City of Aspen / Canary Initiative

Summary

Greenhouse Gas Emissions Inventory, 2004

Last Modified: 27 December 2005 **Rick Heede** Climate Mitigation Services

	Physical Units		Energy Units		GHG Emissions		CO2 Equivalent		Percent of Total
Buildings: electricity			Million Btu						
Electricity (Aspen Municipal Utility/Aspen Elec Dpt)	62,872,609	kWh	641,301	10^6 Btu	39,571	tons CO2	39,571	tons CO2	4.71%
Electricity (MEAN fugitive methane - coal mines)	8	tons CH4	391	10^6 Btu	8	tons CH4	185	tons CO2-e	0.02%
Electricity (Holy Cross)	141,283,859	kWh	1,441,095	10^6 Btu	125,036	tons CO2	125,036	tons CO2	14.87%
Electricity (Xcel fugitive methane - coal mines)	77	tons CH4	3,727	10^6 Btu	77	tons CH4	1,764	tons CO2-e	0.21%
Total electricity	204,156,553	kWh	2,086,514	10^6 Btu	na		166,557	tons CO2-e	19.81%
Buildings: natural gas and propane									
Natural Gas (Kinder Morgan)	1,452,744	ccf	1,252,365	10^6 Btu	73,194	tons CO2	73,194	tons CO2	8.70%
Natural Gas (Kinder Morgan - fugitive methane)	415	tons CH4	20,170	10^6 Btu	415	tons CH4	9,549	tons CO2-e	1.14%
Natural Gas (AM Gas)	363,186	ccf	313,091	10^6 Btu	18,299	tons CO2	18,299	tons CO2	2.18%
Natural Gas (AM Gas - fugitive methane)	104	tons CH4	5,043	10^6 Btu	104	tons CH4	2,387	tons CO2-e	0.28%
Propane (AmeriGas)	250,137	gallons	22,846	10^6 Btu	1,662	tons CO2	1,662	tons CO2	0.20%
Propane (Ferrellgas)	250,137	gallons	22,846	10^6 Btu	1,662	tons CO2	1,662	tons CO2	0.20%
Total natural gas & propane	500,274	gallons	1,636,361	10^6 Btu	na		106,754	tons CO2-e	12.70%
Buildings: other									
AVH Hospital (diesel generator)	1,200	gallons	166	10^6 Btu			13	tons CO2	0.002%
Refrigerants, halocarbons, CFCs, etc.	na		na	10^6 Btu		lbs CO2-e	na	tons CO2-e	
Total buildings	1,200	gallons	3,723,041	10^6 Btu		lbs CO2-e	273,311	tons CO2-e	32.50%
Transportation: highway, around town, buses									
Highway vehicles, driving Hwy 82	12,635,963	gallons	1,580,393	10^6 Btu	125,714	tons CO2	125,714	tons CO2	14.95%
Highway vehicles, around town	3,698,454	gallons	462,569	10^6 Btu	36,720	tons CO2	36,720	tons CO2	4.37%
Tourist road travel to & from Aspen	4,117,548	gallons	514,986	10^6 Btu	40,340	tons CO2	40,340	tons CO2	4.80%
Transit Buses (RFTA)	291,989	gallons	40,499	10^6 Btu	3,139	tons CO2	3,139	tons CO2	0.37%
School Buses (Aspen School District)	17,420	gallons	2,416	10^6 Btu	195	tons CO2	195	tons CO2	0.02%
Other School District vehicles	13,380	gallons	1,673	10^6 Btu	131	tons CO2	131	tons CO2	0.02%
Out-of-school-district fuel (ExEd trips, away games)	5,352	gallons	669	10^6 Btu	56	tons CO2	56	tons CO2	0.01%
Pitkin County Public Works - sheriff etc. (gasoline)	11,870	gals (*0.2	297	10^6 Btu	116	tons CO2	116	tons CO2	0.01%
Pitkin County Public Works heavy vehicles (diesel)	7,581	gals (*0.2	210	10^6 Btu	85	tons CO2	85	tons CO2	0.01%
City of Aspen equipment (diesel fuel)	33,588	gallons	4,201	10^6 Btu	376	tons CO2	376	tons CO2	0.04%
City of Aspen vehicles (gasoline)	62,590	gallons	7,828	10^6 Btu	613	tons CO2	613	tons CO2	0.07%
Aspen Skiing Company (diesel and gasoline consumption)	210,468	gallons	26,323	10^6 Btu	2,007	tons CO2	2,007	tons CO2	0.24%
Off-road (construction equip., snowmobiles, gas widgets)	150,440	gallons	18,816	10^6 Btu	1,654	tons CO2	1,654	tons CO2	0.20%
Ambulances	2,588	gallons	324	10^6 Btu	29	tons CO2	29	tons CO2	0.00%
Total highway vehicles, around town, buses, & misc	21,259,230	gallons	3,113,724	10^6 Btu	211,175	tons CO2	211,175	tons CO2	25.11%
Transportation: commercial and private aviation									
Air Travel - Commercial at Pitkin County Airport	12,983,681	gallons	1,752,797	10^6 Btu	195,637	tons CO2	136,946	tons CO2	16.29%
Air Travel - Commercial at other airports	4,710,566	gallons	635,926	10^6 Btu	70,978	tons CO2	49,685	tons CO2	5.91%
Air Travel - General Aviation (jets)	14,151,249	gallons	1,910,419	10^6 Btu	213,229	tons CO2	149,260	tons CO2	17.75%
Air Travel - General Aviation (turboprops)	699,972	gallons	94,496	10^6 Btu	10,547	tons CO2	7,383	tons CO2	0.88%
Air Travel - General Aviation (piston aircraft)	123,648	gallons	14,861	10^6 Btu	1,621	tons CO2	1,135	tons CO2	0.13%
Air Travel - General Aviation (Air Ambulance flights)	7,413	gallons	891	10^6 Btu	112	tons CO2	78	tons CO2	0.01%
Total commercial and private aviation	32,676,528	gallons	4,409,390	10^6 Btu	492,124	tons CO2	344,487	tons CO2	40.97%
Total transportation	53,936,959	gallons	7,523,114	10^6 Btu		tons CO2	555,662	tons CO2	66.08%
Landfill									
Landfill & Materials Recovery: electricity	110,476	kWh	1,127	10^6 Btu	50	tons CO2	50	tons CO2	0.01%
Landfill & Materials Recovery: diesel fuel	4,849	gallons	673	10^6 Btu		tons CO2	27	tons CO2	0.00%
Landfill: fugitive methane	500	tons CH4	24,291	10^6 Btu	500	tons CH4	11,500	tons CO2-e	1.37%
Total landfill	various		26,090	10^6 Btu		na	11,577	tons CO2-e	1.38%
Nitrous Oxide sources									
Maroon Creek Club	3,285	kg N	na		102	kg N2O	33	tons CO2-e	0.004%
Aspen Golf Course	4,888	kg N	na		153	kg N2O	50	tons CO2-e	0.006%
City of Aspen Parks & athletic fields	1,806	kg N	na		56	kg N2O	18	tons CO2-e	0.002%
Private greenspace within city limits	15,078	kg N	na		470	kg N2O	153	tons CO2-e	0.018%
Private greenspace within Urban Growth Boundary	6,888	kg N	na		215	kg N2O	70	tons CO2-e	0.008%
Total nitrous oxide sources	31,945	kg N	na		997	kg N2O	325	tons CO2-e	0.04%
Total	various	units	11,272,245	10^6 Btu	various units		840,875	tons CO2-e	100%
Methane and nitrous oxide of total emissions					1,104	tons CH4	25,711	tons CO2-e	3.06%
Carbon dioxide of total emissions							815,163	tons CO2	96.94%

Aspen Emissions Inventory for 2004: Electricity

Future inventorists need to update electricity sales by each utility and to check the carbon dioxide and methane emissions factors for each utility's sources of purchased electricity. Note: this is also done through the "electicity carbon factor" worksheet. All calculations are linked and automatically updated.

Richard Heede
Climate Mitigation Services
Snowmass, Colorado

File Started 11 August 2005
Last Modified: 16 December 2005

Emissions of carbon dioxide from the combustion of fossil fuels at power plants supplying electricity to Xcel Energy (via Holy Cross Energy) and to Municipal Energy Agency of Nebraska (MEAN, via Aspen Electric Dept). Zero-carbon renewable sources are accounted for (see note under "Carbon factor"). Methane emissions from coal mines supplying power plant fuel are also included (see note under "Methane" and the "Carbon factor" worksheet).

2004	Electricity		Carbon	Emissions				
	Consumption	Consumption	factor	Carbon Dioxide	Methane	Methane	Total	Total
	kWh	MWh	carbon/kWh	short tons CO2	short tons CH4	tons CO2-eq	tons CO2+CH4	tonnes C-eq
			lb CO2/kWh (del)		lb CH4/MWh	CO2 x 23	lb CO2-equiv/kWh	kg C-eq/kWh
City of Aspen Electric Dept.			1.259		0.26	23	1.265	0.157
Residential: single-family households	15,908,246	15,908		10,012	2.0	47	10,059	2,491
Residential: multi-family 2-4 households	1,634,361	1,634		1,029	0.2	5	1,033	256
Residential: multi-family 5+ households	4,493,457	4,493		2,828	0.6	13	2,841	704
Residential: Total	22,036,064	22,036		13,869	2.8	65	13,934	3,450
Commercial	36,412,851	36,413		22,918	4.7	107	23,025	5,701
Industrial	-	-		-	-	-	-	-
Municipal	4,315,683	4,316		2,716	0.6	13	2,729	676
Other (irrigation pumps)	108,011	108		68	0.0	0	68	17
Total, Aspen Electric Dept.	62,872,609	62,873		39,571	8.0	185	39,756	9,843
			lb CO2/kWh (del)		lb CH4/MWh	CO2 x 23	lb CO2-equiv/kWh	kg C-eq/kWh
Holy Cross Energy			1.770		1.086	23	1.7950	0.222
Residential	76,900,263	76,900		68,057	41.8	960	69,017	17,088
Commercial	59,817,370	59,817		52,938	32.5	747	53,685	13,292
Industrial	-	-		-	-	-	-	-
Municipal	4,566,226	4,566		4,041	2.5	57	4,098	1,015
Total, Holy Cross Energy	141,283,859	141,284		125,036	77	1,764	126,801	31,395
Total, Aspen Elec + Holy Cross	204,156,468	204,156	-	164,607	85	1,949	166,557	41,239

Cell: E12
Comment: Rick Heede:
The carbon factors -- the amount of carbon dioxide per average kWh delivered to customers -- varies depending on the fuel mix of each of the electricity providers serving Aspen. *

Aspen Electric Dept purchased two-thirds of its power from the Nebraska Municipal Power Pool (NMPP) in Lincoln, Nebraska in 2004. Data from NMPP on the amount of fossil generation by type (coal- or gas-fired) are used to calculate the average emission of carbon dioxide per kWh generated. NMPP's own renewable generation (~4 percent) is factored in, as was a factor for the electricity lost in the transmission grid from Nebraska to Aspen (4.6 percent).

Holy Cross Energy estimated the carbon factor for its electricity based on data from Xcel Energy (from which Holy Cross buys most its power). A small grid-loss factor is also applied in order to estimate the amount of carbon dioxide associated with the CONSUMPTION of an average kWh of electricity, and, conversely, how much CO2 is avoided per kWh saved. The Holy Cross/Xcel datum of 1.67 lb CO2/kWh x 1.06 = 1.77 lb CO2/kWh consumed. **

* This simplified version excludes the complexities of power generation and delivery in the United States, such as the time of day, electricity "wheeled in" from other generators, peak power times, base loads, availability of hydro and wind power, maintenance schedules, and so forth. Nonetheless, an average carbon factor can be estimated for each utility. For carbon reduction purposes, the argument can be made that a kWh of electricity saved at night, when coal-fired power plants are providing base load capacity, keeps more carbon in the ground than during peak times (which is roughly breakfast and dinner time in Aspen), when more of the natural gas plants are supplying a larger proportion of the power generated.

** The Energy Information Administration estimates average US T&D losses "between the point of generation and delivery to the customer" at nine percent of gross generation EIA 2005, Annual Energy Review 2004, p. 223. We have reduced this factor to six percent (1.06) to account for the relative proximity of Xcel's power plants to Holy Cross's service area. Losses also occur in local grids, powerlines, and transformers.

Cell: G13
Comment: Rick Heede:
We develop a fugitive methane emissions factors for Holy Cross and MEAN-supplied electricity (each utility uses coal from different regions with varying methane emissions factors).

MEAN purchases and/or generates most of its power from plants burning coal from the Great Northern Plains coal basin. These are typically surface mines with methane emissions factors of 14 ft^3 per short ton produced. Since the net generation of electricity requires -- on average (power plants have widely different heat rates or conversion efficiencies) -- 1.04 lbs of coal per kWh (or 0.96 kWh per lb), then one ton of coal generates 1.92 MWh, or 0.521 tons of coal required per MWh. Great Northern Plains coal emits 14 ft^3 of methane per ton mined, thus for each MWh of electricity supplied by MEAN 0.521x 14 ft^3 CH4 = 7.3 ft^3 of methane for its coal-based generation. To convert to lb of methane: 7.3 ft^3 methane x 0.04228 lb/ft^3 = 0.3086 lb methane per MWh.

A similar calculation for Holy Cross electricity -- supplied by Xcel Energy, which uses Piceance Basin coals. These are primarily surface mines generating 77 ft^3 of methane per ton of coal (if underground mines, then 196 ft^3 per ton in situ), which equals 40.15 ft^3 per MWh of coal-based electricity supplied. To convert to lb of methane: 40.15 ft^3 methane x 0.04228 lb/ft^3 = 1.698 lb methane per MWh.

Note 1: we dilute the above factors by gas-fired generation in the resource mix of both MEAN and Xcel.

In the case of Xcel, 63.97 percent of its generation is by coal, hence we multiply 1.698 lb CH4/MWh x 0.6397 = 1.086 lb CH4 per MWh of total Xcel generation. Since methane is 23 times as powerful a greenhouse gas as carbon dioxide, this equals 24.98 lb CO2-equivalent per MWh, or 0.02498 lb CO2-equiv per kWh.

MEAN's resource mix (of own generation plus WAPA power purchases) was 82.9 percent coal-fired in 2004, this means a methane factor of 0.3086 lb CH/MWh x 0.829 = 0.2558 lb CH4/MWh, or 0.2558 x 23 = 5.884 lb CO2-equivalent per MWh, or 0.005884 lb CO2-e/kWh.

Principal sources:
US Dept of Energy (2005) Voluntary Reporting of Greenhouse Gases (1605b Program: Draft Technical Guidelines, DOE Office of Policy and International Affairs, section 1.E.4.2.1. Coal mining, p. 105-106. The above source reports (on p. 105) an erroneous conversion factor for lb methane per cubic foot (now corrected in this comment and all fugitive methane calculations from 0.418 to 0.04228 lb/cf). This error was confirmed with DOE VRGG technical staff, personal communication, 26Sep05.

Personal communication with MEAN and WAPA staff.

EPA eGRID web-accessible database on utility carbon/MWh; www.epa.gov/cleanenergy/egrid

Note 2: Calculation of Methane emissions per ton of coal consumed (national average method, not used)

Methane emitted from surface mining plus underground mining plus post-mining activities plus CH4 vented less CH4 recovered in 2003 equals 2.87 million tonnes CH4 = 6,327 million lb CH4 (EIA Emissions 2003, p. 43);

Coal production in 2003 totaled 1,071.8 million tons (AER 2003, p. 205);

US national average methane emissions: 5.77879 lb CH4 per ton produced.

This method is not used, since the emissions from the coal mining regions of MEAN and Xcel production is more relevant to our emissions survey and affords greater opportunities for credits and savings than does a national average.

Cell: H13
Comment: Rick Heede:
Fugitive methane emissions of coals mined for each utility's coal-fired power plants diluted by coal-fired percentage of total generation and specific to each utility's coal-mining regions. This column converts tons of methane into tons of CO2-equivalent by multiplying by methane's conversion factor of 23xCO2 (100 hundred year horizon, mole basis), per IPCC Fourth Assessment Report.

Cell: I15
Comment: Rick Heede:
This value calculates the CO2-equivalent factor for each utility's carbon dioxide and methane emissions per average kWh and accounts for all carbon and non-carbon inputs to its resource mix. This factor also accounts for T&D losses from generation to delivery. While the factor has accounted for coal and natural gas fuel inputs (chiefly coal with respect to Aspen's non-renewable sources) as well as fugitve methane from coal mining, this estimate stops at the mine and power plant gates and does not include the energy and emissions arising from transportation of coal, nor the manufacture of loaders and draglines nor the diesel fuel to run the mining and transportation modes. See the Boundary definition in the final report for details.

Cell: B16
Comment: Rick Heede:
2004 summary of sales by sector and purchased electricity (WAPA, MEAN) plus generation sources from Phil Overeynder, Director City of Aspen Electric Dept, 15Aug05.

Cell: E27
Comment: Rick Heede:
See note under "Carbon factor" above. In sum, we have adjusted Holy Cross/Xcel Energy's estimated carbon factor up from 1.67 lb CO2/kWh generated to 1.77 lb CO2/kWh consumed by accounting for T&D losses of six percent (although averages nine percent in US).

Cell: G27
Comment: Rick Heede:
See discussion of fugitive methane per ton of coal mined in Xcel's service territory (chiefly Piceance Creek Basin) at cell H13 above.

