Annex F

Methodology for Estimating Methane Emissions from Petroleum Systems

The methodology for estimating methane emissions from petroleum systems is based on the 1999 EPA draft report, *Estimates of Methane Emissions from the U.S. Oil Industry* (EPA 1999). Seventy activities that emit methane from petroleum systems were examined for this report. Most of the activities analyzed involve crude oil production field operations, which accounted for 97 percent of total oil industry emissions. Crude transportation and refining accounted for the remaining emissions at about one and two percent each, respectively.

The following steps were taken to estimate methane emissions from petroleum systems.

Step 1: Calculate a Detailed Emission Estimate for 1995 Based on the 1999 EPA Report

The emission factors used for the 1995 estimate of methane emissions did not require any changes from those used in the 1999 EPA draft report. An industry peer review process identified improvements to activity data for oil wells and tank venting. These recommendations were incorporated into the estimate provided in this inventory. In addition, the EPA reviewed data on the number of oil well completions each year for two years after the initial estimates to ensure that late reports were incorporated. Enhanced data sources were found for the number of offshore oil production platforms and the number of crude oil loadings into marine vessels. The activity factors for all years are updated to include data from these sources. This format is used as a basis for estimating emissions for the other years in the time series: 1990-94 and 1996-98 by including the appropriate activity factors for each year.

Step 2: Collect Oil Industry Activity Data

Several approaches were used to develop annual activity data for 1990 through 1994 and 1996 through 1998. Most activity data were updated annually at the same level of detail as the 1995 estimate, using reports from the U.S. Department of Energy (DOE) and the oil industry. For cases in which annual data were not available but the activity factors were known to correlate well with changes in oil production rates, the activity factors were scaled from a base year in proportion to annual oil production rate changes. For a small number of sources, 1998 data were not yet available. In these cases, the 1997 activity factors were used. In the few cases where no data was located, activity data based on oil industry expert judgment were used.

Step 3: Selection Emission Factors

The 1995 emission factors were used for all years – 1990 through 1998. Many of the emission factors are based on field tests performed several years ago while others were taken from more recent work. The more recently developed emission factors use tank emission models developed by the American Petroleum Institute for estimating emissions from fixed roof and floating roof tanks.

Step 4: Estimate Emissions for Each Activity

Emissions from each of the 70 petroleum system activities analyzed were estimated by multiplying the activity data for each year by the corresponding emission factor. Table F-1, Table F-2, and Table F-3 provide the 1998 activity factors, emission factors, and emission estimates. Table F- 4 provides a summary of emission estimates for the years 1990 through 1998.

