhaps more likely, a touch overhasty. In most cases, the above due diligence steps will result in a short-list of options, each with its own respective pros and cons. A scorecard can be an effective way to objectively assess each option's merits and demerits, and arrive at a final choice based on the highest total weighted score. For a sample Scorecard for technology selection (see Appendix 5).

Useful resources

Brown, R. C., Bakshi, S., & Mašek, O. (2024). 'Fundamentals of biochar production.' In Biochar for Environmental Management: Science, Technology and Implementation (pp. 57-83). Taylor & Francis. https://doi.org/10.4324/9781003297673-3

Box 4: Technology selection checklist*

1. Technical specification

Compliance, energy efficiency, throughput, reliability.

2. Performance and output

Quality of the end products.

3. Environmental impact

Emission control, off-gas treatment, end of life.

4. Cost and financial considerations

Capital investment, operating costs, Return On Investment (ROI).

5. Technical support and maintenance

Warranty, after-sales service, training, monitoring.

6. Innovation and technology

Research and Development (R&D), future compatibility, feedstock adaptability.

7. Project experience

Implementation elsewhere, references.

8. Compliance and legal aspects

Meets all legal requirements, permits, and licences.

9. Timeframe and delivery

Clear communication delivery schedules.

10. Installation considerations

Skid mounted, crane requirements, necessary.

* See Appendix 5: Model scorecard

Barrier 5

05

Administrative and Regulatory Burdens

Biochar projects do not take place in an isolated bubble in which developers are free to set their own rules.

Burdensome as this feels, close regulatory oversight actually is in the industry's interest. Why? Because for the biochar market to take hold and grow, trust is everything. External parties need to have full confidence in how projects are set up and how they operate. Without it, they will walk away. Simple as that. The best route to such assurance is a clear, well-enforced regulatory framework.

Rules and regulations therefore feature as unavoidable and necessary parts of the biochar business. On the one hand, having a common set of norms and requirements helps weed out poorly managed projects and unprofessional developers. On the other hand, a solid regulatory framework offers reliable, good-faith developers a means to demonstrate their compliance and win market trust.

In the real world, regulations do not always feel so beneficial. Often, quite the opposite. Developers regularly complain about the headache of having to navigate regulatory complexity and jump through administrative hoops. Doing so absorbs considerable management time and can add significantly to operating costs. In addition, it can (and regularly does) lead to project delays or demands for expensive modifications. In the most extreme cases, developers have had to pause or even cancel projects due to regulatory barriers. Needless to say, unresolved regulatory risks serve as a major impediment to a project's bankability.

Complex permitting processes

At its most basic, a permit acts as a biochar developer's formal permission to set up and operate. As such, it represents a non-negotiable step for any bankable investment. Yet, developers report a wide array of permit-related problems. In large part, these derive from the evolving nature of permitting rules and of the associated approval process. Requirements can differ significantly from technology to technology, and from jurisdiction to jurisdiction. They can also be subject to updates and alterations, as policymakers respond to changing market demands, new technology developments, and shifts in public opinion.

Within this confusing picture, the way in which biochar projects are classified can present an extra challenge. In some cases, for example, pyrolysis is considered as incineration, which places biochar in a different class of industry altogether. The byproducts of biochar can lead to similar classification errors, with developers sometimes

mistakenly assigned to the same category as power producers, chemical manufacturers, or waste processors. The latter is especially relevant as most jurisdictions have strict rules about applying waste to land destined for food production. These problems are compounded by the lack of knowledge that many licensing authorities have about modern biochar production. As a rule, most regulators err on the side of caution. This leads them to ask for additional information (e.g., about proof of technology, feedstock sourcing, end-use plans, and safety protocols) or to request modifications, two steps that both carry cost implications for project developers.

Not all permitting problems lie on the regulator's side of the fence. In some cases, proposed projects may present a genuine risk to local communities or to the natural environment. Authorities may legitimately judge that a project's proposed feedstock is environmentally unsustainable, for instance, or that the intended location of a biochar facility is incommensurate with existing land uses. In such circumstances, the extra provisos that the authorities may request serve to avoid costly pitfalls down the track and thus strengthen a project's long term risk profile.

Inconsistent or unclear regulatory guidance

Without question, the regulatory landscape for the biochar industry is highly fragmented. While this is not unusual for an emerging industry, it places an added burden on incumbent players and aspiring entrants alike, as project design and approvals need to be tailored to specific jurisdictional requirements. This makes it difficult and sometimes even impossible to replicate projects in different geographies.

One key feature of regulatory fragmentation is the inconsistency that it leads to between different rules and requirements. Such variance is structural in origin: the biochar industry counts many rule-makers, with little harmonisation between them. Recent years have witnessed the emergence of a plethora of different standard-setters (e.g., Puro.earth, Carbon Standards International, Isometric, Verra), for example, each with their own specific methodologies, MRV requirements, and definitions. The same is true for registries for carbon credits, which overlap in some areas but diverge in others. A similarly disperse set of validation and verification bodies (VVBs) and independent auditors has also sprung up. These third parties play an important role in strengthening the industry's overall governance (i.e., by corroborating that projects are genuinely meeting the respective standards required of them). Yet, they too come with their own lists of documentation requirements and compliance protocols. For developers, the potential for bureaucratic overload and audit fatigue is all too obvious.

Regulatory uncertainty can also arise from a genuine lack of clarity among regulators themselves. Feedstock eligibility and disclosure levels are two regulatory footballs that policy makers regularly kick back and forth, for instance. The most illustrative area of contention, however, is the fierce debate currently waging over the longevity of biochar's sequestration of carbon. The 'permanence question' is dividing both academics and policymakers, with some arguing that a timespan of anything less than 1,000 years makes biochar null and void and others maintaining that 100–300 years is probably sufficient. Current consultations by the European Union on whether or not to include carbon removal methodologies in the bloc's Emissions Trading System (EU ETS), and if so, whether to include biochar within this new category – hang substantially on the conclusion of this very live debate. Disagreement over biochar's projected permanence is also heavily influencing current discussions about biochar's status under the Paris Agreement (via a revised interpretation of Article 6.4) and within ICVCM's Core Carbon Principles. Until a final decision is made in all these cases, lack of clarity for developers will inevitably persist.

High administrative overheads

No-one welcomes form-filling, but extensive documentation and compliance requirements are a fact of life for biochar developers. The administrative load is particularly high at the permitting stage, but developers can expect to face monitoring and disclosure requirements throughout a project's lifespan. While onerous and time-consuming for developers, the practice of continuous data collection and evidence sharing is widely recognised as being vital for establishing market trust and confidence.

Documentation requests come from two primary sources: government agencies (typically, those responsible for planning, environmental management, and industrial affairs), and market actors (particularly, third-party verifiers and independent auditors). The former are concerned with ensuring compliance with local, national, and

international laws, while the remit of the latter is wider, incorporating voluntary standards and investor mandates alongside a developer's legal obligations. In addition to market actors being interested in a wider breadth of issues, they also regularly ask for a higher granularity of information and greater frequency of reporting.

That said, the focus of most documentation requests overlaps significantly between the two groups. Notable priorities relate to feedstock (e.g., type, sourcing, ancillary waste), biochar production (e.g., operational emissions, health and safety, temperature, noise pollution, biochar quality and quantity), end-use (e.g., transport, destination, proof of use, evidence of permanence), and carbon credit issuance. The last of these is especially important for buyers and investors for self-evident reasons. Core aspects of the credit certification process include the undertaking of detailed life cycle assessments (LCAs), coupled with ongoing MRV activities. These help evidence the net positive value of a project's carbon removal.

For credits to be successfully issued, it is also essential that developers can prove "additionality" – namely, that the revenue from selling carbon credits is essential for making the project happen ("catalytic"), and that the carbon removal achieved by the project would not have occurred without this finance. This avoids developers being seen to cash in on the byproduct of an industrial process that would have happened anyway: i.e., with or without revenues from credit sales. Demonstrating additionality is rarely straightforward, involving as it often does complex comparisons between hypothetical scenarios or proving a negative (e.g., feedstock would have not been put to another use or the carbon would not have been stored were it not for the project).

