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DISCUSSION PAPER

CDM Potential of Dairy Sector in India

Smita Sirohi
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Hamburgisches Welt-Wirtschafts-Archiv (HWWA)
Hamburg Institute of International Economics
Neuer Jungfernstieg 21 - 20347 Hamburg, Germany
Telefon: 040/428 34 355
Telefax: 040/428 34 451
e-mail: hwwa@hwwa.de
Internet: http://www.hwwa.de

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e-mail: hwwa@hwwa.de

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CDM Potential of Dairy Sector in India

ABSTRACT

Among the co-operative mechanisms established under the Kyoto Protocol, the Clean Development Mechanism is the only one, which has the potential to assist developing countries in achieving sustainable development by promoting environmentally friendly investment from industrialized country governments and businesses. Although, apart from nuclear energy and deforestation avoidance, all other projects are eligible under CDM, so far, the CDM projects have largely been confined to industrial sector and agricultural sector, in general has been left out.

To assess the issues and opportunities presented by potential international markets for greenhouse gases offsets through the CDM and facilitate implementation of CDM in India, a National Startegy Study on CDM is already underway in the country. However, here again, the agriculture sector, in general, and livestock sector, in particular has not been included in the ambit of NSS, although in India total emissions of methane from livestock are highest. The present study is a pioneering attempt to examine the prospects of CDM projects in the Indian dairy sector. This report discusses the issues of baseline additionality and sustainable development in the context of CDM projects in the dairy sector in India, estimates the cost of various methane mitigation strategies in the sector and highlights the key constraints for the potential CDM projects in this sector.

JEL Classification: Q54, Q18, O13
Key words: CDM, agriculture, dairy, India

Dr. Smita Sirohi
Senior Scientist
Dept. of Dairy Economics, Statistics & Management,
National Dairy Research Institute,
Karnal (Haryana) India 132 001.
Phone: +91 184 2259172
Fax: +91 184 2250042
e-mail: smita@ndri.hry.nic.in

Dr. Axel Michaelowa
Hamburgisches Welt-Wirtschafts-Archiv (HWWA)
Neuer Jungfernstieg 21 - 20347 Hamburg, Germany
Telefon: 040/428 34 309
Telefax: 040/428 34 451
e-mail: a-michaelowa@hwwa.de

CONTENTS

1. Climate change and livestock production: the inter-linkages

Climate change is one of the most significant development challenges facing the international community as most systems (biological or socio-economic) are sensitive to this change. The accumulation of greenhouse gases (GHGs) in the atmosphere due to human activities will lead to an increase in CO_2 concentrations, which is likely to cause temperature increase, changes in the level and seasonal distribution of precipitation, increased wind speed and a greater incidence of extreme events in the times to come. This climate change will affect the production process in agriculture and allied activities. Most international studies that examine the impact on agriculture of climate change due to global warming conclude that in many instances agriculture will be disadvantaged (Reilly 1996; Cline 1992; Evenson 1999; Rosenzweig *et al*. 1998; Saseendran *et al.* 2000). A more recent study predicts unequal impacts of global warming on agriculture across regions (Mendelsohn 2003). For a mid-range temperature rise of 2.5^{o}C, the agriculture in tropical countries is likely to suffer while the temperate and cooler countries will benefit from temperature increase. However, the majority of these studies focus on the impacts on crop yields or on the net revenue from agricultural activity rather than animal production.

In recognition of the problem of potential global climate change, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) established the Intergovernmental Panel on Climate Change (IPCC) in 1988. In its Third Assessment Report, IPCC has assessed the sensitivity, adaptive capacity and vulnerability of natural and human systems to climate change (IPCC 2001a).

1.1 Vulnerability of livestock production to climate change

The performance, health and well-being of the livestock[1] are strongly affected by climate both, directly and indirectly.

