ANNEX F

Methodology for Estimating CH_4 Emissions from Natural Gas Systems

The following steps were used to estimate methane emissions from natural gas systems.

Step 1: Calculate Emission Estimates for Base Year 1992 Using GRI/EPA Study

The first step in estimating methane emissions from natural gas systems was to develop a detailed base year estimate of emissions. The study by GRI/EPA (1996) divides the industry into four stages to construct a detailed emission inventory for the year 1992. These stages include: field production, processing, transmission and storage (i.e., both underground and liquefied gas storage), and distribution. This study produced emission factors and activity data for over 100 different emission sources within the natural gas system. Emissions for 1992 were estimated by multiplying activity levels by emission factors for each system component and then summing by stage. Since publication, the EPA has updated 1992 activity data for some of the components in the system. Table F-1 displays the 1992 GRI/EPA activity levels and emission factors for venting and flaring from the field production stage, and the current EPA activity levels and emission factors. These data are shown to illustrate the kind of data used to calculate emissions from all stages.

Step 2: Collect Aggregate Statistics on Main Driver Variables

As detailed data on each of the over 100 sources were not available for the period 1990 through 1999, activity levels were estimated using aggregate statistics on key drivers, including: number of producing wells (IPAA 1990 through 2000, EIA 2000), number of gas plants (AGA 1990 through 1998; PennWell Corporation 1999, 2000, 2001), miles of transmission pipeline (OPS 1998, 1999, 2000, 2001), miles of distribution pipeline (OPS, 2001), miles of distribution services (OPS, 2001), and energy consumption (EIA 1998, 1999, 2000, 2001). Data on the distribution of gas mains and services by material type was not available for 1990 through 1992 from OPS. For those years, the distribution by type was back calculated from 1993 using compound growth rates determined for the years 1993 through 2000. Table F-2 provides the activity levels of some of the key drivers in the natural gas analysis.

Step 3: Estimate Emission Factor Changes Over Time

For the period 1990 through 1995, the emission factors were held constant, based on 1992 values. However, the natural gas industry is experiencing ongoing broad based technology improvements, which are expected to continue. These improvements have increased operating efficiency, thus reducing methane emissions. An assumed improvement in technology and practices was estimated to reduce emission factors by 5 percent by the year 2020. This assumption, annualized, amounts to a 0.2 percent decline in the 1996 emission factor, a 0.4 percent decline in the 1997 emission factor, a 0.6 percent decline in the 1998 emission factor and a 0.8 percent decline in the 1999 emission factor, all relative to 1995 emission factors.

Step 4: Estimate Emissions for Each Year and Stage

Emissions from each stage of the natural gas industry were estimated by multiplying the activity factors by the appropriate emission factors, summing all sources for each stage, and then subtracting the Natural Gas STAR emission reductions.[1] Methane reductions from the Natural Gas STAR program for the years 1994 through 2000 are presented in Table F- 3. Emission reductions by project are reported by industry partners using actual measurement data or equipment-specific emission factors. Before incorporating the reductions into the Inventory, quality assurance and quality control checks are undertaken to identify errors, inconsistencies, or irregular data. Total

[1] It is assumed that the 5 percent decline in the emissions factor from 1995 to 2020 does not reflect emission reductions attributed to Natural Gas STAR. The emission factor decline accounts for regular technology improvements only. This assumption is being investigated for future inventories.

emissions were estimated by adding the emission estimates from each stage. Table F-4 illustrates emission estimates for venting and flaring emissions from the field production stage using this methodology. Table F-5 presents total natural gas production and associated methane emissions.

Table F-1: 1992 Data and Emissions (Mg) for Venting and Flaring from Natural Gas Field Production Stage

	GRI/EPA Values			*EPA Adjusted Values*		
Activity	**Activity Data**	**Emission Factor**	**Emissions**	**Activity Data**	**Emission Factor**	**Emissions**
Drilling and Well Completion						
Completion Flaring	844 compl/yr	733 Scf/comp	12	400 compl/yr	733 scf/comp	6
Normal Operations						
Pneumatic Device Vents	249,111 controllers	345 Scfd/device	602,291	249,111 controllers	345 scfd/device	602,291
Chemical Injection Pumps	16,971 active pumps	248 Scfd/pump	29,501	16,971 active pumps	248 scfd/pump	29,502
Kimray Pumps	11,050,000 MMscf/yr	368 Scf/MMscf	78,024	7,380,194 MMscf/yr	992 scf/MMscf	140,566
Dehydrator Vents	12,400,000 MMscf/yr	276 Scf/MMscf	65,608	8,200,215 MMscf/yr	276 scf/MMscf	43,387
Compressor Exhaust Vented						
Gas Engines	27,460 MMHPhr	0.24 Scf/HPhr	126,536	27,460 MMHPhr	0.24 scf/HPhr	126,535
Routine Maintenance						
Well Workovers						
Gas Wells	9,392 w.o./yr	2,454 scfy/w.o.	443	9,392 w.o./yr	2,454 scfy/w.o.	443
Well Clean Ups (LP Gas Wells)	114,139 LP gas wells	49,570 scfy/LP well	108,631	114,139 LP gas wells	49,570 scfy/LP well	108,631
Blowdowns						
Vessel BD	255,996 vessels	78 scfy/vessel	383	242,306 vessels	78 scfy/vessel	363
Pipeline BD	340,000 miles (gath)	309 scfy/mile	2,017	340,200 miles (gath)	309 scfy/mile	2,018
Compressor BD	17,112 compressors	3,774 scfy/comp	1,240	17,112 compressors	3,774 scfy/comp	1,240
Compressor Starts	17,112 compressors	8,443 scfy/comp	2,774	17,112 compressors	8,443 scfy/comp	2,774
Upsets						
Pressure Relief Valves	529,440 PRV	34.0 scfy/PRV	346	529,440 PRV	34.0 scfy/PRV	346
ESD	1,115 platforms	256,888 scfy/plat	5,499	1,372 platforms	256,888 scfy/plat	6,767
Mishaps	340,000 miles	669 scfy/mile	4,367	340,200 miles	669 scfy/mile	4,370

