COMMISSION OF THE EUROPEAN COMMUNITIES

Brussels, 15.11.1996
COM(96) 557 final

STRATEGY PAPER FOR REDUCING METHANE EMISSIONS

(COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND TO THE EUROPEAN PARLIAMENT)

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1. EXECUTIVE SUMMARY

Methane, a global issue ?

Since the pre-industrial era, methane (CH4) concentration in the atmosphere has grown continuously, mainly influenced by human activity. Methane is an active greenhouse gas which traps heat (from infrared radiations) and inhibits its release into space, it therefore contributes to the increase of atmospheric and earth surface temperatures and to the "global greenhouse effect". It is currently second to carbon dioxide (CO2) in contributing to global warming. Increasing atmospheric methane concentrations account for 18 percent of the global greenhouse effect compared to approximately 66% for carbon dioxide (see Fig. 2).

Objective of the Communication

The aims of this document are to examine problems and concerns related to atmospheric methane emissions, to identify the main emissions sources and sinks, to introduce some cost-effective means to reduce these emissions and to provide a set of potential measures for incorporating into a Community emissions mitigation strategy. The Communication covers a series of measures that explicitly address the priority sectors, namely agriculture, waste and energy.

At both the Community and international level it has been recognised that a methane reduction policy should be an important element of an overall climate change strategy especially in view of the fact that the implementation of methane reduction strategy could have a more immediate impact compared to measures adopted for CO2. This Communication responds to this challenge by developing for the EU a credible strategy for reducing methane emissions which includes viable policies and measures and that could form a key element in the EU's developing Climate Change Policy.

In this policy framework there are still some questions that need to be resolved on the orientation to take on mitigating methane emissions. An important part of this assessment would be either to achieve a certain reduction target within a certain timeframe (as evoked in the Fifth Environmental Action Programme) or to choose policy measures from a list of options having the most favourable cost-effectiveness ratio up to a certain cut-off point. Such a cut-off point in principle could be determined either by a monetary valuation of the social costs caused by methane emissions or by other suitable methods.

Finally, the assessment of the cost effectiveness for the proposed strategy may require further deeper analyses in order to develop reliable data to underpin concrete policy actions that could be undertaken at the EU level.

Methane main properties

Amongst the principal characteristics of methane which have a harmful impact on the atmosphere, the following are the most important.

First, methane concentration (1.72 ppm) in the atmosphere has nearly doubled since the beginning of this century mainly due to human activity.

Secondly the power with which a greenhouse gas contributes to earth global warming is normally expressed by its Global Warming Potential (GWP). The GWP indicates the power of a gas in relation to the standard substance, CO2, and that by definition has a GWP equal to one. Methane's GWP is

62 times higher than the GWP of CO2, this shows the importance of reducing methane emissions.

Thirdly, stabilization of methane concentration in the atmosphere could be reached today by a reduction of only 10% of the annual global anthropogenic emissions which is definitely less than for CO2 which would require around a 60% cut in annual anthropogenic emissions. Clearly, this difference has repercussions on the span of policies and measures and the amount of resources that has to allocated in order to achieve specific reduction goals. Carbon dioxide remains, however, for the future the main concern for global warming.

Another important parameter is the time methane stays in the atmosphere, 12-17 years against 50-200 years for CO2. This means that the implementation of a strategy to reduce methane emissions would have a more immediate impact on the global greenhouse effect compared to CO2 where the benefit of initiatives would only be perceptible in the medium or long term.

Finally, it must be pointed out that the simple combustion of methane transforms methane into CO2 and eliminates 95% of its warming potential.

EU inventories

Agriculture, waste and energy are the three main anthropogenic methane emissions sources in the EU. Inventories have been quantified in these sectors and are summarized below (CORINAIR 90 data).

Agriculture (45%) stands in first position with methane production resulting from the anaerobic enteric fermentation (digestion) of animals (30%) and that resulting from the anaerobic management of the animal wastes - manures - (15%). Then follows waste (32%) where methane is generated by the anaerobic fermentation of organic matter trapped in landfills. Finally, methane is emitted in the energy sector (23%), in particular in coal mining (12%) and the production, distribution and use of natural gas (8%).

EU inventories (year 1990) of main methane anthropogenic emissions sources

Agriculture		*44.7 %*	*10.2 Mt*
- enteric fermentation (digestion) of ruminant livestock (cattle, sheep) :	30 %		
- livestock manure :	14,7 %		
Waste		*31,5 %*	*7.3 Mt*
- landfills :	30,8 %		
- waste water treatment (sludge) :	0,7 %		
Energy		*23 %*	*5.3 Mt*
- coal mining, transport and storage :	11,4 %		
- gas production and distribution :	8,8 %		
- combustion :	2 %		
- transport :	0.8%		

Mt = million of tonnes

Community strategy to reduce methane emissions

A series of options to reduce methane emissions are set out in this paper as well as policies and measures that are already implemented in some Member States or third countries. Effective options in the most promising sectors, essentially agriculture, waste and energy, are then identified at EU, national, regional and local level and are proposed as potential actions to be carried out in the form of a Community strategy. They are briefly described below.

In the agriculture sector, the most promising area for reducing methane emissions is animal manure management. Anaerobic digesters or simple covered lagoons provide an effective means to limit and to reduce methane emissions. In order to gain acceptance, farmers in the EU must be first made aware of the possibilities offered by these technologies through demonstration programmes and feasibility studies implemented at EU, national, regional and local levels. An EU legal obligation to install recovery systems should then be implemented in a later stage. This obligation would only apply to animal farm husbandry of a certain size (number of animals to be defined).

In the waste sector, a distinction needs to be made between specific measures addressing new and existing landfills and general measures aimed at reducing organic wastes in landfills. For a new anaerobic landfill, action should be taken at the EU level to ensure that the operating permit is only given if other methane reduction options have been investigated and, where these are not feasible, that a highly efficient system is put into place to recover and use any methane produced. For existing landfills EU legislation should require their retrofitting in order to collect and to use the methane wherever possible. Where this is not feasible it should encourage the use of flaring. Higher methane recovery as well as the use and further development of appropriate technologies should be encouraged through additional economic incentives, both at the national and EU levels. In parallel, general measures to reduce the amount of organic wastes in all landfills such as minimising a generation, separate collection, development of recycled products, composting etc.should be taken at EU, national, regional, local levels.

In the energy sector, coal production and consequently methane emissions from this source will continue to decline in the future and it would be extremely difficult to justify any additional expenditures to implement methane recovery techniques. An EU initiative should only encourage Member State to generate programmes promoting the application of the best available technologies for those coal mines that will still be in operation beyond a certain time frame (10 years for instance). The task is easier concerning natural gas emissions where an EU minimum leakages standard could be defined in order to replace the less efficient parts of the transmission and distribution networks for which a second initiative, taken at Member State level, should decrease methane emissions by increasing the pipelines networks control frequency and thus decrease natural gas leaks.

Mitigation of the greenhouse effect and in particular mitigation of methane emissions are by definition global environmental issues and because of their international context need a Community approach rather than individual differentiated actions implemented by Member States. Nevertheless, it cannot be excluded that a certain number of initiatives proposed in the strategy may, because of the subsidiarity principle, be better undertaken at national, regional and local levels. In any event, these initiatives will have to respond to the coordination efforts at both international and Community levels in order to meet future global environmental commitments.

Methane reduction scenarios using similar strategies are also reported in this Communication, (CITEPA study), the results of which are rather significant despite some uncertainties. The study comes to the conclusion that if similar measures were applied in the EU the resulting methane emission reductions could amount to 30% and 41% respectively in 2005 and 2010 in relation to their 1990 levels.

The suggested options are illustrated in the following summary table.

SUMMARY OF EU POLICY MEASURES TO BE CONSIDERED FOR MITIGATING METHANE EMISSIONS

AGRICULTURE

* ***Enteric fermentation***
- promotion of research and incentives (at EU and national level) to develop viable policies and measures

* ***Animal manure***
- anaerobic digesters or covered lagoons (preferably with energy use, if not feasible with flaring)
  . *1st stage* : demonstration programmes at EU, national, regional and local level
  . *2nd stage* : obligation at EU level to install recovery and use systems for animal farm husbandry units above a certain number of animals(number to be defined)

WASTE

* ***General measures***
- promotion at EU, national, regional and local level of measures such as :
  . minimising the generation of organic waste, including packaging
  . encouraging separate collection of organic wastes
  . material recovery of organic waste (through operations such as composting) and energy recovery operations. Preference should be given, where environmentally sound, to the recovery of material over energy recovery operations. It will nevertheless be necessary to take into account the environmental, economic and scientific effects of either operation. The evaluation of these effects could lead, in certain cases, to preference being given to energy recovery.
- economic incentives at EU and national level to promote recycled products

* ***New landfills***
- EU legislation requiring, in the absence of other methane reduction alternatives, that new anaerobic landfills are equipped with methane recovery and use systems

* ***Existing landfills***
- EU legislation requiring the retrofitting of existing landfills with systems for the collection and use of methane wherever possible. Support and encourage methane recovery processes which yield energy through economic incentives at the EU and national level. Where this is not possible encourage the use of flaring

ENERGY

* ***Coal***
- EU recommendation to Member States for CH4 emissions reduction schemes promoting best available recovery techniques in coal mines

* ***Natural Gas***
- setting-up of an EU minimum leakages standard
- increase control frequency of pipelines at national level

International and Community political context

The Intergovernmental Framework Convention on Climate Change (FCCC), ratified by the EC in December 1993, contains specific commitments to take actions to reduce greenhouse gas emissions and to report on the estimated effects of those actions on projected emissions levels, "with the aim of returning individually or jointly to their 1990 levels these anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol". This implies the consideration of greenhouse gases, such as carbon dioxide, methane, nitrous oxide whose concentrations in the atmosphere are increasing above their natural level..

