

# ANNEX H

## Methodology for Estimating CH<sub>4</sub> 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) and the study, *Methane Emissions from the U.S. Petroleum Industry* (Radian 1996). Seventy activities that emit methane from petroleum systems were examined for these reports. 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: Determine Emission Factors for all Activities

The emission factors for sixty-nine of the seventy activities for 1995 are taken from the 1999 EPA draft report, which contains the most recent and comprehensive determination of methane emission factors for the seventy methane emitting activities in the oil industry. For the one activity, gas engines in the production sector, the emission factor is taken from Radian (1996). The emission factors determined for 1995 were assumed to be representative of emissions from each source type over the period 1990 through 2001. Therefore, the same emission factors are used for each year throughout this period.

### Step 2: Determine Activity Levels for Each Year

Activity levels change from year to year. Some factors change in proportion to crude oil rates: production, transportation, refinery runs. Some change in proportion to the number of facilities: oil wells, petroleum refineries. Some factors change proportional to both rate and number of facilities.

For fifty-seven activities, activity levels for 1995 are taken from EPA (1999). For the remaining thirteen activities, the activity levels for 1993 are taken from Radian (1996). These thirteen activity levels were derived from field data collected in 1993, along with 1993 crude oil production and number of wells.

For both sets of data, a determination is made on a case-by-case basis as to which measure of petroleum industry activity best reflects the change in annual activity relative to the base years (1993 and 1995). Publicly reported data from the Minerals Management Service (MMS), Energy Information Administration (EIA), American Petroleum Institute (API), and the Oil & Gas Journal (O&GJ) are used to extrapolate the activity levels from the base year to each year between 1990 and 2001. Data used include total domestic crude oil production, number of domestic crude oil wells, total imports and exports of crude oil, and total petroleum refinery crude runs. The activity data for the transportation sector were not yet available. In this case, it was assumed that all the crude oil that is transported goes to refineries. Therefore, the activity data for the refining sector was used also for the transportation sector. For a small number of sources, 2001 data were not yet available. In these cases, the 2000 activity factors were used. In the few cases where no data was located, oil industry data based on expert judgment was used.

### Step 3: Estimate Methane Emissions for Each Activity for Each Year

Annual emissions from each of the 70 petroleum system activities were estimated by multiplying the activity data for each year by the corresponding emission factor. These annual emissions for each activity were then summed to estimate the total annual methane emissions. For the production sector, the amount of emission reduction achieved by the EPA's Natural Gas STAR program was subtracted from the estimated production emissions. Table H-1, Table H-2 and Table H-3 provide 2001 activity factors, emission factors and emission estimates.

Methane emissions from the Natural Gas STAR program for the years 1990 through 2001 are presented in Table H-4. Table H-5 provides a summary of emission estimates for the years 1990 through 2001.

