2. Methane

Methane (CH_4) is the second largest contributor to global warming among anthropogenic greenhouse gases, after carbon dioxide. It is estimated to be 21 times more effective at trapping heat in the atmosphere than carbon dioxide over a 100-year time period (IPCC, 1996). Over the last 200 years atmospheric methane concentrations have doubled and continue to rise (IPCC, 1997, Dlugokencky, et al., 1998). Methane is emitted from both natural and anthropogenic sources, with the major anthropogenic sources including waste, energy, and agricultural sectors. The anthropogenic sources combined to account for 70 percent of global methane emissions in 1990 (IPCC, 1995).

This chapter presents methane emissions from developed countries for 1990 through 2010 for the following anthropogenic sources:

- Natural gas and oil systems;
- Livestock enteric fermentation;
- Landfilling of solid waste;
- Coal mining activities;
- Livestock manure management;
- Wastewater treatment; and
- Minor sources such as rice, fossil fuel combustion, and agricultural residue burning.

2.1 Overview

As shown in Exhibit 2-1, natural gas and oil, enteric fermentation, and landfilling are consistently the largest sources. In 2000, these three sources account for over 75 percent of the total methane emissions reported for developed countries. The natural gas and oil industry is the largest anthropogenic source of methane emissions. The contribution from this

Exhibit 2-1: Methane Emissions – By Source ($MMTCO_2$)

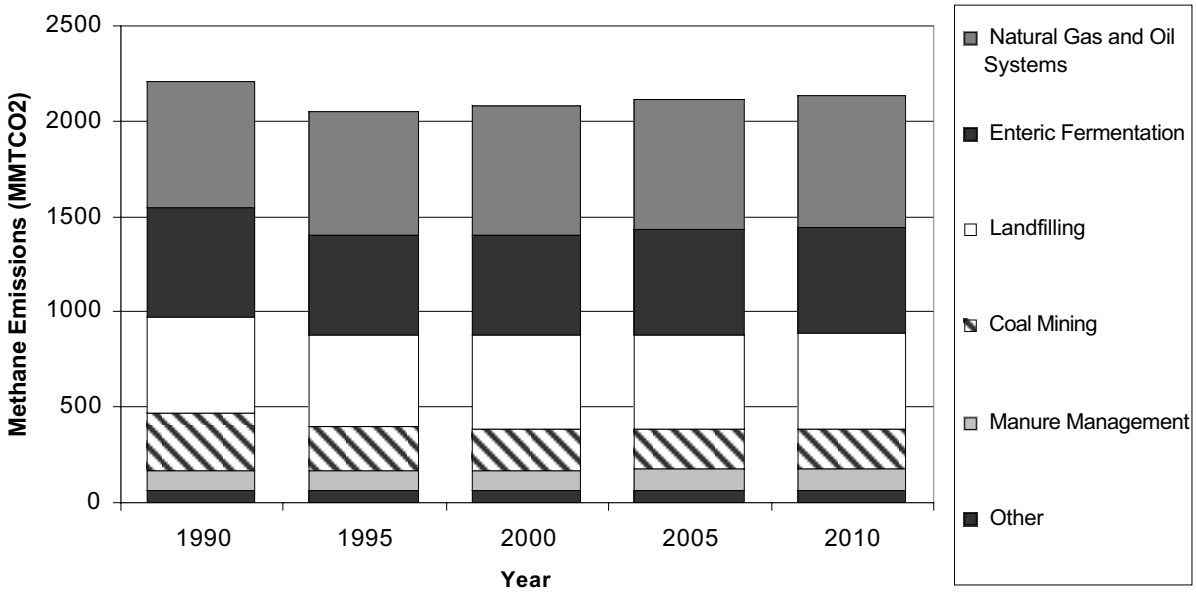


Exhibit 2-2: Total Methane Emissions from Developed Countries ($MMTCO_2$)

Region	1990	1995	2000	2005	2010
EU-15	430	375	379	373	367
Other Western Europe	12	12	13	13	11
Russia	537	497	517	542	559
Eastern Europe	391	301	311	314	313
AUS/NZ	147	144	152	162	171
Japan	32	31	34	33	33
Canada	73	86	82	84	87
U.S.	645	651	642	646	651
Total	2,267	2,097	2,130	2,165	2,191

source increases in absolute terms over the period by more than 30 $MMTCO_2$, as many developed countries shift away from coal consumption in favor of natural gas.

