California Energy Commission

Energy and Greenhouse Gas Emissions Accounting

Energy Aware Planning Guide Workshop

February 18, 2010

Pierre duVair, Ph.D.

Special Projects Office

Fuels & Transportation Division

What are GHGs?

The main greenhouse gases

Greenhouse gases	Chemical formula	Pre-industrial concentration	Concentration in 1994	Atmospheric lifetime (years)***	Anthropogenic sources	Global warming potential (GWP)*
Carbon-dioxide	CO_2	278 000 ppbv	358 000 ppbv	Variable	Fossil fuel combustion Land use conversion Cement production	1
Methane	CH_4	700 ppbv	1721 ppbv	12,2 +/- 3	Fossil fuels Rice paddies Waste dumps Livestock	21 **
Nitrous oxide	N_2O	275 ppbv	311 ppbv	120	Fertilizer industrial processes combustion	310
CFC-12	CCl_2F_2	0	0,503 ppbv	102	Liquid coolants. Foams	6200-7100 ****
HCFC-22	$CHClF_2$	0	0,105 ppbv	12,1	Liquid coolants	1300-1400 ****
Perfluoromethane	CF_4	0	0,070 ppbv	50 000	Production of aluminium	6 500
Sulphur hexa-fluoride	SF_6	0	0,032 ppbv	3 200	Dielectric fluid	23 900

Note : pptv= 1 part per trillion by volume; ppbv= 1 part per billion by volume, ppmv= 1 part per million by volume

* GWP for 100 year time horizon. ** Includes indirect effects of tropospheric ozone production and stratospheric water vapour production. *** On page 15 of the IPCC SAR. No single lifetime for CO_2 can be defined because of the different rates of uptake by different sink processes.**** Net global warming potential (i.e., including the indirect effect due to ozone depletion).

GRID Arendal UNEP

Source: IPCC radiative forcing report ; Climate change 1995, The science of climate change, contribution of working groupe 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

California Energy Commission

Appendix C Calculation References

Converting to CO_2 Equivalent

To incorporate and evaluate non-CO_2 gases in your GHG emissions inventory, the mass estimates of these gases will need to be converted to CO_2 equivalent (CO_2e). To do this, multiply the emissions in units of mass by the GHGs global warming potential (GWP).

Global warming potentials were developed by the Intergovernmental Panel on Climate Change (IPCC) to quantify the globally averaged relative radiative forcing effects of a given GHG, using carbon dioxide as the reference gas. In 1996, the IPCC published a set of GWPs for the most commonly measured greenhouse gases in its Second Assessment Report (SAR). In 2001, the IPCC published its Third Assessment Report (TAR), which adjusted the GWPs to reflect new information on atmospheric lifetimes and an improved calculation of the radiative forcing of carbon dioxide. However, SAR GWPs are still used by international convention and the U.S. to maintain the value of the carbon dioxide "currency". To maintain consistency with international practice, the California Registry requires participants to use GWPs from the SAR for calculating their emissions inventory.

Table C.1 lists the 100-year GWPs from SAR and TAR. The equation above provides the basic calculation required to determine CO_2e from the total mass of a given GHG using the GWPs published by the IPCC.

Converting Mass Estimates to Carbon Dioxide Equivalent			
Metric Tons of CO_2e	=	Metric Tons of GHG	x GWP