All these requirements result in an extensive list of administrative tasks, all of which come at the cost of additional management time and investment in specialist expertise, coupled with the threat of project delays.

> Every single standard and protocol has different rules. You can imagine the difficulty of trying to compare multiple different product types in the market that are theoretically the exact same thing, right? It's inevitably going to create challenges.

Annie Nichols, General Manager for Biochar, Mangrove Systems

Advice for Developers

Documentation and compliance may be an unavoidable part of the project process, but that does not mean their impact needs to be adversely detrimental. If developers have appropriate strategies and resources in place, then the administrative burden can become manageable.

Box 5: Project milestones

Planning

Obtaining the right to build a facility and operate it, covering key issues such as zoning, land use, use of public utilities, and site control.

Permitting

Proving that the facility will meet environmental regulations, as relate to water and air pollution, waste management, hazardous material use, health and safety, etc.

Registry requirements

Submitting documentation to prove that the requirements of the specific registry in question are met and that systems are in place to ensure continued compliance.

Life Cycle Assessment (LCA)

Mapping the "net" CO_2e sequestered through the full life of a project, from material sourcing through to final end-use.

MRV

Creating a set of clear MRV systems and processes, using internal resources, an external dMRV supplier, or a combination of both.

"The overwhelming paperwork and compliance requirements are a significant barrier, particularly for new entrants.

Patrizia Pschera, Environment and Climate Specialist, Carbon Standards International

1

Practical guidance on navigating permitting and regulatory processes

1. Guard against surprises

To borrow from the Scouts, few maxims fit better to the challenges of regulatory compliance than "Be Prepared". At the very outset of a project, developers should create a comprehensive map of the regulatory approvals that their project requires and the associated documentation that these entail. Anticipate that these requirements will differ by jurisdiction and might change over time. In particular, establish up front how a project's choice of pyrolysis, physical biochar, and the feedstock are officially classified, as this will determine which authority has regulatory oversight and will likely influence what requirements are (and are not) needed.

2. Ask around

Consulting local experts familiar with the permitting system and other relevant regulatory processes is a sure way to save time and avoid common mistakes. If a developer is new to a jurisdiction or market and needs a point to the most able local experts, then industry associations are often a good first point of call. Companies that have already gone through the permitting process can also prove an invaluable source of information, as well as a guide to local experts. Don't dismiss speaking to the regulators themselves. Naturally, developers should take steps to ensure this is done transparently and in line with established protocols, so as to avoid any accusation of unduly influencing the regulatory process. That said, most regulators welcome opportunities to engage with developers and answer any queries or doubts that they may have. For developers without the resources or time to navigate each stage of a project's regulatory journey, one option is to contract an external specialist organisation to manage the process from start to finish.

3. Stick at it

Some developers assume that once the rigours of the permitting process have passed, then the regulatory process is behind them. It is true that obtaining a permit is one of the most commercially critical and resource-intensive regulatory hurdles that a project owner will face. Yet, it is far from the only hurdle. In quick order, developers will find themselves being asked for registry submissions, due diligence packages for investors, and multiple other documentation requests. In anticipation, it makes sense not just to leave internal compliance systems in place, but to consider how they might best be bolstered. Obtaining feedback from the permitting authority can be instructive here, as it can ensure that lessons are learned and that improvements can be made for similar submissions in the future.

2

Best practices for managing administrative activities

1. Start early and start 'smart'

The temptation with permitting and other regulatory obligations is to push back the job of documentation until it is asked for. This merely stores up problems for later. Better to set up internal bureaucratic protocols and information management systems early on. This will involve creating clear lines of responsibility, and may necessitate skilling up existing staff or contracting in external subject experts. It will also necessitate investing in MRV technologies. This adds to a project's up front costs, but modern digital MRV (dMRV) solutions in particular take much of the pain out of the data collection, storage, and reporting process as well as improving data quality and accuracy.[20]

2. Streamline information flows

One of the chief causes of administrative overload is poor data management. Developers often spend too much time on compliance not because they don't have the necessary information, but because they don't know where to find it. Establishing a central information repository where developers can quickly access key data for issues of common interest to regulators and standard setters (e.g., emission levels, waste disposal, feedstock procurement, and physical biochar applications) can help immensely here. In the same way, using a recognised standard or certification (e.g., EBC, Puro Standard, CSI) as a benchmark for data collection and disclosure can drive internal efficiencies, as well as signal seriousness and professionalism to the market. Where possible, developers would do well to standardise checklists and templates for recurring compliance requests and documentation processes. All these steps help avoid duplication, improve consistency, and drive administration-related efficiencies.

3. Review, then review again

No administrative system is beyond improvement. However robust a developer's protocols or advanced its MRV technologies, new efficiencies can always be introduced. It might be that common bottlenecks come to light over time, for example, or certain steps are shown to be surplus to requirements. Likewise, legislation might be updated or new standards introduced, necessitating a developer to change its approach or modify its systems.

Box 6: Examples of jurisdictions with favourable regulatory frameworks

Japan

In 2022, the Japanese government accredited biochar use in agriculture within the country's voluntary carbon market. This permits biochar-based credits (known as "J-Credits") to be officially registered and sold through an active exchange network. The government is supporting the certification process, which is overseen by the state-backed JCredit Certification Committee, through the roll out of new dMRV tools. The legislative framework allows for credits to be traded bilaterally between developer and buyer, or indirectly through the Tokyo Stock Exchange (TSE) Carbon Credit Market (launched in October 2023).

United States

While the United States has no unified federal legal regime for carbon credits, all states permit the creation, sale, and purchase of biochar credits through independent registries on the voluntary market. Regulatory requirements differ slightly from state to state; California's AB 1305 imposes transparency requirements on all those trading in CDR credits, for instance. The Climate Action Reserve's U.S. and Canada Biochar Protocol is ICVCM "CCP approved", giving it the highest global integrity label. Other verified registries through which biochar producers can issue credits include Puro.earth, Isometric, and Verra.

United Kingdom

The United Kingdom is building a regulated removals market inside the UK Emissions Trading System. This should be ready by 2029 or before. Policy papers set a permanence benchmark of around 200 years for inclusion, which could make durable biochar eligible once methodologies are finalised.

European Union

The EU Carbon Removal Certification Framework (CRCF) entered into force in December 2024 and is expected to become operational next year. The CRCF sets legal criteria on topics such as quantification, additionality, long term storage, and sustainability. Under the current legal framework, an EU Registry has to be introduced by 2028 or before. In spite of the approval of the CRCF, at present, the EU Climate Law does not allow for the use of carbon removal methodologies to meet the EU emission targets. The same is true for the EU's compliance market, the EU ETS. However, the European Commission is currently consulting about the possibility of including carbon removal methodologies within the EU ETS as part of its Net Zero by 2050 strategy. At issue is the requirement for removals to be "permanent". This is generally interpreted as 1000+ years, which is at the upper end of most estimates for biochar. A final report is expected in mid-2026.

Australia

The Australian Carbon Farming Initiative and its regulatory body, the Clean Energy Regulator, provide a clear legal basis for carbon credits (known as "Australian Carbon Credit Units" or "ACCUs"). However, at present, this does not include biochar. This could change, as a biochar ACCU method has been proposed and currently appears on the official Method Development Tracker. For now, however, it remains unclear if the proposal will be finalised or approved.

Brazil

In late 2024, the Brazilian government created a national cap-and-trade system, the SBCE (under Law 15,042). The system, which will be phased in gradually over the coming years, includes credits from forests/REDD+ but not from agriculture. Biochar is not currently included. However, the government's Carbon Market Secretariat has yet to publish a full list of eligible methodologies, so an outside chance of its inclusion still exists.