Cell: B28
Comment: Rick Heede:
HCE electricity sales within the inventory geographic area in 2004 provided by Bob Gardner and Steve Casey of Holy Cross Energy. Holy Cross supplies electricity within City Limits (outside the City Electric Dept's service territory) as well as buildings and facilities outside City Limits yet within our defined geographic areas-- chiefly contiguous to city limits.

Holy Cross intends to develop a data acquisition protocol based upon the regions within the utility's Township and Range maps. The relevant sectors were identified in a meeting between Bob Gardner and Steve Casey of HCE and Rick Heede of Climate Mitigation Services in Aug05.

Holy Cross Energy supplied data for residential and commercial sales only. We have assumed that "commercial" includes sales to the City of Aspen's buildings, pumps, and facilities and have deducted the 4.57 million kWh from the HCE provided for this study in order to avoid double-counting. See "Municipal" below.

Cell: B32
Comment: Rick Heede:
Holy Cross Energy did not disagggregate electricity sales to the City of Aspen's buildings, facilities, street lights, and miscellaneous. HCE did supply Lee Cassin of the City Env Health Dept for a separate accounting, in which a total of 4.57 million kWh supplied by Holy Cross Energy for the City's buildings and facilities outside its own utility's service territory such as Truscott Place, the ARC (1.74 million kWh), the golf course pumps and buildings (404,600 kWh).

Thus, in our account, we DEDUCT the 4.57 million kWh listed under municipal uses herein from the HCE data supplied for this study listed under "Commercial" above so as to avoid double-counting these sales.

Our purpose is simply to more fully account for all municipal energy uses.

Aspen Emissions Inventory: Electricity carbon factor

MEAN's resource mix must updated for future inventories; average emissions rates per MWh from coal and natural gas power plants should be updated with EIA data; Aspen Electric Dept's electricity supply by source must also be updated.

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started 11 August 2005
Last Modified: 21 December 2005

Data supplied by
Phil Overeynder, philo@ci.aspen.co.us, 970-920-5111
City of Aspen Electric Dept
Jill Jones, jjones@nmppenergy.org, 402-474-4759
Municipal Energy Agency of Nebraska, MEAN/NMPP

Table 1:	Calculation of MEAN carbon factor for electricity sold to Aspen Electric Dept.							
2004	MEAN	US power sector	US power sector	US power sector	US power sector	MEAN	MEAN	MEAN
	MEAN GenMix 2004	Emissions by source	Emissions by source	Electric generation	Elec emissions rate	Total emissions	Emissions rate	Emissions rate
	MWh	Million tonnes CO2	Million sh tons CO2	Billion kWh	lb CO2/kWh gen	short tons CO2	lb CO2/kWh (gen)	lb CO2/kWh (deliv)
Coal (76.9%)	1,522,881	1,904	2,099	1,953	2.150	1,637	2.1501	
Wind (1.6%)	31,584		-			-	-	
WAPA (coal + gas, some hydro)(8.5%)	169,326		-		1.595	135	1.5950	
Natural Gas (0.4%)	6,998	275	303	567	1.070	4	1.0699	
Nuclear (12.6%)	250,243		-			-	-	
Total	1,981,032			3,721	-	1,776	1.7929	1.8790

MEAN percent coal-fired:	82.9%

Table 2:	Aspen Electric Dept carbon factor			
Sources	Generation sources	Emissions rate	Total emissions	Emissions rate
	kWh (2004)	lb CO2/kWh (gen)	short tons CO2	lb CO2/kWh (del)
MEAN	44,141,039	1.7929	39,571	
WAPA (direct)	5,080,666	-	-	
Ruedi Hydro	11,043,562	zero	zero	
Maroon Creek	1,977,686	zero	zero	
Windpower	3,648,918	zero	zero	
Total Gen/Gross Purch.	**65,891,871**			
Total Sold	**62,872,609**		39,571	1.2588
T&D losses & unacc	3,019,262			
Percent losses & unacc	4.58%			

Table 3. Aspen Muni: Renewables and non-carbon fractions		
2004	Renewables fraction	Non-carbon fraction
Renewables source	Aspen Muni kWh, 2004	Aspen Muni kWh, 2004
MEAN wind, hydro/nuclear	1,765,642	7,340,655
WAPA/CRSP direct hydro	5,080,666	5,080,666
Ruedi hydro	11,043,562	11,043,562
Maroon hydro	1,977,686	1,977,686
Aspen wind contract	3,648,918	3,648,918
Total renewables	**23,516,474**	**29,091,487**
Total generation	**65,891,871**	**65,891,871**
Percent renew/non-carbon	**35.69%**	**44.15%**

Table 4:	US averages for 2003 by electric generation source			
2003	Emissions	Emissions	Generation	US power sector
	million tonnes CO2	million tons CO2	Power sector	Elec emissions rate
Table 12.7a All Sectors			Table 8a	lb CO2/kWh gen
Gas	336.2	370.6	649.9	1.140
Coal	1,960.1	2,160.6	1,973.7	2.189
Total fossil	2,405.3	2,651.4	2,758.6	1.922
Table 12.7b Utils	Utils only		Table 8b	
Gas	**275.3**	**303.5**	**567.3**	1.070
Coal	**1,904.4**	**2,099.2**	**1,952.7**	2.150
Total fossil	2,276.1	2,508.9	2,636.4	1.903
Table 12.7c Coml + Indl	CHP (coml + Indl)		Table 8d	
Gas	60.9	67.1	82.6	1.625
Coal	55.7	61.4	21.0	5.847
Total fossil	114.2	125.9	122.3	2.059

Table 5. Emissions factors (CO2-e/kWh consumed)		
	Aspen Muni	Holy Cross Energy
CO2 (incl T&D losses)	1.259	1.770
Methane (as CO2-e)	0.006	0.025
Total CO2-e/kWh	1.265	1.795

Table 6. Holy Cross carbon emissions (system-wide)		
2004	Percent of generation	Tons CO2
Coal	63.97%	728,586
Natural Gas	25.18%	117,338
Renewables	7.51%	-
"Imported - unknown"	3.34%	20,769
Percent renew/non-carbon	**100%**	**866,694**

Cell: C13
Comment: Rick Heede:
MEAN's resource mix by fuel type for 2004 from Jill Jones, MEAN Planning Analyst, 22Aug05. Jones data column in kWh -- which is an error and must mean MWh.

Overall, MEAN data suggest a renewable fract on 3.79 to 4.22 percent for its three Service Schedules. In FY 2004/05, 56.50 GWh were classified as renewable ("includes WAPA hydro, Kimball Wind, and NPPD Wind") of total sales of 1,337.54 GWh. This agrees with our finding that WAPA is far less than 100 percent hydro generation, or the cited mix would be WAPA 169 GWh of 1,981 GWh total, or 8.6 percent, plus the 31.6 GWh wind line item = 1.6 percent.

Cell: D13
Comment: Rick Heede:
U.S. emissions from the electric power sector in EIA (2005) Annual Energy Review 2004, Table 12.7b. Emissions from commercial or industrial CHP units are not included.

Cell: F13
Comment: Rick Heede:
EIA (2005) Annual Energy Review 2004, Table 8.2b Electricity Net Generation: Electric Power Sector, p. 229. Utility-owned plants only (no industrial or commercial CHPs). Data for 2003.

Cell: B17
Comment: Rick Heede:
Western Area Power Administration (WAPA) is typically hydro-power, but WAPA Upper Great Plains (eastern) region is ~70 percent coal and ~30 percent gas; zero hydro is shown. This power has a carbon content of 1,594.96 lb CO2/MWh generated.

Note 1: WAPA carbon content varies by region: Upper Great Plains (west) is all hydro, hence no carbon/kWh. WAPA Rocky Mountain region emitted 1,884.23 lb CO2/MWh generated.

Source: EPA eGRID emissions database; www.epa.gov/cleanenergy/egrid/index.html (See Owner-Based Power Control Area file, worksheet "EGRDPCAO00".)

Note 2: a telephone conversation with John Stonebarger, WAPA Energy Mgmt and Marketing official, tel 605-882-7560 (ref from Sam Miller, WAPA in Billings, 406-247-7466, csmiller@wapa.gov): WAPA owns hydro generation assets along the Missouri River (with zero carbon), but does market power generated by several privately-owned steam plants. We estimate MEAN's emissions (and thus Aspen Electric Dept's) on the basis of carbon-content of purchased power, which in this case includes the fossil plants not owned but marketed with WAPA's own generation, i.e., 1.595 lb CO2/kWh.

Cell: B22
Comment: Rick Heede:
MEAN's coal-fired generation + 70 percent of WAPA's generation plus marketed power as a percent of total MEAN.

Cell: I25
Comment: Rick Heede:
CMS estimates the Aspen Electric Dept renewables fraction as follows:

MEAN is 4 percent renewable (ie, 4 percent of 44.141 GWh). Source: Jill Jones, MEAN, Aug05, to CMS via Phil Overeynder; this renewables fraction combines MEAN's Service Schedules J, K, and M (individual breakdowns were not listed; Aspen gets class M).
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Aspen Muni purchases power from Colorado River Storage Project via WAPA and/or US Bureau of Recretion's mostly hydropower facilities on the Colorado and the Colorado Plateau, e.g., Flaming Gorge on the Green River. "WAPA direct" is 0.986 lb CO2/kWh CRSP emissions divided by coal generation emissions (US average) of 2.15 lb CO2/kWh = 45.86 percent "non-fossil". This equivalence assigns (100. percent - 45.86 percent) 54.14 percent of "WAPA direct" to Aspen Muni's renewable power column, or 5.08 GWh times 0.5414 = 2.751 GWh renewable. This formula may be followed in future years in which Aspen Muni may opt in to additional (non-hydro) power purchases.
Correction, 16Dec05: CMS has determined that WAPA's CRSP delivered only hydropower to Aspen Muni in 2004; Muni opted out of additional power purchases from coal-fired plants in 2004 that were made available via WAPA/CSRP to make up for hydropower shortfalls in drought years.

Ruedi, Maroon Creek, and Windpower are, of course, all renewable.

MEAN's nuclear generation is not entered in this renewable electricity column, even though some proponents and government agencies do preposterously consider nuclear to be a renewable electricity source. The column on the right estimates "non-carbon fraction," and does include MEAN's nuclear generation.

Cell: J25
Comment: Rick Heede:
This is the same calculation as the "renewable fraction" column, but adds MEAN's nuclear generation as follows:

MEAN's nuclear generation is factored into this column, as nuclear is typically considered a zero-carbon source of electricity.** MEAN's nuclear component can be considered non-fossil but not renewable. Then Aspen could add 12.63 percent of MEAN's power supply, or 44.141 GWh times 0.1263 = 5.575 GWh, which would bump Aspen's "non-fossil" from 32.15 percent to 40.61 percent. The nuclear generation does, of course, reduce Aspen's emissions through nuclear's dilution of fossil generation by MEAN, and thus reduces Aspen's average carbon emissions per kWh sold to its customers.

** Zero-carbon electric generation only if one ignores the relatively small but non-zero emissions from uranium mining, coal-fired enrichment services, plant construction, decommissioning, waste storage, transportation, and ultimate waste disposal: Nuclear Energy Agency (2002) estimates 2.5 to 5.7 gC-e/kWh.
Heede (2004) "Black Hydrogen: An Assessement of the U.S. Department of Energy's Plans for Nucler Hydrogen Production," p. 24.

Cell: B27
Comment: Rick Heede:
MEAN's 2004 generation mix is listed in Table 1.

Cell: H27
Comment: Rick Heede:
Four percent of MEAN's total resource mix is renewable. In 2004, Aspen Muni's purchase of 44.1 GWh * 0.04 = 1.77 GWh.

Cell: B28
Comment: Rick Heede:
16Dec05 note: Phil Overeynder to Rick Heede, CMS: "It is true that in aggregate, WAPA purchased coal fired energy to make up part of the difference between their contract obligations and available hydropower. These purchases were at the request of individual CRSP customers and are tracked and billed separately. Each quarter we are given the choice of whether or not to participate in these additional purchases and generally we decline in favor of making up the difference in the contract by purchasing MEAN's available resources. I can quantify this by looking back at the records if you wish to pursue. At any rate, I would argue that close to 100% of our WAPA-CRSP resources are hydroelectric power since Aspen does not generally participate in these optional purchases." CMS has thus eliminated carbon emissions from Aspen Muni's direct power contract with WAPA; that is, from 0.9857 lb CO_2/kWh (gen) to 0.0 lb, reducing emissions for the Muni's procurement of 5.08 GWh from 2,504 tons CO_2 to zero tons.

Pre-Dec05 comments:
CMS initially considered Aspen Muni's direct WAPA contract to be with WAPA's Rocky Mountain Region (1,884.23 lb CO_2/MWh) or with WAPA's Phoenix PCA (690.427 lb/MWh). Phil Overeynder says the Aspen contract is with WAPA's Colorado River Storage Project, NOT the Rocky Mountain region.

CSRP is either US Bureau of Reclamationa (BuRec) Upper Colorado or Lower Colorado Region. The latter is most likely: BuRec Upper Colorado is primarily hydro through its many large and medium-sized dams and powerplants such as Glen Canyon, Flaming Gorge, Blue Mesa, Collbran, etc. However, according to the EPA power plant emissions database, EGRID lists BuRec's Upper Colorado as 985.653 lb CO_2 per MWh. Source: EPA eGRID2000 EGRDECO worksheet line #1795, parent name = BuRec, power control area = WAPA - Rocky Mtn Region.
www.epa.gov/cleanenergy/egrid/index.html

Cell: F37
Comment: Rick Heede:
This analysis uses US average carbon emissions per kWh generated by source (gas and coal, re: MEAN's two fossil sources). We calculate emissions for three classes of power plants (utility-owned "power sector", CHP owned by commercial and industrial sectors), and combined power sector + CHP. Since MEAN procures power from utility-owned power plants, we use the utility only carbon factor for each gas and coal-fired plants, which are highlighted in red on the worksheet. These factors are then used in Table 1 to estimate MEAN's total carbon emissions.

Cell: C38
Comment: Rick Heede:
Energy information Administration (2005) Annual Energy Review 2004. Tables as cited below.

Cell: J38
Comment: Rick Heede:
Holy Cross Energy's carbon coefficient is taken from HCE published data ("New Carbon Report Card," Consumer Connection, Sep04. That datum -- 1.67 lb CO2/kWh -- is adjusted upwards by 6 percent to account for transmission and distribution losses. This US average T&D factor is 9 percent, which CMS arbitrarily reduced to 6 percent in view of Xcel's generation assets being located in Colorado and not requiring long transmissions distances.

Cell: J45
Comment: Rick Heede:
Holy Cross data for system-wide power procurement, chiefly from Xcel Energy, in 2004. Source: Holy Cross Energy (2004) The Consumer Connection, vol 19(3), September.

Note: CMS has relied on HCE data and has not independently calculated the utility's carbon emissions.

Cell: H46
Comment: Rick Heede:
Four percent of MEAN's total resource mix is renewable. In 2004, Aspen Muni's purchase of 44.1 GWh * 0.04 = 1.77 GWh.

Cell: H49
Comment: Rick Heede:
Holy Cross appears to have used a carbon factor for this unknown generation source at 75 percent of the natural gas emissions rate -- ~0.675 lb CO2/kWh. Estimated from HCA data.

Aspen Emissions Inventory for 2004: Natural Gas

Future inventorists must update annual sales from Kinder Morgan and AM Gas. The KMI data includes gas recorded at Town Border Station at Woody Creek less Snowmass Village. KMI data include natural gas transported for AM Gas. The Btu value and pressure adjustments should also be checked.

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started 11 August 2005
Last Modified: 19 October 2005

Data provided by:
Scott Emerson, Dir.
Retail Business Dev & Transportation Svcs.
Kinder Morgan, Inc.
303-763-3597
scott_emerson@kindermorgan.com

Data provided by:
Bart Levine, President
AM Gas, 970-925-2901
Jeff Grebe, President
MechTric Engineering
970-928-9687

Table 1	Natural Gas		Emissions	Emissions				
	Consumption	Consumption	factor	Carbon Dioxide	Methane	Methane	Total	Total
2004	Thousand cf (Mcf)	Billion Btu (10^9)	carbon per btu	short tons CO2	short tons CH4	tons CO2-eq	tons CO2-e	tonnes C-eq
(Altitude adjusted to 1,160 cf/million btu:)	cubic feet/million btu		tonnes C/billion Btu	tons CO2/billion Btu	tons CH4/ton CO2	tons CO2-e/ton CO2	tons CO2-e/billlion Btu	tonnes C-e/billlion Btu
Kinder Morgan Inc.	1,160		14.47	58.44	0.00567	0.13046	66.07	16.36
Residential	726,372	626		36,597	207.6	4,775	41,372	10,243
Commercial	726,372	626		36,597	207.6	4,775	41,372	10,243
Municipal (included above)		-			-	-	-	-
Total, Kinder Morgan	1,452,744	1,252		73,194	415	9,549	82,744	20,486
	Consumption	Consumption	Emissions factor	Carbon Dioxide	Methane	Methane	Total	Total
	Mcf	Billion Btu (10^9)	carbon per btu	short tons CO2	short tons CH4	tons CO2-eq	tons CO2-e	tonnes C-eq
AM Gas, Inc.	1,160							
Residential		-			-	-	-	-
Commercial	363,186	313		18,299	103.8	2,387	20,686	5,121
Total, AM Gas	363,186	313		18,299	104	2,387	20,686	5,121
	Consumption	Consumption	Emissions factor	Carbon Dioxide	Methane	Methane	Total	Total
	Mcf	Billion Btu (10^9)	carbon per btu	short tons CO2	short tons CH4	tons CO2-eq	tons CO2-e	tonnes C-eq
Kinder Morgan + AM Gas	1,815,930	1,565		91,493	519	11,937	103,430	25,607

Total KM West Slope: 6,986 Billion Btu Aspen, percent of WS: 17.9%

Table 2. Calculation of methane emissions rate for the natural gas industry		
Methane from natural gas industry:	6.7	million tonnes CH4
CO2 from natural gas consumption:	1,179.4	million tonnes CO2
Methane emissions rate as CH4	0.00567	kg CH4/kg CO2
Methane emissions rate as CO2-e	0.13046	kg CO2-e/kg CO2
CO2 plus methane emissions rate (short tons)	66.070	tons CO2-e/billlion Btu
Carbon plus methane emissions rate (metric)	16.358	tonnes C-e/billion Btu

Table 3. Carbon factors	
10.077	lb CO2/hundred cf (ccf)
11.392	lb CO2-e/ccf
0.1008	lb CO2 per cubic foot
1,160	cubic feet / million Btu
862.2	Btu per cubic foot
58.44	tons CO2 per billion Btu
116.89	lb CO2 per million Btu

Standard conversions
1 tonne = 1.1023 tons
1 tonne = 1,000 kg
1 kg = 2.2046 lb

Cell: J8
Comment: Rick Heede:
Jeff Grebe reviewed our pressure altitude adjustments, informed our research on Kinder Morgan's PUC filings, and provided helpful background the natural gas measurement protocols at altitude.