As shown in Exhibit 2-2, overall methane emissions from developed countries are likely to decline by approximately 3 percent from 1990 to 2010. The trend is largely the result of the transition of the Former Soviet Union (FSU) and Eastern Europe to market economies, reduction of coal production in key countries due to changes in economic policies, and the modernization of oil and gas facilities. In the EU-15 and Eastern Europe, major coal producing nations anticipate a shift away from coal consumption in favor of natural gas and other fuels, leading to lower coal production and associated methane emissions. At the same time, the EU-15 countries are modernizing and upgrading their gas and oil facilities, so that increased gas production and consumption will result in only modest increases in fugitive emissions from gas facilities.

The only two regions experiencing significant growth are Australia/New Zealand and Canada. Australia and New Zealand are experiencing growth in methane emissions from nearly all sources. In Canada, emissions growth occurs in the agricultural sector.

Livestock enteric fermentation accounts for 24 percent of methane emissions in 2000. Its contribution reflects the relatively large livestock industries in the United States and the EU-15. The primary driver for the large drop in emissions from 1990 to 1995 was the rapid economic restructuring taking place in the former Soviet Union and Eastern Europe. In the transition to market economies, these countries drastically reduced the size of their livestock herds, which led to a decrease in the associated methane emissions. Economic projections indicate that livestock populations and methane emissions will grow in the future.

The third largest source is landfilling of solid waste. Currently, most developed countries dispose of the majority of their waste in landfills, which tend to promote methane generation. Significant efforts are underway in most countries to improve waste management practices, resulting in a relatively stable emission level in spite of overall economic and population growth.

2.2 Natural Gas and Oil Systems

Methane is the principal component (95 percent) of natural gas and is emitted from natural gas production, transmission and distribution, and processing operations. Natural gas is often found in conjunction with oil, thus oil production and processing can also emit methane in significant quantities. In both oil and gas systems, methane is emitted by leaking equipment and deliberate venting throughout the systems, including in production fields, processing facilities, transmission lines, storage facilities, and gas distribution lines.

Total Methane Emissions from Natural Gas and Oil Systems

Year	$MMTCO_2$	Gg CH_4
1990	663	31,600
1995	648	30,900
2000	678	32,300
2005	684	32,600
2010	696	33,100

As shown in Exhibit 2-3, overall methane emissions are projected to increase almost 6 percent. Russia and U.S. are the largest oil and gas producing and consuming countries, and contribute the bulk of the emissions. Russia alone contributes roughly half of developed country emissions from this source and Russian emissions are projected to increase most significantly (53 $MMTCO_2$). In addition, emissions from Australia are expected to almost double the 1990 level by 2010 and the U.S. will experience a modest increase of 9 $MMTCO_2$. The effect of these increases will be moderated by a decrease in emissions in Eastern Europe of 34 $MMTCO_2$.

