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Field Experience with Street Legal Square Baler for Woody Biomass

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Abstract. We conducted a problem analysis in 2005 to recommend an optimal method for collection, transport, and handling of woody biomass in urban centers, suburban landscapes, and forested areas. The analysis concluded that street-legal biomass balers should replace tow-behind chippers to enable woody biomass to be packaged and handled just like other recyclables. Design and development of an engineering prototype street-legal baler for woody biomass was completed in early 2008. Two years of testing and demonstrations in urban, suburban, and forest settings have produced a wealth of technical and market information that will inform commercialization of woody biomass baling technologies. This paper reports on the results of baling and logistics trials across a range of operating environments and biomass materials.

Keywords. *Biomass, baling, supply chain, logistics, recycling, urban*

Introduction

For more than 100 years, baling has proven to be the most economical method for handling, transporting, storage and delivery of hay, recycled paper and similar materials.

Many chipper owner/operators would switch to balers in a heartbeat to improve safety, reduce operating costs, and eliminate neighbor complaints about noise and dust, as well as to simplify woody biomass disposal. If they could sell or direct their woody biomass debris into the bioenergy markets so much the better.

The "sound-science, disciplined design" approach taken by Forest Concepts to create purpose-built baling solutions enables a new generation of baling, bale handling and systems solutions to biomass delivery.

Competition for fiber and fuel is already intense between biopower plants, pellet fuel mills, and the traditional composite wood products industries. Federal incentives, notably the USDA Biomass Crop Assistance Program (BCAP), are trying to stimulate growth in the woody biomass supply. Collection and transport cost for chips greatly limit the supply radius for many biomass buyers in spite of incentives offered. Biomass baling with the Forest Concepts' technologies has the potential to reduce collection and transport costs by more than half thus increasing the cost-effective supply radius.

The 2012 commercial launch of second generation biofuels based on cellulosic feedstocks is rapidly approaching, and governments increasingly support the global priority to switch from imported fossil fuels to bioenergy for heat and power; BUT costly delivery of adequate feedstocks has emerged as a critical limiting factor. Facility developers are scrambling to tie up biomass sources and to site new facilities; BUT the $64,000 question is how large the cost-effective delivery area will be for feedstocks.

Figure 1. Current and project supply area for biopower plant in Northern California.

Biomass feedstock delivery has emerged as one of the critical factors that has stalled development of many planned bioenergy facilities and limited the capacity of others already on-line. Existing methods for at-the-source chipping, shredding and hauling with specialized trucks have proven to be costly in some cases and logistically impractical in others. Additionally, tens of millions of tons of chipped cellulosic biomass is dumped each year because it does not or cannot meet the quality specifications for users. These problems are particularly true for woody biomass produced by tree service firms, landscape managers and municipalities in urban/suburban areas. Our street legal biomass baling technology enables woody biomass to join cardboard, paper, cans and many other materials as important recyclables, AND to be collected and handled just like other baled urban recyclables.

Today, the cost-effective supply distance for chipped hog fuel is about 50-75 km (35 – 50 miles). However, with baled biomass and reasonable infrastructure, the delivery circle can be enlarged to 150 km in most cases and even 300 km in some cases. The Biomass Baler Technology from

Forest Concepts enables facilities to be sited in more rural communities and yet draw feedstocks from urban centers, or to build larger facilities that use economies of scale to reduce their costs as compared to distributed small facilities.

Safety Emphasis

Balers are known to be generally safer to operate than chippers and grinders. The safety zone around a baler system is only a few meters – not much more than the length of the woody materials being handled. In contrast, the safety zone around a chipper is typically 25 to 50 meters, and for tub grinders is 75-100 meters. Chippers and grinders tend to throw large chunks of material up into the air and for long distances while crushers and balers do not. The Forest Concepts street legal biomass baler was specifically designed to operate in residential neighborhoods, parks, and planned communities. All powered equipment has inherent safety risks and must be operated by qualified personnel.

Applications for a Street Legal Biomass Baler

The following chart of woody biomass by source is adapted from the 2005 U.S. federal interagency biomass availability study best known as the Billion Ton Report (Perlack et al. 2005). The study segmented the availability of woody biomass by source as shown by the vertical bars, and the bars were divided by that which is already collected and used (blue), that which is readily available but not currently used due primarily to high collection and transport costs (pink) and the growth expected in the next few years as the economy improves, federal incentives increase, regulatory changes restrict field burning, or other factors. The figure below includes several sources not separately detailed in the Billion Ton Report.

