Life-Cycle Inventory for Wood Pellet Manufacturing in Wisconsin

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Presentation Overview

- Introduction
  - Background
    - CORRIM
- UWGB Wood Pellet Project
  - Goal and Scope
  - Boundary Definitions
  - Data Collection
  - Life-Cycle Inventory Development
- Results / Conclusions
- Questions

Background

The Consortium for Research on Renewable Industrial Materials

- **CORRIM seeks to establish, support, and manage research and education programs focused on environmental impacts from the production, use, and disposal of wood and other bio-based materials.**

Background (cont.)

- The intent is to create:
  - A consistent database to evaluate the environmental performance of wood and alternative materials from resource regeneration or extraction to end use and disposal, i.e., from "cradle to grave"
  - A framework for evaluating life-cycle environmental and economic impacts

Background (cont.)

- The intent is to create:
  - Source data for many users, including resource managers, manufacturers, architects, engineers, environmental protection and energy analysts, and policy specialists
  - An organizational framework to obtain the best science and peer review process possible

CORRIM Biofuels Project Partners

- University of Washington (CORRIM) - Lead
- Mississippi State University
- North Carolina State University
- State University of New York
- University of Tennessee
- University of Wisconsin - Green Bay
- Humboldt State University
- USFS Forest Products Laboratory
- Consultants

Goals for this Project

- Provide LCI data and LCA results for a variety of production and harvesting practices, fire reduction, forest residues, and woody crops in different locations

- Use process models to evaluate the inputs/outputs required for the production of biofuels including ethanol, mixed alcohols, pyrolysis oils, and wood pellet fuels

Barriers Addressed

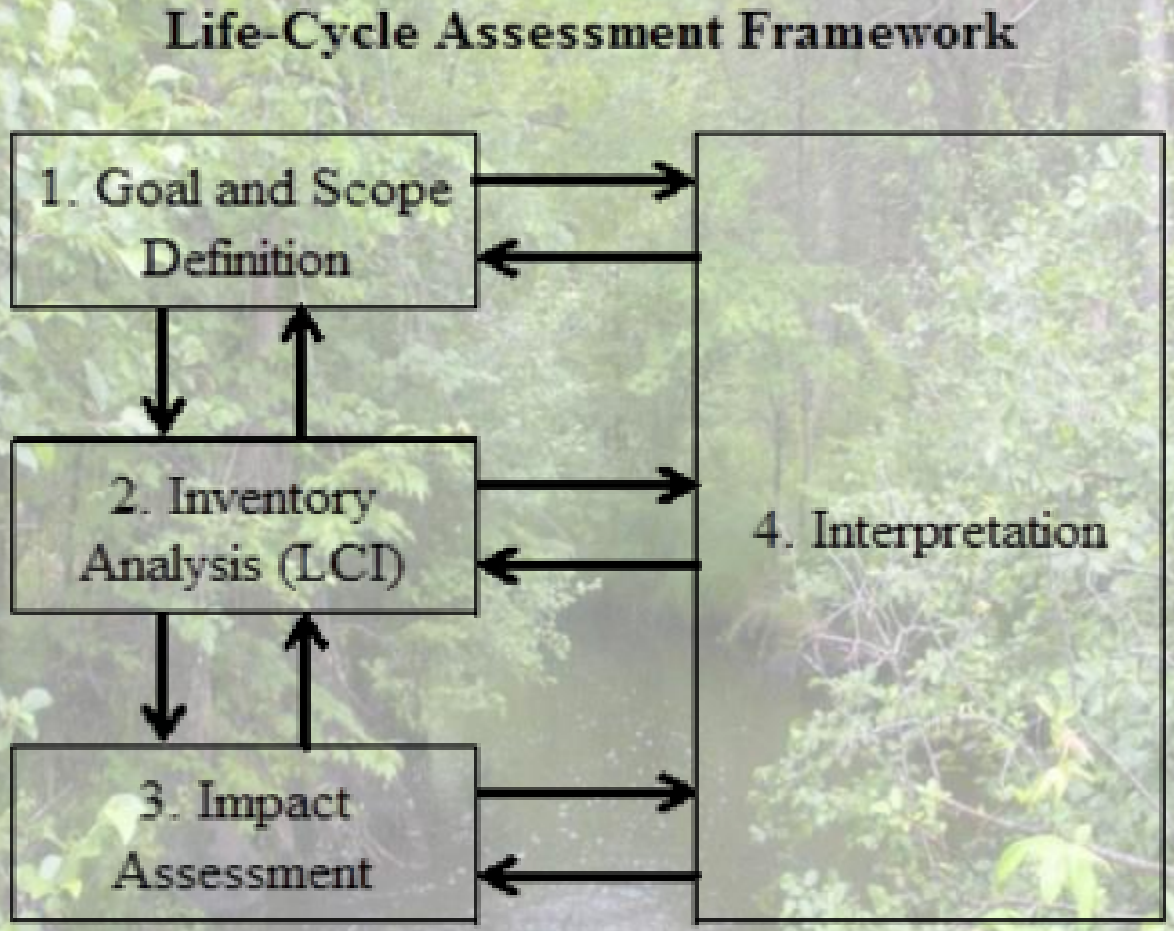
- Misrepresentations on the impacts of bioenergy create confusion about the benefits of bioenergy production, making the industry vulnerable to criticism