Cell: E12
Comment: Rick Heede:
Kinder Morgan supplied natural gas sales data in million Btus per month. Emissions from the combustion of natural gas varies slightly (+/- 3 percent) by its heating value. We use the national average heating value of 14.47 milligrams/Btu or, as it is usually reported, Tg/QBtu (teragrams/quadrillion Btu); in normal parlance this factor equals 14.47 kg of carbon per million Btu, which, at average heating value, equals ~974 cubic feet of gas. Our calculation sidesteps the issue of how many ccf Kinder Morgan sold in 2004 since the data is reported in units of million Btu. Low-heating value natural gas (say below 950 Btu/cf) is typically due to high CO2 content in the supplied gas.

Factors reported in this column include:

14.47 kg C per million Btu.
Source: U.S. Environmental Protection Agency (2005) Inventory of U.S. Emissions and Sinks: 1990-2003, Annex B: Methodology for Estimating the Carbon Content of Fossil Fuels, http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2003.html

Tonnes CO2 per billion Btu simply multiplies C by 3.664191 -- the isotopically accurate conversion factor -- to convert carbon to CO2, assuming full combustion of the natural gas.

* While the energy content of a cubic foot of natural gas is highly dependent on the pressure altitude at which it is delivered, the carbon content per million Btu, which is the method we employ here, only varies slightly, as mentioned above. At normal sea level pressure and energy value, one cubic foot of natural gas has a heating value of 1,027 Btu (but can vary from 950 - 1,100 Btu/cf).

At sea level, one hundred cubic feet (ccf) emits 12.0953 lb CO2 upon combustion. At altitude, both the energy content and the carbon emissions will far less per ccf. A controversy over the tariffs charged Aspen customers has arisen between the City of Aspen and Kinder Morgan: the City contends that the altitude adjustment made by the gas suppliers over-charges local customers for the lowered energy content of the gas supplied. The argument is over a fair price for the energy rather than the volume of gas delivered: it's as if popcorn buyers are being charged extra for the inflated air in the bag rather than the weight of popcorn, or electric customers are charged for a kilowatt-hour but only get 930 watt-hours.

See the cell comment at C15 for our calculation of conversion factor (1,160 cubic feet per million Btu, = 862 Btu per cubic foot). This also means: 14.47 kg of C per million Btu = 116.89 lb CO2 per million Btu also equals (per my calculation) 1,160 cf, then 100 cf = 116.89/11.6 = 10.077 lb CO2 per 100 cf, or 16.44 percent less CO2/cf than at sea level.

Also, the Btu content varies by contract and even by season. Kinder Morgan is required by the Colorado Public Utilities Commission (PUC) to deliver gas with a minimum Btu content of 950 Btu/cf (national average is 1,027 Bt/cf).

Cell: F13
Comment: Rick Heede:
Carbon dioxide emissions are a product of natural gas sales in billion Btu times the carbon emissions factor in column "E."

Cell: G13
Comment: Rick Heede:
See notes in Table 2 below for methodology used to estimate fugitive methane emissions rate applied to Aspen's consumption of natural gas.

Cell: C15
Comment: Rick Heede:
At sea level 1 cubic foot (cf) of natural gas contains, on average, 1,027 Btu. Kinder Morgan's gas averaged 1,070 Btu/cf in 2004.(*) Kinder Morgan's "local billing pressure" (LBP) is 11.87 psi (vs 14.73 at sea level); 11.87/14.73 = 0.80584 altitude adjustment factor. Therefore, 1 cf at 1,070 Btu*0.80584 = 862.3 Btu; conversely, 1 million Btu = 1,160 cf. This is the conversion

factor used here.

However, the City of Aspen has pointed out that Aspen's pressure altitude is 11.04 psi, not KMI's LBP of 11.87 psi. If so, then 11.04/14.73 = 0.7495, or: 1 cf at 1,070 Btu*0.7495 = 802 Btu; conversely, 1 million Btu = 1,247 cf. The City of Aspen argues that Aspen consumers are paying for 862.3 Btu when the actual Btu content of 1 cubic foot is 802 Btu, which means an excess charge of 862.3/802 = 1.0752, or 7.52 percent.

Regardless of the merits of this argument vs KMI's zonal pressure adjustments, we apply Kinder Morgan's altitude cubic foot (ACF) factor: 1 million Btu = 1,160 ACF, and 1 ACF = 862.3 Btu.

(*) Brad Van Dyke, KMI, personal communication, 4Oct05.

Cell: B16
Comment: Rick Heede:
Data from Brad Van Dyke and Scott Emerson of Kinder Morgan, 29Sep05.

Van Dyke: "Attached is a file that provides the total amount of gas that flowed through the Aspen/Snowmass and Woody Creek town border stations in 2004. As noted in the file the estimated portion of the gas related to the Aspen area that flows through the Aspen/Snowmass town border station is about two-thirds. The estimated portion of gas related to residential and commercial in the Aspen area is approximately 50/50. There are no customers classified as industrial."

Emerson is Dir of Retail Business Development & Transportation Svcs., KM, PO Box 281304, Lakewood, CO 80228-8304, scott_emerson@kindermorgan.com, 303-763-3597

Brad_VanDyke@kindermorgan.com

Note 1: CMS apportioned KMI sales to Aspen plus Snowmass Village at the Woody Creek TBS on the relative populations of each area rather than on KMI's estimated "about two-thirds." Our methodology is as follows: Aspen population plus Urban Growth Boundary population plus ToSV plus ToSV UGB factor: Aspen 6,455 pop plus 1,186 UGB = 7,641 total Aspen area population with the emissions boundary as a fractoin of ToSV 2,317 pop plus ToSV UGB pop of 426: Aspen / Aspen plus ToSV = 7,641 / (7,641 + 2,743) = 7,641/10,384 = 73.6 percent. This percentage is applied to KM's total sales (excluding Woody Creek itself) as measured at the Woody Creek TBS, namely 2,127 billion Btu x 0.736 = 1,565 billion Btu, of which 80 percent is estimated as KM sales (1,251 billion Btu) and 20 percent as transported AM Gas (313 billion Btu).

Note 2: KMI could not provide specific data on natural gas transported for AM Gas, and we use AM Gas' estimated 20 percent datum. We did confirm that KMI data includes AM Gas.

Cell: B24
Comment: Rick Heede:
AM Gas supplies natural gas transmitted through KinderMorgan pipelines to several large commercial customers in Aspen. According to AM president Bart Levine, AM delivers ~20 percent of the natural gas consumed in Aspen.

1Oct05: CMS confirmed that Kinder Morgan gas data includes gas transmitted for AM Gas; KMI did not respond to request for specific transported gas quantities or fractional data.

Cell: C34
Comment: Rick Heede:
Kinder Morgan report to the Colorado Public Utilities Commission, for 2004. PUC, Denver, 303-894-2000, www.dora.state.co.us/puc

KM does not report on Aspen or Roaring Fork Valley natural gas sales except for aggregated with sales to all the Western Slope communities served. Reported sales to western slope totaled 6,986 billion Btu, or 17.9 percent (22.4 percent if transported gas to AM Gas is included)..

Cell: D36
Comment: Rick Heede:
We estimate the upstream fugitive emissions of methane from the natural gas system from production through delivery. In 2002 (the most recent data available), U.S. methane emissions from natural gas systems totaled 6.69 million (metric) tonnes; in the same year, natural gas consumption was 22.46 trillion cubic feet (Tcf), which equals 0.0657 lb of methane per hundred cubic feet (ccf) of gas consumed. Thus, (0.0657 lb CH_4/ccf) / 0.04228 lb/cf (standard conversion factor) = 1.554 cf of methane lost per ccf of delivered natural gas = 1.554 percent fugitive

emission rate; that is, a system loss rate relative to delivered natural gas. *

We are NOT attributing this additional emissions source to Kinder Morgan or AM Gas. We are, however, allocating such additional systemic emissions to consumers for whom the production occurs.

The result is that an amount equivalent to 13.05 percent of the CO2 emitted by burning natural gas is emitted as fugitive methane by the natural gas industry. That is, a 0.567 percent fugitive methane rate times methane as 23xCO2 = 13.05 percent as CO2-e.

* Production (1.84 million tonnes CH4), Gas Processing (0.68 million tonnes), Transmission and Storage (2.41 million tonnes), Distribution (1.76 million tonnes CH4), Total (6.69 million tonnes CH4). We are not including the small quantities of methane released from end-use equipment in the residential and commercial sectors (0.01 million tonnes CH4).

Sources: Energy Information Administration (2004) Annual Energy Review 2002; Energy Information Administration (2004) Emissions of Greenhouse Gases in the United States 2003.

See also Kirchgessner, David A., Robert A. Lott, R. Michael Cowgill, Matthew R. Harrison, & Theresa M. Shires (~2000) Estimate Of Methane Emissions From The U.S. Natural Gas Industry, US EPA: AP 42, Fifth Edition, vol. 1 chapter 14, www.epa.gov/ttn/chief/ap42/index.html

Cell: G36
Comment: Rick Heede:
These factors are for easy visibility and are derived from the factors calculated in the main worksheet.
The main factors are 19.7 percent lower than at sea level, eg, 10.077 lb CO2/ccf vs 12.0593 lb CO2/ccf at sea level.

Cell: F37
Comment: Rick Heede:
Derived from Btu content of Kinder Morgan natural gas supply in 2004 with KMI's altitude adjustment plus carbon content per billion Btu. See comment under "Emissions Factor" for details.

Cell: F38
Comment: Rick Heede:
This factor is used to generate results for individual homes and commercial buildings. (It takes the carbon emissions factor and adds the CO2-equivalent of the fugitive methane developed in Table 1 above. As such it adds to CO2 the methane factor shown in Table 2: Methane emissions rate as CO2-e, which in 2004 = 13.05 percent of CO2.)

Aspen Emissions Inventory for 2004: Propane

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started 11 August 2005
Last Modified: 19 October 2005

Future inventorists must request updated propane sales figures from AmeriGas and Ferrellgas (and any new propane vendors serving Aspen).

Data supplied by:	Data not supplied by:
Tad Peed, Mngr.	Ferrellgas, Inc.
AmeriGas	970-945-8611
970-963-3113	
peedt@amerigas.com	

2004	Propane Sales	Approximate consumption	Carbon Factor	Carbon Dioxide	Methane	Total Emissions	Total Emissions
	gallons	Million Btu	lb CO2/gallon	tons CO2	tons CO2-eq	tons CO2-e	tonnes C-eq
Propane vendor			12.669		tons CO2-e/ton CO2		
					0.0492		
AmeriGas (original data from AmeriGas)	250,137	22,846		1,584	78	1,662	412
							-
Ferrellgas (assumed equal to AmeriGas)	250,137	22,846	-	1,584	78	1,662	412
Total propane sold in the Aspen area	500,274	45,692	-	3,169	156	3,325	823

AmeriGas estimate	Gallons Sold	Percent overall	Percent Aspen & TOSV
Aspen Area	250,137	69.0%	81.8%
Woody Creek Area	56,831	15.7%	
Snowmass Village Area	55,597	15.3%	18.2%
Total	362,565	100.0%	

Climate Mitigation Services Confidential

Cell: E13
Comment: Rick Heede:
Carbon factor from Environmental Protection Agency (2005) Inventory of U.S. Emissions and Sinks: 1990-2001 Annex B: Methodology for Estimating the Carbon Content of Fossil Fuels, http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2003.html

Cell: F13
Comment: Rick Heede:
Propane sales times carbon factor of 12.669 lb CO_2 per gallon at full combustion / 2000 lb per ton.

Cell: G13
Comment: Rick Heede:
A fugitive methane rate is applied to the propane production and processing infrastructure. See "methane" comments on the "Natural Gas" worksheet, in which production through delivery methane emissions are allocated to Aspen's consumption of natural gas. In the case of propane, we allocate the US national fugitive emissions rate for natural gas (from which most propane is processed) in the production and gas processing stages: 1.84 million tonnes CH_4 plus 0.68 million tonnes CH_4 of total natural gas system methane emissions of 6.69 million tonnes CH_4, or 2.52 of 6.69 million tonnes CH_4 = 37.7 percent of the natural gas rate, which is 0.13046 tons CO_2-e per ton CO_2 from the propane's combustion. Hence, the propane fugitive methane rate is 0.13046 x 0.377 = 0.0492 tons CO_2-e per ton of propane delivered to and combusted by Aspen customers.

Sources used to estimate the fugitive methane emission rate for natural gas and propane: Energy Information Administration (2004) Annual Energy Review 2002; Energy Information Administration (2004) Emissions of Greenhouse Gases in the United States 2003.

Cell: B18
Comment: Rick Heede:
2004 propane sales data for the Aspen area (by Township) from Tadd Peed, Manager (Carbondale office), 970-963-3113, peedt@amerigas.com; personal communication, 7Sep05.

Cell: B20
Comment: Rick Heede:
Several requests for data have yielded unmet promises to provide Aspen area propane sales for 2004 (most easily by sorting for zip code).

Contact Karen Kraft, 970-945-8611, karenkraft@ferrellgas.com.

Cell: C26
Comment: Rick Heede:
2004 propane sales data for the Aspen area (by Township) from Tadd Peed, Manager (Carbondale office), 970-963-3113, peedt@amerigas.com; personal communication, 7Sep05.

Aspen Emissions Inventory for 2004: Road Vehicles

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started 11 August 2005
Last Modified: 21 November 2005

The principal variables that need to be updated in future fuel and emissions inventories are: (a) traffic count at Castle Creek Bridge, (b) update future VMT within Aspen, and © fuel consumption for each vehicle type (if

Table 1

Commuting and Hwy 82, 2004	Vehicle by type	Average daily traffic, 2004	Annual traffic, 2004	Miles per trip	Miles driven (VMT)	Fuel economy	Fuel consumed	Carbon factor	Carbon dioxide	Carbon
	25-Aug-05	(both directions)	(both directions)		miles	mpg	gallons/yr	CO2/gallon	short tons CO2/yr	tonnes carbon
	7 am - 1 pm									
Valley traffic across Castle Creek Bridge	8,003	23,524	8,586,260							
Passenger cars	25.8%	6,067	2,214,425	25	55,360,617	22.1	2,505,005	19.59	24,542	6,076
Small SUVs and small pick-up trucks	13.3%	3,128	1,141,545	25	28,538,613	20.2	1,412,803	19.59	13,841	3,427
Medium/Large SUVs and large "light" trucks	53.8%	12,648	4,616,603	25	115,415,084	17.0	6,789,123	19.59	66,513	16,468
2-axle medium-duty trucks, RVs	2.6%	623	227,451	25	5,686,265	10.4	546,756	19.59	5,357	1,326
3-axle trucks, dump trucks, etc	3.7%	864	315,427	25	7,885,669	7.4	1,065,631	22.38	11,927	2,953
Semis, combination trucks	0.3%	79	28,968	60	1,738,066	5.6	310,369	22.38	3,474	860
Motorcycles	0.5%	115	41,842	7.5	313,817	50.0	6,276	19.59	61	15
Total	100%	23,524	8,586,260	na	214,938,131	17.0	12,635,963	na	125,714	31,125

Table 2

Tourist travel to & from Aspen	Vehicle by type	Average daily visitor traffic	Aveage annual visitor traffic	Miles per visitor trip	Miles driven (VMT)	Fuel economy	Fuel consumed	Carbon factor	Carbon dioxide	Carbon
		arrivals	arrivals	round trip	miles	mpg	gallons/yr	CO2/gallon	short tons CO2/yr	tonnes carbon
Visitor vehicle arrivals and departures	composite	350	127,750	600	76,650,000	18.62	4,117,548	19.59	40,340	9,987
Total	composite	350	127,750	600	76,650,000	19	4,117,548	20	40,340	9,987

Composite fuel economy of passenger cars, small, medium, and large SUVs and pick-ups: 18.62

Table 3

Driving around town, 2004	Vehicle by type	In-town Aspen Hwy 82 VMT	Arterial roads VMT	Local roads VMT	Total Aspen area VMT	Fuel economy	Fuel consumed	Carbon factor	Carbon dioxide	Carbon
	percent	miles	miles	miles	miles	mpg	gallons/yr	CO2/gallon	short tons CO2/yr	tonnes carbon
Daily VMT in 1997, Aspen Area, by road type		117,706	23,157	14,617	155,480					
Estimated compound growth rate per year		2.57%	2.57%	2.57%						
2004 daily VMT, estimated		140,586	27,658	17,458	185,702					
2004 Annual Aspen VMT, estimated		51,313,774	10,095,263	6,372,262	67,781,299					
Passenger cars	25.8%	13,233,991	2,603,602	1,643,427	17,481,020	22.1	790,996	19.59	7,749	1,919
Small SUVs and light trucks	13.3%	6,822,174	1,342,167	847,193	9,011,533	25.4	354,785	19.59	3,476	861
Large SUVs and "light" trucks	53.8%	27,590,050	5,427,954	3,426,195	36,444,199	18.0	2,024,678	19.59	19,836	4,911
2-axle medium-duty trucks, RVs	2.6%	1,359,305	267,424	168,802	1,795,531	10.4	172,647	19.59	1,691	419
3-axle trucks, dump trucks, etc	3.7%	1,885,074	370,862	234,093	2,490,029	8.0	311,254	22.38	3,484	862
Semis, combination trucks	0.3%	173,119	34,059	21,498	228,676	6.1	37,488	22.38	420	104
Motorcycles	0.5%	250,061	49,196	31,053	330,310	50.0	6,606	19.59	65	16
Total	100%	51,313,774	10,095,263	6,372,262	67,781,299	na	3,698,454	na	36,720	9,091

Table 4

Total of Hwy 82, Tourist Travel, & Around Town	na	na	na	359,369,430	na	20,451,965	na	202,774	50,204	

Cell: C13
Comment: Rick Heede:
The traffic counters do register vehicle classes at both the Castle Creek and Mill & Main Streets:
Class 1: Less than 18 feet,
Class 2: 18-25 feet in length,
Class 3: greater than 25 feet.