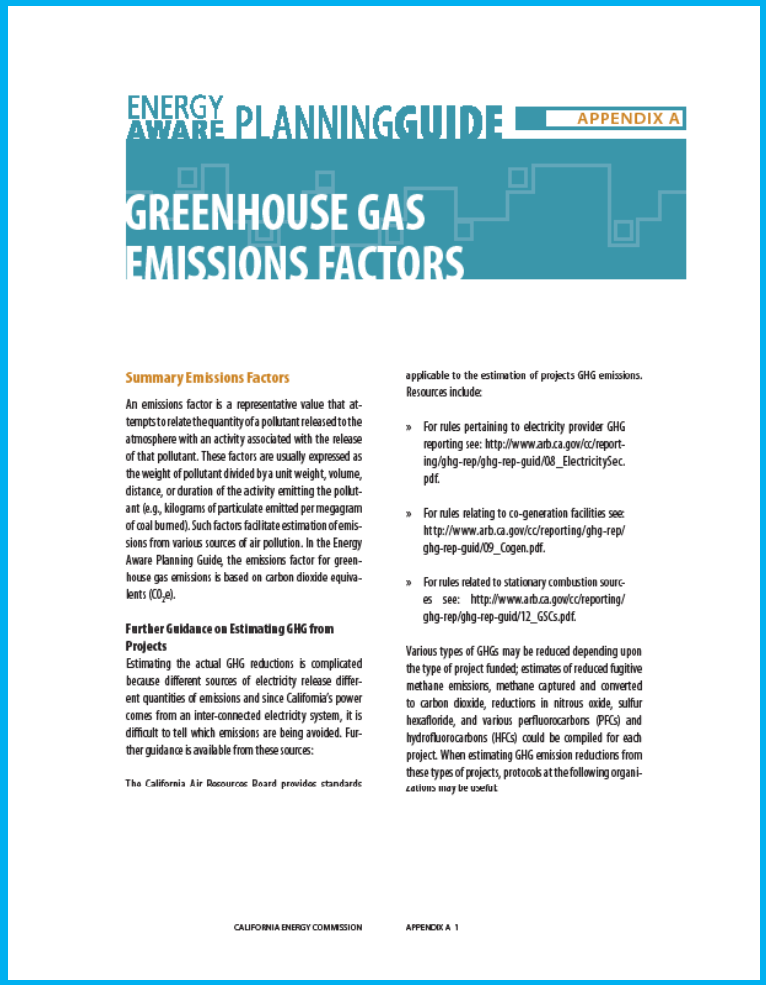
Table C.1 Comparison of GWPs from the IPCC's Second and Third Assessment Reports

Greenhouse Gas	GWP (SAR, 1996)	GWP (TAR, 2001)
CO_2	1	1
CH_4	21	23
N_2O	310	296
HFC-23	11,700	12,000
HFC-32	650	550
HFC-125	2,800	3,400
HFC-134a	1,300	1,300
HFC-143a	3,800	4,300
HFC-152a	140	120
HFC-227ea	2,900	3,500
HFC-236fa	6,300	9,400
HFC-4310mee	1,300	1,500
CF_4	6,500	5,700
C_2F_6	9,200	11,900
C_3F_8	7,000	8,600
C_4F_{10}	7,000	8,600
C_6F_{14}	7,400	9,000
SF_6	23,900	22,000

Source: U.S. Environmental Protection Agency, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003 (April 2005).

94

Global Warming Potential (GWP)



ENERGY AWARE PLANNINGGUIDE APPENDIX A

GREENHOUSE GAS EMISSIONS FACTORS

Summary Emissions Factors

An emissions factor is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned). Such factors facilitate estimation of emissions from various sources of air pollution. In the Energy Aware Planning Guide, the emissions factor for greenhouse gas emissions is based on carbon dioxide equivalents (CO_2e).

Further Guidance on Estimating GHG from Projects

Estimating the actual GHG reductions is complicated because different sources of electricity release different quantities of emissions and since California's power comes from an inter-connected electricity system, it is difficult to tell which emissions are being avoided. Further guidance is available from these sources:

The California Air Resources Board provides standards applicable to the estimation of projects GHG emissions. Resources include:

» For rules pertaining to electricity provider GHG reporting see: http://www.arb.ca.gov/cc/reporting/ghg-rep/ghg-rep-guid/08_ElectricitySec.pdf.

» For rules relating to co-generation facilities see: http://www.arb.ca.gov/cc/reporting/ghg-rep/ghg-rep-guid/09_Cogen.pdf.

» For rules related to stationary combustion sources see: http://www.arb.ca.gov/cc/reporting/ghg-rep/ghg-rep-guid/12_GSCs.pdf.