Nevertheless, current international and Community discussions on the policy response to climate change have so far focused on carbon dioxide (CO2) and halocarbons (CFCs). To date, less attention has been paid to the other greenhouse gases, including methane and nitrous oxide, partly because of the gaps in quantitative knowledge about their sources and sinks. Scientific knowledge has, however, considerably increased on all greenhouse gases and uncertainties about climate impacts have constantly been reduced.

Community policy development so far

In February 1993, the EU through its Fifth Action Programme for Environment "*Towards Sustainability*" committed itself to taking measures for assuring sustainable development. In this perspective, the EU recalled that methane (CH4) is one of the main agents of the greenhouse effect and has defined in its framework on climate change (Chapter 5) a series of actions for greenhouse gases such as CO2, CH4, N2O, CFC's... with the aim, in the particular case of methane, of possibly reducing its emissions. In parallel, through its Environment and Climate research programme, the EU aims at improving knowledge on the sources and sinks of greenhouse gases.

In the January 1996 progress report on the implementation of the Fifth Action Programme for Environment, the assessment made on the climate change issue concluded that priority action is required at EU level to "identify impacts of greenhouse gases other than CO2", it also mentioned that "the Commission is not on schedule to put forward an inventory of the problem and potential measures with reduction targets for methane and nitrous oxide".

In June 1993, a monitoring mechanism for Community CO2 and other greenhouse gas emissions has been established under the Council Decision (93/389/EEC). Article 7.2 specifies that for greenhouse gases other than CO2, "national programmes for the limitation of these gases should be established as policies with regard to these developments".

In the Environment Council conclusions of 15/16 December 1994, the Council "asked the Commission to submit as soon as possible a strategy to reduce greenhouse gases other than CO2, in particular methane and nitrous oxide.

Moreover, the Council Ad Hoc Group on Climate, working on the elaboration of a Community input to the negotiation for a Protocol process under the Berlin Mandate, is currently discussing a Community position in three key areas, agriculture, waste management and industry, and the possibility of inserting policies and measures to limit and/or reduce methane emissions in the Protocol.

2. THE ISSUE

2.1. Methane

Methane (CH4) is a radiatively and chemically active trace greenhouse gas. Being radiatively active, methane traps infrared radiation or heat and contributes to the warming of the Earth. It is currently second only to carbon dioxide (CO2) in contributing to potential future warming. Being chemically active methane enters into complex chemical reactions in the atmosphere, normally the presence of CH4 is naturally removed by the radical hydroxyl (OH) whose concentration is however continuously depleting, that increases not only the abundance of atmospheric methane but also atmospheric concentrations of ozone [1] and stratospheric concentrations of water vapour, which are both greenhouse gases.

2.2. Natural Sources

Variations in methane's atmospheric level over the previous 150.000 years are largely attributed to changes in methane emissions from natural systems, and in particular wetlands. This suggests that there is a risk for increased methane emissions from natural sources as climate changes in the future. The emissions from several of the natural sources, in particular, wetlands, gas hydrates, and permafrost, are strongly governed by environmental variables such as temperature and precipitation. Therefore, climate change induced by humans could actually trigger the release of more greenhouse gases from natural systems and the magnitude of future climate change could increase consequently.

Because of the very limited action that one can undertake in this field, this paper does not discuss further the natural methane sources and sinks nor explores the harmful effects that human activity could have on these. This paper will concentrate only on anthropogenic methane emissions since these are one of the main causes inducing climate change.

2.3. Atmospheric concentrations of Methane

Atmospheric concentrations of methane are increasing. These increases are due to human-related activities that release methane to the atmosphere, partly also because of increases in global population.

In 1990, the methane concentration level was approximately 1.72 ppm[2] - nearly double the level estimated for the beginning of this century. A summary of the ice core data and direct measurement data showing the increase in atmospheric methane concentrations are provided in Figs 1, 2 and 3. Analysis of infrared solar spectra has shown that the atmospheric concentration of methane increased by about 30 percent over the last 40 years.

At present, the current atmospheric amount of methane is approximately 4850 Mt[3]; this amount is thought to be increasing by about 30Mt per year. Atmospheric methane concentrations are expected to continue to increase, although global measurement programs indicate that the rate of increase appears to have slowed in the last several years. The current annual rate of increase of atmospheric methane is about 0.0115 ppm.

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[1] Methane is a major concern in the formation of ozone in the troposphere.

[2] 1ppm = 1ppmv = 1 part per million in volume
1ppb = 1ppbv = 1 part per billion in volume
1ppm = 1000ppb

[3] $1\ \text{Mt} = 10^6\text{t} = 10^9\text{kg}$

2.4. Methane and global climate change

Methane's increasing concentration in the atmosphere has important implications for global climate change. Methane is very effective at absorbing infrared radiation (IR) or heat given off by the earth's surface. By absorbing IR and inhibiting its release into space, the presence of methane contributes to increased atmospheric and surface temperatures, and thus to the "greenhouse effect".

The power with which a greenhouse gas contributes to earth global warming is normally expressed by its Global Warming Potential (GWP). The GWP reflects how more powerful a substance is than the standard substance which is CO2 and that by definition has a GWP equal to one. There is no simple way of calculating the GWP compared to CO2, partly because substances have direct and indirect effects. As already mentioned, methane indirectly contributes to global warming by influencing the amount of ozone in the troposphere and stratosphere, the amount of hydroxyl (OH) in the troposphere and the amount of water vapour in the stratosphere. Methane's indirect effect on warming resulting from these chemical reactions could be comparable in magnitude to its direct effect, although considerable uncertainty remains[4].

The IPCC[5] has recommended using a GWP of 62 which reflects both direct and indirect effects over a time horizon of 20 years, this means that the impact on global warming of 1 tonne of CH4 is 62 times higher than the impact of 1 tonne of CO2. If one considers the same effects over a 100 years time horizon, the GWP will be about 25. Over the same period, it has been estimated that approximately 18 percent of the greenhouse effect is due to increasing atmospheric methane concentrations. The total contribution to radiative forcing of all greenhouse gases in 1990 is shown in Fig 2.

2.5 Stabilization and Reduction of global Methane emissions

Since atmospheric methane has been increasing at a rate of about 30 Mt per year, stabilizing global methane concentrations at current levels would require reductions in methane emissions by approximately the same amount. Such a reduction represents less than 10 percent of current anthropogenic emissions. This reduction is much less than the percentage reduction necessary to stabilize the other major greenhouse gases: CO2 requires approximately a 60 percent reduction; nitrous oxide requires a 70 to 80 percent reduction; and chlorofluorocarbons require a 70 to 85 percent reduction.

Because methane has a relatively short atmospheric lifetime compared to the other major greenhouse gases, reductions in methane emissions will help to ameliorate global warming relatively quickly (CH4 has an average residence time of 12-17 years in the atmosphere, whereas for CO2 it is 50-200 years). Therefore, methane reduction strategies offer an effective means of slowing global warming in the near term. On the other hand, because of the relatively high increase in yearly concentration of methane, a continuation of present trends may have a long-term impact on the global temperature which could be almost as dramatic as that foreseen for continued increases of CO2 concentrations. In conclusion, reduction of CH4 emissions is not only an attractive option in the short term but also a necessary commitment for the long term.

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[4] Typical uncertainty is ± 35% relative to the CO2 reference

[5] International Panel on Climate Change

2.6 Elimination of methane emissions : combustion with/without energy recovery. Economic factors connected to the adopted process.

Methane combustion gives rise to a release of energy followed by emissions of CO2 and water vapour. During combustion one tonne of CH4 is converted into 2.75 tonnes of CO2, this means that if we compare on a equal basis the GWP values (before and after combustion), the pre-combustion GWP value of 62 (for methane) ends-up as a post-combustion GWP value of 2.75 (2.75 x GWP[6] of CO2). By converting CH4 into CO2 in a combustion process, one eliminates 95% of the greenhouse gas effect problem since the CO2 generated during the combustion will only represent 5% of the original methane global warming potential. To the extent that avoidance of methane emissions can be done through collection of CH4 and subsequent combustion with energy utilization, a double bonus can be achieved. Certainly, in this case, there will be no net greenhouse emissions at all because the resulting CO2 from the combustion will be counterbalanced by the saving of fuel that would otherwise have been needed to cover the energy production.

In conclusion, the use of flares (simple combustion without energy recovery) should be recommended for eliminating methane emissions and their associated harmful atmospheric impacts but energy recovery systems should be preferred, if they are economically justified.

It should be noted, however, that out of the complete elimination of recovered methane's contribution to global warming, 95% of the benefit is linked to the combustion of CH4 into CO2 and only the 5% is due to the energy saving resulting from utilising the recovered methane's energy content. In other words, from a climate point of view, the importance of methane recovery lies in the elimination of the CH4 molecules much more than in the use of the energy released during the combustion.

This can be illustrated via the following example : if one assumed that the proposed 10$/barrel for the CO2/energy tax reflects the internalization of the external cost of CO2 emissions, the equivalent figure for methane should be in the order of 1500$ per tonne of CH4, whereas the fuel value of methane for industry is in the range of 240-460/tonne. Consequently, decisions on recovering CH4 for instance from landfills or animal manure (biogas) should be based on a much higher shadow value of the methane recovered than its value as a fuel. In other terms, CH4 recovery just for flaring (combustion without heat recovery) will in many cases make sense if one takes into account the potential release of methane into the atmosphere if it had not been recovered or flared.

