APPENDIX A

CONVERSIONS

Table A.1
Heat Content for Various Fuels

Automotive gasoline		125,000 Btu/gal(gross) = 115,400 Btu/gal(net)
Hydrogen		134,200 Btu/kg(gross) = 113,400 Btu/kg(net)
Diesel motor fuel		138,700 Btu/gal (gross) = 128,700 Btu/gal (net)
Biodiesel		126,206 Btu/gal (gross) = 117,093 Btu/gal (net)
Methanol		64,600 Btu/gal (gross) = 56,560 Btu/gal (net)
Ethanol		84,600 Btu/gal (gross) = 75,670 Btu/gal (net)
Gasohol		120,900 Btu/gal (gross) = 112,417 Btu/gal (net)
Aviation gasoline		120,200 Btu/gal (gross) = 112,000 Btu/gal (net)
Propane		91,300 Btu/gal (gross) = 83,500 Btu/gal (net)
Butane		103,000 Btu/gal (gross) = 93,000 Btu/gal (net)
Jet fuel (naphtha)		127,500 Btu/gal (gross) = 118,700 Btu/gal (net)
Jet fuel (kerosene)		135,000 Btu/gal (gross) = 128,100 Btu/gal (net)
Lubricants		144,400 Btu/gal (gross) = 130,900 Btu/gal (net)
Waxes		131,800 Btu/gal (gross) = 120,200 Btu/gal (net)
Asphalt and road oil		158,000 Btu/gal (gross) = 157,700 Btu/gal (net)
Petroleum coke		143,400 Btu/gal (gross)
Natural gas		
Wet	1,109	Btu/ft^3
Dry	1,027	Btu/ft^3
Compressed	20,551	Btu/pound
	960	Btu/cubic foot
Liquid	90,800	Btu/gal (gross) = 87,600 Btu/gal (net)
Crude petroleum	138,100	Btu/gal (gross) = 131,800 Btu/gal (net)
Fuel Oils		
Residual	149,700	Btu/gal (gross) = 138,400 Btu/gal (net)
Distillate	138,700	Btu/gal (gross) = 131,800 Btu/gal (net)
Coal		
Anthracite - Consumption		21.711×10^6 Btu/short ton
Bituminous and lignite - Consumption		21.012×10^6 Btu/short ton
Production average		21.352×10^6 Btu/short ton
Consumption average		21.015×10^6 Btu/short ton

Table A.2
Approximate Heat Content of Selected Fuels for Electric Power Generation

Fossil Fuels[a]	
Residual Oil (million Btu per barrel)	6.287
Distillate Oil (million Btu per barrel)	5.799
Natural Gas (Btu per million cubic ft)	1,027
Coal (million Btu per Short Ton)	20.411
Biomass Materials[b]	
Switchgrass Btu per pound	7,341
Bagasse, Btu per pound	6,065
Rice Hulls, Btu per pound	6,575
Poultry Litter, Btu per pound	6,187
Solid wood waste, Btu per pound	6,000-8,000

[a] EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383 (2006) (Washington, DC, February 2006), Table G1.

[b] Animal Waste Screening Study, Electrotek Concepts, Inc., Arlington, VA. June 2001.

Table A.3
Alternative Measures of Greenhouse Gases

1 pound methane, measured in carbon units (CH_4)	=	1.333 pounds methane, measured at full molecular weight (CH_4)
1 pound carbon dioxide, measured in carbon units (CO_2-C)	=	3.6667 pounds carbon dioxide, measured at full molecular weight (CO_2)
1 pound carbon monoxide, measured in carbon units (CO-C)	=	2.333 pounds carbon monoxide, measured at full molecular weight (CO)
1 pound nitrous oxide, measured in nitrogen units (N_2O-N)	=	1.571 pounds nitrous oxide, measured at full molecular weight (N_2O)

