1.964 Design for Sustainability **Fall 2006**
Homework #3

Assigned: October 4, 2006
Due: October 11, 2006

Attached are partial data sets for concrete and steel.

Perform a life cycle inventory of the manufacture of 1 cubic meter of concrete **and** 1 cubic meter of rolled section steel using the matrix methodology presented in class. Before you set up your matrices, be sure to go through all the preliminary steps presented in "*LCA: what it is and how to do it* ." You will find that you do not have all of the data necessary to completely fill your matrices. That is fine. Simply fill the spots you don't have data for with a place holder.

Discuss your results. What can you conclude, if anything, about the two materials you compared after the life cycle inventory stage? What additional information would you need to conduct a 'complete' life cycle assessment?

Concrete

Input

Portland cement:	300	kg
Gravel:	1890	kg
Water:	186	kg
Diesel fuel:	22.7	MJ
Electricity:	4.36	kWh
Natural Gas:	1.16	MJ
Light fuel oil:	13.3	MJ
Heavy fuel oil:	3.09	MJ
Lubricating oil:	0.0119	MJ
Transport by 16t truck:	0.998	tkm
Transport by 28t truck:	9.44	tkm
Transport by barge:	49.2	tkm
Transport by rail:	6.82	tkm
Steel:	0.00238	kg
Synthetic Rubber:	0.00713	kg

Output

Waste heat:	15.7	MJ
Waste to inert landfill:	16.9	kg
Waste to municipal incinerator:	0.0951	kg
Concrete production effluent:	0.0143	m3
Concrete:	1	m3

Portland cement

Input

Clinker:	0.903	kg
Gypsum:	0.052	kg
Additional milling substances:	0.045	kg
Transport by 16t truck:	0.00486	tkm
Electricity:	0.0292	kWh

Output

Waste heat:	0.0105	MJ
Portland cement:	1	kg

(Note: No dust emissions taken into account as it is assumed that dust is "fully" recycled)

Clinker

Input

Bauxite:	0.000102	kg
Lime:	0.00392	kg
Limestone:	0.841	kg
Sand:	0.00926	kg
Clay:	0.0331	kg
Natural gas:	0.00681	MJ
Light fuel oil:	0.000374	kg
Heavy fuel oil:	0.0255	kg
Hard coal:	0.0354	kg
Petroleum coke:	0.00391	kg
Electricity:	0.0508	kWh
Transport by 16t truck:	0.0000861	tkm
Transport by 28t truck:	0.00268	tkm
Transport by 40t truck:	0.00211	tkm
Diesel in building machine:	0.0134	MJ
Water:	1.96	kg

Output

Waste heat:	3.62	MJ
Waste to inert landfill:	0.00008	kg
Waste to municipal incineration:	0.000045	kg
Dust to air:	0.0000377	kg
Carbon dioxide:	0.855	kg
Carbon monoxide:	0.000472	kg
Nitrogen oxides:	0.00108	kg
Sulfur dioxide:	0.000355	kg
Clinker:	1	kg

Gypsum

Input

Gypsum (resource):	1	kg
Diesel used in machines:	0.018	MJ
Electricity:	0.000916	kWh

Output

Waste heat:	0.0033	MJ
Dust to air:	0.0016	kg
Gypsum (mined):	0.65	kg

Gravel

Input

Gravel (in ground):	1.04	kg
Water:	1.38	kg
Diesel in building machine:	0.0147	MJ
Transport by 16t truck:	0.00000088	tkm
Transport by 28t truck:	0.0000172	tkm
Light fuel oil:	0.00244	MJ
Electricity:	0.00272	kWh

Output

Waste heat:	0.00977	MJ
Waste to municipal incineration:	0.00000277	kg
Sand:	0.35	kg
Gravel (mined):	0.65	kg

Steel

Input

Pig iron:	0.9	kg
Iron scrap:	0.126	kg
Ferronickel:	0.04	kg
Ferrochromium:	0.0147	kg
Ferromanganese:	0.0139	kg
Molybdenite:	0.0175	kg
Iron ore:	0.022	kg
Coke:	0.00025	MJ
Lime:	0.0425	kg
Natural gas:	0.0375	MJ
Electricity:	0.0219	kWh
Water:	2.7	kg
Transport by 32t truck:	0.0153	tkm
Transport by rail:	0.108	tkm

Output

Waste heat:	0.117	MJ
Dust to air:	0.0000475	kg
Nitrogen oxides:	0.0000125	kg
Carbon monoxide	0.00473	kg
Carbon dioxide	0.0756	kg
Waste to landfill:	0.036	kg
Steel, low-alloyed, BOF:	1	kg

Pig Iron

Input

Sinter:	1.05	kg
Pellets:	0.4	kg
Iron ore:	0.15	kg
Limestone:	0.01	kg
Water:	6	kg
Coke:	0.34	MJ
Coal:	0.15	kg
Electricity:	100	kWh
Transport by 32t truck:	0.00348	tkm
Transport by rail:	0.189	tkm

