Carbon Footprint White Paper

Confidential Internal Review – 2/22/2010 – Rail Based Shipment

Purpose

The mission of International WoodFuels is to manufacture and deliver a solid fuel renewable energy product with the lowest achievable carbon impact. The purpose of this analysis is to define the carbon footprint of our fuel as compared to various fossil fuels, and to define its net impact on the environment.

Executive Summary

Carbon "footprinting" is a focused life cycle analysis designed to quantify Greenhouse Gas (GHG) emissions of a specific product or process, beginning from origin to final consumption or formation. The full life cycle of energy typically spans across the phases of extraction and recovery, processing, transportation and end-use consumption. This paper examines the GHG emissions attributable to wood pellets and other more common fossil-based fuels.

The three GHG emissions relevant to this analysis are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). These molecules absorb infrared radiation reflected off the earth's surface and convert it into heat energy, which contributes to a rise in atmospheric temperature known as global warming. The capacity of these molecules to convert infrared radiation into heat is referred to as global warming potential (GWP), and is measured in "carbon dioxide equivalents" (CO_2e). As described in an Intergovernmental Panel on Climate Change report from 2007, each molecule of methane converts as much radiation as 25 molecules of carbon dioxide, and each molecule of nitrous oxide converts as much radiation as 298 molecules of carbon dioxide.[1] Although methane and nitrous oxide are emitted usually in trace amounts in comparison to carbon dioxide in any given fuel life cycle analysis, their enhanced global warming potentials have a magnified effect on the total GHG emissions.

The carbon footprint analysis laid out in the paper indicates that wood pellets provide roughly 70 – 82% reduction in GHG emissions when compared with a range of typical fossil fuels. The GHG Emissions measured at each step represent the lifecycle of 1 million British Thermal Units (MMBTUs) worth of each fuel.

Life Cycle Emissions ($grams\ CO_2e$ / MMBTU)							
Fuel	**Extraction & Recovery**	**Processing & Refinery**	**Transportation**	**End Use Combustion**	**Total**	**Pellet Footprint Reduction**	
						Percent	*Multiple*
Bituminous Coal	3,773	NA	2,000	93,150	98,923	82%	5.4x
Residual Oil (#6)	3,266	4,920	2,359	79,236	89,782	80%	4.9x
Distillate (#2)	3,266	10,095	2,359	73,846	89,568	80%	4.9x
Propane (LPG)	3,395	7,485	1,437	63,668	75,986	76%	4.2x
Natural Gas (NG)	3,395	3,729	535	53,315	60,975	70%	3.3x
Wood Pellets	5,804	6,433	5,969	0 *	18,206	-	-
Notes: Methane and Nitrous Oxide data for wood pellets pending							

[1] http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_Ch02.pdf

Introduction

The primary differentiator between wood pellets and fossil fuel based thermal energy is the origin of the fuel source, with significant implications for the fuel's carbon footprint. According to the GHG Protocol Guidance on Direct Emissions from Stationary Combustion, "the ultimate chemical composition of and fundamental combustion process for biomass fuels are similar to that of fossil fuels.

However, the origin of the carbon for each type of fuel is quite different. The carbon in biomass is of a biogenic origin. This means that it was recently contained in living and breathing tissues. Carbon in fossil fuels, by comparison, has been trapped in geologic formations for millennia. Because of their biogenic origin, carbon dioxide emissions from biomass fuels can be treated differently from fossil fuel combustion emissions."[2]

Provided sustainable forest management techniques are in place, forest growth subsequent to harvest can sequester all carbon dioxide emissions from combustion and biomass fueled processing. If, however, biomass harvests "exceed growth and regeneration, the resultant depletion of national biomass stocks result in a net "emission" (flux to the atmosphere)", [3] and these net emissions must be included in the fuel's carbon footprint. Unlike carbon dioxide emissions however, the combustion of biomass contributes net additions of methane and nitrous oxide to the atmosphere that cannot be accounted for in the same pathways as carbon dioxide.[2] These GHG emissions are included in the life cycle analysis of biomass fuels like wood pellets. Reliable wood pellet combustion data is still pending, but given the carefully controlled pellet boiler combustion process and fuel metering, it is likely that these results will not contribute significantly to the overall lifecycle of the fuel.

