

# **Biomass Baling into Large Square Bales for Efficient Transport, Storage, and Handling**

James H. Dooley, David Lanning, Christopher Lanning, James Fridley  
Forest Concepts, LLC

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## **Abstract**

Forest Concepts is working under a federal contract from the USDA CSREES SBIR program to develop better methods to collect and transport woody biomass collected from small-scale fuels reduction projects (ranging from residential lots to 20 acre parcels) in the true wildland-urban intermix zone (WUI). Our specific objective is to enable more of the material to be delivered to value-added uses including energy, biorefineries, and engineered wood products. A secondary objective is to enable diversion of urban greenwood from landfills and compost facilities. Our solution to the problem is to develop baling equipment and technology that enable woody biomass to be baled for transport on standard flatbed trucks, rail, and barge. The driving assumption behind our project is that baled biomass a) preserves user values as compared to on-site chipping, and b) facilitates delivery to more distant users than can be economically reached by chip vans or bulk bins. Another consideration for urban and suburban sources is that baling within residential areas produces lower noise, lower dust (and aerosols), and is potentially safer than chipping. We have designed and tested a baler that is a mid-size unit to demonstrate the concepts for equipment, on-site operations, and baled-material distribution logistics. Smaller and larger balers will be defined as appropriate for other markets.

## **Introduction**

Forest Concepts is working to develop better methods to collect and transport woody biomass collected from urban and suburban areas. Our objective is to develop technological solutions to the problem of collecting woody biomass from community wildfire protection projects in the wildland-urban intermix, and to efficiently transport the resulting material to bioenergy and biobased products manufacturers. There are two facets to the problem. Most of the work is done in urban and suburban residential neighborhoods, presenting safety, noise and operational challenges for conventional forest equipment systems. The customers for urban-source biomass are often hundreds of miles away, making high-density transport solutions a necessity. The current situation of on-site chipping with landscape chippers and disposal or land application of the resulting chips is generally acknowledged as costly and inefficient. If more appropriate equipment and logistics systems were available, many of the organizations, governmental entities, and contractors involved in the quest of wildfire protection would adopt the better technical solution.

## **Our Solution to the Problem of Biomass Handling**

Our solution to the problem was to develop equipment and knowledge that enable woody biomass to be baled for transport on standard flatbed trucks, rail, and barge. The driving assumption behind our project was that baled biomass a) preserves user values as compared to on-site chipping, and b) facilitates delivery to more distant users than can be economically reached by chip vans or bulk bins. A secondary consideration, particularly for urban and

suburban sources, was that baling within residential areas produces lower noise, lower dust (and aerosols), and is potentially safer than chipping. The baler that we are developing and testing is a mid-size unit to demonstrate the concepts for equipment, on-site operations, and baled-material distribution logistics. Smaller and larger balers will be defined as appropriate for other markets.

To a large extent, we achieved our research and development objectives. We demonstrated that woody biomass of the type removed from wildland urban interface fire protection projects and urban greenwood can be effectively baled into large square bales and transported on conventional flatbed trucks. We produced several truckloads of baled woody biomass and delivered the bales to distant users in Washington and Oregon. Bale integrity was good during long-haul highway transport on flatbed trucks with tarped loads. Receivers had no problems processing the baled biomass through their existing grinders and chippers. In fact, all receivers observed that the ease of handling bales would likely result in lower processing cost and increased throughput in their grinders. Thus, we validated our hypotheses that baled woody biomass should enable long-distance transport and should reduce the cost of handling and processing by receivers.