Direct effects*:* The direct effects involve heat exchanges between the animal and its environment that are linked to air temperature, humidity, wind-speed and thermal

[1] Livestock means domesticated animals raised for food, fibre or work like cattle, sheep, goat, horses, swine, camels etc. but not including birds. Bovines (cattle and buffaloes) being the predominant livestock species in the world, our discussion will focus largely on this livestock species.

radiation. These linkages have bearing on the physiology of the animal and influence animal performance (e.g., growth, milk and wool production, reproduction) and health.

Hot and humid environmental conditions stress the lactating dairy cow and reduce intake of the nutrients necessary to support milk yield and body maintenance. The primary factors that cause heat stress in dairy cows are high environmental temperatures and high relative humidity. In addition, radiant energy from the sun contributes to stress if cows are not properly shaded. As the environmental temperature increases, the difference between the temperature of the cow's surroundings and her body decreases, and her reliance on evaporative cooling (sweating and panting) to dissipate body heat increases. However, high relative humidity reduces the effectiveness of evaporative cooling and during hot, humid summer weather the cow cannot eliminate sufficient body heat and her body temperature rises. The tremendous amount of body heat that the high yielding dairy cow produces is helpful in cold climates but is a severe liability during hot weather, which implies that temperature increase has adverse effect on the animal. In fact, when the magnitudes (intensity and duration) of adverse environmental conditions exceed threshold limits with little or no opportunity for relief (recovery), animal functions can become impaired by the resulting stress, at least in the short term (Hahn and Becker, 1984; Hahn 1999). Short-term extreme events (e.g., summer heat waves, winter storms) can result in the death of vulnerable animals (Balling, 1982; Hahn and Mader, 1997), which can have substantial financial impacts on livestock producers (Box 1).

Although the level of vulnerability of the farm animals to environmental stresses varies with the genetic potential, life stage and nutritional status of the animals, the studies unambiguously indicate that the performance of farm animals is directly sensitive to climate factors. Kliendinst *et al*. (1993) evaluated the biological response functions developed and validated earlier, with the three widely known Global Circulation Models, the Goddard Institute for Space Studies (GISS), Geophysical Fluid Dynamics Laboratory (GFDL) and United Kingdom Meteorological Office (UKMO) and found substantial reductions in dairy cow performance with climate change.

Hahn *et al*. (1992) point out that in the US the summer weather already reduces production of high-producing dairy cows and beef animals in feedlots. Also the conception rates of dairy cows are reduced by as much as 36% during summer season. With predicted global warming, an additional decline in milk production of about 5-14% (beyond expected summer reductions) may occur particularly in the hot/hot-humid southern regions of the United States.

Box 1

Heat waves and mortality of livestock: some evidence

July 1995 : Heat wave in the mid-central US caused extensive feedlot cattle death and performance losses with an estimated $28 million economic damage.

http://www.ars.usda.gov/is/pr/1997/coolanimals0597.htm

July 1999: 3000 cattle with a value of $ 2 million died from heat in Nebraska feedlots. Economists estimate that feeders lose about 10 times that amount as their surviving cattle become listless, do not eat and lose weight.

Omaha World Herald, July 31, 1999
http://hpccsun.unl.edu/nebraska/owh-july31.html

August 2003: Thousands of pigs, poultry and rabbits in the French regions of Brittany and the Loire died of heat

http://lists.envirolink.org/pipermail/ar-news/Week-of-Mon-20030804/004707.html

Indirect effects: Besides the direct effects of climate change on animal production, there are profound indirect effects as well, which include climatic influences on

- quantity and quality of feed and fodder resources such as pastures, forages, grain and crop by-residues and
- the severity and distribution of livestock diseases and parasites.

Historic data from UK on grassland production from sites at which grassland production has been measured over a run of years with contrasting weather are a valuable resource (Hopkins, 2000) that indicate some of the effects of hot, dry seasons for different types of grass-growing environments, e.g. lowland sites in relatively low rainfall areas of Britain show the greatest reduction of herbage yield in dry seasons. On-going research is also showing that enhanced CO_2 may modify the responses to temperature and water. Weeds of grassland and pests and diseases of grasses and forage legumes may respond to climate changes and confound assumptions of the effects on forage yield. For example, warming may lead to increased damage by clover stem nematode (Harmens *et al.,* 2001, Clifford *et al*., 1996).