To determine the carbon footprint of the premium wood pellets manufactured by WoodFuels, a "typical" pellet carbon footprint has been laid out according to the following system boundaries:

System Boundary

Stages	Details
Harvest and Extraction	Forest Operations
Forest Carbon Inventories	Forest Removals *(CO_2 Stock Depletion / Combustion)*
	Forest Regrowth *(CO_2 Stock Addition / Sequestration)*
Feedstock Transportation	Forest to Pellet Plant
Pellet Production	Electrical Load *(Debarking, grinding, hammermill, pelletizing, cooling, conveying)*
	Biomass Driven *(Drying)*
Pellet Transportation	Pellet Plant to End User

[2] Gillenwater, Michael. "Calculation Tool for Direct Emissions from Stationary Combustion". GHG Protocol July, 2005: page 9.
[3] Intergovernmental Panel on Climate Change (IPCC). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 2, section 334

The harvest and extraction category looks at emissions from equipment used to harvest and gather fiber in the forest. The forest carbon inventories category examines rates of carbon sequestration and feedstock regeneration that occur in the forest plots where pellet biomass is harvested. This calculation compensates for any end user emissions from burning wood pellets in customer boilers, which, (although dependent on combustion practices and feedstock composition of the pellet), is around 90,000 g/ MMBTU. The transportation category accounts for all of the infrastructure and shipping point sources of emissions involved in delivering fiber from the forest to the plant, and delivering finished pellets from the plant to the customer. The processing category accounts for emissions on site at the plant.

Forest Carbon Inventories

This category accounts for production and sequestration of GHG emissions created by the process of burning pellets in a boiler at the customer site. It represents the bulk of the WoodFuels total carbon output, but also establishes the basis on which the pellets become defined as "carbon neutral". Careful forest management and sustainable harvest ensures future growth and steady rates of photosynthesis. Photosynthesis converts atmospheric carbon dioxide into organic biomass, creating oxygen and water as a byproduct. This crucial natural process provides both a reliable biomass feedstock of renewable energy, as well as a method of sequestration for carbon dioxide attributed to the end use combustion of wood pellets.

The stand composition of a given forest acre often includes a range of different timber "grades", dependent primarily on the tree's diameter at breast height (DBH) and species type. The most common grades, in rough order of descending market value, include veneer, sawtimber, stem and topwood fiber, and harvesting residue (forest slash). Historically, wood pellets have been sourced almost entirely from fiber manufacturing residue (sawdust, shavings), but recently have started to include stemwood fiber harvested in thinnings and timber stand improvements (TSI), and understory trees and topwood removed during final crop removals. Thinnings and TSI select for desirable tree species and establish optimal tree spacing to preserve live crown ratios necessary to sustain vigorous growth in the crop trees. While stand composition varies depending on many variables (geography, soil type, climate, forest management practices, etc.), general consensus indicates that forests can sustainably and conservatively provide 1 – 2 tons fiber growth per acre annually for wood pellet feedstock.

Certifying bodies such as the Forest Stewardship Council (FSC) and Sustainable Forestry Initiative (SFI) audit and verify that sustainable practices are carried out in the field. Some 48,000,000 acres of private forest lands are managed under a range of state, FSC and SFI guidelines. These management plans require professional foresters to evaluate the properties, prepare a 10 year management plan, and re-certify the plan each decade while providing annual harvest plans to the owner which define the tonnage allowed for removal for the certified property each year. These guidelines provide a credible link between responsible production and consumption of forest products. Although currently not specifically targeted at carbon sequestration, sustainable forest management and harvesting practices are exceptionally well defined for both federal lands and private properties by both FSC and SFI guidelines. According to a report from the IPCC (Intergovernmental Panel on Climate Change), "In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit."[4] These overseeing bodies, in ensuring

[4] G. J. Nabuurs, et al., in Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the IPCC

consistent growth rates and forest health, are working to prevent the procurement of wood pellet feedstock from contributing net emissions to the atmosphere.

