Jackson Hole

Summary

Community Greenhouse Gas Emissions Inventory, 2008

Last Modified: 10 October 2009

Rick Heede Climate Mitigation Services, 970-927-9511

data not complete

	Physical Units		Energy Units		GHG Emissions		CO2e Equivalent		Percent of Total
Buildings: electricity									
Electricity, Jackson (Lower Valley Energy)	196,729,767	kWh	2,006,644	10^6 Btu	8,119	tons CO2	8,119	tons CO2	2.0%
Electricity, Teton County (Lower Valley Energy)	297,505,330	kWh	3,034,554	10^6 Btu	12,278	tons CO2	12,278	tons CO2	3.0%
Electricity (fugitive methane)	60	tons CH4		10^6 Btu	60	tons CH4	1,500	tons CO2e	0.4%
Total electricity	494,235,097	kWh	5,041,198	10^6 Btu	na	tons CO2e	21,896	tons CO2e	5.3%
Buildings: natural gas and propane									
Natural Gas, Jackson (Lower Valley Energy)	3,889,936	therms	388,994	10^6 Btu	22,735	tons CO2	22,735	tons CO2	5.5%
Natural Gas, Teton County (Lower Valley Energy)	962,958	therms	96,296	10^6 Btu	5,628	tons CO2	5,628	tons CO2	1.4%
Natural Gas (fugitive methane)	7,536,002	cubic feet	7,739	10^6 Btu	162	tons CH4	4,049	tons CO2e	1.0%
Propane (AmeriGas)	951,159	gallons	86,864	10^6 Btu	6,025	tons CO2	6,025	tons CO2	1.5%
Propane (Suburban Propane did not provide data)	-	gallons	-	10^6 Btu	-	tons CO2	-	tons CO2	0.0%
Propane (Lower Valley Energy)	1,452,382	gallons	132,638	10^6 Btu	9,200	tons CO2	9,200	tons CO2	2.2%
Propane (fugitive methane)	33	tons CH4		10^6 Btu	33	tons CH4	828	tons CO2e	0.2%
Heating oil (Conrad & Bischoff did not provide data)		gallons		10^6 Btu		tons CO2		tons CO2e	0.0%
Total natural gas & propane	2,403,574	gallons	712,530	10^6 Btu	na	tons CO2e	48,464	tons CO2e	11.8%
Total buildings	na	gallons	5,753,728	10^6 Btu	na	tons CO2	70,360	tons CO2e	17.2%
							32,411	gas only	7.91% del
							15,225	propane only	3.7%
Transportation: highway, around town, buses, and waste hauling									
Driving on State Highways in Teton County	9,400,790	gallons	1,175,766	10^6 Btu	93,294	tons CO2	93,294	tons CO2	22.8%
Highway vehicles on local roads	2,686,922	gallons	336,056	10^6 Btu	26,665	tons CO2	26,665	tons CO2	6.5%
Tourist driving to Teton County (one-quarter of one-way)	9,029,319	gallons	1,129,306	10^6 Btu	90,312	tons CO2	90,312	tons CO2	22.0%
Driving in Grand Teton National Park	4,001,139	gallons	500,426	10^6 Btu	39,806	tons CO2	39,806	tons CO2	9.7%
Transit Buses (START)	120,924	gallons	16,772	10^6 Btu	1,329	tons CO2	1,329	tons CO2	0.3%
School Buses & other fuel use (Teton School District)	156,521	gallons	21,709	10^6 Btu	1,743	tons CO2	1,743	tons CO2	0.4%
Teton County fuel use (diesel)	1,925	gallons	267	10^6 Btu	22	tons CO2	22	tons CO2	0.0%
Teton County fuel use (gasoline)	42,286	gallons	5,289	10^6 Btu	414	tons CO2	414	tons CO2	0.1%
Town of Jackson fuel use (diesel fuel)	19,357	gallons	2,421	10^6 Btu	217	tons CO2	217	tons CO2	0.1%
Town of Jackson fuel use (gasoline)	26,363	gallons	3,297	10^6 Btu	258	tons CO2	258	tons CO2	0.1%
Waste hauling (Transfer Station to Sublette County Landfill)	51,492	gallons	6,951	10^6 Btu	576	tons CO2	576	tons CO2	0.1%
Total highway vehicles, around town, buses, & waste hauling	25,537,038	gallons	3,198,262	10^6 Btu	254,638	tons CO2	254,638	tons CO2	62.2%
Transportation: commercial and private aviation									
Air Travel - Commercial via Jackson Hole Airport	3,732,881	gallons	503,939	10^6 Btu	39,359	tons CO2	39,359	tons CO2	9.6%
Air Travel - General Aviation (jets)	2,612,123	gallons	352,637	10^6 Btu	27,542	tons CO2	27,542	tons CO2	6.7%
Air Travel - General Aviation (turboprops)	306,594	gallons	41,390	10^6 Btu	3,233	tons CO2	3,233	tons CO2	0.8%
Air Travel - General Aviation (piston aircraft)	44,872	gallons	5,393	10^6 Btu	412	tons CO2	412	tons CO2	0.1%
Total commercial and private aviation	6,696,471	gallons	903,359	10^6 Btu	70,546	tons CO2	70,546	tons CO2	17.2%
Off-road transportation: boating, ski area, snowmobiles, & misc.									
Grand Teton Lodge Company (boat fuel)	15,469	gallons	1,935	10^6 Btu	156	tons CO2	156	tons CO2	0.04%
Signal Mountain Lodge & Leeks' Marina (boat fuel)	13,893	gallons	1,738	10^6 Btu	136	tons CO2	136	tons CO2	0.03%
Grand Teton National Park: NPS vehicles & off-road equipment	102,333	gallons	13,815	10^6 Btu	1,071	tons CO2	1,071	tons CO2	0.26%
Snowmobiles (Grand Teton National Park)	13,998	gallons	1,751	10^6 Btu	137	tons CO2	137	tons CO2	0.03%
Snow King Hill Climb World Championships	1,989	gallons	249	10^6 Btu	19	tons CO2	19	tons CO2	0.00%
Jackson Hole Mountain Resort (diesel & biodiesel)	122,005	gallons	16,471	10^6 Btu	1,356	tons CO2	1,356	tons CO2	0.33%
Jackson Hole Mountain Resort (gasoline)	46,156	gallons	5,773	10^6 Btu	452	tons CO2	452	tons CO2	0.11%
Off-road (construction equip., gas widgets)	38,492	gallons	4,814	10^6 Btu	377	tons CO2	377	tons CO2	0.09%
Total off-road fuel and emissions	354,335	gallons	46,544	10^6 Btu	3,706	tons CO2	3,706	tons CO2	0.9%
Total transportation	32,587,843	gallons	4,148,165	10^6 Btu	254,860	tons CO2e	329,112	tons CO2e	80.3%
Landfill (Jackson Hole's share of Sublette County Landfill)									
Electricity	10,848	kWh	111	10^6 Btu	7	tons CO2	7	tons CO2	0.00%
Propane	4,121	gallons	572	10^6 Btu	16	tons CO2	16	tons CO2	0.00%
Fuel consumption (diesel & gasoline: onsite)	20,931	gallons	2,616	10^6 Btu	145	tons CO2	145	tons CO2	0.04%
Landfill: fugitive methane	318	tons CH4		10^6 Btu	318	tons CH4	7,950	tons CO2e	1.94%
Total landfill	various		3,299	10^6 Btu		na	8,119	tons CO2e	2.0%
Nitrous Oxide sources									
Teton School District athletic fields	1,021	kg N	na		32	kg N2O	10	tons CO2e	0.0%
Town of Jackson & Teton County athletic fields and parks	2,371	kg N	na		74	kg N2O	24	tons CO2e	0.0%
Jackson Hole Golf & Tennis Club	-	kg N	na		-	kg N2O	-	tons CO2e	0.0%
Teton Pines Country Club & Resort	6,308	kg N	na		197	kg N2O	64	tons CO2e	0.0%
3 Creek Ranch Private Golf Club	-	kg N	na		-	kg N2O	-	tons CO2e	0.0%
Shooting Star Golf, Teton Village (estimated)	6,725	kg N	na		210	kg N2O	68	tons CO2e	0.0%
Snake River Sporting Club, Jackson, Wyoming	-	kg N	na		-	kg N2O	-	tons CO2e	0.0%
Private greenspace in Teton County & Town of Jackson	1,434	kg N	na		45	kg N2O	15	tons CO2e	0.0%
Snow King Hill Climb World Championships: nitrous fuel additive	na	kg N	na		2	kg N2O	1	tons CO2e	0.0%
Total nitrous oxide sources	17,859	kg N			557	kg N2O	182	tons CO2e	0.04%
HFCs and refrigerants									
Refrigerant leakage from refrigerators, freezers, and AC units	42	kg HFC-134a	na	10^6 Btu	66	tons CO2e	66	tons CO2e	0.0%
Improper venting of refrigerant at appliance disposal	100	kg R-12	na	10^6 Btu	1,144	tons CO2e	1,144	tons CO2e	0.3%
Refrigerant leakage from vehicle air conditioners	622	kg HFC-134a	na	10^6 Btu	892	tons CO2e	892	tons CO2e	0.2%
Total HFCs	764	kg HFC-134a			2,101	tons CO2e	2,101	tons CO2e	0.5%
Total	various	units	9,905,192	10^6 Btu	various	units	409,652	tons CO2e	100.0%
Credit for LVE greenpower (Town plus County)	13,802,470	kWh	140,785	10^6 Btu	0.089	lb CO2e/kWh	611	tons CO2e	0.1%
Total net emissions after renewable energy credits	various	units	9,764,407	10^6 Btu	various	units	409,041	tons CO2e	99.9%
Methane emissions					540	tons CH4	14,638	tons CO2e	3.6%
Nitrous oxide emissions					557	kg N2O	182	tons CO2e	0.0%
Refrigerant leakage					764	kg HFC-134	2,101	tons CO2e	0.5%
Carbon dioxide emissions							394,832	tons CO2	96.4%

1 ton CH4 = 47.792 million Btu (EPA "Natural Gas Methane Units Converter")

Cell: L2
Comment: Rick Heede:
This worksheet summarizes all sources of greenhouse gas emissions attributable to the community of Jackson Hole for 2008. See the boundary definition in the Summary Report and the set of worksheets for details. All relevant sums -- physical units, energy units, GHG emissions, and CO2e equivalent -- are linked to their respective worksheets and thus automatically updated whenever any changes are made.

Cell: F5
Comment: Rick Heede:
EPA (undated) “Natural Gas Methane Units Converter,” 2 pp., www.epa.gov/gasstar; PDF in Climate / Emissions / Emissions Factors. 1 ton CH4 = 47.792 million Btu

Cell: B16
Comment: Rick Heede:
CMS estimates fugitive methane from the production, processing, pipelining, and distribution of natural gas. It is an estimate of system losses, and is not attributed to Lower Valley Energy. CMS assumes the U.S. average heating valeu of 1,027 Btu per cubic foot in converting tons of fugitive methane into cubic feet.

Cell: B87
Comment: Rick Heede:
LVE provided 2008 data on “green power” purchases in Jackson and the rest of Teton County within this inventory’s emission boundary. This sum (13.8 million kWh) is multplied by LVE’s delivered electricity emission factor.

Cell: I87
Comment: Rick Heede:
LVE’s emission factor per delivered kWh. See “Electricity” worksheet for details.

Jackson Hole Energy & Emissions Inventory: Electricity, 2008

Future inventorists need to update electricity sales by Lower Valley Energy and to check the carbon dioxide and methane emission factors with LVE's power provider (Bonneville Power Administration). All calculations are linked and automatically updated all the way to the Sum2008.xls worksheet and its derived charts.
Note: Carbon offsets from LVE customer' green power purchases are credited in the Sum2008.xls summary and calculated below.

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 2 June 2009
Last Modified: 1 September 2009

Data provided by:
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Jim Webb (Pres. & CEO)
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Data provided by:
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Bonneville Power Administratio
BPA Strategic Planning
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jlschmidt@bpa.gov

		BPA (generation) LVE (delivered) electricity carbon factor		
Janelle Schmidt, BPA (generation)	79.40	lb CO2/MWh	0.0794	lb CO2/kWh (gen)
CMS calculation of T&D losses	3.8%	T&D loss percentage		
LVE emission factor per unit of delivered electricity	82.54	LVE EF/MWh (delivered)	0.0825	lb CO2/kWh (del)

Methane attributed to fossil gen	lb CH4/MWh gen	g CH4/kWh gen
Coal mining	2.90	1.32
Natural Gas systems	6.85	3.11
Petroleum	1.42	0.64
Total	3.99	1.81
If spread across all US electric generation:	2.76	1.25

see worksheet on "Electricity methane factor"

2007	Electricity		Carbon dioxide	Emissions				
	Consumption kWh	Consumption MWh	Emission factor CO2/kWh	Carbon Dioxide tons CO2	Methane tons CH4	Methane tons CO2e	Total tons CO2+CH4	Total tonnes C-eq
	Update this column		lb CO2/kWh (delivered)		lb CH4/MWh	25xCO2	lb CO2-equiv/kWh	kg C-eq/kWh
Town of Jackson			0.0825		0.2427	25	0.0886	0.011
Residential	78,771,311	78,771		3,251	9.6	239	3,490	864
Small Commercial	50,205,325	50,205		2,072	6.1	152	2,224	551
Large Commercial	67,411,307	67,411		2,782	8.2	205	2,986	739
Irrigation	19,720	20		1	0.0	0	1	0
LVE Electric (own use)	129,307	129		5	0.0	0	6	1
Street & other contract lighting	192,797	193		8	0.0	1	9	2
Total, Town of Jackson	196,729,767	196,730		8,119	24	597	8,716	2,158

Jackson + Teton County								
	Residential usage	269,543,603	kWh	Small Com'l usage	90,806,754	kWh	Irrigation, lighting, LV	1,299,089
	Municipal usage		kWh	Large Com'l usage	132,585,651	kWh	Total	494,235,097

	Consumption kWh	Consumption MWh	Emission factor CO2/kWh	Carbon Dioxide tons CO2	Methane tons CH4	Methane tons CO2e	Total tons CO2+CH4	Total tonnes C-eq
Teton County (excluding ToJ)			lb CO2/kWh (delivered)		lb CH4/MWh	25xCO2	lb CO2-equiv/kWh	kg C-eq/kWh
	Update this column		0.0825		0.2427	25	0.0886	0.011
Residential	190,772,292	190,772		7,873	23.2	579	8,452	2,093
Small Commercial	40,601,429	40,601		1,676	4.9	123	1,799	445
Large Commercial	65,174,344	65,174		2,690	7.9	198	2,887	715
Irrigation	332,236	332		14	0.0	1	15	4
LVE-Electric	531,929	532		22	0.1	2	24	6
Street & other contract lighting	93,100	93		4	0.0	0	4	1
Total, Teton County (excluding Jackson)	297,505,330	297,505	-	12,278	36	903	13,180	3,263

Jackson + Teton County								
	Residential emissions	11,941	tons CO2e	Small Com'l emissions	4,023	tons CO2e	Irrigation, lighting, LV	58
				Large Com'l emissions	5,874	tons CO2e	Total	21,896

Teton County & Town of Jackson	Consumption kWh	Weighted factor CO2/kWh	Weighted factor CO2e/kWh	Carbon Dioxide tons CO2	Methane tons CH4	Methane tons CO2e	Total tons CO2+CH4	Total tonnes C-eq
Total, Teton County + Town of Jackson	494,235,097	0.083	0.089	20,396	60	1,500	21,896	5,421
						6.85%	CH4 (CO2e) of total	

		kWh green power		emission factor		CO2 offset		% elec emissions
Credit for LVE greenpower (Town plus County)		13,802,470		0.0886	lb CO2e/kWh	611	tons CO2e	2.8%

Cell: H12
Comment: Rick Heede:
This table summarizes (and is linked to) the “Electricity methane factor” worksheet, which calculates the methane emission rate of coal mining, natural gas systems, and petroleum sources. CMS attributes CH4 emissions on the basis of each energy source generation or electricity. For example, methane emissions from natural gas production in the United States (7.06 million tonnes of methane) in 2007 is diluted by the proportion of natural gas used in the generation of electricity (35.8 percent); the 2.5 million tonnes CH4 attributed to natural gas generation is divided by gas-fired generation of 815 billion kWh: thus 6.85 ob CH4 per MWH, or 3.11 g CH4/kWh. If all energy-related methane emissions (totaling 5.2 million tonnes CH4) is divided by total US generation of electricity (4,157 billion kWh), the the “average” methane emission rate is 2.76 lb CH4 per MWh generated. Which is the figure applied to BPA’s market power: 8.8 percent of 2.76 lb CH4/MWh, or 0.2427 lb CH4 per MWh delivered to LVE’s customers. This calculation is deemed conservative (the factor would be 2.48 times higher if we apply the natural gas-fired emission rate of 6.85 lb CH4 per MWh.

Cell: D14
Comment: Rick Heede (Jul09):
BPA’s Janelle Schmidt provided BPA’s low transmission loss factor of 1.9 percent (BPA uses high voltage AC transmission lines and DC distribution, which reduce line losses). This 1.9 percent T&D loss factor is lower than the U.S. average of approximately 6.5 percent. CMS assumes that local distribution and transformer losses are equivalent to BPA’s factor, which doubles the overall T&D loss rate to 3.8 percent

Cell: G21
Comment: Rick Heede (Aug09):
CMS estimates methane emissions from BPA’s “purchased power” -- 8.8 percent of BPA’s total “generation” (Although BPA does not own its generation, rather the agency buys power from other federal agencies). BPA used eGRID’s emission factor for the region (902 lb CO2 per MWh generated) for the 8.8 percent of BPA’s portfolio of market power.

CMS applies the methane emission factor of 3.11 g CH4 per kWh generated by natural gas (accounting for all methane emitted from the natural gas system times the percentage of US gas production (35.8 percent) used to generate electricity). The EF of 3.11 g CH4 per kWh generated converts to 6.85 lb CH4 per MWh generated, and apply it to 8.8 percent of BPA’s power, or, in effect, 6.85 * 0.088 = 0.6028 lb CH4 per MWh of BPA’s total portfolio.

Cell: H21
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 25xCO2 (100 hundred year horizon, mole basis), per IPCC Fourth Assessment Report.

Cell: E23
Comment: Rick Heede (Jul09):
CMS contacted Wid Ritchie of LVE (307-733-2446) regarding the electricity carbon factor used in the Jackson EnergyTracker (0.741 lb CO2 per kWh, which seemed high for a chiefly hydropowered utility such as BPA, LVE’s sole bulk power provider).

Janelle Schmidt of BPA’s Strategic Planning provided BPA’s bulk power emission rate, based on the following: in 2008, 8.8 percent of total supply is “unspecified” power purchased on the market and is assumed fossil generated (using EPA’s eGRID Western Regional TK factor of 902 lb CO2 per MWh), whereas 91.2 percent are non-carbon (1.4 percent elegible renewable (mostly small hydro), 78.1 percent large hydro, and 11.6 percent nuclear poewr).

The resulting carbon factor for BPA is 79.4 lb CO2/MWh, or 0.0794 lb CO2/kWh, on generation. CMS does not apply BPA’s estimated associated emissions of methane and nitrous oxide (which would raise the factor to 79.8 lb CO2e per MWh, according to Schmidt’s calculations); instead, CMS calculates total upstream emissions of methane based on EIA generation and emissions data, assuming 50/50 mix of coal and gas generation for the 8.8 percent market power. See “Methane” column and cell notes for details.

Cell: B24
Comment: Rick Heede:
Lower Valley Energy provided electricity sales data for 2008 (by month) by rate class for Town of Jackson. Data from Tammy Spraklen, LVE, 30Jun09. CMS adds “Lighting” to Town of Jackson.

Cell: B39
Comment: Rick Heede:
Lower Valley Energy provided electricity sales data for 2008 (by month) by rate class for Town of Jackson. Data from Tammy Spraklen, LVE, 30Jun09. CMS adds “Lighting” to Town of Jackson.

Cell: B61
Comment: Rick Heede:
LVE provided 2008 data on “green power” purchases in Jackson and the rest of Teton County within this inventory’s emission boundary. This sum (13.8 million kWh) is multplied by LVE’s delivered electricity emission factor.

