Forest Resources Pathways
Summary Description

1. DOE Pathway Objectives

The Biomass Program has described four pathways that use forest resources as feedstocks:

1. Pulp and Paper Mill Improvements Pathway
2. Forest Products Mill Improvements Pathway
3. Forest Residues Processing Pathway (added since OBP MYPP)
4. Pulp and Paper Mill Repurposing Pathway (added since OBP MYPP)

The first two pathways have similar objectives; to improve the economics of existing facilities through more efficient utilization of clean wood feedstocks and process residues (e.g. hog fuel and black liquor) for the production of biofuels – defined by the Program as biomass derived liquid transportation fuels that are fungible in today's transportation fuel supply. This near- to mid-term strategy, based on demonstrating new technologies in existing facilities, will begin to lay the technical foundation and build the practical expertise for the other pathways based on lignocellulosic feedstocks.

The objective for the forest residues pathway is to develop and demonstrate new commercially-viable processes and systems to convert forest residues from current logging activities (e.g., logging slash, forest thinnings, understory brush) to biofuels. Both biochemical and thermochemical conversion technologies, individually or in combination, are being evaluated. The use of existing forest residues is seen as a mid-term strategy to bridge the gap between near-term, niche, low-cost biomass supplies and long-term high-volume dedicated woody energy crops. Initially, forest residue supply and conversion systems will be demonstrated in existing primary facilities and ultimately in new, dedicated commercial-scale facilities.

The objective for the pulp and paper mill repurposing pathway is to reconfigure existing but closed[1] or uneconomical mills for exclusive production of biofuels. While the US consumption of paper and wood products will increase over the long term it is not clear what fraction will be domestically produced. Many new overseas mills have the potential to become the low cost producer of many grades and paper and wood products. However, the domestic industry can respond by converting high cost mills to biofuels production.

Other opportunities for the forest resource pathways include production of hydrogen; organic chemicals and petrochemical replacements; and heat and electricity.

2. Pathway Overviews

<u>2.1. Pulp and Paper Mill Pathway</u>

The block flow diagram shown in Figure 1 outlines the current pulp and paper mill process steps and how new processing steps could be incorporated into the existing

[1] 124 pulp and paper mills have closed in the U.S. since 1997 according to the recently published Forest Products Industry Technology Roadmap.

process. The bold lines highlight the routes to biofuels; and the dotted lines identify routes to bioproducts, heat and power. This diagram is not intended to be all inclusive. Other viable processing options should be considered for addition.

The recently updated Forest Products Industry Technology Roadmap[2] describes this pathway and some of the possible technology options in the platform entitled "Advancing the Forest Biorefinery".