- There are few practical and effective methods to develop metrics, define baselines, set targets, and conduct life-cycle assessments to determine the impacts of bioenergy relative to other energy alternatives

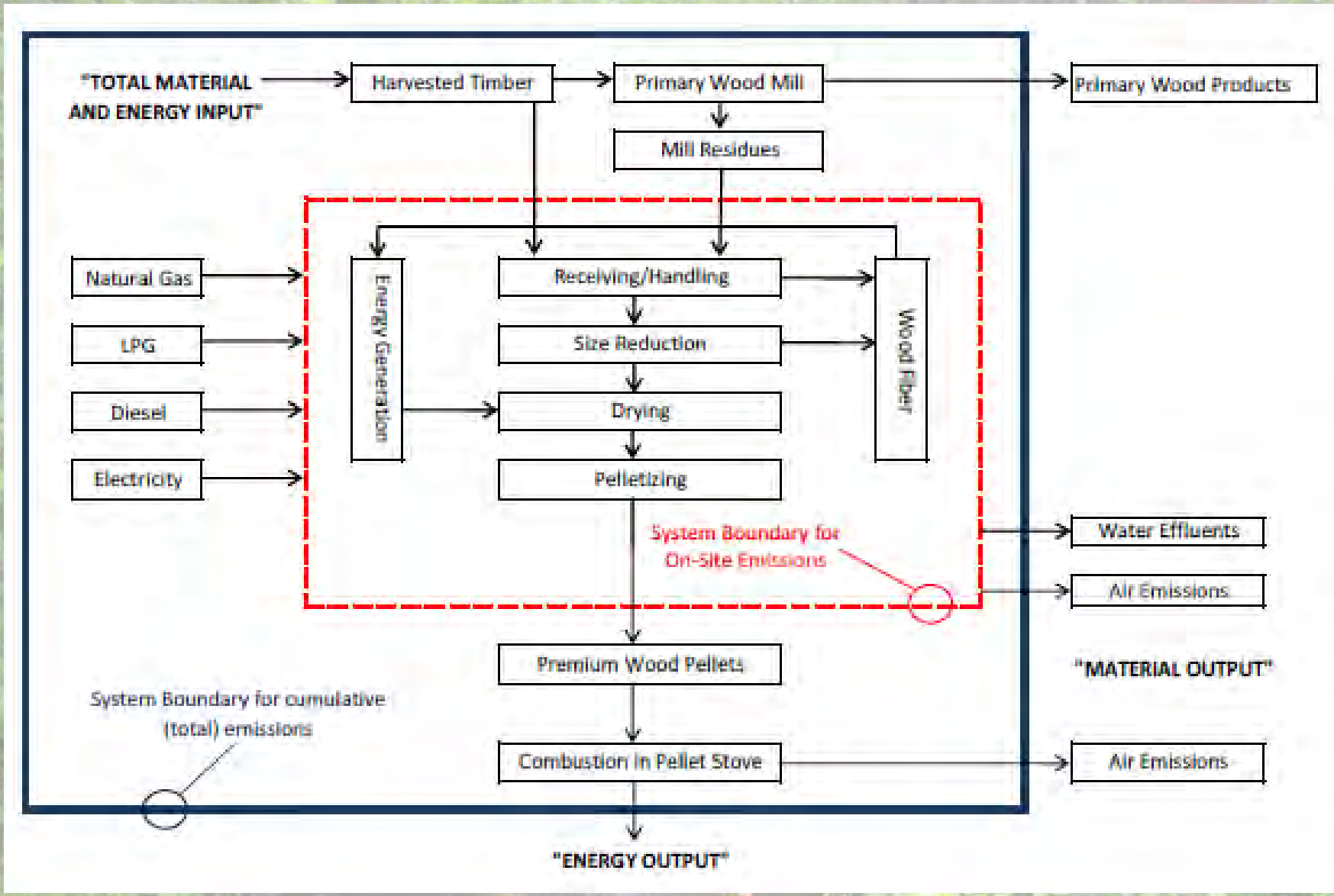
UWGB – Wood Pellet LCI Project Goals and Scope

- Document a Life-Cycle Inventory (LCI) for wood pellet fuel production in Wisconsin
- Track materials and energy inputs/outputs on a short-ton of final product and MJ basis
  - Cradle-to-Gate: compare 3 feedstock scenarios
  - Cradle-to-Grave: timber harvest to residential combustion
- Compare wood pellets to other residential heating fuels