Table A.4
Area Conversions

1 acre[a]	=	0.405 hectare.
1 are	=	119.599 square yards. 0.025 acre.
1 hectare	=	2.471 acres.
[1 square (building)]	=	100 square feet.
1 square centimeter (cm^2)	=	0.155 square inch.
1 square decimeter (dm^2)	=	15.500 square inches.
1 square foot (ft^2)	=	929.030 square centimeters.
1 square inch (in^2)	=	6.451 6 square centimeters (exactly).
1 square kilometer (km^2)	=	247.104 acres. 0.386 square mile.
1 square meter (m^2)	=	1.196 square yards. 10.764 square feet.
1 square mile (mi^2)	=	258.999 hectares.
1 square millimeter (mm^2)	=	0.002 square inch.
1 square rod (rd^2), sq pole, or sq perch	=	25.293 square meters.
1 square yard (yd^2)	=	0.836 square meter.

Source:
National Institute of Standards and Technology, General Tables of Units and Measurements, http://ts.nist.gov/ts/htdocs/230/235/owmhome.htm

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[a] An acre is a unit of area containing 43,560 square feet. It is not necessarily square, or even rectangular. But, if it is square, then the length of a side is equal to the square root of 43,560 or about 208.71 feet.

Table A.5
Areas and Crop Yields

1.0 hectare = 10,000 m^2 (an area 100 m x 100 m, or 328 x 328 ft) = 2.47 acres
1.0 km^2 = 100 hectares = 247 acres
1.0 acre = 0.405 hectares
1.0 US ton/acre = 2.24 t/ha
1.0 metric tonne/hectare = 0.446 ton/acre
100 g/m^2 = 1.0 tonne/hectare = 892 lb/acre
US bushel = 0.0352 m^3 = 0.97 UK bushel = 56 lb, 25 kg (corn or sorghum) = 60 lb, 27 kg (wheat or soybeans) = 40 lb, 18 kg (barley)

A "target" bioenergy crop yield might be:
5.0 US tons/acre (10,000 lb/acre) = 11.2 tonnes/hectare (1120 g/m^2)

Source:
Bioenergy Feedstock Information Network, http://bioenergy.ornl.gov/.

Table A.6
Biomass Energy Conversions

Cord: a stack of wood comprising 128 cubic feet (3.62 m^3); standard dimensions are 4 x 4 x 8 feet, including air space and bark. One cord contains approx. 1.2 U.S. tons (oven-dry) = 2400 pounds = 1089 kg

1.0 metric tonne wood = 1.4 cubic meters (solid wood, not stacked)

Energy content of wood fuel (HHV, bone dry) = 18-22 GJ/t (7,600-9,600 Btu/lb)

Energy content of wood fuel (air dry, 20% moisture) = about 15 GJ/t (6,400 Btu/lb)

Energy content of agricultural residues (range due to moisture content) = 10-17 GJ/t (4,300-7,300 Btu/lb)

Metric tonne charcoal = 30 GJ (= 12,800 Btu/lb)
(but usually derived from 6-12 t air-dry wood, i.e. 90-180 GJ original energy content)

Metric tonne ethanol = 7.94 petroleum barrels = 1262 liters

Ethanol energy content = 11,500 Btu/lb = 75,700 Btu/gallon = 26.7 GJ/t = 21.1 MJ/liter

Ethanol HHV = 84,000 Btu/gallon = 89 MJ/gallon = 23.4 MJ/liter

Ethanol Density (average) = 0.79 g/ml (= metric tonnes/m^3)

Metric tonne biodiesel = 37.8 GJ (33.3 - 35.7 MJ/liter)

biodiesel density (average) = 0.88 g/ml (= metric tonnes/m^3)

Source:
Bioenergy Feedstock Information Network, http://bioenergy.ornl.gov/

Table A.7
Distance and Velocity Conversions

1 in.	= 83.33×10^{-3} ft	1 ft	= 12.0 in.
	= 27.78×10^{-3} yd		= 0.33 yd
	= 15.78×10^{-6} mile		= 189.4×10^{-3} mile
	= 25.40×10^{-3} m		= 0.3048 m
	= 0.2540×10^{-6} km		= 0.3048×10^{-3} km
1 mile	= 63360 in.	1 km	= 39370 in.
	= 5280 ft		= 3281 ft
	= 1760 yd		= 1093.6 yd
	= 1609 m		= 0.6214 mile
	= 1.609 km		= 1000 m