The Transportation Component

The transport of fiber and pellets impacts the carbon footprint assessment at two stages. On the supply side, carbon is attributed to transport of fiber. WoodFuels' raw material is sourced primarily as full log roundwood. "Prior to conversion, biomass feedstocks tend to have lower energy density per volume or mass compared with equivalent fossil fuels. This makes collection, transport, storage and handling more costly per unit of energy (Sims, 2002)[5]. The movement of raw wood pellet feedstock is the most fuel and carbon dioxide intensive transport stage because moisture content is at its highest (~50%) in green, unprocessed wood. To this end, WoodFuels has chosen to locate its pellet plants in close proximity to large forest reserves, which sharply reduces the overall supply side transportation-related carbon footprint.

Once the pellet is manufactured, the WoodFuels footprint is tied to the proximity of its customer base and efficiency of distribution. Wood pellet processing dramatically reduces moisture content from ~50% to ~6%, which significantly increases energy and bulk density. As a result, the energy intensity of delivery (the gallons of fuel consumed in transport per MMBTU of pellet energy delivered to the customer) is reduced significantly. The WoodFuels industrial, commercial, and institutional sales and marketing efforts target bulk customers within a 400 mile radius with onsite storage facilities capable of receiving entire railcars of material during every delivery.

		Logistics and Distances		
Transportation Phase	**Container Load Capacity** *(tons)*	**Annual Quantities** *(tons)*	**Wood Energy Density** *(MMBTU / ton)*	**Number of Loads** *(annually)*
Raw Material to Plant via Truck	25	200,000	8	8,000
Pellets to Customer via Rail	100	100,000	16	1,000
		Fuel Consumption and Efficiencies		
Transportation Phase	**Fuel Source**	**Load MPG** *(blended)*	**Distance** *(miles / round trip)*	**Gallons Consumed** *(annually)*
Raw Material to Plant via Truck	Diesel	4.5	150	266,667
Pellets to Customer via Rail	Diesel	5	800	160,000
		Emissions		
Transportation Phase	**Engine Emission Factors** *(grams CO_2e / gallon)*	**Emissions / Load** *(grams CO_2e)*	**Annual Emissions** *(grams CO_2e)*	**Emissions / MMBTU delivered** *(grams CO_2e)*
Raw Material to Plant via Truck	22,384	746,133	5,969,066,667	3,731
Pellets to Customer via Rail	22,384	3,581,440	3,581,440,000	2,238
			Total	**5,969**

[5] R.E.H., 2004: Biomass, Bioenergy and Biomaterials – future prospects, Biomass and Agriculture - sustainability markets and policies. Pp. 37-61 ISBN 92-64-10555-7. OECD, Paris.

The Process Element

Processing accounts for all carbon output created at the plant. On an annual basis, WoodFuels' manufacturing plants consume about 200,000 tons of raw green wood, operating around 6,667 hours per year (~75% capacity). This produces 100,000 tons of pellets per year, using about 15% of feedstock that arrives at the mill gate to power the drying process.[6]

Most plant processes, including debarking, chipping, conveying, wet and dry grinding, pelletizing, cooling, and bagging, are powered by electricity. Electricity is sourced from the grid, powered by a variable mix of carbon emitting and carbon neutral sources. The generation mix of grid electricity determines the emissions factors from electricity consumption. This analysis assumes that electrical power is sourced from the current generation mix in the state of Virginia. Drying is provided by a small slipstream of dry wood chips, and a relatively insignificant amount diesel fuel is consumed to store fiber, load the debarker and to move finished products into storage.

