Life Cycle Greenhouse Gas (GHG) Emissions Tables, Vista Canyon, Santa Clarita, California

Table 1
Life Cycle Greenhouse Gas (GHG) Emissions From Materials[1] Used for Buildings
Vista Canyon
Santa Clarita, California

Residential and Non-Residential Buildings[2]	Embodied Energy as Percentage of Overall Energy[3]	
	3%	25%
(tonnes CO_2 / year)		
7,380	221	1,845

Notes:
1. All materials were analyzed. See references below for more details.
2. Represents CO_2 emissions from electricity and natural gas use. Refer to Tables 4-10 to 4-22 for calculations.
3. Percentages are based upon LCA studies below. The studies compared energy used in the manufacture and transport of materials to energy use from electricity and natural gas. Varying lifetimes of homes were assumed in each study. As homes become more energy efficient, the portion of GHGs from embodied energy increases.

Abbreviations:
CO_2 = Carbon Dioxide
GHG = Greenhouse Gas
LCA = Life Cycle Analysis

Sources:

Scheuer, C., G.A. Keoleian, and P. Reppe. (2003) Life cycle energy and environmental performance of a new university building: Modeling challenges and design implications. *Energy and Buildings* , **35**(10): p. 1049.
Keoleian, G.A., S. Blanchard, and P. Reppe. (2000) Life-cycle energy, costs, and strategies for improving a single-family house. *Journal of Industrial Ecology* , **4**(2): p. 135.
Sartori, I. and A.G. Hestnes. (2007) Energy use in the life cycle of conventional and low-energy buildings: A review article. *Energy and Buildings* , **39**(3): p. 249.

Winther, B.N. and A.G. Hestnes. (1999) Solar versus green: The analysis of a Norwegian row house. *Solar Energy* , **66**(6): p. 387.

Adalberth, K., A. Almgren, and E.H. Petersen. (2001) Life Cycle Assessment of Four Multi-Family Buildings. *International Journal of Low Energy and Sustainable Buildings* , **2**.

Table 2
Greenhouse Gas (GHG) Emission Factors for the Manufacture of Cement
Vista Canyon
Santa Clarita, California

Data Source	Calcining Emissions[4]	Fossil Fuel Emissions[5]
	(tonnes CO_2/tonne cement)	
EIA[1]	0.5	-
EPA Ap-42[2]	0.5	-
	0.75 - 1.19	
	0.92	
Battelle[3]	0.99	

Notes:

1. From the Energy Market and Economic Impacts of S.280, the Climate Stewardship and Innovation Act of 2007. Calculations are detailed in the Documentation for Emissions of Greenhouse Gases in the United States 2004, pg 35 - 38.

2. From AP-42 section 11.6: Portland Cement Manufacturing. Approximately 500 kg of CO_2 are released per Mg of cement produced during the calcining process; total manufacturing emissions depend on energy consumption (pg 11.6-6). Table 11.6-8 specifies 2,100 lbs CO_2 per ton of clinker produced (ENVIRON used the higher value instead of 1,800 lbs / ton to be conservative). Clinker is a precursor to cement. Using a clinker factor of 0.88 lb clinker/lb cement (from the Battelle report) yields an emission factor of 0.92 tonnes CO_2/tonne cement.

3. From Table 1-2 of the Battelle report. The North American average emission factor is 0.99 kg CO_2/kg cement; the global average is 0.87 kg CO_2/kg cement.

4. There are two main sources of CO_2 emissions from the manufacture of cement: the calcining process and fossil fuel combustion. Calcining emissions result from the chemical reaction of converting limestone ($CaCO_3$) to calcium oxide (CaO) and carbon dioxide (CO_2). CaO is a precursor to concrete and CO_2 is released to the atmosphere.

5. Fossil fuel combustion usually provides the energy necessary to manufacture cement. The emissions from the fossil fuel combustion vary depending on the type of fuel used; in general the combustion accounts for slightly less than half of the CO_2 emissions from the manufacture of cement.