Conclusion

Through both a technological and climate mitigation lens, the upsides of biochar are only too clear. In the carbon market, the facts speak for themselves. Biochar dominates credit deliveries, making up about 86% of the total new credits issued in 2024.[21]

Going forward, this exciting and multi-pronged climate solution is destined to play an increasingly important role in our collective efforts to prevent run-away global heating.

Yet, we only have a small window in which to act. For biochar to make a meaningful dent in atmospheric carbon levels, the production capacity of the sector will need to ramp up massively. And fast. Volumes must increase by multiple orders of magnitude. That can only happen if biochar developers rapidly industrialise. The emergence of a handful of large-scale projects indicates that this is beginning to happen. But the pace and numbers are nowhere near enough.

Developers have a huge trump card: investor demand. Project financiers and carbon credit buyers alike view biochar in an increasingly positive light. In principle, therefore, the capital to take the sector to scale is available. The challenge ahead is to mobilise it. This is eminently doable. Biochar's business fundamentals are sound and its climate credentials are solid. As more industrial projects come online, the stronger the case for biochar will become.

But time is too short to play a waiting game. Ensuring a biochar project's bankability has to be every developer's priority concern from the off. To assist in this endeavour, The Biochar Blueprint explores five financing barriers commonly experienced by biochar companies. Based on this analysis, it suggests a variety of concrete steps that project developers can take to meet investors' expectations and increase their chances of securing funding.

Landing investment – play to your audience

The difference between banking a project or not centres as much on strategy or substance as on presentation, remember perception is reality. With that in mind, below are some suggestions that biochar developers may wish to consider ahead of approaching the market for investment and development.

1. Think like a financier

Biochar developers have enormous subject expertise. From the optimal heating rates and residence times of their pyrolysis process through to the chemical attributes of their chosen feedstock, no-one knows the biochar production process better. But buyers and investors are cut from a different cloth. They talk in terms of retention rates and payback times, milestone plans and exit paths. For developers to stand a chance of securing investment and attracting buyers, some understanding of where financiers are coming from and what they are looking for is an imperative. Developers don't need to become bankers to be bankable, but efforts to see their projects through a financier's eyes will always pay dividends.

2. Pitch like an engineer

Biochar has been around for millennia, but not at the industrial scale that investors want nor that the climate demands. As a relatively new proposition in a relatively new market segment, it is understandable that some perceive it as a novelty. The words "novelty" and "bankability" rarely make comfortable bedfellows, however. Investors are looking for minimal risk and maximum certainty. In conversations with financiers, therefore, developers would do well to stress the conventional aspects of biochar production. This is highly doable. At its core, after all, an industrial biochar facility is an infrastructure asset much like any other

infrastructure asset. Where possible, draw attention to standardised practices and processes. This will raise investors' confidence that projects can scale quickly without technical or regulatory hurdles.

3. Negotiate like a buyer

The lopsided supply-demand dynamic that currently characterises the biochar industry is more than just an economic curiosity. It exerts a profound effect on bargaining power. As the primary purchasers of the relatively few certified biochar credits currently available, the sector's so-called "catalytic buyers" (think Google and Microsoft primarily, but also highly capitalised firms like Swiss Re, Boston Consulting Group, and JPMorgan Chase) hold many of the cards. The natural tendency is to push for terms that meet their needs and fit their interests. Developers may be starting from a weaker negotiating position, but that doesn't require them to capitulate. Above all, buyers want to know that developers can deliver. One-sided terms are actually inimical to both parties in the long run, not just developers. Project owners should therefore take a leaf from the buyer's deal-making book and be clear about the conditions they require to make their project a success.

4. Prepare like an auditor

Infrastructure investors and corporate buyers share a common aversion to surprises. The former wants to know its capital won't be squandered; the latter is anxious that their purchased credits won't backfire and tarnish their reputation. In both cases, the developer that can show it has second-guessed their fears and put steps in place to address them is best placed to win their ear. Not every project risk can be removed entirely. Nor do investors expect as much. But a comprehensive risk management plan with demonstrable action plans and credible targets is an absolute must. Likewise, any steps that developers can take to lock in promised revenue streams and guarantee other key deliverables will earn a major tick. By the same token, avoid measures like ambiguous break-off clauses in offtake agreement that put project outcomes in doubt. In short, as much as finding reasons for financiers to say 'yes', avoid the motivations they may have to say 'no'.

Box 7: Tips for making biochar bankable

1. Tighten offtake contracts

- Ensure clear, fixed obligations (e.g., delivery volumes, schedules, payment timelines)
- Include enforceable remedies for under-delivery or non-delivery
- Align contract duration with investment payback periods
- Use recognised certification standards

2. Secure multi-revenue streams

- Clearly articulate all potential revenue sources (credits, biochar sales, energy, etc.)
- Develop tailored marketing and education strategies to build demand
- Factor byproducts into value-based pricing

3. Mitigate potential risks

- Draw up maintenance plans and contingency protocols
- Guarantee feedstock security (e.g., price, availability, environmental credentials)
- Aggregate small projects or use platform models to diversify risk
- Choose equipment with a strong operational track record and after-sales support

4. Plan for scale

- Design for modularity and scalability
- Look for opportunities to digitise and automate operational processes
- Use standardised documentation and protocols
- Map out local compliance requirements and engage early with local authorities

5. Monitor and report consistently

- Implement digital MRV to optimise data capture and analysis
- Harmonise dataflows and centralise data management
- Provide regular progress reports and facilitate external audits
- Answer investor inquiries promptly and accurately

Our Contributors

The Biochar Blueprint draws on the expertise and insights of leaders across the biochar and carbon removal industries. Their generous contributions via interview have been instrumental in shaping The Biochar Blueprint and without their input, our goal of producing a guide to help developers scale impactful biochar projects would not be possible.

A Healthier Earth

Alastair Collier

A Healthier Earth is the climate tech R&D subsidiary of Pure DC, delivering environmental projects through science, systems thinking, and practical execution. It focuses on three interconnected challenges: removing carbon from the atmosphere, decarbonising digital infrastructure, and helping communities adapt to the impacts of climate change. Alastair Collier, Founder and Chief R&D Officer, is a climate tech innovator and leader with over 10 years of experience in strategic, innovation, and operations leadership roles in capital-intensive and investment-focused organisations. He leads a team of experts who are delivering global climate solutions and carbon removal programmes including the UK's largest biochar carbon removal facility.

Kita

James Kench

Kita is the specialist Carbon and Natural Capital insurance firm. Its mission is to de-risk high-quality projects and enable them to scale. Reduced risk leads to greater flows of upfront capital and accelerates the pace of positive climate impact. James Kench, Kita's Managing Director – Insurance, leads distribution, product development and market engagement at Kita and is a global climate risk executive with a career spanning Europe, Asia and the Americas, with a focus on emerging markets and emerging risks.

Mangrove Systems

Annie Nichols

Mangrove Systems is on a mission to accelerate the deployment of climate solutions by precisely quantifying decarbonisation. It provides a comprehensive digital MRV solution that accurately measures, quantifies, and reports on every molecule of greenhouse gas in operations to support project commercialisation and regulatory compliance. Annie Nichols, General Manager of Biochar, leads the company's go-to-market strategy for its biochar vertical and acts as the in-house subject matter expert. Annie is an expert in carbon removal methodologies, end-to-end certification processes, and digital MRV frameworks.

Puro.earth
Antti Vihavainen

Puro.earth is the world's leading carbon crediting platform for engineered carbon removal. Its mission is to mobilise the world's economy to reward carbon net-negative emissions through the Puro Standard, the world's first standard focused on carbon removal that durably stores carbon from the atmosphere for 100+ years. Antti Vihavainen, Co-Founder and Vice Chairman of Puro.earth, is an expert in topics around the transformation needed to reverse climate change and an entrepreneur with years of experience in strategy creation, implementation and business model innovation.