However, these sizes are not detailed enough for our fuel consumption purposes. We engaged Lee Cassin and the Env Health Dept staff, plus John Krueger of the City Transportation Dept, to survey vehicle types during several mornings during mid-August 2005. The main data set we use was taken on 25Aug05, from 7 am to 1 pm. (Thanks, everybody.) The survey counted 8,003 vehicles, for which the distribution by type is shown below. (We exclude 104 RFTA buses and 20 school buses from this survey; fuel consumption by RFTA and school buses is estimated elsewhere.)

Note: A high fraction of the semis serving Aspen's markets, hardware stores, lumber yards, etc arrive at night and depart before dawn. Our survey may, therefore, have underestimated the number of semis, since the principal vehicle type survey was done from 7am to 1 pm.

Cell: D13
Comment: Rick Heede:
Krueger, John D. (2005) Traffic Counts at The Castle Creek Bridge (memo to Mayor and City Council 7July2005).

Cell: E13
Comment: Rick Heede:
"Average Daily Traffic" times 365 days/yr.

Cell: F13
Comment: Rick Heede:
The typical commute to work is assumed to be 25 miles each direction.# We assume that 2-axle trucks (such as FedEx, UPS,* and other working vehicles) travel 20 miles per trip. Heavier 3-axle trucks are also assumed to travel 25 miles per trip (e.g., an average of originating in El Jebel, Carbondale, or on waste-collection trips between the City and the County Landfill).

Semis travel an average of 240 miles per day (ORNL 2005, TEDB, Table 5.4); we allocate half to other communities served by each semi entering town, thus 60 miles per trip into plus out of town.

We assume half a year of motorcycle driving, reducing the per trip miles from 15 to 7.5 miles per trip-day.

note: RFTA data show the average ridership ending in Aspen is 15 miles, 15.8 miles if Snowmass Village is included, and 28.7 miles if the I-70 corridor is included.

* UPS trucks originate in Glenwood Springs and drive approximately 140 miles per day (of course, route-miles vary). Interviews with several UPS drivers, Aug05. UPS trucks average 12-14 mpg.

Cell: H13
Comment: Rick Heede:
New vehicle fuel economy data are used in combination with average fleet fuel economy data. This leads to two conservatisms: 1. older vehicles may get poorer fuel economy, and 2. actual driving experience suggests that fuel economy is ~10 percent worse than EPA's fuel economy tests. Furthermore, snowy roads increase fuel consumption. Data from ORNL and Federal Highway Administration (see below).

Passenger cars in use average 22.1 mpg. TEDB Table 4.1 (average fuel economy of passenger automobiles in use, 2002 datum from US DOT/Federal Highway Administation (2002) Highway Statistics 2002, Table VM-1; www.fhwa.dot.gov). New passenger cars average 28.7 mpg (TEDB, Table 4.7).

New small SUVs (25.4 mpg) and small pick up trucks (21.7 mpg) averaged to 23.55 mpg. (Table 4.8); in order to reflect actual vehicle stock mpg and the average in-use fuel economy, the new vehicle average of 23.55 is factored by the average new truck mpg of 20.5 (table 4.8) divided by average in-use truck of 17.6 mpg: 17.6/20.5 = 0.8585. Thus the Aspen vehicle population of small SUVs/light trucks is 23.55 mpg times 0.8585 = 20.22.

New large and medium SUVs (17.6 mpg and 21.3) and new large pick up trucks (18.3 mpg) and new small and large vans (23.5 and 18.3 mmpg) are averaged to 19.8 mpg. As above, this new SUV/truck fuel economy is adjusted to reflect the lower mpg of the average vehicle population in use: 19.8 mpg * 0.8585 = 17.0 mpg. Note: propably conservative, considering the weight driven around by the typical SUV and pick-up truck and work van in Aspen. This category also contains Hummers (10-13 mpg, practical experience is closer to 8 mpg), Suburbans, Ford 350s, and similar brontomobiles.

2-axle medium-duty trucks (10-14,000 lb) average 10.4 mpg (Table 5.4).

3-axle trucks single-unit trucks (dump trucks, garbage trucks, etc) average 7.4 mpg (TEDB Table 5.1).

Semis or combination trucks (33,000 lb +) average 6.1 mpg (Table 5.4), 5.2 mpg in Table 5.2, and 5.5 mpg (Table 5.5); we use 5.6 mpg as the average.

Davis & Diegel (2004) Transportation Energy Data Book 2004, Tables 4.1, 4.8, and 5.4, Oak Ridge National Laboratory, USDOE.

Motorcycles: EIA uses 50 mpg (Energy Information Administration/2001 National Household Travel Survey, p. K-37).

Cell: I13
Comment: Rick Heede:
Miles driven / fuel economy. Conservative estimates.

Cell: H25
Comment: Rick Heede:
Average of all vehicle types: VMT / estimated fuel consumption.

Cell: D29
Comment: Rick Heede:
Visitors arriving in private vehicles varies greatly by season. Of Aspen's 7,000 tourist "pillows," average occupancy in the summer is ~70 percent, or 4,900 visitors per night. Average occupancy per room is ~2.0 (to account for visitors who arrived in the same vehicle), and average length of stay varies (in summer) from 1.9 in May to 2.7 nights in July. Assuming 2.3 nights per visit and 2 persons per room and 4,900 occupied pillows and 67 percent arrivals by car means, on average, that 710 tourist vehicles arrive per summer day. (Of course, visitors may do a lot of driving whilst here; we are merely estimating new arrivals per day. Their daily driving is reflected in "Hwy 82" and/or "Driving around town".)

Off-season and winter season arrivals by car are lower than in summer: approximately 2/3 of summer visitors vs 20 percent of winter visitors arrive in personal vehicles. Winter visitors also stay longer: on average about 4.4 days (ranging from 3.2 in Nov to 4.9 in Dec). While occupancy is somewhat higher in winter, the stays are longer and the driving population is smaller. Finally, the 20 percent of winter arrivals by car are typically from the front range or elsewhere in Colorado, thus tending to reduce the average distance driven.

All in all, this estimate assumes that 350 personal vehicles arrive in Aspen every day, on average, throughout the year.

Most of this data was kindly provided by Bill Tomcich of Stay Aspen Snowmass, 920-7120. The derived fuel consumption estimates are the author's.

Note: there is little hard data on which to base a more accurate estimate. The ACRA summer visitor study does not elucidate mode of travel by visitors (nor does it mention any international visitorship). An accurate estimate would estimate visitors by month and with a better sense of the home state or country of visitors who arrive by personal vehicle. Note also that we have not included visitors who drive to Aspen as part of their camping trips to the area, nor drivers who are visiting friends and relatives, nor second home owners who drive here.

Cell: F29
Comment: Rick Heede:
32 percent of Aspen summer visitors are from Colorado -- chiefly the Front range, which is 400 miles round-trip. Californians comprise 8 percent, Texans 6 percent, Floridians (5 percent, Illini 4 percent, and New Yorkers 3 percent. THE ACRA data does not, unfortunately, give the number of summer visitors (percentages are shown instead). However, ACRA data show "four in ten lodging visitors indicate that they flew to get to Aspen."

ACRA (2004) Summer Survey: Understanding the Aspen Summer Visitor, slide #8.

It is probably conservative to use an average distance driven of 600 miles (round-trip) considering the longer distances driven by the substantial number of out-of-state visitors.

Note: we have not diluted the distances driven by tourists arriving in Aspen by allocating a portion of their driving emissions to other destinations also visited en route. Whether Aspen is or is not the principal reason for the visitors' itineraries, it is our purpose to estimate fuel consumption and emissions for visitors arriving in Aspen, regardless of where else they may have visited on their way here.

Cell: H29
Comment: Rick Heede:
We use the composite fuel economy developed for personal vehicle types driven around Aspen. See below (cell K35) for details.

Cell: K35
Comment: Rick Heede:
This is a composite average of fuel consumed and miles driven by pasenger cars plus small SUVs/pick-up trucks plus large SUVs/pick-up trucks. This number is also used to estimate saved fuel from RFTA bus services (a calculation that uses 1.63 persons per vehicle).

Note: this number is driven by data and does not have to be revised. Its revision depends on fuel economy by individual mpg data in the body of the worksheet.

Cell: C39
Comment: Rick Heede:
The traffic counters do register vehicle classes at both the Castle Creek and Mill & Main Streets:
Class 1: Less than 18 feet,
Class 2: 18-25 feet in length,
Class 3: greater than 25 feet.

However, these sizes are not detailed enough for our fuel consumption purposes. We engaged Lee Cassin and the Env Health Dept staff, plus John Krueger of the City Transportation Dept, to survey vehicle types during several mornings during mid-August 2005. The main data set we use was taken on 25Aug05, from 7 am to 1 pm. (Thanks, everybody.) The survey counted 8,003 vehicles, for which the distribution by type is shown below. (We exclude 104 RFTA buses and 20 school buses from this survey; fuel consumption by RFTA and school buses is estimated elsewhere.)

Note: A high fraction of the semis serving Aspen's markets, hardware stores, lumber yards, etc arrive at night and depart before dawn. Our survey may, therefore, have underestimated the number of semis, since the principal vehicle type survey was done from 7am to 1 pm.

Cell: H39
Comment: Rick Heede:
New vehicle fuel economy data used.

Passenger cars average 22.1 mpg.

Small SUVs (25.4 mpg) and small pick up trucks (21.7 mpg) averaged to 23.6 mpg. (Table 4.8)

Large SUVs (17.6 mpg) and large pick up trucks (18.3 mpg) averaged to 18.0 mpg. Note: conservative, considering the weight driven around by the typical pick up truck and work van in Aspen. This category also contains Hummers (10-13 mpg, practical experience is closer to 8 mpg), Suburbans, Ford 350s, and dsimilar brontomobiles.

2-axle medium-duty trucks (10-14,000 lb) average 10.4 mpg (Table 5.4).

3-axle trucks, dump trucks, garbage trucks, etc (19,500-26,000 lb) average 8.0 mpg.

Semis or combination trucks (33,000 lb +) average 6.1 mpg (Table 5.4).

Davis & Diegel (2004) Transportatoin Energy Data Book 2004, Tables 4.1, 4.8, and , Oak Ridge National Laboratory, USDOE.

Motorcycles: EIA uses 50 mpg (Energy Information Administration/2001 National Household Travel Survey, p. K-37).

Cell: B42
Comment: Rick Heede:
VMT estimates for 1997 from Colorado Department of Public Health (2000) Technical Support Document for the PM10 Redesignation Request and Maintenance Plan for the Aspen Area, Air Pollution Control Division, Denver, p. 6.

Cell: B43
Comment: Rick Heede:
Estimated annual compound VMT growth rate from Technical Support Document (cited above, p. 2). Original source: CDOT Entrance to Aspen Environmental Impact Statement. The factor was used to estimate Aspen-area PM10 emissions in 2015; we apply the same growth rate to estimate VMT in 2004.

Cell: B45
Comment: Rick Heede:
Daily VMT times 365.

Aspen Emissions Inventory for 2004: Roaring Fork Transit Authority (RFTA)

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started 11 August 2005
Last Modified: 17 December 2005

Future inventories must update: (a) fuel consumption by RFTA route served (or total RFTA fuel consumption), (b) check future Aspen ridership as a percentage of total "on/offs", (c) update biodiesel percentage (5 percent in 2004), and update average fuel economy by route served.

Data provided by:
Kenny Osier
RFTA Dir Maintenance, kosier@rfta.com
Phil Schultz
Dir Info Techn, pschultz@rfta.com
970-920-1905

RFTA fuel consumption and emissions, 2004

1 metric tonne = 1.1023 short ton; CO2/C = 3.664

	Allocated to Aspen GHG inventory	Vehicle miles per route, 2004	Fuel economy	Fuel consumed per route	Fuel allocated to Aspen GHG inventory	Carbon factor	Carbon dioxide	Carbon
	percent		mpg	gallons	gallons	CO2/gallon	sh tons CO2/yr	tonnes carbon
	22.384 lb CO2 per gallon * (1.0 - (0.05 * 0.7845)) = 22.384 * 0.96078 = 21.506 lb CO2 per gallon					22.384 lb CO2/gal 1 - (0.05*0.7845) (net B5 credit)		
Roaring Fork Transit Agency (excluding I-70 corridor, Woody Creek)								
City shuttles	100%	385,966	5.1	75,091	75,091	21.506	807	200
Galena Street shuttle	100%	31,217	6.4	4,878	4,878	21.506	52	13
Crosstown shuttle	100%	24,201	7.2	3,361	3,361	21.506	36	9
Valley routes	39.1%	2,122,413	5.5	385,893	151,076	21.506	1,625	402
Burlingame	100%	11,770	5.0	2,354	2,354	21.506	25	6
Maroon Bells	50%	39,962	5.0	7,992	3,996	21.506	43	11
Aspen Skiing Company contract	66.7%	275,297	5.0	55,059	36,708	21.506	395	98
Music Festival contract	100%	19,389	5.0	3,878	3,878	21.506	42	10
Maroon Creek Road	100%	49,654	5.0	9,931	9,931	21.506	107	26
Senior Van	50%	11,461	8.0	1,433	716	19.594	7	2
Total	na	2,971,330		549,870	291,989	na	3,139	777

RFTA: Saved Fuel and Emissions

Note: RFTA averages 0.99 pax/vehicle-mile (0.65 on Valley routes). Urbitran, p. 38.

	Allocated to Aspen GHG inventory	Total Ridership	Avoided trips allocated to Aspen routes	Miles per avoided trip	Passenger-miles saved by RFTA bus service	Vehicle-miles saved by RFTA bus service	Fuel saved	Carbon dioxide	Carbon
	percent	riders	riders	miles	miles	miles	gallons	sh tons CO2/yr	tonnes carbon
						occupancy of: 1.63 persons/vehicle			
Roaring Fork Transit Agency (excl. I-70, Woody Creek, GWS, TOSV)									
City shuttles					-	-	-	-	-
Cemetery Lane	100%	82,217	82,217	2	164,434	100,880	5,419	53	13
Hunter Creek	100%	249,139	249,139	1	249,139	152,846	8,211	80	20
Castle/Maroon	100%	427,622	427,622	2	855,244	524,690	28,186	276	68
East End Dial-A-Ride	100%	50,016	50,016	2	100,032	61,369	3,297	32	8
Seasonal shuttles									
Galena Street shuttle	100%	50,845	50,845	1	50,845	31,193	1,676	16	4
Crosstown shuttle	100%	26,883	26,883	1	26,883	16,493	886	9	2
Maroon Creek Road	100%	86,348	86,348	2	172,696	105,948	5,691	56	14
Valley routes	39.1%	1,528,554	598,424	25	14,960,608	9,178,287	493,047	4,823	1,194
Burlingame	100%	25,658	25,658	5	128,290	78,706	4,228	41	10
Maroon Bells	50%	67,462	33,731	10	337,310	206,939	11,117	109	27
Aspen Skiing Company contract	66.7%	528,873	352,600	10	3,525,996	2,163,188	116,204	1,137	281
MAA campus	100%	58,237	58,237	5	291,185	178,641	9,596	94	23
RFTA charters	50%	51,767	25,884	10	258,835	158,794	8,530	83	21
Senior Van	50%	3,676	1,838	4	7,352	4,510	242	2	1
Total	na	3,237,297	2,069,441	na	21,128,849	12,962,484	696,329	6,811	1,686

Composite fuel economy of passenger cars, small, medium, and large SUVs and pick-ups: 18.62

Cell: H11
Comment: Rick Heede:
In this worksheet we estimate those of RFTA's emissions attributable to Aspen's emissions boundary: i.e., RFTA riders in town routes, riders originating or arriving in Aspen (Ruby Park to Airport/AABC/North Forty or stops between) on the Valley Routes, and special service routes (Aspen Skiing Company, Music Festival, etc).

