HIGH TONNAGE FOREST BIOMASS FROM SOUTHERN PINE

STEVE TAYLOR, BOB RUMMER, FRANK CORLEY, TOM GALLAGHER, OLADIRAN FASINA, TIM MCDONALD, MATHEW SMIDT

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BIOMASS CHALLENGE




- To meet U.S. energy goals, high-productivity, low-cost biomass supply systems are needed
- U.S. Department of Energy goals:
  - Logistical systems to produce 100 million dry tons/yr biomass
  - Harvest and transport biomass for $25 per dry ton by 2012

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FEEDSTOCK CHALLENGES

Supply

- Biomass is the South's greatest opportunity for a renewable energy source
  - *200 million acres of forests*
  - *35 million acres of productive pine plantations*
- Two sources of feedstock
  - *Forest residues*
  - *Dedicated energy harvest*

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FOREST RESIDUES

Approximately
40 million tons/yr
available

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FEEDSTOCK CHALLENGES

Supply

- Dedicated southern pine energy plantations can provide significant feedstocks for U.S. biofuel and biopower demands
  - *Biomass yields of 7 dry tons/acre*yr may be possible with genetic advances*
  - *15 million acres of southern pine plantations could produce 105 million tons/yr*

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AUBURN HIGH TONNAGE CONSORTIUM

- Auburn University
- USDA Forest Service
- Corley Land Services
- Tigercat
- Precision Husky
- Biorefinery collaborators
  - Coskata
  - Genera Energy
  - Rentech
- Department of Energy

BIOMASS SUPPLY SYSTEM

Dedicated energy plantation

- *Southern pine*
  - *Loblolly pine is primary species*
  - *Proposed final harvest at age 10 – 12*
  - *Target production of 7 dry tons/acre*year*
- *Benefits*
  - *Increased harvesting productivity (and lower costs) over traditional thinnings*
  - *More frequent cash flow for landowner with flexible management options*

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BIOMASS LOGISTICS SYSTEMS

Traditional Longwood System

- Felling
- Skidding
- Delimbing
- Loading
- Transport
- Log Storage and Handling
- Debarking
- Size Reduction (Chipping)
- Drying
- Conversion

In-woods Chipping System

- Felling
- Skidding
- Delimbing Debarking
- In-woods Chipping
- Transport
- Chip Storage and Handling
- Size Reduction
- Drying
- Conversion

Chip-at-Stump Systems

- Chip-at-Stump
- In-woods Chip Transport
- Loading
- Transport
- Chip Storage
- Size Reduction
- Drying
- Conversion

HARVEST AND TRANSPORT

High Productivity Harvesting System

- *Track-type feller buncher*
  - *High efficiency*
  - *Low site impacts*
- *Wheeled Skidder*
  - *Traditional transport option in southern pine systems*

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HARVEST AND TRANSPORT

High Productivity Processing and Transport

- *In-woods chipping*
  - *High productivity chipper*
  - *Debarking for clean chips*
- *Truck transport*
  - *High capacity trailers*

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HARVEST AND TRANSPORT

High Productivity Harvesting System

- *"Cold" logging system*
  - *Separation of felling, skidding, and chipping*
  - *Higher productivity*
- *"Transpirational drying"*
  - *After felling, bunches remain in forest for 6 weeks to reduce moisture content to near 30%*
  - *Increases transportation efficiency*
  - *Increases energy content and process efficiency*

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<u>Example</u> transport costs for wood chips at various moisture contents (for 60 mile haul distance).

% Moisture	Green Tons per Load	Dry Tons per Load	Cost per Dry Ton
50%	28.0	14.0	$14.40
45%	28.0	15.4	$13.09
40%	28.0	16.8	$12.00
35%	28.0	18.2	$11.08
30%	28.0	19.6	$10.29
25%	28.0	21.0	$9.60

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PROJECT SCOPE

Phase I - R&D

- *Design new machines and systems*
- *Develop benchmarks for existing system productivity, cost, feedstock quality*

Phase 2 - Commercial-Scale Test and Demonstration

- *Test new machines*
- *Test transpirational drying*
- *Test extended shifts*
- *Quantify industry and landowner acceptance*
- *Develop and demonstrate information systems*

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PHASE 1 – R&D

Benchmarking of existing operations

- *Testing typical southern pine tree-length harvesting systems*
  - *Wheeled feller buncher*
  - *Wheeled skidder*
  - *Whole tree chipper*
  - *Trucking to mill*
- *Benchmark tests*
  - *9 month period to document cost, productivity, and feedstock quality*

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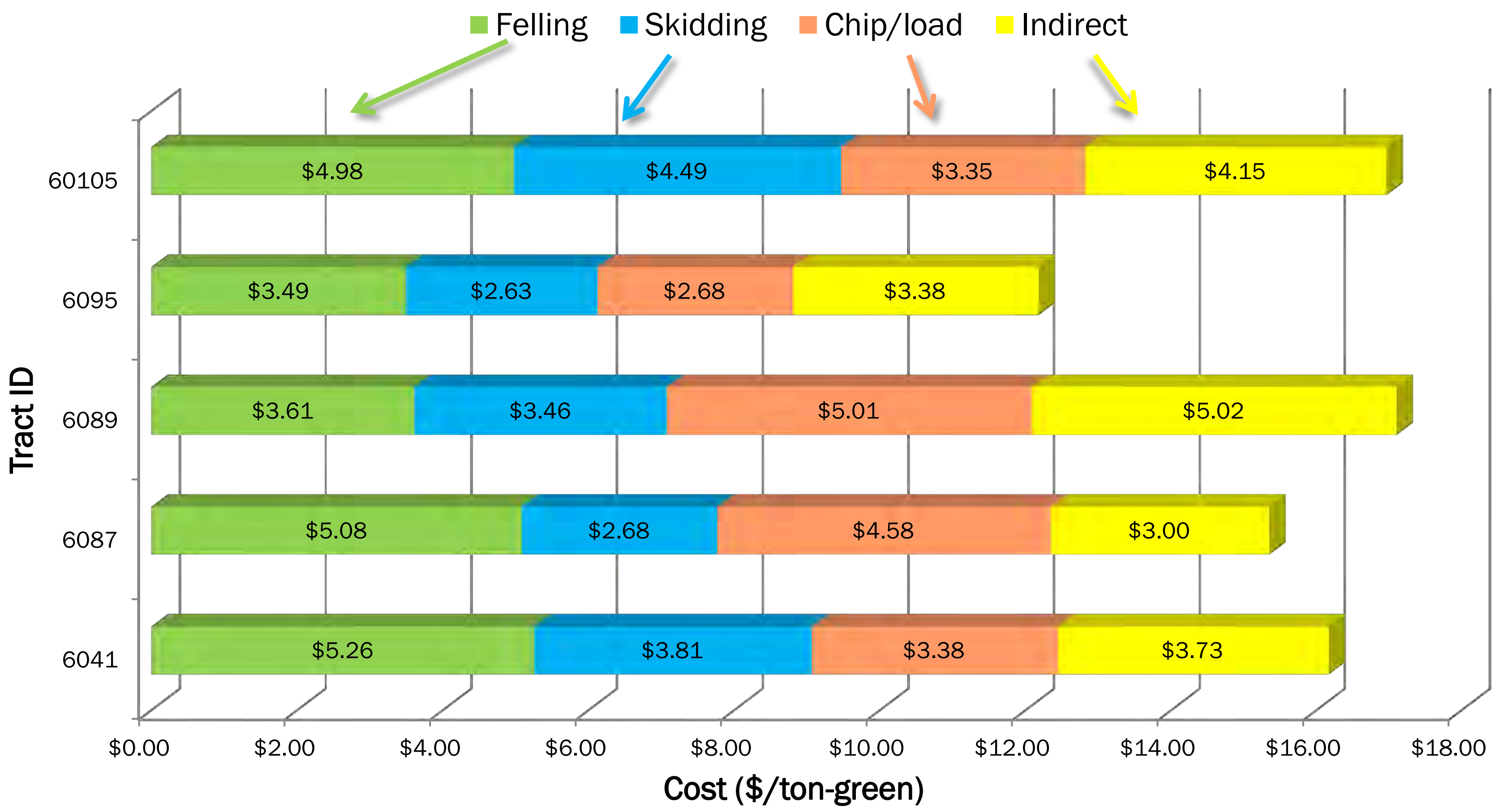
BENCHMARKING COST EXAMPLES