BeZero Carbon
Dr Bojana Bajzelj

BeZero Carbon is an independent carbon ratings agency for the voluntary carbon market. Its carbon ratings and risk tools equip world-leading organisations with the knowledge, tools and confidence to make better climate decisions. Its aim is to scale investment in environmental markets that deliver a sustainable future. Dr Bojana Bajzelj, Vice President for Carbon Removal, leads the company's work on carbon removal and technology-based solution ratings. She is an environmental scientist with a PhD in Environmental Science and Engineering from the University of Cambridge.

BeZero Carbon
Sarah Heard

Sarah Heard is an expert in sustainable development, with a focus on creating new markets that align environmental and economic incentives. Before joining BeZero, she led an innovative function at The Nature Conservancy that used market-based mechanisms to accelerate conservation outcomes and was a consultant on corporate sustainability and environmental economics.

Green Carbon Factory
Harold Joanknecht

Green Carbon Factory is localising the energy transition, operating small-scale energy generation facilities on industrial sites and for heat networks in the Netherlands. These facilities convert clean, local wood chips into green energy for local consumption, as well as into high-quality biochar. Harold Joanknecht, Co-Founder, leads the development and financing of scalable biochar and carbon removal projects in Europe. He is a senior finance and sustainability executive with a background in mechanical engineering and over 20 years of leadership experience across investment banking, corporate finance, and environmental infrastructure.

Green Carbon Factory
Jerom van Roosmalen

Jerom is a mechanical engineer and entrepreneur with over two decades of experience in developing and commercialising clean technologies across the renewable energy and circular economy sectors. As Co-CEO and co-founder of Green Carbon Factory, he leads technology development and operations for small-scale biochar and carbon removal facilities.

Philip Lee
Lev Gantly

Philip Lee LLP is a leading corporate and commercial law firm. Its award-winning Climate Projects practice equips global clients with the legal expertise and strategic insight needed to develop, finance, and scale impactful climate solutions. Lev Gantly, Partner – Climate Projects, is a transactional lawyer and expert in international climate law and policy. He focuses on supporting clients with structuring, developing, and investing in climate change mitigation and adaptation projects and advises a broad range of clients on emission reduction projects, as well as carbon dioxide removal (CDR) through natural and engineered solutions.

Philip Lee LLP
Michael Byrd

Michael is a partner in the Climate Projects practice at Philip Lee (US) LLP. He focuses on the development and financing of engineered carbon removal projects and advises technology developers, project sponsors, investors, and corporate buyers on transaction strategy and execution. His work spans carbon credit prepurchase and offtake agreements, CO_2 transportation and storage arrangements, feedstock supply contracts, and debt and equity financing for first-of-a-kind and scaled projects.

IBI
Luisa Marín

The International Biochar Initiative (IBI) is the global leader catalysing biochar's global impact for climate, environment, and communities. It empowers communities and inspires industries to integrate biochar-based solutions towards healthier ecosystems and economies worldwide. Luisa Marín is Executive Director of the International Biochar Initiative. She previously served as Country Director for General Biochar Systems in Mexico, the country's first industrial-scale biochar production initiative.

USBI

Myles Gray

The US Biochar Initiative is a non-profit focused on supporting the safe and effective use of biochar in agricultural, industrial, and built environment markets. USBI leads demonstrations, training events, and pilots in key biochar markets and also hosts the annual North American Biochar Conference. Myles Gray is the Executive Director of USBI and has been working in biochar for 15 years in academia, consulting, industry, and the non-profit sector, and is a professional water resources engineer. Myles specialises in developing biochar products and markets with a focus on soil amendments, biochar-enhanced fertilisers, horticultural substrates, stormwater treatment, and concrete.

Carbon Standards International

Patrizia Pschera

Carbon Standards International is committed to developing reliable standards for nature based verified carbon sinks and for certified biochar production. Its innovative standards are designed for global application. Patrizia Pschera is Environment and Climate Specialist at Carbon Standards International, where she works on the creation of standardisation frameworks for the carbon markets. Prior to this she was a developer of voluntary carbon projects and studied engineering science.

Supercritical

Sandy Doran

Supercritical is the leading multi-pathway carbon removal marketplace, committed to exceptionally high quality and radical transparency, building trust and credibility in the market. Sandy Doran is Supply Lead at Supercritical, where he leads the day-to-day sourcing function, combining his scientific background with commercial insight to grow Supercritical's network of high-quality carbon removal suppliers. Prior to this he worked on its Climate Science team and developed the company's biochar vetting framework.

Reinova Partners

Ralf Rank

Reinova Partners is a newly established energy transition investment firm. The firm invests in clean electricity, clean fuels, industrial decarbonisation, and other key infrastructure enablers, adding more than capital through active support and business transformation. Ralf Rank is the co-founder of Reinova Partners and brings over 20 years of energy transition infrastructure investing experience. Ralf has held Chief Investment Officer, operating CEO and asset management capability building roles for a leading asset manager, focusing on clean power, decarbonisation, clean fuels, and sustainable solutions across North America and Europe.

Appendix 1

Example structures for biochar deals

Model Type	Key Features	Why Financeable?	Example Projects/ Platforms
Biochar with Offtakes	Multi-year, bankable contracts, robust MRV, co-product sales	Predictable revenue, scalable, creditworthy buyers	Exomad Green, PyroCCS, NetZero
BECCS/DACCS with CfD	Government-backed contracts, compliance market eligibility	Stable, de-risked revenue, public/private co-funding	UK HyNet, Swedish BECCS, UK GGR
Platform/ Aggregator	Standardised contracts, aggregation, MRV, liquidity	Risk diversification, market access	Carbonfuture, Puro.earth, Supercritical
Global South Biochar	Low-cost feedstock, local markets, carbon credits	Low capex/opex, strong local demand	PyroNam, Alcom, Mash Makes, NetZero
Insurance-Enabled	Insurance for key risks, due diligence	Risk mitigation, improved access to finance	Kita, Lloyd's-backed policies

Appendix 2

Paris Agreement: Article 6[22]

1. Parties recognise that some Parties choose to pursue voluntary cooperation in the implementation of their nationally determined contributions to allow for higher ambition in their mitigation and adaptation actions and to promote sustainable development and environmental integrity.

2. Parties shall, where engaging on a voluntary basis in cooperative approaches that involve the use of internationally transferred mitigation outcomes towards nationally determined contributions, promote sustainable development and ensure environmental integrity and transparency, including in governance, and shall apply robust accounting to ensure, inter alia, the avoidance of double counting, consistent with guidance adopted by the Conference of the Parties serving as the meeting of the Parties to this Agreement.

3. The use of internationally transferred mitigation outcomes to achieve nationally determined contributions under this Agreement shall be voluntary and authorised by participating Parties.

4. A mechanism to contribute to the mitigation of greenhouse gas emissions and support sustainable development is hereby established under the authority and guidance of the Conference of the Parties serving as the meeting of the Parties to this Agreement for use by Parties on a voluntary basis. It shall be supervised by a body designated by the Conference of the Parties serving as the meeting of the Parties to this Agreement, and shall aim:

(a) To promote the mitigation of greenhouse gas emissions while fostering sustainable development;

(b) To incentivise and facilitate participation in the mitigation of greenhouse gas emissions by public and private entities authorised by a Party;

(c) To contribute to the reduction of emission levels in the host Party, which will benefit from mitigation activities resulting in emission reductions that can also be used by another Party to fulfil its nationally determined contribution; and

(d) To deliver an overall mitigation in global emissions.

5. Emission reductions resulting from the mechanism referred to in paragraph 4 of this Article shall not be used to demonstrate achievement of the host Party's nationally determined contribution if used by another Party to demonstrate achievement of its nationally determined contribution.

6. The Conference of the Parties serving as the meeting of the Parties to this Agreement shall ensure that a share of the proceeds from activities under the mechanism referred to in paragraph 4 of this Article is used to cover administrative expenses as well as to assist developing country Parties that are particularly vulnerable to the adverse effects of climate change to meet the costs of adaptation.