Results from Queensland also suggest that changes in Queensland's 'safe' livestock carrying capacity can vary by -35% and +70%, without including carbon fertilization effect, depending on location and ±10% changes in rainfall. When the effect of doubled CO_2 was included, the changes in 'safe' carrying capacity ranges from -12 and +115% (Hall *et al*., 1998).

Climate driven models of the temporal and spatial distribution of pests, diseases and weeds have been developed for some key species *e.g*. the temperate livestock tick *Haemaphysalis longicornis* and the tropical cattle tick *Boophilus microplus*. Potential climate change impacts on buffalo fly and sheep blowfly have also been inferred (Sutherst *et al*. 1996). Climate scenarios in New Zealand and Australia have indicated increased incidence of epidemics of animal diseases as vectors spread and extension of cattle tick which is directly related to changes in both temperature and rainfall (Sutherst, 1995).

Thus, in general, climate change-related temperature increase will have adverse impacts on the animal production system.

The Indian context: Interestingly, the vulnerability of animal production to climate change has hardly been documented in the context of India, which possesses the largest livestock population in the world. In 2002, the country had a 520.6 million livestock population (excluding poultry). It accounts for largest number of cattle (world share 16.1%) and buffaloes (57.9%), second largest number of goats (16.7%) and third highest number of sheep (5.7%) in the world (FAOSTAT).

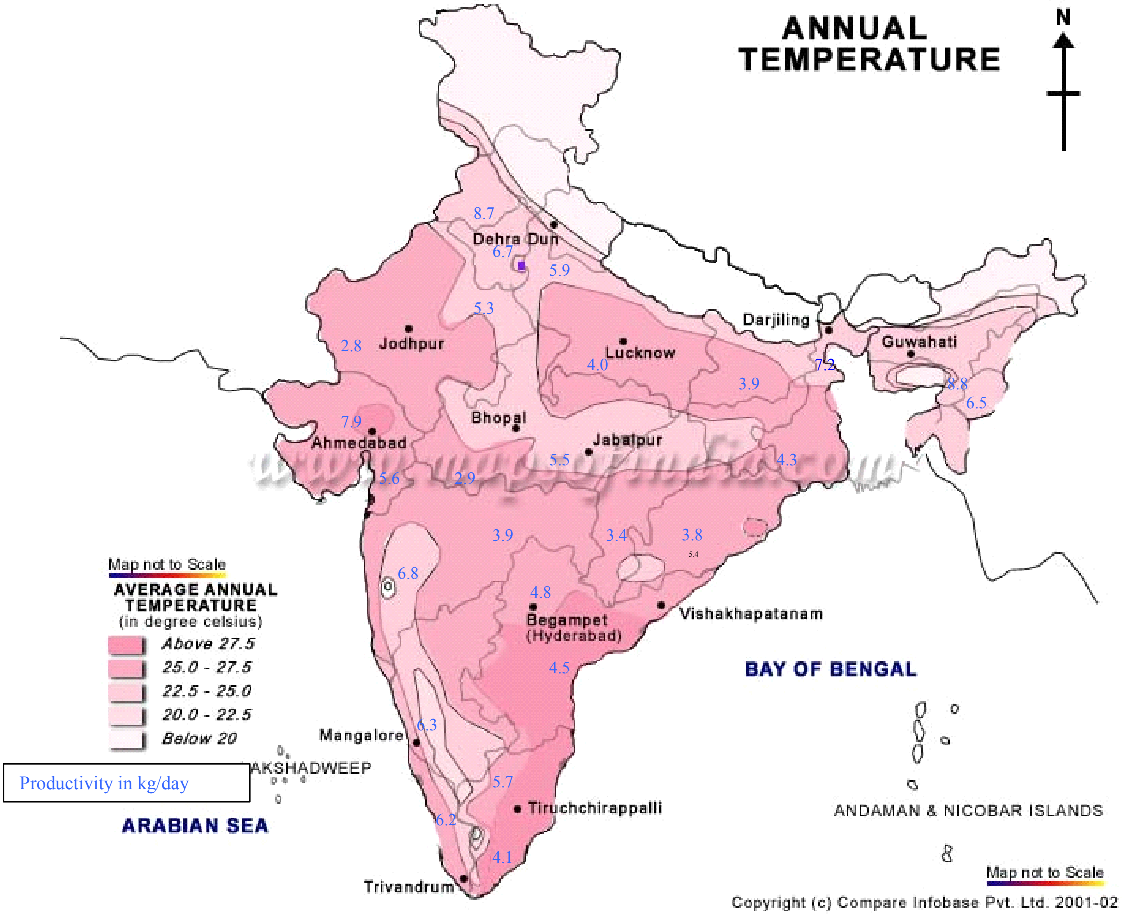
The anticipated negative impact of global warming on the climate of India is large (Nordhaus 1998), due to its huge and growing population of over 1.1 billion, an economy that is closely tied to its natural resource base, a 7500 km long low-lying densely populated coastline and a vast network of snow–fed rivers from the Himalayan glaciers. The livestock production is an integral part of mixed farming system practiced in the entire length and breadth of country and hence is also highly vulnerable to the climate change both directly and indirectly.