Utilization	65% Feller buncher	59% Skidder	50% Loader	59% Chipper

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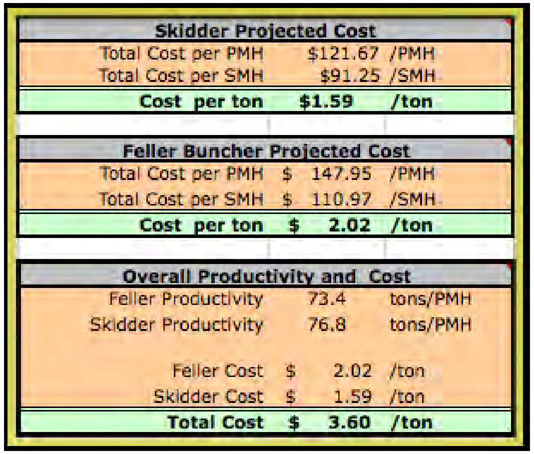
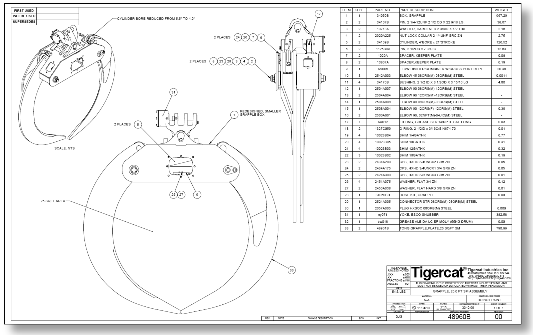
HARVESTING SYSTEM DESIGN

Design activities

- *System design*
  - *Based on models of predicted machine and system productivity / cost*
- *Mechanical design*
  - *Standard engineering design and analysis to meet functional requirements and productivity goals*



Skidder Projected Cost			
Total Cost per PMH	$121.67	/PMH	
Total Cost per SMH	$91.25	/SMH	
Cost per ton	**$1.59**	**/ton**	
Feller Buncher Projected Cost			
Total Cost per PMH	$	147.95	/PMH
Total Cost per SMH	$	110.97	/SMH
Cost per ton	**$**	**2.02**	**/ton**
Overall Productivity and Cost			
Feller Productivity	73.4	tons/PMH	
Skidder Productivity	76.8	tons/PMH	
Feller Cost	$	2.02	/ton
Skidder Cost	$	1.59	/ton
Total Cost	**$**	**3.60**	**/ton**



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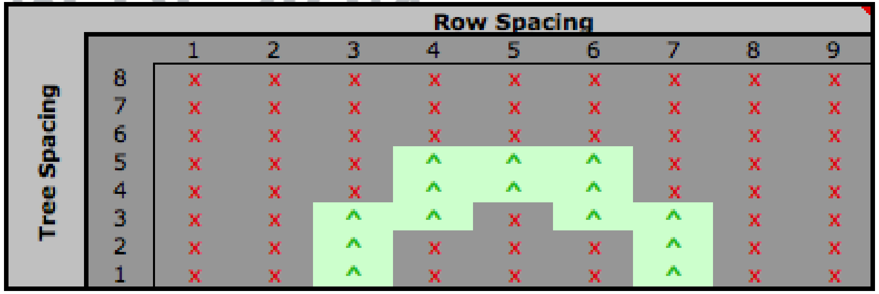
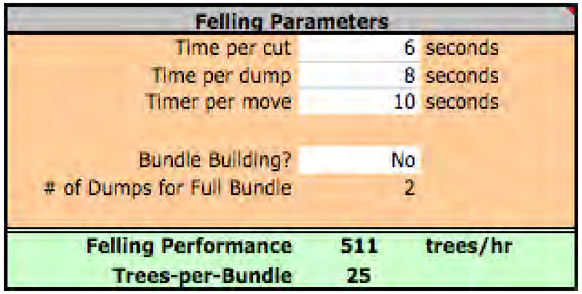
HARVESTING SYSTEM DESIGN

- *Model developed to predict productivity of the tracked feller buncher – wheeled skidder system*
  - *Productivity models for felling and skidding functions*
  - *Machine rate methods used for cost calculations*
  - *Overall system productivity / cost prediction*



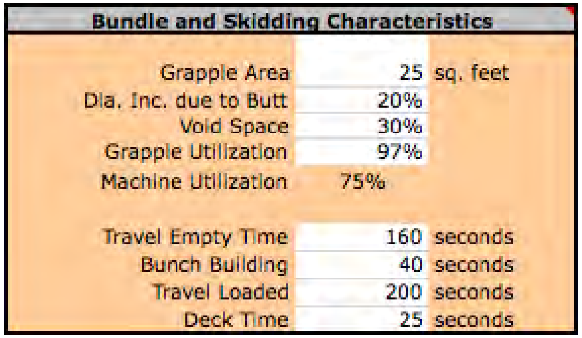
Row Spacing

Tree Spacing	1	2	3	4	5	6	7	8	9
8	x	x	x	x	x	x	x	x	x
7	x	x	x	x	x	x	x	x	x
6	x	x	x	x	x	x	x	x	x
5	x	x	x	^	^	^	x	x	x
4	x	x	x	^	^	^	x	x	x
3	x	x	^	^	x	^	^	x	x
2	x	x	^	x	x	x	^	x	x
1	x	x	^	x	x	x	^	x	x