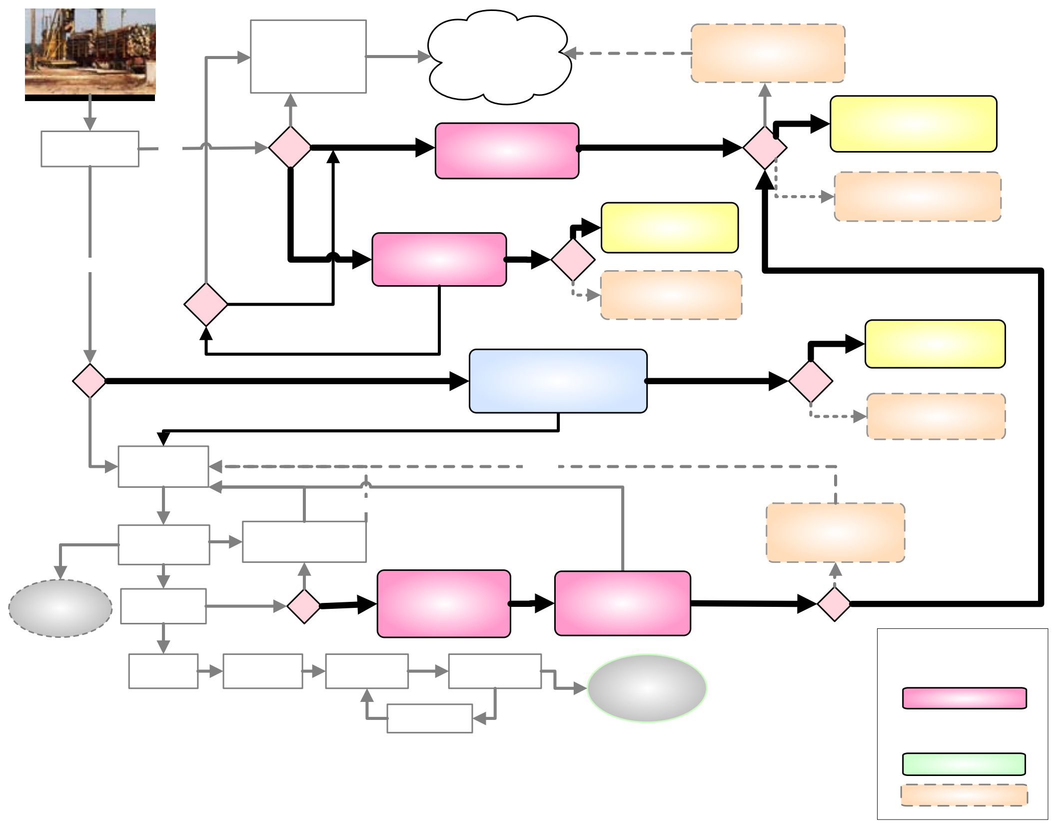

Figure 1: Pulp and Paper Mill Improvements Pathway Diagram

2.1.1 Existing Pulp and Paper Mill Process[3]

The pulp and paper production process starts by debarking and chipping whole logs into clean wood chips, as illustrated by the white boxes in Figure 1. The residual bark and hog fuel is fed to a boiler to produce steam for the facility. Wood chips are fed to the digester, where they are "cooked" to break the lignin bonds of the wood and release cellulose fibers, typically using chemical pulping processes (most of the pulp in the U.S. is produced via the Kraft pulping process). The stock pulp mixture from the digester is screened to separate the cellulose fibers and the spent pulping liquor. The spent pulping liquor, e.g., cooking chemicals, and lignin and fragmented wood components

[2] *Forest Products Industry Technology Roadmap*. (Prepublication version; June 2006). Agenda 2020 Technology Alliance, American Forest & Paper Association, DOE/EERE Industrial Technologies Program. Downloaded from http://www.agenda2020.org/PDF/FP_Roadmap_PrePub.pdf

[3] *Project Profile of the Pulp and Paper Industry 2nd Edition*. (November 2002). EPA/310-R-02-002. EPA Office of Compliance Sector Notebook. .http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/pulppasnp1.pdf

Whole Log Chipping

Hog Fuel

from the digestion process are combusted to recover and recycle the chemicals back to the digester. The remaining pulp is washed and bleached for further processing to paper and paper products.

2.1.2 Pulp and Paper Mill Improvements for Fuel Production

The pulp and paper mill improvements for fuel production are focused on developing and demonstrating new technologies that use existing pulp and paper mill feedstocks and residual hog fuel streams to produce biofuels. The process improvements are described in Table 1.

Table 1. Pulp and Paper Mill Improvements for Fuel Production

Process Category	Process Step(s)	Description
Black Liquor-to-Syngas	6.1 Black Liquor Gasification	Gasify spent pulping liquor; causticize and return Na-based pulping chemicals; validate advantages of co-gasification of spent pulping liquors and other forms of woody biomass
Syngas Cleanup	6.2 Sulfur Recovery and Black Liquor Syngas Cleanup	Recover process chemicals from spent pulping liquor syngas; cleanup spent pulping liquor syngas
Biomass-to-Syngas	6.3 Biomass and Residue Gasification and Cleanup	Feed wood residues to high-pressure gasifier, convert to syngas and cleanup/condition to meet required syngas specifications for downstream operations
Syngas-to-Fuels	6.4 Syngas to Fuels	Produce and evaluate economics of syngas conversion to mixed alcohols, DME and FTL
Biomass-to-Sugars	6.6 Hemicellulose Release and Recovery	Extract C5 and C6 sugars from hemicellulose upstream of the pulp digester without negatively affecting pulp and paper manufacture; upgrade sugars and recover other intermediates
Sugars-to-Fuel	6.7 Mixed Sugars to Ethanol	Ferment all sugars in extract to ethanol and separate/purify ethanol
Biomass-to-Bio-oil	6.9 Biomass Pyrolysis	Develop cost-effective reactor designs/systems to produce bio-oil from hog fuel stream and convert bio-oil to stable intermediate
Bio-oil-to-Fuel	6.10 Bio-oil to Fuel	Convert bio-oil to fuel; recover/purify fuel to meet required specifications

The mixed sugars from the hemicellulose recovery process can also be converted to bioproducts (Process Step 6.7); the syngas from the biomass and black liquor gasification processes can be converted to bioproducts and heat and power (Process Steps 6.4 and 6.5); and the bio-oil from the biomass pyrolysis process can be converted to bioproducts (Process Step 6.9).

