One of the World's Oldest Fuels gets a Makeover and New Market Potential: Torrefaction of Woody Biomass

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According to researchers in Idaho National Laboratory's Bioenergy Program, torrefaction of woody biomass could reduce variability in biomass feedstock and enable development of a commodity-type product for green energy generation and usage.

Biomass was the primary source of energy worldwide until a few generations ago, when the energy-density, storability, and transportability of fossil fuels enabled one of the most rapid cultural transformations in the history of humankind: the industrial revolution. In just a few hundred years, coal, oil, and natural gas have prompted development of highly efficient, high-volume manufacturing and transportation systems that have become the foundation of the world economy. Over-reliance on fossil resources has also led to environmental and energy security concerns. One of the greatest advantages of using biomass to replace fossil fuels is reduced greenhouse emissions and carbon footprint.

Europe is leading the way in offsetting its growing fossil fuel demand with renewable bioenergy, and through policy they have created markets for wood pellet trade to support residential and industrial heating and cofiring with coal to produce electricity. However, in Europe and countries around the world, mobilizing sustainable, cost-effective, and reliable biomass feedstock supplies is one of the greatest constraints limiting expansion of bioenergy production. In order to compete effectively with fossil fuels and garner investor confidence in bioenergy production, biomass supplies can be made more appealing by becoming more like the resources they are intended to replace. Researchers in the Bioenergy Program at Idaho National Laboratory (INL) are focused on developing feedstocks and supply systems that do just that: making woody biomass more like the fuels that have changed the world. One approach they are exploring is torrefaction of wood to give it important "coal-like" handling and heating characteristics.

Biomass Limitations as Fuel

In comparison with fossil fuel resources in general, "as-harvested" woody biomass is less desirable because of its high moisture content, its lack of bulk density, its tendency to degrade, and its low calorific value (CV). All of these factors are interdependent and result in increased costs for energy output. For example, high-moisture-content biomass requires more energy to grind, which is required for feeding it into heating and power-generation appliances. It also leads to decomposition during storage and results in costly dry matter losses. Grinding of high-moisture-content wood chips results in irregular particle shapes, creating yet another handling issue, especially during feeding in co-firing or gasification systems. In terms of chemical composition, high-moisture-content biomass has high oxygen content and less carbon and hydrogen, making it less suitable for thermochemical and cofiring applications.

The Torrefaction Makeover

There is a great deal of interest in torrefaction as a method of transforming biomass into a product more like coal. Torrefaction is not a new technology—it has been used industrially for hundreds of years to roast coffee beans—and its effects on wood chips and other biomass resources directly addresses many biomass limitations that are restricting industry expansion.

Torrefaction occurs as biomass is slowly heated to a temperature range of 200–300°C in an environment without oxygen. This is hot enough to almost completely dry the material and produce chemical changes without causing combustion. When the INL torrefaction unit is running, the air is filled with the spirit of celebration, not only because the surrounding campus smells like a barbeque from the roasting woodchips, but also because researchers know the potential of torrefaction to be a game-changing bioenergy industry technology. Thermal treatment studies at INL on both woody and herbaceous biomass have focused on understanding the subtleties of change that occur to biomass as it is heated, which are depicted in Figure 1.