**Table H-1: 2001 CH<sub>4</sub> Emissions from Petroleum Production Field Operations**

Activity/Equipment	Emission		Activity		Emissions (Bcf/yr)
	Factor	Units	Factor	Units	
<b>Vented Emissions</b>					<b>48.027</b>
Oil Tanks	18	scf of CH <sub>4</sub> /bbl crude	1,251	MMbbl/yr (non stripper wells)	22.086
Pneumatic Devices, High Bleed	345	scfd CH <sub>4</sub> /device	142,872	No. of high-bleed devices	17.998
Pneumatic Devices, Low Bleed	35	scfd CH <sub>4</sub> /device	265,334	No. of low-bleed devices	3.342
Chemical Injection Pumps	248	scfd CH <sub>4</sub> /pump	28,595	No. of pumps	2.589
Vessel Blowdowns	78	scfy CH <sub>4</sub> /vessel	186,546	No. of vessels	0.015
Compressor Blowdowns	3,775	scf/yr of CH <sub>4</sub> /compressor	2,532	No. of compressors	0.010
Compressor Starts	8,443	scf/yr. of CH <sub>4</sub> /compressor	2,532	No. of compressors	0.021
Stripper wells	2,345	scf/yr of CH <sub>4</sub> /stripper well	329,434	No. of stripper wells vented	0.818
Well Completion Venting	733	scf/completion	4,731	Oil well completions	0.003
Well Workovers	96	scf CH <sub>4</sub> /workover	40,050	Oil well workovers	0.004
Pipeline Pigging	2.40	scfd of CH <sub>4</sub> /pig station	0	No. of crude pig stations	0.000
Offshore Platforms, Gulf of Mexico	1,283	scfd CH <sub>4</sub> /platform	1,832	No. of oil platforms	0.858
Offshore Platforms, Other U.S. Areas	1,283	scfd CH <sub>4</sub> /platform	23	No. of oil platforms	0.011
<b>Fugitive Emissions</b>					<b>2.587</b>
Offshore Platforms, Gulf of Mexico	56	scfd CH <sub>4</sub> /platform	1,832	No. of oil platforms	0.037
Offshore Platforms, Other U.S. Areas	56	scfd CH <sub>4</sub> /platform	23	No. of oil platforms	0.000
Oil Wellheads (heavy crude)	0.13	scfd/well	14,422	No. of hvy. crude wells *	0.001
Oil Wellheads (light crude)	16.6	scfd/well	190,144	No. of lt. crude wells *	1.045
Separators (heavy crude)	0.15	scfd CH <sub>4</sub> /separator	10,972	No. of hvy. crude seps.	0.001
Separators (light crude)	14	scfd CH <sub>4</sub> /separator	99,858	No. of lt. crude seps.	0.505
Heater/Treaters (light crude)	19	scfd CH <sub>4</sub> /heater	75,716	No. of heater treaters	0.530
Headers (heavy crude)	0.08	scfd CH <sub>4</sub> /header	13,929	No. of hvy. crude hdrs.	0.000
Headers (light crude)	11	scfd CH <sub>4</sub> /header	43,183	No. of lt. crude hdrs.	0.171
Floating Roof Tanks	338,306	scf CH <sub>4</sub> /floating roof tank/yr.	24	No. of floating roof tanks	0.008
Compressors	100	scfd CH <sub>4</sub> /compressor	2,532	No. of compressors	0.092
Large Compressors	16,360	scfd CH <sub>4</sub> /compressor	0	No. of large comprs.	0.000
Sales Areas	41	scf CH <sub>4</sub> /loading	1,764,218	Loadings/year	0.071
Pipelines	0	scfd of CH <sub>4</sub> /mile of pipeline	30,467	Miles of gathering line	0.000
Well Drilling	0	scfd of CH <sub>4</sub> /oil well drilled	7,437	No. of oil wells drilled	0.000
Battery Pumps	0.24	scfd of CH <sub>4</sub> /pump	160,200	No. of battery pumps	0.014
<b>Combustion Emissions</b>					<b>4.186</b>
Gas Engines	0.24	scf CH <sub>4</sub> /HP-hr	15,950	MMHP-hr	3.828
Heaters	0.52	scf CH <sub>4</sub> /bbl	2117.4	MBbl/yr	0.001
Well Drilling	2,453	scf CH <sub>4</sub> /well drilled	7,437	Oil wells drilled, 1995	0.018
Flares	20	scf CH <sub>4</sub> /per Mcf flared	492,582	Mcf flared/yr	0.010
Offshore Platforms, Gulf of Mexico	481	scfd CH <sub>4</sub> /platform	1,852	No. of oil platforms	0.325
Offshore Platforms, Other U.S. Areas	481	scfd CH <sub>4</sub> /platform	23	No. of oil platforms	0.004
<b>Process Upset Emissions</b>					<b>0.561</b>
Platform Emergency Shutdowns	256,888	scfy/platform	1,875	No. of platforms	0.482
Pressure Relief Valves	35	scf/yr/PR valve	176,866	No. of PR valves	0.006
Well Blowouts Offshore	5.0	MMscf/blowout	2.25	No. of blowouts/yr	0.011
Well Blowouts Onshore	2.5	MMscf/blowout	24.8	No. of blowouts/yr	0.062
<b>Total (excluding stripper wells)</b>					<b>55.36</b>