<u>2.2. Forest Products Mill Pathway</u>

The block flow diagram shown in Figure 2 outlines the current primary wood processing mill process steps and how new processing steps could be incorporated into the existing process. The bold lines highlight the routes to biofuels; and the dotted lines identify routes to bioproducts, heat and power. This diagram is not intended to be all inclusive. Other viable processing options should be considered for addition. The current pathway diagram does not include operations characteristic of secondary wood processing mills - mills utilizing primary mill products to make products such as containers and pallets, furniture, flooring, millwork, etc. This is due to the relatively small size of individual mills as well as their dispersed locations.

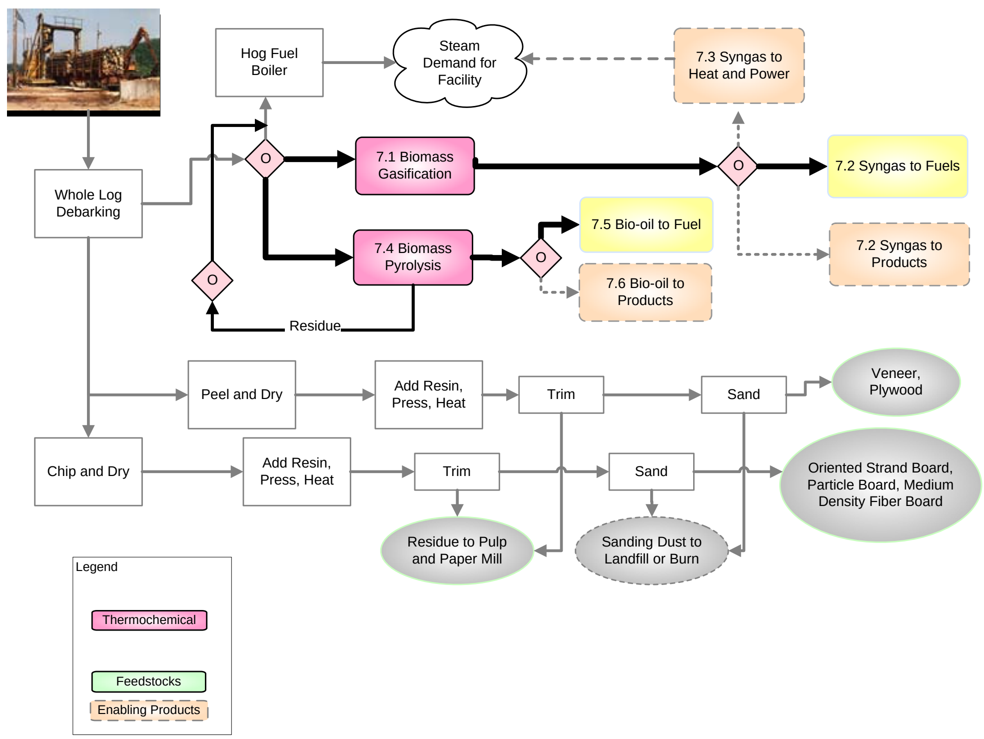

Figure 2: Forest Products Mill Improvements Pathway Diagram

2.2.1 Existing Forest Products Mill Processes[4]

The forest products production process (in primary wood processing mills) starts by debarking whole logs, as illustrated by the white boxes in Figure 2. The residual bark and hog fuel is fed to a boiler to produce steam for dryer operations within the facility. The debarked logs are processed to produce dimension lumber, plywood panels and reconstituted wood products (particleboard, oriented strandboard, medium density fiberboard, etc.) or engineered wood products. For dimension lumber, plywood and reconstituted wood products, the final process steps are trimming and sanding. Depending on the locale the trimmed material is recycled within the mill, or sold to pulp and paper mills for further processing; sawdust is landfilled or burned.

2.2.2 Forest Products Mill Improvements for Fuel Production

Since the average forest products mills are smaller than the average pulp and paper mill and they typically lack a large industrial waste water treatment facility, forest products mill improvements for fuel production are focused on thermochemical technologies that use existing primary wood processing mill hog fuel streams to produce biofuels. The process improvements are described in Table 2.

[4] *Project Profile of the Lumber and Wood Products Industry*. (September 1995). EPA/310-R-95-006. EPA Office of Compliance Sector Notebook. http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/lumber.html

Table 2. Forest Products Mill Improvements for Fuel Production

Process Category	Process Step(s)	Description
Biomass-to-Syngas	7.1 Biomass Gasification	Feed biomass to high-pressure gasifier, convert to syngas and cleanup/condition to meet required syngas specifications for downstream operations
Syngas-to-Fuels	7.2 Syngas to Fuels	Convert conditioned syngas to biofuels (mixed alcohols, DME, FTL) and separate fuel to meet required specifications
Biomass-to-Bio-oil	7.4 Biomass Pyrolysis	Produce bio-oil from hog fuel stream and convert bio-oil to stable intermediate
Bio-oil-to-Fuel	7.5 Bio-oil to Fuel	Convert bio-oil to fuel; recover/purify fuel to meet required specifications

The syngas from the biomass gasification processes can be converted to bioproducts and heat and power (Process Steps 7.2 and 7.3); and the bio-oil from the biomass pyrolysis process can be converted to bioproducts (Process Step 7.6).