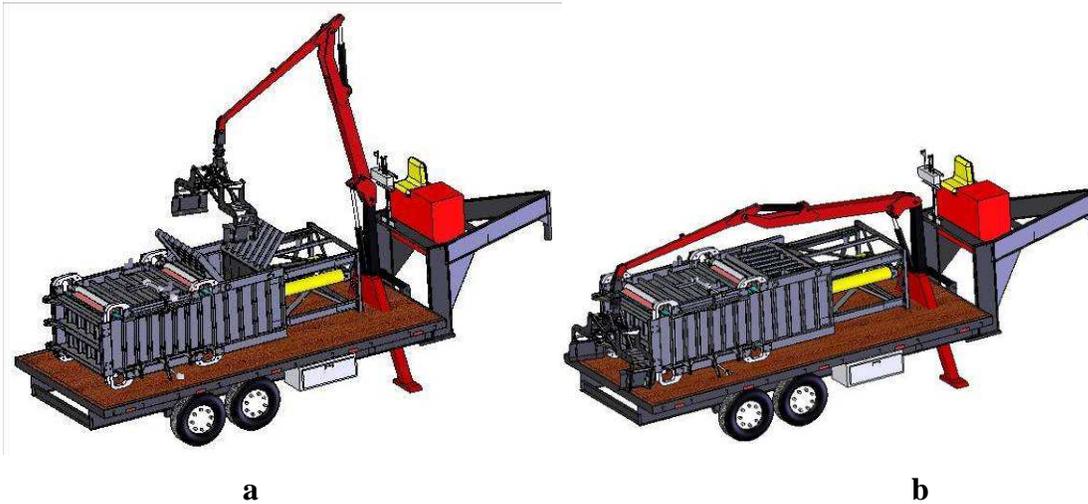
Commercial implementation of the project results will require design and manufacture of a new “biomass class” of balers – either by existing industrial or agricultural baler makers or by biomass processing equipment makers as a product line extension. Receivers of woody biomass bales demonstrated that they can handle and process the material with existing equipment. However, addition of bale squeezes, bale busters and infeed conveyors is expected to substantially reduce handling and processing costs. Investment by biomass handlers in such equipment, all of which exists on the market today, will not be made until sufficient quantity of baled woody biomass is available to justify the capital investment.

Many of the project activities were conducted with full participation of others in the profession, industry and public. One major public demonstration was held in Medford, Oregon and another was held in the Seattle, Washington area. Industry field demonstrations were held in Hoquiam and Kettle Falls, Washington. In all, presentations were made at eleven events and conferences to-date, and at least three more are scheduled later in 2008.

The first year of the project (SBIR Phase I) focused on problem definition and development of operational specifications for baling systems. During that phase, more than 60 interviews and site visits were conducted across four western states. The development phase began with a year-long science and fundamental engineering effort to extend the existing knowledge base – primarily from research conducted by Stokes, Stuart and others in the late 1970s. Major advancements in knowledge included 1) the development of compression vs. bale density relationships, 2) woody biomass shear bar design and performance data, 3) Poisson’s ratio for baling woody biomass, and 4) methods to classify woody biomass physical parameters. Select results have been or will be reported in conference proceedings, posters and other outreach events. A number of patent applications are in process in preparation of licensing the technologies, and certain results are being held as trade secrets.

The project culminated with the design, fabrication and testing of a custom woody biomass baler for use in urban and suburban areas as a substitute for arborist-type chippers. Beginning in July 2007, our engineering team of Dave Lanning, Chris Lanning, Taneka Aristidou, and Jim Fridley began the process of designing a prototype biomass baler. The design is fully documented in proprietary design reports, computerized analyses, and detailed drawings. Fabrication began in

October 2007 and was completed in March 2008. The baler was designed to be integrated with our existing smallwood trailer and self-loader as shown in the computer models below.



**Figures 1a, 1b.** Computer model of self-loader trailer with prototype baler and specially designed grapple as engineered in November 2007.



**Figures 2a, 2b.** Fully assembled self-loader trailer with prototype baler and grapple during initial testing in April 2008.

Fabrication and debugging of the baler was completed at the Forest Concepts shop in Auburn, WA. Machined components and flat steel waterjet and laser cutting were outsourced. Our team did all the welding, hydraulic circuitry, electronics, wiring and assembly. Two features of the design are particularly notable. The baler hydraulic system is entirely “fly by wire, under automated sequencing of a programmable logic controller (PLC). This enables automatic sequencing of bale compression chamber cycles and bale ejection positioning. This frees the loader operator to concentrate mostly on loading and handling biomass. The hydraulic power unit runs on a small 30 horsepower engine that provides power to both the baler and loader. Two pumps are used. One is a high flow low pressure gear pump and the other is as low flow high pressure pump. The PLC controller allocates flow from each pump and an attached accumulator to maximize cylinder speeds while minimizing horsepower consumed.