Jackson Hole Energy & Emissions Inventory: electricity and natural gas CO_2 and methane factors

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 24 June 2009
Last Modified: 1 September 2009

Table 1 US emissions by generating source 2007 (EIA *Annual Energy Review*)

2007	Emissions	Emissions	Generation	Elec emissions rate
	million tonnes CO_2	million tons CO_2	billion kWh	lb CO_2/kWh gen
Table 12.7a All Sectors	Table 12.7a		Table 8.2a	
Coal	2,002.4	2,207.2	2,016.5	**2.189**
Gas	432.4	476.6	896.6	**1.063**
Petroleum	67.1	74.0	65.7	**2.252**
Other gases			13.5	
Total fossil	2,501.8	2,757.8	2,992.3	**1.843**
Other (MSW, Geo, Hydro, Nuclear)	14.8	16.3	1,164.4	**0.028**
Total Generation	2,516.6	2,774.0	4,156.7	**1.335**
Electric Power Sector	Table 12.7b		Table 8.2b	
Coal	1,950.7	2,150.3	1,998.4	**2.152**
Gas	371.4	409.4	814.8	**1.005**
Petroleum	55.0	60.6	61.3	**1.978**
Other gases			4.0	
Total fossil	2,377.1	2,620.3	2,878.5	**1.821**
Other (MSW, Geo, Hydro, Nuclear)	11.8	13.0	1,126.8	**0.023**
Total Generation	2,388.9	2,633.3	4,005.3	**1.315**
Commercial & Industrial Sectors	Table 12.7c		Table 8.2d	
Coal	51.63	56.9	18.1	**6.288**
Gas	60.96	67.2	81.9	**1.641**
Petroleum	12.11	13.3	4.4	**6.068**
Other gases			9.4	
Total fossil	124.70	137.5	113.8	**2.416**
Other (MSW, Geo, Hydro, Nuclear)	3.20	3.5	37.6	**0.188**
Total Generation	127.90	141.0	151.4	**1.862**

Table 2 US methane emissions by generating source 2007

2007	Emissions	Emissions	Generation	Elec emissions rate	Elec emissions rate	Source to energy	Elec emissions rate	Elec emissions rate	
	million tonnes CH_4	million tons CH_4	billion kWh	lb CH_4/kWh gen	g CH_4/kWh gen	percent	g CH_4/kWh gen	lb CH_4/MWh gen	
Table 12.5 Methane emissions	Table 12.5		Table 8.2a		If all source to gen		harmonized	0.00220462	lb per gram
Coal mining	2.84	3.13	1,998	0.003	1.42	92.6%	1.32	2.90	
Natural Gas systems	7.06	7.78	815	0.019	8.66	35.8%	3.11	6.85	
Petroleum	0.92	1.01	61	0.033	15.01	4.3%	0.64	1.42	

Methane emissions attributed to fossil generation	million tonnes CH_4	percent	million tonnes CH_4	million tons CH_4	billion kWh	lb CH_4/MWh gen	g CH_4/kWh gen
Coal mining	2.84	92.6%	2.6	2.90	1,998	2.90	1.32
Natural Gas systems	7.06	35.8%	2.5	2.79	815	6.85	3.11
Petroleum	0.92	4.3%	0.0	0.04	61	1.42	0.64
Total	10.82		5.2	5.73	2,875	3.99	1.81
If spread across all US electric generation:			5.2	5.73	4,157	2.76	1.25

Table 3 Calculation of methane emissions rate for the natural gas industry

Methane from natural gas industry:	**7.06**	million tonnes CH_4	
CO_2 from natural gas consumption:	**1,237**	million tonnes CO_2	EIA 2008, methane GWP
Methane emissions rate as CH_4	**0.00571**	kg CH_4/kg CO_2	25xCO_2
Methane emissions rate as CO_2e	**0.14274**	kg CO_2e/kg CO_2	
CO_2 plus methane emissions rate (short tons)	**66.787**	tons CO_2e/billlion Btu	
Carbon plus methane emissions rate (metric)	**16.535**	tonnes C-e/billlion Btu	

Table 6

tonnes CH_4 from gas system, 2007	7,063,000	tonnes
Bcf produced, 2007	19,089	Bcf
g CH_4 per cf of gas produced, 2007	0.370	g CH_4/cf

Table 4 Carbon factors (Jackson Hole)

		Standard conversions
116.89	lb CO_2/million Btu	1 tonne = 1.1023 ton
133.57	lb CO_2e/million Btu	1 tonne = 1,000 kg
0.0117	lb CO_2/cf	1 kg = 2.2046 lb
0.0134	lb CO_2e/cf	
1.169	lb CO_2/ccf	
1.336	lb CO_2e/ccf	
11.69	lb CO_2/Mcf	
13.36	lb CO_2e/Mcf	
1,017	cubic feet/million Btu	
983.3	Btu/cubic foot	
58.44	tons CO_2/billion Btu	

Table 5 Carbon factors (Standard sea level)

117.08	lb CO_2/million Btu (sea level)
0.121	lb CO_2/cf (sea level)
120.59	lb CO_2/Mcf (sea level)
973.7	cubic feet/million Btu (sea level)
1,027.0	Btu/cubic foot
58.44	tons CO_2/billion Btu

Cell: E11
Comment: Rick Heede:
Energy information Administration (2008) Annual Energy Review 2007. Tables as cited below.

Cell: C17
Comment: Rick Heede:
Blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels.

Cell: F38
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: C39
Comment: Rick Heede:
Energy information Administration (2008) Annual Energy Review 2007. Tables as cited below.

Cell: H42
Comment: Rick Heede:
2007: 1045 of 1128 tons produced = 92.6 percent to power generation.

Cell: H43
Comment: Rick Heede:
2007: 6,841 Bcf to electric generation of 19,089 Bcf produced = 35.8 percent to power generation.
23,047 Bcf consumed in 2007: 29.7 percent to power generation.

Cell: H44
Comment: Rick Heede:
2007: 0.293 million bbl consumed for power of 6.847 million bbl per day of US production (since methane emissions in petroleum sector is predominantly from production, not refining) = 4.28 percent to power generation.
If attributed to total US consumption (20.68 miilion bbl per day), then power is 1.42 percent.

Cell: B46
Comment: Rick Heede:
This table calculates the methane emission rate of coal mining, natural gas systems, and petroleum sources. CMS attributes CH4 emissions on the basis of each energy source generation or electricity. For example, methane emissions from natural gas production in the United States (7.06 million tonnes of methane) in 2007 is diluted by the proportion of natural gas used in the generation of electricity (35.8 percent); the 2.5 million tonnes CH4 attributed to natural gas generation is divided by gas-fired generation of 815 billion kWh: thus 6.85 ob CH4 per MWH, or 3.11 g CH4/kWh. If all energy-related methane emissions (totaling 5.2 million tonnes CH4) is divided by total US generation of electricity (4,157 billion kWh), the the "average" methane emission rate is 2.76 lb CH4 per MWh generated. Which is the figure applied to BPA's market power: 8.8 percent of 2.76 lb CH4/MWh, or 0.2427 lb CH4 per MWh delivered to LVE's customers. This calculation is deemed conservative (the factor would be 2.48 times higher if we apply the natural gas-fired emission rate of 6.85 lb CH4 per MWh.

Cell: H54
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, 96.22 lb CO2/Mcf vs 120.593 lb CO2/Mcf at sea level.

Cell: J55
Comment: Rick Heede:
lb CO2 per million Btu should be the same in Aspen as at sea level at STP. The minor difference derives from the factors supplied by SourceGas. This factor is from the DOE.

Cell: E56
Comment: Rick Heede:
Energy Information Administration (2008) Annual Energy Review 2007; Energy Information Administration (2008) Emissions of Greenhouse Gases in the United States 2007. Note: EIA has adopted the IPCC FAR GWP value of methane = 25xCO2, EIA 2008, page 12: "Methane. In its Fourth Assessment Report, the IPCC developed revised global warming potential factors (GWPs) for selected gases. The GWP for methane was revised from the previously published value of 23 in the IPCC's Third Assessment Report to 25 in the Fourth Assessment Report. The revised GWP for methane is used in this report. In addition, this report incorporates an increase in the density of methane from 42.28 to 42.37 pounds per thousand cubic feet, in order to provide consistent temperature and pressure values for methane in all EIA data."

Jackson Hole Energy & Emissions Inventory: Natural Gas, 2008

Future inventorists must update annual sales from Lower Valley Energy to Town of Jackson and the rest of Teton County. Enter updated data in column C (divide LVE data in therms by 10^4 to get sales in billion Btu).

Richard Heede
Climate Mitigation Services
Snowmass, Colorado

File Started 1 June 2009
Last Modified: 1 September 2009

Data provided by:
Tammy Spraklen &
Jim Webb (Pres. & CEO)
Lower Valley Energy
307-885-6125
tammys@lvenergy.com

Table 1	Natural Gas		Emissions factor	Emissions				
	Consumption	Consumption		Carbon Dioxide	Methane	Methane	Total	Total
2008	Therms (10^5 Btu)	Billion Btu (10^9)	carbon per btu	short tons CO2	short tons CH4	tons CO2e	tons CO2e	tonnes C-eq
	cubic feet/million btu	Btu per cubic foot (adj)	tonnes C/billion Btu	tons CO2/billion Btu	tons CH4/ton CO2	tons CO2e/ton CO2	tons CO2e/billlion Btu	tonnes C-e/billlion Btu
Town of Jackson	1,017	983.30	14.47	58.44	0.00571	0.14274	66.79	16.54
	Update this column							
Natural Gas sales (coml & resl)	3,744,677	374.5		21,886	125.0	3,124	25,010	6,192
LVE natural gas use	145,259	14.5		849	4.8	121	970	240
Total, Town of Jackson	3,889,936	389	-	22,735	130	3,245	25,980	6,432

2008	Consumption	Consumption	Emissions factor	Carbon Dioxide	Methane	Methane	Total	Total
	Therms (10^5 Btu)	Billion Btu (10^9)	carbon per btu	short tons CO2	short tons CH4	tons CO2e	tons CO2e	tonnes C-eq
Teton County (excluding ToJ)	1,017							
	Update this column							
Natural Gas sales (coml & resl)	960,092	96.0		5,611	32.0	801	6,412	1,588
LVE Gas (own use)	2,866	0.3		17	0.1	2	19	5
Total, Teton County (excluding Jackson)	962,958	96	-	5,628	32	803	6,431	1,592

Table 2	Consumption	Consumption	Emissions factor	Carbon Dioxide	Methane	Methane	Total	Total
2008	Mcf	Billion Btu (10^9)	carbon per btu	short tons CO2	short tons CH4	tons CO2e	tons CO2e	tonnes C-eq
Total, Teton County + Town of Jackson	4,852,894	485		28,363	162	4,049	32,411	8,024
						12.49% CH4 (CO2e) of total		
		Natural Gas sales (coml	31,422 tons CO2e			LVE natural gas use	989 tons CO2e	
			96.95%				3.05%	

Table 3

Calculation of methane emissions rate for the natural gas industry		
Methane from natural gas industry:	7.06	million tonnes CH4
CO2 from natural gas consumption:	1,237	million tonnes CO2
Methane emissions rate as CH4	0.00571	kg CH4/kg CO2
Methane emissions rate as CO2e	0.14274	kg CO2e/kg CO2
CO2 plus methane emissions rate (short tons)	66.787	tons CO2e/billlion Btu
Carbon plus methane emissions rate (metric)	16.535	tonnes C-e/billlion Btu

EIA 2008, methane GW
25xCO2

Table 4

Carbon factors (Jackson Hole)	
116.89	lb CO2/million Btu
133.57	lb CO2e/million Btu
0.0117	lb CO2/cf
0.0134	lb CO2e/cf
1.169	lb CO2/ccf
1.336	lb CO2e/ccf
11.69	lb CO2/Mcf
13.36	lb CO2e/Mcf
1,017	cubic feet/million Btu
983.3	Btu/cubic foot
58.44	tons CO2/billion Btu

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

Table 5

Carbon factors (Standard sea level)	
117.08	lb CO2/million Btu (sea level)
0.121	lb CO2/cf (sea level)
120.59	lb CO2/Mcf (sea level)
973.7	cubic feet/million Btu (sea level)
1,027.0	Btu/cubic foot
58.44	tons CO2/billion Btu

EIA revised the density of methane from 42.28 to 42.37 pounds per thousand cubic feet

Cell: E12
Comment: Rick Heede:
Lower Valley Energy supplied natural gas sales data in therms (10^5 Btu). Emissions from the combustion of natural gas varies slightly (+/- 3 percent) by its heating value. CMS uses 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.

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 be less per ccf.

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” (in tonnes) and converted to tons in column “F”.

Cell: G13
Comment: Rick Heede:
See notes in Tables 3-5 below for methodology used to estimate fugitive methane emissions rate applied to the consumption of natural gas.

Cell: C15
Comment: Heede (Jul09)
CMS does not have a Btu value per cubic foot of delivered natural gas for LVE’s system. At sea level 1 cubic foot (cf) of natural gas contains, on average, 1,027 Btu.

SourceGas calculated a thermal conversion factor in its 2008 Rate Case of 823.2 Btu per cf, or 1,215 cf per million Btu, in Aspen. Woody Creek: 1,198 cf/million Btu, and Snowmass Village: 1,232 cf/million Btu. Since billing pressure adjustment is altitude dependent (and on the caloric value of the gas pipelined), CMS estimates Jackson Hole’s (elevation 6,237 feet) pressure adjustment is proportional to that in Woody Creek, Colorado (elevation 7,347 ft): 1,198 cf/10^6 Btu * (6,237/7,347) = 1,198 * 0.8489 = 1,017 cf per million Btu, or, conversely, 983.3 Btu per cf.

Rick Heede:
At sea level 1 cubic foot (cf) of natural gas contains, on average, 1,027 Btu.

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.

Cell: B16
Comment: Rick Heede:
Lower Valley Energy provided electricity sales data for 2008 (by month) by rate class for Town of Jackson. Data from Tammy Spraklen, LVE, Jul09. CMS adds “Lighting” to Town of Jackson.

Cell: B26
Comment: Rick Heede:
Lower Valley Energy provided electricity sales data for 2008 (by month) by rate class for Town of Jackson. Data from Tammy Spraklen, LVE, 30Jun09. CMS adds “Lighting” to Town of Jackson.

Cell: D46
Comment: Rick Heede (Aug09):
We estimate the upstream fugitive emissions of methane from the natural gas system from production through delivery. In 2007, U.S. methane emissions from natural gas systems totaled 7.063 million (metric) tonnes; in the same year, natural gas consumption was 23.055 trillion cubic feet (Tcf; US dry gas production totaled 19.278 Tcf), which equals 0.6754 lb of methane per thousand cubic feet (Mcf) of gas consumed. Thus, (0.6754 lb CH4/Mcf) / 42.37 lb/Mcf (standard conversion factor, revised by EIA in 2008) = 15.94 cf of methane lost per Mcf of delivered natural gas = 1.594 percent fugitive emission rate; that is, a system loss rate relative to delivered natural gas. This is prior to accounting for the GWP value of methane, done below and in Table 2. *

We are NOT attributing this additional emissions source to Lower Valley Energy’s gas delivery. We are, however, allocating such additional systemic emissions to consumers for whom the production occurs.

The result is that an amount equivalent to 14.27 percent of the CO2 emitted by burning natural gas is emitted as fugitive methane by the natural gas industry. That is, a 0.571 percent fugitive methane rate times methane as 25xCO2 =

14.27 percent as CO_2e.

* Production (2.03 million tonnes CH_4), Gas Processing (0.66 million tonnes), Transmission and Storage (2.41 million tonnes), Distribution (1.97 million tonnes CH_4), Total (7.06 million tonnes CH_4). We are not including the small quantities of methane released from end-use equipment in the residential and commercial sectors (0.01 million tonnes CH_4). EIA 2008.

Sources: Energy Information Administration (2008) Annual Energy Review 2007; Energy Information Administration (2008) Emissions of Greenhouse Gases in the United States 2007. Note: EIA has adopted the IPCC FAR GWP value of methane = 25xCO_2, EIA 2008, page 12: “Methane. In its Fourth Assessment Report, the IPCC developed revised global warming potential factors (GWPs) for selected gases. The GWP for methane was revised from the previously published value of 23 in the IPCC’s Third Assessment Report to 25 in the Fourth Assessment Report. The revised GWP for methane is used in this report. In addition, this report incorporates an increase in the density of methane from 42.28 to 42.37 pounds per thousand cubic feet, in order to provide consistent temperature and pressure values for methane in all EIA data.”

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.h

Cell: G46
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, 96.22 lb CO_2/Mcf vs 120.593 lb CO_2/Mcf at sea level.

Cell: I47
Comment: Rick Heede:
lb CO_2 per million Btu should be the same in Aspen as at sea level at STP. The minor difference derives from the factors supplied by SourceGas. This factor is from the DOE.

Cell: E48
Comment: Rick Heede:
Energy Information Administration (2008) Annual Energy Review 2007; Energy Information Administration (2008) Emissions of Greenhouse Gases in the United States 2007. Note: EIA has adopted the IPCC FAR GWP value of methane = 25xCO_2, EIA 2008, page 12: “Methane. In its Fourth Assessment Report, the IPCC developed revised global warming potential factors (GWPs) for selected gases. The GWP for methane was revised from the previously published value of 23 in the IPCC’s Third Assessment Report to 25 in the Fourth Assessment Report. The revised GWP for methane is used in this report. In addition, this report incorporates an increase in the density of methane from 42.28 to 42.37 pounds per thousand cubic feet, in order to provide consistent temperature and pressure values for methane in all EIA data.”

Jackson Energy & Emissions Inventory: Propane, 2008

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 1 June 2009
File last modified: 20 August 2009

Future inventorists must request updated propane sales figures from AmeriGas, Suburban Propane, and Lower Valley Energy. Enter data in column “C”. The calculations are automatic and are linked to the summary worksheet.

Data not provided by:	Data not provided by:	Data provided by:
Jean Konowalczyk	Andy Owens	Tammy Spraklen &
AmeriGas	Suburban Propane	Jim Webb (Pres. & CEO)
610-768-3623	307-733-3628	Lower Valley Energy
jean.konowalczyk@amerigas.com	aowens@suburbanpropane.com	307-885-6125
		tammys@lvenergy.com

Note: JHMR consumed 2.81 million gallons in 2008 | 2,813,726 | gallons

2008	Propane Sales	Consumption	Carbon Factor	Carbon Dioxide	Methane	Total Emissions	Total Emissions
	gallons	Million Btu	lb CO2/gallon	tons CO2	tons CO2e	tons CO2e	tonnes C-e
Propane vendor			12.669		tons CO2e/ton CO2		
	Update this column				0.0544		
AmeriGas	951,159	86,872		6,025	328	6,353	1,573
							-
Suburban Propane		-		-	-	-	-
Lower Valley Energy (Town of Jackson)	175,098	15,992		1,109	60	1,169	290
Lower Valley Energy (Teton County)	1,252,747	114,417		7,935	432	8,367	2,072
Lower Valley Energy (LVE own use)	24,537	2,241		155	8	164	41
Total propane sold in Jackson Hole	**2,403,541**	**219,523**		**15,225**	**828**	**16,053**	**3,974**

Methane, tons, @25xCO2	33.12	tons CH4
Methane, percent of total	5.16%	

Conversions

1 gallon propane	91,333	Btu
1 bbl of propane	3.84	million Btu
1 million Btu	10.95	gallons
1 million Btu	138.71	lb CO2
1 million Btu	146.25	lb CO2e
1 gallon propane	12.669	lb CO2
1 gallon propane	0.028	lb CH4
1 gallon propane	13.358	lb CO2e

Cell: C19
Comment: Rick Heede:
CMS note: Make sure total propane includes all JHMR consumption.

Cell: E22
Comment: Marta Darby:
2007 factor from CCX - 0.006 metric tons CO2/gallon (conversion to lbs. : 1 metric ton = 2204.6 pounds). CMS corrected this calculation (12Dec08) -- converting from 0.006 tonnes CO2 to lb per gallon is far too inaccurate. CMS uses standard EF of 12.669 lb CO2 per gallon from DOE, EPA, etc.

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: F22
Comment: Rick Heede:
Propane sales times carbon factor of 12.669 lb CO2 per gallon at full combustion / 2000 lb per ton.