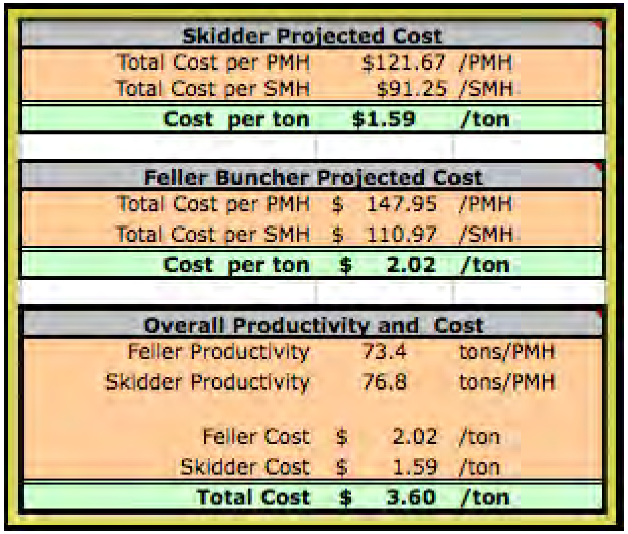
Felling Parameters

Time per cut	6	seconds
Time per dump	8	seconds
Timer per move	10	seconds
Bundle Building?	No	
# of Dumps for Full Bundle	2	
Felling Performance	**511**	**trees/hr**
Trees-per-Bundle	**25**	



Bundle and Skidding Characteristics

Grapple Area	25	sq. feet
Dia. Inc. due to Butt	20%	
Void Space	30%	
Grapple Utilization	97%	
Machine Utilization	75%	
Travel Empty Time	160	seconds
Bunch Building	40	seconds
Travel Loaded	200	seconds
Deck Time	25	seconds



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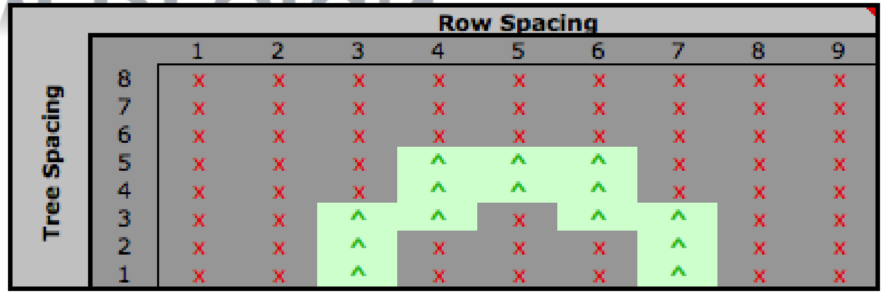
HARVESTING SYSTEM DESIGN

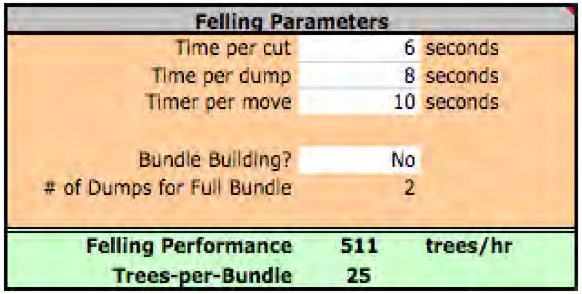
- *Model results target average system productivity >70 green tons/PMH*
- *Predicted (theoretical minimum) costs for felling and skidding <$4.00 per green ton*
  - *$2.00 /ton felling*
  - *$1.60/ton skidding*



Row Spacing

Tree Spacing

	1	2	3	4	5	6	7	8	9
8	x	x	x	x	x	x	x	x	x
7	x	x	x	x	x	x	x	x	x
6	x	x	x	x	x	x	x	x	x
5	x	x	x	^	^	^	x	x	x
4	x	x	x	^	^	^	x	x	x
3	x	x	^	^	x	^	^	x	x
2	x	x	^	x	x	x	^	x	x
1	x	x	^	x	x	x	^	x	x



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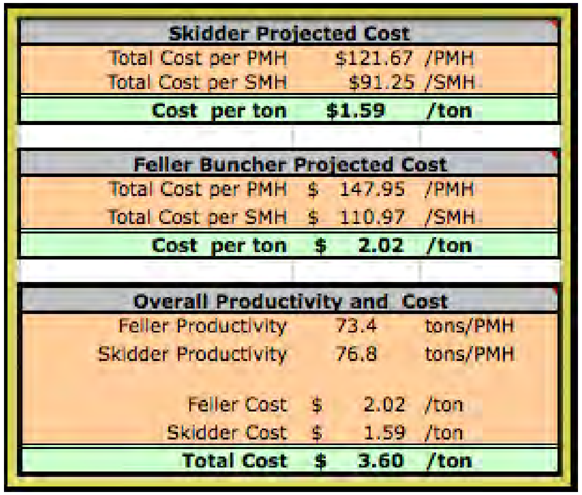

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FELLER BUNCHER DESIGN

- *Tigercat 845 D tracked feller buncher*
  - *EPA Tier 4i compliant engine*
  - *High speed, low cost shear felling head*
  - *Designed for trees up to 18 in. dbh; average dbh = 6 in.*
  - *Energy recovery system for swing mechanism*
  - *ER boom system provides energy recovery and planar motion*