Energy and emissions from electricity and natural gas consumption used at RFTA's main bus barn across from the Airport is not specifically estimated here, but is included in the Electricity and Natural Gas worksheets. Energy used in downvalley facilities is not included.

Cell: C12
Comment: Rick Heede:
Most of these routes are fully allocated to the City of Aspen emissions boundary. We ascribe one-half of the fuel consumed on the Maroon Bells and the senior van routes to Aspen. Two-thirds of the ASC fuel consumption is allocated to Aspen (since these routes service Buttermilk, Highlands, and Snowmass Ski Areas, and only Snowmass is outside the boundary.

The 2003 Boarding and Alighting Survey asked 45 thousand RFTA riders where they got on and got off. 35.81 percent (8,062 of 22,511) indicated Aspen.

Note: "Aspen", in RFTA's survey, includes Ruby Park terminal to the Truscott bus stop. The fuel and emissions inventory boundary includes riders to Country Inn, AABC, and the Airport. We thus add one-half of the riders from Aspen who alight from Country Inn through Brush Creek (that is, half of 1,502 surveyed riders, or an additional 751). Thus, 8,062 plus 751 = 8,813 of 22,511 equals 39.15 percent of all RFTA's riders are attributable to Aspen and its immediate community.

Even though every RFTA bus serving the Hwy 82 corridor drive into or out of Aspen, we allocate 39.15 percent of the fuel used by RFTA on Valley routes to serving Aspen. Estimated "on/offs" for RFTA's Valley routes in 2003 total 3,109,148, of which 1,217,222 represents Aspen's share.

Cell: D12
Comment: Rick Heede:
Vehicle miles data from Kenny Osier, RFTA Director of Maintenance, personal communication, 16Aug05.

Cell: E12
Comment: Rick Heede:
Revised from data supplied by Kenny Osier, RFTA Director of Maintenance, personal communication.

Cell: F12
Comment: Rick Heede:
Fuel consumption by RFTA route from Kenny Osier, RFTA Director of Maintenance, personal communication, Aug05. Slightly revised 2Dec05 (with data from Osier and Blankenship).

Cell: G12
Comment: Rick Heede:
Fuel consumed per RFTA route multiplied by the percent allocated to Aspen and its emissions boundary.

Cell: H12
Comment: Rick Heede:
Carbon emissions per gallon of diesel and gasoline from EIA data. Diesel emissions are reduced by the fuel's biodiesel component. In RFTA's case (2004), B5 is used, which is 5 percent biodiesel mixed with conventional diesel.

While life-cycle net carbon savings estimates vary widely (see below), we use a net savings of 78.45 percent based on teh NREL report cited below. The emissions benefit of using B5 fuel is thus petroleum diesel times 0.95 plus an adjustment for the net carbon savings of biodiesel fuel: the carbon coefficient is 22.384 lb CO_2 per gallon * (1.0 - (0.05 * 0.7845)) = 22.384 * 0.9608 = 21.506 lb CO_2 per gallon.

The upstream carbon emissions from biodiesel production are not analyzed here. Such an analysis would include fuel inputs to growing, fertlizing, harvesting, transporting soy or other organic feedstocks, processing electricity and fuels, and storage and delivery fuel inputs. The net carbon savings from biodiesel is certainly less than the carbon absorbed from the atmosphere in the carbon fixation phase of the feedstock. Note that upstream emissions from conventional fuels are not attributed to diesel and gasoline consumption by RFTA or other consumers in Aspen. Estimates of "wells-to-tank" energy inputs range from 20 to 30+ percent above the emissions from the fuels' combustion, depending on the bondary definitions used. See Wang (2001).

Net carbon savings estimates vary widely: from zero to 80+ percent; some organizations assume 100 percent carbon neutrality. National Renewable Energy Laboratory (1998) "Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus," May1998, 314 pp., which concluded that biodiesel reduces net emissions of CO2 by 78.45% compared to petroleum diesel. Mark Delucchi of Institute for Transportation Studies University of California, Davis suggests that the use of biofuels would increase greenhouse gas emissions as land is converted from forests, wetland and conservation reserve acres to grow more corn and soybeans. European research suggests a range of 40 to 56 percent carbon savings.

Cell: I12
Comment: Rick Heede:
Gallons per route times CO2 per gallon / 2000 lb per ton.

Cell: C31
Comment: Rick Heede:
Most of these routes are fully allocated to the City of Aspen emissions boundary. We attribut one-half of the fuel consumed on the Maroon Bells and the senior van routes to Aspen. Two-thirds of the ASC fuel consumption is allocated to Aspen (since these routes service Buttermilk, Highlands, and Snowmass Ski Areas, and only Snowmass is outside the boundary).

Cell: D31
Comment: Rick Heede:
Ridership data for 2004 from Phil Schultz, RFTA's Information Technologist and data-hound, personal communication, 29Aug05. We exclude Glenwood Springs "Ride" (151,212 riders), I-70 corridor service to Silt, New Castle, and Rifle (49,349 riders), and ADA in Aspen and GWS (294 riders). Total RFTA 2004 ridership: 3.51 million.

In-town shuttles, Burlingame, and MAA shuttles are fully allocated to within the inventory boundary. The Valley routes are allocated 39.1 percent to within the boundary, based on "on/offs" from Ruby Park to AABC (see RFTA fuel consumption comment for detail). Two-thirds of Ski Co ridership is allocated to Aspen (since Aspen Mtn, Highlands, and Buttermilk bases are both within the boundary, and the buses serving Snowmass Mountain are transporting Aspen locals and visitors to Snowmass more than the other way around).

Cell: E31
Comment: Rick Heede:
"Avoided trips" estimates the ridership carried by RFTA's transit services on a route-by-route basis. Most routes are fully allocated to Aspen, such as the City and Seasonal shuttles. The Valley routes carried 1.529 million riders, of which 39.1 percent is attributed to Aspen and its emissions boundary (out to Airport/AABC/North Forty). Note that we use a vehicle occupancy of 1.63 persons per vehicle in the fuel savings estimate in this table and do NOT assume that each rider would drive single-occupancy.

Cell: F31
Comment: Rick Heede:
This column assumes average distance ridden per route based on interviews with RFTA staff and this report's reviewers. The Valley routes comprise the main component. Aspen to Snowmass Village is ~14 route miles, Basalt is ~20 route miles, El Jebel is 24 route miles, Carbondale is 32 route miles, and Glenwood Springs ~44 route miles, with relatively minor ridership to Aspen from the I-70 corridor. No definitive estimate can be made with respect to average distance ridden over several valley routes, and CMS assumes that 25 miles is a reasonable estimate of average distance travelled by riders to and from Aspen.

RFTA provided transportation to 3.1 million riders on the Hwy 82 corridor in 2003, based on a series of ridership surveys conducted in 2003. The same survey also estimated average miles traveled on Valley routes at 15.0 miles per passenger (15.7 miles if Snowmass Village is included, and 28.7 miles if the I-70 riders are included). These averages include the larger proportions (60.9 percent) of Valley route riders who travel between major stops outside of the Aspen emissions boundary. Thus, of the 39.1 percent of Valley passengers that boarded or alighted in Aspen (or out to the Airport), we estimate saved fuel from 25 miles of avoided driving attributable to RFTA's bus service. This savings estimate also factors in occupancy per vehicle of 1.63. See note below.

Shorter route miles and average distance ridden are estimated and checked with RFTA staff, 21Nov05.

Cell: G31
Comment: Rick Heede:

"Passenger-miles" is "avoided trips" times estimated average miles per trip/route.

Cell: H31
Comment: Rick Heede:
The fuel and emissions savings estimate factors in occupancy per vehicle of 1.63; meaning that we estimate the fuel consumed on the basis of 1.63 RFTA riders would drive one vehicle to or from Aspen in the absence of RFTA services.

Occupancy data from Mt. Sopris Project Team (1993) Origin and Destination Summer Survey, Mt. Sopris Transportation Project Final Report, p. 65. The Survey logged 15,180 person-trips in 9,303 vehicle-trips (Aspen, eastbound, workday). Recreational trips logged a higher occupancy of 2.43 persons/vehicle, whereas work trips logged 1.22 persons/vehicle.

Cell: I31
Comment: Rick Heede:
Fuel saved is a function of vehicle-miles saved times the fuel economy of the average vehicle presumptively used to get people where they want to go in the absence of RFTA bus service. Some riders would hitchhike, or carpool, or bicycle, or move closer to work, or not go. This study assumes none of these alternatives, and estimates fuel savings as if all riders would need access to a car, or a shared car (hence the 1.63 occupancy rate). The calculation is based on the same composite fuel economy of vehicles entering Aspen in August 2004 (see worksheet on "Road Vehicles").

Cell: B36
Comment: Rick Heede:
RFTA's Year Round City Service includes (for 2004): Cemetery Lane (82,217), Hunter Creek (249,139), Castle/Maroon (427,622), and East End Dial-a-ride (50,016); total 812,994 riders.

RFTA 2004 Ridership data from Phil Schultz, RFTA Dir IT, 29Aug05.

Cell: B45
Comment: Rick Heede:
Total Valley Service (1,597,038 riders) less Woody Creek (9,184 riders) and Town of Snowmass Village (59,300 riders). Valley Service to Snowmass Village is included, since that proportion of toal ridership has been accounted for in the percentage allocation to Aspen (39.1 percent of total riders).

Cell: J54
Comment: Rick Heede:
Composite fuel economy for the vehicle types assumed to be used for commuting -- passenger cars, small SUVs/small pick-up trucks, and large SUVs/large pick-up trucks -- is derived in the "Road Vehicles" worksheet. Note that we also apply a commuter occupancy of 1.63 persons per vehicle.

Aspen Emissions Inventory: Aspen Schools, City, SkiCo, & misc. fuel use

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started 11 August 2005
Last Modified: 17 December 2005

Future inventorists should update each of the fuel-consumption categories by contacting the entities listed on this worksheet and in the comments to each section. The specific data required and the methodology used to makes estimates are discussed in comments.

Data provided by:
Fred Brooks, ASD Bus Fleet Mngr, 925-3760, x4010
Rego Omerigic, County Vehicle Fleet Mngr, 920-5393
Ellie Nieslanik, Valley Co-op, 970-704-4210
Landon Dean, T-Lazy-Seven Ranch, 970-925-4614
Auden Schendler, Aspen Skiing Co, 970-300-7152

	Vehicle miles traveled (VMT)	Fuel consumed	Fuel consumed	Fuel economy	Carbon factor	Attributed to Aspen	Carbon dioxide	Carbon
	(if known)	Diesel	Gasoline	mpg	CO2/gallon	Percent	sh tons CO2/yr	tonnes carbon
Aspen School District					diesel / gasoline			
School buses	116,607	17,420		6.7	22.38	100%	195	48
Other School District vehicles	136,091		13,380	10.2	19.59	100%	131	32
Out-of-district fuel (ExEd trips, away games)			5,352	-	20.99	100%	56	14
Total School vehicles		17,420	18,732				382	95
								-
								-
Pitkin County Public Works Dept.								-
Trucks, plows, etc. (diesel fuel)		37,905			22.38	20%	85	21
Sheriff and other vehicles (gasoline)			59,350		19.59	20%	116	29
Total Pitkin County vehicles		37,905	59,350				201	50
								-
City of Aspen								-
Trucks, plows, etc. (diesel fuel)		33,588			22.38	100%	376	93
Sheriff and other vehicles (gasoline)			62,590		19.59	100%	613	152
Total Pitkin County vehicles		33,588	62,590				989	245
								-
Construction and off-road equipment								-
Fuel deliveries by Roaring Fork Coop	na	129,000			22.38	100%	1,444	357
Snowmobiles	na		2,000		19.59		20	5
Misc off-road equip. (mowers, etc)	na		19,440		19.59		190	47
Total off-road vehicles		129,000	21,440				1,654	409
								-
Aspen Skiing Company					Biodiesel credit			-
Snow groomers, other diesel vehicles		152,902			18.87	100%	1,443	357
Snowmobiles, misc vehicles (gasoline)			57,566		19.59	100%	564	140
Total Pitkin County vehicles		152,902	57,566				2,007	497
								-
Total ASD, City, County, ASC, & misc.	na	217,913	162,112	na	na	na	5,233	799

Cell: D12
Comment: Rick Heede:
Fuel consumption data sources are listed for each entity included.

Cell: F12
Comment: Rick Heede:
Fuel economy is derivd from VMT and fuel consumption data provided by Aspen School District fleet manager. Newer school buses use less fuel per mile.

Cell: B14
Comment: Rick Heede:
Fuel consumption and route miles in 2004 from Fred Brooks, Bus Fleet Manager, personal communication, 22Aug05. Tel. 925-3760, x 4010

Cell: B15
Comment: Rick Heede:
The Aspen School District operated 18 buses in the 2004/2005 school year on 14 routes. The fleet drives 73,222 miles in the 176-day school year. The average bus route (though it varies greatly) is 29.7 miles and the fleet drives an average of 416 miles per school day.

Cell: B16
Comment: Rick Heede:
The District also operates 25 other vehicles -- such as Suburbans for field trips, maintenance vehicles, and snowplows that were driven 43,385 miles in 2004 and consumed 13,380 gallons of (chiefly) gasoline.

Cell: B17
Comment: Rick Heede:
The fuel consumed by "other school district vehicles" above do not include fuel purchased on the road for the two dozen long-distance Experiential Education outings (as far as South Dakota, for example, or to Moab in a fleet of Navigators and the like); nor are the several trips by the Varsity and other sports teams beyond range of the fuel in the vehicles' tanks.

In lieu of having an accounting of these fuel purchases we assume such out-of-district fuel consumption at 40 percent of the consumption by "other school district vehicles."

Note: the fuel economy is the average of diesel fuel and gasoline.

Cell: B21
Comment: Rick Heede:
Fuel data for 2004 from Rego Omerigic, Pitkin County Public Works Fleet Manager, 8Aug05. Tel 970-920-5393; rego@co.pitkin.co.us

Cell: B27
Comment: Rick Heede:
Fuel data for 2004 from Chicago Climate Exchange "City of Aspen - CCX Preliminary Emissions Analysis," based on data supplied by Lee Cassin, City Env Health Dept.
Data for fuel purchased for City-owned vehicles in 2004. We assign 100 percent of such fuel use to the emissions inventory (unlike County fuel purchases, of which we assign twenty percent to Aspen).

Cell: B34
Comment: Rick Heede:
Fuel data of diesel fuel sales to Aspen zip codes in 2004 from Ellie Nieslanik, accounting, and Bill Bransman, fuel sales, Roaring Fork Valley Coop, personal communication, 9Aug05. Tel 970-704-4210.

While such deliveries are chiefly fuel for construction equipment, a variety of other end-users also receive diesel fuel for off-road equipment such as tractors and backhoes.

A complete assessment of such uses has not been made, however, and we use the Coop fuel deliveries as a proxy for construction and off-road equipment. It is likely a conservative estimate considering that many contractors and excavators purchase their own fuel.

Cell: B35
Comment: Rick Heede:
We have not estimated fuel purchased for snowmobiles. 2,000 gallons is probably conservative for T-Lazy-7 Ranch at Maroon Creek. Snowmobile use by the Aspen Skiing Company is not included here, but such fuel use (as well as for groomers) is estimated in SkiCo's emissions inventory.

Cell: B36
Comment: Rick Heede:
There is no accurate way to estimate fuel used by mowers, trimmers, blowers, snow-removal equipment and generators and fuel-burning widgets around Aspen. We assume 4 gallons per household for lawn mowers and similar noise-generators per year as a minimal estimate of widget fuel consumption. Aspen housing units is estimated at 6,439 population in 2002 / Pitkin County's persons per household of 1.325 = 4,860 housing units. 4,860 hh x 4 gallons/hh-yr = 19,440 gallons per year. The real number, if professional gardening or contract snowplowing services are included, could easily be ten times higher.

Housing data from Venturoni (2004) 2004 Pitkin County Community Survey, slide #4, NW Colorado Council of Govts.

Cell: B40
Comment: Rick Heede:
Fuel data from Aspen Skiing Company, Auden Schendler, 23Nov05. Diesel and gasoline consumption is reported by ski area; we include Aspen Mtn, Highlands, and Buttermilk, and exclude Snowmass Ski Area.

Cell: G40
Comment: Rick Heede:
20 percent of SkiCo's diesel consumption is 100 percent biodiesel. While life-cycle net carbon savings estimates vary widely (see below), we use a net savings of 78.45 percent based on the NREL report cited below. The emissions benefit of using B5 fuel is thus petroleum diesel times 0.95 plus an adjustment for the net carbon savings of biodiesel fuel: the carbon coefficient is 22.384 lb CO_2 per gallon * (1.0 - (0.20 * 0.7845)) = 22.384 * 0.8431 = 18.872 lb CO_2 per gallon.

Also see the notes under RFTA's biodiesel calculation.

