MANUFACTURO® | CHARM INDUSTRIAL

CHARM INDUSTRIAL

SCALES CARBON REMOVAL

WITH MANUFACTURO

OVERVIEW

Charm Industrial is pioneering a new approach to carbon removal by converting agricultural and forestry residues into two valuable outputs: bio-oil and biochar. The bio-oil is injected deep underground, where it can remain sequestered for thousands of years—offering a scalable, long-term method of carbon removal. The resulting biochar is applied to soil, where it enhances fertility, improves water retention, and contributes to stable carbon sequestration in the ground.

Although often overlooked, decomposing or burned biomass releases an estimated 3.5 billion tons of CO_2 annually—about 7% of global emissions. By transforming this residue stream into durable forms of carbon removal, Charm is permanently removing carbon from the atmosphere.

But Charm isn't just advancing how carbon is removed—they're also redefining how it's measured, verified, and valued. By engineering precise processes and leveraging Manufacturo for integrated data capture and emissions tracking, Charm is quantifying exactly how much carbon is being removed. In a space where estimates and assumptions have long prevailed, Charm is bringing scientific rigor and traceable accountability to carbon removal

Operating at the leading edge of carbon removal brings operational complexity. Charm's production combines continuous thermal processing with discrete manufacturing tasks, real-time machine data, and strict safety and documentation protocols. To scale while staying agile, the team needed a manufacturing management platform flexible enough to evolve with them. They chose Manufacturo.

THE CHALLENGE:

SCALING INNOVATION, NOT OVERHEAD

Charm's production environment is uniquely complex, exceeding the capabilities of a conventional MES. Key challenges include:

HYBRID MANUFACTURING MODES

Combining continuous "hot flow" pyrolyzer runs (12 hours to 5 days) with discrete tasks requiring precise procedural control.

STRICT SAFETY PROTOCOLS

for high-temperature equipment and material handling.

VARIABILITY IN BIOMASS

Moisture content and weather conditions can impact processing outcomes.

FIRST-OF-ITS-KIND MACHINERY

Much of the equipment is still in R&D, with performance evolving over time.

MULTI-SITE COORDINATION

between bio-oil and biochar production in Colorado and bio-oil injection in Kansas.

Before Manufacturo, paper forms were used for data collection. Operators recorded information manually, and engineers entered data into disconnected spreadsheets—requiring guesswork, increasing labor costs, and limiting opportunities to learn from the production process.

> “We needed a system that could handle real-time inputs, adapt to ongoing process development, and support the level of data integrity required to quantify carbon removal. Manufacturo gives us that flexibility—allowing us to iterate quickly, integrate machine and operator data, and evolve our workflows as we scale,”
>
> Jackson Lisec | **Lead Manufacturing Engineer at Charm**

MANUFACTURO® | CHARM

THE SOLUTION:

FLEXIBILITY BY DESIGN

Charm implemented Manufacturo in just three months—a timeline that stands in sharp contrast to ERP rollouts that can take years.

Manufacturo didn’t just speed up deployment. It gave Charm the tools to:

BRIDGE CONTINUOUS AND DISCRETE MANUFACTURING

Engineers use Manufacturo’s process plan module to embed real-time calculations into operator workflows—turning biomass weight, moisture content, and throughput into immediate, actionable results without custom development.

DATA CAPTURE AND QUALITY CONTROL WITHOUT THE GUESSWORK

All data is now captured digitally at the point of use. Tablets with built-in validation fields ensure technicians input accurate, structured data—reducing errors and streamlining compliance. Automated formulas have replaced manual calculations, helping standardize outputs across variable inputs.

BUILD A SCRIPTABLE, ENGINEER-OWNED PLATFORM

Charm's engineers write their own scripts and connect directly to the data model, enabling continuous process improvement without vendor delays or external consultants. "Basic scripting knowledge is enough," Lisec said. "It's a platform engineers can own."

CONNECT MACHINE AND OPERATIONAL DATA

Manufacturo links to SCADA and PLC systems through APIs, enabling machine-generated time series data to automatically populate corresponding work orders. This ensures traceability for both oil and char, while capturing the high-quality data needed to quantify carbon removal.

REAL-TIME SOP UPDATES ACCELERATE PROCESS UNDERSTANDING

Charm continues to refine its processes as it learns how variables like biomass quality and runtime affect outcomes. With SOPs and redlines embedded in Manufacturo, engineers can revise procedures instantly, creating a real-time feedback loop that accelerates learning and shortens iteration cycles.