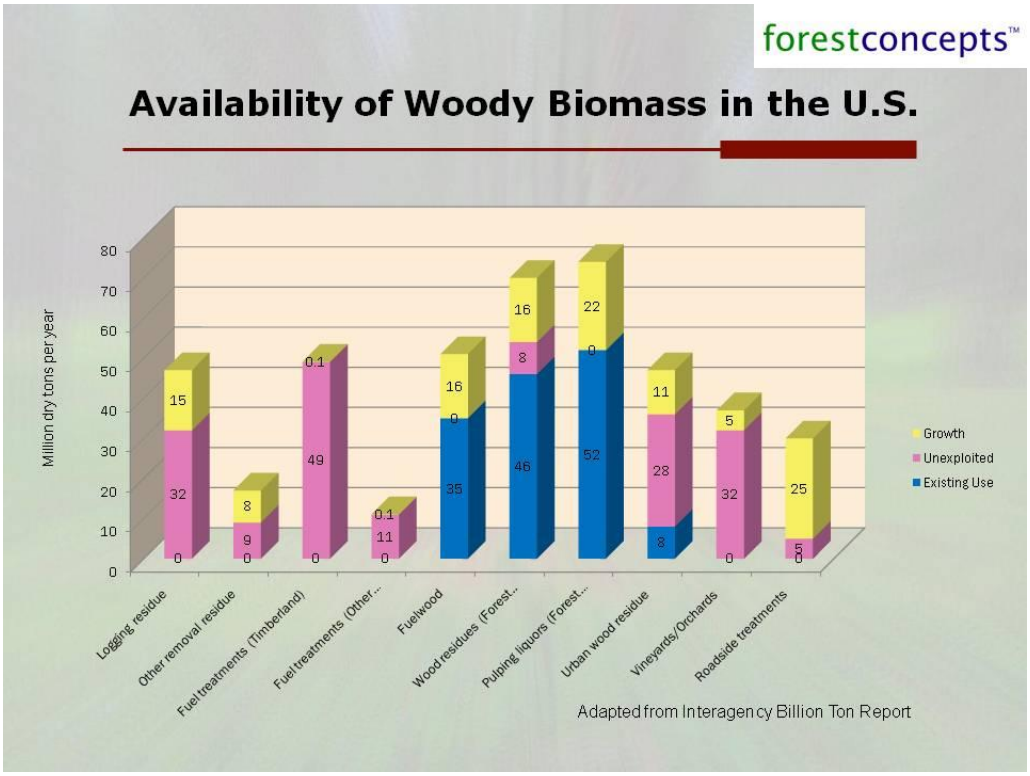

Figure 2. Availability of woody biomass in the United States.

The design specifications for the Forest Concepts street legal biomass baler were crafted to replace existing chippers and to capture market growth in the Fuel Treatments, Urban Wood Residue, Vineyard/Orchard, and Roadside Vegetation Management Treatments sectors of the above chart. Preliminary designs of large baler models for logging residue are complete, but are outside the scope of this paper.

The urban/suburban/agricultural woody biomass market sectors can be aggregated into fewer groups based on the type of customer entity. The list below is in rank order with the strongest demand listed first:

- Arborists – tree service firms
- Agriculture – orchards, vineyards
- Forestry – forest management (not logging)
- Parks, golf courses, green spaces, planned communities, corporate sites, preserves, ranches
- Municipalities, county and state agencies, highway departments
- Landscapers
- Consumers

Forest Concepts has tested and demonstrated an engineering prototype street legal baler in most of these sectors. A summary of the field testing is the primary objective of this paper.

Design of a Street Legal Woody Biomass Baler

The engineering design parameters and development of the Forest Concepts baler technology have been previously described in other conference papers. The logic for handling woody biomass in large square bales was presented in 2006 (Dooley et al. 2006). Design factors including functional requirements and constraints were described in 2007 (Lanning et al. 2007). Testing and evaluation of the baler functions were presented at the Council on Forest Engineering conference in 2008 (Dooley et al. 2008). Results of time-motion and productivity were reported at the Society of American Foresters annual meeting in 2009 (Dooley et al. 2009).