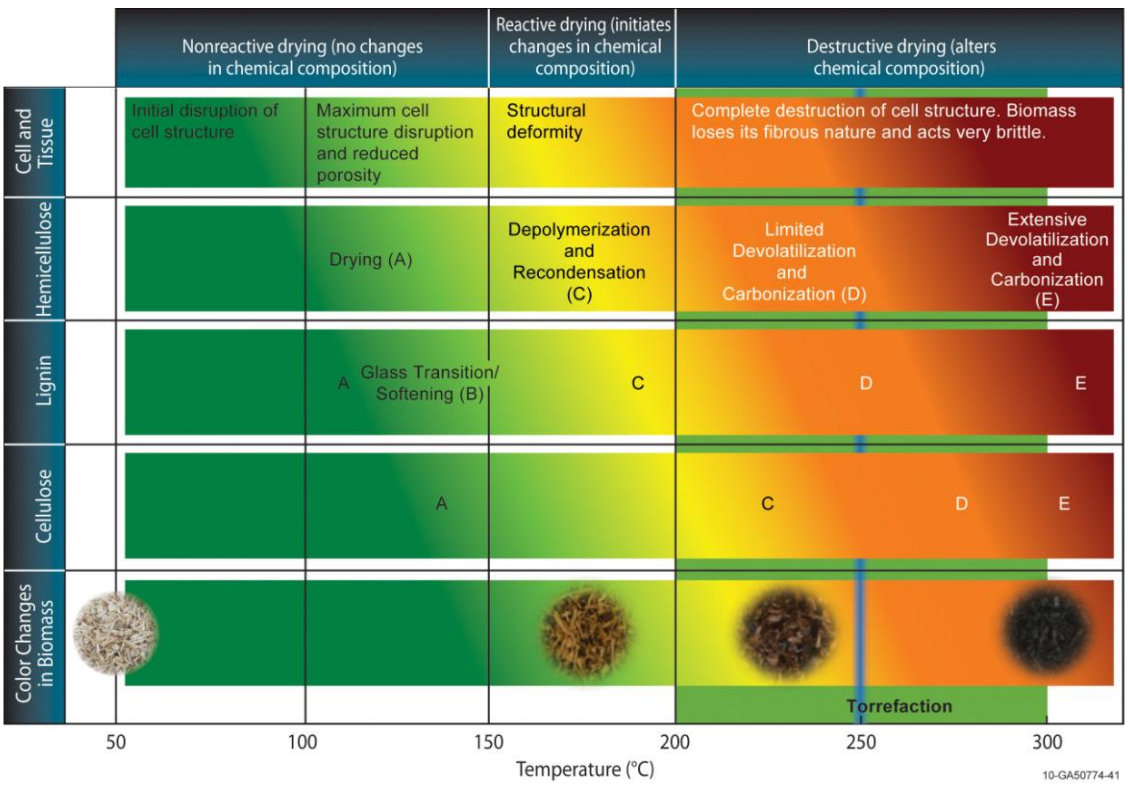

Figure 1. Spectrum of biomass degradation at different temperatures of thermal treatments.

At thermal treatment temperatures of 50–150°C, biomass loses free water, or the water that flows throughout the plant tissues, which reduces the material’s overall bulk density. At temperatures of 150–200°C, hydrogen and carbon bonds begin to break, which allows elimination of bound water, or water that is held tightly in the plant’s micropores, and causes the biomass to lose its fibrous nature, making it even easier to grind.

Finally, at temperatures of 200–300°C, or the torrefaction range, not only has the material given up most of its moisture while retaining most of its energy value (70% of initial wood weight and 90% of initial energy content), it actually undergoes chemical changes that greatly improve its coal-like qualities. Carbonization and devolatilization occur, resulting in emission of off-gases that can be recycled to help power the torrefaction process. Destruction of the plant's cell structure makes it even more brittle, further improving its grindability and making the material more uniform and consistent. The combination of these changes reduces the material's ability to rehydrate, so its sheds rather than absorbs external moisture and is far less prone to rot. Torrefied biomass has similar combustion characteristics as coal, and the blackened material appears more like coal.

Torrefied/Densified Biomass: Near-Term Uniform Biomass Commodity Potential

Torrefaction of ground wood results in a product with ~22 mmBTU per ton, which is comparable to 24 mmBTU per ton of low ranking coals like peat, lignite and brown coals; however, the difference in bulk density makes it difficult for biomass to be cost-competitive with coal, which has a bulk density of 850 kg per m^3 compared to torrefied wood at ~230 kg per m^3.

Combined torrefaction and pelletization was proposed by the Energy Research Centre of the Netherlands (ECN) for production of high energy and mass density biomass for energy applications. Densifying torrefied wood by pelleting or briquetting increases the bulk density to 750 to 850 kg per m^3, significantly reducing transportation and logistics limitations because larger volumes of material can be handled in one load for a similar cost. Figure 2 shows examples of undensified and densified torrefied wood products.