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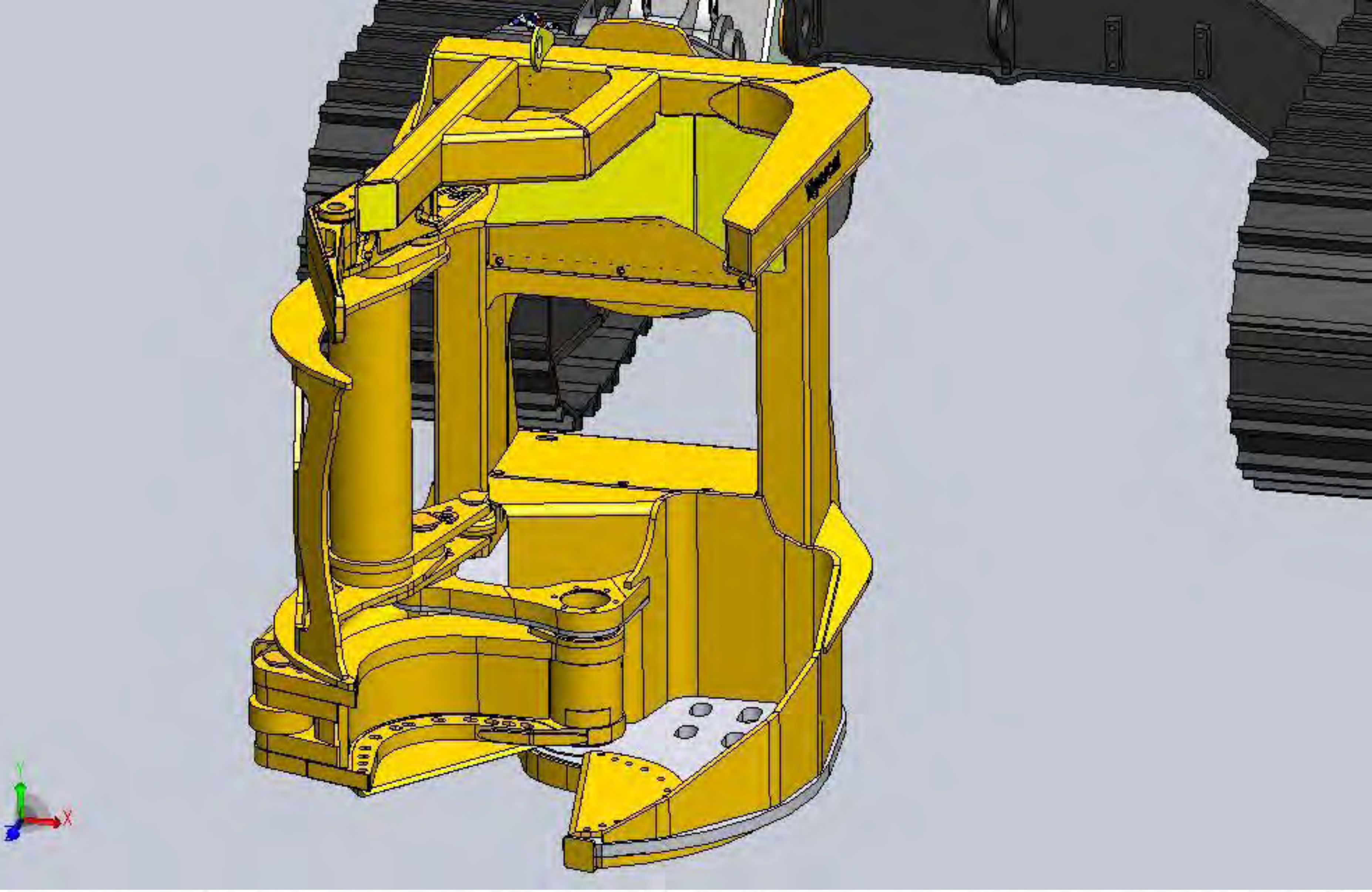

- DT1802 Biomass Harvesting High Speed Shear
- 1.5 seconds to open or close shear

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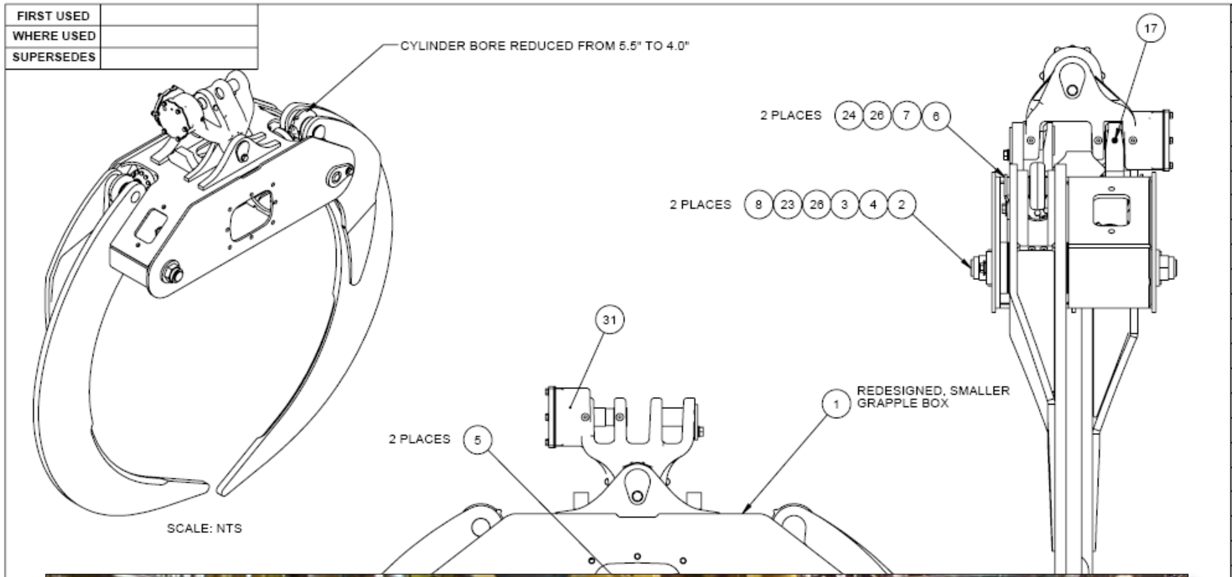
Wheeled Skidder Design

- *Tigercat 635 D wheeled skidder*
  - *25 sq. ft. grapple*
  - *98 tree capacity at 6 in. tree diameter*

FIRST USED	
WHERE USED	
SUPERSEDES	



ITEM	QTY.	PART NO.	PART DESCRIPTION	WEIGHT
1	1	34059B	BOX, GRAPPLE	967.29
2	2	34167B	PIN, 2 1/4-12UNF 2 1/2 OD X 22 9/16 LG.	38.67
3	2	13713A	WASHER, HARDENED 2 3/8ID X 1/2 THK	2.16
4	2	2920A225	NUT LOCK COLLAR 2 1/4UNF GRC ZN	2.75
5	2	34169B	CYLINDER, 4"BORE x 21"STROKE	126.52
6	2	1125B09	PIN, 2 1/2OD x 7 3/4LG	12.63
7	2	1029A	SPACER, KEEPER PLATE	0.08
8	2	13867A	SPACER,KEEPER PLATE	0.19
9	1	AV005	FLOW DIVIDER/COMBINER W/CROSS PORT REL'F	20.46
10	3	2542A003	ELBOW 45 08ORS(M)-08ORB(M) STEEL	0.0011
11	4	34170B	BUSHING, 2 1/2 ID X 3 1/2OD X 3 15/16 LG	4.80
12	1	2504A007	ELBOW 90 08ORS(M)-12ORB(M) STEEL	-
13	2	2504A004	ELBOW 90 12ORS(M)-12ORB(M) STEEL	-
14	1	2504A008	ELBOW 90 08ORS(M)-08ORB(M) STEEL	-
15	1	2508A004	ELBOW 90 12ORS(F)-12ORS(M) STEEL	0.39
16	2	2500A001	ELBOW 90, 02NPT(M)-04JIC(M) STEEL	-
17	7	AA012	FITTING, GREASE STR 1/8NPTF SAE LONG	0.03
18	2	1327C059	O-RING, 2 1/2ID x 3/16C/S N674-70	0.01
19	4	10023B04	SHIM 1/4GATHK	0.77
20	4	10023B05	SHIM 10GATHK	0.41
21	4	10023B03	SHIM 12GATHK	0.32
22	3	10023B02	SHIM 16GATHK	0.18
23	2	2434A200	CPS, HXHD 3/4UNCX2 GR8 ZN	0.05
24	2	2434A175	CPS, HXHD 3/4UNCX1 3/4 GR8 ZN	0.05
25	2	2424A300	CPS, HXHD 3/8UNCX3 GR8 ZN	0.01
26	4	2451A075	WASHER, FLAT 3/4 ZN	0.12
27	2	2450A038	WASHER, FLAT HARD 3/8 GR9 ZN	0.01
28	1	34060BH	HOSE KIT, GRAPPLE	0.00
29	1	2524A005	CONNECTOR STR 08ORS(M)-08ORB(M) STEEL	-
30	1	2657A005	PLUG HXSOC 08ORB(M) STEEL	0.000
31	1	cy071	YOKE, ESCO SNUBBER	382.58
32	1	bw018	GREASE ALBIDA LC EP MOLY (55KG DRUM)	0.00
33	2	48961B	TONG,GRAPPLE,PLATE,25 SQFT SM	790.89

ON | ECN | INIT.