National Renewable Energy Laboratory (1998) "Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus," May1998, 314 pp., which concluded that biodiesel reduces net emissions of CO_2 by 78.45% compared to petroleum diesel.

Aspen Emissions Inventory for 2004: Commercial Aviation

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started 11 August 2005
2-Jan-06

This worksheet estimates gallons of jet fuel consumed and carbon dioxide emissions attributable to revenue-passengers flying into and out of Aspen in 2004. See comments below for details. Future emissions inventorsts should update enplanement and deplanement data from the FAA and/or the Aspen Pitkin Airport staff.

Table 1 — Fuel and Emissions from passengers flying to and/or out of Aspen, 2004

65.5 percent use ASE	Aspen Enplanements	US origin	Miles flown per trip	International	Miles flown per trip	Total Passenger Miles Flown	Jet fuel "consumed"	Carbon	Carbon Dioxide
	100 percent	80 percent		20 percent			gallons	metric tonnes C	short tons CO2
							0.0272 gallons / passenger-mile	0.2476 tonne C / short ton CO2	0.574 lb CO2 / passenger-mile
Deplanements	178,837	143,070	1,100	35,767	5,000	336,213,560	9,149,178	23,892	96,501
Enplanements	183,719	146,975	1,100	36,744	5,000	345,391,720	9,398,938	24,544	99,136
Totals	362,556	290,045		72,511		681,605,280	18,548,116	48,436	**195,637**

Table 2 — Fuel and Emissions from Aspen residents & visitors flying to and from other Airports

34.5 percent do not use ASE	DIA , EGE, GJT enplanements	US origin	Miles flown	International	Miles flown	Total Passenger Miles Flown	Jet fuel "consumed"	Carbon	Carbon Dioxide
	100 percent	95 percent		5 percent			gallons	metric tonnes C	short tons CO2
Deplanements	94,193	89,484	1,100	4,710	5,000	121,980,515	3,319,383	8,668	35,011
Enplanements	96,765	91,927	1,100	4,838	5,000	125,310,413	3,409,997	8,905	35,967
Totals	190,958	181,410		9,548		247,290,928	6,729,380	17,573	**70,978**

Note 1: we have not included the related global warming impacts of high-altitude aircraft operations such as vapor trail formation, NOx, particulates, etc.

Table 3 — Proportion of total emissions allocated to communities in the Roaring Fork Valley

		Carbon	Carbon Dioxide
		metric tonnes C	short tons CO2
City of Aspen community:	70%	46,207	186,631
Town of Snowmass Village:	15%	9,901	39,992
Rest of Pitkin County	10%	6,601	26,662
Garfield and Eagle County:	5%	3,300	13,331
Total emissions by commercial aircraft using the Aspen and other Colorado airports, 2004:		66,010	266,615

Table 4

	Airport Fuel Sales				C/CO2 emissions	
	Jet Fuel (GA)	Jet Fuel (Coml)	Av Gas	Total Fuel Sales	Carbon	Carbon Dioxide
	gallons	gallons	gallons	gallons	metric tonnes C	short tons CO2
2004						
January	345,935	165,004	3,108	514,047	1,342	5,419
February	401,235	195,317	2,639	599,191	1,564	6,318
March	494,106	210,717	5,938	710,761	1,855	7,491
April	100,380	30,841	2,599	133,820	349	1,408
May	79,493	20,350	2,928	102,771	267	1,080
June	279,929	52,200	5,546	337,675	880	3,555
July	475,512	44,818	6,288	526,618	1,373	5,547
August	496,135	52,070	8,447	556,652	1,451	5,861
September	269,138	35,116	6,220	310,474	809	3,267
October	190,248	23,070	4,237	217,555	567	2,289
November	158,801	30,998	2,254	192,053	501	2,023
December	380,147	156,919	3,745	540,811	1,411	5,701
Total 2004	3,671,059	1,017,420	53,949	4,742,428	12,369	**49,960**

We have calculated the emissions of carbon dioxide resulting from the combustion of jet fuels and AvGas sold at the Airport. These totals are NOT added to emissions from aircraft arriving or departing, since we have estimated the total fuel used by all aircraft operating into and out of Aspen for 2004.

Carbon emissions from the combustion of jet fuel and aviation gasoline are 21.1 and 18.4 lbs CO2 per gallon consumed, respectively.

Table 5 — Aspen traveler averages

	Enpl/Deplane	Jet Fuel gallons (1 way)	Passenger miles miles (one way)	CO2 tons (one way)	CO2 lb (one way)
Total all airports	553,514	25,277,495	928,896,208	266,615	266,615
Allocated to Aspen (70 percent)	387,460	17,694,247	650,227,345	186,631	186,631
Aspen traveler *average* per trip:	na	45.7	1,678	0.48	963

Cell: D12
Comment: Rick Heede:
the 80/20 split between domestic and international originations is based on winter visitors flying into Aspen.

Cell: E12
Comment: Rick Heede:
The average "passenger trip" in 2002 was 850 miles. Davis, Stacy C. (2004) Transportation Energy Data Book 2004, Oak Ridge National Laboratory, Oak Ridge, TN, Table 9.2. We assume 1,100 miles per trip in lieu of the longer distance traveled by domestic visitors to Aspen.

LAX to Aspen (via DEN, 730 + 130 miles) 860 miles, LGA to ASE is 1,770 miles, MIA to ASE is 1,800 miles, Chicago ORD to ASE is 1,010 miles, Houston is 914 miles, Washington DC is 1,570 miles. Since NY/NJ/PA, Chicago, and LA are the three most important originations for winter visitors, we use 1,100 miles as a reasonable average flying distance for year-round travel distances.

Based on a conversation with Kris McKinnon, ASC Mng Dir Worldwide Marketing. Air travel distances from www.webflyer.com

Cell: F12
Comment: Rick Heede:
International visitors comprise roughly 20 percent of winter visitors, according to Aspen Skiing Company data (personal communication, 17Aug05). The precise fraction is proprietary to ASC. This does NOT equal year-round aveage of visitors to Aspen or Valley resident travel, hence this percentage may be adjusted.

Cell: G12
Comment: Rick Heede:
We estimate that the average international visitor (and international travel by outbound residents) is ~5,000 miles, which is likely conservative. This is equivalent to a flight from London to Aspen (4,770 miles) or Paris (4,980 miles). Rio de Janeiro is 5,930 miles, Sydney is 8,220 miles, and Tokyo is 5,720 miles. Of course, a number of visitors fly in from Canada, Mexico, Venezuela, and other closer countries to average out the number of visitors from Australia and elsewhere in Asia.

The three most important international markets for the Aspen Skiing Company (personal communication 17Aug05) are the UK, Australia, and Brazil.

Cell: H12
Comment: Rick Heede:
Passengers deplaning and enplaning at Aspen times average distance flown for domestic and international routes (1,100 and 5,000 miles, respectively).

Cell: I12
Comment: Rick Heede:
2002 data shows average fuel consumption on all Certificated Air Carriers (Domestic and International) was 0.0272 gallons per passenger-mile. This mixes all routes, carriers, aircraft types, distances, and load factors (72 percent in 2002). While the type of equipment and numbers of passengers by carrier flying into Aspen is known (e.g., 74.3 percent of deplanements arrived on United Air-Wisconsin in 2004), we have chosen to use the national average fuel and carbon emissions per passenger-mile across all domestic and international routes rather than estimating emissions for the Denver to Aspen leg of the numerous flight visitors and residents take.

Source for fuel consumption and passenger-mile data: Davis, Stacy C. (2004) Transportation Energy Data Book 2004, Oak Ridge National Laboratory, Oak Ridge, TN, Table 9.2. Total air carrier fuel consumption in 2002: 2.408 Q (~17.84 billion gallons). Total General aviation energy use: 0.142 Q (~1.05 billion gallons).

Cell: K12
Comment: Rick Heede:
Using the ORNL data cited in the comment I15, we calculate emissions as 0.5740 lb CO2 per passenger-mile. As stated above, this is an average for all routes, equipment types, distances, and load factors for all domestic and international carriers flying in the US in 2002.

Cell: K21
Comment: Rick Heede:
An average of 65.5 percent of visitors and residents of Aspen who do fly do so in and out of the Aspen Airport, according to the Pitkin County Survey. 31.8 percent travel to DIA for flights, although GJT, EGE, and other airports are also used.

In other words, we estimate that an additional amount of travelers and miles flown depart from other airports. The number of travellers using other airports is thus (1-0.655)/0.655 times 362,556 travellers out of Aspen = 0.527 times 362,556 = 190,958 deplanements and emplanements at non-Aspen airports.

This datum averages respondents from the business surveys, voter surveys, and assessor surveys collected by Linda Venturoni (2004) 2004 Pitkin County Community Survey, Northwest Colorado Council of Governments, slide 21; www.nwc.cog.co.us

Cell: F22
Comment: Rick Heede:
Since internaitnal visitors are more likely to fly all the way to Aspen rather than drive from DIA, we reduce the international fraction from 20 percent above to 5 percent for travel to other airports.

Cell: G22
Comment: Rick Heede:
We use the same estimated travel distance for the few international visitors flying into (and residents flying out of) other airports: 5,000 miles.

Cell: H22
Comment: Rick Heede:
Passengers deplaning and enplaning at Aspen times average distance flown for domestic and international routes (1,100 and 5,000 miles, respectively).

Cell: I22
Comment: Rick Heede:
See note under jet fuel consumed, above.

Cell: K22
Comment: Rick Heede:
Using the ORNL data cited in the comment I15, we calculate emissions as 0.5740 lb CO2 per passenger-mile. As stated above, this is an average for all routes, equipment types, distances, and load factors for all domestic and international carriers flying in the US in 2002.

Cell: B29
Comment: Rick Heede:
Such impacts have been estimated to range between two to 3.5 times the impact of converting jet fuel to carbon dioxide in the atmosphere.

IPCC (1999) Aviation and the Global Atmosphere - Summary for Policymakers.

Cell: G43
Comment: Rick Heede:
We convert short tons (2000 lb) of carbon dioxide to metric tonnes of carbon at CO2/C = 3.664191. From Kevin Baumert, World Resources Institute, May05: "CO2 conversion is, precisely: C=12.0107 + O=15.9994 x 2 = 44.0095/12.0107 = 3.664191"

Cell: H43
Comment: Rick Heede:
Carbon emissions from the combustion of jet fuel and aviation gasoline is 21.1 and 18.4 lbs CO2 per gallon consumed, respectively. Source: US Energy Information Administration.

Formula: (sum jet fuel columns) * 21.1 lbs CO2 per gallon)/2000 lbs per short ton plus (AvGas column * 18.4 lbs CO2 per gallon)/2000 lbs per short ton = total airport fuel sales combusted to carbon dioxide (short tons).

Cell: H60
Comment: Rick Heede:
This table calculates trip lengths, fuel consumption, and CO2 emissions per "average" trip for Aspen travelers, mixing domestic and international travelers.

Aspen Emissions Inventory for 2004: General Aviation

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started 11 August 2005
Last Modified: 18 September 2005

See comment B4

The Aspen Pitkin Airport handled 37,500 general aviation arrivals and departures in 2004. This worksheet develops a profile of the typical aircraft and missions flown, ie, size, performance, fuel flow, passengers onboard, distance flown, and total carbon dioxide emissions for the flights into and out of Aspen in 2004. See comment at B4.

Future emissions inventories may simply update operational data from (available from the Airport staff) and Air Ambulance operations (available from Pitkin County Emergency Services). Future inventories may also change fuel consumption rates, aircraft performance, and other factors.

Table 1 — Jet Turbine Aircraft Operations

	Total GA Operations	Jet aircraft (percent)	Jet operations	Total jet fuel (gallons)	Jet fuel/trip lb jet fuel	lb/gallon	Jet fuel/trip gallons	
Total general aviation operations:	25,020	75%	18,765	12,650,971	4,517	6.7	674	
Total Air Taxi operations:	12,468	90%	11,221	7,565,099				
Total GA plus AT operations:	37,488	na	29,986	20,216,069			Carbon	Carbon Dioxide
						Lb CO2/gallon	metric tonnes C	short tons CO2
		Total jet fuel consumed		20,216,069	gallons	21.10	52,792	213,229

Table 2 — Turbo Prop Aircraft Operations

	Total GA Operations	Turboprops (percent)	Turboprop operations	Total jet fuel (gallons)	Trip distance One way (hrs)	Fuel rate (gallons/hr)	Jet Fuel/trip gallons	
Total GA operations:	25,020	15%	3,753	750,600	2.5	80.0	200	
Total Air Taxi ops:	12,468	10%	1,247	249,360				
Total GA plus AT ops:	37,488	na	5,000	999,960			Carbon	Carbon Dioxide
						Lb CO2/gallon	metric tonnes C	short tons CO2
		Total jet fuel consumed		999,960	gallons	21.10	2,611	10,547

Table 3 — Air Ambulance Flights (helicopters & fixed-wing)

	Total Operations	Trip distance Roundtrip (hrs)	Fuel rate (gallons/hr)	Total fuel (gallons)				
Air ambi fixed-wing flights:	55	1.50	60	4,950				
Air ambi helicopter flights:	47	1.50	80	5,640				
Total Air Amulance operations:	102	na	140	10,590			Carbon	Carbon Dioxide
						Lb CO2/gallon	metric tonnes C	short tons CO2
		Total jet fuel consumed		10,590	gallons	21.10	28	112

Table 4 — Civil, Local, & Itinerant Flights (piston aircraft)

	Total Operations	Trip distance (hrs)	Fuel rate (gallons/hr)	Total fuel (gallons)				
Gen'l Aviation - piston aircraft	2,502	3.00	20	150,120				
Local sightseeing, T&Gs, training	1,105	1.50	16	26,520				
Total GA piston + "Civil" ops:	3,607			176,640			Carbon	Carbon Dioxide
						Lb CO2/gallon	metric tonnes C	short tons CO2
		Total Av Gas consumed		176,640	gallons	18.36	401	1,621

Table 5

	Carbon metric tonnes C	Carbon Dioxide short tons CO2
Total emissions by General Aviation aircraft using the Aspen Pitkin Airport, 2004:	55,832	225,509

Table 6 — Proportion of total emissions allocated to communities in the Roaring Fork Valley

		Carbon metric tonnes C	Carbon Dioxide short tons CO2
City of Aspen neighborhood:	70%	39,083	157,856
Town of Snowmass Village:	20%	11,166	45,102
Rest of Pitkin County	6%	3,350	13,531
Garfield and Eagle County:	4%	2,233	9,020
Total emissions by General Aviation aircraft using the Aspen Pitkin Airport, 2004:		55,832	225,509

Cell: B4
Comment: Rick Heede:
A survey of jet turbine aircraft parked at Aspen Base Operations and Airport ramps totaled 38 on 30Jul05 in size ranging from light Cessna Citations and Lears to large Gulfstream and Challenger aircraft with ramp weights from 10,800 to 91,400 lb.

The preponderance of aircraft were of the heavier, longer-range, larger-capacity variety of personal or corporate jets. We averaged the fuel consumption for a basket of business jets from the Citation Bravo up to the Gulfstream 550.* The eleven jets sampled average 674 gallons (4,517 lb) of jet fuel for a 1,000 nautical mile trip, which is a standard operational and cost estimation mission in the jet fleet management business. This also equals the performance of a Bombardier Challenger 604 and 1.11 times the fuel consumption of a Raytheon Hawker 800 XP -- both typical of the variety of aircraft flying into Aspen. **

It is likely that the selected baseline trip of 1,000 nm is conservative relative to the origins and destinations of the "average" flight to Aspen. It is, however, a standard industry measure, and fuel consumption data will be published annually for a variety of production aircraft.

Another conservatism in the 2004 fuel and carbon emissions estimate is that we have used the fuel performance of mostly new production models, and the fleet average is somewhat lower "mpg" than the new aircraft. Specific fuel consumption for each type of aircraft has (and will continue to) improve.

Finally, we have not accounted for the other atmospheric impacts of buring jet fuel at high altitudes, namely vapor trail formation, particulates such as sulfur dioxide, NOx, and other impacts on the radiative balance of the atmosphere. Some researchers estimate such impacts are approximately 1.5 to 3.5 times the direct impact of the carbon emissions. See IPCC 1999.

* Citation Bravo (371 gallons) up to the Gulfstream III (1,069 gallons). Other aircraft performance in our review (all fuel consumption per 1,000 nm mission): Lear 45 (433 gallons); Lera 60 (477 gallons); Hawker 800XP (604 gallons); Citation X (576 gallons); Falcon 2000 (540 gallons); Challenger 604 (674 gallons); Gulfstream 550 (834 gallons), Gulfstream G-III (1,069 gallons); Gulfstream G-IV (972 gallons); and Gulfstream G-V (865 gallons). See Business & Commerical Aviation (2004) Operations Planning Guide, pp. 56-85. A "mission" includes fuel consumed for a typical sequence from start, taxi, clearance, take-off, climb, cruise, descent, landing, and taxi to stop.

** The Hawker 800XP specification sheet (www.raytheonaircraft.com/hawker/) lists trip fuel used for a 1,000 nm trip (with 4 passengers) as 4,069 lb. The flight time is 2 hrs 25 minutes, or 4,069 lb / 6.7 lb/gallon = 607 gallons; 607 gallons / 145 minutes = 4.19 gallons per minute. This means an average fuel rate 1.90 "miles per gallon" for the whole trip, with better cruise performance once the aircraft is at altitude. With six passengers, this equates to 1.85 lb CO_2 per passenger-mile (compare to air carriers' average of 0.574 lb CO_2 per passenger-mile).