Cell: G22
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: 2.03 million tonnes CH4 plus 0.66 million tonnes CH4 of total natural gas system methane emissions of 7.06 million tonnes CH4, or 2.69 of 7.06 million tonnes CH4 = 38.102 percent of the natural gas rate -- which is 0.14274 tons CO2e per ton CO2 (see Natural Gas worksheet, table 2) -- from the propane's combustion. * Hence, the propane fugitive methane rate is 0.14274 x 0.38102 = 0.05439 tons CO2e per ton of propane delivered to and combusted by Aspen customers.

* Production (2.03 million tonnes CH4), Gas Processing (0.66 million tonnes), Transmission and Storage (2.41 million tonnes), Distribution (1.97 million tonnes CH4), Total (7.06 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). EIA 2008.

Sources: Energy Information Administration (2008) Annual Energy Review 2007; Energy Information Administration (2008) Emissions of Greenhouse Gases in the United States 2007.

Cell: B27
Comment: Rick Heede (Aug09):
Wendy Koelfgen received preliminary and estimated data from Mel at the Jackson Hole office of AmeriGas, 20Aug09, although unable to give an accurate accounting due to an antiquated billing system that does not track sales by County or zip code or customers' billing address. Mel did provide the company's projected sales for 2009 -- 1.498 million gallons -- and further said that 2009 is expected to be 5 percent higher than 2008, and that Teton County sales comprised approximately two-thirds of total sales.

CMS encourages AmeriGas to track propane sales within Teton County so that a more accurate account can be provided in future years.

The formula for estimate Teton County's proportion of 2008 sales based on projected 2009 sales: "=1498000*0.952381*0.6667"

Cell: B29
Comment: Rick Heede
9Oct08, Rick contacted Scott Brockelmeyer at Ferrellgas HQ in Kansas (scottbrockelmeyer@ferrellgas.com, 913-661-1830) for assistance in acquiring propane sales data for Aspen, by zip code. 17Nov08 update: Ferrellgas' Brian Mater will get 2007 propane sales for zipcodes 81611 and 81612. Data received 25Nov08, sorted by delivery zip codes 81611 and 81612 or calendar year 2007. Largest delivery totaled 3,960 gallons, smallest 156 gallons, 33 of 67 customers took delivery in 2007, average delivery for all 67 customers was 541 gallons (1,097 gallons for 33 deliveries in 2007).

Marta
8/19/08: FerrellGas declined to provide data. {Spoke with Karen Kraft on the phone who said her boss told her to not work with us on this.}

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: B31
Comment: Rick Heede:
Lower Valley Energy provided propane sales data for 2008 (by month) by rate class for Town of Jackson and the rest of Teton County. Data from Tammy Spraklen, LVE, Jul09.

Cell: B33
Comment: Rick Heede:
Lower Valley Energy provided propane sales data for 2008 (by month) by rate class for Town of Jackson and the rest of Teton County. Data from Tammy Spraklen, LVE, Jul09.

Cell: B35
Comment: Rick Heede:
Lower Valley Energy provided propane sales data for 2008 (by month) by rate class for Town of Jackson and the rest of Teton County. Data from Tammy Spraklen, LVE, Jul09.

Cell: E44
Comment: Rick Heede:
Basic data from EIA Emission Coefficients (1605b Program), e.g., 532.085 lb CO2 per bbl, 139.178 lb CO2 per million Btu, and 3.836 million Btu per bbl (AER 1995).

Jackson Hole Energy & Emissions Inventory: Driving on State Highways in Teton County

The principal variables that need to be updated in future fuel and emissions inventories is the traffic and VMT data from the Wyoming Dept of Transportation summarized in Table 2 below. Inventorists may elect to update fuel consumption for each vehicle type (if needed).

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 1 June 2009
File last modified: 28 August 2009

Wy DOT
Transportation Surveys
307-777-4190

Data from:
Tory L. Thomas, P.E.
District Traffic Engineer
Rock Springs
307-352-3033
Tory.Thomas@dot.state.wy.us

Table 1

Driving on State Highways	Vehicle by type	Miles driven (VMT)	Fuel economy	Fuel consumed	Carbon factor	Carbon dioxide	Carbon
	23-Jul-09	miles	mpg	gallons/yr	CO2/gallon	tons CO2/yr	tonnes carbon
Passenger cars (sedans, stationwagons, etc)	25.8%	44,169,681	22.5	1,963,097	19.59	19,232	4,762
Small SUVs and small pick-up trucks	28.5%	48,841,474	20.2	2,417,895	19.59	23,688	5,865
Medium/Large SUVs and large "light" trucks	39.7%	67,953,355	17.0	3,997,256	19.59	39,161	9,696
2-axle medium-duty trucks	1.0%	1,698,834	10.4	163,349	19.59	1,600	396
3-axle trucks, dump trucks, etc	1.2%	2,123,542	7.4	286,965	22.38	3,212	795
Semis, combination trucks	1.0%	1,698,834	5.7	298,041	22.38	3,336	826
RVs and camper trailers	1.0%	1,698,834	8.5	199,863	23.38	2,337	579
Motorcycles	1.7%	2,972,959	40.0	74,324	19.59	728	180
Total	**100%**	**171,157,513**	**18.2**	**9,400,790**	**19.85**	**93,294**	**23,098**

Table 2

		Update this column				Subtract	
	2007 Vehicle Miles on State Highways by County: Teton County					Grand Teton NP	Net Non-GTNP
Vehicle travel data for Teton County	Roadway length	Vehicle Miles/day	Vehicle Miles/day	Vehicle Miles/year	Vehicle Miles/year	Vehicle Miles/year	Vehicle Miles/year
	Mileage	DVMT*	DVMTT**	Annual DVMT*	Annual DVMTT**	"GTNP driving"	
Interstate	-	-	(Class 4 and above)	-			
Other Principal Arterial	115.1	433,219		158,124,925			
Minor Arterial	17.6	134,027		48,920,023			
Major Collector	6.6	51,908		18,946,497			
Minor Collector	-	-		-			
Local	5.0	3,201		1,168,423			
Total	144.2	622,356	30,613	227,159,868	11,173,879	56,002,355	171,157,513

**Daily Vehicle Miles Traveled by Trucks

* Daily Vehicle Miles Traveled

CMS deducts GTNP's VMT on state highways within the park
The 50 million VMT in the park is thus subtracted from the WY DOT's estimate of VMT on State Highways so as to avoid double counting.

Vehicle Class	Truck classifications
Class 1 Light duty	The Class 1 truck GVWR ranges from 0-6000 lbs.[1] Examples of trucks in this class include the Toyota Tacoma and GMC Sonoma.
Class 2	The Class 2 truck GVWR ranges from 6,001-10,000 lbs.[1] Examples of vehicles in this class include the Nissan Titan and the Ford E-250.
Class 3, Medium duty	The Class 3 truck GVWR ranges from 10,001-14,000 lbs. Examples of vehicles in this class include the Ford F-350 and the GMC Sierra 3500.
Class 4	The Class 4 truck GVWR ranges from 14,001-16,000 lbs. Examples of vehicles in this class include the Ford F-450 and the GMC W4500.
Class 5	The Class 5 truck GVWR ranges from 16,001-19,500 lbs. Examples of trucks in this class include the International MXT and GMC Topkick.
Class 6	The Class 6 truck GVWR ranges from 19,501-26,000 lbs. Examples of trucks in this class include the International Durastar and GMC Topkick C5500.
Class 7, Heavy duty Kenworth dump truck	The Class 7 GVWR ranges from 26,001-33,000 lbs. Examples of trucks in this class include the International TranStar 8500.
Class 8	The Class 8 truck GVWR is anything above 33,000 lbs.

Cell: E14
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). CMS assumes that the average biker has a larger and loaded motorcycle and/or a rider or both, and that 40 mpg is more reasonable fuel economy.

Cell: F14
Comment: Rick Heede:
Miles driven / fuel economy. Conservative estimates.

Cell: E26
Comment: Rick Heede:
Average of all vehicle types: VMT / estimated fuel consumption.

Cell: H32
Comment: Rick Heede:
CMS subtracts estimated VMT within Grand teton National Park made on designated State Highways (which CMS estimates on the "GTNP driving" worksheet as 56.0 of 70.4 million vehicle miles driven with GTNP. The 50 million VMT in the park is thus subtracted from teh WY DOT's estimate of VMT on State Highways so as to avoid double counting.

Cell: G33
Comment: Rick Heede:
Totry Thomas of the Wyoming Dept of Transportion (contact info on sheet) provided VMT data for Teton County by roadway type. The Dept's Transportation Survey groupd can be contacted at 307-777-4190. These estimates and traffic counts are made annually for every WY county.

Cell: D34
Comment: Rick Heede:
Wy DOT's worksheet "County Sum 2" details mileage and VMT for Teton County (and other WY counties) by roadway type in "Daily Vehicle Miles Traveled." CMS multiplies this column by 365 days per year to get annual VMT.

Cell: C42
Comment: Rick Heede:
Total roadway length of state highways in the Wyoming DOT dataset for Teton County. CMS estimated roadway length by measuring distance on the map used to designate the inventory boundary, counting only roadways marked with Route Numbers: 112 miles.

Jackson Hole Energy & Emissions Inventory: Driving on local roads, in-town and rural

CMS relies on WY DOT data for vehicle-miles traveled on State Highways within Teton County (see worksheet "Driving in State Highways"). CMS does not have similar data on driving on Town of Jackson or Teton Village local roads. CMS assumes that local driving is equivalent to WY DOT data on "minor arterial" vehicle VMT. This assumption and thus the result may be revised .

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 1 June 2009
File last modified: 28 August 2009

Table 1

Driving on local roads, in-town, etc.	Vehicle by type	Miles driven (VMT)	Fuel economy	Fuel consumed	Carbon factor	Carbon dioxide	Carbon
	23-Jul-09	miles	mpg	gallons/yr	CO2/gallon	tons CO2/yr	tonnes carbon
Passenger cars (sedans, stationwagons, etc)	25.8%	12,624,522	22.5	561,090	19.59	5,497	1,361
Small SUVs and small pick-up trucks	28.5%	13,959,808	20.2	691,080	19.59	6,771	1,676
Medium/Large SUVs and large "light" trucks	39.7%	19,422,342	17.0	1,142,491	19.59	11,193	2,771
2-axle medium-duty trucks	1.0%	485,559	10.4	46,688	19.59	457	113
3-axle trucks, dump trucks, etc	1.2%	606,948	7.4	82,020	22.38	918	227
Semis, combination trucks	1.0%	485,559	5.7	85,186	22.38	953	236
RVs and camper trailers	1.0%	485,559	8.5	57,125	23.38	668	165
Motorcycles	1.7%	849,727	40.0	21,243	19.59	208	52
Total	100%	48,920,023	18.2	2,686,922	19.85	26,665	6,602

State Highway VMT
Vehicle Miles/year CMS assumes equiv to "Minor arterial"
48,920,023

Cell: C16
Comment: Rick Heede:
Vehicle types were surveyed (informally and unscientifically) by CMS staffers Rick Heede and Lis Conners on 23 and 24 July 2009 at Mercill and Cache. 403 vehicles were counted by type of vehicle. Fuel economy are estimated in mpg in column E.

Cell: D16
Comment: Rick Heede:
VMIT data for driving on local roads in Jackson Hole -- in subdivisions, Teton Village, Jackson, Kelly, and private property -- is not available. CMS assumes that the total such driving is equivalent to WY DOT's estimate for driving on "minor arterial" State Highway roads. This assumption may be revised in the next inventory, or earlier, if better information becomes available.

Cell: E16
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). CMS assumes that the average biker has a larger and loaded motorcycle and/or a rider or both, and that 40 mpg is more reasonable fuel economy.

Cell: F16
Comment: Rick Heede:
Miles driven / fuel economy. Conservative estimates.

Cell: K16
Comment: Rick Heede:
"Minor arterial" VMT, per Wyoming DOT data. See the "Driving on State Highways" worksheet for details.

Cell: E28
Comment: Rick Heede:
Average of all vehicle types: VMT / estimated fuel consumption.

Jackson Hole Energy & Emissions Inventory: Driving within Grand Teton National Park

The principal variables that need to be updated in future fuel and emissions inventories is data on traffic counts and estimated vehciel miles traveled within Grand Teton National Park (if updated by the National Park Service), summarized in Table 2. CMS used the lates such report available, with data for 2003. Table 2 is linked to Table 1, which is linked to and automatically updates the inventory summary sheet: Sum2008.xls

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 1 June 2009
File last modified: 26 August 2009

GTNP	Recreational visitors
2008	2,485,987
2007	2,588,574
2006	2,406,476
2005	2,463,442
2004	2,360,373

Data from:
Grand Teton National Park (2005) Public Use reporting and Counting Instructions, www.nps.gov/grte/parkmgmt/statistics.htm
National Park Service (2004) Grand Teton National Park Traffic Package, 8 pp.

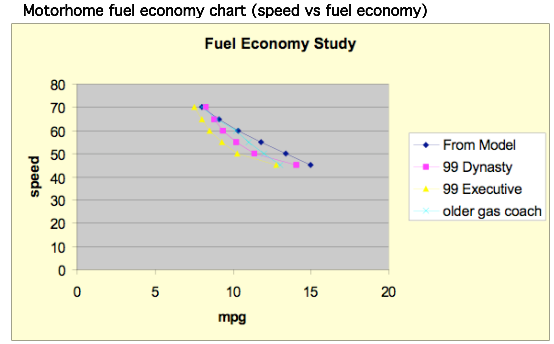
Table 1

Grand Teton National Park: visitors	Vehicle by type	Vehicle by type	Vehicle by type	Vehicle Miles	Fuel economy	Fuel consumed	Emission factor	Carbon dioxide	Carbon
	Station 2412	Station 2416	Average	VMT (miles)	mpg	gallons/yr	CO2/gallon	tons CO2/yr	tonnes carbon
Tour buses + shuttles and transit	0.67%	0.44%	0.56%	390,801	6.4	61,063	22.38	683	169
Passenger sedans: 33% of "passenger cars"	27.15%	27.26%	27.20%	19,155,129	22.5	851,339	19.59	8,341	2,065
Light SUVs and pick-up trucks: 33%	27.15%	27.26%	27.20%	19,155,129	20.2	948,274	19.59	9,290	2,300
Medium/heavy SUVs and pick-up trucks: 33%	27.15%	27.26%	27.20%	19,155,129	17.0	1,126,772	19.59	11,039	2,733
Light-duty trucks	2.80%	3.86%	3.33%	2,344,807	7.4	316,866	19.59	3,104	769
Heavy duty trucks	0.32%	0.79%	0.56%	390,801	5.6	69,786	22.38	781	193
RVs	4.79%	2.56%	3.68%	2,587,738	8.5	304,440	22.38	3,407	844
Vehicles pulling trailer	4.91%	3.76%	4.34%	3,052,475	14.0	218,034	19.59	2,136	529
Motorcycles	5.07%	6.81%	5.94%	4,182,630	40.0	104,566	19.59	1,024	254
Total	100%	100%	100%	70,414,639	17.6	4,001,139	19.90	39,806	9,855

Table 2

Table 2	Distance	Daily Traffic	Vehicle Miles (Update this column)	State highways	Non-state highways
	miles	AADT	VMT	VMT	VMT
North-South Hwy. - South Park Bdry. To Airport Rd.	4.68	5,801	9,909,268	9,909,268	
North-South Hwy. - Airport Rd. to Moose Junction	2.73	4,135	4,120,321	4,120,321	
North-South Hwy. - Moose Junction to Antelope Flats Rd.	0.95	2,929	1,015,631	1,015,631	
North-South Hwy. - Antelope Flats Rd. to Moran Junction	11.46	2,574	10,766,785	10,766,785	
North-South Hwy. - Moran Junction to East Park Bdry.	7.66	1,155	3,229,265	3,229,265	
Teton Park Rd. - Moose Jct. To So. Jct. Jenny Lake Loop Rd.	7.47	1,845	5,030,485	5,030,485	
Teton Park Rd. - So. Jct. To No. Jct. Of Jenny Lake Loop Rd.	5.49	1,575	3,156,064		3,156,064
Teton Park Rd. - Jenny Lake Loop Rd. to North Entrance Rd.	7.51	1,597	4,377,617		4,377,617
Gros Ventre Rd. - North-South Hwy. To East Park Bdry.	10.32	624	2,350,483		2,350,483
North Entrance Rd. - Moran Junction to Teton Park Rd.	4.31	2,183	3,434,186	3,434,186	
North Entrance Rd. - Teton Park Rd. to Colter Bay Village	5.17	3,091	5,832,872	5,832,872	
North Entrance Rd. - Colter Bay Village to Flagg Ranch	14.64	2,097	11,205,529	11,205,529	
Wilson Rd. - Teton Park Rd. to Southwest Park Bdry.	7.03	729	1,870,578		1,870,578
Antelope Flats Road - North-South Hwy. To Teton Forest Rd	3.29	405	486,344		486,344
Colter Bay Entrance Rd. - North Entrance Rd. to Colter Bay	0.65	2,205	523,136		523,136
Jenny Lake Loop Rd. - No. Jct. To So. Jct. Of Teton Park Rd.	5.73	788	1,648,063		1,648,063
North Entrance Rd. - Flagg Ranch to Yellowstone NP Bdry.	2.88	1,387	1,458,014	1,458,014	
Total			70,414,639	56,002,355	14,412,284

Motorhome fuel economy chart (speed vs fuel economy)



Bob Gummersall, Chief Technical Advisor Bob_Gummersall@rversonline.org

Cell: G15
Comment: Rick Heede (Aug09):
CMS applies fuel economy data from the Transportation Energy Data Book (cited below). Buses are not listed; CMS assumes tour buses are equivalent to trucks in weight class 7 (26,000 to 33,000 lbs) at 6.4 mpg; TEBD Table 5.4.

Passenger cars get an average of 22.5 mpg.

Light-duty trucks, as cited in the Grand Teton National Park Traffic Package, Classes 3 and 5, correspond to fuel economies of 10.5 and 7.9 mpg, respectively. CMS assumes that Class 3 trucks comprise two-thirds of the vehicles, thus weighted average of 8.8 mpg.

Heavy-duty trucks in Classes 6 through 13: Class 6 vehicles average 7.0 mpg, Class 7 average 6.4 mpg, and Class 8 average 5.7 mpg. CMS averages these vehicles to 6.4 mpg.

RVs, Recreational Vehicles, achieve a wide range of fuel economies from as low of ~3 mpg to a high of ~14 mpg. CMS averages this range to 8.5 mpg.

Vehicles pulling a trailer is not in the FHWA or DOT vehicle taxonomy. CMS assumes the large SUV or large personal truck fuel economy of 18.0 mpg, minus 4 mpg for pulling a trailer, or 14.0 mpg.

Motorcycles: EIA uses 50 mpg (Energy Information Administration/2001 National Household Travel Survey, p. K-37). CMS assumes that the average biker has a larger and loaded motorcycle and/or a rider or both, and that 40 mpg is more reasonable fuel economy.

Davis, Diegel, & Boundy (2009) Transportation Energy Data Book, edition 28, Oak Ridge National Laboratory, USDOE, www-cta.ornl.gov/rpts. Tables 4.1, 4.8, and 5.4.

Cell: H15
Comment: Rick Heede:
Miles driven / fuel economy.

Cell: B19
Comment: Rick Heede:
The traffic count and VMT data in the National Park Service (2004) “Grand Teton National Park Traffic Package” aggregates all personal vehicles -- sedans (typically called “cars”), light, medium, and heavy SUVs and pick-up trucks -- into one category. Such vehicles have a wide range of fuel economies, e.g., Hummers at ~9 mpg to Priuses at ~44 mpg. CMS disaggregates these vehicles into passenger sedans, Light SUVs & trucks, nd Medium/Heavy SUVs and trucks, with average fuel economies from ORNL data. CMS assumes that each sub-category comprise one-third of all personal vehicles, and which conforms to the data collected by CMS in teh worksheet “Traffic Survey 2009.”
Also see the “Fuel economy” cell note.

Cell: G27
Comment: Rick Heede:
Average of all vehicle types: VMT / estimated fuel consumption.

Cell: E32
Comment: Rick Heede:
From a future edition of National Park Service (2004) Grand Teton National Park Traffic Package, 8 pp., if available.