TOLERANCE UNLESS NOTED
.XXX ±.005
.XX ±.010
FRACTIONS ±1/16
ANGLES 1/2°

Tigercat®

Tigercat Industries Inc.
40 Consolidated Drive, P.O. Box 544
Paris, Ontario, Canada N3L 3T6
Tel:(519)442-1000 Fax:(519)442-1855

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UNITS: IN & LBS
GRAPPLE, 25.0 PT SM ASSEMBLY
MATERIAL: N/A
COATING - SEE RS003: DO NOT PAINT
PROJECTION
DATE: © 11/04/10
SCALE: 1:16 UNLESS NOTED
ESTIMATED WEIGHT: 3349.99
SHEET NUMBER: 1 OF 1
DRAWN BY: DJG
APPROVED BY:
DRAWING NUMBER: 48960B
REVISION: 00

AU
UN
CENTE
AND

SKIDDING COST AND PRODUCTIVITY

648 JOHN DEERE

- 926’ skid distance
- 5.5 minutes per cycle
- 3.1 tons per cycle
- 30 tons/PMH
- $90/PMH
- $3.00 per ton

630D TIGERCAT

- 1005’ skid distance
- 5.3 minutes per cycle
- 8.8 tons per cycle
- 100 tons/PMH
- $130/PMH
- $1.30 per ton

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IN WOODS CHIPPING

- *Precision WTC2675 disk chipper*
  - *Multiple configurations possible*
    - *4 or 8 knives*
    - *Pulp chips*
    - *Microchips*
  - *Clean chips possible with addition of flail delimber*

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CHIPPING COST AND PRODUCTIVITY

PRECISION 2300

- Ave. 34 minutes/load
- 30 tons/PMH
- $280/PMH
- $9.33/ton

PRECISION 2675

- Ave. 19 minutes/load
- 70 tons/PMH
- $333/PMH
- $4.76/ton

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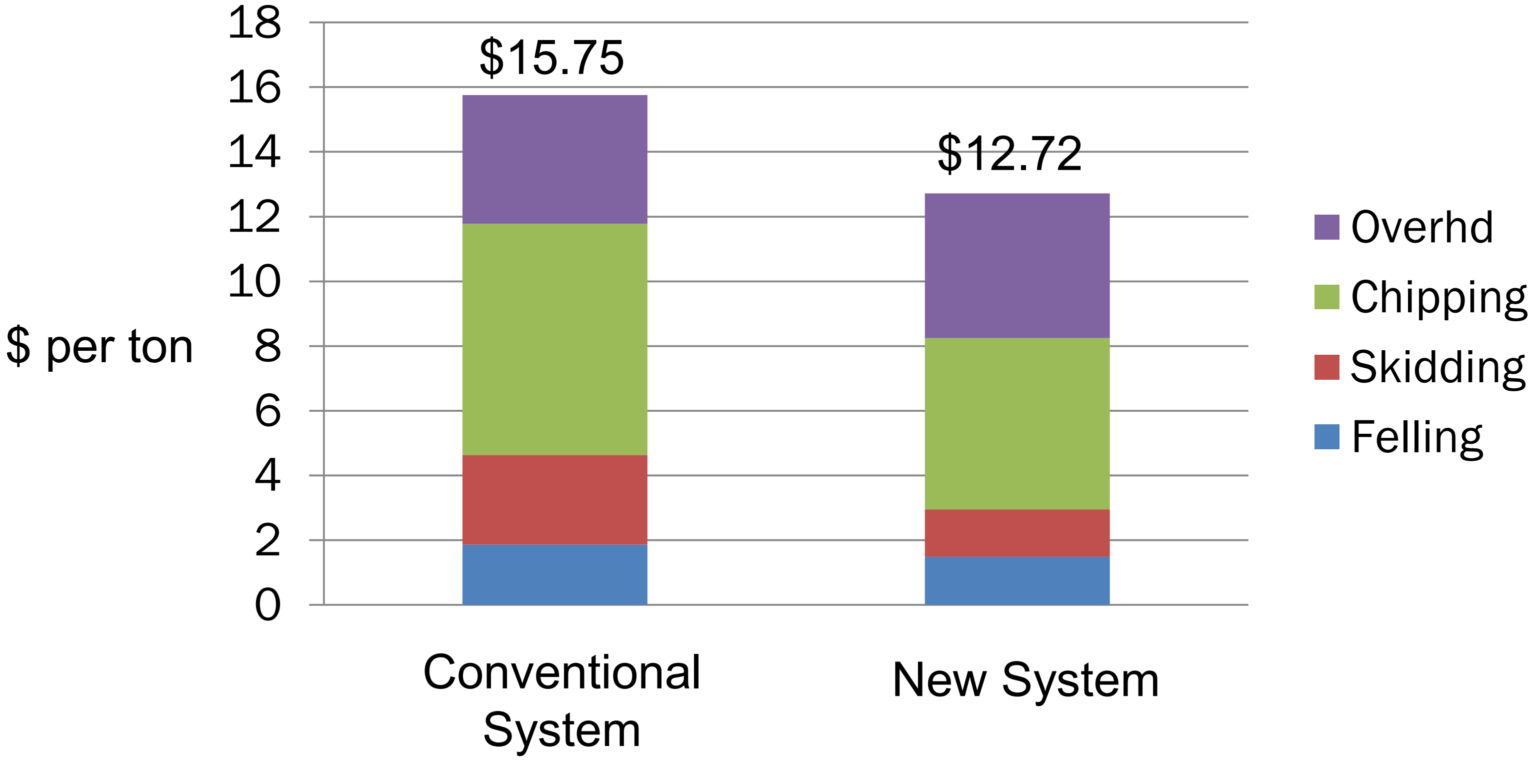
SYSTEM COST COMPARISON