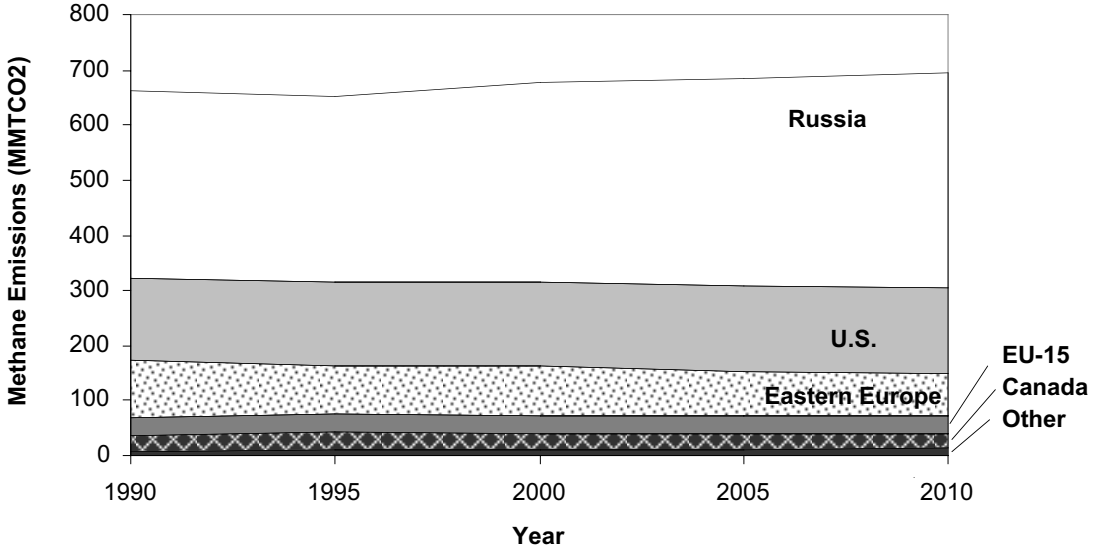
Although demand for gas may be growing in certain regions, for a variety of technical, economic and environmental reasons, emissions are unlikely to increase at the rate of production. Leakage and venting do not necessarily increase linearly with throughput, and newer equipment tends to leak less than older equipment.

Future methane emission levels may be lower than projected here due to some important trends in the sector. First, in many countries, concern is increasing about the contribution of oil and gas facilities to deteriorating local air quality, particularly emissions of non-methane volatile organic compounds. Measures designed to mitigate these emissions, such as efforts to reduce leaks and venting, have the ancillary benefit of reducing methane emissions. Second, economic restructuring in the FSU and Eastern Europe may lead to a modernization of gas and oil facilities. For example, Germany anticipates a reduction in emissions from the former East German system through upgrades and improved maintenance. Russia also plans to focus on opportunities to reduce emissions from its oil and gas system as part of modernization activities.

2.3 Livestock Enteric Fermentation

Methane is emitted as part of the normal digestive process of livestock, particularly in ruminant animals (i.e., cattle, buffalo, sheep, and goats). The size of the livestock populations and the management practices in use, particularly feed intake, drive emissions. Thus, demand for livestock products (primarily milk and meat) and efficiency improvements will be the primary drivers of enteric fermentation emissions in the future.

Exhibit 2-3: Methane Emissions from Natural Gas and Oil Systems 1990 through 2010 ($MMTCO_2$)



Total Methane Emissions from Livestock Enteric Fermentation		
Year	$MMTCO_2$	Gg CH_4
1990	576	27,500
1995	525	25,000
2000	527	25,100
2005	547	26,100
2010	552	26,300