2.7 Methane emissions in an EU context

An inventory of anthropogenic methane emissions sources for the year 1990 is given in Table 2. This inventory is a synthesis of national specific inventories established per Member State of the EU and supplied to the European Environment Agency (EEA). They have been prepared under the CORINAIR 90 data base programme and include the last updated final and provisional inventories (January 1995). The results are extended to the new enlarged EU; data from former West Germany and former German Democratic Republic are merged into one set of data for Germany. Table 3 summarizes the methane emissions sources per main sector in the EU-15.

The anthropogenic methane emissions in the EU amount to approximately 23 Mt per year which represent about 6% of global emissions estimated at 385 Mt per year.

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[6] CO2 global warming potential is 1 by definition

3. EU METHANE SOURCES AND PRESENT INVENTORIES

Eleven main source sectors (including natural sources) are covered by the CORINAIR 90 summary given in Table 2 which shows the contribution of each sector to global EU emissions. The following conclusions, see also Table 3, can be deduced from the anthropogenic methane emissions.

3.1. Agriculture

Emissions from agriculture represent the greatest source of methane emissions in the EU. They are estimated at **10.2 Mt** for the year 1990 and account for **44,7%** of European emissions. These emissions come mainly from:

- enteric fermentation (digestion) of ruminant livestock (cattle, sheep) : 30 %
- livestock manure : 14.7 %

3.2. Waste

Emissions from waste treatment and disposal represent the second source of methane emissions in the E.U. They are estimated at **7.3 Mt** for the year 1990 and account for **32%** of European emissions. These emissions come mainly from:

- landfills : 30.8 %
- waste water treatment (sludge) : 0.7 %

If the emissions from unmanaged and unaccounted open dumps are taken into consideration, waste might become the first methane emitter in the EU.

3.3. Energy

Emissions from energy represent the third source of methane emissions in the EU. They are estimated to **5.3 Mt** for the year 1990 and account for **23.3%** of European emissions. These emissions come mainly from:

- coal mining, transport and storage : 11.4 %
- gas production and distribution : 8.8 %
- combustion : 2 %
- transport : 0.8%

4. OPTIONS FOR REDUCING METHANE EMISSIONS . SOME MEASURES REPORTED BY MEMBER STATES AND THIRD COUNTRIES.

The unique characteristics of methane emissions, described in Chapter 1, demonstrate the importance of promoting strategies to reduce the amount of methane discharged into the atmosphere. On top of that, methane is a source of energy as well as a greenhouse gas and implementing emissions control options could lead to additional economic benefits, see also Chapter 5. Furthermore, advanced and well-demonstrated technologies are today commercially available.

Options to reduce methane emissions from major sources (agriculture, waste treatment and disposal, energy) will be developed further in the following pages. A summary in Table 4 of the annex illustrates the technical/economical aspects and the effectiveness of these options.

In the context of the FCCC[7], a compilation and a synthesis of recent national communications from Annex I Parties has been prepared. This preliminary review shows the present trends in policies and measures used by the Parties to mitigate climate change. Some 25 communications were analyzed, 12 of them coming from EU Member States. Only key considerations about this assessment are reported in this chapter and cover each sector of interest that is described below. In addition to these comments, some actions undertaken by individual Member States are also reported.

Anthropogenic sources of methane emissions which represent less than 1% of EU-emissions are not considered in this chapter (e.g. waste water treatment, rice cultivation).

4.1 AGRICULTURE

4.1.1 Enteric fermentation

Methane is produced as part of the normal digestion process of ruminant animals (e.g cattle, sheep, goats) as they digest their feed in their forestomach, or rumen. Some of this methane which is exhaled or eructated by the animal is, on an purely energy basis, considered as a feed conversion inefficiency; feed energy converted to methane cannot be used by the animal for maintenance, growth or production of product.

Other pseudo-ruminant animals (such as pig and horses) and humans also produce methane by enteric fermentation, but the total emission is small compared to the emission of ruminants. Therefore, in this chapter only measures for reducing methane emissions from cattle and sheep are treated.

Three options for reducing methane emissions from ruminant livestock are presented here.

-Livestock reduction

A very effective option for reducing animal methane emissions is obviously the reduction in the animals number. However, at the European level, the actual trend for the following years, even if highly uncertain, indicates a slight reduction in ruminant numbers. This reduction will also be affected indirectly by the application of agricultural policy measures other than those aiming at livestock reduction.

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[7] Framework Convention on Climate Change

The EU indeed controls agricultural overproduction by imposing charges and by fixing of quotas. Existing policies have already reduced animal numbers during the past years. The milk-quota instrument proved to be very effective in reducing the milk surplus and dairy cattle numbers. Agri-environmental measures such as economic incentives promoting, where appropriate, the extensification of animal farming contribute to lowering livestock density and may lead to livestock reduction. In the future, the evolution of agricultural policy may affect livestock populations, for example, the efforts to reduce manure surpluses may lead to the reduction of the number of animals but the maintenance and conservation of the landscape may require in some areas the maintenance or increase of the livestock density rate.

Moreover, reducing EU methane emissions by restricting livestock numbers is only possible if ruminants are not raised elsewhere to compensate for reduced EU milk/meat output. In fact, at the global level, a transfer of production to less technologically advanced countries may even have perverse effects, if the manure there is treated in a less environmentally conscious way. A reduction of consumption of products from ruminants might be therefore an alternative to the global reduction of the number of animals.

Today, even if the balance of policies and measures shows a reduction in animal numbers, it is difficult on the European level to assess the impacts of these measures in 2000 and beyond and to see to what extent and for which animal types the reduction could actually take place. However, no drastic changes between 1990 and 2000 should be expected.

-*Increase of feed conversion efficiency*

Some measures can be taken to improve animal efficiency by decreasing energy losses through methanogenesis e.g. the alkali/ammonia treatment of low digestibility straws, the supplements of molasses/urea multinutrient blocks, the defaunation through mineral/protein supplements. These nutrition options don't have much potential when applied to European livestock as most animals already receive a carefully composed diet which has a high digestibility and contains sufficient nutrients. However, some options might be applicable like an increased level of feed intake, the replacement of roughage with concentrates and a change in the composition of concentrates.

An increase in level of feed intake changes rumen VFA-content[8] in such a way that less acetate and more propionate is formed, with lower methane emissions as a consequence. The production level of the animal will generally increase as well.

As roughage contains a high degree of structural carbohydrates (fibres), replacement of part of the roughage in the animal diet with concentrates will generally improve propionate generation and decrease methane production.

If the composition of the currently added concentrates is changed towards one with less fibres, a methane reduction is possible. Alternatives are starch and sugars. By replacing 25 % of structural carbohydrates with non-structural carbohydrates a CH4 reduction of almost 20 % is predicted.

-*Increase of animal productivity*

For completeness this item, even if questionable, is presented as a third potential option.

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[8] Methanogenic bacteria are inhibited by ammonia and by the volatile fatty acid (VFA) propionate. By sustaining a sufficient level of ammonia and shifting the rumen VFA-composition towards more propionate and less acetate, methane production can be reduced.

By adding production enhancing agents to animal feed, or by injecting animals with these agents, animal productivity (milk, beef) can be improved, methane emissions per agricultural product can be decreased. Emissions reductions per unit of 5 % to 30 % have been demonstrated. Currently several antibiotics, ionophores and halogenated compounds are being used for production stimulation, some of which have a direct effect on methanogenesis in the rumen as well.

Finally, apart from adding agents, animal production can be also improved through transgenetic manipulations or biotechnology reproduction techniques.

4.1.2 Livestock manure

If livestock manure is kept under anaerobic (absence of air) conditions and with temperatures higher than about 15°C, methanogenic bacteria will produce methane. At this stage, a controlled fermentation of manure can be started. Methane emissions from anaerobic digestion (fermentation) constitute an energy resource that can be then recovered. Manure management and recovery techniques enable methane to be collected. This recovered methane (biogas) can be either flared (combusted) or used for energy generation (heat and/or electricity) for on-farm purposes or for sale (see Chapter 5). As already mentioned in Chapter 2, the flaring process decreases by up to 95% the harmful atmospheric effect of the recovered methane if this gas was actually emitted, whereas methane recovery and use eliminate completely this harmful effect and even contribute to a greater greenhouse effect reduction by decreasing the overall balance of CO2 emissions. The final stabilized products produced by the anaerobic digestion can be utilized as feed and aquaculture supplements in fish farming or as crop fertilizers.

If livestock manure is kept under aerobic (presence of air) conditions (by turning the manure regularly or by forced ventilation), aerobic transformation of the product will take place replacing CH4 emissions by CO2 emissions. That process will lead to a stabilized compost which then can be used as a crop fertilizer. Clearly in this process, the energy resource and benefits of the biogas (CH4) are lost but its main advantage stays in the replacement of a powerful greenhouse gas by a weak one which leads to a drastic reduction, up to 95%, of the residual emissions' GWP (see Chapter 2).

Generally, policy measures to reduce livestock population will have indirect consequences on the livestock manure reduction strategy and will subsequently greatly influence the methane emissions from this source.

Two options using anaerobic recovery techniques to reduce methane emissions from livestock manure are presented here.

-*Covered lagoons*

Manure management in lagoons is associated with relatively large-scale intensive farm operations. Manure solids are washed out of the livestock housing facilities with large quantities of water, and the resulting slurry flows into primary lagoons. Due to anaerobic conditions the manure is converted into significant methane emissions, provided temperatures remain high enough. By placing an impermeable floating cover over the lagoon and applying negative pressure, methane can be recovered . Methane recovery efficiencies up to 80 % can be achieved.

-*Digesters*

Digesters are special reactors designed to enhance the anaerobic decomposition of organic material and thus maximize methane emissions production inside the reactor for recovery. As a rough approximation, anaerobic digester will reduce the potential for methane emissions by two third or more, leaving the remaining one third of the compounds in the effluent. Methane may still be generated from the effluents. Therefore, efficient digesters with gas recovery systems may reduce methane emissions by up to 70 %, with larger reductions at longer.