Cell: I52
Comment: Rick Heede:
Fuel economy of driving 10 mph slower (65 to 55 mph) model at www.rversonline.org/ArtFuelCostAnalysis.html
Vehicle Weight = 29000. You will notice from the chart that by reducing speed by 10 miles per hour (mph) from 65 mph to 55 mph, there is a 40% increase in fuel economy from 8.5 miles per gallon (mpg) to 12.5 mpg.

Bob Gummersall, Chief Technical Advisor Bob_Gummersall@rversonline.org And Dick Lucas New Rversonline Writer dick_lucas@agilent.com

Jackson Hole Energy & Emissions Inventory: Tourist driving to Jackson Hole (one-way)

CMS uses traffic counts at Grand Teton National Park as the basis of vehicles traveling to Jackson Hole in 2008. GTNP traffic counts are reduced from 2.49 million counts to 1.07 million to reflect unique vehicles rather than multiple entries and is based on the Park's own methodology; see Table 3 for details. Future inventorists may find better tourism data for Jackson Hole and revise the present methodology and results.

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 1 June 2009
File last modified: 30 August 2009

CMS surveyed vehicles' state of origin (at lodging parking lots), and computed the average distance driven one-way to Jackson as 637 miles; CMS, however, attributed one-quarter of the miles driven to the Jackson Hole fuel and emissions inventory (and the remainder to other places visited en route to Jackson). Vehicle types and fuel economy data are from established sources.

Table 1

Driving on State Highways	Vehicle by type	Number of tourist vehicles	Miles driven (VMT)	Fuel economy	Fuel consumed	Carbon factor	Carbon dioxide	Carbon
	23-Jul-09		miles	mpg	gallons/yr	CO2/gallon	tons CO2/yr	tonnes carbon
			159					
		25 percent of average tourist driving distance (one-way)						
Passenger sedans: 33% of "passenger cars"	28.5%	305,831	48,673,547	22.5	2,163,269	19.59	21,194	5,247
Light SUVs and pick-up trucks: 33%	28.5%	305,831	48,673,547	20.2	2,409,582	19.59	23,607	5,845
Medium/heavy SUVs and pick-up trucks: 33%	28.5%	305,831	48,673,547	17.0	2,863,150	19.59	28,050	6,945
RVs	3.8%	41,316	6,575,491	8.5	773,587	22.38	8,658	2,144
Vehicles pulling trailer	4.5%	48,736	7,756,396	14.0	554,028	22.38	6,201	1,535
Motorcycles	6.2%	66,780	10,628,141	40.0	265,704	19.59	2,603	644
Total	**100%**	**1,074,325**	**170,980,670**	**18.9**	**9,029,319**	**20.00**	**90,312**	**22,360**

Table 2 — Re-calculating percent of tourist vehicles

	Percent of GTNP traffic study	Vehicles per hundred	Percent of tourist vehicles
Tour buses + shuttles and transit	0.56%	not tourist vehicle	
Passenger sedans: 33% of "passenger cars"	27.20%	27.20	28.5%
Light SUVs and pick-up trucks: 33%	27.20%	27.20	28.5%
Medium/heavy SUVs and pick-up trucks: 33%	27.20%	27.20	28.5%
Light-duty trucks	3.33%	not tourist vehicle	
Heavy duty trucks	0.56%	not tourist vehicle	
RVs	3.68%	3.68	3.8%
Vehicles pulling trailer	4.34%	4.34	4.5%
Motorcycles	5.94%	5.94	6.2%
Total	100.00%	95.56	100.0%

Table 3 — Average distance driven by tourist vehicles

State of origin	Vehicle Count	Mid-state distance to JAC	
CA	3	900	2,700
CO	2	440	880
ID	10	200	2,000
IL	1	1,200	1,200
KS	1	900	900
KT	1	1,500	1,500
MA	1	2,000	2,000
MI	1	1,350	1,350
MN	4	870	3,480
MS	1	1,460	1,460
MT	5	250	1,250
NC	1	1,770	1,770
NJ	1	1,880	1,880
NM	1	740	740
NV	1	690	690
PA	1	1,740	1,740
SD	2	540	1,080
TX	2	1,350	2,700
UT	4	300	1,200
VA	1	1,770	1,770
WA	2	680	1,360
WY	10	200	2,000
Total	56	22,730	35,650
		average (with WY)	637 miles one-way
	46	22,530	33,650
		average (without WY)	732 miles one-way

Table 4 — GTNP visitors and vehicle counts

GTNP recreational visitors 2008	2,485,987	visitors	
CMS reverse calculation of GTNP unique vehicle counts	1,074,325	vehicles in 2008	2,943 veh. per average day

CMS note: this figure is subject to revision: CMS has not accounted for tourists who do not enter Grand Teton National Park, eg, town or the ski area only.

Cell: C13
Comment: Rick Heede:
Vehicle type data from Table 2.

Cell: D13
Comment: Rick Heede:
Number of tourist vehicles is based on visitor data at Grand Teton National Park. See Table 4 for methodology, source data, and results.

Cell: E13
Comment: Rick Heede:
CMS computes average miles driven one-way by tourists drving to Jackson Hole in Table 3, which average 637 miles one-way. (Their driving, VMT, fuel use, and emissions within Teton County are estimated in a separate worksheet “Teton County local driving”.)

CMS attributes one-quarter of these miles -- and thus fuel and emissions -- to the Jackson Hole energy and emissions inventory by assuming that Jackson comprises one-quarter of the reason for their road trip, and the otherthree-quarters are attibutable to other destinations en route, such as Yellowstone, or camping in Pinedale, or visiting grandma in Laramie. This assumption may be revised.

Cell: F13
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). CMS assumes that the average biker has a larger and loaded motorcycle and/or a rider or both, and that 40 mpg is more reasonable fuel economy.

Cell: G13
Comment: Rick Heede:
Miles driven / fuel economy. Conservative estimates.

Cell: B17
Comment: Rick Heede:
The traffic count and VMT data in the National Park Service (2004) “Grand Teton National Park Traffic Package” aggregates all personal vehicles -- sedans (typically called “cars”), light, medium, and heavy SUVs and pick-up trucks -- into one category. Such vehicles have a wide range of fuel economies, e.g., Hummers at ~9 mpg to Priuses at ~44 mpg. CMS disaggregates these vehicles into passenger sedans, Light SUVs & trucks, nd Medium/Heavy SUVs and trucks, with average fuel economies from ORNL data. CMS assumes that each sub-category comprise one-third of all personal vehicles, and which conforms to the data collected by CMS in teh worksheet “Traffic Survey 2009.”
Also see the “Fuel economy” cell note.

Cell: F23
Comment: Rick Heede:
Average of all vehicle types: VMT / estimated fuel consumption.

Cell: I28
Comment: Rick Heede:
CMS staff (Rick Heede & Lis Conners) sampled vehicles in the Town of Jackson by license plate and state of origin. Most vehicles were counted at lodges in town. CMS did not sample license plates at campgrounds (but future inventorists should do so).

CMS approximates the distance "as the crow flies" driven from each state listed (using each state's major population centers or each state's middle). CMS does account for the additional distance driven in actual conditions, nor side-trips and diversions.

Cell: B30
Comment: Rick Heede:
The traffic count and VMT data in the National Park Service (2004) "Grand Teton National Park Traffic Package" aggregates all personal vehicles -- sedans (typically called "cars"), light, medium, and heavy SUVs and pick-up trucks -- into one category. Such vehicles have a wide range of fuel economies, e.g., Hummers at ~9 mpg to Priuses at ~44 mpg. CMS disaggregates these vehicles into passenger sedans, Light SUVs & trucks, nd Medium/Heavy SUVs and trucks, with average fuel economies from ORNL data. CMS assumes that each sub-category comprise one-third of all personal vehicles, and which conforms to the data collected by CMS in teh worksheet "Traffic Survey 2009."
Also see the "Fuel economy" cell note.

Cell: B44
Comment: Rick Heede:
Total number of "recreational visitors" to GTNP in 2008. This, however, represents people, whereas CMS is interested in cars. It turns out that GTNP does not count people -- it counts vehicles entering various entrance stations, which are fitted with inductive loops embedded in the macadam. Non-recreational vehicles are deducted by assuming that between 100 and 300 vehicles per day are park and concessionaire vehicles.

Also, vehicle counts are multiplied by 0.89 (to account for vehicles that enter the park more than once per day, and/or enter the park in subsequent days if staying more than one day. GTNP staff also use a persons per vehicle multiplier of 2.7 (Jun-Aug) and 2.4 (Sep-May), which CMS "averages" to 2.6 PPV (since 61 percent of total visitors are Jun-Aug).

Thus, if we reverse-calculate: 2.49 million "visitors" in 2008 means: (2.49 million / 0.89) / 2.6 = 1.08 million vehicle counts.

Sources: Grand Teton National Park (2005) Public Use reporting and Counting Instructions, www.nps.gov/grte/parkmgmt/statistics.htm

www.nature.nps.gov/stats/park.cfm, & www.nps.gov/grte

Cell: B46
Comment: Rick Heede:
See cell note above.

Jackson Hole Energy & Emissions Inventory: START Transit, 2008

Future inventories must update: (a) fuel consumption by START Transit, and (b) update biodiesel consumption.

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 1 June 2009
File last modified: 20 July 2009

Data provided by:
Michael Wackerly
START Transit
mwackerly@ci.jackson.wy.us
307-732-8650

Table 1	START bus ridership and fuel consumption						START bus emissions				
	Riders	Vehicle	Diesel	Biodiesel (B5)	Diesel (conv)	Gasoline	Biodiesel (B5)	Diesel (conv)	Gasoline	Total	Carbon
		miles	gallons	gallons	gallons	gallons	tons CO2/yr	tons CO2/yr	tons CO2/yr	tons CO2/yr	tonnes carbon
			Update this column	Update this column	Update this column	Update this column					
January	125,954	96,679	16,804		16,804	648		188	6	194	53
February	118,011	90,707	15,272		15,272	669		171	7	177	48
March	112,181	98,109	15,231		15,231	644		170	6	177	48
April	38,139	45,488	7,016		7,016	536		79	5	84	23
May	41,118	35,410	5,412		5,412	726		61	7	68	18
June	67,476	41,544	6,957	6,957		700	75	-	7	82	22
July	78,799	44,428	7,711	7,711		677	83	-	7	90	24
August	67,925	42,605	7,591	7,591		663	82	-	6	88	24
September	57,150	45,218	7,104	7,104		641	76	-	6	83	23
October	39,035	34,647	5,557		5,557	536		62	5	67	18
November	31,080	28,789	4,628		4,628	467		52	5	56	15
December	104,030	97,054	13,786		13,786	950		154	9	164	45
Annual Total	**880,898**	**700,678**	**113,069**	**29,364**	**83,706**	**7,854**	**316**	**937**	**77**	**1,329**	**363**

Table 2	Biodiesel credit				Conversion
	B5 emission factor	Diesel EF	Gasoline EF		Conversion
	lb CO2/gallon	lb CO2/gallon	lb CO2/gallon		lb CO2/lb C
	21.506	22.384	19.564		3.664

Table 3	Fuel and emissions from would-be-driving (assuming no START Bus)						
	START ridership		Cars per day	VMT	Fuel consumed	Emissions	
	riders per year	riders per day	occupancy/veh	trip length (miles)	composite mpg	composite emissions	
	880,898	2,413	1.63	12	19.15	1.022	
					gallons	tons CO2-e	
Would-be drivers, per year	880,898		540,428	6,485,139	338,627	3,318	tons CO2/year
Would-be-drivers, per day		2,413	1,481	17,768	928	9.1	tons CO2/day

Table 4	START fuel consumption		
2008	Emission Coefficient	Total emissions pounds	Total emissions tons
gallons	lb CO2/gallon		
Gasoline 7,854	19.564	153,662	77
Diesel 83,706	22.384	1,873,668	937
Biodiesel 29,364	21.506	631,491	316
Total Fuel 120,924		2,658,821	1,329
Average emission coefficient, 2008		21.9876	lb CO2/gallon

Percent biodiesel: 1.30%

Table 5	Net START savings	
	Fuel consumed	Emissions
	gallons/yr	tons CO2/yr
Would-be drivers	338,627	3,318
START Bus	120,924	1,329
Net savings	**217,704**	**1,988**

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

Cell: I33
Comment: Rick Heede (Jun09):
CMS uses 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 CO2 per gallon * (1.0 - (0.05 * 0.7845)) = 22.384 * 0.8431 = 21.51 lb CO2 per gallon.

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.

Cell: H43
Comment: Rick Heede:
CMS assumes an average trip length of 12 miles (~mileage from Jackson to Teton Village) per substituted driving for START riding. Many routes are quite long (e.g., to Driggs or Alpine), but CMS does have a breakdown of ridership and fuel and distances for each routs.

Cell: D55
Comment: Rick Heede:
Distillate fuel (petroleum diesel) less carbon savings of biodiesel, based on NREL estimate of life-cycle carbon savings: 78.45 percent.

Cell: G57
Comment: Rick Heede:
Average biodiesel of total diesel over the whole year (~1.3 percent).

Jackson Hole Energy & Emissions Inventory: Schools, County, Town, JHMR, & misc. fuel use

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 make estimates are discussed in the cell comments.

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 1 June 2009
File last modified: 31 August 2009

Data provided by:

CoryAnn Degoey
Teton County School District
307-733-2767
cdegoey@teton1.k12.wy.us

Anna Olson/Jon Bishop
Jackson Hole Mountain Resort
307-739-2707
jonb@jacksonhole.com

Gina MacIlwraith
Grand Teton Lodge Company
307-734-0108
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Signal Mtn Lodge
307-543-2831
jryan@signalmtnlodge.com

Sherri Dimit
Sublette County Landfill
307-276-5792
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EPA Vehicle & Fuel Emissions Lal
Craig Harvey
harvey.craig@epa.gov

Jackson/ Teton "EnergyTracker"

	Vehicle miles traveled (VMT)	Fuel consumed	Fuel consumed	Fuel economy	Carbon factor	Attributed to Jackson Hole	Carbon dioxide	Carbon	
	(if known)	Diesel (gallons)	Gasoline (gallons)	mpg	CO2/gallon	Percent	tons CO2/yr	tonnes carbon	
Teton School District		Update this column	Update this column		diesel / gasoline				
School buses		145,321		-	22.38	100%	1,626	403	
Other School District vehicles			6,200	-	19.59	100%	60.7	15	
Out-of-district fuel (field trips, away games)		5,000			22.38	100%	56.0	14	
Total School vehicles		150,321	6,200				1,743	432	
Teton County	cell comments updated	chiefly "TCSO"	get definition	adjust for biodiesel when START makes available (Jun-Aug)					
Trucks, plows, etc. (diesel fuel)		1,925			22.38	100%	21.5	5	
Sheriff and other vehicles (gasoline)			42,286		19.59	100%	414	103	
Total Teton County vehicles		1,925	42,286				436	108	
Diesel: FAIR, TCSO, Weed&Pest, and Learning Center only. Where is snow plowing, road maintenance, etc?									
Town of Jackson	cell comments updated			adjust for biodiesel when START makes available (Jun-Aug)					
Trucks, plows, etc. (diesel fuel)		19,357			22.38	100%	217	54	
Police and other vehicles (gasoline)			26,363		19.59	100%	258	64	
Total Town of Jackson vehicles		19,357	26,363				475	118	
Teton County waste hauling to Sublette County	cell comments updated								
Waste transfer trucks (TTS to Sublette County Landfill)		51,492			22.38	100%	576	143	
Total Teton County waste hauling		51,492	-				576	143	
Boats, snowmobiles, & off-road equipment									
Grand Teton Lodge Company (boat fuel)		3,501	11,968		22.38	100%	156	39	
Signal Mountain Lodge & Leeks' Marina (boat fuel)			13,893		19.59	100%	136	34	
Grand Teton National Park: NPS vehicles & off-road equipment	snowmobile hrs	49,320	53,013			100%	1,071	265	
Snowmobiles (Grand Teton National Park)	3,167	4.4	13,998		19.59	100%	137	34	
Snow King Hill Climb World Championships	360	5.5	1,989		19.59	100%	19.5	5	
Snow King Hill Climb World Championships: nitrous fuel additive		fuel rate: gals/hr	na	2 kg of N2O leakage	296.00	100%	0.5	0	CO2e
Misc off-road equip. (mowers, blowers, etc)	na		38,492		19.59	100%	377	93	
Total off-road vehicles		52,821	133,353				1,898	470	
Snowmobile for an hour (excluding driving the machine somewhere):	87	lb CO2/hr							
Jackson Hole Mountain Resort					Biodiesel credit	cell comments updated			
Snow groomers, other diesel vehicles (diesel)		115,500			22.38	100%	1,293	320	
Snow groomers, other diesel vehicles (B10 biodiesel)		2,403			20.63	100%	24.8	6	
Snow groomers, other diesel vehicles (B20 biodiesel)		4,102			18.87	100%	38.7	10	
Snowmobiles, misc vehicles (gasoline)			46,156		19.59	100%	452	112	
Total Jackson Hole Mountain Resort fuel use		122,005	46,156				1,808	448	
Total Other Fuel Use & Emissions									
Total School District, Town, County, JHMR, & misc.	na	397,921	254,358	na	na	na	6,360	1,575	

Cell: D15
Comment: Rick Heede:
Fuel consumption data sources are listed for each entity included.

Cell: F15
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: B17
Comment: Rick Heede
Fuel data from Corianne DeGoey of teh Teton School District via Wendy Koelfgen. CMS is unable to confirm if the data includes fuel used on road trips (away games, field trips, etc), fuel purchased while away, or fuel used in miscellaneous equipment such as mowers and plows. Note: it took three months to acquire this data.

Cell: B24
Comment: Rick Heede (Jun09):
Fuel data for 2008 from the SGM file “EnergyTrackerJacksonJun09.xls” Since this file is updated by Town of Jackson staff, CMS has not linked fuel consumption.

Cell: B25
Comment: Rick Heede:
Of 2008 total diesel consumption, 45.2 percent is by “TCSO”, and 37.9 percent by “FAIR”.

Cell: B26
Comment: Rick Heede:
Of 2008 total diesel consumption, 80.7 percent is by “TCSO”.

Cell: B30
Comment: Rick Heede:
Fuel data for 2008 from the SGM file “EnergyTrackerJacksonJun09.xls” Since this file is updated by Town of Jackson staff, CMS has not linked fuel consumption.

Cell: B31
Comment: Rick Heede:
Of total diesel consumption in 2008, 79.6 percent is for “PW Streets” vehicles, and 10.7 percent by “Water Operations.”.

Cell: B32
Comment: Rick Heede:
Of total gasoline consumption in 2008, 65 percent is for police vehicles.

Cell: B36
Comment: Rick Heede (Jun09):
WasteBank Sanitation is local operator of waste transfer to Sublette County Landfill for Waste Connections, Inc., a large trash hauler serving most of US. Data from Dennis Miserany, 25Jun09:

1,398 loads in 2008, 29,771 tons transferred, 84 miles one-way, 51,491.6 gallons diesel, 3 FreightRunner (FreightLiner) trucks.

Cell: B37
Comment: Rick Heede:
Of total diesel consumption in 2008, 79.6 percent is for “PW Streets” vehicles, and 10.7 percent by “Water Operations.”.

Cell: B42
Comment: Rick Heede (Jul09):
Fuel sales at the Grand Teton Lodge Company’s fuel docks from Gina MacIlwraith, EHS Coordinator, 307-734-0108, gmacilwraith@gtlc.com: Calendar Year 2008 fuel sales at the marina (this will include both GTLC usage and guest)
Super unleaded - 11,967.9 gal
Diesel - 3500.9

Cell: B43
Comment: Rick Heede:
Jaosn Ryan & Matt Moore provided boat fuel sales for both Signal Mountain Lodge (7,943 gallons) and Leeks’ Marina (5,950 gallons) in 2008.