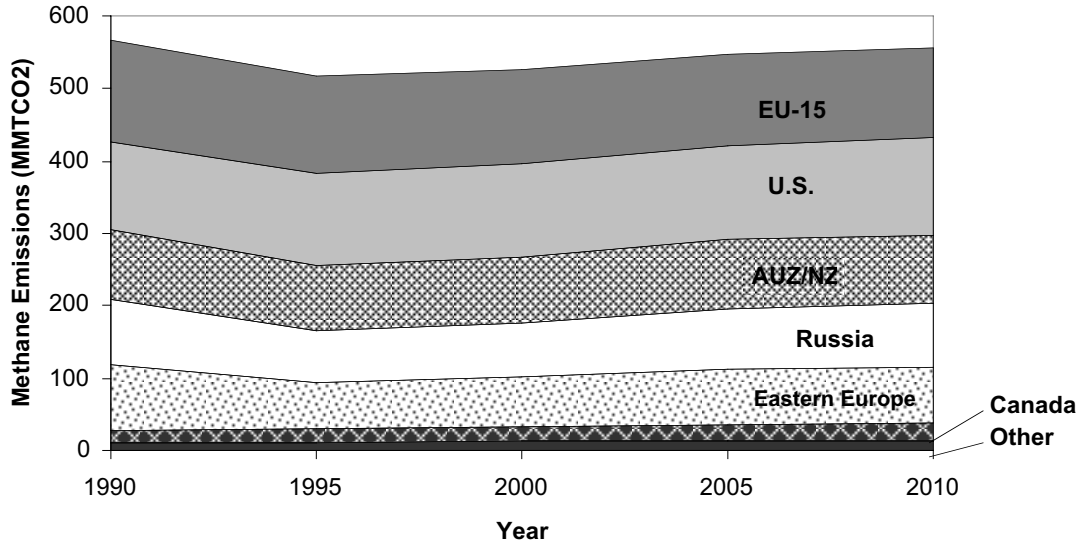
In developed countries, methane emissions from enteric fermentation are expected to be about 4 percent lower in 2010 than in 1990. Emissions dropped by over 9 percent between 1990 and 1995, and are expected to increase slowly after 1995. The decline between 1990 and 1995 was attributable to declines in livestock populations in Europe and Russia. In the EU-15, where approximately two-thirds of all cows are dairy cows, the cattle population is falling by around 2 percent per year due to milk quotas and increasing yields per animal. The number of beef cows (as well as sheep and goats) is stable and emissions are not expected to increase in the EU-15 after 2000. During the 1990s, the farm industries in Eastern European countries and Russia reduced their livestock production as part of their transition to market economies. Production in these countries is expected to increase between 2000 and 2010, leading to corresponding emission increases.

As shown in Exhibit 2-4, emission levels in the remaining countries are expected to be relatively flat, following changes in livestock populations. In the U.S. and Canada, cattle populations will grow in response to increased demand for milk and meat products. The effect on emissions will be offset somewhat by increased production efficiencies. The stable emission levels in Japan, Australia, and other western European countries reflect predictions of stable or decreased populations of cattle.

2.4 Landfilling of Solid Waste

Methane is produced and emitted from the anaerobic decomposition of organic material in landfills. The major drivers of emissions are the amount of organic material deposited in landfills, the extent of anaerobic decomposition, and the level of landfill methane collection and combustion (e.g., energy use or flaring). Because organic material deep within landfills takes many years to decompose completely, past landfill disposal practices greatly influence present day emissions.

Exhibit 2-4: Methane Emissions from Livestock Enteric Fermentation 1990 through 2010 ($MMTCO_2$)



Total Methane Emissions from Landfilling of Solid Waste		
Year	$MMTCO_2$	Gg CH_4
1990	501	23,900
1995	481	22,900
2000	490	23,300
2005	492	23,400
2010	496	23,600

Solid waste disposal is the third largest anthropogenic source of methane in developed countries and accounts for nearly one quarter of their anthropogenic methane emissions. The small decline in emissions from 1990 to 1995 in the EU-15 and U.S. is due to collection and flaring or use of landfill methane. As shown in Exhibit 2-5, although emissions are projected to grow in developed countries between 1995 and 2010, they are not expected to exceed 1990 levels. In many countries, landfill methane emissions are not expected to grow despite continued or even increased landfilling of waste, because of non-climate change related regulations.

The only region that expects an increase in emissions from this source is Eastern Europe, where solid waste will be diverted increasingly to managed landfills as a means of improving overall waste management. Methane emissions are expected to increase at a steady rate from 1995 to 2010.