LCI versus LCA



Boundary Definitions



Process Steps

Life-Cycle Stage	Typical Equipment Used	Typical Fuel Consumed
Timber Harvest	Chain Saw, Wheeled Cable Skidder, Grapple Skidder, Front End Loader, Feller Buncher	Gasoline, Diesel
Primary Processing (Sawmilling)	Lift Truck, Cut-Off Saw, Debarker, Circular Saw, Chipper, Edger, Trimmer, Planer, Dryer, Walnut Steamer	Gasoline, Diesel, Residual Fuel Oil, Natural Gas, LPG, Electricity (Coal), Wood Waste
Secondary Processing (Pelletmilling)	Lift Truck, Front End Loader, Skidsteer, Chipper, Hogmill, Hammermill, Dryer, Pelletmill, Cooler, Automated Bagger	Gasoline, Diesel, Natural Gas, LPG Electricity (Coal), Wood Waste, Wood Pellets
Transportation	Combination Truck (Semi w/ Trailer)	Diesel
Residential Combustion	Pellet Stoves, Fireplace w/ Inserts	Wood Pellets

Data Acquisition

Timber Production:

- Oneil, Elaine E., Leonard R. Johnson, Bruce R. Lippke, James B. McCarter, Marc E. McDill, Paul A. Roth, and James C. Finley. 2010. Life-cycle impacts of Inland Northwest and **Northeast/North Central forest resources**. P29-51

* Wood and Fiber Science Vol 42: CORRIM Special Issue: Second Report March 2010 (ISSN 0735-6161): 164pp

Primary Manufacturing:

- Bergman, Richard, Scott Bowe. Module C: Life Cycle Inventory of **Hardwood Lumber Manufacturing in the Northeast and North Central United States**
- Bergman, Richard, Scott Bowe. M. Module D: Life Cycle Inventory of **Softwood Lumber Manufactured in Northeastern and North Central United States**

* Lippke, Bruce, Jim Wilson, Leonard Johnson, Maureen Puettmann. 2009. Phase II Research Report. Life Cycle Environmental Performance of Renewable Materials in the Context of Building Construction.

Data Acquisition (cont.)

Fuel Combustion:

- Environmental Protection Agency (EPA). 2001. AP-42 Section 1.6: Wood Residue Combustion in Boilers.
- Houck, James E. & Brian Eagle. 2006. Control Analysis and Documentation for Residential Wood Combustion in the MANE-VU Region.
- Houck, James E. & Paul E. Tiegs. 1998. Residential Wood Combustion Technology Review Volume 1. Technical Report.






Data Acquisition (cont.)

The nation's primary laboratory for renewable energy and energy efficiency research and development

U.S. Life Cycle Inventory (US LCI) Database

- Created to help LCA practitioners answer questions about environmental impact
- This database provides individual gate-to-gate, cradle-to-gate and cradle-to-grave accounting of the energy and material flows into and out of the environment that are associated with producing a material, component, or assembly in the U.S.

Data Acquisition (cont.)

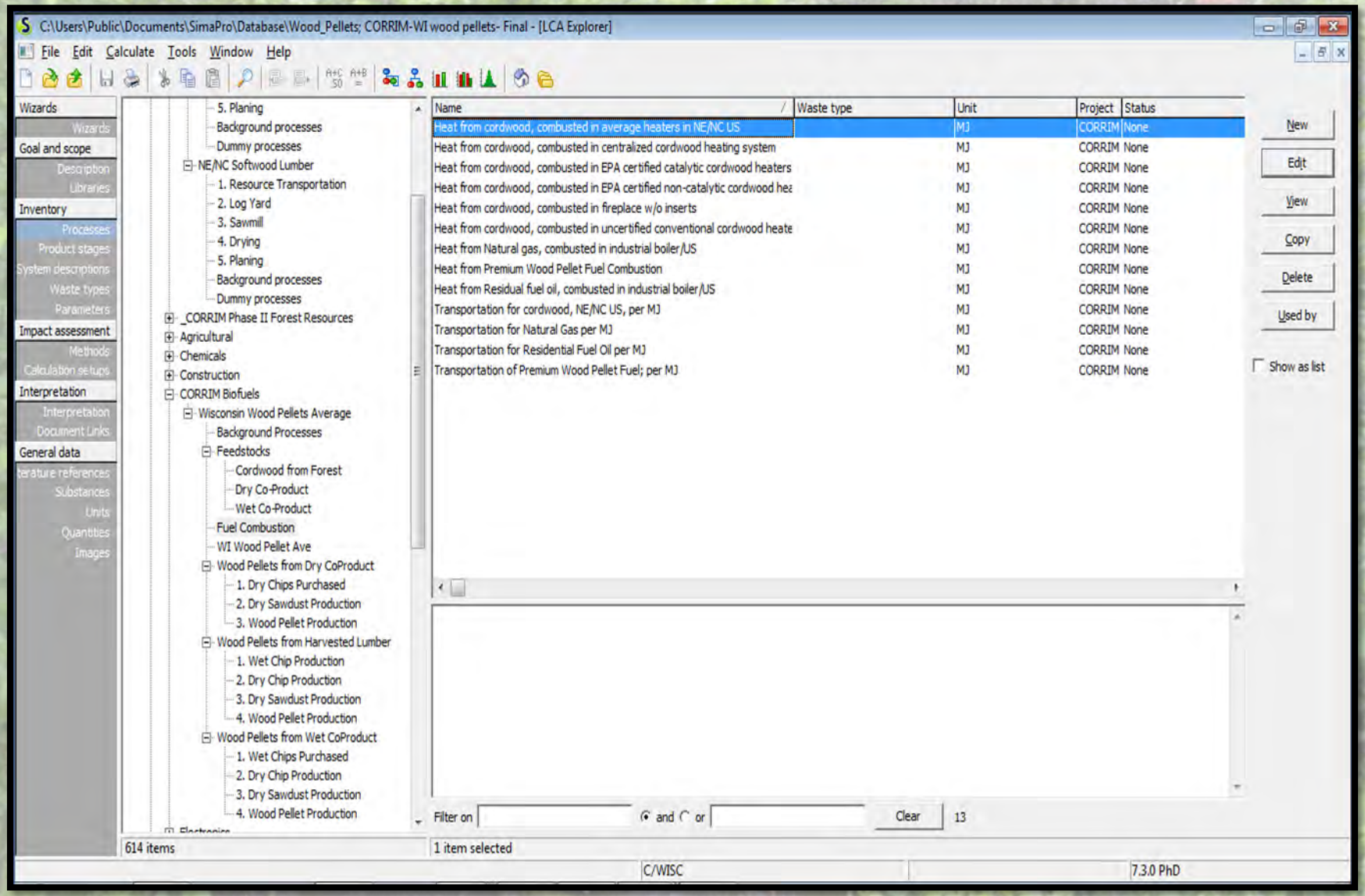
- Survey of Wisconsin Pellet Mills
  - Total energy usage
    - Separated by unit process
    - Based on actual production data
- Threshold must be met for inclusion of data in the US LCI database
  - 60% or more of the industry production