2.3 Forest Residues Pathway

The block flow diagram shown in Figure 3 outlines the process steps and multiple options for producing fuels, chemicals and power from forest residues. The bold lines highlight the routes to biofuels; and the dotted lines identify routes to bioproducts. This diagram is not intended to be all inclusive. Other viable processing options should be considered for addition.

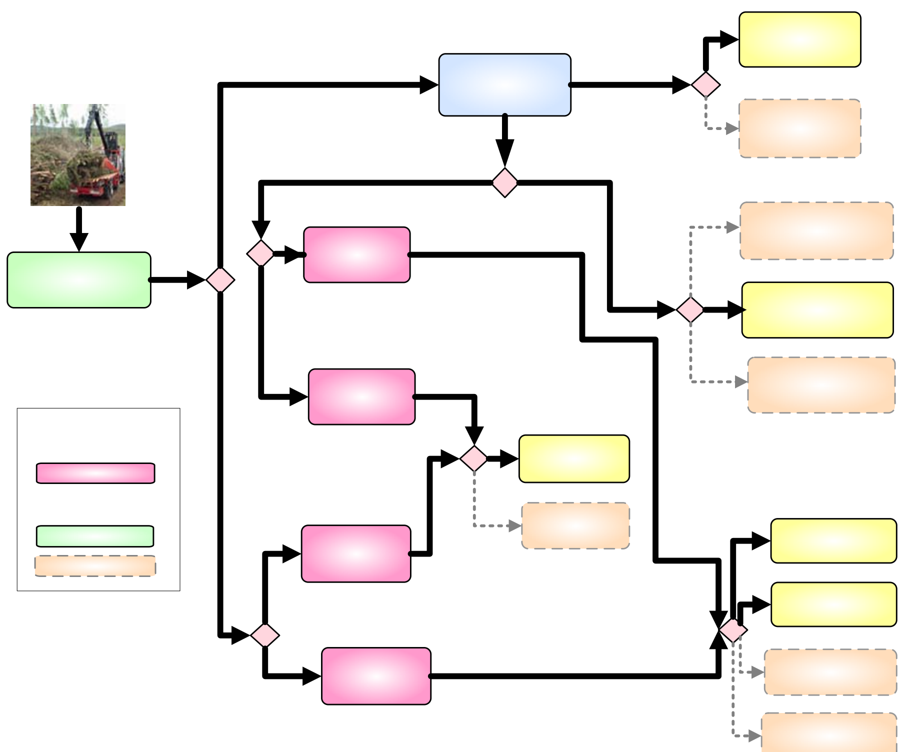

Figure 3: Forest Residues Processing Pathway Diagram

2.3.1 Forest Residues Processing for Fuel Production

Fuel production options for forest residues are focused on developing and demonstrating integrated biochemical and thermochemical processes and systems for converting forest residues to biofuels, as described in Table 3.

Table 3. Forest Residues Processing for Fuel Production

Process Category	Process Step(s)	Description
Feedstock Logistics	8.1 Forest Residues Collection and Logistics	Collect, store, transport and preprocess forest residues to meet cost, quality, quantity and sustainability requirements.
Biomass-to-Sugars	8.2 Fractionation of Forest Residues	Produce mixed sugars from forest residues with cost-effective pretreatment and enzymatic hydrolysis, using low-cost enzymes, with simultaneous heat and power production
Sugars-to-Fuel	8.3 Mixed Sugars to Ethanol	Ferment mixed sugars to ethanol and separate/purify ethanol
Lignin Intermediates-to-Fuel	8.6 Fuels from Lignin Intermediates	Convert lignin intermediates to fuel that meets desired specifications
Lignin Intermediates-to-Syngas	8.8 Lignin Gasification	Feed lignin intermediates to high-pressure gasifier, convert to syngas and cleanup to meet required syngas specifications for downstream operations
Lignin Intermediates-to-Bio-oil	8.9 Lignin Pyrolysis	Produce bio-oil from lignin intermediates and convert bio-oil to stable intermediate
Syngas-to-Fuel	8.10 Syngas to Fuels	Convert conditioned syngas to biofuels (mixed alcohols, DME, FTL) and separate fuel to meet required specifications
Syngas-to-Fuel	8.12 Syngas to Hydrogen	Convert conditioned syngas to hydrogen and separate/recover hydrogen to meet required specifications
Bio-oil-to-Fuel	8.13 Bio-oil to Fuel	Convert bio-oil to fuel; recover/purify fuel to meet required specifications
Biomass-to-Syngas	8.15 Biomass Gasification	Feed forest residues to high-pressure gasifier, convert to syngas and cleanup to meet required syngas specifications for downstream operations
Biomass-to-Bio-oil	8.16 Biomass Pyrolysis	Produce bio-oil from forest residues and convert bio-oil to stable intermediate

The mixed sugars from the fractionation process can also be converted to bioproducts (Process Step 8.4); syngas can be converted to products, including heat and power (Process Steps 8.10 and 8.11); bio-oil can be converted to bioproducts (Process Step 8.14); and lignin intermediates can be converted to products, including heat and power (Process Steps 8.5 and 8.7).