Cell: B44
Comment: Rick Heede:
GTNP fuel use data from Margaret Wilson, Park Planner, 3Aug09:
FY 2007 Park Operations Fuel Consumption:
· Diesel
o Bus 139
o Construction 22419
o Heavy duty 13315
o Light truck 7857
o Small engine 5590
49320
· Unleaded
o Sedans 2423
o Construction 623
o Heavy duty 103
o Hybrids 237
o Light trucks 47995
o Small engines 1435
o Snowmobiles 156
o Unknown 41
53013

Cell: B45
Comment: Rick Heede (Dec08):
National Vehicle and Fuel Emissions Laboratory US Environmental Protection Agency. CMS data from Craig Harvey, harvey.craig@epa.gov: 1.571 million snowmobiles used 395.7 million gallons in 89.5 million hrs (2000). CMS calc: 395.7/89.5 = 4.42 gallons per hour; assuming gasoline EF of 19.594 lb CO2 = 86.63 lb CO2 per hour.

CMS requested snowmobile visitor data from GTNP (Margaret Wilson, ref to: GTNP Monthly stats rpt**); 2008: 982 "snowmobilers - private" year to date, plus 7 "snowmobilers - guided." CMS assumes an average of 3 hrs per snowmobiler, or 989 x 3 = 2967 hrs. Wilson provided data for NPS ranger and staff snowmobile use: 200 hrs in 2008. The park was closed to snowmobiles in 2008, except for Jackson Lake, which is reflected in the data. 2007 saw a total of 615 private and 3663 guided snowmobilers.

** www.nature.nps.gov/stats/viewReport.cfm?selectedReport=ParkMonthlyReport.cfm

Cell: B46
Comment: Rick Heede:
CMS assumes that the 300+ racers in the 2008 Hill Climb World Championships at Snow King Mountain each race or run their machines for 1.2 hours over the four-day event (each successful race to the top takes one to 2 minutes, ~1,500 foot vertical climb; fastest time in 2008 was RMSHA Junior Jay Mentaberry at 57.6 seconds). CMS also increases the EPA-datum of 4.42 gallons per hour by 25 percent due to the fuel-intensive nature of the race, including the modifcations, larger-than typical machines (600 to 1,000 cc), etc. CMS does not attribute the fuel and emissions from driving hundreds of large rigs and trailers for the competitors, or the 10,000 spectators, -- many of whom drive hundreds of miles en route to Jackson. Such driving is instead included in the "Tourist driving to Jackson" worksheet.

Note: CMS does not have an accurate estimate of fuel consumption orhours of engine operation for all the snowmobiles in this four-day event, and the result may be revised if better information is acquired.

Snow King Hill Climb World Championships researched for # of competitors (>300), 400 volunteers, # races, 4-days of competition, 10,000 fans, etc. Snow Devil members Rick Budge only guy to have raced every year since 1975. Also see www.youtube.com/watch?v=5ogNwsZWgk8 (2008 race, 5-min video)

Popular Mechanics article (Feb06): World Championship Snowmobile Hill Climb. John Galvin . Popular Mechanics, Feb06. www.popularmechanics.com/outdoors/adventures/2304856.html The sport of hill climbing is simple: Race a nitrous-fueled, titanium-paddled snow sled straight up a mountain--without maiming yourself or the fans. Etc.

Cell: B47
Comment: Rick Heede:
Many sleds are nitrous "fueled," "the evaporation and expansion of liquid nitrous oxide in the intake manifold causes a large drop in intake charge temperature, resulting in a denser charge, further allowing more air/fuel mixture to enter the cylinder." (Wiki) CMS assumes that the injected N2O is destroyed in the engine, and while it is likely that there is substantial leakage prior to injection, CMS assumes a mere 2 kg of leakage until more reliable data can be found.

Cell: B48
Comment: Rick Heede (Jun09:
ORNL's (2007) Transportation Energy Data Book, 26th edition, Table 2.10, shows US fuel consumption for mowing equipment (1.261 billion gallons), Soil & Turf equipment (0.799 billion gallons), Wood cutting equipment (0.270 billion gallons), Leaf blowers (0.220 billion gallons), Snowblowers (0.047 billion gallons), and Trimming equipment (0.134 billion gallons). Total equals 2.731 billion gallons, and includes both commercial and residential uses. The average annual fuel consumption in the US

is thus (mid-2006 population of 299 million) 2,731 million gallons / 299 = 9.13 gallons per capita.

Since we do not have a residential sector breakdown, CMS uses the ORNL datum of 9.13 gallons per capita per year as an estimate of fuel used per household. County owner-occupied houses and condos: 4,216 (we do not estimate fuel use at Teton County's 3,472 apartment units): 4,216 hh * 9.13 gallons/hh = 38,492 gallons of fuel for gas-powered widgets in 2008.

Teton County data: www.city-data.com/county/Teton_County-WY.html: County population in July 2007: 20,002; (55% urban, 45% rural); County owner-occupied houses and condos: 4,216; Renter-occupied apartments: 3,472;

http://quickfacts.census.gov/qfd/states/56/56039.html
Population, 2008 estimate 20,376; Housing units, 2007 12,160

Cell: B50
Comment: Rick Heede:
National Vehicle and Fuel Emissions Laboratory US Environmental Protection Agency. CMS data from Craig Harvey, harvey.craig@epa.gov: 1.571 million snowmobiles used 395.7 million gallons in 89.5 million hrs (2000). CMS calc: 395.7/89.5 = 4.42 gallons per hour; assuming gasoline EF of 19.594 lb CO2 = 86.63 lb CO2 per hour.

Cell: B52
Comment: Heede, (Jul09):
Bishop (JHMR Env Mngr., jonb@jacksonhole.com) sent 2008 consumption data: 2008 total: 168,161 gallons gallons, or 10.6 percent increase over 2005 fuel consumption.

JHMR (2006) Sustainability Report, page 8: 25,593 gallons (unleaded), 105,430 gallons (diesel), 21,000 gallons (B20 biodiesel)), =152,020 gallons total.

Cell: G52
Comment: Rick Heede (Jun09):
CMS uses a net savings of 78.45 percent based on the NREL report cited below. The emissions benefit of using B20 fuel is thus petroleum diesel times 0.80 plus an adjustment for the net carbon savings of biodiesel fuel: the carbon coefficient is 22.384 lb CO2 per gallon * (1.0 - (0.20 * 0.7845)) = 22.384 * 0.8431 = 18.872 lb CO2 per gallon.

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.

Jackson Hole Emissions Inventory: Commercial Air Travel, 2008

Estimated fuel use and CO2 emissions by airline, route miles, and aircraft departing Jackson Hole Airport

Climate Mitigation Services
Richard Heede
17-Aug-09

Future inventorists will get a file of annual flights by each airline serving the Jackson Hole Airport, the type of aircraft used, and passengers enplaned. Unless the mix of airlines, type of aircraft, load factors, or markets served changes greatly, inventorists may simply multiply the number of flights in a future year by the factor shown in cell M58 (“emissions per average flight departing JAC, in tons CO2 per flight”).

If any of the factors has changed substantially, then a re-working of the worksheet “JAC Load Factors 2008” (supplied by the Airport Administration) and the worksheet below must be undertaken, including, if warranted, a review of aircraft fuel performance.

CMS uses results from Method One in the Jackson Hole inventory

Method One: Fuel rate by aircraft type, flights, and distance flown

Method Two: Fuel and emissions on the basis of per-passenger-mile flown

Airline / Equipment / Destination / # of flights: linked to “JAC Load Factors 2008” worksheet

Route miles / km: www.webflyer.com/travelmilemarker

Airline	Equipment	Destination	# of flights	Route miles	km	Aircraft type	Fuel rate (gallons/mile)	Fuel consumption (gallons)	Emissions (tons CO2)	Passengers (estimated)	Distance (pax-miles)	Fuel consumptio (gallons)	Emissions (tons CO2)	Percent (of Method One)
American	B757	CHI	66	1,170	1,883	B757	2.381	183,869	1,939	10,015	11,717,316	269,281	2,839	146%
American	B757	DFW	264	1,040	1,674	B757	2.381	653,756	6,893	40,059	41,661,568	957,444	10,095	146%
Delta	MD-90	SLC	1	205	330	MD-90	3.082	632	7	118	24,190	556	6	88%
Delta	B757	SLC	197	205	330	B757-200	3.002	121,246	1,278	24,963	5,117,394	117,605	1,240	97%
Delta	B757	ATL	112	1,570	2,527	B757-200	2.381	418,693	4,415	14,192	22,281,603	512,064	5,399	122%
Skywest	CRJ700	SLC	1,275	205	330	CRJ-700	1.837	480,125	5,062	64,507	13,223,935	303,905	3,204	63%
Skywest	Emb120	SLC	6	205	330	Embraer 120	0.826	1,016	11	47	9,635	221	2	22%
United	A319	CHI	210	1,170	1,883	A319	1.954	480,104	5,062	18,647	21,817,002	501,386	5,287	104%
United	A319	DEN	469	406	653	A319	2.084	396,879	4,185	41,645	16,907,866	388,567	4,097	98%
United	A320	DEN	128	406	653	A320	2.095	108,853	1,148	11,997	4,870,782	111,938	1,180	103%
United	B757	DEN	357	406	653	B757	2.381	345,122	3,639	46,336	18,812,416	432,337	4,559	125%
Frontier	Q400	DEN	253	406	653	Q400	1.373	140,989	1,487	11,110	4,510,660	103,662	1,093	74%
Frontier	A319	DEN	91	406	653	A319	2.084	77,006	812	8,385	3,404,310	78,236	825	102%
Mesa/UAL	Dash8	DEN	365	406	653	Dash-8	0.906	134,190	1,415	8,591	3,487,946	80,158	845	60%
Northwest	A319	MSP	112	870	1,400	A319	1.954	190,400	2,008	11,183	9,729,210	223,591	2,358	117%

	gallons jet fuel	tons CO2	pax	pax-miles	gallons jet fuel	tons CO2	percent
Total flights 3,906	3,732,881	39,359	311,795	#########	4,080,951	43,029	109.3%

Emissions per average flight departing Jackson Hole Airport 10.08 tons CO2e

Jet fuel EF	Fuel /pax-mile	CO2/pax-mile
lb CO2/gallon	gallons/pax-mile	lb CO2/pax-mile
21.088	0.0230	0.4846

1 mile = 1.60934 km

Cell: K15
Comment: Rick Heede:
Airlines do not publish fuel rates. MIT's Global Airline Industry Program, Airline Data Project (web.mit.edu/airlinedata/) only lists fuel rates in terms of "block hour" fuel rates of categories of commercial aircraft (e.g., narrow body jet).
CMS has relied on fuel estimates from the Danish Environment Ministry publication "GHG emissions from international aviation and allocation options," (www2.mst.dk/common/Udgivramme/Frame.asp?http://www2.mst.dk/udgiv/Publications/2003/87-7972-489-2/html/kap09_eng.htm). CMS calculated aircraft fuel consumption for 56 makes and models of commercial airliners (from the regional turboprops such as the Embraer 120 and DeHavilland Dash-Q400 to the longer-haul B737, A319, and B757s and the A330 and B747).
These source data and calculations are the CMS workbook "JetCalculator2009". Stage distances, fuel rates in grams of fuel per "Available Seat Km" (and per "Revenue Passenger Km") are converted to low and high fuel rates for each make and model of commercial airliner, and converted to fuel consumption for each aircraft in gallons per mile flown. This allows CMS to estimate fuel burn for the airlines serving Jackson Hole Airport (JAC) for the 3,906 flights departing JAC in 2008 by airline, type of aircraft used, and distance flown. CMS used its own fuel calculations for 17 flights aboard the CRJ700 (flights that averaged 1.84 gallons per mile), since the Danish Ministry report does not include CRJ700 fuel consumption data.
CMS will revise these calculations with airline data if the airlines provide data on fuel consumption for the routes, distances, passenger loading, and aircraft used for the Jackson Hole routes calculated here.
CMS is aware that the carriers have improved the load factor and fuel performance of their fleets given the sharp increases in fuel costs in 2008. Consequently, CMS encourages the airlines to provide actual data that may lower each airline's fuel consumption and CO_2 emissions for their JAC routes.

Cell: L15
Comment: Rick Heede:
Estimated fuel consumption (not verified by the airlines due to proprietary concerns) is the product of # of flights to each destination airport, route miles, and each aircraft type's fuel rate.

Cell: K19
Comment: Rick Heede:
CMS data for the B757 indicates a fuel rate of 2.46 gallons per mile flown (four flights ranging from 2.24 to 2.70 gallons per mile over distances raning from SLC-WASH 1,850 miles, CHI-DEN 925 miles, DEN-SNA 895 miles, EWR-DEN 1,601 miles).
CMS applies the higher fuel rates calculated from Danish Ministry aircraft data referenced above: 14 airlines submitted data on flights ranging from 1,600 to 3,617 km, fuel rates of 17 to 29 grams of fuel per "Available Seat Km", from which CMS calculates aircraft fuel performance of 1.76 to 3.00 gallons per aircraft mile flown. CMS uses the average fuel rate corresponding to medium-haul flights (2.38 gallon per mile) for all B757 flights, except for the short-haul flights to SLC (205 miles) of 3.00 gallons per mile.
This fuel rate may be revised if any of the three carriers -- American, Delta, and United -- flying B757 out of Jackson Hole Airport provide actual fuel consumption data for this route. CMS is aware that the carriers have improved the load factor and fuel performance of their fleets given the sharp increases in fuel costs in 2008. Consequently, CMS encourages the airlines to provide actual data that may lower each airline's fuel consumption and CO_2 emissions.

Cell: K23
Comment: Rick Heede:
The Danish Ministry fuel performance data suggests the MD-90 burns 2.23 to 3.08 gallons per mile flown (stagedistances from 645 to 1,340 km). CMS uses the higher rate for this single flight to SLC, a 205-mile trip distance.

Cell: K25
Comment: Rick Heede:
CMS uses the average fuel rate corresponding to medium-haul flights (2.38 gallon per mile) for all B757 flights, except for the short-haul flights to SLC (205 miles) of 3.00 gallons per mile.
Danish Ministry report with CMS calculations.

Cell: K29
Comment: Rick Heede:
CMS estimates based on ~100 flights on various airlines, load factors, and distances flown, after which flight the captain provided specific fuel burn from gate to gate. Naturallly, these estimates vary. For example, the four Airbus 319 flights varied from 1.57 to 1.95 gallons per statute mile, and the 17 CRJ-700 flights varied from 1.04 to 2.93 gallons per mile.
CMS uses the average of 17 CRJ700 flights: 1.837 gallons per mile flown. The primary source for commercial aircraft performance -- the Danish Environment Agency study referenced above -- does not list fuel data for the CRJ700; the CRJ100 is listed, carries ~50 passengers compared to the CRJ700's ~70 seats, for which the short-haul flights (~380 miles) averaged 1.63 gallons jet fuel per mile flown (medium-haul flights averaged 0.83 gallons per mile). In lieu of SkyWest supplying actual fuel data for this 205-mile route from SLC to JAC, CMS uses the CMS database of fuel rates.

Cell: K31
Comment: Rick Heede:
CMS data indicates a fuel rate of 1.477 gallons per mile. CMS uses the Danish Ministry fuel rate for shorter flights, since the 6 flights from SLC to JAC is over a 205-mile route.

Cell: K33
Comment: Rick Heede:
The Danish Ministry fuel performance data suggests the A319 burns 1.82 to 2.08 gallons per mile flown (for stages between 808 and 2,131 km). CMS uses the average of 1.95 gallons per mile flown for the longer 1,170-mile Chicago and the 870-mile Minneapolis routes flown by United and Northwest, respectively. CMS uses the higher fuel rate (2.08 gallons per mile) for the shorter 406-mile flights to Denver flown by United and Frontier.
CMS data base of fuel performance indicates average fuel consumption of 2.11 gallons per mile.

Cell: K37
Comment: Rick Heede:

The Danish Ministry fuel performance data suggests the A320 burns 1.24 to 2.95 gallons per mile flown (for stages between 696 and 2,700 km). CMS uses the average of 2.09 gallons per mile flown.
CMS data base of fuel performance indicates average fuel consumption of 2.11 gallons per mile.

Cell: K41
Comment: Rick Heede:
The Danish Ministry fuel performance data suggests the Q400 burns 1.37 gallons per mile flown (average stage of 500 km). Frontier is encouraged to revise this estimate fuel burn rate on its JAC route.

Cell: K45
Comment: Rick Heede:
The Danish Ministry fuel performance data suggests the Dash-8 burns 0.91 gallons per mile flown (average stage length is 266 km). CMS' own data suggests an average of 0.96 gallons per mile flown.

Cell: M59
Comment: Rick Heede:
Calculated by CMS (see "US emission factor 2007" worksheet) and accounts for combustion factor (99 percent), methane, and nitrous oxide, and uses IPCC and EPA factors. This calculation excludes radiative forcing factors (such as high-altitude impacts of nitrogen oxides, vapor trails, and cloud formation).

Jackson Hole Energy & Emissions Inventory: General Aviation, 2008

The Jackson Hole Airport handled 32,848 general aviation & military arrivals and departures in 2007.
Future emissions inventories may simply update operational data from (available from the Airport staff). Future inventories may also change fuel consumption rates, aircraft performance, and other factors.

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 1 June 2009
File last modified: 18 August 2009

Data source
Michelle Buschow
Jackson Hole Airport administration
307-733-7682
Michelleb@jacksonholeairport.com

Average 1,000 nm flight in a private jet: 3.87 tons CO_2e

50% to account for *one way* of travel

Table 1	General aviation, air taxi, military, and civilian (local) aircraft operations, fuel consumption, and emissions by aircraft type									
	50% of Total Non-Carrier Ops	Percent by aircraft type	Operations by aircraft type	Fuel consumption rate by aircraft type & distance	Total fuel	Fuel emission factor	CO_2e emissions	Allocated to Jackson Hole	CO_2e emissions	Carbon
				gallons per trip	(gallons)	lb per gallon	tons CO_2e	percent	tons CO_2e	metric tonnes C
	Update this column									
Turbofan jets	11,224	63.4%	7,114	367	2,612,123	21.088	27,542	100%	**27,542**	7,517
Turboprop singles	11,224	15.0%	1,686	131	221,697	21.088	2,338	100%	**2,338**	638
Turboprop twins	11,224	9.9%	1,107	77	84,897	21.088	895	100%	**895**	244
Piston singles	11,224	9.9%	1,107	27	30,100	18.355	276	100%	**276**	75
Piston twins	11,224	1.9%	211	70	14,773	18.355	136	100%	**136**	37
Total operations, jet fuel, & CO_2e		100%	11,224		2,963,590	100	31,187		31,187	8,511

Average of turbofan jets			
nm	Fuel rate gal / nm	Gallons	lb CO_2
613	0.617	367	7,743

Fuel rate in mpg	1.9
Average tons CO_2	3.9

Average of turboprop singles			
nm	Fuel rate gal / nm	Gallons	lb CO_2
			0
295	0.268	77	1,618

Fuel rate in mpg	4.4
Average tons CO_2	0.8

Average of turboprop twins			
nm	Fuel rate gal / nm	Gallons	lb CO_2
307	0.484	131	2,773

Fuel rate in mpg	2.7
Average tons CO_2	1.4

Average of piston singles			
nm	Fuel rate gal / nm	Gallons	lb CO_2
251	0.124	27	499

Fuel rate in mpg	10.6
Average tons CO_2	0.2

Average of piston twins			
nm	Fuel rate gal / nm	Gallons	lb CO_2
385	0.180	70	1,286

Fuel rate in mpg	6.3
Average tons CO_2	0.6

Average of all JAC landings			
nm	Fuel rate gal / nm	Gallons	lb CO_2
495	0.528	261	5,497

Fuel rate in mpg	2.2
Average tons CO_2	2.7

Cell: F17
Comment: Rick Heede:
CMS computed the average fuel rate for 135 turbofan jets landing at Jackson Hole Airport over nine days in July 2009 (see worksheet "JAC Landings Jul09 sort" in AirportOpsPaxFuelGlycolLandingsAug09.xls). These jets ranged from very light jets to Bombardier Challengers & Gulfstreams, flew distances ranging from Bozeman to Boston (131 and 1,735 nautical miles, respectively), and have estimated fuel consumption rates ranging from 0.34 to 1.09 gallons per nm. The average jet traveled 613 nautical mile (705 statute miles), consumed 367 gallons at an average fuel rate of 0.617 gallons per nm (equivalent to 1.9 mpg), and emitted 7,743 lb CO2 (3.9 tons CO2) for the average trip.

Since jets fly longer missions (613 nm vs 301 nm for turboprops) at a higher fuel rate (0.617 gallons/nm vs 0.376 gallons/nm for turboprops), jets flew 78.5 percent of miles, consumed 89.1 percent of the fuel, and emitted 89.3 percent of the total CO2 for the profiled aircraft.