Small scale digesters are relatively simple to build and operate. As such, they are an appropriate strategy for small isolated farms and for regions with technical, capital, and material resources constraints. The recovery of high quality fertilizer from digesters may be an even more important benefit than the energy supplied from biogas.

Large-scale digesters, often more technologically advanced digesters, are usually heated and require greater capital investment per unit. Advanced designs can greatly improve the performance of livestock manure digesters and can operate in colder regions.

4.1.3. Description of some measures reported by Member States and Third Countries.

FCCC : Approximately 10% of all policies and measures reported on CH4 were directed towards agriculture. Only nine Parties have provided real measures to reduce CH4 from enteric fermentation or livestock manure. Mention is rather made of policy instruments such as information/education programmes aimed at the improvement of livestock productivity and manure management. However, indirect measures have been reported, like the reduction of livestock population, which clearly affects methane emissions from enteric fermentation and livestock manure.

Netherlands : One of the main instruments put in place in the Netherlands is a manure policy which will not allow more phosphate being put on the land than is taken up by the crop. This policy measure should result in a decrease of cattle and manure and reduce indirectly CH4 emissions from crops.

Germany : Germany has enforced the Animal Husbandry Act which should lead to a reduction of methane emissions through the improvement of animal digestive efficiency.

France : Considering that levels and conditions of emissions in the agriculture sector are insufficiently known, France has launched a research programme, in particular on enteric fermentation and manure management.

4.2 WASTE TREATMENT AND DISPOSAL

4.2.1 Landfills

Methane is generated in the sub-layers of landfills as a direct result of the natural decomposition of organic solid waste in anaerobic condition. The organic component of landfilled waste is broken down by methanogenic bacteria in a complex biological process which produce methane, carbon dioxide and other gases, in a similar way to the storage or manure digestion.

Several options can reduce methane emissions from landfills, some of them by up to 90 percent. These available options are briefly described below.

-Anaerobic (no air) landfill management : methane recovery and utilization

When the landfill is capped by an impermeable layer, anaerobic conditions are enhanced inside the landfill and methane gas generation is accelerated. Emissions of methane to the atmosphere can be prevented by removing this generated waste gas. When recovery wells are installed inside the landfill and by applying a vacuum pressure the methane gas can be collected. Recovery efficiencies of 50 to 80% are achievable, with methane concentrations varying from 30 to 70%.

There are two options for the medium quality gas typically recovered, energy generation or flaring.

First, the recovered landfill gas can be used to generate energy, electricity and/or heat. Electricity can be generated on-site or at a nearby power plant, using internal combustion engines or gas turbines. Landfill gas can be also used directly as a fuel source without conversion to electricity, it can be sold with little or no processing as a medium quality gas for local industrial, residential or commercial heating and energy needs or be processed into high quality gas and sold to natural gas supply systems. Second, landfill gas can be flared (combusted) where there is insufficient gas to justify an energy project or as an initial step before implementing utilization options.

These options would eliminate either completely (up to 100%) or almost completely (up to 95%) the harmful atmospheric effects of methane gas emitted from landfills.

-Aerobic (with air) landfill management

In an aerobic landfill the ratio of CH4 to CO2 production is shifted towards CO2 production, as a consequence of the improved oxidation in the landfill. Methanogenic bacteria are prevented from functioning and consequently aerobic bacteria are able to convert organic waste into carbon dioxide and water. Instead of being fermentated, the organic waste is composted.

In order to sustain aerobic conditions in a landfill, specific designs are necessary, as described hereafter.

In semi-aerobic landfilling air can diffuse through the landfill as it is supplied through the leachate collection pipes located at the bottom of the landfill. Pipe diameters should be large enough to both collect leachate from and supply air to the landfill. Compared to anaerobic landfills a methane production reduction of 50% can be achieved.

The re-circulatory semi-aerobic landfill system is an improved version of the semi-aerobic system. The rate of decomposition and purification of leachate is enhanced, by recirculating the leachate to the landfill so as to encourage aerobic bacterial growth as more oxygen and nutrients are available. Compared to anaerobic landfills a methane production reduction of 80% can be achieved.

The aerobic landfill system uses an air blower to force air into the landfill layers. The air is pumped into landfill through separate pipes down in the landfill. With this system, methane production reductions of 90% are feasible.

-Reduced landfilling of organic waste

The reduced landfilling of organic waste can be achieved firstly by minimising the amount of organic waste which is generated. Where this is not possible, organic wastes should be made subject to recovery operations such as, for example, composting.

In composting facilities organic waste is converted under aerobic conditions into carbon dioxide, water and mainly compost, which can be applied as a soil conditioner. In extensive systems the organic waste is just regularly turned; in intensive systems forced ventilation is applied.

It should be noted that several emerging recovery technologies are being developed which may reduce methane emissions from organic waste management, like the controlled anaerobic digestion (i.e. biogasification) to produce methane or the pyrolysis (i.e. thermal conversion) to produce oil or gas.

Some organic waste such as paper could be made subject to its own recycling process enabling its reintroduction in the paper production process. Council Directive 94/62/EC on packaging and packaging waste already lays down criteria for the reduction and recycling of packaging and packaging wastes.

The establishment of efficient recovery operations is often dependent on the availability of appropriately sorted wastes to feed the relevant recovery process. The separate collection of organic wastes will therefore need to be considered.

Organic waste can also be made subject to energy recovery operations. Although preference should usually be given to material recovery operations such as composting, in certain cases the effect of this preference on the environment and the economy as well as technological constraints may weigh in favour of the energy recovery option.

4.2.2 Description of some measures reported by Member States and Third Countries.

FCCC : Most countries reported on measures to promote recycling and minimize waste. These were being implemented through regulations, policy guidelines and technical standards. Several countries reported on guidelines to change business practices and lifestyles, promotion of recycling and waste minimization, technical standards to regulate packaging and municipal waste, taxes (landfill levies, tariffs on wastes) as policy tools to reduce waste volumes and voluntary agreements to stimulate recycling in households, small business and industry.

Several Parties reported on policies and measures to improve sewage treatment and reduce methane emissions from landfills, focusing on the curtailment of landfills and technical standards to reduce their CH4 emissions. In some cases, financial incentives have been introduced to promote the development of sewage treatment facilities and support projects that use biogas.

Some countries have adopted voluntary agreements to promote recovery and use of energy from wastes.

United Kingdom : UK policies aim to reduce the amount of methane from landfills by :
- adopting policies which promote waste minimisation and recycling, including energy recovery.
- introducing further measures to promote the use of methane from landfills as an energy source and the flaring of methane (conversion of CH4 in CO2)

The government is also promoting energy recovery from waste through orders requiring public electricity supply companies in England and Wales to obtain more electricity from renewable sources. One economic instrument under consideration is introducing a levy on landfill. This could have a significant impact on the amount of waste going to landfill.

Austria : In order to substitute fossil fuels with renewables energies and in particular CH4 from landfills, Austria has established regulations concerning the supply of electricity into the public grid through an ordinance on landfills.

Finland : The waste management development programme according to the Finnish government calls for a rigorous reduction in the number of landfills. One aim is to have just 200 landfills by 2000. By reducing their number, more effort and resources could be dedicated to the management and the supervision of the existing landfills in order to reduce their harmful environmental effects. Another aim is to reduce the volume of waste dumped in landfills by increasing waste recovery and reuse.

France : Since July 1992, France has a regulation that should modify completely the present waste management strategy focusing mainly on waste recycling and valorisation. Accordingly, by 2002 only final wastes will be disposed and newly installed landfills dealing with organic wastes should recover and incinerate the methane emissions.

4.3 ENERGY

4.3.1 Extraction and distribution of fossil fuels

4.3.1.1 Coal

Methane is produced during coalification (the process of coal formation) and remains trapped under pressure in the coal seam and surrounding rock strata. This trapped methane is released when the coal seam is fractured and will eventually be emitted into the atmosphere or will seep back into the mine workings as the coal is mined.

Because methane is highly explosive, mine air containing methane is removed from the mine workings, and is generally vented directly into the atmosphere. The same kind of techniques can be adapted to recover methane. One of the most important characteristics of mined coal is its coal rank which determines the gas content per unit of mass (e.g lignite versus anthracite).

Reducing CH4 emissions from coal mining requires two types of technologies, recovering technologies and utilization technologies (flaring of recovered gas is also possible).

Three recovery techniques and their associated utilization options are briefly presented here.The most significant methane emissions and gas use optimizations are likely to occur by employing a combination of these recovery strategies.

-Enhanced gob recovery

The highly fractured area of coal and rock that is created by the caving of the mine roof after the coal is removed is a gob area, it can release significant quantities of methane into the mine which afterwards is evacuated through the air ventilation system. If this gas is recovered before entering the mine, recovery becomes more efficient and ventilation requirements can be reduced.

The main recovery techniques include the vertical gob wells drilled from the surface and the boreholes drilled from in-mine workings into the gob areas. Methane recovery efficiencies can range from 20 to 50%.

The main option for utilizing the recovered medium quality gas is on-site power generation with either gas turbines or internal combustion engines. Power is used directly on-site or sold to nearby electricity users or to supply companies.

-Pre-mining degasification

Recovering the methane before the coal is mined through pre-mining degasification can be attractive because methane is removed before the air from the mine workings can mix with it. The two primary recovery technologies are in-mine horizontal boreholes and vertical wells, drilled from the surface in advance of mining.

Due to its high calorific value, the recovered gas can be used in many applications such as electricity generation, gas distribution systems and industrial heating. It consistently contains 95 % of methane and can be sold in high quality pipeline systems. Methane recovery efficiencies up to 70% can be achieved.