A Gulfstream G-IV will use ~0.97 gallons fuel per nm, or 1.18 statute mpg, and a 1,000 nm trip would emit 10.25 tons of carbon dioxide (2.54 tonnes carbon). With eight passengers this means an emissions rate of 2.23 lb CO_2 per passenger mile. This "Hummer of the Sky" is outperformed (in terms of fuel, not time efficiency) by a street Hummer H2 at, say, 9 mpg and four on-board: 0.54 lb CO_2 per pax-mile. Or rouhly equivalent if the Hummer is transporting only the driver (2.17 lb CO_2/pax-mile).

However, "the larger the aircraft the fewer the passengers" seems to hold true at Aspen's GA operations. Gulfstream aircraft -- often configured for eight or nine passengers -- typically carry one or two passengers. With two passengers, a 1,000 nm trip in a G-II would consume about 1,220 gallons of fuel and emit 12.84 tons of CO_2 or 11.2 lb CO_2 per passenger-mile (25,680 lb CO_2 / 1,151 miles / 2 pax).

The G-IV will use an average of 7.1 gallons per minute, or 7.6 ounces per second. On take-off, however, the older G-II will consume 12,000 lb/hr at full thrust (three times cruise fuel consumption of 4,000 lb/hr). 12,000 lb/hr = 200 lb/min = 3.33 lb/sec = 0.5 gallons/sec = 10.5 lb CO_2/sec = 1.3 kgC/sec. One mississippi.

Cell: D15
Comment: Rick Heede:
Aspen Airport General Aviation (GA) operations for 2004 from Dave Ulane, Airport Operations Manager. From FAA data.

Cell: H17
Comment: Rick Heede:
See comment at B8 for details of our estimate of typical fuel consumption.

Cell: J20
Comment: Rick Heede:
We convert short tons (2000 lb) of carbon dioxide to metric tonnes of carbon at CO_2/C = 3.664191. From Kevin Baumert, World Resources Institute, May05: "CO_2 conversion is, precisely: C=12.0107 + O=15.9994 x 2 = 44.0095/12.0107 = 3.664191"

Cell: K20
Comment: Rick Heede:
Carbon emissions from the combustion of jet fuel equals 21.1 lbs CO_2 per gallon consumed.
Source: US Energy Information Administration.

Cell: D25
Comment: Rick Heede:
Aspen Airport General Aviation (GA) operations for 2004 from Dave Ulane, Airport Operations Manager. From FAA data.

Cell: H25
Comment: Rick Heede:
A 600 n-mile mission in a turboprop averages ~2.5 hours at a fuel burn of ~80 gallons per hour (range for production aircraft is on the order of 58 gallons per hour for a Cessna Grand caravan to Beech King Air 350 at 112 gallons per hour).

Source: Business & Commercial Aviation (2004) "2004 Operations Planning Guide," pp. 60 & 78.

Cell: C37
Comment: Rick Heede:
Flight for Life data from Pitkin County Emergency Services (Rich Walker, Director), 20July2005.

Total helicopter flights in 2004: 47;
Total fixed-wing flights in 2004: 55.
We assume that each flight is 120 miles each way, 240 miles roundtrip (and represent an average of a flight to Grand Junction and a flight to the Front Range; in 2004, flights to each area were roughly fifty-fifty).

We use the Eurocopter BK-117 helicopter to estimate fuel consumption rate for emergency choppers (the BK-117 is frequently used in such service). It is an 8 passenger helicopter originally designed in 1977. In the EMS configuration it is capable of carrying a pilot, patient and 5 other passengers or a pilot, two patients and three other passengers. It is powered by two 700 horsepower Lycoming LTS 101-750-B1 engines. The craft uses 80 gallons of jet fuel per hour of operation, max speed in 150 knots (173 mph).
www.flightforlife.net/aircraft.htm

Thus, a typical flight from Grand Junction or the Front Range of 120 miles takes approximately 45 minutes each way and would consume an estimated 120 gallons round trip.

Cell: C45
Comment: Rick Heede:
We have allocated 10 percent of total GA operations in 2004 to single-engine and twin piston aircraft. Thus 0.10 of 25,020 ops = 2,502 AvGas-burning aircraft.

Cell: C46
Comment: Rick Heede:
Data for total Civil operations ("CI") is from the FAA via David Ulane of the Aspen Pitkin Airport and tracked yearly by airport operations staff.

The FAA-designated and recorded "Civil" flights are typically locally-based aircraft and Flights for Life (EMS). The locally-based flights are air training, sightseeing, touch-and-goes (TGs), and similar flights that originate and return to Aspen.

We subtract Pitkin Emergency Services "Flight for Life" operations for 2004 (see above) and allocate the remained to such local flights, which we estimate are of 1.5 hr duration and of an aircraft mix of piston twins and singles buring 16 gallons per hour.

Cell: K48
Comment: Rick Heede:
Carbon emissions from the combustion of aviation gasoline equal 18.355 lbs CO_2 per gallon consumed.
Source: US Energy Information Administration.

Aspen Emissions Inventory: Pitkin County Landfill: Emissions and Savings

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started 11 August 2005
Last Modified: 29 September 2005

Future inventorists must update electricity and diesel fuel purhcased by the Pitkin County Landfill, update recovered materials flows, and check commingled materials by weight. The estimate of methane generation and/or our estimated fraction emitted to the atmosphere must also be checked.

Data provided by: Chris Hoofnagle
Solid Waste Manager, Pitkin County Landfill
923-3487
chrisho@co.pitkin.co.us
Also: Dr. Jean Bogner
Landfills +, Inc.
630-665-0872

Table 1: Emissions	Electricity	Fuel consumed	Carbon factor	Methane emissions	Methane factor	Attributed to Aspen	Carbon dioxide (Aspen's share)	Carbon (Aspen's share)
	kWh	gallons	lb CO2/kWh & /gallon	short tons CH4	short tons CO2-eq	Percent	sh tons CO2-eq/yr	tonnes carbon (C-eq)
Pitkin County Landfill					CO2 x 23			
Electricity	110,476		1.795			50%	50	12
Fuel consumption (diesel)		4,849	22.38			50%	27	7
Fugitive methane (60 percent of 150 cfm generated)				1,000	23,000	50%	11,500	2,847
Total Pitkin County Landfill							11,577	2,866
Biosolids, short tons, 2004:	1,953	0.02	2% tons as methane	39.05	898	100%	898	222
					Total Landfill if WTF is included:		12,475	

Table 2: Saved emissions	Quantities Recycled and Sold	Carbon dioxide savings per tonne recycled	Total Pitkin County carbon dioxide savings	Attributed to Aspen	Carbon dioxide (Aspen's share)	Carbon (Aspen's share)
Pitkin County Landfill: Savings from Recycling	tonnes	tonnes CO2-eq/tonne	tons CO2-eq	Percent	sh tons CO2-eq/yr	tonnes carbon (C-eq)
Office paper	113	5.4	673	60%	404	100
Newsprint	1,184	2.5	3,264	60%	1,958	485
Cardboard	524	3.0	1,732	60%	1,039	257
Commingled materials	1,174	na	na	60%	na	na
Plastics (10.5 percent of commingled)	123	2.0	272	60%	163	40
Aluminum (6.5 percent of commingled)	76	15.7	1,321	60%	793	196
Glass (65 percent of commingled)	763	0.4	337	60%	202	50
Steel (18 percent of commingled)	211	2.3	536	60%	322	80
Total Landfill recycling savings	2,996	na	8,134	60%	4,881	1,208

tonne = 1,000 kg
ton = 2000 lb
1 tonne = 1.1023 ton
1 kg = 2.2046 lb

Note: This savings estimate is generic and does not necessarily reflect local collection or disposal energy expenditures vs savings.
Note: Emissions from diesel fuel used by waste and recycled materials haulers are included in the transportation worksheets as a percentage of "3-axle trucks".

Cell: F13
Comment: Rick Heede:
See note under Fugitive methane, in which we allocate a fraction of estimated methane generation as emissions through the landfill's topsoil as fugitive methane emitted to the atmosphere.

Cell: H13
Comment: Rick Heede:
Approximately 50 percent of the Landfill waste is generated in Aspen. The other 50 percent is from Basalt and upstream from Basalt in Ptikin County. Estimate from Hoofnagle, personal communication, 19Jul05.

Cell: B15
Comment: Rick Heede:
Fuel and electricity consumption in 2004 from Chris Hoofnagle, Solid Waste Manager, personal communication, 17Aug05. Tel. 923-3487, chrisho@co.pitkin.co.us.

Cell: B16
Comment: Rick Heede:
Hoofnagle: 110,476 kWh in 2004; 50,700 kWh of which is used in recycling operations (balers, crushers, lighting, etc).

Cell: B17
Comment: Rick Heede:
4,849 gallons of diesel fuel consumed in 2004 by the Landfill's compliment of ~dozen loaders, dozers, trucks, graders, and excavators.

Cell: B18
Comment: Rick Heede:
Methane generation is roughly 150 cubic feet per minute. Hoofnagle, personal communication, 17Aug05: "An estimate of current methane generation rate would be on the order of 150 cubic feet per minute (cfm) for the Pitkin County Landfill.   This estimate is based on design capacity of 2.24 million megagrams, and refuse disposed from 1999 through 2002. This is a very rough estimate."

150 cfm times 60 x 24 x 365 = 78.84 million cubic feet (Mcf); 1 cf of methane equals 0.04228 lb: thus 78.84 Mcf x 0.04228 lb/cf = 1.6666776 short tons of methane. We assume that 60 percent (1,000 short tons) of this amount of generated methane is released to the atmosphere annually.

Note: This estimate may be too high for a small landfill in a dry/high altitude climate. Verify with Hoofnagle and other sources.

Methane conversion (lb/cf): U.S. Dept of Energy (2005) Voluntary Reporting of Greenhouse Gases (1605b) Program: Draft Technical Guidelines, DOE Office of Policy and International Affairs, p. 105. (Note: this conversion factor was off by a factor of 10 too high (said 0.418 lb/cf instead of 0.04228 lb/cf); called VRGG technical staff at 800-803-5182 to correct their draft guidelines.

Note 2: We have not estimated fugitive methane from the Landfill's receipt of about 10 yards (one truck load) of biosolids from the Aspen Wastewater Treatment Plant every ~3 days. Hoofnagle data: 3.9 million lb of biosolids from the WTF in 2004. This equals 1,771 metric tonnes. If two percent of this mass is converted to methane = 35.42 tonnes of CH_4, times 23 x CO_2 = 814.7 tonnes CO_2-equivalent.

Note 3: Dr Jean Bogner, Landfill +, Inc (Wheaton, IL) points out that the Pitkin methane generation estimate is probably derived with the EPA LandGEM model and estimation software. As such, it probably over-estimates generation rates (does not account for chemical interactions, soil oxidation rates, microbial processes). She cannot refine the Pitkin Landfill estimate without carefully evaluating local conditions, landfill content, additions over several years, decomposition rates, etc. As a precautionary adjustment, CMS reduces the Pitkin estimate by fifty percent (of that allocated to the CIty of Aspen).

Cell: B20
Comment: Rick Heede:
The landfill received a total of 1,953 tons of biosolids from the Aspen Sanitation Wastewater Treatment plant (about 3-4 truck loads per week). We assume in this preliminary estimate that 2 percent is released as methane gas during its storage and curing period prior to being mixed in with composted wastes, chipped wood fiber, and other soils and sold as various grades of topsoil and compost.

Biosolids delivery data from Chirs Hoofnagle, Solid Waste Manager, Aug05.

This calculation does not estimate the methane emissions that would result from anaerobic digestion of the biosolids in the landfill, that is, if buried.

Cell: D25
Comment: Rick Heede:
Waste, Recycling, and Climate Change Frank Ackerman, Director or the Research and Policy Division of GDAE, Tufts University, Medford MA, USA. See www.tufts.edu/tuftsrecycles/energy.htm

Abstract: Waste management has at least five types of impacts on climate change, attributable to (1) landfill methane emissions, (2) reduction in industrial energy use and emissions due to recycling and waste reduction, (3) energy recovery from waste, (4) carbon sequestration in forests due to decreased demand for virgin paper, and (5) energy used in long-distance transport of waste. A recent U.S. EPA study provides estimates of overall per-ton greenhouse gas reductions due to recycling. Calculations using these estimates suggest that the U.S. could realize substantial greenhouse gas reductions through increased recycling, particularly of paper.

Cell: G25
Comment: Rick Heede:
We allocate 50 percent of the savings from recycled materials to Aspen.

Cell: B26
Comment: Rick Heede:
Fuel and electricity consumption in 2004 from Chris Hoofnagle, Solid Waste Manager, personal communication, 17Aug05. Tel. 923-3487, chrisho@co.pitkin.co.us.

Cell: B30
Comment: Rick Heede:
Commingled recycled materials sold in 2004: 1,174.7 metric tonnes (2.590 million lb). Data from Hoofnagle, 17Aug05.

Chris Hoofnagle estimated commingled fractions as follows: "Ratios of the commingle pile are probably more like 65% glass, 18% steel, 8% plastic, and 4% aluminum; by weight." (28Sep05)

Cell: B31
Comment: Rick Heede:
Ackerman (see ref above) estimates savings for HDPE as 1.5 tonne CO2-eq saved per tonne recycled, LDPE as 2.0 tonne CO2-eq saved per tonne recycled, and PET as 2.5 tonne CO2-eq saved per tonne recycled. We average to 2.0 tonne CO2-eq saved per tonne recycled.

Cell: B32
Comment: Rick Heede:
The aluminum recycling rate in Aspen is ~11.2 lb/cap-yr (76 tonnes/yr in commingled recyclables divided by Aspen’s population within the UGB of 8,993 = 5.1 kg/cap-yr). This compares favorably to Seattle (4.1 kg/cap-yr), Bergen County 6.8 kg/cap-yr) and the U.S. average (3.5 kg/cap-yr); 1996 data from EPA/Ackerman; www.tufts.edu/tuftsrecycles/energy.htm, Table 2.

Cell: B33
Comment: Rick Heede:
Aspen's glass recycling rate is low compared to Waiheke Island (off Auckland, NZ) whose 8,000 permanent residents recycle 100 tonnes per month vs Aspen's 8,993 residents (residents within city limits plus within Aspen's Urban Growth Boundary) who recycle 763 tonnes in 2004, 60 percent of which is attributed to Aspen UGB. Waiheke Island residents thus recycle 150 kg of glass per capita vs Aspen's residents 51 kg per year.

Aspen's glass recycling rate compares better to Seattle (25 kg/cap-yr), Bergen County (26 kg/cap-yr) and the U.S. average (11 kg/cap-yr); 1996 data from EPA/Ackerman; www.tufts.edu/tuftsrecycles/energy.htm, Table 2.

Aspen Emissions Inventory: Nitrous Oxide Sources

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started 11 August 2005
Last Modified: 4 October 2005

Update data on fertilizer applications rates at the City and Maroon Creek Clubs, city parks, city athletic fields, and privately-owned greenspace.

Data provided by: John
Maroon Creek Club Grounds Manager
544-1666
jgu@mccaspen.com

City of Aspen Parks and Golf Depts

Table 1: Nitrous oxide emissions	Nitrogen in fertilizer applied	Direct N2O	Indirect N2O (volatilized)	Indirect N2O (run-off & leaching)	Total Nitrous Oxide	Carbon dioxide-equivalent emissions	Carbon-equivalent emissions
	kg Nitrogen/yr	kg N2O	kg N2O	kg N2O	kg N2O	sh tons CO2-eq	tonnes C-eq
						296 x CO2	
Maroon Creek Club (organic)	3,285	52.56	10.51	39.42	102.5	33.4	8.3
City of Aspen Golf Course	4,888	78.21	15.64	58.66	152.5	49.8	12.3
City of Aspen Parks	1,806	28.90	5.78	21.67	56.3	18.4	4.6
Private greenspace within City limits	15,078	241.25	48.25	180.94	470.4	153.5	38.0
Private greenspace within Urban Growth Boundary	6,888	110.21	22.04	82.66	214.9	70.1	17.4
Total Nitrous Oxide Emissions	**31,945**	**511**	**102**	**383**	**997**	**325**	**81**

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Table 2: Organic fertilizer application:	kg N	variable	fixed factor	kg N2O
Direct:	1,000	0.8	0.020	16
Indirect (volat.)	1,000	0.2	0.016	3
Indirect (leach)	1,000	0.3	0.040	12
Total N2O emissions for a 1,000 kg N application (example):				31.2

Table 3: Synthetic fertilizer application:	kg N	variable	fixed factor	kg N2O
Direct:	1,000	0.9	0.020	18
Indirect (volat.)	1,000	0.1	0.016	2
Indirect (leach)	1,000	0.3	0.040	12
Total N2O emissions for a 1,000 kg N application (example):				31.6

Direct emission calculation:
Direct N2O emissions = N applied (kg N) * fractiondirect * 0.02 kg N2O/kg N
Indirect emission calculation:
Volatilization N2O = N applied (kg N) * fractionvolatilized * 0.016 kg N2O/kg N
Run-off/leaching N2O = N applied (kg N) * fractionrunoff * 0.04 kg N2O/kg N

Table 1.H.16. Fractions by nitrogen source	fraction-direct	fraction-volatilized	fraction-runoff
Synthetic commercial fertilizers	0.9	0.1	0.3
Organic commercial fertilizers and manure	0.8	0.2	0.3

Cell: D12
Comment: Rick Heede:
Direct emission calculation:
Direct N2O emissions (kg N2O) = N applied (kg N) * fraction(direct) * 0.02 kg N2O/kg N

U.S. Dept of Energy (2005) Voluntary Reporting of Greenhouse Gases (1605b) Program: Draft Technical Guidelines, DOE Office of Policy and International Affairs, pp. 191-92.