7. The Conference of the Parties serving as the meeting of the Parties to this Agreement shall adopt rules, modalities and procedures for the mechanism referred to in paragraph 4 of this Article at its first session.

8. Parties recognise the importance of integrated, holistic and balanced non-market approaches being available to Parties to assist in the implementation of their nationally determined contributions, in the context of sustainable development and poverty eradication, in a coordinated and effective manner, including through, inter alia, mitigation, adaptation, finance, technology transfer and capacity-building, as appropriate. These approaches shall aim to:

(a) Promote mitigation and adaptation ambition;

(b) Enhance public and private sector participation in the implementation of nationally determined contributions; and

(c) Enable opportunities for coordination across instruments and relevant institutional arrangements.

9. A framework for non-market approaches to sustainable development is hereby defined to promote the non-market approaches referred to in paragraph 8 of this Article.

Appendix 3

Main revenue streams from biochar projects

Revenue Stream	Description	Market Maturity/Value
Carbon Removal Credits	Sale of CDR credits (voluntary/ compliance markets)	High, premium prices, main driver
Physical Biochar Sales	Soil amendment, construction, animal feed	Mature in agriculture, emerging in construction
Energy/Heat/Co-products	Sale of heat, electricity, bio-oil, syngas	Variable, site-specific
Waste Management Fees	Tipping fees for accepting waste feedstock	Project/region dependent

Appendix 4

Top 10 best practices for managing technological and operational risks in biochar projects

1. Select proven, reliable technology

Choose pyrolysis or gasification equipment with a strong operational track record at the intended scale, from reputable suppliers who can provide after-sales support, spare parts, and technical assistance. Avoid unproven or cheapest-available options, as these often lead to operational failures and higher maintenance costs.

2. Ensure feedstock security and suitability

Secure long term, reliable, and local feedstock supply contracts that match the technology's requirements (moisture content, particle size, contaminants). Co-locate production with feedstock sources where possible to minimise logistics and cost risks.

3. Conduct rigorous due diligence and technology assessment

Use objective scoring matrices, checklists, and expert reviews to compare technology options, assess supplier credibility, and evaluate operational performance data before procurement.

4. Design for modularity and scalability

Deploy modular, standardised plant designs that can be replicated and scaled, reducing complexity, learning curves, and capital risk. Modular units also allow phased investment and easier troubleshooting.

5. Implement robust MRV (Measurement, Reporting, Verification) systems

Adopt digital MRV platforms and automate data collection (e.g., sensors, geotagging, satellite imagery) to ensure accurate, transparent, and low-cost verification. This supports cash flow, investor confidence, and credit issuance.

6. Develop comprehensive operational protocols and training

Create detailed operational manuals, safety protocols, and staff training programmes for all critical processes (feedstock handling, pyrolysis operation, emissions control, maintenance, fire risk). Invest in workforce development to address skills gaps.

7. Plan for redundancy, maintenance and downtime

Build in redundancy for critical equipment and plan for regular preventive maintenance to avoid unplanned outages. Keep spare parts inventory and have contingency plans for machinery breakdowns or feedstock interruptions.

8. Mitigate fire and environmental risks

Implement fire detection, suppression, and dust control systems; monitor thermographic data and manage hot work procedures. Ensure compliance with local environmental regulations and best practices for emissions and waste management.

9. Align contract structures with risk management

Structure offtake and supply contracts with clear remedies for under-delivery, price adjustment mechanisms, and enforceable terms. Use insurance products (e.g., non-delivery, credit invalidation) to de-risk delivery and revenue streams.

10. Engage early with regulators and certification bodies

Understand and plan for permitting, certification, and compliance requirements from the outset. Engage with certification bodies (e.g., Puro, CSI, EBC) and local authorities early to avoid delays and ensure project eligibility for carbon credits.

Appendix 5

Sample scoring matrix for biochar technology selection

Criteria	Weight	Score (1-5)	Weighted Score	Example Projects/Platforms
1. Technical Specification	10%			Compliance with industry standards and regulations related to pyrolysis equipment. Capacity and throughput of the equipment to handle the required volume of feedstock efficiently. Energy efficiency and waste heat recovery capabilities to minimise operational costs. Reliability and uptime, ensuring consistent and uninterrupted operations. Safety features and certifications to prevent accidents and protect the environment. Precision and accuracy of control.
2. Performance and output	10%			Quality of the end products (e.g., biochar, syngas, bio-oil) in terms of purity and consistency. Demonstrated track record of achieving optimal yields and desired properties of the pyrolysis products.
3. Environmental impact	10%			Emission control measures to minimise greenhouse gas emissions and air pollutants. Efficient off-gas treatment systems to reduce harmful by-products and odours. Compliance with environmental regulations and a commitment to sustainable practices. Provision for end of life with minimal environmental impact. Embodied carbon of equipment (bills of materials).
4. Cost and financial considerations	30%			Initial capital investment required for equipment acquisition and installation. Operating costs, including energy consumption, maintenance, and labour. Expected return on investment and payback period.

Criteria	Weight	Score (1-5)	Weighted Score	Example Projects/Platforms
5. Technical support and maintenance	10%			Availability of spare parts and ease of maintenance. Warranty and after-sales service offered by the supplier. Training and technical support provided to the operating staff. Remote monitoring. Maintenance schedule.
6. Innovation and technology	3%			Uniqueness and innovation of the pyrolysis technology offered. Research and development initiatives to improve efficiency and product quality. Compatibility with future advancements and potential for upgrades. Ability to handle various types of feedstock (e.g., agricultural waste, municipal solid waste, plastics) effectively.
7. Project experience and references	10%			Experience and successful implementation of similar pyrolysis projects. Positive references from previous customers or partners.
8. Compliance and legal aspect	7%			Adherence to all legal requirements, permits, and licenses necessary for operating the equipment. Commitment to ethical business practices and social responsibility.
9. Timeframe and delivery	7%			Ability to meet the project timeline and deliver the equipment within the specified period. Risk of supplier ability to deliver. Clear communication on lead times and delivery schedules.
10. Installation considerations	3%			Is it skid mounted or does it require a crane, how many people are required for install, what utilities are required for installation, how long does it take?

Scoring guidance:

1 = Poor/High Risk/Not Demonstrated

2 = Below Average/Some Weaknesses

3 = Average/Acceptable

4 = Good/Low Risk/Well Demonstrated

5 = Excellent/Best-in-Class/ Proven at Scale

How to use:

1. Assign a score (1-5) for each criterion based on evidence, references, and due diligence.
2. Multiply the score by the weight to get the weighted score.
3. Sum the weighted scores for each technology option.
4. The highest total weighted score indicates the best-fit technology for your context.

Tips on use:

- Adjust weights to reflect a project's specific priorities (e.g., increase weight for CAPEX/OPEX if cost is most critical).
- Use the "Notes/Evidence" column to document supporting data, references, or concerns.
- Use the matrix as a discussion tool with internal teams, investors, or procurement committee.

Appendix 6

Main types of project insurance

Non-delivery insurance

Insurance can cover the risk that a biochar project fails to deliver the contracted volume of carbon credits (e.g., due to operational failure, feedstock interruption, fire, or other unforeseen events). This gives lenders and buyers confidence that, even if the project underperforms, they will be compensated (either in cash or replacement credits), making future cash flows more predictable and reliable.

Credit insurance (non-payment)

Insurance can protect lenders or project developers against the risk that a buyer defaults on payment for carbon credits or that a project developer defaults on a loan. This reduces counterparty risk and can make it easier to secure debt financing.

Political risk insurance

Insurance can cover losses if a government changes laws or regulations in a way that negatively affects the project (e.g., revoking carbon credit eligibility, changing carbon market rules, or expropriation). This is especially relevant for projects in jurisdictions with less stable regulatory environments.