Output

Waste heat:	0.49	MJ
Dust to air:	0.0000319	kg
Sulfur dioxide:	0.000133	kg
Nitrogen oxides:	0.0000798	kg
Carbon monoxide:	0.00134	kg
Carbon dioxide:	0.000415	kg
Waste to landfill:	0.0207	kg
Pig iron:	1	kg

Iron Ore

Input

Iron ore (resource):	1	kg
Water:	0.0115	kg
Diesel in building machine:	0.0255	MJ
Electricity:	0.00142	kWh

Output

Waste heat:	0.00513	MJ
Dust to air:	0.00288	kg
Iron ore:	0.462	kg

Sinter

Input

Iron ore:	1.5	kg
Lime:	0.05	kg
Transport by 32t truck:	0.002	tkm
Transport by rail:	0.309	tkm
Natural gas:	0.0363	MJ
Coke:	1.43	MJ
Water:	0.5	kg
Electricity:	0.01	kWh

Output

Waste heat:	1.54	MJ
Dust to air:	0.000206	kg
Nitrogen oxides:	0.000527	kg
Sulfur dioxide:	0.00126	kg
Carbon monoxide:	0.0257	kg
Carbon dioxide:	0.204	kg
Hydrocarbons:	0.000137	kg
Sinter:	1	kg

Pellets

Input

Iron ore:	1.5	kg
Bentonite:	0.04	kg
Transport by 40t truck:	0.00401	tkm
Transport by rail:	0.0241	tkm
Water:	0.09	kg
Natural gas:	0.069	MJ
Electricity:	0.025	kWh

Output

Waste heat:	0.531	MJ
Dust to air:	0.000075	kg
Nitrogen oxides:	0.000315	kg
Sulfur dioxide:	0.000134	kg
Carbon monoxide:	0.00021	kg
Carbon dioxide:	0.0237	kg
Hydrocarbons:	0.0000223	kg
Pellets:	1	kg

Steel, section bar rolling

Input

Cumulative energy:	1.74	MJ

Output

Carbon dioxide:	0.14	kg
Nitrogen oxides:	0.00024	kg
Sulphur dioxide:	0.00032	kg
Dust to air:	0.00005	kg
Rolled section bar:	1	kg

Transport by 16t truck

Input			Output			
Diesel fuel:	0.211	kg	Methane:	0.0000251	kg	
			Carbon monoxide:	0.00139	kg	
			Carbon dioxide:	0.666	kg	
			Nitrogen oxides:	0.00636	kg	
			Sulfur dioxide:	0.000127	kg	
			Particulates:	0.000913	kg	
			Waste Heat:	9.59	MJ	
			Truck operation:	1	tkm	(average load factor = 50%)

Transport by 28t truck

Input			Output			
Diesel fuel:	0.29	kg	Methane:	0.0000216	kg	
			Carbon monoxide:	0.00126	kg	
			Carbon dioxide:	0.913	kg	
			Nitrogen oxides:	0.00885	kg	
			Sulfur dioxide:	0.000174	kg	
			Particulates:	0.000928	kg	
			Waste Heat:	13.2	MJ	
			Truck operation:	1	tkm	(average load factor = 50%)

Transport by 40t truck

Input			Output			
Diesel fuel:	0.348	kg	Methane:	0.0000197	kg	
			Carbon monoxide:	0.00114	kg	
			Carbon dioxide:	1.1	kg	
			Nitrogen oxides:	0.00992	kg	
			Sulfur dioxide:	0.000209	kg	
			Particulates:	0.000875	kg	
			Waste heat:	15.8	MJ	
			Truck operation:	1	tkm	(average load factor = 50%)

Transport by rail

Input			Output			
Diesel fuel:	0.00226	kg	Methane:	0.000000294	kg	
Electricity:	0.0396	kWh	Carbon monoxide:	0.0000357	kg	
			Carbon dioxide:	0.00712	kg	
			Nitrogen oxides:	0.000124	kg	
			Sulfur dioxides:	0.00000136	kg	
			Particulates:	0.0000748	kg	
			Waste heat:	0.245	MJ	
			Freight train operation:	1	tkm	

Electricity

Input		Output	
Hard Coal	0.613 kg	Sulfur Dioxide	0.00402 kg
Natural Gas	0.25 MJ	Nitrogen oxides:	0.00252 kg
		Carbon monoxide	0.000125 kg
		Carbon dioxide:	0.979 kg
		Methane	2.02×10^{-9} kg
		Hydrocarbons:	0.0000129 kg
		Dust to Air:	0.00173 kg
		Electricity	1 kWh

Transport by barge

Input		Output	
Hard Coal	0.00023 kg	Waste heat:	0.01199 MJ
Water	2.0185 kg	Nitrogen oxides:	0.0001 kg
Clay	5.9×10^{-6} kg	Carbon monoxide	1.8×10^{-5} kg
		Carbon dioxide:	0.00858kg
		Methane	1.2×10^{-5} kg
		Hydrocarbons:	1.4×10^{-7} kg
		Dust to Air:	7.8×10^{-6} kg
		Sulfur Dioxide	0.00173 kg
		Barge operation	1 tkm