CMS research shows jets comprised 135 (63.4 percent) of the 213 operations profiled. Turboprop singles (15 percent) and turboprop twins (9.9 percent) comprised 24.9 percent of the 213 operations profiled.

Cell: H17
Comment: Rick Heede:
Jet fuel factor is typically cited (e.g., by EPA and EIA) as 21.095 lb CO2 per gallon (based on 19.33 kg carbon per million Btu). CMS -- in the attached worksheet "US Coml Ave 2006" -- accounts for 1 percent of liquid fuel not combusted to CO2 (per EPA and IPCC) and also accounts for associated methane and nitrous oxide emissions (EIA fuel factors for Jet fuel). The net result is 21.088 lb CO2e per gallon of jet fuel.

Cell: L18
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"

Specific fuel consumption of aircraft makes and models

GHG emissions from international aviation and allocationoptions

Danish Environment Ministry

www2.mst.dk/common/Udgivramme/Frame.asp?http://www2.mst.dk/udgiv/Publications/2003/87-7972-489-2/html/kap09_eng.htm

CMS	17-Aug-09

/ ASK = per Available Seat km

Conversions

1.000 kg		1 kg fuel =	
2.205 lb		0.32904 gallon fuel	
1.000 gallon Jet-A		1 km =	1 mile =
6.700 lb		0.62137 mile	1.60934 km

Emission factor

21.088 lb CO2 per gallon Jet-A

Aircraft type	Average stage distance [km]	Fuel [g/ASK]	Fuel [g/RPK]	Seats	No. of Airlines	Stage distance: Low	Stage distance: High	Stage distance: Average	Fuel rate: Low (g/ASK)	Fuel rate: High (g/ASK)	Fuel rate: Average (g/ASK)	Seats: Low	Seats: High	Seats: Average	kg fuel per stage: High?	kg fuel per stage: Low?	kg fuel: Average	kg fuel per km: High?	kg fuel per km: Low?	kg fuel per km: Average	gallons fuel per mile: High?	gallons fuel per mile: Low?	gallons fuel per mile: Average	lb CO2 per passenger-mile: High?	lb CO2 per passenger-mile: Low?	g CO2 per passenger-km: High?	g CO2 per passenger-km: Low?
															Low distance * High fuel rate * Ave seats	High distance * Low fuel rate * Ave seats.											
Bae jet stream 31**	231-245	60-66	119*	19	2	231	245	238	60	66	63	19	19	19	290	279	284	1.25	1.14	1.20	0.66	0.60	0.63	0.74	0.67	207.7	188.8
Bae jet stream 41**	390	52	96	30	1	390	390	390	52	52	52	30	30	30	608	608	608	1.56	1.56	1.56	0.83	0.83	0.83	0.58	0.58	163.7	163.7
Embraer 120**	359-411	45-52	86*	30	2	359	411	385	45	52	49	30	30	30	560	555	557	1.56	1.35	1.46	0.83	0.71	0.77	0.58	0.50	163.7	141.6
Dornier 328**	385	43	65	32	1	385	385	385	43	43	43	32	32	32	530	530	530	1.38	1.38	1.38	0.73	0.73	0.73	0.48	0.48	135.3	135.3
Saab 340B**	304-338	46-52	84*	34	2	304	338	321	46	52	49	34	34	34	537	529	533	1.77	1.56	1.67	0.94	0.83	0.88	0.58	0.51	163.7	144.8
Embraer 135	567-613	37-64	83*	37	2	567	613	590	37	64	51	37	37	37	1,343	839	1,091	2.37	1.37	1.87	1.25	0.72	0.99	0.71	0.41	201.4	116.5
De Havilland Dash-8-100	259-272	45	76*	37-39	2	259	272	266	45	45	45	37	39	38	443	465	454	1.71	1.71	1.71	0.91	0.91	0.91	0.50	0.50	141.6	141.6
ATR 42**	235-365	39-47	70*	46-48	5	235	365	300	39	47	43	46	48	47	519	669	594	2.21	1.83	2.02	1.17	0.97	1.07	0.52	0.44	147.9	122.8
Saab 2000**	456	41	66	47	1	456	456	456	41	41	41	47	47	47	879	879	879	1.93	1.93	1.93	1.02	1.02	1.02	0.46	0.46	129.0	129.0
Fokker 50**	278-368	30	48-76	46-50	4	278	368	323	30	30	30	46	50	48	400	530	465	1.44	1.44	1.44	0.76	0.76	0.76	0.34	0.34	94.4	94.4
Embraer 145	513-796	40-47	72*	50	3	513	796	655	40	47	44	50	50	50	1,206	1,592	1,399	2.35	2.00	2.18	1.24	1.06	1.15	0.52	0.45	147.9	125.9
ATR 72**	295-399	30-36	56*	64-68	6	295	399	347	30	36	33	64	68	66	701	790	745	2.38	1.98	2.18	1.26	1.05	1.15	0.40	0.34	113.3	94.4
Fokker 28	512-585	50-59	81-94	65-75	2	512	585	549	50	59	55	65	75	70	2,115	2,048	2,081	4.13	3.50	3.82	2.19	1.85	2.02	0.66	0.56	185.7	157.4
De Havilland Dash-8-Q400	500	36	58	72	1	500	500	500	36	36	36	72	72	72	1,296	1,296	1,296	2.59	2.59	2.59	1.37	1.37	1.37	0.40	0.40	113.3	113.3
AVRO RJ 85	532-661	63*	89L-112	69-80	2	532	661	597	63	63	63	69	80	75	2,497	3,102	2,800	4.69	4.69	4.69	2.49	2.49	2.49	0.70	0.70	198.3	198.3
Canadair jet 100/145	621-1107	32 -63	46-87	48-50	4	621	1,107	864	32	63	48	48	50	49	1,917	1,736	1,826	3.09	1.57	2.33	1.63	0.83	1.23	0.70	0.36	198.3	100.7
DC-9-10	640-1040	65-68	107*	60-78	3	640	1,040	840	65	68	67	60	78	69	3,003	4,664	3,834	4.69	4.49	4.59	2.48	2.38	2.43	0.76	0.73	214.0	204.6
Bae 146-300	513	39	60	89	1	513	513	513	39	39	39	89	89	89	1,781	1,781	1,781	3.47	3.47	3.47	1.84	1.84	1.84	0.44	0.44	122.8	122.8
Fokker 100	494-961	41-54	66*	97-98	3	494	961	728	41	54	48	97	98	98	2,601	3,842	3,221	5.27	4.00	4.63	2.79	2.12	2.45	0.60	0.46	170.0	129.0
DC-9-30	552-1181	33-58	77*	83-117	8	552	1,181	867	33	58	46	83	117	100	3,202	3,897	3,549	5.80	3.30	4.55	3.07	1.75	2.41	0.65	0.37	182.6	103.9
B737-100/200	229-1250	28-64	62*	95-123	13	229	1,250	740	28	64	46	95	123	109	1,598	3,815	2,706	6.98	3.05	5.01	3.69	1.62	2.66	0.71	0.31	201.4	88.1
DC-9-40	782-1390	38-54	69*	100-127	3	782	1,390	1,086	38	54	46	100	127	114	4,793	5,995	5,394	6.13	4.31	5.22	3.25	2.28	2.76	0.60	0.42	170.0	119.6
B737-500	604-1274	37-39	57*-72L	103-122	4	604	1,274	939	37	39	38	103	122	113	2,650	5,303	3,977	4.39	4.16	4.28	2.32	2.20	2.26	0.44	0.41	122.8	116.5
MD-87	741-852	38-44	61-64*	110-125	3	741	852	797	38	44	41	110	125	118	3,831	3,804	3,818	5.17	4.47	4.82	2.74	2.36	2.55	0.49	0.42	138.5	119.6
B717-200	759	23	33	119	1	759	759	759	23	23	23	119	119	119	2,077	2,077	2,077	2.74	2.74	2.74	1.45	1.45	1.45	0.26	0.26	72.4	72.4
DC-9-50	203-743	48-61	80*	115-134	3	203	743	473	48	61	55	115	134	125	1,542	4,440	2,991	7.59	5.98	6.79	4.02	3.16	3.59	0.68	0.54	192.0	151.1
A319	808-2131	28-32	42-53L	120-126	5	808	2,131	1,470	28	32	30	120	126	123	3,180	7,339	5,260	3.94	3.44	3.69	2.08	1.82	1.95	0.36	0.31	100.7	88.1
B737-300/700	685-2525	24C-36	46*-59L	120-155	12	685	2,525	1,605	24	36	30	120	155	138	3,391	8,333	5,862	4.95	3.30	4.13	2.62	1.75	2.18	0.40	0.27	113.3	75.5
B727-100	2062	37	79	170	1	2,062	2,062	2,062	37	37	37	170	170	170	12,970	12,970	12,970	6.29	6.29	6.29	3.33	3.33	3.33	0.41	0.41	116.5	116.5
B727-200	319-1887	36-83	66*	95-179	15	319	1,887	1,103	36	83	60	95	179	137	3,627	9,307	6,467	11.37	4.93	8.15	6.02	2.61	4.32	0.93	0.40	261.2	113.3
MD-80 & DC-9-80	855-1790	31-40	51*	114-160	10	855	1,790	1,323	31	40	36	114	160	137	4,685	7,602	6,144	5.48	4.25	4.86	2.90	2.25	2.58	0.45	0.35	125.9	97.6
A320-100/200	696-2700	16C-38	18C -52	110-183C	14	696	2,700	1,698	16	38	27	110	183	147	3,875	6,329	5,102	5.57	2.34	3.96	2.95	1.24	2.09	0.42	0.18	119.6	50.4
MD-90-30/50	645-1340	29-40	48*-53	141-150	4	645	1,340	993	29	40	35	141	150	146	3,754	5,654	4,704	5.82	4.22	5.02	3.08	2.23	2.66	0.45	0.32	125.9	91.3
B737-400	630-2257	24-33	46*	140-170	6	630	2,257	1,444	24	33	29	140	170	155	3,222	8,396	5,809	5.12	3.72	4.42	2.71	1.97	2.34	0.37	0.27	103.9	75.5
B737-800	1126-3848	26-36	38*-58	146-179	4	1,126	3,848	2,487	26	36	31	146	179	163	6,587	16,258	11,422	5.85	4.23	5.04	3.10	2.24	2.67	0.40	0.29	113.3	81.8
A321	763-787	16C-24	18C -40	182-220C	3	763	787	775	16	24	20	182	220	201	3,681	2,531	3,106	4.82	3.22	4.02	2.55	1.70	2.13	0.27	0.18	75.5	50.4
B757-200	1600-3617	17C -29	19C -38*	158-233C	14	1,600	3,617	2,609	17	29	23	158	233	196	9,071	12,021	10,546	5.67	3.32	4.50	3.00	1.76	2.38	0.32	0.19	91.3	53.5
A310-300	994-3401	27	37-52L	222	2	994	3,401	2,198	27	27	27	222	222	222	5,958	20,386	13,172	5.99	5.99	5.99	3.17	3.17	3.17	0.30	0.30	85.0	85.0
B757-300	NR	NR	25CL	252	1							252	252	252													
B767-200/200ER	941-5746	23-37	46*	168-264	6	941	5,746	3,344	23	37	30	168	264	216	7,520	28,546	18,033	7.99	4.97	6.48	4.23	2.63	3.43	0.41	0.26	116.5	72.4
A300-600	1333-2705	30*	40-47L	228-270	2	1,333	2,705	2,019	30	30	30	228	270	249	9,958	20,206	15,082	7.47	7.47	7.47	3.96	3.96	3.96	0.34	0.34	94.4	94.4
A300B4-120	2794	27C	27C	298C	1	2,794	2,794	2,794	27	27	27	298	298	298	22,481	22,481	22,481	8.05	8.05	8.05	4.26	4.26	4.26	0.30	0.30	85.0	85.0
B767-300/300ER	796-5387	19C -32	21C -52	188-322C	9	796	5,387	3,092	19	32	26	188	322	255	6,495	26,100	16,298	8.16	4.85	6.50	4.32	2.57	3.44	0.36	0.21	100.7	59.8
L-1011-500	1776	42	56	244	1	1,776	1,776	1,776	42	42	42	244	244	244	18,200	18,200	18,200	10.25	10.25	10.25	5.43	5.43	5.43	0.47	0.47	132.2	132.2
DC-10-10	2073-3702	21-42	48*	267-379	7	2,073	3,702	2,888	21	42	32	267	379	323	28,122	25,111	26,616	13.57	6.78	10.17	7.18	3.59	5.39	0.47	0.23	132.2	66.1
A330-200/300	3081-3169	19C-21C	20C-28	196-409C	3	3,081	3,169	3,125	19	21	20	196	409	303	19,572	18,214	18,893	6.35	5.75	6.05	3.36	3.04	3.20	0.23	0.21	66.1	59.8
A340-200/300	7393	NR	29 -36L	212-291	2	7,393	7,393	7,393				212	291	252													
DC-10-30	4085-6023	29C -45	34CL-46*	229-	7	4,085	6,023	5,054	29	45	37	229	370	300	55,056	52,313	53,684	13.48	8.69	11.08	7.14	4.60	5.87	0.50	0.32	141.6	91.3
MD-11	4384-7150	23-41	31-60*	232-376	5	4,384	7,150	5,767	23	41	32	232	376	304	54,642	49,993	52,317	12.46	6.99	9.73	6.60	3.70	5.15	0.46	0.26	129.0	72.4
L-1011-100/200	2021-2998	30-37	43*	299-361	2	2,021	2,998	2,510	30	37	34	299	361	330	24,676	29,680	27,178	12.21	9.90	11.06	6.47	5.24	5.85	0.41	0.34	116.5	94.4
B777-200/300	870-7888	18D -36	27D -56	202-477D	7	870	7,888	4,379	18	36	27	202	477	340	10,633	48,204	29,418	12.22	6.11	9.17	6.47	3.24	4.85	0.40	0.20	113.3	56.7
B747-200/300	589-6817	23-52	32-108	310-389	5	589	6,817	3,703	23	52	38	310	389	350	10,704	54,798	32,751	18.17	8.04	13.11	9.62	4.26	6.94	0.58	0.26	163.7	72.4
B747-100/100SR	921-5735	28D-33	40-46	447-536D	4	921	5,735	3,328	28	33	31	447	563	505	15,348	81,093	48,221	16.67	14.14	15.40	8.82	7.49	8.16	0.37	0.31	103.9	88.1
B747-400	970-7883	24D -34	37L -53	343-569D	6	970	7,883	4,427	24	34	29	343	569	456	15,039	86,272	50,655	15.50	10.94	13.22	8.21	5.80	7.00	0.38	0.27	107.0	75.5

Cell: B28
Comment: Rick Heede:
Wikipedia: The CRJ100 was stretched 5.92 meters (19 feet 5 inches), with fuselage plugs fore and aft of the wing, two more emergency exit doors, plus a reinforced and modified wing. Typical seating was 50 passengers, the maximum load being 52 passengers. The CRJ100 featured a Collins ProLine 4 avionics suite, Collins weather radar, GE CF34-3A1 turbofans with 41.0 kN (4,180 kgp / 9,220 lbf), new wings with extended span, more fuel capacity, and improved landing gear to handle the higher weights. It was followed by the CRJ100 ER subvariant with 20% more range, and the CRJ100 LR subvariant with 40% more range than the standard CRJ100.

The CRJ700 is a stretched 70-seat derivative of the CRJ200, equipped with the General Electric CF34-8C1 engine. Maximum speed is Mach 0.85 at a maximum altitude of 41,000 feet (12,500 m). Depending upon payload, the CRJ700 can travel up to 2250 statute miles (3,600 km) with current engines, and a new variant with CF34-8C5 engines will be able to travel up to 2895 miles (4,660 km).
The CRJ700 features a new wing with leading edge slats and a stretched and slightly widened fuselage, with a lowered floor. This enables the aircraft to carry up to 78 passengers with a crew of 2 plus cabin crew. The first flight was in 1999 and it entered service in 2001. It competes with the Embraer 170. The CRJ700 comes in three subvariants - Series 700, Series 701 and Series 702. The 700 is limited to 68 passengers, the 701 to 70 passengers and the 702 to 78 passengers.

www.skywest.com: System-wide, SkyWest Airlines operates 180 Bombardier Canadair Regional Jets and was the first airline to order the CRJ in 1989. The CRJ-700 has a range of 1,685 nautical miles, a ceiling of 41,000 feet and a normal cruising speed of 515 miles per hour.

General Aviation & Air Carrier & Air Taxi Operations, Jackson Hole Airport 2008

Richard Heede
Climate Mitigation Services
17-Aug-09

This worksheet adjusts the Air Carrier vs non-Air Carrier operations at Jackson Hole Airport for 2008. The FAA tower classifies as Air Taxi any operation (either a Landing or Take-off) by an aircraft with 59 or fewer seats, even if the aircraft is operated by an airline. CMS makes this adjustment so that fuel and emissions from all non-Air

Table 1 — Air Carrier flights departing from Jackson Hole, 2008, that are classified as Air Taxi flights in FAA data

2008	Destination	Aircraft	Passengers Enplaned	Seats	Departing flights	Load factor	Arriving flights	Total operations
United / Mesa Express	JAC-SLC	Dash-8: 37 seats	8,591	13,505	365	63.6%	365	730
SkyWest	JAC-SLC	Embraer: 30 seats	47	180	**6**	26.1%	6	12
Air Taxi and Carrier operations adjustment					371		371	**742**

Table 2 — Original and revised Air Taxi operations, 2008

	Original Air Taxi ops	Minus reclassified ops	Revised Air Taxi ops
Air Taxi operations	7,279	742	**6,537**

Table 3 — Original and revised Air Carrier operations, 2008

	Original Air Carrier ops	Plus reclassified ops	Revised Air Carrier ops
Air Carrier operations	6,899	742	**7,641**

Table 4 — Aircraft Operations Report from the FAA tower at JAC

From Michelle Buschow JAC to Heede, CMS

2008	Itinerant						Local		Totals
Month	Air Carrier	Air Taxi	Air Carrier + Air Taxi	General Aviation	Military	Total Itinerant	Civilian	Total Local	2008
January	503	565	1,068	905	9	1,982	72	72	2,054
February	534	537	1,071	874	17	1,962	56	56	2,018
March	654	608	1,262	873	-	2,135	44	44	2,179
April	272	485	757	544	20	1,321	44	44	1,365
May	426	463	889	920	27	1,836	430	430	2,266
June	938	682	1,620	1,351	13	2,984	518	518	3,502
July	1,015	846	1,861	1,895	25	3,781	392	392	4,173
August	1,049	896	1,945	1,910	75	3,930	458	458	4,388
September	653	651	1,304	1,621	20	2,945	406	406	3,351
October	301	450	751	856	22	1,629	188	188	1,817
November	185	460	645	530	10	1,185	38	38	1,223
December	369	636	1,005	673	7	1,685	68	68	1,753
Totals	6,899	7,279	14,178	12,952	245	27,375	2,714	2,714	30,089

Source: *Federal Aviation Administration Air Traffic Control Tower/JAC (via airport administration office)*

Table 5 — Revised aircraft operations at JAC, 2008 (Air Carrier plus non-Air Carrier)

	Air Carrier	Air Taxi	Air Carrier + Air Taxi	General Aviation	Military	Total Itinerant	Civilian	Total Local	Total operations
Revised operations	7,641	6,537	14,178	12,952	245	27,375	2,714	2,714	30,089
Percent of total	25.4%	21.7%		43.0%	0.8%		9.0%		100.0%

Table 6 — Revised "General Aviation" operations at JAC, 2008 (all non-Air Carrier operations)

	Air Taxi	General Aviation	Military	Civilian	Total "Genl Aviation" ops
Revised Air Taxi + GA + Military + Civilian	6,537	12,952	245	2,714	22,448
Percent of General Aviation (rev)	29.1%	57.7%	1.1%	12.1%	100.0%

US commercial aviation fleet average emission factors

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 22 December 2008
File last modified: 10 August 2009

IPCC Global Warming Potential (GWP), FAR 2007	
GWP factor methane, FAR:	25 x CO2
IPCC FAR: Physical Science Basis, Table 2-14.	
GWP factor nitrous, FAR:	298 x CO2