2.4 Pulp and Paper Mill Repurposing for Fuel Production

Pulp mills are a very attractive site for production of biofuels since all pulp mills already have many unit operations required for a modern biorefinery, e.g., biomass collection and handling infrastructure, digesters that could also be used for pretreatment, boilers for combustion of low-quality biomass (hog fuel or forest residues) and spent pulping liquors, very large scale, industrial waste water treatment systems, and permits to operate.[5] The pulp and paper mill improvements pathway (Section 2.1) for fuel production is focused on developing and demonstrating new technologies that use existing pulp and paper mill feedstocks and residual hog fuel streams to produce biofuels. In contrast, complete repurposing of a pulp mill would involve ending pulp and paper production and reconfiguring the mill for exclusive production of biofuels.

The block flow diagram shown in Figure 4 outlines the process steps for producing ethanol in a repurposed pulp and paper mill. This diagram is not intended to be all inclusive. Other viable processing options should be considered for addition.

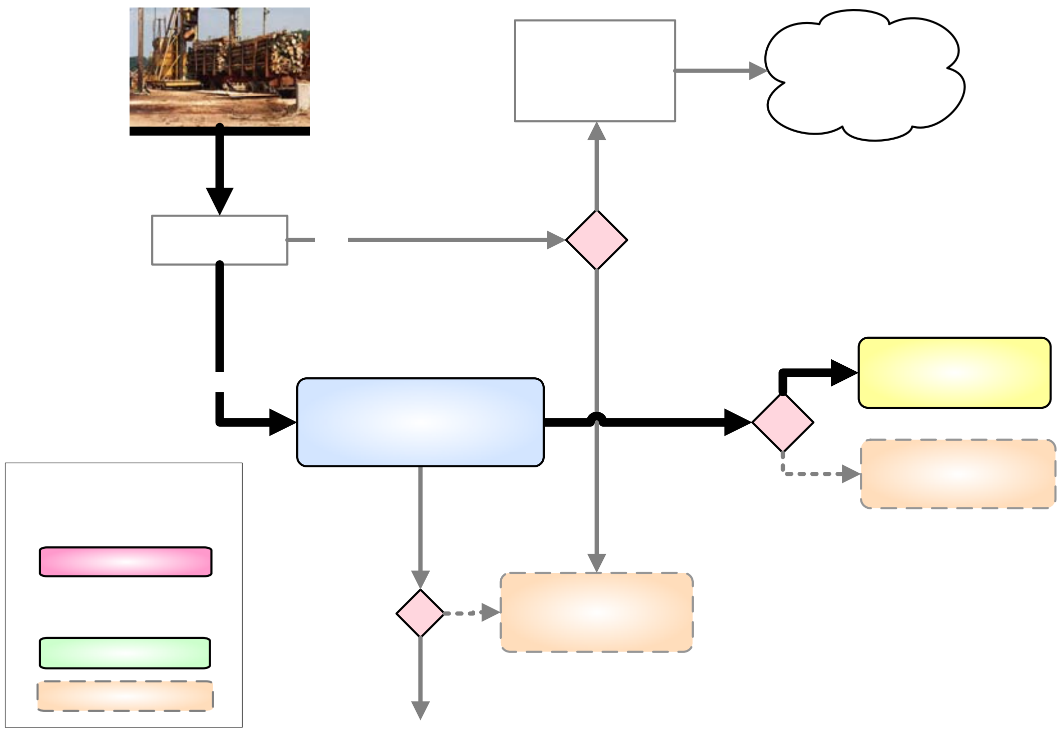

Figure 4: Pulp and Paper Mill Repurposing Pathway Diagram

The process steps for the repurposed pulp and paper mill are described in Table 4.

[5] Personal correspondence with Dr. Steven Kelley. Dr Kelley has estimated that a typical pulp mill with 2,000 OD tpd of wood could be repurposed to produce between 41 and 55 million gallons of ethanol per year (60 to 80 gallons of ethanol/ton of wood). While the same mill could continue to produce paper and use a portion of the hemicellulose sugars to make 4.1 to 5.5 million gallons of ethanol per year. Also, depending on the specific plant, this in-place capital may reduce the capital costs of ethanol production by $1.00 to $1.25 per gallon.