-Ventilation air utilization

Most mine gas is released to the atmosphere through the ventilation air system which is used in underground coal mines for safety reasons.The methane content of the vented air must be below 5 % for safety reasons (frequently 0.5 %).

In spite of its low concentration, it appears that there may be opportunities to use ventilation air as combustion air in turbines or boilers. However, the technical and economic feasibility has not yet been demonstrated. Methane recovery efficiencies can range from 10 to 90%.

4.3.1.2 Natural gas

Methane is the primary constituent of natural gas, and significant quantities can be emitted to the atmosphere from components and operations throughout a country's natural gas system. Emissions sources generally include gas and oil wells, processing and storage facilities and transmission and distribution systems. Oil wells are also natural gas emissions sources, even if small. Usually the oil pumped at the well-station is a two-phase mixture (liquid and gas) releasing natural gas that can be recovered. Emissions primarily result from the normal operations of many natural gas system components, such as venting and incomplete flaring (combustion) at oil and gas wells, compressor station operations, gas processing facilities, gas-operated control devices and unintentional leaks (fugitive emissions).

Two emissions reduction strategies are briefly discussed here.

-Reduced venting and effective flaring during production

In oil production, the gas must be separated from the oil and the recovered gas is normally used if there is a demand for natural gas as an energy source. Where demand for gas does not exist, the gas is directly released (venting), burned off (flaring), or reinjected into the field to help maintain formation pressure or to "dispose" of the unwanted gases generated during oil production. Although venting and flaring of gases are strictly controlled and reinjecting of gas is increasingly used, significant methane emissions reduction from production facilities can still be achieved through increased effectiveness of flaring and reinjecting operations.

Emissions from gas production arise during exploration, extraction losses and system upsets. Reducing emissions from these sources involves marginal improvements in existing practices that will also reduce safety hazards from methane leaks and reduce wastage. In this way methane recovery efficiencies up to 50% can be achieved.

-Improved leak detection and pipeline repair

Gas pipelines are subject to corrosion and subsequently develop chronic leaks. Preventing and repairing these leaks will reduce fugitive emissions but also achieve at the same time the following triple bonus : increased safety of installations, reduced economic cost of gas losses and finally reduced environmental damages. These results can be achieved through a number of actions including improved leak detection and pipeline inspection, preventative maintenance and replacement programs, and the increased use of corrosion resistant materials (e.g., coated steels, PVC, PE). In this way methane recovery efficiencies up to 80% can be achieved.

4.3.2 Combustion

Methane emissions from stationary and mobile fossil fuel combustion sources (see Table 2) can be reduced by altering combustion processes to reduce the amount of gases produced or by using exhaust control technologies, such as catalytic converters, to reduce emissions of some gases after the combustion process has taken place.

The feasibility of some of these options has not yet been demonstrated and, in many cases, the potential for reducing methane emissions has not been well quantified. CH4 emissions from fossil fuel combustion can be considered as a minor source category in the methane inventory (less than 3 %).

4.3.3 Description of some measures reported by Member States and Third Countries.

FCCC : Policies to reduce fugitive fuel emissions associated with fossil fuel production such as coal mining and natural gas were reported. Such policies took the form of low-emission guidelines and information programmes to encourage voluntary action.

Netherlands : Offshore fields are responsible for 80% of the methane emissions in the Netherlands. Measures are being discussed by government and gas producing companies, in particular regarding the increased use of gas on offshore platforms.

France : Mainly for safety considerations, "GDF"[9] replaced from 1990 to 1993 6000 km of the old gas network. The intention was to devote one billion francs per year from 1993 to 2000 to replace 1000 km/year of the old existing network. Indirect effects on methane emissions are expected as well from this measure. France claims that losses might be reduced by 27kt/year for the period 1990 to 2000.

United Kingdom : The UK government has adopted a working assumption that methane emissions from coal mining, 0.8Mt in 1990, could fall by about a half by 2000. It is encouraging utilities to increase the proportion of methane taken from mines and will take steps to require utilities to publish periodic statements of their approach to limiting methane emissions. UK authorities recently commissioned a study to elaborate the technical potential, cost and effectiveness of possible measures to limit methane emissions from UK deep mined coal production.

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[9] Gaz de France

5. EU POLICY MEASURES TO BE CONSIDERED

The aim of this chapter is to introduce and discuss the best policy options for controlling methane emissions from each source (agriculture, waste, energy). These options are based on some existing policies or studies about cost-effective measures to reduce methane emissions. However, the lack of literature on cost-effectiveness analysis has to be recognized. The non-availability of quantified data on this matter, in particular those referring to least-cost measures for society may lead to some concerns on a proposed methane strategy is well-founded. Additional work and studies at EU and Member State levels would in fact be welcome. In this context, the work performed by ECOFYS ("Cost-effectiveness of emission reducing measures for methane in the Netherlands") should be highlighted. An illustration of the results obtained is given in Fig. 5.

5.1 AGRICULTURE

When addressing the policy measures to be considered in this sector, in particular those concerning the reduction of methane emissions from livestock farming, attention should be paid to the need for a consistent approach to all the environmental issues linked to this sector and the relevant (existing or proposed) legislation.

5.1.1 Enteric fermentation

- *livestock reduction*

More accurate data on methane emissions induced by current multi-sectorial measures in the agricultural field are indispensable to identify clearly the potential and the need for livestock reduction in order to influence future policy formulation in this field. Consequently, in the short term, the implementation of a livestock reduction measure does not seem to be an appropriate option.

- *increase of feed conversion efficiency*

These options are available but the costs and to what extent these options can be implemented in the EU are unknown, currently no reliable data are available on methane reductions and their associated costs. An essential measure that could be considered is the reinforcement of present knowledge at EU and national level by promoting research or launching a new research campaign to identify more precisely methane emissions resulting from this option.

- *increase of animal productivity*

In some EU countries like the Netherlands, Denmark and Germany, production enhancing agents are currently banned for dairy cattle. In addition to this there is a strong resistance against the further use in livestock of production enhancing agents. This will influence the eventual implementation of such measure in the future. Most of the enhancing agents and the genetic techniques are still the subject of research and are not expected to be exploited before 2000.

These options are not easy to express in terms of cost-effectiveness, except for the enhancing agents whose costs are relatively small compared to the saving achieved per animal.

As a consequence, more research at EU and national level is needed on enteric fermentation. Therefore the mentioned options will not be considered as presently viable.

It should be noted that promoting this type of technological incentive in the EU would lead to fewer animals but it might increase in particular the "intensive" character of animal husbandry, therefore disconnecting cattle keeping from land use. There are several implications of such a policy on the environment:

1) a bigger concentration of animal waste (manure) could produce through excessive spreading on land to harmful effects on soils and waters and there would be a risk of conflict with the EU Nitrate Directive if the spreading threshold value is overridden.

2) less grass and less roughage could also mean that landscape and natural features are negatively affected. Managed and maintained natural spaces may progressively disappear and lead to abandoned natural spaces (problems like erosion, biotopes, area fires may arise)

3) the creation of new efficient cow species ("turbo cows") may influence their biodiversity.

In response to this, the EU in the framework of the Agri-Environment regulation is financing (through farmers premiums of the EAGGF) promotion actions aimed at safeguarding the "less productive" animals and relocating these in their original areas and climates.

5.1.2 <u>Livestock manure</u>

The successful development of manure-to-energy facilities depends on several important regional factors including, the ambient temperature and climate; the economic, technical and material resources; the local regulatory requirements and the specific benefits of developing an energy resource and a high quality fertilizer.

From the cost-effectiveness point of view, the most promising technology seems to be the installation of small and medium-scale power units generating heat or/and electricity that are, simple to build, to operate and to maintain . The energy use for on-farm (or neighbouring-farm) purposes can also be easily implemented. Their investment cost is relatively small and the double benefits (fertilizer and energy) may be quite high. However the future acceptance and development of these technologies still require the demonstration of their usefulness. This is why in a first stage, accompanying measures such as demonstration programmes, promotion campaigns, financial incentives and local feasibility studies should be defined at EU, national, regional and local level. In a second stage, the technology should be introduced through an EU obligation legislation for animal farm husbandry larger than a certain number of animals(number to be defined). At this stage, however, this obligation would have to be integrated with existing agricultural and environmental policies such as the Nitrate Directive and the extensive modes of ruminant farming.

Larger-scale power units generating gas or/and electricity mainly for sale are not recognized as cost effective tools. Farms in the EU are in the main relatively dispersed, important transport means would have to be developed, first to collect the intensive manure products (mainly sludges and liquids) that have to be processed and secondly, after digestion, to recover the large amount of stabilized effluent that has to be either dispersed on lands and crops as fertilisers or used for other applications.

The policy measures to be considered should therefore be organized in two stages :

* Stage 1: elaboration of demonstration programmes with public subsidies in order to illustrate the reliability of such equipment. Covered lagoons or anaerobic digesters must gain the acceptance of animal farmers by demonstrating their

economic viability and their technical reliability.

* Stage 2: EU obligation to introduce such technology for animal farm husbandry larger than a certain number of animals.(number to be defined)

5.2 WASTE TREATMENT AND DISPOSAL

Community action in this field may be best split into three areas : general measures aimed at reducing the amount of organic waste which is landfilled, new landfills and existing landfills.

General measures

A promising area for methane reduction is in reducing the amount of organic waste which goes into landfills. This cost-effective technique must be considered as a part of a global scheme of waste elimination, which gives priority to waste prevention. However, where waste arises, improved processing of the organic fraction should be encouraged. The facilitation of increased recovery may require additional measures such as the setting up of appropriate composting standards and criteria as well as encouraging the separate collection of organic wastes to improve the supply of appropriate inputs into the various recovery processes. Composting in particular has the advantage of being a cost-effective measure which requires small investments, has low operating costs and can yield relatively high revenues if the end-product is of sufficient quality to be sold as a soil conditioner. Although preference should usually be given to material recovery unless there are environmental, economic and technological arguments to the contrary, energy recovery from organic waste may also be an option.