Abbreviations:
AP-42 = Compilation of Air Pollutant Emission Factors
CO_2 = carbon dioxide
EIA = Energy Information Administration
EPA = Environmental Protection Agency
kg = kilogram
NA = Not Available
Mg = megagram = 1,000 kg

Sources:
EIA Energy Market and Economic Impacts of S.280, the Climate Stewardship and Innovation Act of 2007. August 2007. http://www.eia.doe.gov/oiaf/servicerpt/csia/special_topics.html

EPA AP42 Section 11.6: Portland Cement Manufacturing. http://www.epa.gov/ttn/chief/ap42/ch11/final/c11s06.pdf

Battelle. Humphreys, K. and Mahasenan, M. Climate Change: Toward a Sustainable Cement Industry. March 2002.

Table 3
Quantities of Infrastructure Materials
Vista Canyon
Santa Clarita, California

CONCRETE			
Material	**Projected Material Needed[1]**	**Area[2]**	**Total Weight[3]**
	(tonnes/acre)	**(acres)**	**(tonnes)**
Concrete	48	185	8,811
Total	---	---	8,811
		Total Concrete (cu yd)[4]	4,856
ASPHALT			
Material	**Projected Material Needed[1]**	**Area[2]**	**Total Weight[3]**
	(tonnes/acre)	**(acres)**	**(tonnes)**
Asphalt	73	185	13,449
Total	---	---	13,449
		Total Asphalt (cu yd)[4]	17,130

Abbreviations:
ft = foot
in = inch
lb = pound
sq ft = square foot
cu ft = cubic foot
cu yd = cubic yard
GHG = Greenhouse Gas

Notes:
1. Estimated materials needed (tonnes/acre) are based on previous experience with similarly sized projects. Calculations are based on the expected need for utilities infrastructure: sewers, water pipes, storm drains, and electric, gas, cable, and telephone conduits etc.
2. Acreage of development provided by Vista Canyon Ranch, LLC.
3. Total material quantities (tonnes) for concrete and asphalt are calculated by converting tonnes/acre of material into mass in tonnes using the acreages of the development.
4. Total material quantities (yd^3) are calculated using densities provided by AP-42.

Sources:
AP-42 conversions available at http://www.epa.gov/ttn/chief/ap42/appendix/appa.pdf

Table 4
Greenhouse Gas (GHG) Emissions from Manufacture of Materials
Vista Canyon
Santa Clarita, California

Material	Emission Factor	Volume of Material	Mass of Material	Emissions from Manufacture of Material
	(tonnes CO_2/tonne material)	(yd^3)	(tonnes)	(tonnes CO_2)
Cement (in concrete)[1]	0.990	728	826	818
Asphalt[2]	0.018	17,130	13,449	235
TOTAL				**1,053**

Abbreviations:
CO_2 = carbon dioxide
yd^3 = cubic yard

Notes:

1. Concrete is composed of cement, water, aggregate, and chemical admixtures; concrete mixtures are approximately 15% cement by volume (Portland Cement Association). Cement accounts for almost all of the CO_2 emissions associated with the manufacture of conrete. The cement emission factors provided by AP-42 cover a wide range of processing technologies and emission factors, so ENVIRON used the cement emission factor provided by the Battelle report.

2. From AP-42 section 11.1: Hot Mix Asphalt Plants. Tables 11.1-5 and 11.1-7. ENVIRON assumed an average emission factor from batch mix hot asphalt plants and drum mix hot asphalt plants.
3. Because the manufacture of cement is the main contributor to CO_2 emissions in the production of concrete, ENVIRON assumed that the emissions from the manufacture of cement are equal to the emissions from the overall manufacture of concrete.