Invalidation insurance

Covers the risk that carbon credits are invalidated due to changes in methodologies, regulatory shifts, or fraud/negligence. This gives buyers and financiers more confidence in the long term value of credits.

Reversal risk insurance

For biochar, the risk is that stored carbon might be released (e.g., through fire, improper application, or mismanagement). Insurance can cover the cost of replacing credits if a reversal occurs, or replenish buffer pools as required by standards and Article 6.4. This is increasingly expected by buyers and required by standards.

Appendix 7

"The legal nature of carbon credits."

Kita, July 2025

Why is the legal nature of carbon credits important?

The legal nature of carbon credits determines how they are treated under private law – how they can be owned, transferred, used as collateral or handled in insolvency. In many jurisdictions, the legal status of verified carbon credits (VCCs) remains uncertain. While derivatives linked to VCCs may fall under existing regulatory frameworks in some markets, there is often far less clarity around the legal status of the underlying credits themselves.

This lack of legal definition creates risk and uncertainty for market participants, particularly in cross-border transactions where inconsistent rules can undermine enforceability and trust. It also limits the development of robust market infrastructure and hinders access to finance – for example, by making it more difficult to use VCCs as collateral or structure them into investment products.

Ultimately, this issue matters to a wide range of stakeholders, including project developers, investors, financial intermediaries and regulators. Without a clear, harmonised legal foundation for carbon credits, the carbon markets will continue to struggle to unlock mainstream capital flows.

What is currently happening in the industry that improves how carbon credits can be treated legally?

One of the most significant developments is the work of the International Institute for the Unification of Private Law (UNIDROIT). The Working Group is developing legal principles to clarify how private law applies to VCC transactions, with the final guidance expected in 2026. As recognised in the Draft Principles, legal uncertainty remains a key barrier to scaling finance and market efficiency, and these principles aim to provide clearer rules for ownership, transfer and enforceability. By offering guidance to market participants, legal advisors, and courts, and by encouraging legislative alignment across jurisdictions, UNIDROIT's work is expected to help reduce transaction costs, support cross-border consistency and strengthen the legal foundation of carbon markets. "UNIDROIT's work is important and helpful because it offers guidance that respects the differences between civil law and common law jurisdictions, and its publications are a valuable resource for legal practitioners worldwide", says Peter Mayer.

This work is timely, given the implementation of Article 6 of the Paris Agreement, which establishes the framework for international cooperation through carbon markets. As countries begin operationalising Article 6 mechanisms, including the use of internationally transferred mitigation outcomes (ITMOs), the line between voluntary and compliance markets is becoming more fluid. Legal clarity at the domestic and international levels will be essential to ensure VCCs can interact reliably with Article 6 markets, where issues such as ownership, transfer and the avoidance of double counting are subject to international rules and reporting requirements.

In parallel, several jurisdictions are making progress at the domestic level. Australia has legally defined its compliance credits (ACCUs) as personal property and Brazil has introduced a legal framework for tradeable emissions instruments under its new regulated carbon market. The U.S. Commodity Futures and Trading Commission views VCCs as tradeable intangible instruments. In England and Wales, allowances and related instruments under the ETS are treated as financial instruments, but the legal nature of VCCs has yet to be definitively determined. Stakeholders believe that they are likely to be treated as intangible property under common law, and recent VAT guidance signals growing official recognition of their economic value. These are encouraging signs of momentum, but such final clarity remains to be seen. Most jurisdictions have yet to address the legal status of VCCs in a systematic way, underscoring the importance of

ongoing international coordination and national regulatory engagement. This has also been the subject of recent international arbitrations, notes DeMarco, in reference to the ICSID arbitration in *Koch v. Canada*.

How does the legal nature of carbon credits impact carbon credit transactions?

Within individual transactions, the legal nature of carbon credits and the uncertainties around aspects such as ownership, transfer and enforceability are generally handled within the contracts and deal structures specific to that transaction. "The voluntary carbon market is built on contracts which makes it essential for market participants to understand the implications and enforceability of contractual choice-of-law provisions", says Peter Mayer. From the insurance perspective, this enables insurability because the policy can sit behind the terms and governing law of a specific legally-binding contract.

Greater challenges lie in the legal nature of carbon credits as it affects the development of market infrastructure and interoperability. Without legal certainty around what a VCC is, what rights it conveys and how it can be validly transferred or encumbered, even the most sophisticated registries or trading platforms cannot provide the trust and functionality required for a scalable market. For example, a technology platform might enable seamless transfers between Registry A and Registry B, but if it's unclear whether a VCC transferred in the process constitutes a legal transfer of property, counterparties face significant legal and financial risk. This undermines the potential for innovations like centralised clearing or integration between compliance and voluntary markets and limits broader market participation – particularly from institutional investors and lenders who require legal clarity to manage risk and structure transactions.

What is the role of registries under this topic?

Registries play a fundamental role in tracking issuance, ownership and retirement of carbon credits. In many ways, they function like ledgers, similar to those in other financial systems. However, unlike securities markets – which rely on central securities depositories regulated under clear legal frameworks – carbon registries are unregulated and operate without a unified regime. This creates some limitations. For example, registries may not resolve disputes over ownership or legal title. And registry entries, while evidencing a transaction, may not in themselves confer legal rights enforceable in court. As the market grows, there is increasing interest in aligning registry functions with broader legal standards used in other asset markets, to reduce legal risk and improve interoperability.

What is the relevance to carbon insurance?

Insurance plays a critical role in building trust and resilience in the voluntary carbon market, providing a uniform market mechanism to allocate risk. Industry conversations increasingly point to the potential for mandatory insurance as a way to strengthen market integrity, for example in relation to CORSIA. However, insurance is a regulated, legally binding contract and functions best in markets where there is legal clarity around the underlying asset or contract being insured. In the carbon markets, greater legal clarity around what VCCs represent – particularly in terms of ownership, transfer and enforceability – will enable insurers to design even more precise, responsive products that support project developers, buyers and investors alike, helping the market scale with confidence.

One area where this becomes particularly visible is in the role of buffer pools. If VCCs are recognised as property, this has implications for how carbon registry buffer pools are structured and managed – particularly if proprietary rights and obligations begin to flow to and from these pools. This shift would require buffer pools to meet higher legal standards, making insurance an increasingly important tool to manage reversal and other project risks.

What is one point you wish people better understood regarding the legal nature of carbon credits?

Just as financial markets rely on well-defined legal frameworks for intangible assets, the carbon markets require similar clarity to function effectively. Greater consensus on the legal treatment of verified carbon credits – whether through international initiatives like UNIDROIT or coordinated national efforts – is essential to support market integrity, reduce legal risk and enable scalable investment.

Find out more

Principles on the Legal Nature of VCCs by UNIDROIT

Voluntary Carbon Markets by IOSCO

Legal Nature of Voluntary Carbon Credits: France, Japan, Singapore by ISDA

Legal Implications of Voluntary Carbon Credits by ISDA

The Legal Character of Voluntary Carbon Credits by GenZero and Allen & Gledhill

Report on the Legal and Regulatory Aspects of Voluntary Carbon Credits by the Legal High Committee for Financial Markets of Paris

De-risking carbon markets: Managing legal uncertainty in the treatment of carbon credits by Herzog Law and BeZero Carbon

Appendix 8

Mangrove Systems: biochar production monitoring framework

Standard approach and opportunities for improvement

Category	Monitoring Parameter	Standard Collection Approach	Opportunity to Improve
UPSTREAM: Feedstock Management	Feedstock Sourcing	Evidence files (e.g., invoices) showing source location	Implement geolocation tagging at source
	Feedstock Transport	Standard driving distance calculations from origin to facility and intermediaries	Install telematics with geolocation tracking to capture actual trip distance and fuel consumption
	Feedstock Processing	Evidence files indicating processing type (e.g., chipped, ground)	Monitor with telematics installed on processing machinery for actual fuel or electricity usage
	Feedstock Mass	Weighbridge or loader scale measurements	Supplement with volumetric readings via camera systems