Various types of GHGs may be reduced depending upon the type of project funded; estimates of reduced fugitive methane emissions, methane captured and converted to carbon dioxide, reductions in nitrous oxide, sulfur hexafloride, and various perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs) could be compiled for each project. When estimating GHG emission reductions from these types of projects, protocols at the following organizations may be useful:

Issues related to GHG Emission Factors

Emission Factors in the Guide

Table 1: Summary Emissions Factors for Energy Use in California

Type of Energy Reduced	CO2e Emissions Factor	Units	Data Type /Source:
Electricity	690	lbs CO_2 / MWh	California – specific data from updated macroeconomic analysis of Climate strategies presented in the March 2006 climate action team report Final report Prepared by: Economics subgroup Climate action team October 15, 2007
Natural Gas	11.68	lbs CO_2 / therm	National Average from the Environmental Protection Agency. AP42 Natural Gas Source Emissions Factor, July 1998.
Transportation Energy Use – Per Gallon of Fuel			
Gasoline	19.4	lbs CO_2 / gallon	Environmental Protection Agency. EPA420-F-05-001 February 2005.
Diesel	22.2	lbs CO_2 / gallon	Environmental Protection Agency. EPA420-F-05-001 February 2005.
Transportation Energy Use – Per Mile			
Fuel use / vehicle	12,000 miles per year and 21 miles per gallon for average passenger vehicle in California	Emission Factors (EMFAC) Model 2007 Version 2.3	
Water Pumping and Treatment			
Northern California	0.00395	kWh / gallon	California Energy Commission. Refining Estimates of Water Related Energy Use in California, December 2006.
Southern California (south of Tehachapi Mountains)	0.0127	kWh / gallon	California Energy Commission. Refining Estimates of Water Related Energy Use in California, December 2006.

- The Climate Action Reserve: http://www.climateactionreserve.org/how-it-works/protocols.
- The Climate Registry: http://www.theclimateregistry.org/resources/protocols.
- Climate Leaders Program: http://www.epa.gov/stateply/resources/index.html.
- USEPA GHG Reporting: http://www.epa.gov/climatechange/emissions/ghgrulemaking.html.
- ANSI ISO 14064-2 (2006): https://www.ansica.org/wwwversion2/outside/GHGgeneral.asp?menuID=200.

Helpful Conversion Factors

Powers of Ten

- 10 deka (da).
- 10^3 kilo (k).
- 10^6 mega (M).
- 10^9 giga (G).
- 10^12 tera (T).

California Energy Commission

Local Government Operations Protocol

8.81 kg = 19.42 lbs

www.arb.ca.gov/cc/protocols/localgov/localgov.htm

Table G.1 Default Factors for Calculating CO_2 Emissions from Fossil Fuel Combustion