Table F-1: CH_4 Emissions from Petroleum Production Field Operations

Activity/Equipment	Emission Factor	Units	Activity Factor	Units	Emissions (Bcf/yr)
Vented Emissions:					
Oil Tanks	18	scf of CH_4/bbl crude	1,354	MMbbl/yr (non stripper wells)	24.234
Pneumatic Devices, High Bleed	345	scfd CH_4/device	147,424	No. of high-bleed devices	18.575
Pneumatic Devices, Low Bleed	35	scfd CH_4/device	273,788	No. of low-bleed devices	3.450
Chemical Injection Pumps	248	scfd CH_4/pump	29,803	No. of pumps	2.698
Vessel Blowdowns	78	scfy CH_4/vessel	196,206	No. of vessels	0.015
Compressor Blowdowns	3,775	scf/yr of CH_4/compressor	2,670	No. of compressors	0.010
Compressor Starts	8,443	scf/yr. of CH_4/compressor	2,670	No. of compressors	0.023
Stripper wells	2,345	scf/yr of CH_4/stripper well	348,867	No. of stripper wells vented	0.818
Well Completion Venting	733	scf/completion	7,064	Oil well completions	0.005
Well Workovers	96	scf CH_4/workover	43,013	Oil well workovers	0.004
Pipeline Pigging	2.40	scfd of CH_4/pig station	0	No. of crude pig stations	0.000
Offshore Platforms, Gulf of Mexico	1,283	scfd CH_4/platform	1,843	No. of oil platforms	0.863
Offshore Platforms, Other U.S. Areas	1,283	scfd CH_4/platform	22	No. of oil platforms	0.010
Total Vented Emissions					**50.706**
Fugitive Emissions:					
Offshore Platforms, Gulf of Mexico	56	scfd CH_4/platform	1,843	No. of oil platforms	0.038
Offshore Platforms, Other U.S. Areas	56	scfd CH_4/platform	22	No. of oil platforms	0.000
Oil Wellheads (heavy crude)	0.13	scfd/well	15,837	No. of hvy. crude wells *	0.001
Oil Wellheads (light crude)	16.6	scfd/well	208,800	No. of lt. crude wells *	1.267
Separators (heavy crude)	0.15	scfd CH_4/separator	11,524	No. of hvy. crude seps.	0.001
Separators (light crude)	14	scfd CH_4/separator	104,926	No. of lt. crude seps.	0.531
Heater/Treaters (light crude)	19	scfd CH_4/heater	71,860	No. of heater treaters	0.503
Headers (heavy crude)	0.08	scfd CH_4/header	8,843	No. of hvy. crude hdrs.	0.000
Headers (light crude)	11	scfd CH_4/header	80,486	No. of lt. crude hdrs.	0.319
Floating Roof Tanks	338,306	scf CH_4/floating roof tank/yr.	24	No. of floating roof tanks	0.008
Compressors	100	scfd CH_4/compressor	2,797	No. of compressors	0.102
Large Compressors	16,360	scfd CH_4/compressor	0	No. of large comprs.	0.000
Sales Areas	41	scf CH_4/loading	1,901,362	Loadings/year	0.077
Pipelines	0	scfd of CH_4/mile of pipeline	30,467	Miles of gathering line	0.000
Well Drilling	0	scfd of CH_4/oil well drilled	13,440	No. of oil wells drilled	0.000
Battery Pumps	0.24	scfd of CH_4/pump	172,051	No. of battery pumps	0.015
Total Fugitive Emissions					**2.862**
Combustion Emissions:					
Gas Engines	0.08	scf CH_4/HP-hr	17,634	MMHP-hr	1.411
Heaters	0.52	scf CH_4/bbl	2,282	MBbl/yr	0.001
Well Drilling	2,453	scf CH_4/well drilled	9,420	Oil wells drilled, 1995	0.023
Flares	20	scf CH_4per Mcf flared	533,139	Mcf flared/yr	0.011
Offshore Platforms, Gulf of Mexico	481	scfd CH_4/platform	1,843	No. of oil platforms	0.323
Offshore Platforms, Other U.S. Areas	481	scfd CH_4/platform	22	No. of oil platforms	0.004
Total Emissions from Combustion					**1.773**
Process Upset Emissions:					
Platform Emergency Shutdowns	256,888	scfy/platform	1,865	No. of platforms	0.479
Pressure Relief Valves	35	scf/yr/PR valve	190,615	No. of PR valves	0.007
Well Blowouts Offshore	5.0	MMscf/blowout	2.25	No. of blowouts/yr	0.011
Well Blowouts Onshore	2.5	MMscf/blowout	31.4	No. of blowouts/yr	0.079
Total Emissions from Upsets					**0.576**
Total (excluding stripper wells)					**55.92**

Table F-2: 1998 CH_4 Emissions from Petroleum Transportation

Activity/Equipment	Emission Factor	Units	Activity Factor	Units	Emissions (Bcf/yr)
Vented Emissions:					
Tanks	0.021	scf CH_4/yr/bbl of crude delivered to refineries	5,434	MMbbl crude feed/yr	0.112
Truck Loading	0.520	scf CH_4/yr/bbl of crude transported by truck	67.2	MMbbl crude feed/yr	0.035
Marine Loading	2.544	scf CH_4/1000 gal. crude marine loadings	35,314,579	1,000 gal./yr loaded	0.090
Rail Loading	0.520	scf CH_4/yr/bbl of crude transported by rail	13	MMbbl. crude by rail/yr	0.007
Pump Station Maintenance	36.80	scf CH_4/station/yr	536	No. of pump stations	0.000
Pipeline Pigging	39	scfd of CH_4/pig station	1,072	No. of pig stations	0.015
Total Vented Emissions					**0.259**
Fugitive Emissions:					
Pump Stations	25	scfCH_4/mile/yr.	53,614	No. of miles of crude p/l	0.001
Pipelines	0	scf CH_4/bbl crude transported by pipeline	7,639	MM bbl crude piped	0.000
Floating Roof Tanks	58,965	scf CH_4/floating roof tank/yr.	824	No. of floating roof tanks	0.049
Total Fugitive Emissions					**0.050**
Combustion Emissions:					
Pump Engine Drivers	0.24	scf CH_4/hp-hr	NA	No. of hp-hrs	NA
Heaters	0.521	scf CH_4/bbl.burned	NA	No. of bbl. burned	NA
Total Combustion Emissions					**0.000**
Total					**0.309**