In the absence of systematic research studies examining the impact of climate change on animal production, it would be somewhat conjectural to outline the vulnerability of Indian livestock to climate change. Nevertheless, an attempt is made in this direction to highlight some important points. The effect of climate change towards animal production will follow the general trend of unequal distribution of changes and there will be both positive and negative impacts depending up the region and season.

The mean summer (April to June) temperature of India ranges from 25 to 45^{0}C in most parts of the country. Higher temperature during summer months would increase the heat stress in animals, particularly in crossbred cows. The crossbred cows, which are high yielders and more economic to farmers, are more susceptible to heat stress compared to local cows and buffaloes. The proactive management counter measures during heat waves (e.g. providing sprinklers or changing the housing pattern etc.) or animal nutrition strategies to reduce excessive heat loads are often expensive and beyond the means of small and marginal farmers who own most of the livestock. Superimposing the average productivity of crossbred cows in various regions on the temperature map of India, it can be seen that in general, the productivity level is lower in regions where mean annual temperature is higher (Map 1). An increase in temperature is therefore, most likely to reduce the total optimum area where high yielding dairy cattle can be economically reared.

Where high temperatures are associated with decline in rainfall or increased evapo-transpiration, the possibility of economically rearing animals would be further limited as decline in rainfall shall aggravate the feed and fodder shortage in the area. The greatest impact would perhaps be on the pastoral families, who would migrate to arable areas to secure their livelihood. This would entail significant dislocation costs for these livestock keepers. However, at the same time positive impacts can also be or in the in high altitudes would decrease maintenance requirement of animals and increase the productivity of winter pastures. Possible benefits of climate change during cooler seasons though not well documented, are likely to be less than the consequential negative hot weather impacts (Hahn *et al*., 1992), especially if the cold season is much shorter than the hot one.

MAP 1: Annual temperature and average productivity of crossbred animals



Map Courtesy: **www.mapsofindia.com**

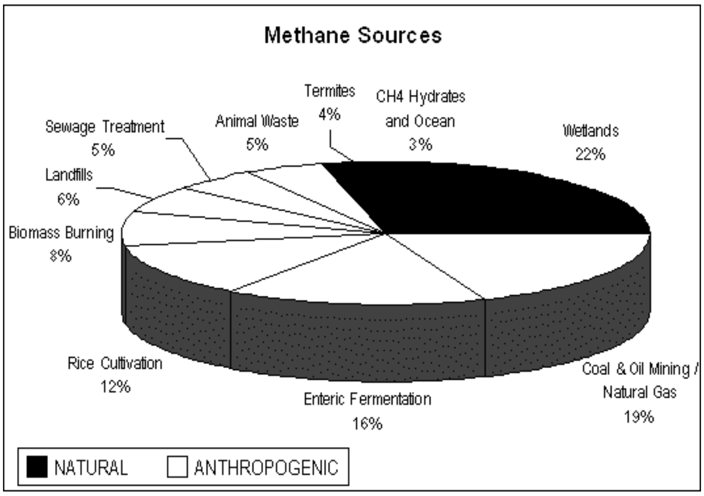
1.2 Contribution of Livestock to Climate Change