Fuel Type	Heat Content	Carbon Content (Per Unit Energy)	Fraction Oxidized	CO_2 Emission Factor (Per Unit Energy)	CO_2 Emission Factor (Per Unit Mass or Volume)
Coal and Coke	**MMBtu / Short ton**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / Short ton**
Anthracite Coal	25.09	28.26	1.00	103.62	2,599.63
Bituminous Coal	24.93	25.49	1.00	93.46	2,330.04
Sub-bituminous Coal	17.25	26.48	1.00	97.09	1,674.86
Lignite	14.21	26.30	1.00	96.43	1,370.32
Unspecified (Residential/ Commercial)	22.05	26.00	1.00	95.33	2,102.29
Unspecified (Industrial Coking)	26.27	25.56	1.00	93.72	2,462.12
Unspecified (Other Industrial)	22.05	25.63	1.00	93.98	2,072.19
Unspecified (Electric Utility)	19.95	25.76	1.00	94.45	1,884.53
Coke	24.80	31.00	1.00	113.67	2,818.93
Natural Gas (By Heat Content)	**Btu / Standard cubic foot**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / Standard cub. ft.**
975 to 1,000 Btu / Std cubic foot	975 – 1,000	14.73	1.00	54.01	Varies
1,000 to 1,025 Btu / Std cubic foot	1,000 – 1,025	14.43	1.00	52.91	Varies
1,025 to 1,050 Btu / Std cubic foot	1,025 – 1,050	14.47	1.00	53.06	Varies
1,050 to 1,075 Btu / Std cubic foot	1,050 – 1,075	14.58	1.00	53.46	Varies
1,075 to 1,100 Btu / Std cubic foot	1,075 – 1,100	14.65	1.00	53.72	Varies
Greater than 1,100 Btu / Std cubic foot	> 1,100	14.92	1.00	54.71	Varies
Weighted U.S. Average	1,029	14.47	1.00	53.06	0.0546
Petroleum Products	**MMBtu / Barrel**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / gallon**
Asphalt & Road Oil	6.636	20.62	1.00	75.61	11.95
Aviation Gasoline	5.048	18.87	1.00	69.19	8.32
Distillate Fuel Oil (#1, 2 & 4)	5.825	19.95	1.00	73.15	10.15
Jet Fuel	5.670	19.33	1.00	70.88	9.57
Kerosene	5.670	19.72	1.00	72.31	9.76
LPG (average for fuel use)	3.849	17.23	1.00	63.16	5.79
Propane	3.824	17.20	1.00	63.07	5.74
Ethane	2.916	16.25	1.00	59.58	4.14
Isobutene	4.162	17.75	1.00	65.08	6.45
n-Butane	4.328	17.72	1.00	64.97	6.70
Lubricants	6.065	20.24	1.00	74.21	10.72
Motor Gasoline	5.218	19.33	1.00	70.88	8.81
Residual Fuel Oil (#5 & 6)	6.287	21.49	1.00	78.80	11.80
Crude Oil	5.800	20.33	1.00	74.54	10.29
Naphtha (<401 deg. F)	5.248	18.14	1.00	66.51	8.31
Natural Gasoline	4.620	18.24	1.00	66.88	7.36
Other Oil (>401 deg. F)	5.825	19.95	1.00	73.15	10.15
Pentanes Plus	4.620	18.24	1.00	66.88	7.36
Petrochemical Feedstocks	5.428	19.37	1.00	71.02	9.18
Petroleum Coke	6.024	27.85	1.00	102.12	14.65
Still Gas	6.000	17.51	1.00	64.20	9.17
Special Naphtha	5.248	19.86	1.00	72.82	9.10
Unfinished Oils	5.825	20.33	1.00	74.54	10.34
Waxes	5.537	19.81	1.00	72.64	9.58

Source: U.S. EPA, *Inventory of Greenhouse Gas Emissions and Sinks: 1990-2005* (2007), Annex 2.1, Tables A-31, A-32, A-35, and A-36, except: heat content factors for Unspecified Coal (by sector), Naphtha (<401 deg. F), and Other Oil (>401 deg. F) (from U.S. Energy Information Administration, *Annual Energy Review 2006* (2007), Tables A-1 and A-5) and Carbon Content and Heat Content factors for Coke and LPG (from EPA Climate Leaders, Stationary Combustion Guidance (2007), Table B-1). A fraction oxidized value of 1.00 is from the Intergovernmental Panel on Climate Change (IPCC), *Guidelines for National Greenhouse Gas Inventories* (2006).
Note: Default CO_2 emission factors (per unit energy) are calculated as: Carbon Content × Fraction Oxidized × 44/12. Default CO_2 emission

LCFS – Carbon Intensity

The standards are expressed as the· carbon intensity of gasoline and diesel fuel and their alternatives. Measured on a **lifecycle basis**, the carbon intensity represents the equivalent amount of carbon dioxide ($C0_2e$) emitted from each stage of producing, transporting, and using the fuel in a motor vehicle.

LCFS – Carbon Intensity con't

Depending on the circumstances, GHG emissions from each step can include carbon dioxide ($C0_2$), methane, nitrous oxide (N_20), and other GHG contributors. Moreover, the overall GHG contribution from each particular step is a function of the energy that the fuel contains. Thus, carbon intensity is expressed in terms of grams of $C0_2$ equivalent per megajoule (g *$C0_2e/MJ$).*

Carbon Intensity of Transportation Energy Sources

(LCFS, 4/09)