The drying process fuel is provided by a slipstream of fine woody biomass internal to the plant fiber supply. This consists solely of woodmeal dust and small chips extracted from the end of the second hammermill before the dryer. As this source is the same as the fiber that supplies the pellet material, this feedstock is classified as sustainably harvested. As a result, similar to the combustion of wood pellets, the drying component of the process can be considered "carbon neutral," with the exception of nitrous oxide and methane emissions.

Unlike other older rotary dryers commonly used in retrofitted pellet plants, the WoodFuels' EcoTherm Dryer only reduces moisture content to ~12% (rather than 5-7%) before entering the pelletizer. Consequently, this negates the need for steam pre-conditioning of over-dried woodmeal prior to entering the pelletizer, where the pellet is reduced finally to 5%. It also allows the burner to maintain a lower combustion temperature.

[6] Mani, S. A System Analysis of Biomass Densification Process. Ph.D. thesis. Department of Chemical & Biological Engineering. The University of British Columbia: Vancouver, BC, 2005

Processing Operating Metrics				
Stages	**Energy Generation Source**	**Demand at Capacity**	**Operational Hours**	**Total Consumption**
Drying	Biomass Burner	2.1 tons / hour	6,667	14,001 tons of woodmeal
Electrical Phases	Electricity from Grid	2.5 mW	6,667	16,668 mWh
		Biomass Dryer Emissions		
Methane Emissions *(g / ton output)*	**N_2O Emissions** *(g / ton output)*	**CO_2e Emissions** *(g CO_2e / ton output)*	**Annual Emissions** *(g CO_2e)*	**Emissions / Pellet Output** *(g CO_2e / MMBTU of pellets)*
*117.93	**0.00	2,948	294,833,500	**184**
		Virginia Grid Energy Mix *** *(Electric Transmission and Distribution Loss: 8%)*		
Plant Source	**Plant Conversion Efficiency**	**Grid Energy Mix**	**CO_2e Emissions factors** *(g CO_2e / mWh)*	**Weighted Emissions factors** *(g CO_2e / mWh)*
Coal - Fired	34%	45%	1,122,755	507,485
Oil - Fired	35%	3%	848,375	22,906
Natural Gas - Fired	40%	14%	499,689	69,457
Non Carbon	NA	38%	0	0
			Total	**599,848**
		Electricity Emissions		
	Energy Intensity *(g CO_2e / mWh)*	**Total Annual Emissions** *(g CO_2e)*	**Emissions / Pellet Output** *(g CO_2e / MMBTU of pellets)*	
	599,848	9,997,965,328	**6,249**	
		Total Process Emissions *(Dryer and Electric)*		
		6,433		

* Methane EPA emission factor SCC 30700607 (direct wood-fired rotary dryer, softwood). No Ecotherm dryer data available (probably insignificant)

** N_20 emissions data pending, although probably insignificant or nonexistent

*** http://www.americaspower.org/The-Facts/

Harvesting

Harvesting accounts for the carbon output from gathering feedstock in the forest. This includes all of the logging processes and conveyance to roadside for the transport of fiber to the pellet plant.

Harvest Operating Metrics					
Harvest Mode	**Plant Supply** *(%)*	**Total Tonnage** *(annual)*	**Harvest Efficiency** *(gal / green ton)*	**Emissions Factor** *(g CO_2e / gal)*	**Harvest Emissions / Pellet Output** *(g CO_2e / MMBTU of pellets)*
Chainsaw *(gasoline)*	10%	20,000	0.60	19,564	1,467
CTL/ Forwarder *(diesel)*	40%	80,000	0.65	22,384	1,819
Mechanized *(diesel)*	50%	100,000	0.90	22,384	2,518
				Total	**5,804**

Conclusions

Based on the data referenced in this white paper, the extraction, production, distribution and combustion of wood pellets throughout its lifecycle generates 18,766 grams of CO_2 equivalents per MMBTU of wood pellets. These life cycle emissions are 3.2 – 5.2 times <u>lower</u> than other comparable fossil fuels.

