RENNEBURG

A White Paper

Torrefaction of Wood Biomass

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HEYL & PATTERSON

CUSTOM ENGINEERED PRODUCTS AND SERVICES

Introduction

Biomass is biological material from living or recently living organisms, and represents the world's largest renewable resource. Plant matter such as trees, branches and stumps can be broken up into wood chips and pellets that can then be used to generate electricity or produce heat. Torrefaction is a thermochemical process that reduces the moisture content of wood biomass and increases its energy density, transforming it into a charred material resembling charcoal.

Through this process, volatiles and biopolymers are removed from the wood, along with the moisture. All that remains of the original wood is a smaller, blackened solid that can be made into dense pellets of bio-coal. Torrefaction can reduce the mass of wood by up to 30% (dry mass basis), resulting in a denser, higher-valued product that can be transported more economically than wood chips.

With Heyl & Patterson's torrefaction equipment, wood retains up to 90% of its energy value. This energy-dense end-product can be used as a replacement for coal or co-fired with coal in electric power plants. This man-made coal can provide energy rates of up to 23.7 million BTU per ton. Natural coal generally provides 28.4 million BTU per ton.

- **Biomass**
  Biological material from living or recently living organisms, such as wood, waste, hydrogen gas or alcohol fuels that can be used as a renewable energy source
- **Cellulose**
  Structural component of the primary cell wall of green plants and algae, used to produce paper, cardboard, cellophane and rayon
- **Energy Density**
  Amount of energy stored in a given system or region of space per unit volume or per unit mass
- **Hemicellulose**
  Natural polymer present in plant cell walls
- **Hydrophobic**
  Exclusion of water molecules, describing the segregation and repulsion between water and certain substances
- **Lignin**
  Complex chemical compound that sequesters atmospheric carbon into the living tissues of woody perennial vegetation
- **Pyrolysis**
  Thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen
- **Thermochemical**
  Chemical reaction and/or physical transformation associated with energy and heat

The Torrefaction Process

Torrefied wood is made by mild pyrolysis of wood biomass within a torrefaction reactor, or rotary calciner, at temperatures of 500-600° F (260-320° C). This removes water and low boiling-point organics and partially breaks down cellulose, hemicellulose and lignin. Reaction gases can be captured and used as a supplemental fuel source for the process. Torrefaction achieves a stable moisture content of 0-3%, reduction of mass by 30%, retention of 90% of original energy content and removal of smoke producing agents. Torrefied wood has a heating value of approximately 10,000 BTU per pound.

During heating, biomass releases volatile gases. If not completely combusted, these gases can be carcinogenic, just like smoke from forest fires. During the torrefaction process, these gases are captured and completely combusted, and the heat is used to dry the incoming biomass material. After combustion, the exhaust gases are then non-polluting and harmless to human health.

The main form of processed biomass in use today is pelletized dry sawdust. These wood pellets represent a relatively clean fuel that is internationally available, easy to handle and has a relatively low transport cost. Wood pellets work well in coal-fired plants and are regarded as a proven technology.

However, standard wood pellets have their drawbacks. Pellets need dedicated silo storage to avoid degradation, and co-firing with coal may influence primary air requirements, combustion behavior, heat transfer, boiler efficiency, by-products and emissions. These various issues mean that wood pellets are not a commodity fuel that can be blended with coal in whatever proportions are desired.

Torrefaction creates a biomass product with superior handling and co-firing capabilities than standard wood pellets. Due to its hydrophobic nature, torrefied wood pellets can be stored in the open air, which eliminates the need for silos. Torrefied wood represents a true commodity fuel.

Businesses that rely on coal can benefit by replacing some of that coal with the renewable energy of torrefied wood. Regions with the highest coal use have the greatest opportunity to implement positive change by substituting torrefied wood for some of their coal.

Characteristics of torrefied wood:

- High energy content (approximately 10,000 BTU/lb)
- Hydrophobic (repels water) to prevent rot. Torrefied wood can be stockpiled outside like coal.
- Friable (can be crumbled or pulverized)
- Ability to be pelletized or briquetted

Process Overview

Green Wood Chips

ATMOSPHERE

AIR POLLUTION CONTROL

Clean Air

H2O, VOCs & Particulate Matter

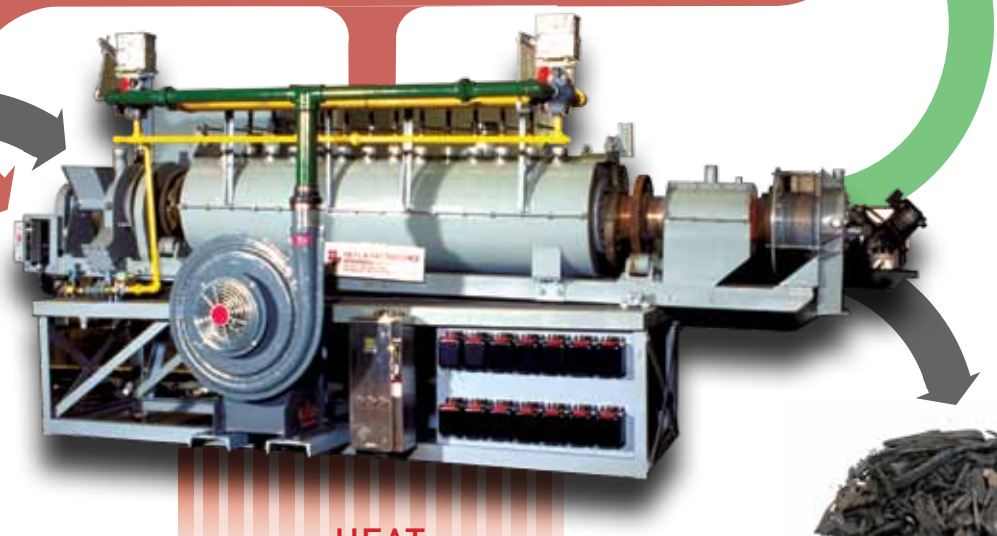
DRYER*

Sweep Gas (H2O, VOCs, Other Gases)

HEAT

Stack Gas Heat Recovery

Low Moisture Wood Chips



HEAT

Torrefaction Calciner

Torrefied Wood Chips

PELLETIZER

Torrefied Wood Pellets

*Use of a dryer is for high moisture feed material only.
It can be omitted when low moisture feed is available.