Table 4. Pulp and Paper Mill Repurposing for Fuel Production

Process Category	Process Step(s)	Description
Biomass to Sugars	9.1Fractionation of Wood	Modify pulp mill equipment and process configuration to maximize production of low cost mixed sugars from wood with cost-effective pretreatment and enzymatic hydrolysis, using low-cost enzymes.
Sugars-to-Fuel	9.2 Mixed Sugars to Ethanol	Ferment all sugars in extract to ethanol and separate/purify ethanol
Lignin Intermediates to Heat and Power	9.3 Combined Heat and Power from Lignin Intermediates	Convert residual lignin into heat, and potentially power, supplying plant utility requirements and possible export.

The mixed sugars can also be converted to bioproducts (Process Step 9.4). There are also a number of possibilities for use of the lignin residual steam.

3.0 Forest Resources Potential

3.1 Pulp and Paper Mill Improvements

Today, the residues and intermediates generated in pulp and paper mills (bark and hog fuel residues from wood preparation processes and spent pulping liquor from the pulping process) are used to meet the heat and power demands of the mills. A portion of this material could be converted to ethanol or other biofuels. The pulp and paper mill residues and intermediates available for biofuels production, as estimated in the USDA/DOE Billion Ton Study[6], are summarized in Table 5. The Billion Ton Study differentiates between primary wood processing mills and secondary wood processing mills in the residue resource summary, and residues used in pulp and paper mills are included in the primary wood processing mills. Approximately 56% of the residues shown for the primary wood processing mills are for pulp and paper mills, 41 % for wood processing mills, and the remaining 3% is used by the chemical industry.[7]

The efficient use of pulping liquors and on-site wood residues are critical to meeting the current internal energy demands of the process. For purposes of this analysis it was assumed that virtually all of these materials would be consumed within the plant and therefore significant amounts would only be available for producing additional biofuels products if additional fuel were introduced into the process. It is possible to bring in additional forest biomass resources to completely satisfy the internal energy demands of the facility as well as provide sufficient feedstock for extra power generation[8] and/or liquid fuels production. These resources would come from other forest residues that are currently unexploited as summarized in Table 7.

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[6] *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*. (April 2005). US Department of Energy and US Department of Agriculture. http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf

[7] Personal correspondence with Robert Perlack regarding technical details of the Billion Ton Study. (July 2006).

[8] A cost-Benefit Assessment of Biomass Gasification Power Generation in the Pulp and Paper Industry. (October, 2003). E. Larson, S. Consonni, R. Katofsky. http://www.agenda2020.org/PDF/BLGCC%20FINAL%20REPORT%208%20OCT%202003.pdf

Table 5. Total Potential of Residues and Intermediates from Pulp and Paper Mills

Feedstock	Total Annual Production	Quantity used within plant or part of product mix		Feedstock Available for Biofuels	% of Total Available for Biofuels
	million dry tons/year	million dry tons/year	million dry tons/year	million dry tons/year	%
Baseline		Energy	Product +		
Wood Residues	52.7	22.6	29.0	1.0	1.9%
Pulping Liquors*	52.1	22.6	29.0	0.0	0.0%
Subtotal				1.0	
Future Case with Industry Growth					
Wood Residues	68.5	68.5	0.0	0.0	0.0%
Pulping Liquors	74.0	74.0	0.0	0.0	0.0%
Subtotal				0.0	

*Values are the biomass equivalent of the black liquor on an energy basis.

3.2 Forest Products Mill Improvements

Most of the residues generated in large wood processing mills—i.e., all primary facilities and larger secondary facilities—are recovered for further processing to marketable products or for heat and power production to meet onsite energy demands. Residues generated in smaller secondary wood processing mills are difficult to recover because they are more dispersed. The wood residues available for bioenergy production from the forest products mill improvements pathway, based on the joint USDA/DOE Billion Ton Study[9,10], is summarized in Table 6.

Table 6. Total Potential Residues from Forest Products Mills

Feedstock	Total Annual Production	Quantity used within plant or part of product mix		Feedstock Available for Biofuels	% Available for Biofuels
	million dry tons/year	million dry tons/year	million dry tons/year	million dry tons/year	%
Baseline		Energy	Product +		
Primary Mill Wood Residues	38.6	16.7	21.3	0.7	1.8%
Secondary Mill Wood Residues	15.6	0.0	9.5	6.1	39.1%
Subtotal				6.8	
Future Case with Industry Growth					
Primary Mill Wood Residues (30% Inc.)	50.2	21.6	27.6	0.9	1.8%
Secondary Mill Wood Residues (30% Inc.)	20.3	0.0	12.4	7.9	39.1%
Subtotal				8.8	

9 *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*. (April 2005). US Department of Energy and US Department of Agriculture. http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf

10 Fuelwood is included in the Billion Ton Study as a resource available for bioenergy but is not included as a resource available for biofuels production for this evaluation. Based on personal correspondence with Robert Perlack regarding the details of the Billion Ton Study approximately 90% of fuelwood is used for residential heating and the remainder for commercial purposes.