1 ft/sec = 0.3048 m/s = 0.6818 mph = 1.0972 km/h
1 m/sec = 3.281 ft/s = 2.237 mph = 3.600 km/h
1 km/h = 0.9114 ft/s = 0.2778 m/s = 0.6214 mph
1 mph = 1.467 ft/s = 0.4469 m/s = 1.609 km/h

Table A.8
Energy Unit Conversions

1 Btu	= 778.2 ft-lb	1 kWhr	= 3412 Btu[a]
	= 107.6 kg-m		= 2.655×10^{6} ft-lb
	= 1055 J		= 3.671×10^{5} kg-m
	= 39.30×10^{-5} hp-h		= 3.600×10^{6} J
	= 39.85×10^{-5} metric hp-h		= 1.341 hp-h
	= 29.31×10^{-5} kWhr		= 1.360 metric hp-h
1 kg-m	= 92.95×10^{-4} Btu	1 Joule	= 94.78×10^{-5} Btu
	= 7.233 ft-lb		= 0.7376 ft-lb
	= 9.806 J		= 0.1020 kg-m
	= 36.53×10^{-7} hp-h		= 37.25×10^{-8} hp-h
	= 37.04×10^{-7} metric hp-h		= 37.77×10^{-8} metric hp-
	= 27.24×10^{-7} kWhr		= 27.78×10^{-8} kWhr
1 hp-h	= 2544 Btu	1 metric hp-h	= 2510 Btu
	= 1.98×10^{6} ft-lb		= 1.953×10^{6} ft-lb
	= 2.738×10^{6} kgm		= 27.00×10^{4} kg-m
	= 2.685×10^{6} J		= 2.648×10^{6} J
	= 1.014 metric hp-h		= 0.9863 hp-h
	= 0.7475 kWhr		= 0.7355 kWhr

[a]This figure does not take into account the fact that electricity generation and distribution efficiency is approximately 29%. If generation and distribution efficiency are taken into account, 1 kWhr = 11,765 Btu.

Table A.9
Fuel Efficiency Conversions

MPG	Miles/liter	Kilometers/L	L/100 kilometers
10	2.64	4.25	23.52
15	3.96	6.38	15.68
20	5.28	8.50	11.76
25	6.60	10.63	9.41
30	7.92	12.75	7.84
35	9.25	14.88	6.72
40	10.57	17.00	5.88
45	11.89	19.13	5.23
50	13.21	21.25	4.70
55	14.53	23.38	4.28
60	15.85	25.51	3.92
65	17.17	27.63	3.62
70	18.49	29.76	3.36
75	19.81	31.88	3.14
80	21.13	34.01	2.94
85	22.45	36.13	2.77
90	23.77	38.26	2.61
95	25.09	40.38	2.48
100	26.42	42.51	2.35
105	27.74	44.64	2.24
110	29.06	46.76	2.14
115	30.38	48.89	2.05
120	31.70	51.01	1.96
125	33.02	53.14	1.88
130	34.34	55.26	1.81
135	35.66	57.39	1.74
140	36.98	59.51	1.68
145	38.30	61.64	1.62
150	39.62	63.76	1.57
Formula	MPG/3.785	MPG/[3.785/1.609]	235.24/MPG

Table A.10
Mass Conversions

	TO				
FROM	Pound	Kilogram	Short ton	Long ton	Metric ton
Pound	1	0.4536	5.0×10^{-4}	4.4643×10^{-4}	4.5362×10^{-4}
Kilogram	2.205	1	1.1023×10^{-3}	9.8425×10^{-4}	1.0×10^{-3}
Short ton	2000	907.2	1	0.8929	0.9072
Long ton	2240	1016	1.12	1	1.016
Metric ton	2205	1000	1.102	0.9842	1