Life-Cycle Inventory

Three Feedstock Scenarios

- **Wood Pellets from Whole Logs:**
  - Timber harvested by the pellet manufacturers
- **Wood Pellets from Wet Co-Product:**
  - Chips from sawmill >35% Moisture
- **Wood Pellets from Dry Co-Product:**
  - Sawdust and shavings from sawmill <35% Moisture

SimaPro Modeling Software



Raw Material (Wood) Inputs

Oven-Dry Wood Inputs per Short Ton Premium Wood Pellets (6.5% MC) Output		Wood Pellets from Whole Logs	Wood Pellets from Wet Co-Product	Wood Pellets from Dry Co-Product	Wisconsin Average	
Raw Materials		Weighted Average	Weighted Average	Weighted Average	Weighted Average	Feedstock %
Standing Timber (Hardwood)	m3	1.06	-	-	0.30	23.21
Standing Timber (Softwood)	m3	0.62	-	-	0.18	5.16
Wet Feedstock (Hardwood)	kg	-	477.00	-	59.90	7.06
Wet Feedstock (Softwood)	kg	-	371.66	-	46.70	5.50
Dry Feedstock (Hardwood)	kg	-	-	849.28	501.67	59.07
Total Wood in Pellets	**kg**	**850.40**	**848.66**	**849.28**	**849.45**	**100**
Wood Used for Energy	kg	149.78	136.21	160.50	154.50	x
Total Wood (Oven-Dry kg)	**kg**	**1000.18**	**984.87**	**1009.78**	**1003.95**	**x**

*Densities: Hardwood Timber: 580 kg/m3; Softwood Timber: 380 kg/m3 (CORRIM)

Average Wood In: Wood Out Ratio = 1.18:1

Fuel Consumption (Upstream)

Fuel Consumption by Process of Premium Wood Pellet Production in WI		Wood Pellets from Whole Logs	Wood Pellets from Wet Co-Product	Wood Pellets from Dry Co-Product	WI Weighted Average	
Timber Harvest		Weighted Average	Weighted Average	Weighted Average	Weighted Average	% Energy
Diesel	Liters	7.92	3.70	3.70	5.62	98.24
Gasoline	Liters	0.13	0.06	1.17E-04	0.11	1.76
Total Fuel Energy	MJ	311.19	145.34	143.32	221.48	100
Co-Product Production						
Diesel	Liters	-	1.92	6.56	4.12	6.48
Gasoline	Liters	-	0.18	0.57	0.36	0.51
Natural Gas	Liters	-	20.18	47.48	30.61	0.05
Propane	Liters	-	3.79E-05	0.13	<0.01	<0.01
Electricity	kWh	-	49.10	172.60	108.22	15.82
Wood (Oven-Dry)	kg	-	0.07	160.58	94.95	77.14
Total Fuel Energy	MJ	-	259.74	4108.68	2462.01	100
Total Upstream Fuel	**MJ**	**311.19**	**405.09**	**4252.00**	**2683.49**	**x**

Energy Consumption (Upstream)