The animal production system which is vulnerable to climate change is itself a large contributor to global warming through emission of methane and nitrous oxide.

Like carbon dioxide (CO_2), methane (CH_4) is a radiatively and chemically active trace gas. Methane's radiative activity refers to properties that cause it to trap infrared radiation (IR), or heat, enhancing the greenhouse effect. Its chemically active properties have indirect impacts on global warming as the gas enters into chemical reactions in the atmosphere that not only affect the period of time methane stays in the atmosphere (i.e. its lifetime), but that also play a role in determining the atmospheric concentrations of tropospheric ozone and stratospheric water vapour, both of which are also greenhouse gases. These indirect and direct effects make methane a large contributor, second only to carbon dioxide, to potential future warming of the earth.

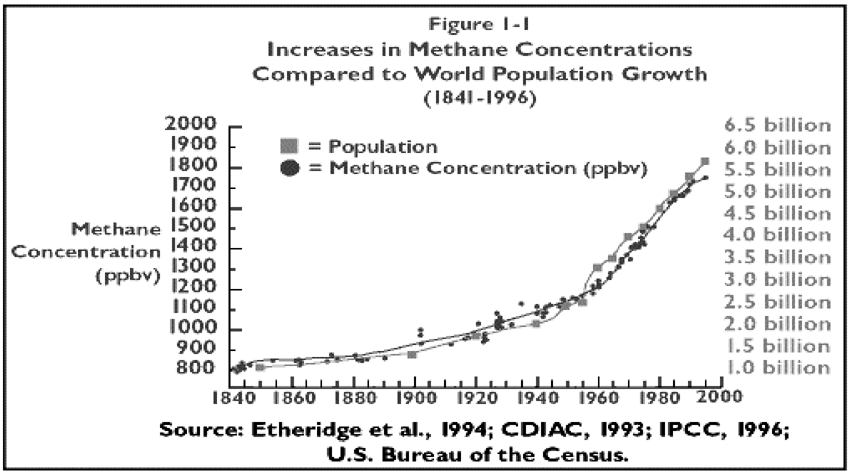
Since 1750, atmospheric concentrations of methane have increased by 150 % from 700 to 1745 ppbv in 1998 (IPCC, 2001b) and are still increasing. Methane concentration in the atmosphere is largely correlated with anthropogenic activities and these sources currently represent about 70% of total annual emissions (Fig. 1). The increase in concentration of this gas are found to be roughly parallel to world population growth (Fig. 2).

Fig. 1: Sources of Methane Emissions



***Source*: Harvey *et al.* 2003**

Fig. 2: Increases in Methane Concentrations and World Population Growth (1841-1996)



The global warming potential (GWP)[2] of methane is 21 times more than carbon dioxide. This raises particular concerns about global warming because over a 100-year period it is 21 times more effective at trapping heat in the atmosphere than carbon dioxide. The other side of this aspect means that because of its potency on a ton-by-ton basis, methane reductions have a larger impact on climate change than reductions in carbon dioxide.