Table A.11
Power Conversions

	TO					
FROM	Horsepower	Kilowatts	Metric horsepower	Ft-lb per sec	Kilocalories per sec	Btu per sec
Horsepower	1	0.7457	1.014	550	0.1781	0.7068
Kilowatts	1.341	1	1.360	737.6	0.239	0.9478
Metric horsepower	0.9863	0.7355	1	542.5	0.1757	0.6971
Ft-lb per sec	1.36×10^{-3}	1.356×10^{-3}	1.84×10^{-3}	1	0.3238×10^{-3}	1.285×10^{-3}
Kilocalories per sec	5.615	4.184	5.692	3088	1	3.968
Btu per sec	1.415	1.055	1.434	778.2	0.2520	1

Table A.12
Volume and Flow Rate Conversions[a]

1 U.S. gal	= 231 in.^{3}	1 liter	= 61.02 in.^{3}
	= 0.1337 ft^3		= 3.531 x 10^{-2} ft^3
	= 3.785 liters		= 0.2624 U.S. gal
	= 0.8321 imperial gal		= 0.2200 imperial gal
	= 0.0238 bbl		= 6.29 x 10^{-3} bbl
	= 0.003785 m^3		= 0.001 m^3
	A U.S. gallon of gasoline weighs 6.2 pounds		
1 imperial gal	= 277.4 in.^{3}	1 bbl	= 9702 in.^{3}
	= 0.1606 ft^3		= 5.615 ft^3
	= 4.545 liters		= 158.97 liters
	= 1.201 U.S. gal		= 42 U.S. gal
	= 0.0286 bbl		= 34.97 imperial gal
	= 0.004546 m^3		= 0.15897 m^3
1 U.S. gal/hr	= 3.209 ft^3/day		= 1171 ft^3/year
	= 90.84 liter/day		= 33157 liter/year
	= 19.97 imperial gal/day		= 7289 imperial gal/year
	= 0.5712 bbl/day		= 207.92 bbl/year
	For Imperial gallons, multiply above values by 1.201		
1 liter/hr	= 0.8474 ft^3/day		= 309.3 ft^3/year
	= 6.298 U.S. gal/day		= 2299 U.S. gal/year
	= 5.28 imperial gal/day		= 1927 imperial gal/year
	= 0.1510 bbl/day		= 55.10 bbl/year
1 bbl/hr	= 137.8 ft^3/year		= 49187 ft^3 /year
	= 1008 U.S. gal/day		= 3.679 x 10^5 U.S. gal/year
	= 839.3 imperial gal/day		= 3.063 x 10^5 imperial gal/year
	= 3815 liter/day		= 1.393 x 10^6 liter/day

[a] The conversions for flow rates are identical to those for volume measures, if the time units are identical.

Table A.13
International Energy Conversions

To:	Terajoules	Giga-calories	Million tonnes of oil equivalent	Million Btu	Gigawatt-hours
From:	*multiply by:*				
Terajoules	1	238.8	2.388×10^{-5}	947.8	0.2778
Gigacalories	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Million tonnes of oil equivalent	4.1868×10^{4}	107	1	3.968×10^{7}	11,630
Million Btu	1.0551×10^{-3}	0.252	$2.52 \text{ X } 10^{-8}$	1	2.931×10^{-4}
Gigawatthours	3.6	860	8.6×10^{-5}	3412	1

Table A.14
SI Prefixes and Their Values

	Value	Prefix	Symbol
One million million millionth	10^{-18}	atto	a
One thousand million millionth	10^{-15}	femto	f
One million millionth	10^{-12}	pico	p
One thousand millionth	10^{-9}	nano	n
One millionth	10^{-6}	micro	µ
One thousandth	10^{-3}	milli	m
One hundredth	10^{-2}	centi	c
One tenth	10^{-1}	deci	d
One	10^{0}		
Ten	10^{1}	deca	da
One hundred	10^{2}	hecto	h
One thousand	10^{3}	kilo	k
One million	10^{6}	mega	M
One billion[a]	10^{9}	giga	G
One trillion[a]	10^{12}	tera	T
One quadrillion[a]	10^{15}	peta	P
One quintillion[a]	10^{18}	exa	E

[a] Care should be exercised in the use of this nomenclature, especially in foreign correspondence, as it is either unknown or carries a different value in other countries. A "billion," for example, signifies a value of 10^{12} in most other countries.