Energy Consumption by Process of Premium Wood Pellet Production in WI		Wood Pellets from Whole Logs	Wood Pellets from Wet Co-Product	Wood Pellets from Dry Co-Product	WI Weighted Average	
Timber Harvest		Weighted Average	Weighted Average	Weighted Average	Weighted Average	% Energy
Coal	MJ	10.92	5.08	7.13	7.76	2.84
Natural Gas	MJ	16.57	7.71	10.83	11.77	4.31
Crude Oil	MJ	353.09	164.32	230.66	250.78	91.87
Uranium	MJ	3.75	1.74	2.45	2.66	0.98
Total	MJ	384.34	178.86	251.07	272.97	100
Co-Product Production						
Coal	MJ	-	415.74	1548.80	967.98	23.10
Natural Gas	MJ	-	79.38	1051.00	631.40	15.07
Crude Oil	MJ	-	122.89	566.48	350.38	8.36
Uranium	MJ	-	146.88	547.11	341.94	8.16
Wood (Oven-Dry)	MJ	-	1.35	3211.51	1899.08	45.32
Total Fuel Energy	MJ	-	766.24	6924.89	4190.78	100
Total Upstream Energy	**MJ**	**384.34**	**945.10**	**7175.95**	**4463.76**	**100**

Fuel Consumption (On-Site)

Fuel Consumption by Process of Premium Wood Pellet Production in WI		Wood Pellets from Whole Logs	Wood Pellets from Wet Co-Product	Wood Pellets from Dry Co-Product	WI Weighted Average	
Wood Pellet Production		Weighted Average	Weighted Average	Weighted Average	Weighted Average	% Energy
Diesel	Liters	1.84	1.67	0.81	1.21	2.59
Natural Gas	Liters	0.07	0.07	0.03	0.05	0.00
Propane	Liters	0.16	0.16	0.14	0.15	0.00
Electricity	kWh	187.83	173.58	143.01	159.56	31.67
Wood (Oven-Dry)	kg	149.78	136.10	3.66	59.62	65.74
Total Fuel Energy	MJ	3743.19	3411.64	619.38	1813.79	100
Transportation						
Diesel Transportation	tkm	99.29	231.01	241.40	199.87	100
Total Fuel Energy	MJ	99.29	231.01	241.40	199.87	100
Total On-Site Energy	**MJ**	**3842.48**	**3642.65**	**860.78**	**2013.66**	**x**

Energy Consumption (On-Site)

Fuel Consumption by Process of Premium Wood Pellet Production in WI		Wood Pellets from Whole Logs	Wood Pellets from Wet Co-Product	Wood Pellets from Dry Co-Product	WI Weighted Average	
Wood Pellet Production		Weighted Average	Weighted Average	Weighted Average	Weighted Average	% Energy
Coal	MJ	1693.59	1573.56	1294.30	1441.59	39.30
Natural Gas	MJ	278.23	269.95	219.22	240.71	6.56
Crude Oil	MJ	209.68	467.17	317.08	270.95	7.39
Uranium	MJ	598.46	555.96	457.32	509.38	13.89
Wood (Oven-Dry)	MJ	2995.60	2722.00	22.63	1205.10	32.86
Total Energy	**MJ**	**5775.57**	**5588.64**	**2310.54**	**3667.74**	**100**
Transportation						
Coal	MJ	3.58	8.33	8.70	7.32	2.84
Natural Gas	MJ	5.44	12.65	13.20	11.12	4.31
Crude Oil	MJ	115.85	269.50	281.17	236.83	91.87
Uranium	MJ	1.23	2.86	2.99	2.51	0.98
Total Energy	MJ	126.10	293.35	306.05	257.79	100
Total On-Site Energy	**MJ**	**5901.67**	**5881.99**	**2616.59**	**3925.53**	**x**

Cradle-To-Gate Fuel Consumption

Cradle-to-Gate Inputs per Short Ton Premium Wood Pellets Output		Wood Pellets from Whole Logs	Wood Pellets from Wet Co-Product	Wood Pellets from Dry Co-Product	Wisconsin Average	
Fuel Usage (Cradle-to-Gate)						MJ %
Electricity	kWh	187.83	222.69	315.60	270.21	20.71
Diesel	Liters	9.76	7.29	11.07	11.34	9.35
Natural Gas	Liters	0.07	20.25	47.51	31.50	0.03
Propane	Liters	0.16	0.16	0.27	0.16	<0.01
Gasoline	Liters	0.13	0.24	0.57	0.48	0.36
Wood Fuel	kg	149.78	136.17	164.23	154.57	65.82
Transportation	tkm	99.29	231.01	241.40	199.87	4.26
Total Fuel Energy	**MJ**	**4,154**	**4,048**	**5,113**	**4,697**	**100**
Total Fuel Energy	**BTU**	**3,936,915**	**3,836,517**	**4,845,977**	**4,452,034**	**100**

*Fuel Energy Content based on Higher Heating Value (HHV)