Community measures could help to implement this process with the collaboration of regions or municipalities through focused information programmes, particularly where organic waste minimisation projects and collection schemes are concerned.

Efforts should be made at EU level, as a first priority, to prevent the production of packaging wastes and in addition to reuse, recycle and otherwise recover packaging wastes. Further, the use of recycled materials in the packaging itself should be encouraged. Problems of price competitiveness of recycled products could be overcome by the introduction of economic incentives to promote their use.

If the policy measures outlined above were to be implemented it would result in a substantial reduction in the organic wastes to be landfilled in the future.

New landfills

If other methane reduction options have been investigated and where these are not feasible, technologies to recover and to use the methane emitted should be installed in new landfills. With regard to this, upcoming Community legislation will propose that permits for new landfills will depend on systems for the recovery and processing of any methane produced being in place before the landfill is opened for business. In particular the legislation will require appropriate measures to be taken to control the accumulation and migration of landfill gases which will have to be collected, treated and used in a manner which "minimises damage to or deterioration of the environment and risk to human health" according to strict standards.

Existing landfills

The policies referred to above will have relatively little impact on already dumped wastes which are the main CH4 emissions contributors. Therefore, specific actions must be developed in this direction. Account must be taken of the fact that the existing landfills were not designed to be methane production plants hence making their retrofitting for this purpose difficult.

However, technologies do exist and are already in use in a limited number of sites. Measures requiring the application of these technologies to anaerobic landfills should be promoted. EU legislation should require the retrofitting of existing landfills with systems for the collection and use of methane wherever possible. The recovered gas could be either sold, used on site, converted into electricity or if none of these options are feasible, it should be flared. An upcoming Community legislation will require plans to be produced for existing landfill sites which include an assessment of these options. In the future there may also be a need for economic incentives, both at the national and EU levels, to encourage higher methane recovery as well as the use and further development of appropriate technologies. EU funds will need to be made available for research to find ways of improving retrofitting techniques.

Methane recovery systems for anaerobic landfills in operation today are faced with certain problems when it comes to methane utilization due to the variability of its production (quality, pressure and flow) and the fact that it is not easy to introduce these techniques into a gas distribution network. Therefore, the gas recovered is generally used on site or flared, which eliminates at least 95% of the greenhouse effect problem caused by emitted methane gas (see chapter 2). Despite the considerable associated investment and operational costs involved in the recovery and use of this gas, the large reduction potential with regard to the greenhouse effect still makes these measures cost-effective (see chapter 2.6).

5.3 ENERGY

5.3.1 Extraction and distribution of fossil fuels

5.3.1.1 Coal

The recovery methods largely determine the quality and quantity of gas recovered, which in turn determine the possible utilization options. Developing uses for recovered methane is required if emission reductions are to be achieved. The sale and/or use of methane can offset the costs of recovery in certain cases. In addition to the reduction of methane emissions into the atmosphere, improving methane recovery techniques can result in safer, more productive mines with lower ventilation costs.

EU coal production will decrease between 1990 and 2005/2010 leading to a fall in CH4 emissions. Moreover, existing policies in countries which are important coal producers would allow their CH4 emissions to be reduced by 40% in 2010 compared to the 1990 level.

Technologies for recovering CH4 are already technically available, additional emission reduction could be achieved by the generalization of CH4 recovery techniques. Therefore, the state of the art working with the best available technologies should be defined and applied as soon as possible.

However, their application to EU coal mines is dependent on the specific nature of the mines in concerned Member States. EU coal production will decline in the coming years and coal mines will have to close progressively. In general, the coal sector represents a financial burden for those Member States that subsidize coal mining industry and so it would be extremely difficult to justify any additional expenditures needed to implement CH4 recovery techniques.

Consequently, an EU initiative should not go beyond encouraging those Member States concerned to establish CH4 emission reduction programmes or schemes by promoting the application of the best available recovery techniques for those coal mines that will still be in operation beyond a certain timeframe (10 years for instance). Another initiative that might be envisaged is the reinforcement of the financial instrument emerging from the budget line of the European Community for Steel and Coal (ECSC) one of whose objectives is to fund research projects promoting the best available methane emission reduction technologies.

5.3.1.2 Natural gas

Implementation of existing techniques to reduce leakages requires financing and proper incentives. Therefore, a first measure could be the setting-up of an EU minimum leakages standard aiming at the replacement of the less efficient parts of the transmission and distribution networks by appropriate substitution materials. This would be implemented in each Member State concerned according to a specific time schedule. One minimum leakages standard proposal could be $350m^3$/km/year. France and in particular GDF (Gaz De France) estimated that gas losses in modern networks using materials like welded carbon steel, coated steel or polyethylene may amount to $350m^3$/km/year whereas leakages in existing grey cast iron network were estimated to $3500m^3$/km/year. As mentioned in section 4.3.3, France is currently replacing of part of its old gas network. A second measure may consist in increasing the pipeline control frequency. A study performed by CITEPA (see section 5.4) shows that by doubling the control frequency in Europe to about 800 km inspected each year, (present EU average control is 400 km/year/man), may result in a leak rate cut of 50%.

Unlike coal consumption gas consumption is expected to increase by 60% by 2010 compared to 1990.

5.3.2 Combustion

Considering the very modest contribution of combustion (less than 3%), there is no immediate need to adopt policy measures on this source. Moreover, as regards the transport sector, the popularisation of catalytic converters is expected to reduce these emissions to some extend.

5.4 CONCLUSION

In conclusion, the following table sets out the Commission's ideas for an action programme for mitigating EU methane emissions. The policy measures suggested in the previous sections for the three main sectors are summarized and reported in the following table.

SUMMARY OF EU POLICY MEASURES TO BE CONSIDERED FOR MITIGATING METHANE EMISSIONS

AGRICULTURE

* *Enteric fermentation*
  - promotion of research and incentives (at EU and national level) to develop viable policies and measures

* *Animal manure*
  - anaerobic digesters or covered lagoons (preferably with energy use, if not feasible with flaring)
  . *1st stage* : demonstration programmes at EU, national, regional and local level
  . *2nd stage* : obligation at EU level to install recovery and use systems for animal farm husbandry larger than a certain number of animals(number to be defined)

WASTE

* *General measures*
  - promotion at EU, national, regional and local level of measures such as :
    . minimising the generation of organic waste, including packaging
    . encouraging separate collection of organic wastes
    . material recovery of organic waste (through operations such as composting) and energy recovery operations. Preference should be given, where environmentally sound, to the recovery of material over energy recovery operations. It will nevertheless be necessary to take into account the environmental, economic and scientific effects of either operation. The evaluation of these effects could lead, in certain cases, to preference being given to energy recovery.
  - economic incentives at EU and national level to promote recycled products

* *New landfills*
  - EU legislation requiring, in the absence of other methane reduction alternatives, that new anaerobic landfills are equipped with methane recovery and use systems

* *Existing landfills*
  - EU legislation requiring the retrofitting of existing landfills with systems for the collection and use of methane wherever possible. Support and encourage methane recovery processes which yield energy through economic incentives at the EU and national level. Where this is not possible encourage the use of flaring

ENERGY

* *Coal*
  - EU recommendation to Member States for CH4 emission reduction schemes and promoting best available recovery techniques in coal mines

* *Natural Gas*
  - setting-up of an EU minimum leakages standard
  - increase control frequency of pipelines at national level

With regard to this proposed strategy, reference could be made to a study (CITEPA) financed by the EU and completed in November 1993. In this report, future trends of methane emissions in the EU, before the enlargement (EU-12), were determined for the years 2005 and 2010 from two emissions scenarios :

- a first scenario called "existing policies" scenario, based on current national policies in use in different Member States (EU-12) in 1993, leads to a first assessment of methane emissions reduction as given in the following table.
- a second scenario, more ambitious, called the "recommended Community programme" scenario, based on the "existing policies" scenario to which a set of complementary policy measures has been added, is relatively similar to the proposed strategy and leads to a second assessment showing a more drastic reduction of methane emissions, see also table hereunder.

Observation : the set of Community actions suggested by this study as well as the results obtained from the emissions forecasts could be easily transposed and extrapolated to a EU of 15 Member States instead of 12 without changing adversely the overall conclusions brought forward by these two scenarios.

It should be noted that within each sector (agriculture, waste, energy), a certain number of measures, launched in some Member States, already had or will have additional indirect effects on the proposed CH4 emissions reduction strategy, although these measures did not or will not as such address specifically the issue. This is the case in particular for agriculture and energy where reduced methane emissions are expected beyond the year 2000 because of a fall in livestock numbers reduction as a result of the Common Agricultural Policy and because of a fall in EU coal production. These effects have been taken on board in the reduction forecast assessments of the CITEPA study.