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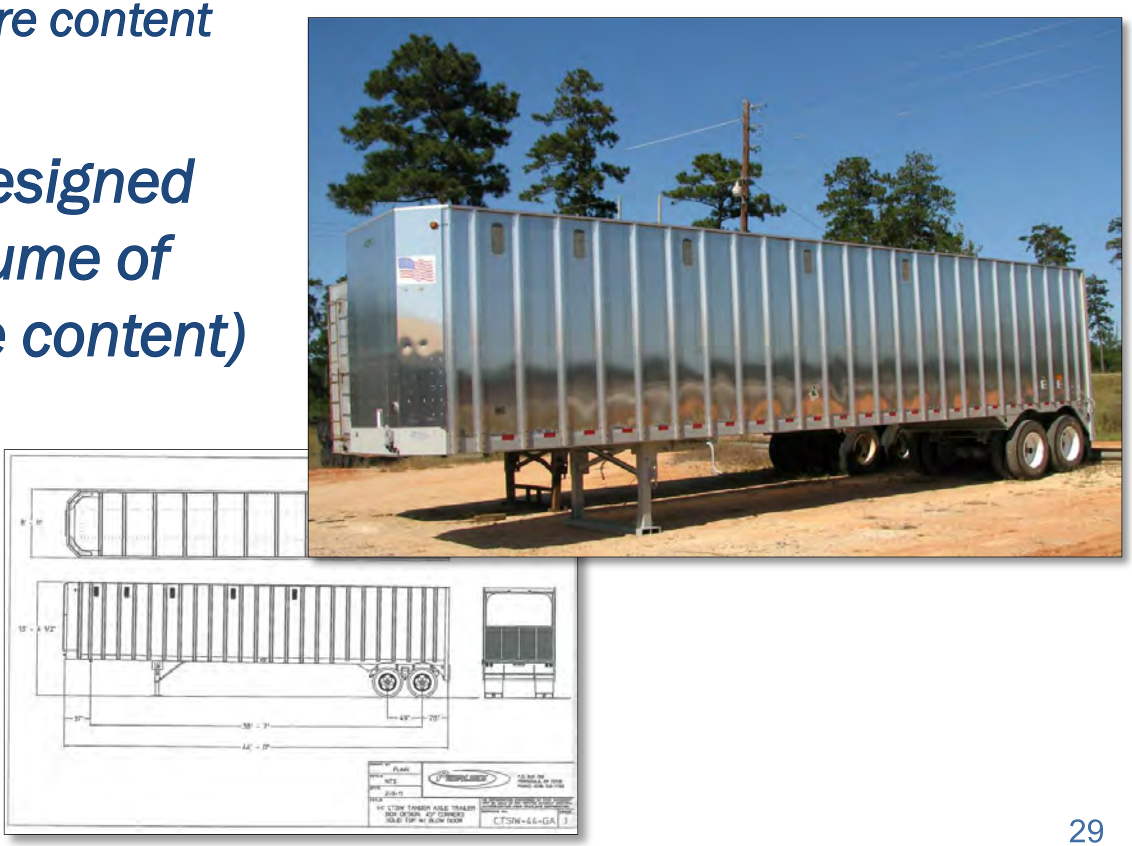
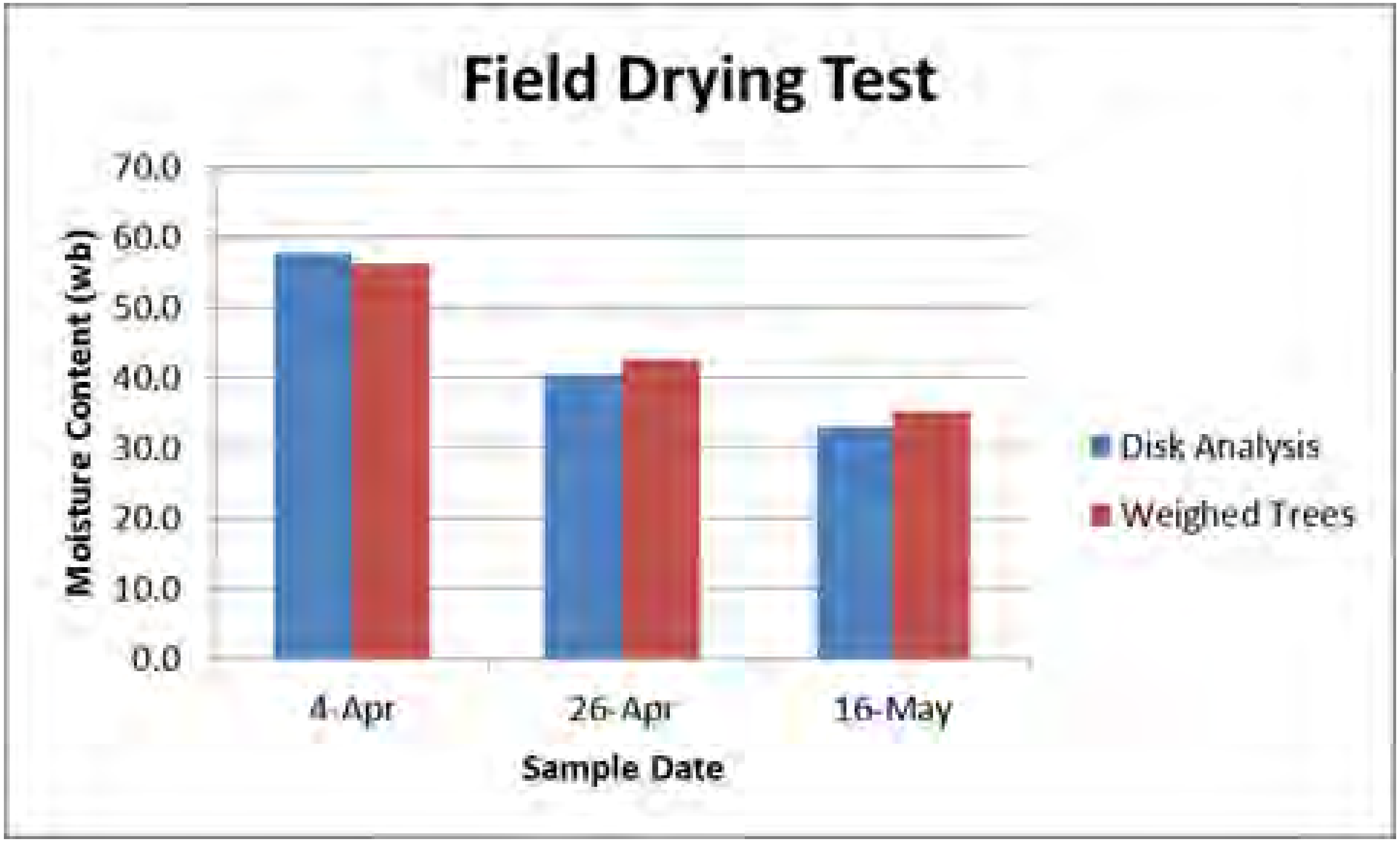
TRAILER DESIGN

- *Harvesting system designed for transpirational drying of wood*
  - *Trees allowed to dry in field for up to 6 weeks to reduce moisture content near 30%*
- *High capacity trailers designed to transport greater volume of wood (at lower moisture content)*
  - *Designs up to 114 cu. yds.*
  - *Volume increases up to 30%*