*HHV of one short ton of premium wood pellet fuel: 17,303 MJ or 16,400,000 BTU

Cradle-To-Gate Energy Consumption

Cradle-to-Gate Inputs per Short Ton Premium Wood Pellets Output		Wood Pellets from Whole Logs	Wood Pellets from Wet Co-Product	Wood Pellets from Dry Co-Product	Wisconsin Average	
Energy Consumption (Cradle-to-Gate)						MJ %
Non-Renewable Fuel						
Coal	MJ	1,708.09	2,002.71	2,858.93	2,424.65	28.90
Natural Gas	MJ	300.24	369.70	1,294.24	895.01	10.67
Crude oil	MJ	678.63	1,023.88	1,395.38	1,108.95	13.22
Uranium	MJ	603.44	707.45	1,009.86	856.50	10.21
Renewable Fuel						
Wood	MJ	2,995.60	2,723.35	3,234.14	3,104.18	37.00
Total Energy Consumption	**MJ**	**6,286**	**6,827**	**9,793**	**8,389**	**100**
Total Energy Consumption	**BTU**	**5,958,297**	**6,471,174**	**9,282,030**	**7,951,927**	**100**

*Fuel Energy Content based on Higher Heating Value (HHV)
*HHV of one short ton of premium wood pellet fuel: 17,303 MJ or 16,400,000 BTU

Energy Return on Investment (EROI)

Wood Pellets From:

- **Whole Logs = 2.75:1**
- **Wet Co-Product = 2.53:1**
- **Dry Co-Product = 1.77:1**
- **WI Average = 2.06:1**

* Based on Higher Heating Values

Cradle-to-Grave Comparisons

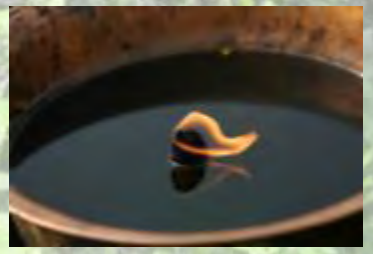
Comparing Residential Heating Fuels per MJ energy output:

- **Cordwood**

- **Wood Pellets**

- **Natural Gas**

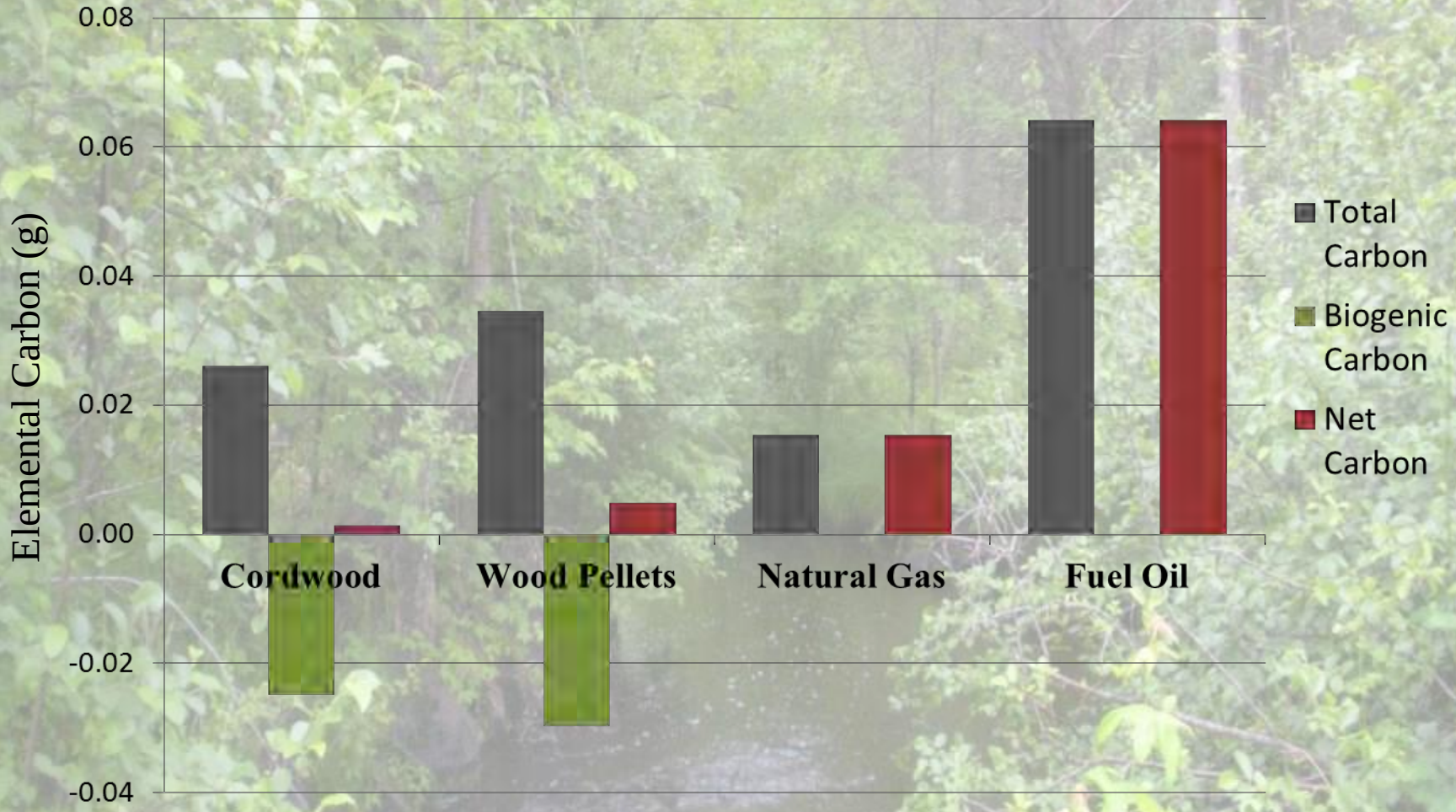
- **Residential Heating Fuel Oil**



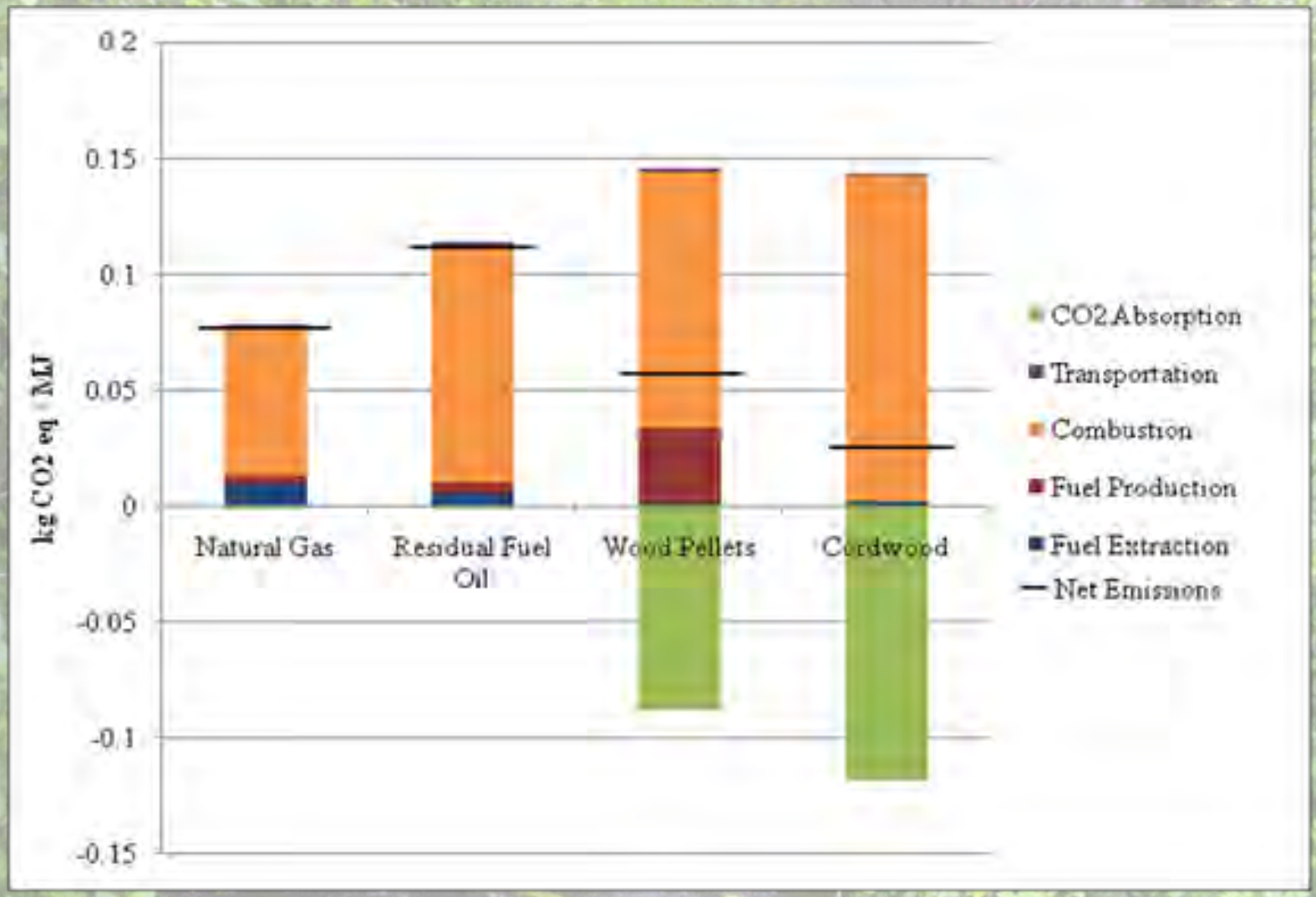
Fossil Fuel Inputs per MJ Output

	Cordwood	Wood Pellets	Natural Gas	Fuel Oil
Source	MJ/MJ	MJ/MJ	MJ/MJ	MJ/MJ
Coal	0.001	0.140	0.013	0.030
Nat Gas	0.002	0.052	1.383	0.058
Crude Oil	0.032	0.066	0.011	1.429
Uranium	0.000	0.050	0.004	0.010
Total:	**0.035**	**0.307**	**1.411**	**1.527**