WoodFuels is evaluating opportunities to further reduce its process carbon dioxide emissions. For example, the use of various biodiesel fuel blends (manufactured from waste food-based oils) offers the potential to reduce greenhouse gas emissions from truck transportation. The option to install a biomass cogeneration plant at each pellet plant or direct power purchase agreements from local renewable power generation facilities (like hydro, wind, biomass or solar power) could further reduce emissions currently contributed by process electrical consumption.

Fossil Fuel Comparison

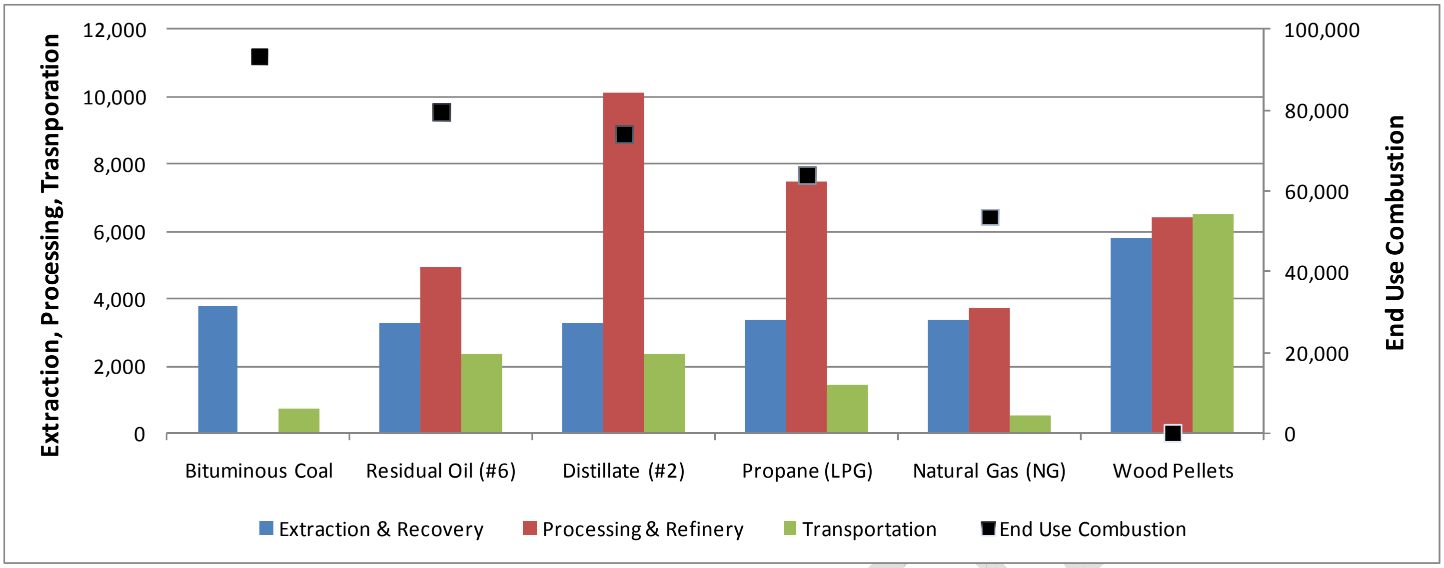
Carbon accounting for fossil-fuels is evaluated in the same fashion as wood pellets, by separating emission stages into four categories: extraction, processing, transportation and consumption.

The fundamental difference is that the combustion of fuel oil at the customer site is not carbon neutral. Fossil fuel combustion deposits carbon into the atmosphere that had been sequestered and stored underground for millions of years, at a rate far exceeding the reabsorption and sequestration of the natural carbon cycle. The analysis below examines the life cycle analysis for the principal fossil fuels: coal, residual oil (#6), distillate oil (#2), natural gas, and liquefied petroleum gas (butane/propane mix). The recovery, processing and transportation data was all sourced from the Argonne GREET model[7], and the end user combustion emission factors were sourced from the EPA's Factor Information Retrieval database[8].