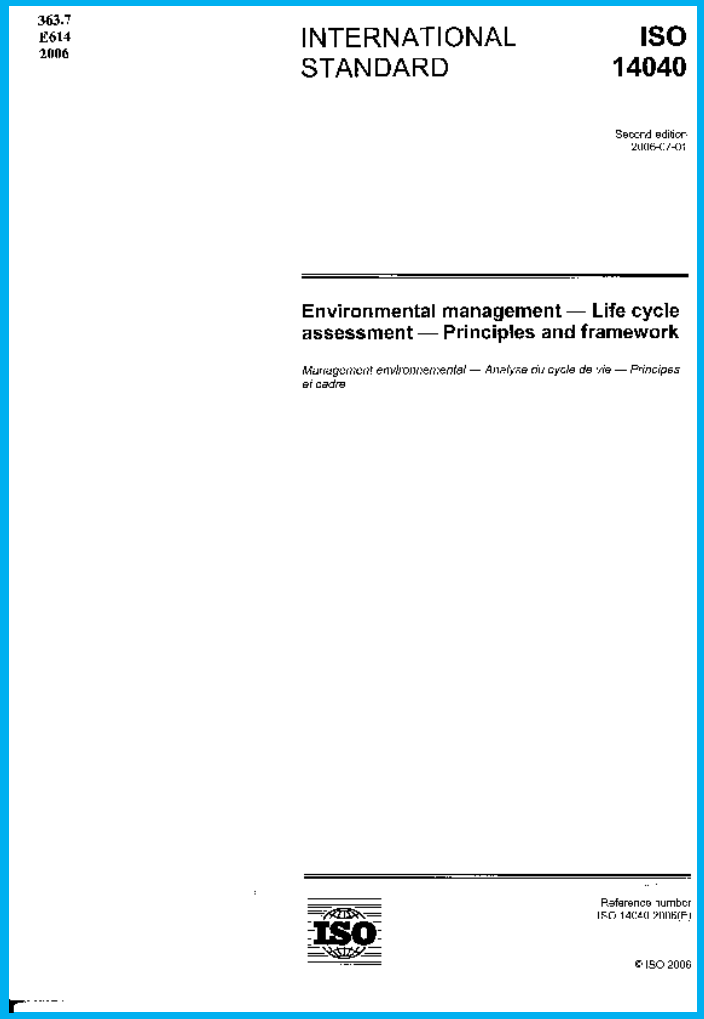
www.arb.ca.gov/fuels/lcfs/lcfs.htm

Table ES-8
Adjusted Carbon Intensity Values
for Gasoline and Fuels that Substitute for Gasoline

Fuel	Pathway Description	Carbon Intensity Values (gCO_2e/MJ)		
		Direct Emissions	Land Use or Other Effect	Total
Gasoline	CARBOB - based on the average crude oil delivered to California refineries and average California refinery efficiencies	95.86	0	95.86
	CaRFG-CARBOB and a blend of *100%* average Midwestern corn ethanol to meet a 3.5% oxygen content by weight (approximately *10%* ethanol)	*96.09*	--	*96.09* [1]
	CaRFG-CARBOB and a blend of an 80% Midwestern corn ethanol and 20% California corn ethanol to meet a 3.5% oxygen content by weight blend (approximately 10% ethanol)	95.85	--	95.85 [1]
Ethanol from Corn	Midwest average; 80% Dry Mill; 20% Wet Mill; Dry DGS	69.40	30	99.40
	California; Dry Mill; Wet DGS; NG	50.70	30	80.70
	California average; 80% Midwest Average; 20% California; Dry Mill; Wet DGS; NG	65.66	30	95.66
	Midwest; Dry Mill; Dry DGS	68.40	30	98.40
	Midwest; Wet Mill	75.10	30	105.10
	Midwest; Dry Mill; Wet DGS	60.10	30	90.10
	California; Dry Mill; Dry DGS; NG	58.90	30	88.90
	Midwest; Dry Mill; Dry DGS; 80% NG; 20% Biomass	63.60	30	93.60
	Midwest; Dry Mill; Wet DGS; 80% NG; 20% Biomass	56.80	30	86.80
	California; Dry Mill; Dry DGS; 80% NG; 20% Biomass	54.20	30	84.20
	California; Dry Mill; Wet DGS; 80% NG; 20% Biomass	47.44	30	77.40
Ethanol from Sugarcane	Brazilian sugarcane using average production processes	27.40	46	73.40
Electricity	California average electricity mix	124.10	0	41.37 [2]
	California marginal electricity mix of natural gas and renewable energy	104.70	0	34.90 [2]
Hydrogen	Compressed H_2 from central reformina of NG	142.20	0	61.83 [3]
	Liquid H_2 from central reformina of NG	133.00	0	57.83 [3]
	Compressed H_2 from on-site reformina of NG	98.30	0	42.74 [3]
	SB 1505 Scenario; Compressed H_2 from on-site reforming with renewable feedstocks	76.10	0	33.09 [3]