“TRANSPIRATIONAL” DRYING



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INFORMATION SYSTEMS

- *Chipping*
  - *Fuel consumption monitoring*
  - *Sensor for mass flow of chips*
  - *Sensors for biomass properties*
    - *Moisture content*
    - *Energy content*
    - *Ash content*

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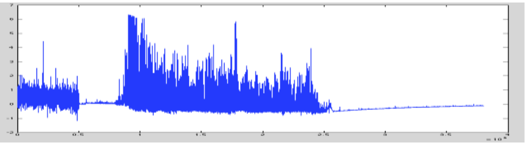
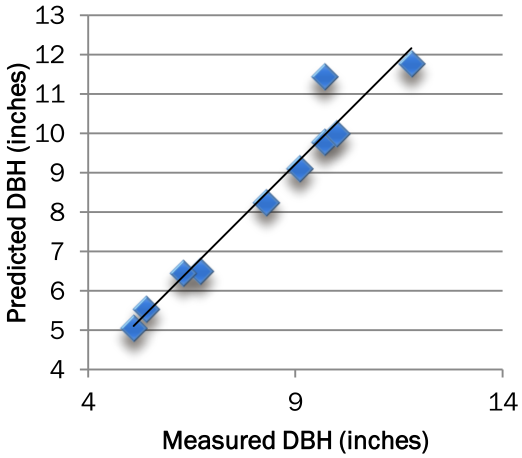
INFORMATION SYSTEMS

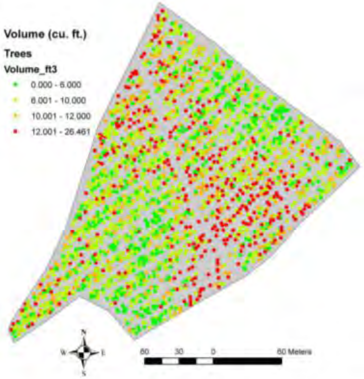
- In-stream determination of fuel characteristics





INFORMATION SYSTEMS

- *Improved system management is key to meeting cost goals*
- *Feller buncher systems to monitor productivity*
  - *Productivity information gathered and displayed using CAN bus (e.g. trees/hr)*
  - *Machine location and tree size collected by GPS and CAN bus to develop biomass yield information*
  - *Machine performance (fuel consumption, etc.) supplied by CAN bus*
- *Skidder productivity monitoring systems use GPS and CAN bus*



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PRODUCTION DATA

379 trees cut, 1 hour, 49 minutes, 9 seconds = 208 trees hour^{-1}
80 accumulations, 4.7 trees accumulation^{-1}

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FEEDSTOCK QUALITY

- *Biofuel industry emphasized the importance of understanding harvesting system effects on feedstock quality*
- *Feedstock data collected from:*
  - *Standing trees*
  - *Trees harvested with feller buncher and skidder*

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FEEDSTOCK QUALITY BASELINE

Data from standing trees (loblolly pine)

		Energy (BTU/lb)	Carbon (%)	Ash (%)	Alkali (% of ash)	Silica (%)
Auburn site	**Foliage**	8195^{a}	49.52 ^{a}	2.59^{a}	92.71 ^{a}	0.005^{a}
	Limbs	7773^{a}	48.65^{b}	1.38^{b}	94.10^{a,b}	0.000^{b}
	Stem without Bark	8111^{a}	48.18^{b}	0.40^{c}	97.93^{c}	0.000^{b}
	Bark	8029^{a}	51.64^{d}	1.37^{b}	80.61^{d}	0.001^{b}
Corley benchmark sites	**Stem without Bark**	8714^{x}	49.71^{x}	0.38^{x}	94.04^{x}	0.000^{x}
	Bark	9131^{y}	52.76^{y}	1.30^{y}	89.14^{y}	0.180^{y}

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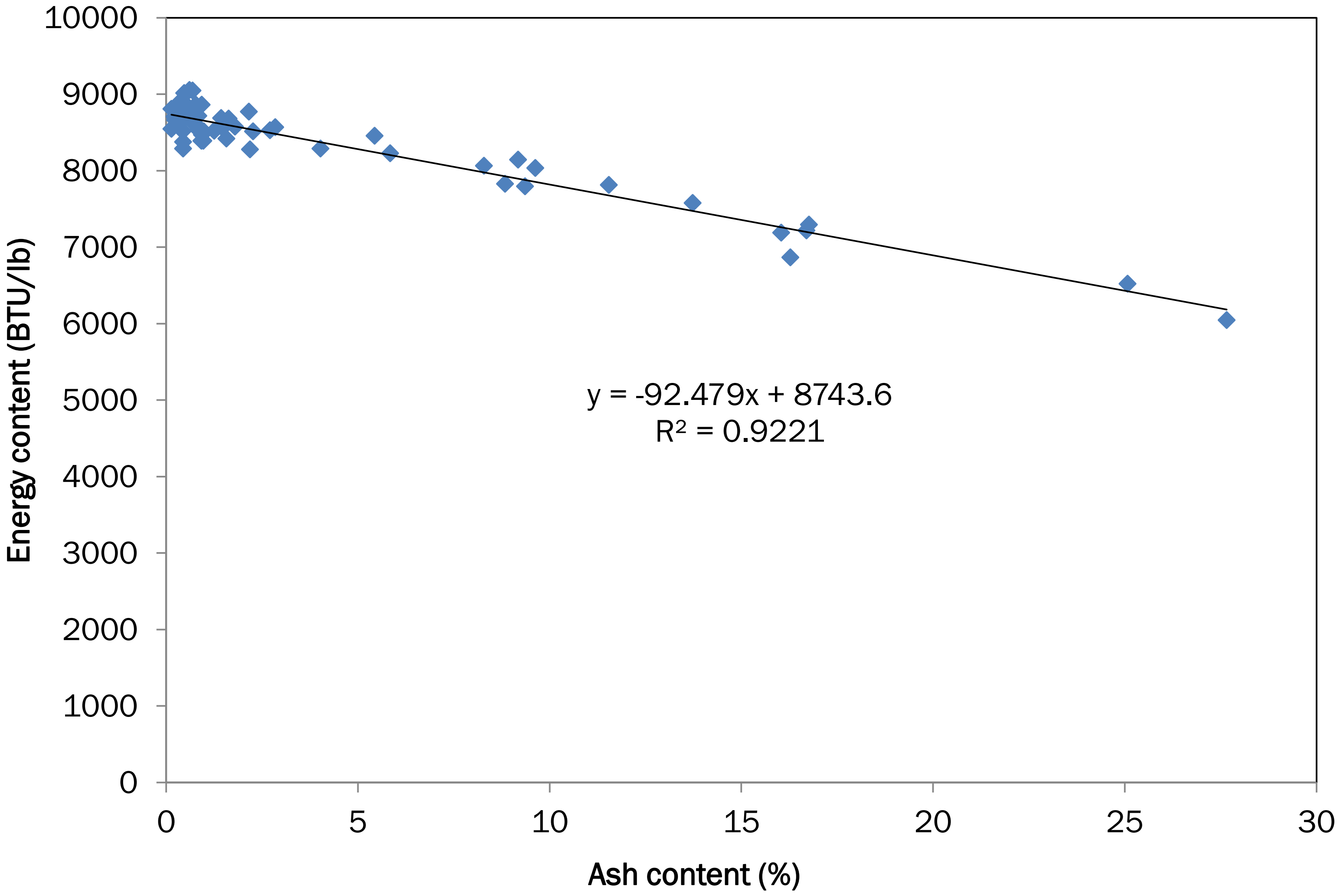
HANDLING EFFECTS ON QUALITY