Table 1a — Data on fuel, energy, and CO2 emissions for U.S. domestic service, 2006

TEBD 28th edition, data for 2007

Domestic air carriers	1,847	trillion Btu, 2007, Domestic air carriers, TEBD Table 2.5
International air carriers	419	trillion btu, international air carriers, 2007
General aviation	205	trillion btu, general aviation, 2007 (jet fuel only)

TEBD 28, 2008, Table 2-12: certificated route	
6,122	vehicle miles (millions)
595,327	passenger-miles (millions)
97.24	load factor (persons/veh)
301,684	Btu per vehicle-mile
3,102	Btu per passenger-mile
1,847	Total energy use (trillion Btu)
135,000	heat content (Btu per gallon)

ORNL Transportation Energy Data Book
http://cta.ornl.gov/data/index.shtml

Table 1b

	0.0230	gallons per pax-mile, 2007
	21.088	lb CO2e per gallon of jet fuel (Table 2c)
U.S. domestic service, 2007	0.4846	US average lb CO2e/passenger-mile, 2007
DEFRA, "long-haul" service, 2007	0.3747	lb CO2/passenger-mile (international)
CMS, ASE-DEN short haul service	0.9615	lb CO2/passenger-mile (DEN-ASE)

Table 2a — Calculation of emission coefficients for Jet Fuel

19.33	kgC/million Btu (EPA 2008: Annex 2: Methodology, Table A-30)
70.83	kg CO2/million Btu (CMS result above)
42.61	lb C/million Btu
3.66	CO2/C
156.15	lb CO2 "content"/million Btu
135,000	heat content of Jet Fuel (Btu per gallon)
7.41	gallons per million Btu
21.08	lb CO2 "content"/gallon
0.99	oxydation factor (per IPCC 1997; EPA Annex 2: Methodology)
20.87	lb CO2 emission factor per gallon of Jet Fuel, 2006

Table 2b — Methane & nitous oxide emission coefficients (Jet Fuel, per EIA 1605)

70.88	kg CO2/million Btu (EIA 2008 Form 1605 Instructions, App'x H: Fuel Emission Factors)
0.27	g CH4/gallon Jet Fuel
0.01	kg CO2e of methane emissions per gallon Jet
0.31	g N2O /gallon Jet Fuel
0.09	kg CO2e of nitrous emissions per gallon Jet
0.10	kg CO2e (methane + nitrous) per gallon Jet Fuel
70.98	Final total EIA: kg CO2e per gallon

Table 2c — Final CMS-calculated jet fuel coefficient w methane & nitrous & oxidation factor

70.93	CMS: kg CO2e per gallon (no methane & nitrous, before oxidation factor)
21.080	lb CO2 "content" per gallon (before oxidation factor)
20.869	lb CO2 emission factor per gallon (with oxidation factor applied)
0.219	lb CO2e (methane + nitrous) per gallon Jet Fuel
21.299	CMS: lb CO2e per gallon before oxidation factor
21.088	Final total CMS: lb CO2e per gallon Jet Fuel with oxidation factor CMS uses this factor in aviation emissions, and includes methane and nitrous oxide emissions & oxidation factor (99 percent)
156.21	lb CO2e per million Btu

Table 2d — Average per passenger-mile emission factors, various sources & years

year	lb CO2/pax-mile	notes
Sep06-Dec08	0.5452	CMS field research: 37 US flights average
Sep06-Dec08	0.4279	37 flights: total CO2 / (total miles * ave pax load)
2004 (TEBD)	0.5740	CMS: US domestic average (TEBD-25)
2005 (TEBD)	0.5048	CMS: US domestic average (TEBD-26)
2006 (TEBD)	0.5094	CO2e; CMS: US domestic average (TEBD-27)
2007 (TEBD)	0.4846	CO2e; CMS: US domestic average (TEBD-28)

Table 3 — Airline Fuel Cost and Consumption (All carriers - Scheduled)

	Domestic			International			Total		
	Consumption (million gallons)	Cost (million dollars)	Cost per Gallon (dollars)	Consumption (million gallons)	Cost (million dollars)	Cost per Gallon (dollars)	Consumption (million gallons)	Cost (million dollars)	Cost per Gallon (dollars)
2000	13,904	$ 10,811	$ 0.78	5,123	$ 4,388	$ 0.86	19,026	$ 15,198	$ 0.80
2001	13,112	$ 10,025	$ 0.76	4,956	$ 3,990	$ 0.81	18,068	$ 14,014	$ 0.78
2002	12,287	$ 8,603	$ 0.70	4,572	$ 3,335	$ 0.73	16,859	$ 11,938	$ 0.71
2003	12,417	$ 10,315	$ 0.83	4,451	$ 3,838	$ 0.86	16,868	$ 14,154	$ 0.84
2004	13,380	$ 15,141	$ 1.13	4,765	$ 5,691	$ 1.19	18,145	$ 20,832	$ 1.15
2005	13,271	$ 21,658	$ 1.63	5,040	$ 8,601	$ 1.71	18,311	$ 30,258	$ 1.65
2006	12,907	$ 24,881	$ 1.93	5,221	$ 10,536	$ 2.02	18,128	$ 35,417	$ 1.95
2007	12,877	$ 26,628	$ 2.07	5,428	$ 11,684	$ 2.15	18,304	$ 38,312	$ 2.09
2008 (Jan-Oct)	10,468	$ 32,611	$ 3.12	4,671	$ 15,759	$ 3.37	15,138	$ 48,369	$ 3.20

Table 4 — FAA / Bureau of Transportation Statistics

	Scheduled Service						All Services		
	Revenue Pax Enplanements	Revenue Pax ton-miles	Rev. Freight ton-miles	Over-all avail ton-miles	Over-all rev. load factor	Aircraft Rev. Departures	Revenue Pax ton-miles	Rev. Freight ton-miles	Over-all avail ton-miles
	millions	millions	millions	millions	percent	millions	millions	millions	millions
2000	666	69,250	21,143	158,878	58.4%	9.0	70,800	30,221	172,574
2004	703	73,368	26,682	171,650	59.0%	11.4	75,207	37,958	171,650
2005	739	77,901	26,841	178,969	59.2%	11.6	79,512	39,292	200,282
2006	744	79,680	28,233	179,454	60.8%	11.3	80,946	39,754	198,937
2007	769	82,849	28,585	184,759	60.8%	11.4	84,098	39,842	204,328

Airline Activity, Oct06-Sep07, National Summary, U.S. Flights): 676 million passengers   www.transtats.bts.gov/

Table 2e — TEBD 27, 2008, Table 9-2: U.S. domestic & international certificated route

8,220	vehicle miles (millions)
810,098	passenger-miles (millions)
3,266	Btu per passenger-mile
2,646	Total energy use (trillion Btu)
135,000	heat content (Btu per gallon)
0.0242	gallons per pax-mile, 2006
21.09	lb CO2e per gallon of jet fuel (Table 2c)
0.5102	US average lb CO2e/passenger-mile, 2006

ORNL Transportation Energy Data Book
http://cta.ornl.gov/data/index.shtml

CMS note: very slight difference btw Table 1 (domestic) and Table 2e (dom & int).

Cell: M12
Comment: Rick Heede:
Jet fuel varies slightly in quality from year to year (19.40 kgC in 1990, but at 19.33 kgC since 1996; EPA (2008) Inventory of US GHG 1990-2006, Annex 2: Methodology, Table A-30)

Cell: D13
Comment: Rick Heede:
Domestic air carriers' domestic consumption only; see below for international air carriers and general aviation.

Cell: D14
Comment: Rick Heede:
"One half of fuel used by domestic carriers in international operation." Fn C.

Cell: D15
Comment: Rick Heede:
TEBD Table 2.5, 2007: 204.7 trillion Btu (jet fuel), plus 38.9 trillion Btu (AvGas). Table 2.12 shows 231,600 GA aircraft.

Cell: E27
Comment: Rick Heede (Jan09):
CMS re-calculated the emission coefficient for jet fuel in Tables 2a, 2b, and 2c, which is based on EIA and EPA factor of 19.33 kg carbon per million Btu and accounts for both associated methane and nitrous oxide emissions (EIA fuel factors) and the fuel oxidation factor (99 percent oxidation to CO2). The result is 21.088 lb CO2e per gallon of jet fuel.

The conventional EIA factor is slightly higher, at 21.095 lb CO2 per gallon, since the methane and nitrous adjustment compensates for EIA's non-consideration of the oxidation factor (although the EPA and IPCC list the oxidation factor as 99 percent, as used here).

Cell: E30
Comment: Rick Heede:
CMS adopts DEFRA emission factor for "long haul" (>6,482 km or 4,028 miles), revised in 2007 to 0.1056 kg CO2 per passenger km, which converts to 0.3747 lb CO2 per passenger-mile. CMS uses this factor for international flights in the Aspen GHG inventory for 2007.

CMS note: while DEFRA is the oft-cited source (e.g, basis for WRI's air travel factors), CMS considers this factor on the high side for long haul flights. The reason is personal experience and actual fuel consumption data for longer domestic flights taken from Sep06-Dec08 with higher load factors and that trended toward ~0.3 lb CO2/pax-mile. Some flights with high load factor were lower (e..g, 0.22 lb CO2/pax-mile). CMS has not taken an international flight in recent years. CMS applies the DEFRA factor but anticipates further research by DEFRA and other institutions will result in lowered emission factors for long haul flights in the near future. Shorter flights, however, are likely to increase toward 1.0 lb CO2/pax-mile -- up from the current DEFRA datum of 0.561 lb CO2/pax-mile.

UK DEFRA (2007) Passenger transport emissions factors: Methodology paper, London, 17 pp

Cell: E32
Comment: Rick Heede (Jan09):
CMS has calculated the fuel consumption and emission factor based on CMS acquisition of fuel data and passenger loading for 15 specific flights between Aspen and Denver (ASE & DEN) taken by CMS principal Rick Heede from Sep06 to May09.

Emission factors ranged from low of 0.603 lb CO2 per passenger-mile (DASH-8, 750 lb fuel, 32 of 37 pax, Sep08) to a high of of 3.82 lb CO2 per passenger-mile (CRJ700, 2,452 lb fuel, 16 of 66 pax, Dec08). A simple average of all 13 flights is 1.174 lb CO2/pax-mile.

A more reasonable calculation is to divide total emissions for all flights (68,412 lb CO2) by the product of total miles flown (1,704 miles) and average load (41.2 passengers) for an average emission factor of 0.9615 lb CO2/pax-mile. CMS applies this factor to the Denver to Aspen (and return) portion of each deplaning passenger arriving in Aspen (177,630 pax) or departing Aspen (183,632 pax) in 2007.

Note: CMS will attempt to disaggregate total passenger enplanements heading to Denver vs enplaning on flights with other destinations (e.g., SLC, LAX, CHI, etc).

Cell: N45
Comment: Rick Heede (Jan09):
CMS requested specific fuel consumption data "gate to gate" from the pilot after each of 37 flights taken from Sep06 through Dec08, but excluding 13 legs from Aspen to Denver or vice versa. These flights were chiefly on United Airlines (also Delta and Continental) in Airbus 320s, Boeing 737 and 777 and 767 and 757, Embraer, and CRJ200 and 700 aircraft on distances ranging from 40 to 2900 nmiles and load factors averaging 88.9 percent. Fuel consumption on all 37 flights totaled 430,700 lb, total distance flown was 28,772 miles (24,997 nm), and emissions of 1.34 million lb CO2. Emissions averaged 0.5452 lb CO2 per passenger mile for this set of flights. Average load factor of 88.9 percent.

See note below for alternate calculation. CMS field research is presented for comparison purposes only, and are not used to calculate emissions for the Aspen inventory -- except for the short haul between Aspen and Denver for which national or official data is unavailable.

Cell: N46
Comment: Rick Heede:

Instead of averaging the lb CO_2/pax-mile for the 37 flights (as done above), this measure calculates the average differently: total emissions for all flights based on fuel data divided by (total miles flown times average passengers onboard). Which, for the 37 flights Sep-6-Dec08, is 1.34 million lb CO_2 / (28,772 miles times 109 pax) = 0.4279 lb CO_2/pax-mile. This calculation is a reasonable metric, but is made here for comparison purposes only.

Cell: N47
Comment: Rick Heede:
CMS calculated average per passenger mile emissions of 0.5740 lb CO_2/pax-mile in 2004 using the same source as the above calculation for 2006: ORNL's TEBD, various tables.

Cell: N48
Comment: Rick Heede:
CMS calculated average per passenger mile emissions of 0.5048 lb CO_2/pax-mile in 2005 using the same source as the above calculation for 2006: ORNL's TEBD, various tables.

Cell: N49
Comment: Rick Heede:
CMS calculation of ORNL TEBD data for year 2006. Methodology has been revised and improved to account for oxidation factor of 99 percent (ie., non-combustion of 1 percent of the carbon in the fuel) as well as inclusion of methane and nitrous oxide emissions (data from EIA 1605 emission factors). This revision changes the emission factor from 21.095 lb CO_2/pax-mile in 2004 to 21.088 lb CO_2e/pax-mile in 2006.

Cell: N50
Comment: Rick Heede:
CMS calculation of ORNL TEBD data for year 2006. Methodology has been revised and improved to account for oxidation factor of 99 percent (ie., non-combustion of 1 percent of the carbon in the fuel) as well as inclusion of methane and nitrous oxide emissions (data from EIA 1605 emission factors). This revision changes the emission factor from 21.095 lb CO_2/pax-mile in 2004 to 21.088 lb CO_2e/pax-mile in 2006.

Jackson Hole Energy & Emissions Inventory: Teton County Landfill: Emissions and Savings

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 1 June 2009
File last modified: 21 August 2009

Future inventorists must update electricity and diesel fuel purchased by the Sublette 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.

Dr. Jean Bogner
Landfills +, Inc.
630-665-0872

Data provided by:
Heather Overholser
Exec Dir.
Jackson Community Recycling
307-733-7678
hoverholser@tetonwyo.org

Data provided by:
Brad Klingman
Solid Waste Manager
& Sherri Dimit
Sublette County Landfill
307-276-5792
scwm@wyoming.com

Table 1: Emissions	Electricity	Fuel consumed	Carbon factor	Methane emissions	Methane factor	Attributed to Teton County	Carbon dioxide (Teton's share)	Carbon (Aspen's share)
Sublette County Landfill	kWh	gallons	lb CO2/kWh & /gallon	tons CH4	tons CO2e	Percent	tons CO2e	tonnes carbon (C-eq)
	Update this column	Update this column			Methane GWP: 25xCO2			
Electricity	10,848		2.202			62.7%	7	2
Propane		4,121	12.67			62.7%	16	
Fuel consumption (diesel)		19,042	22.38			62.7%	134	33
Fuel consumption (gasoline)		1,889	19.59			62.7%	12	3
Fugitive methane (from Table 2)	(update cell note)			507	12,670	62.7%	7,950	1,968
Total Sublette County Landfill attributed to Jackson Hole							8,119	2,010
Teton County share of Sublette County Landfill wastes	29,577	47,138	Teton percent:	62.7%		Teton's share of CH4	318.0	tons CH4

Table 2 Estimated methane generation and emissions, 2007	tons methane
Methane generated (low: 295 cfm)	3,285
Methane generated (high: 483 cfm)	5,378
Methane emitted (low: 1,023 tonnes)	1,128
Methane emitted (high: 1,440 tonnes)	1,587
Methane emitted (average of high and low)	1,357

Golder Associates (2007) *Landfill Gas Evaluation of the Pitkin County Solid Waste Center*, Lakewood CO, 41 p., www.golder.c

Table 3 Preliminary est. of Sublette methane: proxy of Pitkin County	Waste-in-place, cu. Yds	Est. methane leakage
Pitkin County Landfill	27,000,000	1,357
Sublette County Landfill	13,440,000	507
Percent Sublette of Pitk	49.8%	
Reduce factor by 25%	37.3%	as a conservatism

Table 4 Waste hauling truck fuel economy	
Loads, 2008	1,398
Average loads per day	5.38
Waste hauled, tons	29,771
Miles, one-way	84
Total truck miles	234,864
Truck mpg	4.56
Waste per capita, lbs	2,922
Recycling per capita, lbs	1,560

Teton County waste hauling to Sublette County	Table 5	gallons		CO2 per gallon		tons CO2e	tonnes carbon (C-eq)
		Update this column					
Waste transfer trucks (TTS to Sublette County Landfill)		51,492		22.38	100%	576	143
Total Teton County waste hauling		51,492	-			576	143

1,000 cf methane = 42.37 lb

Table 6: Saved emissions (recycling)	Quantities Recycled and Sold	CO2e savings per tonne recycled	Total Teton County CO2e savings	Attributed to Teton County	Teton's share, CO2e	Teton's share, Ce		Teton County population, 2008
	tonnes	tonnes CO2e/tonne	tons CO2e	Percent	tons CO2e/yr	tonnes carbon (C-eq)		20,376
Jackson Community Recycling: recycled items								recycling rate: lb/cap-yr
Aluminum Cans	21	15.7	355	100%	355	88		2.2
Office Paper	201	5.4	1,198	100%	1,198	297		22
Corrugated Cardboard	1,434	3.0	4,743	100%	4,743	1,174		155
Glass / all colors	1,168	0.4	515	100%	515	128		126
Magazines	485		-	100%	-	-		53
Newspapers	702	2.5	1,934	100%	1,934	479		76
Telephone Directories	33		-	100%	-	-		3.6
Steel Food Cans	55	2.3	139	100%	139	34		5.9
Scrap Metal	15		-	100%	-	-		1.6
Bottles #2 HDPE	18	1.5	30	100%	30	7		2.0
Bottles #1 PET	53	2.5	147	100%	147	36		5.8
Plastic Bags	6	2.0	12	100%	12	3		0.6
Hazardous Waste	33	na		100%	-	-		3.6
Electronic Waste	40		-	100%	-	-		4.3
Subtotal JCR recycling	4,264				9,074	2,247		461
Teton Transfer Station: recycled items						-		
Glass / all colors	6	0.4	2	100%	2	1	tonne = 1,000 kg	0.6
Scrap Metal	796		-	100%	-	-	ton = 2000 lb	86
Concrete (TTS)	987		-	100%	-	-	1 tonne = 1.1023 ton	107
Tires (TTS)	31		-	100%	-	-	1 kg = 2.2046 lb	3.4
Wood/Compostables (TTS)	8,330		-	100%	-	-		901
Subtotal TTS recycling	10,150			100%	2	1		1,098
Total recycling savings	14,414	na	8,722	100%	9,076	2,247		1,560
Note: This savings estimate is generic and does not necessarily reflect local collection or disposal energy expenditures vs savings.								Aluminum

Cell: F13
Comment: Rick Heede (2005):
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.

Jan09 update: CMS adopts the IPCC Fourth Assessment Report's revised GWP factor for methane, up from 23xCO2 to 25xCO2 (one hundred year time horizon).

Cell: G13
Comment: Heede (Feb09):
Energy Information Administration (2008) Emissions of Greenhouse Gases in the United States 2007. GWP, methodolgoy, p 12: Methane. In its Fourth Assessment Report, the IPCC developed revised global warming potential factors (GWPs) for selected gases. The GWP for methane was revised from the previous value of 23 in the IPCC's Third Assessment Report to 25 in the Fourth Assessment Report. The revised GWP for methane is used in this report. In addition, this report incorporates an increase in the density of methane from 42.28 to 42.37 pounds per thousand cubic feet, in order to provide consistent temperature and pressure values for methane in all EIA data.

Cell: H13
Comment: Rick Heede:
Klingman: ~62 percent of annual waste received is hauled in from Teton County.

Cell: B14
Comment: Rick Heede:
Fuel and electricity consumption in 2008 from Sherri Dimit.

Cell: E16
Comment: Rick Heede (Jul09):
CMS uses emission rates for Sublette County Landfill's electricity provider (PacifiCorp Rocky Mountains) data from EPA eGRID 2005 CMS is using the eGRID EGCO05 file, row 1251: 2,207.17 CO2/MWh. Sherri sent fuel & elec usage.

Other data: PacifiCorp-East 2,151.4 lb CO2/MWh (West: 609.7 CO2/MWh) in PCAL05 row 77.