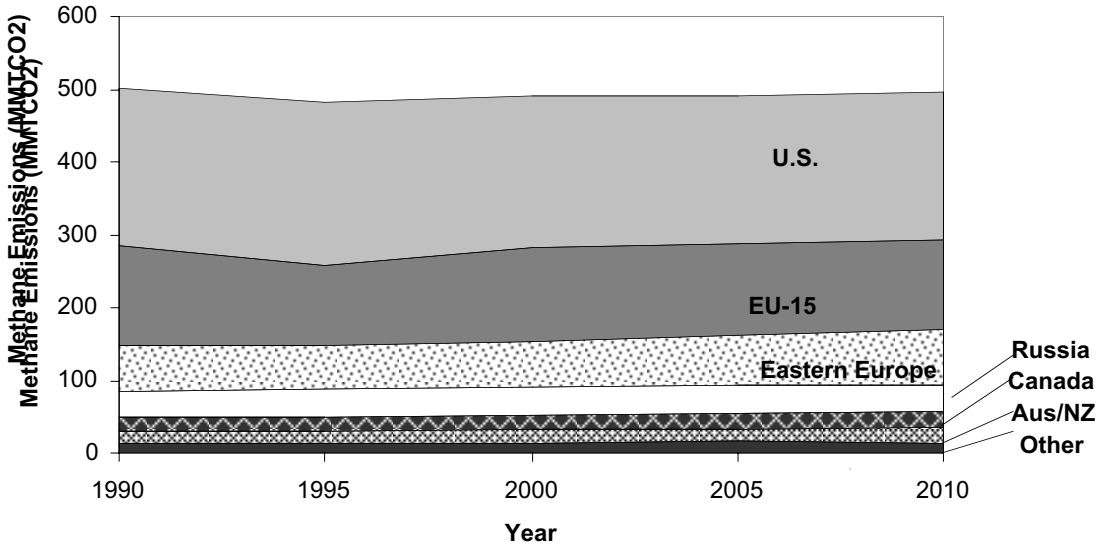
2.5 Coal Mining Activities

The methane emitted during coal mining and post-mining activities is a function of the amount of methane contained in the coal and the type of mining. In general, deeper, higher ranked coals contain more methane, and longwall mining releases more methane than other types of underground mining.

Methane is emitted from underground mining either through the mine's ventilation system or degasification system. Prior to mining, a portion of the methane in and around the coal seam can be recovered and used for energy, so that methane emissions during mining can be reduced. In most countries, a small number of the gassiest underground mines usually account for a large percentage of overall methane emitted.

Total Methane Emissions from Coal Mining Activities		
Year	$MMTCO_2$	Gg CH_4
1990	303	14,400
1995	229	11,000
2000	216	10,300
2005	217	10,300
2010	216	10,300

Exhibit 2-5: Methane Emissions Landfilling of Solid Waste 1990 through 2010 ($MMTCO_2$)



As shown in Exhibit 2-6, overall emissions declined significantly during the last decade and are expected to remain near 2000 levels out to 2010. Restructuring of the energy industries in Europe and FSU resulted in a decline in coal production, particularly at gassier mines. In Russia and other Eastern European coal producing countries, many of the gassiest underground mines have closed. Since the integration of East and West Germany, total German coal production has also dropped, due to the government's gradual removal of subsidies.

Emissions from coal mining activities are expected to decrease in the U.S. through 2010 because production is shifting from underground coal mines to surface mines. Additionally, coal mines in the U.S. are increasingly recovering methane from degasification systems.