Torrefaction Equipment

ADVANTAGES OF HEYL & PATTERSON'S TORREFACTION REACTOR

- Multizone, accurate temperature control to handle varying feedstocks
- Specialized seals to prevent oxygen infiltration
- Low sweep gas volume needed to inert atmosphere and recover off-gases for supplemental fuel source
- Proven technology for other applications

In order to create torrefied wood, commercial-grade thermal processing equipment is required. The equipment must create an atmosphere that will heat biomass without allowing it to burn. Temperatures and conditions suitable for a thermo-chemical change in the wood must be sustained within the equipment.

The Renneburg Rotary Calciner from Heyl & Patterson uses an indirect heat source to continuously process bulk materials that are combustible, potentially contaminating and thermally sensitive. Low moisture wood is fed into a rotating calciner shell, which is enclosed and heated from the exterior in a stationary furnace. This guarantees complete separation of heat source and biomass during processing. The rotation and slope of the rotary shell motivates the material through the chamber from feed point to the discharge at the opposite end.

Heat from the calciner causes the wood to give off water vapor, volatile organic compounds (VOCs) and other gases. The combustion of these off gases is recovered by the calciner and is used to heat the process. For high moisture feed material, a rotary dryer can be added to the starting point. The dryer will reduce the moisture content in the material so that it can then be moved to the calciner.

Heyl & Patterson's drying and processing equipment ensures that biomass undergoes a full treatment process without damaging the end product. This means the torrefied wood being produced will not degrade in quality over time.

Under optimal conditions, the Heyl & Patterson equipment would be located near the source of the feedstock, to greatly improve the economics of using biomass as a viable energy source. The cost associated with transportation from the feedstock source to the customer is greatly reduced by the increase in energy density of the material through torrefaction.

Torrefied wood can be blended with currently-used coal as feed into the boiler to moderate the change. Blending torrefied wood in the boiler feed has been proven to improve boiler efficiency and reduce sulfur dioxide (SO2) emissions. This offers significant advantages over 100% coal usage on a same-cost basis, including the overall reduction in power plant emissions.

Heyl & Patterson's pilot plant testing laboratory can determine the appropriate processing conditions for all applications. From a test to a small toll run, our lab facility can provide the scalable data to determine the exact criteria for your process.

Uses for Torrefied Wood

Wood that has been torrefied can be used in a variety of commercial operations, and can help power plants operate with lower carbon dioxide emissions. Power plants that utilize coal as a basis of energy can add torrefied wood to their firing processes. Factories, such as steel plants, that utilize coal or other resources to heat metals can add torrefied biomass to their processes as well. There is also a growing demand for biomass-fueled residential heating systems. Wood heaters are already in use to heat homes and water, and torrefied wood may make mass production of such systems practical.

Torrefied wood fuels can be easily applied as:

- High-grade smokeless fuels for industrial, commercial and domestic (residential heating or backyard grilling) use
- Solid fuel for direct co-firing with pulverized coal at electric power plants
- Upgraded feedstock for fuel pellets, briquettes and other densified biomass fuels
- Feedstock in gasification processes
- Soil additive to improve plant growth and health

Reasons To Use Bio-Coal

In addition to the positive impact on the environment, there are many reasons to use torrefied wood in addition to or in place of other heating and energy resources. They include:

- The energy density of torrefied wood is 5–6 times higher than wood chips and about 1.5 times higher than ordinary wood pellets
- The torrefaction process creates such a dense product that transportation costs are reduced. More quantities of fuel can be packed into the same amount of space, reducing the number of loads required to provide the same amount of energy.
- Wood that has been fed through the torrefaction process is more efficient in plant processes due to the chemical and physical properties of the resulting material.
- Beyond the capital cost of the torrefaction equipment itself, the cost of producing torrefied wood is affordable.

Although infrastructure is not yet in place to allow for the use of torrefied wood in many commercial and residential applications, the potential for such use definitely exists. In a time when governments and corporations seek ideas for sustainable resources, torrefaction provides a ready-to-use process for building upon.

- Process uses no chemicals or toxic substances
- Nearly nonexistent moisture content
- Resistant to biodegradation
- Can be stored for long periods of time
- Resistant to insects
- Treated through the core
- Utilizes the same material handling and pulverizing equipment as coal

About the authors

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About Heyl & Patterson Inc.

Founded in 1887 in Pittsburgh, PA, Heyl & Patterson Inc. provides high quality, custom engineered solutions for thermal processing and bulk material handling applications around the globe. Our Renneburg thermal processing products and services include some of the largest high-efficiency Dryers and Coolers in the world, as well as Calciners, Powder & Bulk Material Processors and Pilot Plant Laboratory Testing. Heyl & Patterson innovated the Railcar Dumper Unloader and offers a wide range of bulk material handling equipment, including Railcar & Barge Movers and Barge Unloaders.

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