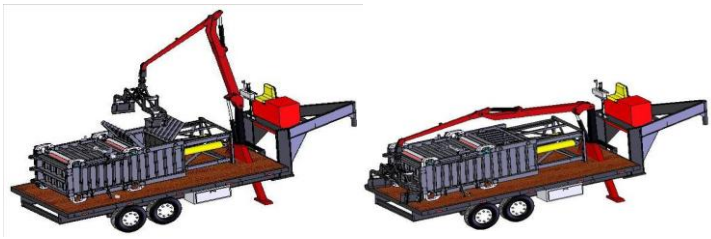

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Figure 3. Computer model of self-loader trailer with prototype baler and specially designed grapple as engineered in November 2007.

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Figure 4. Fully assembled self-loader trailer with prototype baler and grapple during initial testing in April 2008.

Figure 5. 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 infeed 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.

Field Experience in a Municipal Setting

Forest Concepts conducted a two-day field trial and demonstration in cooperation with the City of Auburn, Washington. The objective of the field trial was to evaluate baling of woody biomass as an alternative to chipping. The current practice of chipping provides chip mulch for use on City parks and landscapes, as well as a source of biomass to local compost producers. A premise of the field trial was that baled biomass could be collected and consolidated just like other recyclables and sold to cogeneration and other bioenergy facilities in the region.

The parks and roads maintenance crews collected tree trimmings for approximately three weeks prior to the trial and dumped them on a play field at the GSA Park on “C” Street in Auburn. Several additional truckloads were delivered during the trial and dumped in space that opened up as earlier piles were baled.

The entire field of woody biomass provided by the City of Auburn resulted in nine bales that weighed approximately 600 kg (1,300 pounds) each.

Figure 6. Field trial with City of Auburn, Washington to bale brush from parks and road maintenance operations.

On Thursday morning under rainy/snowy skies, a public demonstration was held for Auburn Mayor Lewis and others. Engineer David Lanning from Forest Concepts explained the biomass baling concept and how our two-person crew of Tom Broderick on the chainsaw and Chris Lanning in the operator's chair processed the piles into bales. By the end of the field trial on a warm, sunny early Friday afternoon, all of the woody biomass was baled into a stack of nine bales. As can be seen in the photographs, the material ranged from dormant hardwood branches to fresh green conifer prunings.

Figure 7. Baled City of Auburn woody biomass was shipped in standard trailer to Grays Harbor Paper where it was ground into hog fuel for their cogeneration plant.

Baled woody biomass from the Auburn trial was picked up by a Grays Harbor Paper Company truck as a back-haul after delivering recycled paper to Seattle. The use of conventional trucks that deliver paper from Hoquiam to Seattle to back-haul fuel for the mill enables delivery of low cost biomass fuel.

Field Experience in a Residential Setting

An important set of design criteria and baler specifications related to safe operation in residential neighborhoods as an alternative to conventional arborist chippers for collecting residential greenwood biomass. Low noise, small safety zone, and all-curbside operation were among the neighborhood friendly design criteria.

Figure 8. Collection and baling of winter hardwood prunings in a residential neighborhood.

The engineering prototype baler was operated in a residential neighborhood to bale winter prunings from a large maple tree. The prunings had been stacked near the curb by the homeowner. As can be seen in the above photos the loader could easily reach across the sidewalk to pick up the prunings for loading into the baler. A ground crew member ensured that walkers did not enter the workspace and picked up any material that was too small or dispersed for the loader to collect.

Field Experience in a Forestry Setting

An early impetus for the development of a street legal woody biomass baler was to enable capture and cost-effective delivery of thinnings resulting from forest management and wildfire risk reduction projects in the wildland-urban interface. As it was in the case for operating in residential neighborhoods, baling in support of forest thinning hand crews typically is along roads with recreational traffic. Baler productivity only needs to be sufficient to keep up with a 4-6 person ground crew – typically 1-4 tons per day.

Figure 9. Baling tops and limbs from roadside thinning on the Deschutes National Forest.

Several field trials were conducted in forest settings to evaluate the performance and design of the engineering prototype baler. One trial was conducted near Sisters, Oregon on the Deschutes National Forest. The site had been thinned about one month prior to the baler trial

and merchantable logs were removed while the brush, branches and tops were piled along a roadside. The road connected two recreational camping areas in the Metolius river corridor. One operator and one ground crew member worked their way down the biomass windrow and baled the material in the order it was piled. Log segments up to 400 mm (16 inches) diameter were cut to 1.5 m lengths to fit into the baler and other long branches were slashed as they were picked up by the grapple loader. Resulting bales were set along the road for later pickup by the logging contractor.