Additionally, methane's chemical lifetime is relatively short, about 12 years compared to 120 years for carbon dioxide. This relatively short lifetime makes methane an excellent candidate for mitigating the impacts of global warming because emissions reductions could lead to stabilization or reduction in methane concentrations within 10 to 20 years in the atmosphere, therefore, the impact of current emissions will be less over longer time frame. Thus, programmes and policies that target reductions in methane emissions can help mitigate the rate of climate change at a faster rate than those that target reductions in emissions of carbon dioxide and other longer-lived greenhouse gases. Methane is recognized as a potent contributor to global warming in the Kyoto Protocol, and Parties to the United Nation's Framework Convention on Climate Change acknowledged the need to stabilize methane emissions globally. The Kyoto Protocol specifically identifies methane and five other species of gas as needing to be stabilized in order to achieve the emissions targets of the industrialized world. Since methane emissions are often associated with wasted energy, capturing these emissions will improve operational efficiency, and could perhaps reduce the cost of meeting emission-reduction targets by the industrialized countries.

Nitrous oxide (N_2O) is another potent greenhouse gas, the primary anthropogenic emissions of which are thought to come from agricultural fertilizers, and to a lesser degree, fossil fuel combustion and biomass burning. The GWP of nitrous oxide is 321.

There are two sources of GHG emissions from livestock:

1) From the digestive process

2) From animal wastes

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[2] The concept of global warming potential (GWP) has been developed to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas. This measurement of GWP relies on carbon dioxide as the reference gas. Thus, the GWP of a greenhouse gas is the ratio of global warming (both direct and indirect), also known as radiative forcing, from one unit mass of a greenhouse gas to one unit mass of carbon dioxide over a period of time. We use the GWPs agreed in the Kyoto Protocol.

1.2.1 Emissions from digestive process

***Process**:* Methane is produced in herbivores as a by-product of 'enteric fermentation[3]', a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream. The level of methane production by animals depends on the type of digestive system the animal has. Herbivores animals can be classified into three groups on the basis of their digestive physiology; ruminant (eg. cattle, buffalo, sheep, goats, camels), pseudo-ruminant (e.g. horses, mules, asses) and monogastric (eg. swine) animals. The animals belonging to later two categories have relatively lower methane emissions because much less methane producing fermentation takes place in their digestive systems and therefore will not be considered in the further discussion in this paper. Most livestock related methane is produced by enteric fermentation of food in the digestive tracts of ruminant livestock. The unique digestive system of a ruminant animal, such as cattle, consists of a four part stomach, which includes the rumen, reticulum, omasum and abomasum. The rumen is the first and largest compartment, making up about 80 percent of the total stomach volume, and is unique to ruminant animals. In the process of enteric fermentation, the microbial organisms such as bacteria, protozoa and fungi present in the rumen convert the plant matter in the animals' digestive tract into nutrients such as sugars and organic acids and are used by the animals for energy and growth. Unlike in humans and other non-ruminant mammals, where the food has a relatively short residence time in the gut and so there is little fermentation and associated methane production, in ruminant animals coarse feedstuffs are retained in the rumen for a considerable period of time in the presence of a large and diverse microbial population, allowing extensive fermentation. A number of gaseous by- products of the fermentation which are not used by the animal are mainly removed from the rumen by eructation (Dougherty et al., 1965). Methane is produced by the methanogenic archaebacteria located mainly in the rumen, and is released as gas into the atmosphere. A small proportion of methane is absorbed in the blood and is eliminated through the lungs.

***Factors affecting enteric emissions*:** The average daily feed intake and the percentage of this feed energy which is converted to methane are the two important determinants of methane emissions from livestock.

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[3] Enteric fermentation is the anaerobic fermentation of polysaccharides and other feed components in the gut of animals. Methane is produced as a waste product of this fermentation process.

- **Average daily feed intake** for any particular livestock type can vary considerably with the energy requirement of the animal for the physiological function of the animal, which includes both, the energy required for the maintenance of the animal[4] and energy required for production[5]. The livestock characteristics (age, weight and species), health and living conditions influence the energy requirement of the animals. For instance, the energy requirement of *Bos indicus*, the cattle species that is commonly reared in Asia, is about 10% lower than beef breeds of *Bos taurus* in Europe and in North America (NRC, 1996).