2 Calculated value, land use part of the value
2 Adjusted by an EER factor of 3.0 to account for power train efficiency improvements over gasoline engines
3 Adjusted by an EER factor of 2.3 to account for power train efficiency improvements over gasoline engines

California Energy Commission



363.7
E614
2006

INTERNATIONAL STANDARD

ISO 14040

Second edition
2006-07-01

Environmental management — Life cycle assessment — Principles and framework

Management environnemental — Analyse du cycle de vie — Principes et cadre

Reference number
ISO 14040:2006(E)

Life Cycle Analysis (LCA)

www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=37456

What's Your Electricity Footprint?

California Utility	2005	2006	2007
LADWP	1,304	1,239	1,228
SDG&E	546	781	806
SMUD	616	555	714
PG&E	489	456	636
SCE	666	641	631

CA Climate Action Registry reporting

eGRID

Estimates of CA Statewide electricity generation average output mix:

- **878.71 lbs/MWh** 2004 CAMX-WECC CA
- **724.12 lbs/MWh** 2005 CAMX-WECC CA

Note: This shows an 18% decline in one year!

http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html

kWh Consumed or Avoided?

- GHGs of today's electricity resource mix…will NOT be the GHGs of our future electricity mix
- Which generation resource is not "used"…when you avoid consuming a kWh?
- Which generation resources are not needed if you reduce your electricity demand?
- If spot market purchases are reduced, what are the GHGs of those electricity supplies?

Some Key Factors on Electricity

- Progress in achieving the California RPS
- Emissions Performance Standard (SB1368)
- Phasing out of once-through-cooling (OTC)
- Retirement of older, less efficient plants
- Local grid reliability needs
- Availability of low cost hydroelectric power
- Effectiveness of energy efficiency program
- Technology developments (e.g., CCS)

What's Most Important on Energy?

- Reasonably accurate method of tracking how much energy is currently used; information about the sources of energy consumed
- Creating a GHG emissions inventory
- Identify opportunities to reduce consumption
- Using purchasing power to better understand energy an supplier's relative GHG intensity
- Improve understanding about the "indirect" impacts of energy consumption

Reducing Energy Consumption

- Establishing a sound “baseline” of activities that consume energy
- Making the effort to evaluate, monitor, and verify energy savings
- Opportunities to partner with others on projects that reduce energy consumption
- Follow the rapidly evolving world of GHG project protocols and carbon markets

Carbon Market is Growing…

Dear Energy-L readers

Assets under management by carbon funds grew by 26% to $16 billion last year, despite the continuing uncertainty about future international action on climate change.

Research by Environmental Finance and Carbon Finance identified 88 investment vehicles that are either operational or actively raising funds to buy carbon credits from projects that reduce emissions of greenhouse gases. A further seven funds are at the planning stage, and fund managers are optimistic about the prospects for 2010. Full details on all these funds are listed in Carbon Funds 2009/10 - to find out more go to http://www.environmental-finance.com/envfin/books.htm

Thank You!

More information:

- **CARB GHG Inventory & Mandatory Reporting**
  www.arb.ca.gov/cc/ccei.htm
- **ICLEI GHG Analysis Protocol (IEAP) :**
  www.iclei.org/index.php?id=ghgprotocol
- **GHG Protocol (WRI/WBCSD):**
  www.ghgprotocol.org
- **US EPA**
  www.epa.gov/statelocalclimate/state/activities/ghg-inventory.html