Data from chipped trees

	Energy (BTU/lb)	Ash (%)	Carbon (%)
Whole tree Not skidded	8715[a]	0.84[a]	49.92[a]
Delimbed tree Not skidded	8702[a]	0.72[a]	50.16[a]
Whole tree skidded	8566[b]	2.85[b]	50.09[a]

ENERGY VERSUS ASH CONTENT (PINE)



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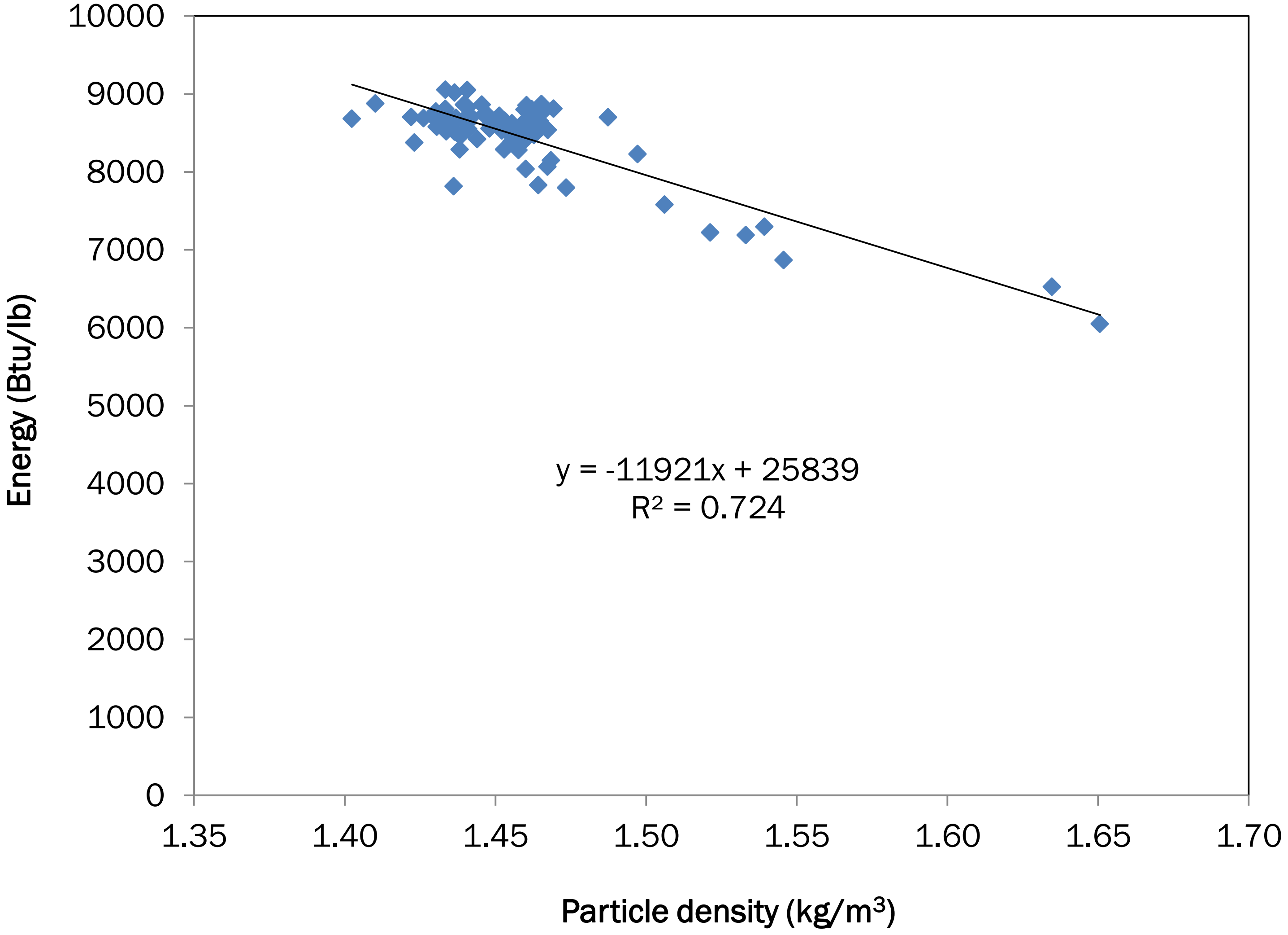
ENERGY CONTENT VS. PARTICLE DENSITY



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LANDOWNER AND LOGGER ACCEPTANCE

Will landowners accept short rotation pine energy plantation?

Will loggers accept new equipment and operating practices?

Focus groups:

- 5 landowner groups
- 5 logger groups
- 100+ landowners
- 30 loggers

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LANDOWNER BIOENERGY CONCERNS

My decision to produce and sell trees for conversion to energy…	
- The "right" price	1.3
- A steady market	1.6
- The environmental impacts of intensive forest management	2.6
- The benefit to the local economy	2.7
- A sense that I am addressing a larger problem	2.9
- Long term contracts with buyers	3.1
- Enrollment in BCAP	3.6

Short rotation forest management practiced on some of my property will likely fit with my objectives to:	
- Provide income	1.9
- Protect soil and water resources	3.0
- Protect the visual appearance of my property	3.1
- Provide wildlife habitat	3.2
-Enhance my personal enjoyment	3.5

Average Score
1 = Very Important
7 = Not Important

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LOGGER BIOENERGY CONCERNS

My decision to invest in equipment for harvesting biomass could be determined by	
- Profitability	1.9
- Long term contracts with buyers	2.0
- A steady market	2.0
- The "right" price	2.1
- The benefit to the local economy	2.8
- A sense that I am addressing a larger problem	3.1

Current barriers to investing in equipment for harvesting biomass are	
- Markets for biomass	2.0
- Availability of long term contracts	2.3
- Source of timber for biomass	2.4
- Adoption of new technology	2.6
-Access to financing	2.7
-Availability of trucking (contractors or drivers)	2.8
- Labor availability	2.8

Averages
1 = Strongly Agree
7 = Strongly Disagree

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SUMMARY

- High yield pine plantations can supply significant portion of U.S. biofuel and biopower feedstocks.
- New techniques and high-productivity machines can reduce delivered costs.
- Producers will adopt new systems if the market develops.