**Figures 3.** Field trial of prototype biomass baler at BRC Inc. yard waste facility in Auburn, WA.

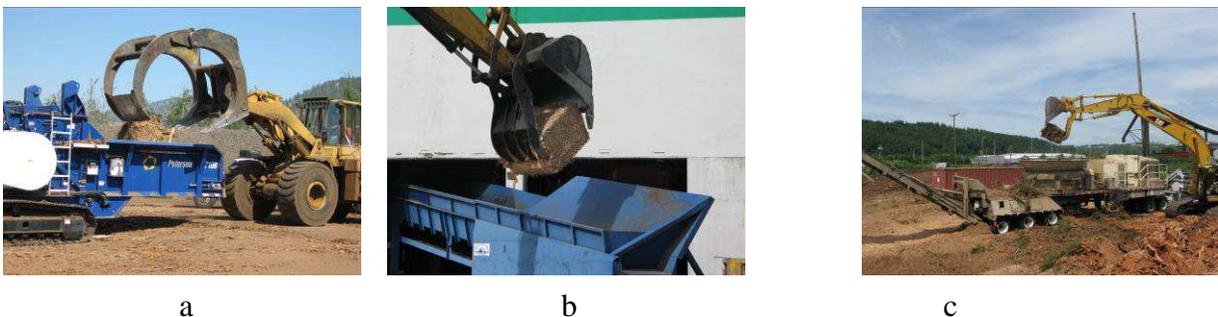
The photos above show how the loader picks up biomass from the ground and places it into a top-loading infeed section. During bale compression the two finger-grates close to pack biomass into the chamber and form the top surface of the baler. Completed bales are ejected out the curb side of the baler to facilitate tying and lifting by the loader. Finished bales can be lifted onto companion haul trailers or trucks, or set on the roadside for later collection.



**Figures 4.** Bales of woody biomass produced by the prototype and research balers.

We conducted bale processing experiments with biomass processors in Washington and Oregon.

- Rainier Wood Recyclers – Auburn, WA – 6 miles
- Cedar Grove Compost – Maple Valley, WA – 19 miles
- Grays Harbor Paper and Cogeneration – Hoquiam, WA – 94 miles
- Vaagen Brothers Lumber / Avista Power – Colville, WA – 353 miles
- Biomass One – Medford, OR – 426 miles



**Figures 5a, 5b, 5c.** Woody biomass bales being processed by cooperators. a) Vaagen Brothers processing with Peterson horizontal axis grinder, b) Rainier Wood Recyclers dropping onto infeed conveyor to large fixed Universal Grinder, c) Grays Harbor Paper & Cogeneration feeding into large tub grinder.

All materials for the field trials were baled and then palletized for handling and shipment. Depending on the type of material in each bale, the bales were either stacked two or three high for trucking. The five biomass users in Washington and Oregon who processed prototype bales all commented that baled biomass would be easier and less costly to handle and process than bulk biomass. The processing demonstration held in Medford, Oregon at the Biomass One cogeneration plant was attended by more than twenty observers from the forest products industry, local agencies and the Bureau of Land Management. All other user trials were restricted to company employees due to safety concerns by the cooperators. However, photos, video and sample materials were obtained for use in off-site public presentations.

## **Conclusions**

Research and development activities conducted under USDA CSREES SBIR Phase II funding provide important science, engineering, and performance knowledge that enable design of specialized balers for woody biomass and specification of handling systems at centralized collection points or end users.

We demonstrated the technical and economic viability of baling woody biomass and delivery to distant users as an alternative to chipping for local waste disposal. New scientific and engineering knowledge was developed to a) characterize woody biomass in the context of preserving value and enabling baling; b) shearing and compression properties of both individual biomass pieces and bulk material; and c) handling and transportation characteristics of baled woody biomass. Design data was developed that will reduce the time and risk for licensees to bring commercial biomass balers to market.

## **Acknowledgements**

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