3.3 Forest Residues
The forest residues available for biofuel production, as estimated in the USDA/DOE Billion Ton Study[11], are summarized in Table 7.

Table 7. Total Potential Forest Residues[12]

Feedstock	Total Annual Production	Quantity used within existing plants or part of product mix		Feedstock Available for Biofuels	% of Total Available for Biofuels
	million dry tons/year	million dry tons/year	million dry tons/year	million dry tons/year	%
Baseline		Energy	Product +		
Logging Residue	31.7	0.0	0.0	31.7	100.0%
Other Removal Residue	9.2	0.0	0.0	9.2	100.0%
Fuel Treatments (Timberland)	48.6	0.0	0.0	48.6	100.0%
Fuel Treatments (Other Forestland)	11.0	0.0	0.0	11.0	100.0%
Subtotal				100.5	
Future Case with Industry Growth and Recovery Improvement					
Logging Residue	46.4	0.0	0.0	46.4	100.0%
Other Removal Residue	17.4	0.0	0.0	17.4	100.0%
Fuel Treatments (Timberland)	48.6	0.0	0.0	48.6	100.0%
Fuel Treatments (Other Forestland)	11.0	0.0	0.0	11.0	100.0%
Subtotal				123.4	

[11] *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*. (April 2005). US Department of Energy and US Department of Agriculture. http://feedstockreview.ornl.gov/pdf/billion_ton_vision.pdf
[12] *Ibid.* Future case assumes industry growth and recovery improvement.

3.4 Pulp and Paper Mill Repurposing

Resource information is not available since this is a new pathway. Table 8 is provided to capture thoughts.

Table 8. Total Potential Residues and Intermediates from Repurposed Pulp and Paper Mills

Feedstock	Total Annual Production	Quantity used within plant or part of product mix		Feedstock Available for Biofuels	% of Total Available for Biofuels
	million dry tons/year	million dry tons/year	million dry tons/year	million dry tons/year	%
Baseline		Energy	Product +		
Repurposed Pulpwood					
Wood Residues					
Subtotal					
Future Case with Decline in Traditional Products					
Repurposed Pulpwood					
Wood Residues					
Subtotal					

4. Forest Resources Ethanol[13] Production Potential

The estimated ethanol production potential from the available from forest product mill residues and unexploited forest residues are summarized in Tables 9 and 10 respectively. Yield values are based on specific process configurations and technical performance levels.

- 2012 yield value is based on an evaluation of corn stover and includes hydrolysis and fermentation of carbohydrates and combustion of fermentation residue for heat and power production.[14] This yield is consistent with the corn stover conceptual process design that meets the $1.07 ethanol cost target.
- 2030 yield values also based on corn stover.[15]
  - "Biochem only" case includes hydrolysis and fermentation of carbohydrates, but at improved levels of performance compared to 2012.
  - "Bio and Thermo" case includes hydrolysis and fermentation of carbohydrates and gasification of fermentation residue followed by mixed alcohol synthesis.

While there are differences in yields between corn stover and woody residues due to different feedstock compositions, the yield information for corn stover was applied to all the forest mill residue and forest residue types. Composition differences could be expected to reduce yields, in some instances dramatically. This is most likely true for

[13] Due to the emphasis of cellulosic ethanol in the President's Advanced Energy Initiative, estimates of fuel ethanol potential have been developed for all lignoocellulosic feedstocks. This is not intended to preclude consideration of other biofuels but rather to serve as a common fuel product to evaluate the relative contribution of different feedstock types as well establish a basis for comparing other biofuel options.
[14] *30x30: A Scenario for Supplying 30% of 2004 Motor Gasoline with Ethanol by 2030.* (6/30/06 Draft). Appendix D, Table D-2 for feedstock information and Appendix E, Table E-2 for conversion information.
[15] *30x30: A Scenario for Supplying 30% of 2004 Motor Gasoline with Ethanol by 2030.* (6/30/06 Draft). Appendix G, Figure G-1.

residue streams with significant amounts of bark or that are high in wood extractives such as hog fuel.

Quantities of ethanol produced shown in Tables 9 and 10 are calculated by multiplying the feedstock available by the 2030 target yields.