THE RESULTS:

MEASURABLE IMPROVEMENTS IN OPERATIONS AND IMPACT

With Manufacturo powering their operations, Charm has unlocked new levels of efficiency, accuracy, and agility—turning complexity into opportunity across the production lifecycle.

DIGITIZED FORMS AND SOPS

Operators now use tablets to access and complete forms in real time, eliminating paper, minimizing search time, and ensuring up-to-date compliance.

REDUCED MANUAL INPUTS AND HEADCOUNT

With data entry handled at the source, Charm has streamlined operations—eliminating a dedicated data entry role and improving efficiency across the floor.

EMPOWERED ENGINEERING TEAMS

Manufacturing engineers now own their process configurations. They can quickly iterate on procedures, build custom scripts, and access live data for analysis without needing outside support.

REAL-TIME INSIGHTS FOR CARBON REMOVAL VERIFICATION

Charm is integrating MRV (Measurement, Reporting, Verification) protocols directly into Manufacturo, enabling accurate tracking of emissions, water use, and biomass flows for trusted carbon credit generation. Crucially, they're focused not only on how much carbon is removed—but also on ensuring their process does not emit more than it sequesters. By measuring emissions across each phase of production, Charm is building a verifiable, data-backed foundation for true climate impact.

SITE-TO-SITE TRANSFER AND INJECTION MONITORING

Manufacturo tracks inventory transport from Colorado to the Kansas injection site and records how much oil is injected underground. Role-based permissions ensure each team only accesses data relevant to their site—improving security and accountability.

ADDITIONAL BENEFITS:

SITE-LEVEL CUSTOMIZATION AND CONTROL

Whether in Colorado, Kansas, or any other injection site nationwide, each Charm site operates with its own view and dataset in Manufacturo. Teams can only access records relevant to their location, which Lisec says, "feels like a dedicated platform for each site." That structure is essential for managing regulated activities like injection, which require traceable, localized control without losing enterprise-wide integrity.

LOOKING AHEAD:

ENABLING THE NEXT PHASE OF GROWTH

Charm's next generation pyrolyzer designs will increase the carbon density of their bio-oil and reduce downtime—creating a more cost-effective, higher-quality carbon credit for customers. As the team applies DFMA (Design for Manufacturing and Assembly) principles to optimize these systems, Manufacturo remains central to their iterative, data-driven process

"We're not just tracking production—we're learning from it," said Jackson Lisec, Lead Manufacturing Engineer at Charm. "Partnering with Manufacturo gives us the feedback loop and powerful data sets we need to scale smarter—and push forward a vision of transparency in carbon removal."

With Manufacturo, Charm can capture, categorize, and analyze everything from carbon intensity to injection volume—positioning the company to lead the carbon removal industry in both scientific accountability and operational excellence.

"Charm Industrial is operating at the intersection of manufacturing innovation and climate science. Supporting their mission requires more than a traditional MES—it demands a flexible, scriptable platform that can adapt in real time to novel equipment, evolving processes, and exacting data requirements. With Manufacturo, Charm's engineers can configure, connect, and continuously refine operations across production, transport, and injection—enabling a traceable, high-integrity carbon removal pipeline. We're proud to power the operational backbone of such a transformative approach to carbon removal."

CHARM

ABOUT CHARM INDUSTRIAL

Charm Industrial is a climate technology company that converts agricultural and forestry residues into a carbon-rich liquid known as bio-oil, which is then injected deep underground for long-term carbon storage. In addition to bio-oil, Charm also produces biochar, a co-product used to enhance soil health and sequester additional carbon in agricultural applications. By combining innovative biomass conversion with scientifically grounded measurement and verification practices, Charm delivers a scalable, high-integrity approach to carbon removal—and is helping set the standard for transparency and accountability in the carbon dioxide removal market.

MANUFACTURO

ABOUT MANUFACTURO

Manufacturo is a modern, all-in-one manufacturing management platform built to support high-complexity operations. It integrates essential capabilities—including MES, QMS, WMS, Purchasing, Costing, MRP, Document Management, Demand & Supply Planning, BOM Management, Factory Scheduling, and Maintenance Management—into a single, connected digital thread. Manufacturo empowers teams with real-time visibility, streamlined coordination, and full traceability across every stage of production, helping manufacturers scale smarter and operate with greater agility.