**Table H-2: 2001 CH<sub>4</sub> Emissions from Petroleum Transportation**

Activity/Equipment	Emission		Activity		Emissions (Bcf/yr)
	Factor	Units	Factor	Units	
<b>Vented Emissions</b>					<b>0.216</b>
Tanks	0.021	scf CH <sub>4</sub> /yr/bbl of crude delivered to refineries	5,522	MMbbl crude feed/yr	0.114
Truck Loading	0.520	scf CH <sub>4</sub> /yr/bbl of crude transported by truck	45.3	MMbbl crude feed/yr	0.024
Marine Loading	2.544	scf CH <sub>4</sub> /1000 gal. crude marine loadings	23,713,616	1,000 gal./yr loaded	0.060
Rail Loading	0.520	scf CH <sub>4</sub> /yr/bbl of crude transported by rail	7.4	MMbbl. Crude by rail/yr	0.004
Pump Station Maintenance	36.80	scf CH <sub>4</sub> /station/yr	490	No. of pump stations	0.000
Pipeline Pigging	39	scfd of CH <sub>4</sub> /pig station	980	No. of pig stations	0.014
<b>Fugitive Emissions</b>					<b>0.050</b>
Pump Stations	25	scfCH <sub>4</sub> /mile/yr.	48,990	No. of miles of crude p/l	0.001
Pipelines	0	scf CH <sub>4</sub> /bbl crude transported by pipeline	7,551	MM bbl crude piped	0.000
Floating Roof Tanks	58,965	scf CH <sub>4</sub> /floating roof tank/yr.	824	No. of floating roof tanks	0.049
<b>Combustion Emissions</b>					<b>0.000</b>
Pump Engine Drivers	0.24	scf CH <sub>4</sub> /hp-hr	NA	No. of hp-hrs	NA
Heaters	0.521	scf CH <sub>4</sub> /bbl.burned	NA	No. of bbl. Burned	NA
<b>Total</b>					<b>0.283</b>