Table 9. Total Biofuels Potential of Residues from Forest Products Mill Industry

Feedstock Type	Output Available for Biofuels Production (Million Dry Tons)	2012 Target Ethanol Yield (Gal. per Dry Ton)	2030 Target Ethanol Yield (Gal. per Dry Ton, Biochem only)	2030 Target Ethanol Yield (Gal. per Dry Ton, Bio & Thermo)	2030 Potential Annual U.S. Ethanol Production (Million Gal., Biochem only)	2030 Potential Annual U.S. Ethanol Production (Million Gal., Bio & Thermo.)
Primary Mill Wood Residues	0.9	90	103.5	114.5	93	103
Secondary Mill Wood Residues	7.9	90	103.5	114.5	818	905
TOTAL	8.8				**911**	**1,008**

Table 10. Total Biofuels Potential of Unexploited Forest Residues

Feedstock Type	Output Available for Biofuels Production (Million Dry Tons)	2012 Target Ethanol Yield (Gal. per Dry Ton)	2030 Target Ethanol Yield (Gal. per Dry Ton, Biochem only)	2030 Target Ethanol Yield (Gal. per Dry Ton, Bio & Thermo)	2030 Potential Annual U.S. Ethanol Production (Million Gal., Biochem only)	2030 Potential Annual U.S. Ethanol Production (Million Gal., Bio & Thermo.)
Logging Residue	46.4	90	103.5	114.5	3,280	3,630
Other Removal Residue	17.4	90	103.5	114.5	950	1,050
Fuel Treatments (Timberland)	48.6	90	103.5	114.5	5,030	5,560
Fuel Treatments (Other Forestland)	11.0	90	103.5	114.5	1,140	1,260
TOTAL	**123.4**				**10,400**	**11,500**

Fuel potential information is not available for repurposed pulp and paper mills since this is a new pathway. Table 11 is provided to capture thoughts.

Table 11. Total Biofuels Potential of Repurposed Pulp and Paper Mills

Feedstock Type	Output Available for Biofuels Production (Million Dry Tons)	2012 Target Ethanol Yield (Gal. per Dry Ton)	2030 Target Ethanol Yield (Gal. per Dry Ton, Biochem only)	2030 Target Ethanol Yield (Gal. per Dry Ton, Bio & Thermo)	2030 Potential Annual U.S. Ethanol Production (Million Gal., Biochem only)	2030 Potential Annual U.S. Ethanol Production (Million Gal., Bio & Thermo.)
Repurposed Pulpwood		90	103.5	114.5		
Wood Residues		90	103.5	114.5		
TOTAL						

Additional Potential Forest-based Resources

Urban wood residues (Table 12) and wood fiber residuals from agricultural operations (Table 13) are other potential sources for biofuels production.

For the purposes of this evaluation it is assumed that the urban wood residues would probably be used for heat and/or power generation due to its variability and expected levels of contaminants. However, if converted to ethanol at a yield of 100 gal/ton (assuming the average carbohydrate composition supported this level) via a biochemical route, the feedstock available in the future case could result in up to 3.9 billion gallons per year.

Table 12. Total Potential Urban Wood Residues[16]

Feedstock	Total Annual Production	Quantity used within plant or part of product mix		Feedstock Available for Biofuels	% of Total Available for Biofuels
	million dry tons/year	million dry tons/year	million dry tons/year	million dry tons/year	%
Baseline					
Construction Residue	11.6		3.0	8.6	74.1%
Demolition Debris	27.7		16.1	11.6	41.9%
Woody Yard Trimmings (MSW)	9.8		8.0	1.8	18.4%
Wood (MSW)	13.2		7.3	5.9	44.7%
Subtotal				27.9	
Future Case with Growth *					
Construction Residue				12.0	
Demolition Debris				16.2	
Woody Yard Trimmings (MSW)				2.5	
Wood (MSW)				8.2	
Subtotal				38.9	

*11 million ton increase from baseline was spread proportionally over all elements.

[16] *Ibid.* Future case assumes general growth in the overall economy.

The wood fiber produced from agricultural operations would have compositional characteristics similar to forest products residues and could be converted to biofuels using similar technologies, resulting in another 950 to 1,050 million gallons of ethanol.

Table 13. Potential Wood Fiber Residues[17]

Feedstock	Total Annual Production	Quantity used within plant or part of product mix		Feedstock Available for Biofuels	% of Total Available for Biofuels
	million dry tons/year	million dry tons/year	million dry tons/year	million dry tons/year	%
Baseline		Energy	Product +		
Wood Fiber (from Ag)	0.2	0.0	0.0	0.2	100.0%
All Other Scenarios and Cases					
Wood Fiber (from Ag)	9.2	0.0	0.0	9.2	100.0%

[17] *Ibid.*