2.6 Livestock Manure Management

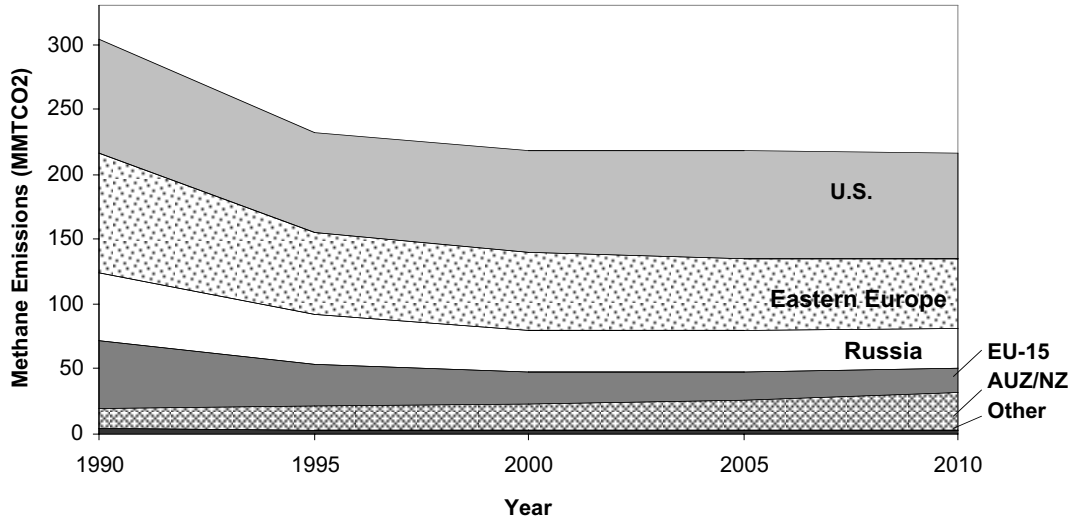
Methane is a by-product of the anaerobic decomposition of livestock manure. Anaerobic conditions usually occur at large confined animal management facilities that manage and store manure as a liquid or slurry. Lagoons, pits, and tanks at large dairy and swine farms are the major source of emissions. Along with the type of manure management, the amount and composition of manure produced and temperature also influence emissions.

Total Methane Emissions from Livestock Manure Management

Year	$MMTCO_2$	Gg CH_4
1990	102	4,840
1995	98	4,680
2000	103	4,930
2005	107	5,080
2010	109	5,210

Methane emissions from manure management will grow by 5 percent between 1990 and 2010 due to the growth in animal populations necessary to meet expected demand for milk and meat, and the increased use of liquid manure management systems. These two factors are principally responsible for the increases in the U.S. and Canada from 1995 onward. Russia and many Eastern European countries are reducing their livestock production in the short-term as part of their economic transition. However, as shown in Exhibit 2-7, livestock production and thus emissions are expected to begin a slow increase after 2000. The slight decline in methane emissions anticipated by the EU-15 is primarily due to the

Exhibit 2-6: Methane Emissions from Coal Mining Activities 1990 through 2010 ($MMTCO_2$)



projected decrease in livestock populations, particularly in the number of dairy cows where populations are controlled to comply with market ceilings. The animal population growth rates will be relatively flat or minimal in Australia, other Western Europe countries, and Japan.