Category	Monitoring Parameter	Standard Collection Approach	Opportunity to Improve
MIDSTREAM: Production Process	Pyrolysis Emissions	Annual stack emissions testing	Deploy continuous emissions monitoring system (CEMS)
	Pressure Readings	Manual pressure sensors, gauges, or meters	Integrate with IoT and dMRV platform for real-time pressure data
	Reactor Temperature	In-line temperature measurements	Integrate with IoT and dMRV platform for real-time temperature data
	Co-product Production (e.g., electricity, heat, bio-oil)	Varies by co-product type	Enhance measurement improvements based on co-product
	Electricity Usage	Standard electricity meter readings	Install telematics on on-site machinery and equipment for precise electricity consumption data
	Fuel Usage	Fuel procurement logs	Install telematics on on-site machinery and equipment for precise, real-time fuel usage readings
	Maintenance	Maintenance log documenting materials used (e.g., lubricants, oil)	Implement digital maintenance tracking system with IoT and dMRV integration

Category	Monitoring Parameter	Standard Collection Approach	Opportunity to Improve
DOWNSTREAM: Biochar Processing, Distribution and Application	Biochar Production	Weighbridge or loader scale measurements	Connect with IoT and dMRV direct integration
	Water Added	Ongoing moisture testing at a lab or on-site manual water measurement	Install volumetric water meters or automated moisture sensors with remote monitoring
	Biochar Processing	Log of biochar mass processed	Install telematics on processing machinery to monitor actual fuel or electricity usage
	Biochar Transport	Standard driving distance calculations from facility to destination with intermediaries logged	Install telematics with geolocation tracking for actual trip distance and fuel consumption
	Biochar Application	Evidence files (e.g. invoices) of where biochar is delivered to and what type of application occurred	Implement QR code tracking with application type and process inputs integrated into dMRV system
	Soil Temperature	Standard soil temperature studies based on application site	Deploy QR code tracking with geolocation verification at application sites
Biochar Characteristics: Quality Testing	Organic Carbon Content	Third-party accredited lab testing	Establish on-site lab testing capabilities
	Hydrogen to Organic Carbon Ratio	Third-party accredited lab testing	Establish on-site lab testing capabilities
	Heavy Metals	Third-party accredited lab testing	Establish on-site lab testing capabilities
	PAHs, PCBs, Dioxins/ Furans	Third-party accredited lab testing	Establish on-site lab testing capabilities
	Material Impurities	Third-party accredited lab testing	Establish on-site lab testing capabilities

Appendix 9

Bankability of offtake agreements: a legal perspective on financing carbon removal projects

Philip Lee, 2025

Introduction

Novel carbon removal technologies demand substantial capital to move out of the lab and deploy at pilot and, ultimately, commercial scale. Project developers must balance significant costs relating to R&D and project development, as pressure for the sector to collectively scale to gigaton removal capacity requires undertaking technology de-risking efforts and project deployment planning in parallel. To date, project developers have largely relied on venture capital-led fundraises to cover the majority of such costs.

The current equity financing model is not fit for purpose for the much more complex and expensive commercial scale project deployments targeted to come online before the end of this decade and throughout the next. Instead, for the sector to scale, institutional lenders need to enter the space and provide project financing – limited recourse debt financing banked on the future cash flows of a project – for carbon removal projects.

To unlock project financing, it will take concerted effort to address remaining concerns relating to, for example, technology performance, availability of carbon transportation and storage infrastructure, and project costs. A hurdle to unlocking project finance that can be overcome immediately, however, is requiring that offtakes are bankable – a key building block for project finance across energy and infrastructure sectors. Although "bankability" and "project finance" are terms increasingly used in the space, the sector lacks sufficient consensus around what a bankable standard requires in terms of how offtakes are structured.

What bankability means for offtakes

A project being "bankable" means that a third-party lender has determined that all project risks have been identified, mitigated, and properly allocated in a manner that the lender is confident of debt repayment and adequate protection in a downside scenario. This requires a 360-degree assessment of projects, with the review of the project's offtakes forming part of such process. For an offtake agreement to support project financing, lenders will focus on four key questions:

1. **How firm are the contractual commitments?** Delivery volumes and schedules, payment timelines, and regimes for under-delivery must be robust enough to convince lenders that future cash flows are reliable.
2. **Can exposures and risks be quantified and allocated upfront?** Undefined remedies or pen-ended liabilities create uncertainty that undermines financing.
3. **What is the credit standing of the parties?** Remedies must be backed by creditworthy counterparties or credit support mechanisms that have real teeth.
4. **How does the offtake align with the wider project?** Offtake terms must fit seamlessly into, and integrate the terms of, the broader suite of project and finance documents, such as carbon transportation and storage arrangements, engineering, procurement and construction contracts, operation and maintenance contracts, as well as the primary bilateral or syndicated facility agreement.

Firmness of commitments

Lenders look first and foremost to the delivery and payment regime. Fixed term schedules with interim delivery obligations are essential, and any flexibility in delivery schedules, such as a floating start date, must be anchored by a longstop trigger. Milestones tied to development progress (e.g., project registration with a carbon standard, achievement of commercial operation, etc.) can provide additional assurance.

Under-delivery regimes are equally important. While some buyers adopt vague "agree to agree" regimes for addressing delivery shortfalls, lenders expect pre-agreed mechanisms to cover any scenario where a project developer is unable to deliver the contracted quantity of credits. These can include, for example, agreed permitted rollover thresholds, obligations to procure replacement credits, and/or the payment of liquidated damages.

Payment terms must also adhere to a tight timeline, with limited cure periods. Except for limited and negotiated instances, lenders expect the parties to be firmly bound to their delivery and purchase commitments. Anything that weakens the enforceability of delivery or payment obligations, such as overly broad change in law clauses, unclear force majeure regimes, or insufficiently defined change in methodology regimes, may be flagged as a bankability risk.

Quantification of exposure

Bankability requires that each party's exposure be quantified in advance. This means knowing the maximum downside in a termination scenario, as well as any potential exposure pre-termination event. Anchoring damages to costs of replacement transactions, setting pre-agreed liquidated damages amounts, and agreeing to caps are examples of market-aligned tools lenders expect to see. Open-ended obligations, vague "bad actor" triggers, or liability regimes that cannot be modelled ex ante are inconsistent with project finance principles. Understanding how these items interact with the limitations on liability and indemnification obligations in the offtake agreement is also critical.

Creditworthiness of the parties

The enforceability of remedies depends on the creditworthiness of the parties. Lenders will assess the financial strength of both the project developer and buyer entities and the availability of any credit support to backstop payment and performance obligations (e.g., a parent guarantee or letter of credit). Where credit support is required, parties may be obligated to provide such credit support on Day-1 or, as a middle ground, in the future based on performance and/or change in creditworthiness. Importantly, the creditworthiness of the buyer matters just as much as that of the project developer, as it underpins the reliability of the revenue stream against which lenders would be advancing funds.

An offtake for a direct air carbon capture and storage (DACCS) or bioenergy with carbon capture and storage (BECCS), for example, must be read together with the associated carbon transportation and storage agreement to ensure liabilities, such as reversal risk, are properly passed through from project developer to storage provider. Monitoring, reporting and verification obligations must also be aligned with the requirements of the applicable carbon standard for the offtake. If liabilities or remedies are mismatched, lenders may see the revenue stream as less stable.

Conclusion

The bankability of an offtake agreement is not a boxchecking exercise; rather, it's a holistic assessment of structure, risk allocation, and enforceability of the offtake. Project developers who approach offtake negotiations with lender expectations in mind can transform these contracts into powerful instruments that unlock debt financing and accelerate commercialisation. By securing firm commitments, quantifying exposure, ensuring creditworthy backing, and aligning upstream and downstream obligations, offtake agreements can provide the confidence lenders need to underwrite first-of-a-kind projects. Done right, they not only bridge financing gaps but also set the foundation for long term success in scaling carbon removal solutions.