Abbreviations:
CO_2 = carbon dioxide
yd^3 = cubic yard

Sources:
Battelle. Humphreys, K. and Mahasenan, M. Climate Change: Toward a Sustainable Cement Industry. March 2002.
EPA AP42 section 11.1: Hot Mix Asphalt Plants. Tables 11.1-5 and 11.1-7.
http://www.epa.gov/ttn/chief/ap42/ch11/final/c11s01.pdf
Portland Cement Association. Cement and Concrete Basics.
http://www.cement.org/basics/concretebasics_concretebasics.asp

Table 5
Greenhouse Gas (GHG) Emissions from Transportation of Infrastructure Raw Materials
Vista Canyon
Santa Clarita, California

Material	Total Mass Transported	Distance from Source Location[2]	Mass-Distance[3]	Emission Factor[4,5]	Total Emissions
		Local Source	Local Source	Truck	
	(tonnes material)	(miles)	(tonne-miles)	(grams CO_2/tonne-mile)	(tonnes CO_2)
Concrete	8,811	100	881,103	253	223
Asphalt	13,449	100	1,344,900		340
TOTAL					**563**

Notes:

1. For manufacturing emissions, only the amount of cement is considered; however, for transportation emissions, the entire mass of concrete is considered because the concrete mix is transported from the source locations.
2. The materials are assumed to originate from local sources located 100 miles from Vista Canyon.
3. Mass distance is the mass of material multipled by the distance traveled. ENVIRON assumed that the concrete and asphalt come from local sources.
4. Emission factors for truck calculated from DOE EERE energy intensity indicators. EERE data is presented in Btu / ton mile. These were converted using AP-42 conversion factors for energy in different types of fuel, and CCAR GRP emission factors for mass CO_2 emitted per gallon of fuel. Trucks are assumed to run on diesel.
5. Emissions calculated by multiplying the mass-distance by the emission factor. ENVIRON assumed that all materials will be transported by truck.

Abbreviations:

CO_2 = carbon dioxide

Sources:

DOE EERE energy intensity indicators. http://intensityindicators.pnl.gov/trend_data.stm Transportation sector data.
AP42 conversions available at http://www.epa.gov/ttn/chief/ap42/appendix/appa.pdf

Table 6
Summary of Life Cycle Greenhouse Gas (GHG) Emissions from Buildings, Infrastructure
Vista Canyon
Santa Clarita, California

Emissions Source[1]		Emissions from Manufacture of Materials[3]	Emissions from Transportation of Materials[4]	Total Emissions	Assumed Lifetime of Emissions Source[5]	Total Annualized Emissions[6]	Total Annual Emissions from VCR[7]	LCA Fraction of Total Emissions[8]
		(tonnes CO_2)			(years)	(tonnes CO_2 / year)	(tonnes CO_2 / year)	(%)
Buildings[2]	Low Estimate	221		221	40	6	15,892	0.03%
	High Estimate	1845		1,845		46		0.29%
Infrastructure		1,053	563	1,616		40		0.25%
TOTAL		1838 - 3461		1838 - 3461		46 - 87		0.29% - 0.54%

Abbreviations:
CO_2 = carbon dioxide
LCA = Life Cycle Assessment

Notes:
1. ENVIRON estimated LCA emissions from two sources: buildings, and infrastructure.
2. Emissions from buildings are shown as a range from a low to a high estimate based on the range presented in Table 1. The values in Table 1 are multiplied by the assumed lifetime of 40 years to yield total emissions in tonnes CO_2.
3. Emissions from the manufacture of materials for infrastructure are from Table 4.
4. Emissions from the transportation of materials for infrastructure are from Table 5.
5. The assumed lifetime of emissions source may be adjusted; here ENVIRON has assumed a conservatively short lifetime of 40 years.
6. Total emissions are divided by the assumed lifetime of emissions sources to yield the total annualized emissions.
7. From Table 4-35.
8. The LCA fraction of total emissions is calculated by dividing the total annualized emissions by the total emissions from Vista Canyon.