Table F-2: Activity Factors for Key Drivers

Variable	Units	1990	1995	1996	1997	1998	1999	2000
Transmission Pipelines Length	miles	291,990	296,947	292,186	294,304	302,706	296,581	293,774
Wells								
GSAM Appalachia Wells*	# wells	120,162	123,092	122,700	120,037	117,878	118,723	118,723
GSAM N Central Associated Wells*	# wells	3780	3641	3417	3409	3,361	3,361	3,361
GSAM N Central Non-Associated Wells*	# wells	3,105	6,323	7,073	6,701	8,664	8,548	8,548
GSAM Rest of US Wells*	# wells	145,100	164,750	173,928	173,550	190,387	180,178	180,178
GSAM Rest of US Associated Wells*	# wells	277,301	264,837	264,807	264,185	254,848	254,848	254,848
Appalch. + N. Central Non-Assoc. + Rest of US	# wells	268,367	294,165	303,701	300,288	316,929	307,449	307,449
Platforms								
Gulf of Mexico Off-shore Platforms	# platforms	3,798	3,868	3,846	3,846	3,963	3,975	4019
Rest of U.S. (offshore platforms)	# platforms	24	23	24	23	23	23	23
N. Central Non-Assoc. + Rest of US Wells	# platforms	148,205	171,073	181,001	180,251	199,051	188,726	188,726
Gas Plants								
Number of Gas Plants	# gas plants	761	675	623	615	558	581	585
Distribution Services								
Steel – Unprotected	# of services	5,500,993	6,151,653	5,775,613	5,518,795	5,463,253	5,751,250	5,676,582
Steel - Protected	# of services	19,916,202	21,002,455	18,593,770	19,078,467	18,478,344	18,310,719	17,775,878
Plastic	# of services	16,269,414	26,044,545	26,187,536	27,800,401	28,629,388	28,796,952	31,644,014
Copper	# of services	1,379,237	1,445,380	1,519,625	1,498,050	1,464,019	1,458,518	1,434,091
Total	# of services	43,065,846	54,644,033	52,076,544	53,895,713	54,035,004	54,317,439	56,530,565
Distribution Mains								
Steel – Unprotected	miles	91,267	94,058	88,412	85,166	86,639	84,534	82,817
Steel – Protected	miles	491,120	503,288	484,526	479,278	484,963	459,298	468,932
Cast Iron	miles	52,644	50,625	51,542	47,669	47,587	45,865	44,736
Plastic	miles	202,269	353,735	350,699	385,373	400,627	415,210	446,554
Total	miles	837,300	1,001,706	975,179	997,486	1,019,816	1,004,907	1,043,039

* GSAM (Gas Systems Analysis Model) is a natural gas supply, demand, and transportation model used by the Federal Energy Technology Center of the U.S. Department of Energy (GSAM 1997).

Table F- 3. Methane reductions from the Natural Gas STAR program (Tg)

Process	1994	1995	1996	1997	1998	1999	2000
Production	0.10	0.12	0.19	0.25	0.29	0.38	0.48
Processing	-	-	-	-	-	-	-
Transmission and Storage	0.07	0.09	0.08	0.11	0.15	0.18	0.23
Distribution	0.02	0.02	0.01	0.03	0.02	0.02	0.02

Table F-4: CH_4 Emission Estimates for Venting and Flaring from the Field Production Stage (Mg)

Activity	1990	1995	1996	1997	1998	1999	2000
Drilling and Well Completion							
Completion Flaring	5.4	5.9	6.1	6.0	6.3	6.1	6.1
Normal Operations							
Pneumatic Device Vents	567,778	655,386	692,033	687,785	757,995	717,231	715,785
Chemical Injection Pumps	36,449	43,111	45,666	45,256	50,352	47,769	47,673
Kimray Pumps	134,247	147,191	151,572	149,492	157,342	152,492	152,184
Dehydrator Vents	41,436	45,432	46,784	46,142	48,565	47,068	46,973
Compressor Exhaust Vented Gas Engines	119,284	137,690	145,389	144,497	159,247	150,683	150,379
Routine Maintenance							
Well Workovers Gas Wells	531	582	600	591	622	603	602
Well Clean Ups (LP Gas Wells)	101,118	110,868	114,168	112,601	118,514	114,861	114,629
Blowdowns							
Vessel BD	256	292	306	303	329	314	314
Pipeline BD	1,710	1,852	1,908	1,894	1,997	1,932	1,928
Compressor BD	1,548	1,730	1,802	1,786	1,920	1,837	1,833
Compressor Starts	3,462	3,871	4,031	3,995	4,296	4,110	4,102
Upsets							
Pressure Relief Valves	326	376	397	395	435	412	411
ESD	6,764	6,882	6,834	6,816	7,006	7,013	7,075
Mishaps	925	1,003	1,033	1,025	1,081	1,045	1,043

Table F-5: U.S. Total Natural Gas Production (Trillion Ft^3/yr) and Associated CH_4 Emissions (Gg)

Activity	1990	1995	1996	1997	1998	1999	2000
Production	17.8	18.6	18.9	18.9	18.7	18.6	19.1
CH_4 Emissions from Production	1,404	1,470	1,466	1,397	1,496	1,329	1,226