These results are presented in the following summary table giving the reduction forecasts with regard to the 1990 level of CH4 emissions in 2005/2010 based on two mitigating scenarios :
a) existing policies
b) additional EU policy measures to be considered

	2005 Existing policies	**2005 Recommended policies**	**2010 Existing policies**	**2010 Recommended policies**
AGRICULTURE	- 7.00 %	- 24 %	- 9.70 %	- 34 %
WASTE	- 11.1 %	- 45 %	- 14.5 %	- 60 %
ENERGY	- 18.5 %	- 24 %	- 25.3 %	- 34 %
TOTAL	**- 10.6 %**	**- 30 %**	**- 14.3 %**	**- 41 %**

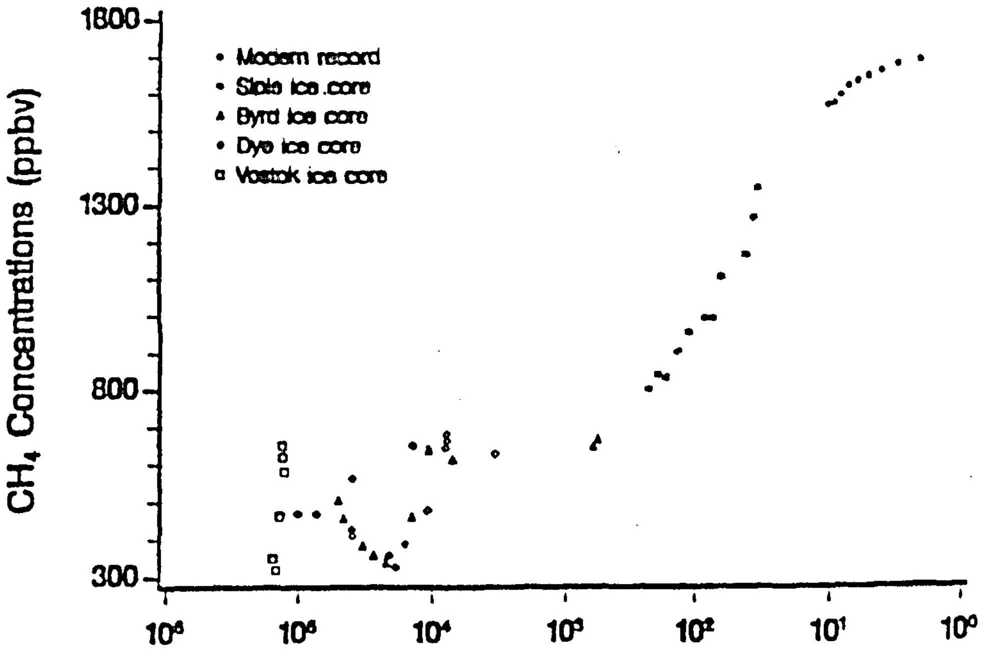
(Source : CITEPA NOV. 1993, EU-12)

As shown in this table, emissions reductions of 30% and 41% could be expected in 2005 and 2010 with regard to the 1990 level if the so called "policy measures to be considered" scenario was implemented. The table shows also that in this case, compared to the "existing policies" scenario, the expected methane emissions reduction could also triple. However, in order to avoid any misinterpretation of the results emerging from the CITEPA study, the reader must be aware of the present lack of knowledge of several parameters concerning methane such as for instance the emission factors on which there is considerably uncertainty in current available data. That uncertainty is, therefore, reflected in the results of the study.

ANNEX

- Figures
- Tables
- Bibliography

Measurements of Global Methane Concentrations



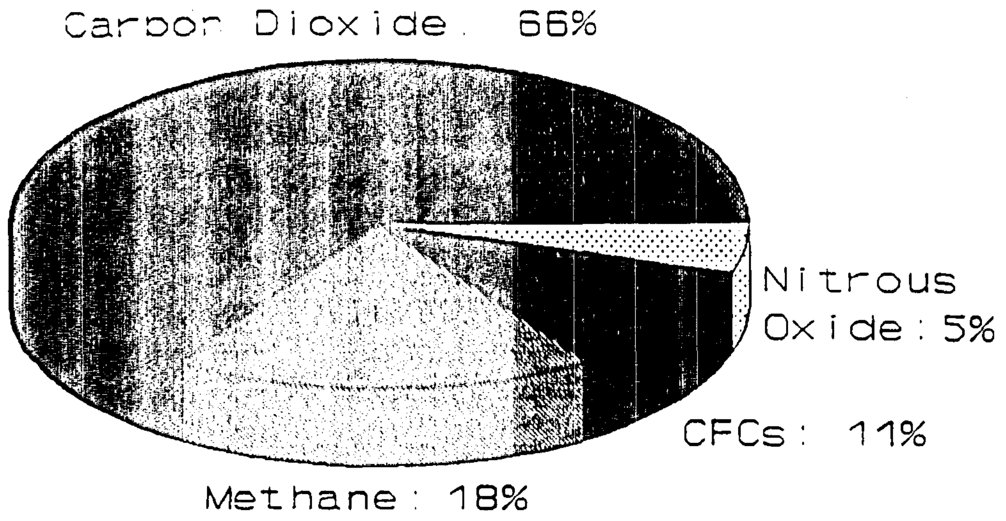
Annual atmospheric CH_4 concentrations during the past 160,000 years (derived from ice cores and the NOAA/CMDL flask sampling network).

Source: Oak Ridge (1990).

Fig 1

ppbv = ppb = part per billion (in volume)

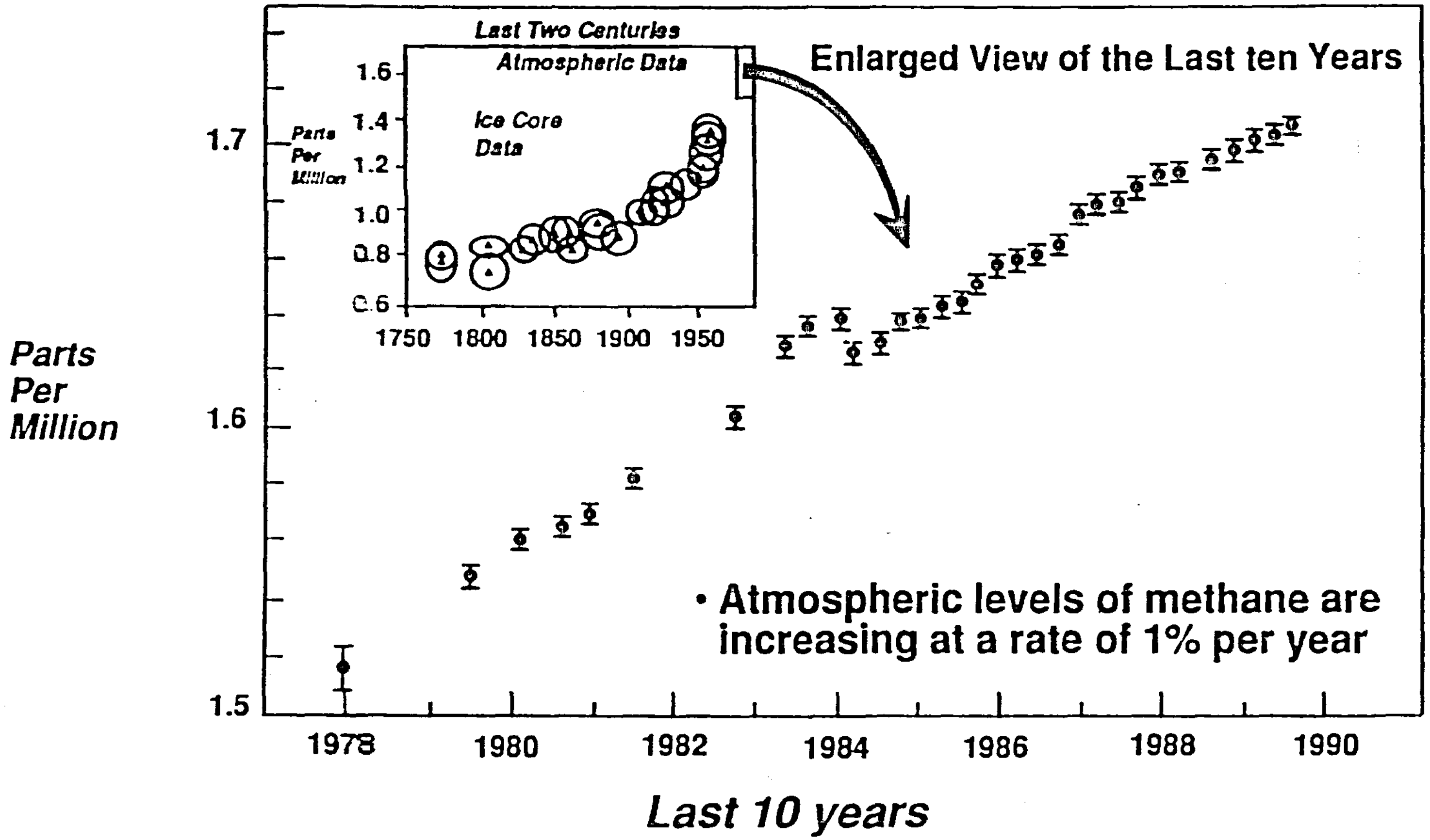
Global Contribution to Integrated Radiative Forcing by Gas for 1990[1]



Estimated on a carbon dioxide equivalent basis using IPCC (1990a) global warming potentials (GWPs) for a 100-year time horizon. Anthropogenic emissions only.

[1] This chart is used to present a general understanding of methane's contribution to future warming based on the GWPs presented in IPCC (1990a). However, these GWPs are continually being revised due to a variety of scientific and methodological issues. It is likely that the contribution of CFCs presented will decrease and that the contribution of other gases will be about the same or greater upon further investigation.