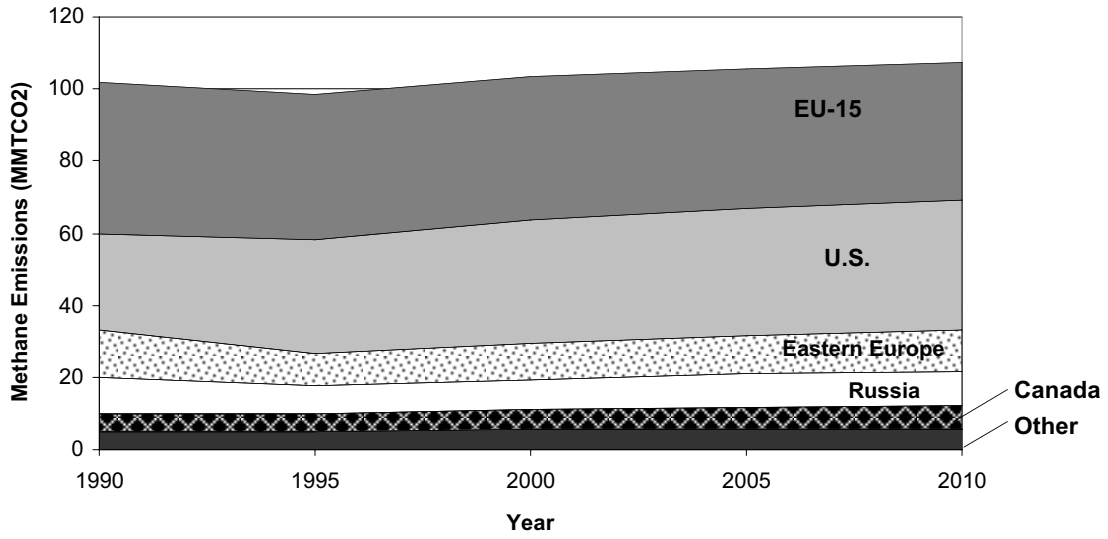
2.7 Wastewater Treatment

Methane is emitted both incidentally and deliberately during the handling and treatment of municipal and industrial wastewater. The organic material in the wastewater produces methane when it decomposes anaerobically. The amount of organic material produced and the extent to which it is broken down anaerobically drive the emissions. Most developed countries rely on centralized aerobic wastewater treatment to handle their municipal wastewater, so that methane emissions are small and incidental. Industrial wastewater can also be treated anaerobically, with significant methane being emitted.

Total Methane Emissions from Wastewater		
Year	$MMTCO_2$	Gg CH_4
1990	37	1,770
1995	36	1,720
2000	36	1,740
2005	38	1,770
2010	38	1,800

Proper wastewater handling and treatment is vital to protect surface water, groundwater, and public health. Most developed countries have had an extensive infrastructure to handle urban wastewater for some time, so the main trend in municipal wastewater emissions is associated with changes in population. Exhibit 2-8 projects a slow and steady increase in emissions from 2000 through 2010, in response to these population changes. Heightened attention to the problems of industrial wastewater may lead to a change in treatment practices. If anaerobic treatment is used without methane recovery, net emissions could increase substantially. Additionally, the potential exists for emissions to be higher than estimated because this study excludes the effects of wastewater discharged into lakes and rivers.

Exhibit 2-7: Methane Emissions from Livestock Manure Management 1990 through 2010 ($MMTCO_2$)



The small decrease in emissions in Eastern Europe between 1990 and 1995 is due to lower industrial wastewater contributions to the system and increases in the amount of wastewater treated by advanced wastewater treatment systems that include aerobic processes and bio-gas capture. Growth in emissions after 2000 primarily reflects expected increases in industrial productivity and population growth in the Eastern Europe.

Although there is a general lack of data for this source, most experts believe that emissions are relatively small compared to other sources. Therefore, the effect of this uncertainty on total methane emissions is likely to be small.

2.8 Other Sources

Methane is emitted from other agricultural and non-agricultural sources including:

- Rice cultivation: Methane emissions result from the anaerobic decomposition of organic material in flooded rice fields;
- Agricultural residue burning and savannah burning: Methane emissions from burning activities result from incomplete combustion;
- Land conversion: Methane emissions result when burning is used to clear land;
- Fossil fuel combustion from stationary and mobile sources;[1]
- Biomass fuel combustion;
- Waste incineration; and
- Miscellaneous industrial processes.

The smaller agricultural sources are insignificant in many developed countries, which may account for the omissions of these sources in some countries' National Communications. Although rice cultivation is a major source of methane emissions globally, it is not considered a major source in this report because Japan is the only developed country with significant emissions from this source.

Total Methane Emissions from Other Agricultural Sources

Year	$MMTCO_2$	Gg CH_4
1990	29	1,390
1995	30	1,420
2000	31	1,470
2005	30	1,430
2010	30	1,440

Exhibit 2-8: Methane Emissions from Wastewater Treatment 1990 through 2010 ($MMTCO_2$)

Total Methane Emissions from Other Non-Agricultural Sources		
Year	$MMTCO_2$	Gg CH_4
1990	55	2,630
1995	51	2,410
2000	50	2,370
2005	51	2,440
2010	54	2,560

For other agricultural sources, emissions from developed countries are projected to remain stable through 2010. The lack of reporting on these sources does not allow for accurate analysis of the trends in either category. For other non-agricultural sources, emissions drop 8 percent between 1990 and 1995, but return to 1990 levels by 2010.

2.9 Explanatory Notes

1. The amount of methane emitted from fuel combustion is driven by the amount of fuel combusted and the combustion technology used.