Table A.15
Metric Units and Abbreviations

Quantity	Unit name	Symbol
Energy	joule	J
Specific energy	joule/kilogram	J/kg
Specific energy consumption	joule/kilogram•kilometer	J/(kg•km)
Energy consumption	joule/kilometer	J/km
Energy economy	kilometer/kilojoule	km/kJ
Power	kilowatt	Kw
Specific power	watt/kilogram	W/kg
Power density	watt/meter^3	W/m^3
Speed	kilometer/hour	km/h
Acceleration	meter/second^2	m/s^2
Range (distance)	kilometer	km
Weight	kilogram	kg
Torque	newton•meter	N•m
Volume	meter^3	m^3
Mass; payload	kilogram	kg
Length; width	meter	m
Brake specific fuel consumption	kilogram/joule	kg/J
Fuel economy (heat engine)	liters/100 km	L/100 km

APPENDIX B

BIOMASS CHARACTERISTICS

APPENDIX B

BIOMASS CHARACTERISTICS

Biomass feedstocks and fuels exhibit a wide range of physical, chemical, and agricultural/process engineering properties. Despite their wide range of possible sources, biomass feedstocks are remarkably uniform in many of their fuel properties, compared with competing feedstocks such as coal or petroleum. For example, there are many kinds of coals whose gross heating value ranges from 20 to 30 GJ/tonne (gigajoules per metric tonne; 8,600-12,900 Btu/lb). However, nearly all kinds of biomass feedstocks destined for combustion fall in the range 15-19 GJ/tonne (6,450-8,200 Btu/lb). For most agricultural residues, the heating values are even more uniform – about 15-17 GJ/tonne (6,450-7,300 Btu/lb); the values for most woody materials are 18-19 GJ/tonne (7,750-8,200 Btu/lb). Moisture content is probably the most important determinant of heating value. Air-dried biomass typically has about 15-20% moisture, whereas the moisture content for oven-dried biomass is around 0%. Moisture content is also an important characteristic of coals, varying in the range of 2-30%. However, the bulk density (and hence energy density) of most biomass feedstocks is generally low, even after densification, about 10 and 40% of the bulk density of most fossil fuels. Liquid biofuels have comparable bulk densities to fossil fuels.

Most biomass materials are easier to gasify than coal because they are more reactive with higher ignition stability. This characteristic also makes them easier to process thermochemically into higher-value fuels such as methanol or hydrogen. Ash content is typically lower than for most coals, and sulphur content is much lower than for many fossil fuels. Unlike coal ash, which may contain toxic metals and other trace contaminants, biomass ash may be used as a soil amendment to help replenish nutrients removed by harvest. A few biomass feedstocks stand out for their peculiar properties, such as high silicon or alkali metal contents – these may require special precautions for harvesting, processing and combustion equipment. Note also that mineral content can vary as a function of soil type and the timing of feedstock harvest. In contrast to their fairly uniform physical properties, biomass fuels are rather heterogeneous with respect to their chemical elemental composition.

Among the liquid biomass fuels, biodiesel (vegetable oil ester) is noteworthy for its similarity to petroleum-derived diesel fuel, apart from its negligible sulfur and ash content. Bioethanol has only about 70% the heating value of petroleum distillates such as gasoline, but its sulfur and ash contents are also very low. Both of these liquid fuels have lower vapor pressure and flammability than their petroleum-based competitors – an advantage in some cases (e.g., use in confined spaces such as mines) but a disadvantage in others (e.g., engine starting at cold temperatures).

The following pages contain three tables that show some "typical" values or range of values for selected compositional, chemical and physical properties of biomass feedstocks and liquid biofuels. Figures for fossil fuels are provided for comparison.