To simplify this review, the analysis assumes domestic sources of fossil fuels, which, in the model, consist of coal, crude oil and natural gas. This unrealistically improves each fuel's energy efficiency figures in comparison to a more realistically defined global source mix. The distances for each transportation phase were chosen to replicate a typical pathway that on average an MMBTU of each fuel would follow to a bulk energy customer.

Additionally, in this particular assessment, liquefied petroleum gas excludes crude oil as a feedstock. Because limited processing and distribution data was available for distillate fuel, the analysis substitutes data for low-sulfur diesel, a closely related fuel. The tables throughout the following pages show a summary of the net life cycle carbon dioxide equivalent emissions for each fuel.

[7] http://www.transportation.anl.gov/modeling_simulation/GREET/
[8] http://www.epa.gov/ttnchie1/software/fire/index.html


Extraction, Processing, Trasnporation
End Use Combustion
12,000
10,000
8,000
6,000
4,000
2,000
0
100,000
80,000
60,000
40,000
20,000
0
Bituminous Coal
Residual Oil (#6)
Distillate (#2)
Propane (LPG)
Natural Gas (NG)
Wood Pellets
Extraction & Recovery
Processing & Refinery
Transportation
End Use Combustion

Residual Oil *(#6 heating oil)*	Crude Feedstock: Recovery		Residual: Refining, Transmission, Distribution and Combustion					
	Recovery	**Transportation** *(Domestic Oil Well to U.S. Crude Refinery)*	**Residual Oil Refining**	**Residual Oil Refining: Non-Combustion Emissions**	**Residual Oil Transportation** *(Crude Refinery to Bulk Terminal)*	**Residual Oil Distribution** *(Bulk Terminal to Central Heating Plant)*	**End User Combustion**	**Total**
GHG Emissions: grams/MMBTU of fuel throughput								
CO_2	2,741.78	507.64	4,156.92	543.12	782.45	966.45	78,722.47	88,420.84
CH_4: non-combustion	11.51							11.51
CH_4: combustion	8.82	1.09	7.90		1.11	1.24	1.44	21.60
N_2O	0.06	0.01	0.08		0.02	0.02	1.60	1.79
Total grams CO_2 Equivalent	**3,266**	**539**	**4,377**	**543**	**816**	**1,005**	**79,236**	**89,782**
<u>Transportation Assumptions</u>			**<u>Transportation Assumptions</u>**					
Oil Well to Crude Refinery			*Crude Refinery to Bulk Terminal*					
Mode	**Share**	**Distance**	**Mode**	**Share**	**Distance**			
Barge	5%	800 miles	Barge	25%	800 miles			
Pipeline	90%	800 miles	Pipeline	25%	800 miles			
Rail	5%	800 miles	Rail	50%	800 miles			
			Bulk Terminal to Central Heating Plant					
			Mode	**Share**	**Distance**			
			Truck	100%	200 miles			

Distillate Fuel *(#2 Heating Oil)*	Crude Feedstock		Low Sulfur Diesel: Refining, Transmission, Distribution and Combustion					
	Recovery	Transportation *(Domestic Oil Well to U.S. Refinery)*	LS Diesel Refining	LS Diesel Refining: Non-Combustion Emissions	LS Diesel Transportation *(Crude Refinery to Bulk Terminal)*	LS Diesel Distribution *(Bulk Terminal to Central Heating Plant)*	End User Combustion	Total
GHG Emissions: grams/MMBTU of fuel throughput								
CO_2	2,741.78	507.64	8,240.34	1,019.54	782.45	966.45	73,574.00	87,832.21
CH_4: non-combustion	11.51	0.00						11.51
CH_4: combustion	8.82	1.09	15.66		1.11	1.24	0.71	28.63
N_20	0.06	0.01	0.15	1.34	0.02	0.02	0.85	2.46
Total grams CO_2 Equivalent	**3,266**	**539**	**8,677**	**1,419**	**816**	**1,005**	**73,846**	**89,568**