Cell: E12
Comment: Rick Heede:
Indirect emission calculation:
Volatilization N2O (kg N2O) = N applied (kg N) * fraction(volatilized) * 0.016 kg N2O/kg N

U.S. Dept of Energy (2005) Voluntary Reporting of Greenhouse Gases (1605b) Program: Draft Technical Guidelines, DOE Office of Policy and International Affairs, pp. 191-92.

Cell: F12
Comment: Rick Heede:
Indirect emission calculation:
Run-off/leaching N2O (kg N2O) = N applied (kg N) * fraction(runoff) * 0.04 kg N2O/kg N

U.S. Dept of Energy (2005) Voluntary Reporting of Greenhouse Gases (1605b) Program: Draft Technical Guidelines, DOE Office of Policy and International Affairs, pp. 191-92.

Cell: H12
Comment: Rick Heede:
The Global Warming Potential (GWP) of nitrous oxide is 296 times that of carbon dioxide over a 100-year time horizon. IPCC (2001) Climate Change 2001: The Scientific Basis, Table 6.7, p. 388.

Cell: B15
Comment: Rick Heede:
Maroon Creek Club uses organic fertilizer applied at a rate of 2.25 to 2.5 lb per 1,000 sq.ft. MCC has 70 acres (@43,560 sq.ft/ac), thus 6,861 to 7,623 lb Nitrogen, which converts to an average of 3,285 kg N.

Cell: B16
Comment: Rick Heede:
Data from Aspen Parks and Golf Depts via Lee Cassin, 4Oct05. Original data for golf course: 359 lb on tees, 9,980 lb on fairways + roughs + clubhouse grounds, and 437 lb on greens = 10,776 lb of nitrogen applied = 4,888 kg N.

Cell: B17
Comment: Rick Heede:
Data from Aspen Parks and Golf Depts via Lee Cassin, 4Oct05. Original data varies by year, but in 2004 1,081lb in neighborhood parks, 2,700 lb on athletic fields, and 200 lb for landscaping and trees = total of 3,981 lb = 1,806 kg N.

City application in 1998 = 2,762 lb, 2000 = 2,962 lb, 2002 = 3,281 lb N.

Note: these estimates are not measured application but recommended application rate by type of area times area.

Cell: B18
Comment: Rick Heede:
We do not have purchase or application date for private yards and commercial properties by owners or contractors, and we (conservatively) assume the following:

That the City of Aspen's 2,544 acres is 75 percent privately-owned with one-half the application rate of city parks and fields (1.2 rather than ~2.4 lb per 1,000 sq.ft.) on the one-third of privately-owned land that we assume is fertilized greenspace: 2,544 acres times 0.75 times 0.33 = 636 acres (@43,560 sq.ft.) = 27.7 million sq.ft. with 1.2 lb N per 1,000 sq.ft. = 33,242 lb N = 15,078 kg N.

Cell: B19
Comment: Rick Heede:
Land within city limits totals 2,544 acres and land within the Urban Growth Boundary totals 4,868 acres. We apply half the application rate of the low rate used within city limits to the additional UGB acreage of 2,324 acres:

That the UGB area outside city limits of 2,324 acres is 75 percent privately-owned with one-half the application rate of city parks and fields (1.2 rather than ~2.4 lb per 1,000 sq.ft.) on the one-sixth of privately-owned land that we assume is fertilized greenspace: 2,324 acres times 0.75 times 0.1667 = 290.5 acres (@43,560 sq.ft.) = 12.65 million sq.ft. with 1.2 lb N per 1,000 sq.ft. = 15,185 lb N = 6,888 kg N.

UGB area data from Bridgette Kelly, City of Aspen Pitkin County GIS and Mapping Dept., personal communication, 4Oct05.

Cell: E23
Comment: Rick Heede:
These tables are taken from U.S. Dept of Energy (2005) Voluntary Reporting of Greenhouse Gases (1605b) Program: Draft Technical Guidelines, DOE Office of Policy and International Affairs, pp. 191-92.

The DOE/EIA methodology is generally consistent with the IPCC Guidelines and the US EPA's Annex 3: Methdological Descriptions for Additional Source or Sink Categories (Annex 3 to EPA's (2005) Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2003),
yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2005.html

Aspen School District

High School, Middle School, & Elementary School

Electricity and natural gas consumption: 2004

Rick Heede
Climate Mitigation Services
City of Aspen GHG Inventory (CAGI)
27-Dec-05

Compiled from data provided by:
Scott Cooper
ASD Dir Facilities & Grounds
429-3508
scooper@aspenk12.net

	Electricity (Holy Cross Energy)				CO2 emissions by School and per sq.ft.							
	Elementary	Middle School	High School	Total ASD	Elementary School		Middle School		High School		All schools	
	kWh/mo	kWh/mo	kWh/mo	kWh/mo	Total tons CO2-e	lbs CO2-e/sqft	Total tons CO2-e	lbs CO2-e/sqft	Total tons CO2-e	lbs CO2-e/sqft	Total tons CO2-e	lbs CO2-e/sqft
2004					Floor area:	110,000	Floor area:	80,000	Floor area:	178,000	Floor area:	368,000
					lb CO2-e/kWh	1.795	lb CO2-e/kWh	1.795	lb CO2-e/kWh	1.795	lb CO2-e/kWh	1.795
January	89,500	71,640	195,000	356,140	80	1.5	64	1.6	175	2.0	320	1.7
February	79,500	64,800	161,000	305,300	71	1.3	58	1.5	144	1.6	274	1.5
March	77,500	64,920	149,000	291,420	70	1.3	58	1.5	134	1.5	262	1.4
April	73,000	62,160	132,000	267,160	66	1.2	56	1.4	118	1.3	240	1.3
May	72,500	62,520	155,000	290,020	65	1.2	56	1.4	139	1.6	260	1.4
June	95,000	72,600	190,000	357,600	85	1.6	65	1.6	171	1.9	321	1.7
July	72,500	40,320	150,000	262,820	65	1.2	36	0.9	135	1.5	236	1.3
August	68,000	38,280	135,000	241,280	61	1.1	34	0.9	121	1.4	217	1.2
September	75,000	51,360	132,000	258,360	67	1.2	46	1.2	118	1.3	232	1.3
October	70,500	61,800	162,000	294,300	63	1.2	55	1.4	145	1.6	264	1.4
November	80,000	72,000	202,000	354,000	72	1.3	65	1.6	181	2.0	318	1.7
December	85,000	70,920	183,000	338,920	76	1.4	64	1.6	164	1.8	304	1.7
Total 2004	938,000	733,320	1,946,000	3,617,320	842	15.3	658	16.5	1,747	19.6	3,247	17.6

	Electricity consumption per sq.ft.			
	Elementary	Middle School	High School	Total ASD
2004	kWh/sqft	kWh/sqft	kWh/sqft	kWh/sqft
Sq.ft./school:	110,000	80,000	178,000	368,000
Total 2004	8.53	9.17	10.93	9.83

	Summary: Total CO2 emissions by School and per sq.ft. (natural gas plus electricity)							
	Elementary School		Middle School		High School		All schools	
	Total tons CO2-e	lbs CO2-e/sqft	Total tons CO2-e	lbs CO2-e/sqft	Total tons CO2-e	lbs CO2-e/sqft	Total tons CO2-e	lbs CO2-e/sqft
Electricity:	842	15.3	658	16.5	1,747	19.6	3,247	17.6
Nat Gas:	695	12.6	386	9.6	680	7.6	1,761	9.6
	1,537	27.9	1,044	26.1	2,427	27.3	5,007	27.2

	Natural Gas (Kinder Morgan)					CO2 emissions by School and per sq.ft.							
	Elementary	Middle School	High School	HS Kitchen	Total Gas	Elementary School		Middle School		High School		All schools	
	ccf/mo	ccf/mo	ccf/mo	ccf/mo	ccf/mo	Total tons CO2-e	lbs CO2-e/sqft	Total tons CO2-e	lbs CO2-e/sqft	Total tons CO2-e	lbs CO2-e/sqft		lbs CO2-e/sqft
2004						Floor area:	110,000	Floor area:	80,000	Floor area:	178,000	Floor area:	368,000
						lb CO2-e/ccf	11.392	lb CO2-e/ccf	11.392	lb CO2-e/ccf	11.392	lb CO2-e/ccf	11.392
January	9,564	10,561	17,496	2,287	39,908	54	1.0	60	1.5	113	1.3	227	1.2
February	11,333	11,515	18,756	2,942	44,546	65	1.2	66	1.6	124	1.4	254	1.4
March	6,916	7,452	12,008	1,513	27,889	39	0.7	42	1.1	77	0.9	159	0.9
April	4,788	5,977	7,504	1,389	19,658	27	0.5	34	0.9	51	0.6	112	0.6
May	4,629	4,353	5,478	650	15,110	26	0.5	25	0.6	35	0.4	86	0.5
June	61,267	1,339	2,603	206	65,415	349	6.3	8	0.2	16	0.2	373	2.0
July	22	125	1,541	51	1,739	0	0.0	1	0.0	9	0.1	10	0.1
August	103	141	1,884	42	2,170	1	0.0	1	0.0	11	0.1	12	0.1
September	2,417	202	2,227	785	5,631	14	0.3	1	0.0	17	0.2	32	0.2
October	3,539	7,377	6,216	2,792	19,924	20	0.4	42	1.1	51	0.6	113	0.6
November	4,132	5,845	7,203	2,590	19,770	24	0.4	33	0.8	56	0.6	113	0.6
December	13,280	12,879	15,070	6,177	47,406	76	1.4	73	1.8	121	1.4	270	1.5
Total 2004	121,990	67,766	97,986	21,424	309,166	695	12.6	386	9.6	680	7.6	1,761	9.6

Cell: F11
Comment: Rick Heede:
Electricity consumption data from Scott Cooper, 14 August 2005. Aspen School District buildings are in Holy Cross Energy service territory. The electricity consumption data do NOT include the district's Bus Barn.

Cell: H15
Comment: Rick Heede:
Emissions factor for carbon and fugitive methane emissions from delivered electricity (Holy Cross) from "Electricity" worksheet.

Cell: F16
Comment: Rick Heede:
Holy Cross rate class is 63A for the Aspen School District.

Cell: E20
Comment: Rick Heede:
Our data from HCE is for Jan-Apr2004 only, and we use 2003 data for May-December.

Cell: I43
Comment: Rick Heede:
Emissions factor for carbon and fugitive methane emissions from delivered natural gas (U.S. average) from "Natural Gas" worksheet.

Cell: C49
Comment: Rick Heede:
The datum for June 2004 is really 61,267 ccf, perhaps from an undisclosed gas leak, or from a serious billing error (dollars charged the District is in line with the escalated gas usage). Check with Kinder Morgan.

Wastewater Treatment Facility

(Aspen Sanitation District)

Electricity and natural gas consumption: 2004

Rick Heede
Climate Mitigation Services
City of Aspen GHG Inventory (CAGI)
21-Jul-05

Compiled from data provided by: Tracy Dillingham
ACSD WWTF Sup't
925-7262 Ext 101

	Electricity (Holy Cross Energy)				Treated Inflow		C/CO2 emissions (elec)	
	Main & Filter	Digester Bldg	Other	Total elec	Monthly Inflow	Elec efficacy	Carbon	Carbon
	kWh/mo	kWh/mo	kWh/mo	kWh/mo	Million gallons	gallons/kWh	metric tonnes C	short tons CO2
2004								lb CO2-e/kWh
								1.795
January	173,184	106,901	8,487	288,572	55.9	194	64.1	259
February	190,319	107,718	10,676	308,713	51.3	166	68.6	277
March	173,294	97,114	8,240	278,648	57.3	206	61.9	250
April	167,083	82,276	7,241	256,600	36.8	144	57.0	230
May	149,441	97,686	7,068	254,195	36.2	142	56.5	228
June	182,857	109,630	9,174	301,661	44.2	147	67.0	271
July	162,785	93,169	7,735	263,689	57.6	218	58.6	237
August	205,215	127,581	8,502	341,298	53.3	156	75.8	306
September	183,652	111,431	6,285	301,368	43.0	143	67.0	270
October	146,104	89,979	8,778	244,861	36.4	148	54.4	220
November	147,494	89,580	7,802	244,876	36.7	150	54.4	220
December	141,337	79,330	9,543	230,210	50.6	220	51.2	207
Total 2004	2,022,765	1,192,395	99,531	**3,314,691**	559.2	169	736.5	**2,975**

	Natural Gas (Kinder Morgan)						C/CO2 emissions (gas)	
	Acct 077327	Acct 028399-1	Acct 028399-2	Acct 028399-3	Acct 0291612	Total Gas	Carbon	Carbon
	ccf/mo	ccf/mo	ccf/mo	ccf/mo	ccf/mo	ccf/mo	metric tonnes C	tons CO2-e
2004								lb CO2-e/ccf
								11.392
January	390	1,666	0	1,030	0	3,086	4.4	18
February	754	1,836	9,815	1,868	286	14,559	20.5	83
March	1,037	1,618	5,409	1,052	621	9,737	13.7	55
April	421	830	872	2,486	645	5,254	7.4	30
May	190	140	440	1,353	187	2,310	3.3	13
June	1,453	355	1,767	197	186	3,958	5.6	23
July	55	9	1,555	0	171	1,790	2.5	10
August	0	1,185	29	7	1,255	2,476	3.5	14
September	0	5	10	40	0	55	0.1	0
October	25	0	85	67	0	177	0.2	1
November	5	66	77	133	238	519	0.7	3
December	329	1,116	700	1,507	391	4,043	5.7	23
Total 2004	4,659	8,826	20,759	9,740	3,980	**47,964**	67.6	**273**

Note: Dillingham and Matherly both substantiated that fugitive methane from Aspen's Wastewater Treatment Facility is incidental, minor, and unmeasured.
Personal communication, 21Jul05.

Cell: I13
Comment: Rick Heede:
We convert short tons (2000 lb) of carbon dioxide to metric tonnes of carbon at CO2/C = 3.664191. From Kevin Baumert, World Resources Institute, May05: "CO2 conversion is, precisely: C=12.0107 + O=15.9994 x 2 = 44.0095/12.0107 = 3.664191"

Cell: J13
Comment: Rick Heede:
We use the carbon intensity of Holy Cross Energy's resource mix in 2004:
63.97 percent coal-fired
25.18 natural gas-fired
7.51 percent renewables, and
3.34 percent unknown (with assumed carbon content)

Published in Holy Cross newsletter "The Consumer Connection" of Sep2004, p. 2.

Cell: J15
Comment: Rick Heede:
Emissions factor for carbon and fugitive methane emissions from delivered electricity (Holy Cross) from "Electricity" worksheet.

Cell: B16
Comment: Rick Heede:
Billing periods are typically the ninth day of the previous month through the 8th day of the designated month. Holy Cross.

Cell: F16
Comment: Rick Heede:
Holy Cross rate class is 63A for the main plant (main, Filter, and Digester buildings) and equals $0.045 per kWh in Jan04 and $0.050 per kWh in Mar04. The Jan04 total usage cost = $13,339 (not including franchise fees (if any), capacity charges, taxes, etc. We do not have copies of the full bill for each month. However, based on Jan03 alone, the average cost is $13,339/288,572 kWh = $0.04622 / kWh.

Cell: H32
Comment: Rick Heede:
Kinder Morgan bills for Aspen Sanitation Dept are in five accounts (some show zero consumption in some months). Billing periods are inconsistent, ranging from 28 to 66 days (eg, February 2004).

Cell: C33
Comment: Rick Heede:
Photocopied bills provided by Aspen Sanitation do not show complete acct numbers, hence consumption should not be attributed to certain accts or uses. Data is simply entered here in order to provide a sum (Total Gas by month and for 2004).

Cell: I34
Comment: Rick Heede:
We convert short tons (2000 lb) of carbon dioxide to metric tonnes of carbon at CO2/C = 3.664191. From Kevin Baumert, World Resources Institute, May05: "CO2 conversion is, precisely: C=12.0107 + O=15.9994 x 2 = 44.0095/12.0107 = 3.664191"

Cell: J34
Comment: Rick Heede:
Carbon emissions of pipeline natural gas is 120.593 lbs CO2/1000 cubic feet (cf). Source: US Energy Information Administration.

Kinder Morgan sales are in units of ccf (100 cf), hence the formula is gas sales times 12.0593 lbs CO2.

Cell: J36
Comment: Rick Heede:
Emissions factor for carbon and fugitive methane emissions from delivered natural gas (U.S. average) from "Natural Gas" worksheet.

Cell: B37
Comment: Rick Heede:
Kinder Morgan billing periods range from 28 days to 66 days in our 2004 sample; some reading dates are estimated.

Cell: H37
Comment: Rick Heede:
Holy Cross rate class is 63A for the main plant (main, Filter, and Digester buildings) and equals $0.045 per kWh in Jan04 and $0.050 per kWh in Mar04. The Jan04 total usage cost = $13,339 (not including franchise fees (if any), capacity charges, taxes, etc. We do not have copies of the full bill for each month. However, based on Jan03 alone, the average cost is $13,339/288,572 kWh = $0.04622 / kWh.