References for further information:

US DOE Biomass Feedstock Composition and Property Database
PHYLLIS - database on composition of biomass and waste
Nordin, A. (1994) Chemical elemental characteristics of biomass fuels. Biomass and Bioenergy 6, pp. 339-347.

Source:
Information in Appendix B is from a fact sheet by Jonathan Scurlock, Oak Ridge National Laboratory, Bioenergy Feedstock Development Programs. P.O. Box 2008, Oak Ridge, TN 37831-6407.

Table B.1
Composition of Selected Feedstocks

		Cellulose (%)	Hemi-cellulose (%)	Lignin (%)
Bioenergy Feedstocks	corn stover	35	28	16-21
	sweet	27	25	11
	sorghum	**	**	**
	sugarcane	32-48	19-24	23-32
	bagasse	**	**	**
	sugarcane	**	**	**
	leaves	**	**	**
	hardwood	45	30	20
	softwood	42	21	26
	hybrid	42-56	18-25	21-23
	poplar	**	**	**
	bamboo	41-49	24-28	24-26
	switchgrass	44-51	42-50?	13-20
	miscanthus	44	24	17
	Arundo donax	31	30	21
Liquid Biofuels	bioethanol	N/A	N/A	N/A
	biodiesel	N/A	N/A	N/A
Fossil Fuels	Coal (low rank; lignite/sub-bituminous)	N/A	N/A	N/A
	Coal (high rank bituminous/anthracite)	N/A	N/A	N/A
	Oil (typical distillate)	N/A	N/A	N/A

Source:
Jonathan Scurlock, Oak Ridge National Laboratory, Bioenergy Feedstock Development Programs. P.O. Box 2008, Oak Ridge, TN 37831-6407

Note:
N/A = Not Applicable.
** = Data not available.

Table B.2
Chemical Characteristics of Selected Feedstocks

		Heating value (gross, unless specified; GJ/t)	ash (%)	sulfur (%)	potassium (%)	Ash melting temperature [some ash sintering observed] (C)
Bioenergy Feedstocks	corn stover	17.6	5.6	**	**	**
	sweet	15.4	5.5	**	**	**
	sorghum	**	**	**	**	**
	sugarcane	18.1	3.2-5.5	0.10-	0.73-0.97	**
	bagasse	**	**	0.15	**	**
	sugarcane	17.4	7.7	**	**	**
	leaves	**	**	**	**	**
	hardwood	20.5	0.45	0.009	0.04	[900]
	softwood	19.6	0.3	0.01	**	**
	hybrid	19.0	0.5-1.5	0.03	0.3	1350
	poplar	**	**	**	**	**
	bamboo	18.5-19.4	0.8-2.5	0.03-0.05	0.15-0.50	**
	switchgrass	18.3	4.5-5.8	0.12	**	1016
	miscanthus	17.1-19.4	1.5-4.5	0.1	0.37-1.12	1090 [600]
	Arundo donax	17.1	5-6	0.07	**	**
Liquid Biofuels	bioethanol	28	**	<0.01	**	N/A
	biodiesel	40	<0.02	<0.05	<0.0001	N/A
Fossil Fuels	Coal (low rank; lignite/sub-bituminous)	15-19	5-20	1.0-3.0	0.02-0.3	~1300
	Coal (high rank bituminous/anthracite)	27-30	1-10	0.5-1.5	0.06-0.15	~1300
	Oil (typical distillate)	42-45	0.5-1.5	0.2-1.2	**	N/A

Source:
Jonathan Scurlock, Oak Ridge National Laboratory, Bioenergy Feedstock Development Programs. P.O. Box 2008, Oak Ridge, TN 37831-6407

Note:
N/A = Not Applicable.
** = Data not available.