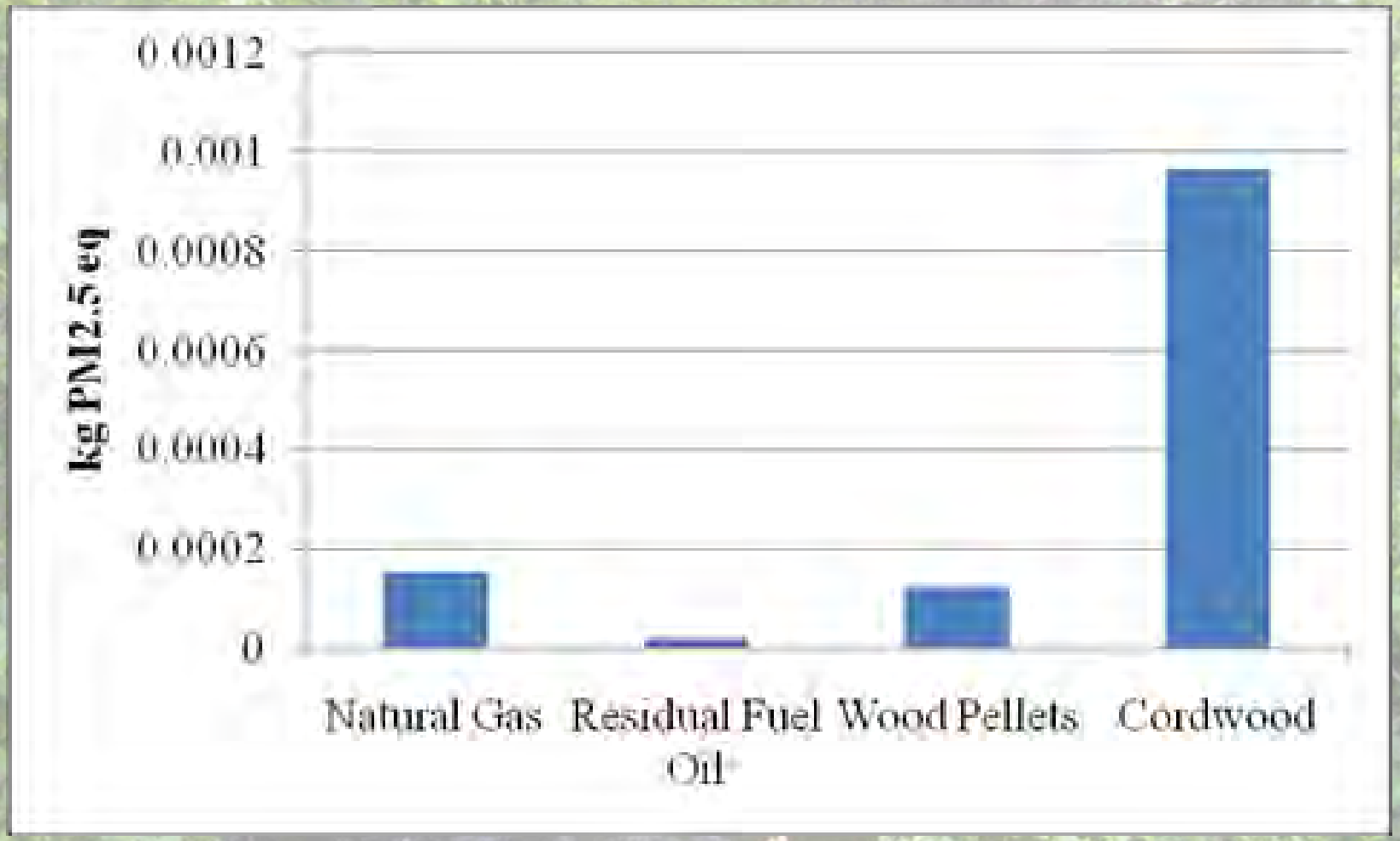
Total Carbon Emissions per MJ of Residential Heat



GHG Emissions per MJ of Residential Heat



Respiratory health effects per MJ Residential Heat



Summary of Results

- Wood Pellets from Self-Harvested Timber have the lesser environmental footprint
- Wood accounts for 65% of fuel used for pellet production, but only 37% percent of total energy consumed
- Wood pellets use 73% less fossil fuel inputs than natural gas
- Benefits of pellet fuel depends on the goal
  - Fossil fuels reduction, emissions, local economic development, convenience, etc.

Acknowledgements

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- US Department of Energy
- WI Focus on Energy

CORRIM
Consortium for Research on Renewable Industrial Materials

focus on energy
Partnering with Wisconsin utilities

Any Questions?
Thank You

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