Cell: B20
Comment: Heede (Aug09):
CMS estimates Jackson Hole's emissions of methane from its waste-in-place and annual contributions to the Sublette County Landfill. Sublette does not quantify its emissions of methane from the anearobic digestion of buried biological materials, although it may be required to do so in the near future when its waste-in-place exceeds the reporting requirement. CMS roughly estimates Sublette Landfill's methane emissions on the basis of waste-in-place compared to the Pitkin County Landfill, whose methane emissions have been carefully quantified. See the cell notes under Table 3 below for details.

CMS adopts the findings of the Golder Associates report (2007), averaging the high and low estimates of total methane emitted (1,023 to 1,440 tonnes CH4 in 2007), or average of 1,357 (short) tons CH4. CMS also adopts the IPCC FAR GWP value of methane at 25xCO2. See cell notes to Tables 1 and 2.

Cell: C26
Comment: Rick Heede:
Golder Associates (2007) Landfill Gas Evaluation of the Pitkin County Solid Waste Center, Lakewood CO, 41 pp., Table 1.

Golder estimates that between 1,907 and 3,356 tonnes of methane is recoverable (2007), rising to 2,562 to 4,161 tonnes per year at peak in 2021. At $20 per tonne carbon credit, this recovery is worth $128,000 - $245,000 (2007), rising to $171,000 - $ $303,000 in 2021.

Cell: G26
Comment: Rick Heede:
Sublette County Landfill has waste-in-place slightly below the threshhold that would require an estimate of fugitive methane to be made and filed with the State Dept of Env Quality and the U.S. EPA. (Dob Doctor WY DEQ, July09.)

In lieu of a formal estimate of Sublette's emissions of methane -- using EPA's LandGEMS software, for example, in which CMS is not proficient -- CMS submits a very preliminary estimate of Sublette's methane emissions based on Pitkin County's waste-in-place and substantiated emissions (see the Golder Associates report cited at Table 2).

Climate, precipitation, waste-in-place, waste composition, landfill cover, age of waste, biological factors, altitude, and other factors affect actual or estimated emissions of methane. CMS assumes that Pitkin County's landfill has similiar characteristics and that its annual methane rate is proportionally similar to Sublette County Landfill's emission rate as a fraction of each landfill's waste-in-place, as shown in this table.

As a conservatism, and until a thorough estimate of Sublette's actual methane rate can be estimated, CMS reduces the proportional emission rate by one-quarter (i.e., from 49.8 percent * 75% = 37.4 percent). Sublette equals, in this calculation, 1,357 tons of methane times 37.4 percent = 507.5 tons of methane.

In Table 1 above, 62.7 percent of Sublette's total emissions will be attributed to Teton County based on the annual contribution of waste originating in Teton County.

These calculations are preliminary, and CMS encourages the WY DEQ or Sublette County Landfill to revise and improve this estimate.

Cell: J26

Comment: Rick Heede:
Data from Dennis Miserany, WestBank Sanitation. They run three FreightRunner trucks (FreightLiner) five days per week.

Cell: E30
Comment: Information Systems:
Sherri Dimit: “As of June 2009 it is estimated that 1,344,000 cubic yards of landfill capacity has been consumed with the total landfill capacity estimated at 14,850,000 cubic yards. “

Cell: B36
Comment: Rick Heede (Jun09):
WasteBank Sanitation is local operator of waste transfer to Sublette County Landfill for Waste Connections, Inc., a large trash hauler serving most of US. Data from Dennis Miserany, 25Jun09:

1,398 loads in 2008, 29,771 tons transferred, 84 miles one-way, 51,491.6 gallons diesel, 3 FreightRunner (FreightLiner) trucks.

Cell: C42
Comment: Rick Heede (Jun09):
Data from Overholser for FY2008.

Cell: D42
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: G42
Comment: Rick Heede:
We allocate 50 percent of the savings from recycled materials to Aspen.

Cell: J42
Comment: Rick Heede:
http://quickfacts.census.gov/qfd/states/56/56039.html
Population, 2008 estimate: 20,376

Cell: B54
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: J68
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.

Jackson Hole Emissions Inventory: Nitrous Oxide Sources, 2008

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 1 June 2009
File last modified: 31 August 2009

Update data on fertilizer applications rates on Town and County athletic fields and parks, local golf courses, Teton County School District, and privately-owned greenspace.

Data provided by

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Mike Kitchen
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Jackson Hole Golf & Tennis Club
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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 CO2e	tonnes C-eq	
	Update this column					296 x CO2		
Teton School District athletic fields	1,021	16.3	3.3	12.2	31.8	10.4	2.6	done
Town of Jackson & Teton County athletic fields and parks	2,371	37.9	7.6	28.5	74.0	24.1	6.0	done
Jackson Hole Golf & Tennis Club (update cell and data)		0.0	0.0	0.0	-	-	-	data not provided
Teton Pines Country Club & Resort	6,308	100.9	20.2	75.7	196.8	64.2	15.9	done
3 Creek Ranch Private Golf Club		0.0	0.0	0.0	-	-	-	data not provided
Shooting Star Golf, Teton Village (estimated)	5,928	94.8	19.0	71.1	184.9	60.3	14.9	data estimated
Snake River Sporting Club, Jackson, Wyoming		0.0	0.0	0.0	-	-	-	data not provided
Private greenspace in Teton County & Town of Jackson	1,434	22.9	4.6	17.2	44.7	14.6	3.6	done
Total Nitrous Oxide Emissions	**17,061**	**273**	**55**	**205**	**532**	**174**	**43**	

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: D17
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: E17
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: F17
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: H17
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: B20
Comment: Rick Heede (Jun09):
Kevin Thibeault, Teton Schools: “75 lbs of Nitrogen per acre” on ~30 acres of school athletic fields.

Cell: B21
Comment: Rick Heede (18Jun09):
Data from Al Zuckerman, Parks Superintendent: “Most of our fine turf is bluegrass and receives our highest level of care including regularly scheduled irrigation, mowing, aerating, topdressing, fertilizing, weed control, etc. We are responsible for turf care on government building grounds, athletic fields and parks. The fine turf amounts to approximately 48 acres. Other sites we maintain at a lower level of maintenance are our inventory of undeveloped open space that someday may be developed for more intense use. These undeveloped areas are typically planted in dryland grass mixtures or the original range grasses. At these sites we spray for noxious weeds and may mow them once or twice a year.
Because of the length of our growing season we typically make two fertilizer applications a year. One is in late June and the other is in the Fall after the grass stops growing but before it goes dormant. An example of what we commonly use for the application in June is 27-5-8 w4%Fe,7%S, 50% PSCU. We apply it at a rate of 1.5 lbs. per 1,000 square feet. This slow release application gets us through most of the growing season. The Fall application is urea, 46-0-0. We apply this at a rate of 1 lbs. per 1,000 square feet. This application stores energy in the roots and helps with spring green-up. So, we are applying about 2.5 lbs. of N per 1,000 square feet per year.
The formula is: =2.5*(48*43560/1000)/2.2046.

Cell: B23
Comment: Rick Heede (Jun09):
Greens and tees: 3.5 lb N per 1,000 sf: 5.5 acres, fairways and other turf: 3.0 lb N per 1,000 sf: 100 acres. Mike Kitchen, personal communication.

Cell: B25
Comment: Rick Heede:
New golf course. Bill Shrum, 4Aug09, Golf Course Mngr.: “Shooting Star will be completing and submitting an annual operations report at the end of each calendar year to both Teton County, WY and the Teton Conservation District. This report is to contain all nutrient applications and will be public information which you would be able to access.”
CMS made a preliminary estimate (cannot wait for Dec09): assume 100 acres of fertilized area and an application rate of 3.5 lbs N per 1,000 sf.

Cell: B27
Comment: Rick Heede:
CMS does not have purchase or application date for private yards and commercial properties by owners or contractors, and we (conservatively) assume the following:
That the County’s owner-occupied houses and condos -- 4,216 units -- average 500 sq ft of fertilized area (2.1 million sq ft), and that the application rate is 1.5 lb N per 1,000 sqft (equal to the Town of Jackson’s application rate on town parks and athletic fields). Thus 2,108 * 1.5 lb N = 3,162 lb N, or 1,435 kg N.
www.city-data.com/county/Teton_County-WY.html: County population in July 2007: 20,002; (55% urban, 45% rural); County owner-occupied houses and condos: 4,216.

Cell: E32
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

Jackson Hole Energy & Emissions Inventory: HFC & CFC refrigerants

Update data on the number of households and vehicles in Jackson and Teton County, and, if warranted, update leakage rates of refrigerants in various equipment types. All other computations are carried through to the sums below and are linked to the summary worksheet.
Future inventorists also need to confirm and/or revise the preliminary calculation of improper disposal of R-12 and R-134a refrigerant.

Richard Heede
Climate Mitigation Services
Snowmass, Colorado
File Started: 17 July 2009
Last Modified: 31 August 2009

Data from:
US Census Bureau
EIA RECS (household) data
IPCC Fourth Assessment Rpt
US EPA

Data from:
Vincent Cleary, Ayala, & Corey (2004) “Emissions of Hfc-134a From Light-Duty Vehicles in California,” California Air Resources Board, SAE, May04.

Table 1: Unit calculation	# of Households	# of Refrigerators	# of Freezers	# of Room ACs	# of Central AC	Total home refrigerant units	# of Vehicles	# of Vehicles with air conditioning
	#	ave. fridges/HH	ave. freezers/HH	ave. Room ACs/HH	ave. Central ACs	#	ave. vehicles/hh	vehicles w. AC/hh
	Update this column	1.18	0.35	0.0250	0.103		2.133	0.6
Jackson Hole households & appliances	12,160	14,349	4,256	304	1,246	20,155	25,937	15,562
Total households, appliances, & vehicles in Jackson Hole	12,160	14,349	4,256	304	1,246	20,155	25,937	15,562

Table 2: Leakage rate calculation for appliances		# of Refrigerators	# of Freezers	# of Room ACs	# of Central AC	Total home refrigerant units	Emissions	Emissions
		leakage rate (g/unit-yr)					GWP coefficient	tons CO2e
		2.000	1.500	1.000	5.000		1,430	
		kg HFC-134	kg HFC-134	kg HFC-134	kg HFC-134	kg HFC-134	tonnes CO2-e	tons CO2-e
Refrigerant leakage from all fridges, freezers, and AC units		28.70	6.38	0.30	6.23	41.62	59.51	66

Table 3: Refrigerant venting at appliance disposal	Units disposed 2008	R12	R134a	R12	R134a	R12	R134a	Emissions
CMS note: this calculation is speculative and must be verified in the next inventory		Charge per unit (g)	Charge per unit (g)	kg R-12 vented	kg HFC-134a vented	CO2e of R-12 vented	CO2e of HFC-134a	tons CO2e
Improper venting of refrigerant at appliance disposal	750	200	150	100	37.5	1,090	53.63	1,144

Table 4: Leakage rate calculation for vehicle ACs			leakage rate (g/veh-yr)			Total vehicle AC leakage	Tonnes of CO2 equivalent	Emissions
				40			GWP coefficient	tons CO2e
				kg HFC-134		kg HFC-134	1,300	
							tonnes CO2e	tons CO2e
Refrigerant leakage from automobile AC units				622.49		622.49	809.24	892

Total halocarbon emissions, in tons CO2e	2,101

Table 5	HFC-134a leakage rate using Cal Air Resources Board data	
	Cal Air Resources Board, HFC-134a loss per vehicle, grams/yr:	80.00
	Average refrigerant charge per vehicle:	800.0
	Average leakage rate per light-duty vehicle per annum:	10.00%

http://quickfacts.census.gov/qfd/states/56/56039.html
Population, 2008 estimate 20,376; Housing units, 2007 12,160

Table 6	Global Warming Potential (GWP), by refrigerant species			
	R12	R22	R134a	R404A
	R12 GWP	R22 GWP	R134a GWP	R404a GWP
GWP factor FAR	10,900	1,810	1,430	3,260
GWP factor SAR	8,100	1,500	1,300	3,260

Cell: D14
Comment: Rick Heede:
Energy Information Administration (2005) Residential Energy Consumption Survey, Table D8. Appliances in Mountain Households, Selected Years, 1980-2001. www.eia.doe.gov/emeu/consumption/index.html

Data for 2001: 82 percent of 7 million "Mountain Households" have one refrigerator, and 18 percent have two or more. The average household thus has (assuming that none have three or more) 1.18 refrigerators. This does not include "separate freezers" (35 percent).

Cell: E14
Comment: Rick Heede:
Energy Information Administration (2005) Residential Energy Consumption Survey, Table D8. Appliances in Mountain Households, Selected Years, 1980-2001. www.eia.doe.gov/emeu/consumption/index.html

Data for 2001: 35 percent of 7 million "Mountain Households" have an additional freezer. The average household thus has 0.35 freezers (in additional, that is, to those in refrigerators).

Cell: F14
Comment: Rick Heede:
Ditto as for Central AC: 10 percent of Mountain Households have room AC units, of which CMS assumes one-quarter for Jackson's cooler climate, or 0.1/4 = 0.025.

Cell: G14
Comment: Rick Heede:
Energy Information Administration (2005) Residential Energy Consumption Survey, Table D8. Appliances in Mountain Households, Selected Years, 1980-2001. www.eia.doe.gov/emeu/consumption/index.html

Data for 2001: 41 percent of 7 million "Mountain Households" have Central AC. CMS has not verified the installation rate of Central air conditioning in Jackson's cooler high-altitude climate; CMS assumes that one-quarter of the Mountain Central AC rate for JAckson Hole, The average household thus has 0.41/4 Central AC equals 0.1 per household.

Cell: I14
Comment: Rick Heede:
US Bureau of the Census, in NREL TEDB 28th edition, Table 8.2: 244.0 million household vehicles / 114.4 million US households in 2006 = 2.133 veh/hh. Also 26,352 miles driven per hh per year.

Cell: B17
Comment: Rick Heede:
Teton County data: www.city-data.com/county/Teton_County-WY.html: County population in July 2007: 20,002; (55% urban, 45% rural); County owner-occupied houses and condos: 4,216; Renter-occupied apartments: 3,472;

http://quickfacts.census.gov/qfd/states/56/56039.html
Population, 2008 estimate 20,376; Housing units, 2007 12,160

Cell: F22
Comment: Rick Heede:
"Pin holes, corrosion, mechanical fatigue and other issues yield average leakage rates from 1 to 3 grams per year from world class production processes. Failures typically are early in life from manufacturing defects, or much later in life from cumulative wear out effects."

"Domestic refrigerators typically contain a 50 to 200 gram refrigerant charge."

Globally, "refrigerators annually consume approximately 17,500 metric tons of refrigerant. Two-thirds of this is required for the 75,000,000 new refrigerators. The other one-third is used during the 4.5 to 5 million field repair procedures necessary to service the approximate 1.5 billion units in the installed base."

McInerney et al (1999) "Refrigerant Emission Control Opportunities."

CMS assumes an average refrigerant charge of 150 grams and a leakage rate of 2.0 g per refrigerator (toward the lower end of the range cited above). CMS also assumes a lower leakage rate for freezers (1.5 g/yr) and room ACs (1.0 g/yr), and 5.0 g/yr for central AC units.

Cell: B32
Comment: Rick Heede:
Teton County Solid Waste Transfer Facility accepts HFC and CFC-containing appliances, and requires that the Recycling Center hire a qualified refrigerant recovery specialist to remove and properly dispose of the refrigerant charge before the appliance is disposed of. However, CMS has learned that most if not all of the "recovered" refrigerant is simply vented to the atmosphere. CMS has not verified this process. CMS estimates the annual emissions of both R-12 and HFC-134a refrigerants.

According to one (confidential) estimate, 3 to 4 appliances such as refrigerators and freezers are pumped out per day but their refrigerant improperly disposed of, that is, vented to the atmosphere rather than destroyed or sent to a disposal center. CMS assumes 3 appliances per weekday, since this data is not tracked, and that 2 such appliances are old and contain 200 g of R-12 refrigerant, and 1 is a newer units charged with 150 g of HFC-134a.

Future research may elucidate this issue and cause the CMS estimate to be revised.

Cell: F35
Comment: Rick Heede:
Vincent, Richard C., Kevin William Cleary, Alberto Ayala, & Richard Corey (2004) "Emissions of Hfc-134a From Light-Duty Vehicles in California," California Air Resources Board, Society of Automotive Engineers, May04, SAE # 2004-01-2256.

Abstract: The current refrigerant in mobile air conditioning (AC) systems, HFC-134a (also known as R134a), is a potent greenhouse gas (GHG) with a global-warming potential (GWP) of 1300. Its emissions from 2009 and subsequent model-year (MY) light-duty vehicles may be regulated under the terms of a law (Sec. 43108.5, Health and Safety Code) adopted in California in 2002. To support regulation development, we have estimated direct emissions of HFC-134a from vehicular AC systems in California by a novel, three-prong method that uses: 1) data on the consumption of HFC-134a by California commercial fleets, 2) surveys of vehicle owners on AC system repair incidence, and 3) data on repair incidence among California commercial fleet vehicles. Although these sources do not report direct emission rates of HFC-134a, the data reflect actual leakage integrated over long periods from vehicles in all stages of useful life. Results from the analysis suggest that in California, the typical light-duty vehicle loses approximately 1.4 kg of HFC-134a over a 16-year average lifetime, and HFC-134a emissions in 2003 were approximately 80 grams per vehicle. These results are consistent with the limited data available from emission measurements but less than the estimates annually published by U.S. EPA.

Note: CMS, as a conservatism, reduces this leakage rate by half to 40 grams per vehicle per year (at least until the high -- 80 g/yr -- leakage rate cited above is confirmed).

EPA's Mobile Air Conditioning Climate Protection Partnership. "In the United States alone, vehicle air conditioners consume 7 billion gallons of gasoline every year, equivalent to over 16 million metric tons of carbon equivalent (MMTCE). Refrigerant leakage adds another 8.7 MMTCE to atmospheric emissions of greenhouse gases."

"The Mobile Air Conditioning Climate Protection partnership is making great progress. On Earth Day 2004, it announced the Improved Mobile Air Conditioning (IMAC) 30/50 project with ambitious goals to reduce vehicle air conditioning fuel consumption by at least 30 percent and cut refrigerant emissions by 50 percent."

"The greenhouse gas reduction calculation is based on tests conducted by the Society of Automotive Engineers and industry data.
The new machines recover an average of 120 grams more HFC-134a refrigerant ea
AC systems are professionally repaired 20 to 25 million times per year
20 million repairs saving 120 grams each = one million metric tons of carbon equivalent."

www.epa.gov/cppd/mac/

Cell: D46
Comment: Rick Heede:
Vincent, Richard C., Kevin William Cleary, Alberto Ayala, & Richard Corey (2004) "Emissions of Hfc-134a From Light-Duty Vehicles in California," California Air Resources Board, Society of Automotive Engineers, May04, SAE # 2004-01-2256.

Abstract: The current refrigerant in mobile air conditioning (AC) systems, HFC-134a (also known as R134a), is a potent greenhouse gas (GHG) with a global-warming potential (GWP) of 1300. Its emissions from 2009 and subsequent model-year (MY) light-duty vehicles may be regulated under the terms of a law (Sec. 43108.5, Health and Safety Code) adopted in California in 2002. To support regulation development, we have estimated direct emissions of HFC-134a from vehicular AC systems in California by a novel, three-prong method that uses: 1) data on the consumption of HFC-134a by California commercial fleets, 2) surveys of vehicle owners on AC system repair incidence, and 3) data on repair incidence among California commercial fleet vehicles. Although these sources do not report direct emission rates of HFC-134a, the data reflect actual leakage integrated over long periods from vehicles in all stages of useful life. Results from the analysis suggest that in California, the typical light-duty vehicle loses approximately 1.4 kg of HFC-134a over a 16-year average lifetime, and HFC-134a emissions in 2003 were approximately 80 grams per vehicle. These results are consistent with the limited data available from emission measurements but less than the estimates annually published by U.S. EPA.

Cell: C54
Comment: Rick Heede:
IPCC (2007) Fourth Assessment Report, Physical Science Basis, p. 212.

Cell: G54
Comment: Rick Heede:
IPCC FAR does not list R404a GWP. ICLEI (2008), p. 151 shows SAR GWP value as 3,260xCO_2 (100-year time horizon). SAR values for R12: 8,100xCO_2, R22: 1,500xCO_2, and R134a: 1,300xCO_2.