Table B.3
Physical Characteristics of Selected Feedstocks

		Cellulose fiber length (mm)	Chopped density at harvest (kg/m3)	Baled density [compacted bales] (kg/m3)
Bioenergy Feedstocks	corn stover	1.5	**	**
	sweet	**	**	**
	sorghum	**	**	**
	sugarcane	1.7	50-75	**
	bagasse	**	**	**
	sugarcane	**	25-40	**
	leaves	**	**	**
	hardwood	1.2	**	**
	softwood	**	**	**
	hybrid	1-1.4	150 (chips)	**
	poplar	**	**	**
	bamboo	1.5-3.2	**	**
	switchgrass	**	108	105-133
	miscanthus	**	70-100	130-150 [300]
	Arundo donax	1.2	**	**
Liquid Biofuels				(typical bulk densities or range given below)
	bioethanol	N/A	N/A	790
	biodiesel	N/A	N/A	875
Fossil Fuels	Coal (low rank; lignite/sub-bituminous)	N/A	N/A	700
	Coal (high rank bituminous/anthracite)	N/A	N/A	850
	Oil (typical distillate)	N/A	N/A	700-900

Source:
Jonathan Scurlock, Oak Ridge National Laboratory, Bioenergy Feedstock Development Programs. P.O. Box 2008, Oak Ridge, TN 37831-6407

Note:
N/A = Not Applicable.
** = Data not available.

APPENDIX C

ASSUMPTIONS

APPENDIX C

ASSUMPTIONS

ESTIMATION METHODS FOR PRIMARY MILL RESIDUES

The forestry residue data included in this book are the same as that used in the DOE/USDA publication entitled "Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion Ton Annual Supply." The resource estimates contained in the following tables have been disaggregated to states.

Primary Mill Residues

Primary mill residues include bark, coarse residues (chunks and slabs), and fine residues (shavings and sawdust) generated at sawmills that process harvested wood. The mill residue data were downloaded by state and county from the U.S. Forest Service's Timber Product Output database (http://www.fia.fs.fed.us/tools-data/tools/). Because primary mill residues tend to be clean, uniform, concentrated, and of a low moisture content, most of these materials are already used for products or boiler fuel at the mills. The U.S Forest Service estimates current usage by type as follows:

- Bark – 80% used as fuel and 13% used in products
- Coarse residues – 85% used in products and 13% used as fuel
- Fine residues – 55% used as fuel and 42% used in products

This leaves a very small amount (~2%) of unused primary mill material available for energy. Residues are also generated at secondary processing mills (e.g., millwork, furniture, flooring, containers, etc.). Secondary mill residue data are not collected by the U.S. Forest Service.

ESTIMATION METHODS FOR URBAN WOOD RESIDUES

The state-level estimates provided for urban wood residues are consistent with the estimates found in the DOE/USDA publication entitled "Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion Ton Annual Supply."

Residues for MSW Landfills

MSW consists of a variety of items ranging from organic food scraps to discarded furniture and appliances. Wood and yard and tree trimmings are the two sources within this residue stream that are potentially recoverable for energy use. The wood component includes discarded furniture, pallets, containers, packaging materials, lumber scraps (other than new construction and demolition), and wood residuals from manufacturing. McKeever (2004) estimates the total wood component of the MSW stream at slightly more than 13 million dry tons. About 55% of this material is either recycled as compost, burned for power production, or unavailable for recovery because of excessive contamination. In total about 6 million dry tons of MSW wood is potentially available for energy. The other component of the MSW stream — yard and tree trimmings — is estimated at 9.8 million dry tons. However, only 1.5 million dry tons is considered potentially available for recovery after accounting for what is currently used and what is unusable.

Residues from Construction and Demolition Debris Landfills

The amount of available construction and demolition residue is correlated with economic activity (e.g., housing starts), population, demolition activity, and the extent of recycling and reuse programs. McKeever (2004) estimates annual generation of construction and demolition debris at 11.6 and 27.7 million dry tons, respectively. About 8.6 million dry tons of construction debris and 11.7 million dry tons of demolition debris are considered potentially available for energy. Unlike construction residue, which tends to be relatively clean and can be more easily source-separated, demolition debris is often contaminated, making recovery much more difficult and expensive.

Reference: McKeever, D. 2004. “Inventories of Woody Residues and Solid Wood Waste in the United States, 2002.” Ninth International Conference, Inorganic-Bonded Composite Materials. Vancouver, British Columbia. October 10-13.