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3 The main engineered CDR solutions at present include direct air capture (DAC), Bioenergy with Carbon Capture and Storage (BECCS), enhanced rock weathering, and marine CDR (mCDR), such as ocean fertilisation, ocean alkalinity enhancement, and direct ocean capture.

4 Fortune Business Insights recently valued the global biochar market size at US$763.48 million in 2024; the market analysis provider projects a compound annual growth rate of 13.60% between now and 2032, putting biochar's estimated value of US$2,097.72 million by the end of the forecast period. Fortune Business Insights (2025). 'Biochar market size, share and industry analysis.' 13 October. https://www.fortunebusinessinsights.com/industry-reports/biochar-market-100750

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Page 6:

6 Over recent years, PPAs have become increasingly more sophisticated, with the most robust including government-backed price guarantees to guard against fluctuations in the electricity market. Most notably, the United Kingdom has pioneered a contract model for low-carbon electricity generation projects known as a 'Contract for Difference' (CfD). CfD contracts provide developers with a guaranteed, pre-set "strike price" for the electricity they produce over a long term contract. If the market price for electricity is below the strike price, the government pays the generator the difference; and, vice versa, if the market price is above the strike price, the generator pays the government back the difference. The mechanism thereby offers stable, long term revenues for developers.

Page 7:

7 Introduced in 2024, the Carbon Removals and Carbon Farming (CRCF) provides standardised rules for certification, verification, and a transparent EU registry for certified units.

8 The UK Greenhouse Gas Removals (GRG) Standard refers to the regulatory and technical standards being developed by the UK government, through the British Standards Institution (BSI), to ensure the permanence and credibility of carbon removal projects needed to meet the UK's net zero by 2050 target. These standards will dictate the minimum permanence period for captured carbon (at least 200 years) and will be integrated into the UK Emissions Trading Scheme (ETS) and other regulatory frameworks to attract private investment in GGR technologies like Direct Air Capture (DAC) and Bioenergy with Carbon Capture and Storage (BECCS)

Page 10:

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12 The most likely first mover is the EU Emissions Trading System (ETS). The EU is revising ETS to potentially include domestic CDR (e.g., BECCS, DACCS), but Article 6 credits will not be eligible under ETS. Separately, Article 6 credits are approved for 2040 targets – up to 5% of emissions can be offset, enabling a 90% net reduction. Article 6 refers to the Paris Agreement clause governing the transfer of regulated carbon credits ("International Mitigation Outcomes," or ITMOs) (Appendix 2). Analysts expect biochar to remain included for 2040 targets but excluded from ETS domestic CDR due to concerns over permanence.

13 Other technologies in the carbon removal segment are direct air capture (DAC), and Bio-Energy with Carbon Capture and Storage (BECCS), and Enhanced Rock Weathering (ERW).

Page 12:

14 For example, if the spot price for high-quality biochar credits is US$200/$tCO_2$, a forward payment contract might be priced at US$138–US$162/tCO_2. See: Supercritical (2025). 'Locked in or Left Behind,' p.19.

Page 16:

15 https://puro.earth/biochar

16 https://www.carbonfuture.com/products/mrv

Page 17:

17 Gate fees are sometime presented as a fourth revenue stream. However, evidence from related industries suggests that these types of premiums can become quickly eroded with feedstock inflation (energy from waste, bio-oils from vegetable oils). In some cases, in fact, gate-fee models end up transforming into costs for developers in the medium term (i.e. three years onwards). The advice to developers is therefore not to rely on gate fees as a long term secure form of revenue.

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Page 23:

19 Developers in the Global South are typically able to secure key inputs such as land, labour, and feedstock at lower prices than those operating in the Global North. A project in Africa or Latin America, for example, might therefore be viable at a price of, say, US$80–US$100/tCO_2. In contrast, input costs in Global North markets such as the United States and Europe tend to be higher, which means projects only become viable at a higher price point (i.e. around US$200/$tCO_2$ or above).

Page 36:

20 dMRV solutions include hardware capabilities, such as temperature and weight sensors and Internet of Things-enabled (IoT) devices, as well as software solutions, such as Big Data analysis, geolocation monitoring, and artificial intelligence-empowered reporting programs.

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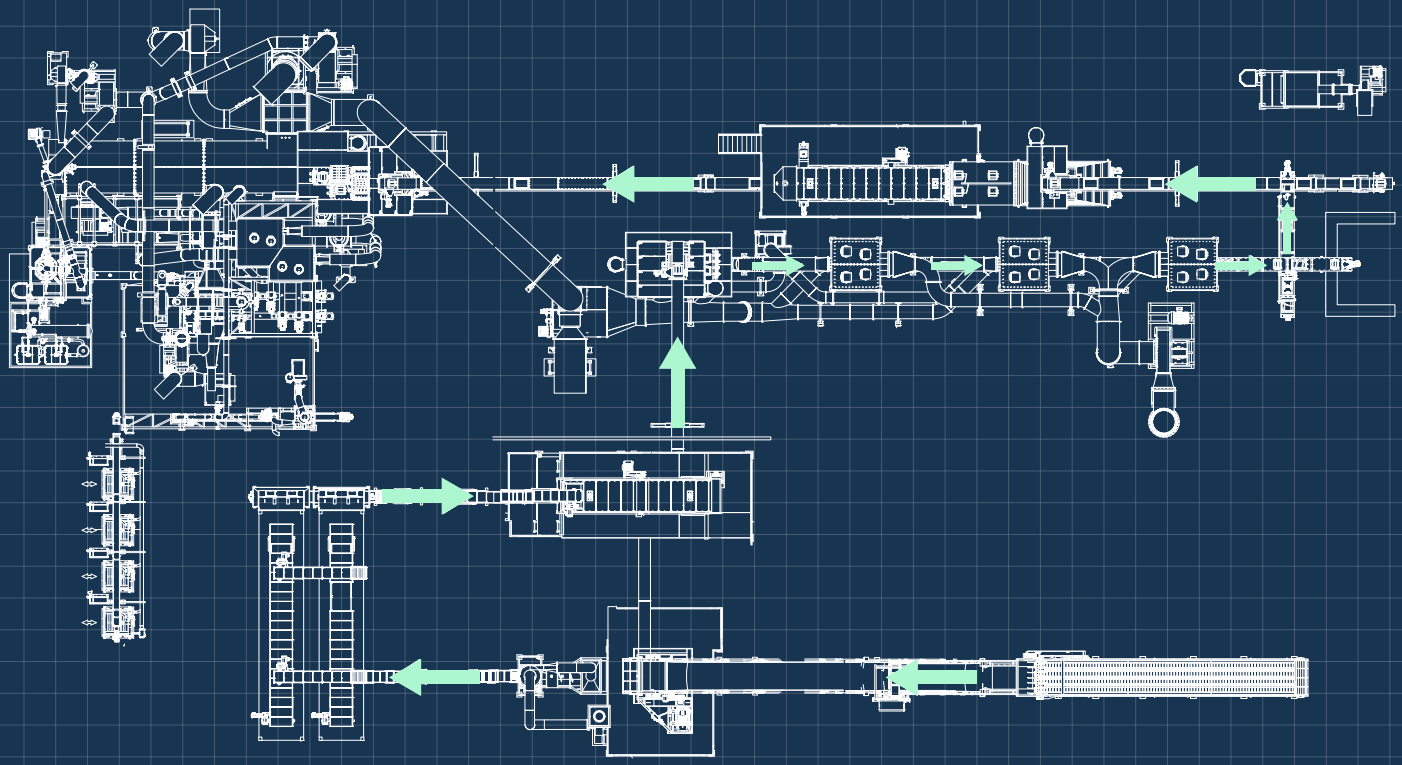

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