Figure 2. Torrefied wood chips (left) and pelleted torrefied wood (right).

Figure 3 shows the order of preprocessing operations proposed by the ECN to produce a uniform commodity feedstock that handles and performs more like coal and can be used to produce a variety of renewable energy products.

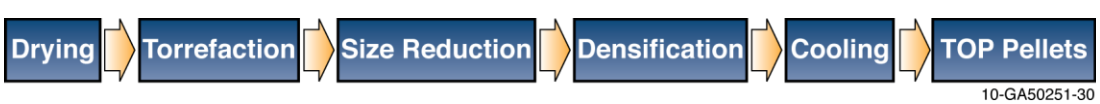

Figure 3. Flow diagram for production of torrefied wood pellets.

In comparison with conventional wood pellets, the ECN estimates a 30% logistics cost savings when transporting torrefied, pelleted biomass in the existing pellet infrastructure. Torrefied densified wood products have great near-term market potential because (1) they are compatible with existing high-volume transportation infrastructures and (2) existing conversion facilities and appliances can use the material or be readily adapted to.

Improved Product Attributes of Torrefied Biomass

Torrefaction also upgrades biomass with product attributes that will not only make biomass easier to trade alongside other energy commodities, but also reduces risks posed to feedstock producers and biorefiners by fluctuating demand and supply balances. These attributes enable cost-competitive, reliable feedstock supplies and consistent, uniform physical, chemical, and storage properties to meet biorefinery specification requirements.

Cost-Competitive, Reliable Feedstock Supplies

Reduced logistics costs – The ECN reports that torrefaction and densification increase bulk density nearly four-fold and can reduce logistics costs by 30%.

Reduced preprocessing costs – INL grinding studies on torrefied biomass find significant reduction in grinding energy required (50–70% less) as compared to raw biomass.

Improved storability – Hydrophobicity studies conducted by INL and Oak Ridge National Laboratory (ORNL) find that torrefaction dramatically reduces the need for expensive covered storage and helps to retain energy value during storage and long-distance transportation.

Consistent, Uniform Physical, Chemical, and Storage Properties

Improved flowability – Grinding studies at INL have found that torrefied biomass has better particle size and shape sphericity after grinding, which makes it easier to handle in existing high-volume transportation systems and more suitable for thermochemical applications, like gasification, cofiring and pyrolysis.

Reduced variability – The ECN has found that torrefied biomass has more consistent moisture content (less than 3%) and pulverizes more evenly than untreated biomass, resulting in better blending of varying plant fractions.

Improved energy value – Torrefaction studies conducted by INL indicate that biomass retains most of its energy content while giving up moisture and low-energy-content volatiles, which increases heating value and improves combustion efficiency.

Increased Product Outlets and Market Flexibility

Torrefaction is an effective way to make biomass into an energy commodity more like conventional energy commodities, but one the greatest advantages of torrefied densified biomass is that it offers environmental and energy security advantages over fossil fuels. This makes use of woody biomass attractive for a variety of heating and energy production applications. Improved physical, chemical, and storage properties make torrefied wood pellets a good replacement for regular wood pellets in co-firing and gasification plants. High-energy-content torrefied wood pellets increase the thermal energies of combustion and gasification systems.

There are a number of existing or near-term applications for torrefied wood pellets, including (1) industrial, commercial, and domestic heat; (2) cofiring directly with pulverized coal for power generation, (3) pyrolysis oil production, and (4) other advanced bioenergy applications under development. The variety of product outlets for torrefied and densified biomass gives feedstock producers and biorefiners greater flexibility in buying and selling biomass products to meet future energy demands.

ACKNOWLEDGEMENTS

This work is supported by the U.S. Department of Energy, under DOE Idaho Operations Office Contract DE-AC07-05ID14517. Accordingly, the U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this manuscript, or allow others to do so, for U.S. Government purposes.

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