Figure 10. Baling wildfire protection riparian thinnings on Yakama Nation forest land.

Another forestry biomass trial was held in central Washington in cooperation with the Yakama Nation forest managers. This particular test was planned to evaluate the potential for baling “old and dry” slash piles from riparian thinning that had been done two years earlier. The woody biomass had been piled in small “haystacks” for burning, but weather conditions for safe pile burning had not been favorable, resulting in old dry piles that were now a fire hazard themselves.

We found that the dry ponderosa and lodgepole pine branches and stems could be baled into bales that weighed approximately 500 kg (1,100 lb.). Since the woody material had already been slashed to short pieces in anticipation of pile burning, the ground crew work was minimal.

Field Experience with Christmas Trees from Residential Collection

Two national waste collection and management firms cooperated with Forest Concepts to explore the potential to bale residential Christmas trees into high density bales for trucking from urban centers to biopower and cogeneration customers in distant rural communities.

Figure 11. Route truck unloading whole Christmas trees and baling into high density bales for shipping to biopower customer. Photo of completed bales includes some bales from other hardwood prunings as well as the Christmas tree bales.

In the weeks after Christmas, most urban waste collectors run special routes to pick up used Christmas trees with their compactor trucks as shown in the photo above. In spite of the degree of compaction in the truck, the trees do not form a block that enables subsequent handling. Upon ejection from the truck body, the trees tend to spring back into their original shape. Forest Concepts conducted trials with two national waste management firms. In the trial with Waste Management, Inc. the route truck contained about 90 trees, of which 78 trees were baled into one high density biomass bale using the Forest Concepts engineering prototype baler. Similar results were obtained from a truckload of trees from Allied Waste Services. If a baler was used to either collect trees along the residential routes or was used at a fixed location to bale the material from all routes into high density bales, the resulting bales could easily be trucked to end users.

Field Experience with Mesquite from Pipeline Corridor Maintenance

Vegetation management along roadsides, under power lines, and along pipeline corridors is costly, but could be a significant source of woody biomass if there was a cost-effective way to collect and transport the material.

Figure 12. Baling of winter-harvested mesquite from pipeline corridor vegetation management project in Texas.

The engineers were asked to conduct a baling trial on Texas mesquite for a potential baler customer. Rather than ship the engineering prototype to Texas, it was more cost effective for the vegetation management contractor to ship a truckload of mesquite to the Forest Concepts facility in Auburn, WA. The City of Auburn provide a site at a city park to conduct the study.

The mesquite was in the form that it was cut by the contractor who typically grinds or chips the mesquite waste into fuel. Long pieces were cut to 1.5 m lengths by our ground crew as the grapple loader placed material into the baling chamber of our engineering prototype baler. There were no difficulties to bale the mesquite into high density bales that weighed approximately 650-700 kg (1,400 - 1,600 lb.). The entire truckload shown in the first photo was baled into five high density bales.

Conclusion

Baling of woody biomass, brush, and other cellulosic biomass greatly simplifies logistics and transportation to users via conventional trucks and rail. The Forest Concepts street-legal woody biomass baler is designed to replace many of the small chippers in use today by agencies, contractors, utilities and others. High density bales are easier to load, unload and store than are chips. With proper stacking, woody biomass bales dry down under natural air conditions.

Logistics and business methods for baled biomass follow the familiar recycling paradigms already in use for paper, cardboard, and aluminum cans. Baling technology will enable cellulosic biomass to join the recycled materials infrastructure. Within a few years, biomass should become "*just another recyclable*" An added benefit of baling vs. chipping at the source is that end users of baled biomass will be able to process the material into precisely the form and purity they need.

Forest Concepts conducted field trials and demonstrations in each of the launch markets and application areas for a new class of street-legal biomass balers. The equipment performed as expected in most respects and engineering data was collected that will inform design of commercial models of a baler.

Acknowledgements

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- Alamo Group and Jones Tree Service to provide the Texas mesquite for the mesquite baling trial.
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- Yakama Nation forestry division for organizing a field trial and demonstration on their riparian thinning site.

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