Table F- 3: CH_4 Emissions from Petroleum Refining

Activity/Equipment	Emission Factor	Units	Activity Factor	Units	Emissions (Bcf/yr)
Vented Emissions:					
Tanks	20.6	$scfCH_4$/Mbbl	1,910	Mbbl/cd heavy crude feed	0.014
System Blowdowns	137	$scfCH_4$/Mbbl	14,889	Mbbl/cd refinery feed	0.743
Asphalt Blowing	2,555	$scfCH_4$/Mbbl	498	Mbbl/cd production	0.465
Total Vented Emissions					**1.223**
Fugitive Emissions:					
Fuel Gas System	439	$McfCH_4$/refinery/yr	159	Refineries	0.070
Floating Roof Tanks	587	scf CH_4/floating roof tank/yr.	767	No. of floating roof tanks	0.000
Wastewater Treating	1.88	$scfCH_4$/Mbbl	14,889	Mbbl/cd refinery feed	0.010
Cooling Towers	2.36	$scfCH_4$/Mbbl	14,889	Mbbl/cd refinery feed	0.013
Total Fugitive Emissions					**0.093**
Combustion Emissions:					
Atmospheric Distillation	3.61	$scfCH_4$/Mbbl	14,889	Mbbl/cd refinery feed	0.020
Vacuum Distillation	3.61	$scfCH_4$/Mbbl	6,756	Mbbl/cd feed	0.009
Thermal Operations	6.02	$scfCH_4$/Mbbl	1,907	Mbbl/cd feed	0.004
Catalytic Cracking	5.17	$scfCH_4$/Mbbl	4,932	Mbbl/cd feed	0.009
Catalytic Reforming	7.22	$scfCH_4$/Mbbl	3,257	Mbbl/cd feed	0.009
Catalytic Hydrocracking	7.22	$scfCH_4$/Mbbl	1,352	Mbbl/cd feed	0.004
Hydrorefining	2.17	$scfCH_4$/Mbbl	1,530	Mbbl/cd feed	0.001
Hydrotreating	6.50	$scfCH_4$/Mbbl	8,140	Mbbl/cd feed	0.019
Alkylation/Polymerization	12.6	$scfCH_4$/Mbbl	1,071	Mbbl/cd feed	0.005
Aromatics/Isomeration	1.80	$scfCH_4$/Mbbl	916	Mbbl/cd feed	0.001
Lube Oil Processing	0.00	$scfCH_4$/Mbbl	188	Mbbl/cd feed	0.000
Engines	0.006	$scfCH_4$/hp-hr	1,467	MMhp-hr/yr	0.008
Flares	0.189	$scfCH_4$/Mbbl	14,889	Mbbl/cd refinery feed	0.001
Total Combustion Emissions					**0.090**
Total					**1.405**

Table F- 4: Summary of CH_4 Emissions from Petroleum Systems (Gg)

Activity	1990	1991	1992	1993	1994	1995	1996	1997	1998
Production Field Operations	**1,263**	**1,276**	**1,232**	**1,175**	**1,144**	**1,136**	**1,111**	**1,109**	**1,075**
Tank venting	564	570	548	519	502	493	485	484	466
Pneumatic device venting	559	564	545	521	506	507	491	490	475
Wellhead fugitives	24	26	25	24	25	25	25	24	24
Combustion & process upsets	46	46	45	45	45	45	45	46	45
Misc. venting & fugitives	70	70	69	67	66	66	65	65	64
Crude Oil Transportation	**7**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**
Refining	**25**	**24**	**24**	**25**	**25**	**25**	**26**	**27**	**27**
Total	**1,294**	**1,307**	**1,262**	**1,206**	**1,175**	**1,168**	**1,143**	**1,142**	**1,108**

Note: Totals may not sum due to independent rounding.