**Table H-3: 2001 CH<sub>4</sub> Emissions from Petroleum Refining**

Activity/Equipment	Emission		Activity		Emissions (Bcf/yr)
	Factor	Units	Factor	Units	
<b>Vented Emissions</b>					<b>1.223</b>
Tanks	20.6	scfCH <sub>4</sub> /Mbbbl	1,941	Mbbbl/cd heavy crude feed	0.015
System Blowdowns	137	scfCH <sub>4</sub> /Mbbbl	15,128	Mbbbl/cd refinery feed	0.755
Asphalt Blowing	2,555	scfCH <sub>4</sub> /Mbbbl	485	Mbbbl/cd production	0.453
<b>Fugitive Emissions</b>					<b>0.091</b>
Fuel Gas System	439	McfCH <sub>4</sub> /refinery/yr	153	Refineries	0.067
Floating Roof Tanks	587	scf CH <sub>4</sub> /floating roof tank/yr.	767	No. of floating roof tanks	0.000
Wastewater Treating	1.88	scfCH <sub>4</sub> /Mbbbl	15,128	Mbbbl/cd refinery feed	0.010
Cooling Towers	2.36	scfCH <sub>4</sub> /Mbbbl	15,128	Mbbbl/cd refinery feed	0.013
<b>Combustion Emissions</b>					<b>0.092</b>
Atmospheric Distillation	3.61	scfCH <sub>4</sub> /Mbbbl	15,352	Mbbbl/cd refinery feed	0.020
Vacuum Distillation	3.61	scfCH <sub>4</sub> /Mbbbl	6,875	Mbbbl/cd feed	0.009
Thermal Operations	6.02	scfCH <sub>4</sub> /Mbbbl	2,055	Mbbbl/cd feed	0.005
Catalytic Cracking	5.17	scfCH <sub>4</sub> /Mbbbl	5,194	Mbbbl/cd feed	0.010
Catalytic Reforming	7.22	scfCH <sub>4</sub> /Mbbbl	3,239	Mbbbl/cd feed	0.009
Catalytic Hydrocracking	7.22	scfCH <sub>4</sub> /Mbbbl	1,362	Mbbbl/cd feed	0.004
Hydrotreating	2.17	scfCH <sub>4</sub> /Mbbbl	1,825	Mbbbl/cd feed	0.001
Hydrotreating	6.50	scfCH <sub>4</sub> /Mbbbl	8,382	Mbbbl/cd feed	0.020
Alkylation/Polymerization	12.6	scfCH <sub>4</sub> /Mbbbl	1,065	Mbbbl/cd feed	0.005
Aromatics/Isomeration	1.80	scfCH <sub>4</sub> /Mbbbl	934	Mbbbl/cd feed	0.001
Lube Oil Processing	0.00	scfCH <sub>4</sub> /Mbbbl	162	Mbbbl/cd feed	0.000
Engines	0.006	scfCH <sub>4</sub> /hp-hr	1,467	MMhp-hr/yr	0.008
Flares	0.189	scfCH <sub>4</sub> /Mbbbl	15,128	Mbbbl/cd refinery feed	0.001
<b>Total</b>					<b>1.406</b>

**Table H-4: CH<sub>4</sub> Reductions from Natural Gas STAR program (Gg)**

Activity	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
<b>Production Field Operations</b>	<b>2</b>	<b>7</b>	<b>14</b>	<b>28</b>	<b>48</b>	<b>54</b>	<b>61</b>	<b>75</b>	<b>79</b>	<b>89</b>	<b>89</b>	<b>85</b>
Tank venting	2	7	14	28	48	54	61	75	79	89	89	85
<b>Crude Oil Transportation</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>
Refining	-	-	-	-	-	-	-	-	-	-	-	-

**Table H-5: Summary of CH<sub>4</sub> Emissions from Petroleum Systems (Gg)**

Activity	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
<b>Production Field Operations</b>	<b>1,278</b>	<b>1,289</b>	<b>1,236</b>	<b>1,181</b>	<b>1,141</b>	<b>1,122</b>	<b>1,107</b>	<b>1,090</b>	<b>1,058</b>	<b>996</b>	<b>977</b>	<b>979</b>
Tank venting	558	557	528	486	451	439	425	409	390	349	343	345
Pneumatic device venting	525	535	517	507	504	497	496	495	485	470	460	460
Wellhead fugitives	26	26	24	24	24	25	25	25	25	24	22	22
Combustion & process upsets	103	105	101	99	98	98	98	98	96	92	91	91
Misc. venting & fugitives	65	66	65	64	64	63	63	63	62	61	60	60
<b>Crude Oil Transportation</b>	<b>7</b>	<b>6</b>	<b>5</b>	<b>5</b>								
<b>Refining</b>	<b>25</b>	<b>24</b>	<b>24</b>	<b>25</b>	<b>25</b>	<b>25</b>	<b>26</b>	<b>27</b>	<b>27</b>	<b>27</b>	<b>28</b>	<b>27</b>
<b>Total</b>	<b>1,309</b>	<b>1,320</b>	<b>1,267</b>	<b>1,212</b>	<b>1,172</b>	<b>1,153</b>	<b>1,138</b>	<b>1,123</b>	<b>1,090</b>	<b>1,029</b>	<b>1,010</b>	<b>1,011</b>

Note: Totals may not sum due to independent rounding.