Transportation Assumptions (from oil well to crude refinery)

Oil Well to Crude Refinery

Mode	Share	Distance
Barge	5%	800 miles
Pipeline	90%	800 miles
Rail	5%	800 miles

Transportation Assumptions

Crude Refinery to Bulk Terminal

Mode	Share	Distance
Barge	25%	800 miles
Pipeline	25%	800 miles
Rail	50%	800 miles

Bulk Terminal to Central Heating Plant

Mode	Share	Distance
Truck	100%	200 miles

Natural Gas	Natural Gas: Recovery, Processing, Transmission, Distribution and Combustion					
	NG Recovery	NG Processing	NG Processing: Non-Combustion Emissions	NG Distribution *(NG Field to Central Heating Plant)*	End User Combustion	Total
GHG Emissions: grams/MMBTU of fuel throughput						
CO_2	1,616.55	1,722.84	1,237.00	450.66	53,000.08	58,027.13
CH_4: non-combustion	66.03	29.84				95.87
CH_4: combustion	4.68	0.47		3.20	1.02	9.36
N_2O	0.04	0.04		0.01	0.97	1.06
Total grams CO_2 Equivalent	**3,395**	**2,492**	**1,237**	**535**	**53,315**	**60,975**
<u>Transportation Assumptions</u>						
Natural Gas Field to Central Heating Plant						
Mode	**Share**	**Distance**				
Pipeline	100%	1,500 miles				

Liquified Petroleum Gas *(Propane)*	Natural Gas Feedstock				Liquified Petroleum Gas: Production, Transmission, Distribution and Combustion				
	NG Recovery	NG Processing	NG Processing: Non-Combustion Emissions	NG Transportation *(Natural Gas Field to Liquefied Petroleum Gas Plant)*	LPG Production	LPG Transportation *(Liquefied Petroleum Gas Plant to Bulk Terminal)*	LPG Distribution *(Bulk Terminal to Central Heating Plant)*	End User Combustion	Total
GHG Emissions: grams/MMBTU of fuel throughput									
CO_2	1,616.55	1,722.82	1,237.00	30.04	2,274.43	622.27	547.66	62,306.64	70,357.42
CH_4: non-combustion	66.03	29.84		7.36					103.23
CH_4: combustion	4.68	0.47		0.21	4.22	0.85	0.71	1.00	12.13
N_2O	0.04	3.06	1.55	0.00	0.05	0.02	0.01	4.49	9.21
Total grams CO_2 Equivalent	**3,395**	**3,392**	**1,698**	**220**	**2,395**	**648**	**569**	**63,668**	**75,986**

Transportation Assumption

Natural Gas Field to Liquefied Petroleum Gas Plant

Mode	Share	Distance
Pipeline	100%	50 miles

Transportation Assumption

Liquefied Petroleum Gas Plant to Bulk Terminal

Mode	Share	Distance
Barge	25%	800 miles
Pipeline	25%	800 miles
Rail	50%	800 miles

Bulk Terminal to Central Heating Plant

Mode	Share	Distance
HHDT (truck)	100%	200 miles

Bituminous Coal	Coal: Mining, Cleaning, Transportation and Combustion				
	Coal Mining and Cleaning	Coal Mining: Non-Combustion Emissions	Coal Transportation to Power Plants	End User Combustion	Total
GHG Emissions: grams/MMBTU of fuel throughput					
CO_2	810.89		1,322.76	92,423.48	94,557.13
CH_4: combustion	1.10	117.23	31.77	9.24	159.34
N_20	0.01		0.03	1.66	1.71
Total grams CO_2 Equivalent	**842**	**2,931**	**2,127**	**93,150**	**99,050**
Transportation Assumption					
Coal Mine to Spreader / Stroker Powerplant					
Mode	**Share**	**Distance**			
Rail	100%	800 miles			