Fig 2

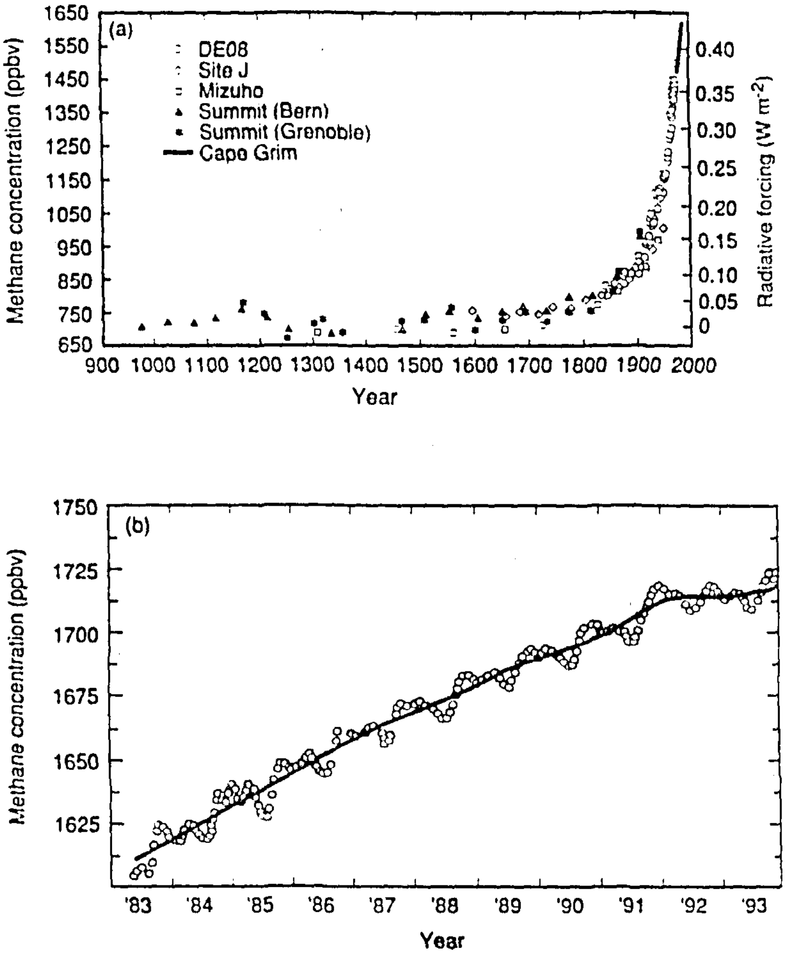


Enlarged View of the Last ten Years

- Atmospheric levels of methane are increasing at a rate of 1% per year

Sources: Stauffer et al, 1985; Blake & Rowland, 1988

Fig 3



(a) CH_4 concentration derived from Antarctic ice cores over the past 1000 years. Direct observations of CH_4 concentration from Cape Grim, Tasmania, are included to demonstrate the smooth transition from ice core to atmospheric measurements. The radiative forcing resulting from increases in CH_4 relative to the pre-industrial period are indicated on the right-hand axis. The effect of overlap with N_2O is accounted for according to IPCC (1990). (b) Globally averaged CH_4 concentration for 1983 to 1993 showing the decline in growth rate during 1992 and 1993.

fig 4

ppbv = ppb = part per billion (in volume)

SET OF MEASURES	CH_4 emission reduction	CO_2 emission reduction	Specific costs
	kton CH_4/yr	kton CO_2/yr	Dfl/ton CH_4
Gas-production			
1 Increased gas utilization	11 (1%)	0	-160
2 Further increased gas utilization	22 (2%)	0	-18
3 Offshore flaring	6 (1%)	-14	1000
Gas-distribution			
4 Replace grey cast-iron network	52 (5%)	0	4500
5 Double leak control frequency	9 (1%)	0	3000
Animal manure			
6 Adjustment of stable/storage	18 (2%)	0	0
7 Large-scale digestion	4 (0%)	16	-120
8 Farmscale digestion (mesophilic)	6 (1%)	16	960
9 Farmscale digestion (psychrophilic)	12 (1%)	27	1100
Landfills; waste gas recovery			
10 Electricity generation	72 (7%)	158	-95
11 Upgrading	31 (3%)	39	-70
12 Flaring	51 (5%)	0	16
Landfills; reduced landfilling			
13 Composting	5 (1%)	-2	600
14 Fermentation	1 (0%)	1	1300
15 Incineration	6 (1%)	96	15700
Total	307 (31%)	336	

Table Emission reducing measures for methane in the year 2000, as described in this study

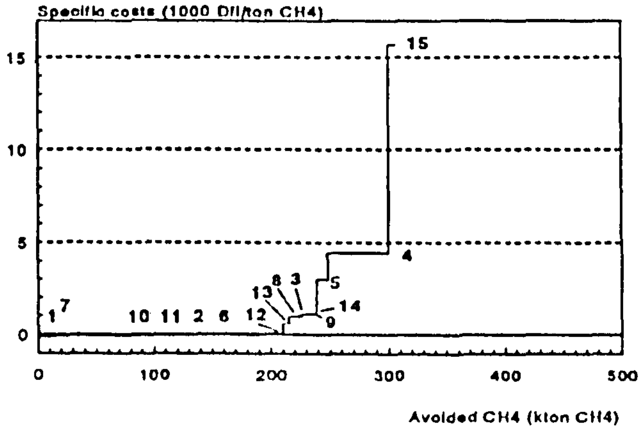


Figure Supply curve of methane mitigating measures for the year 2000 in the Netherlands: extra/avoided CO_2-emissions excluded. Numbers refer to Table A.

fig. 5

Estimated Present Day Sinks and Sources of Methane
(Lelieveld & Crutzen, 1993)

Estimated Sinks and Sources of methane	Mt y^{-1}
Sources	
Natural sources	
Natural wetlands (swamps, marshes, tundra, etc.)	125 + 70
Termites	30 ± 30
Oceans	10 ± 5
Freshwater	5 ± 5
CH4 hydrate destabilisation	5 ± 5
Subtotal natural sources	175
Anthropogenic sources	
Rice fields	70 ± 50
Enteric fermentation (mainly ruminants)	80 ± 20
Landfills	40 ± 25
Biomass burning	30 ± 15
Animal wastes	25 ± 10
Domestic sewage	25 ± 10
Coal mining	35 ± 10
Gas and oil drilling, gas venting, gas transmission	80 ± 45
Subtotal anthropogenic sources	385
Total sources	560 ± 90
Sinks	
Reaction with OH in the troposphere	455 ± 50
Removal by soils	30 ± 25
Reactions with OH, Cl and O (^{1}D) in the stratosphere	45 ± 10
Total sinks	530 ± 85
Atmospheric increase[10]	30 ± 5

Table 1

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[10] based on CH4 concentration measures increments

CORINAIR 1990 Summary
(Anthropogenic sources)

CH_4 in tonnes	A	B	DK	D	F	FL	GR	I	IRL	L	NL	ES	P	S	UK
Public power, cogeneration and district heating	100	137	866	6000	1100	1100	963	3803	0	3	550	8912	356	938	200
Commercial, institutional and residential combustion	7800	3958	6106	112000	149900	6500	21	16733	3580	426	1900	44174	6913	9608	500
Industrial combustion	1200	2718	710	10000	6600	2100	25	9527	200	37	1600	7300	2904	4173	0
Production processes	NE	14118	40	6000	5900	AZ	1413	7614	0	0	8100	3880	1547	14	0
Extraction and distribution of fossil fuels	91600	42437	11938	1547000	310100	100	363756	347460	10180	1628	940	683662	1978	0	1210500
Solvent use	0	0	0	--	0	NE	0	0	0	0	20	0	0	NE	0
Road transport	2700	9161	1811	70000	22300	1880	3733	25229	1160	172	6400	11446	1391	12718	10500
Other mobile sources/machinery	IE	0	1056	2000	600	7550	876	8154	40	14	160	1629	169	3498	300
Waste treatment and disposal	311000	4620	121600	2249000	739500	67100	202467	1302802	138340	3838	378000	506711	35180	179755	1088000
Agriculture	202600	262564	263123	2052000	1611200	163000	362674	1764207	642610	17650	520000	874158	203662	205078	1076100
Corinair 1990 Total per MS	617000	339703	407250	6054000	2847200	249330	935928	3485529	796110	23768	917670	2141872	254100	415782	3386100

Table 2

CORINAIR 1990 Summary
(Anthropogenic sources)

CH4 in kilotonnes(1000tonnes)	**Total for EU per sector**	**Total for EU per sector (%)**
Public power, cogeneration and district heating	25	0,11
Commercial, institutional and residential combustion	370	1,62
Industrial combustion	49	0,22
Production processes	49	0,21
Extraction and distribution of fossil fuels	4623	20,21
Solvent use	0.02	0
Road transport	181	0,79
Other mobile sources/machinery	26	0,11
Waste treatment and disposal	7328	32,04
Agriculture	10221	44,69
Corinair 1990 Total for EU	**22872**	**100**

Table 3

TECHNICAL OPTIONS TO REDUCE METHANE EMISSIONS

TECHNICAL OPTIONS	CH4 REDUCTION	AVAILABILITY	COSTS
AGRICULTURE			
Enteric fermentation			
Livestock reduction	max %	--	--
Increase of feed conversion efficiency	10 - 20 % ?	Available	?
Increase of animal productivity	5 - 30 %	Available	Low
Livestock manure			
Covered lagoons	up to 80 %	Available	Low/Medium
Digesters	up to 70 %	Available	Low/Medium
WASTE TREATMENT AND DISPOSAL			
Landfills			
Anaerobic landfill management : methane recovery and utilization	30 - 70 %	Available	Medium
Aerobic landfill management	over 80 %	R & D	High
Semi-aerobic landfill management	up to 50 %	Available	Medium
Reduced landfilling of waste	up to 100 %	Available	Low/Medium
ENERGY			
Coal mining			
Enhanced gob well recovery	20 - 50 %	Available	Low
Pre-mining degasification	up to 70 %	Available	Medium/high
Ventilation air utilization	10 - 90 %	R & D	Low/Medium
Natural gas			
Reduced venting & flaring	up to 50 %	Available	Low
Improved leak detection & pipeline repair	up to 80 %	Available	Low/Medium

Table 4

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