The feeding situations (grazing or stall-fed) also have a bearing on the energy requirement as additional energy is required by grazing animals to obtain their food.

- **Methane conversion efficiency**, the other important determinant of methane emission in livestock, depends on rumen microflora[6] and the quality (digestibility, nutrient composition and energy value) of the feed. In fact, the diversity, size and activity of the microbial population in the rumen which determines the efficiency of fermentation in the rumen (and hence methane emissions) is itself largely influenced by diet. Therefore, type of feed and fodder intake by the livestock has a dominant influence on the production of methane in the rumen.

1.2.2 Emissions from animal wastes:

Methane and Nitrous oxide are the two important GHG emitted from animal wastes.

Methane emissions from manure

Process: Animal wastes contain organic compounds such as carbohydrates and proteins. These relatively complex compounds are broken down naturally by

[4] The basic metabolic functions to stay alive.
[5] E.g. growth, lactation, wool production, work or gestation, as the case be.
[6] Bacteria are the principal micro-organisms that ferment carbohydrates in the rumen (Hungate, 1966). The type of bacteria required depends on the animal's diet. For an animal fed on forage and concentrates, both cellulolytic and amylolytic bacteria must be present to maximize rumen efficiency. The composition of micro-organisms in the rumen is also important in determining the composition of products from the fermentation process. For example, certain bacteria can shift the fermentation process from less-reduced to more-reduced end products, reducing the amount of methane produced (Wolin, 1974).

bacteria. In the presence of oxygen, the action of aerobic bacteria results in the carbon being converted to carbon dioxide. The emission of carbon dioxide is part of the natural cycling of carbon in the environment and results in no overall increase in atmospheric carbon dioxide. The carbon dioxide, originally absorbed from the atmosphere through photosynthesis by the plants which formed the livestock feed, is simply being released. However, in the absence of oxygen, anaerobic bacteria transform the carbon to methane and so the decomposition of livestock wastes under moist, oxygen free (anaerobic) environments results in an increase in the concentration of greenhouse through production of methane.

Factors: The amount of methane released from animal manure depends on many variables such as :

- **Methane producing potential of manure**: Each type of animal waste has its characteristic content of degradable organic matter (material that can be readily decomposed), moisture, nitrogen and other compounds. As a consequence, the maximum methane producing potential of the different manures varies both across species and, in instances where feeding practices vary, within a single species.

- **Quantity of manure produced** which depends on feed intake and digestibility

- **Waste management system used**: The most important factor affecting the methane emissions from animal wastes is how the manure is managed (e.g. whether it is stored as a liquid or spread as a solid). Metabolic processes of methanogenes leads to methane production at all stages of manure handling. In the modern intensive livestock practices, where animals are often housed or kept in confines spaces, manure is often stores in tanks or lagoons. Liquid systems tend to encourage anaerobic conditions and to produce significant quantities of CH_4. On the other hand, when livestock are in fields and their manure ends up being spread thinly on the ground, aerobic decomposition usually predominates and these aerobic solid waste management approaches may produce little or no methane at all.

- **Climate**: The warmer the climate the more biological activity takes place and the greater is the potential for methane evolution. Also, where precipitation causes high soil moisture contents, air is excluded from soil pores and the soils become anaerobic again increasing the potential for methane release even for wastes which have been spread. Hence, higher temperatures and moist conditions also promote CH_4 production.

Nitrous oxide emissions from animal wastes

Process: Animal wastes contain nitrogen in the form of various complex compounds. Nitrous oxide forms and is emitted to the atmosphere via the microbial processes of nitrification and denitrification. The majority of nitrogen in wastes is in ammonia form. Nitrification occurs aerobically and converts this ammonia into nitrate, while de-nitrification occurs anaerobically and converts the nitrate to nitrous oxide.

Factors: The generation of nitrous oxide is influenced by

- **Nitrogen concentration**: The rate of nitrification will be higher for animal wastes which contain more nitrogen. The nitrogen excreted by the animals in turn depends upon the quantity and quality of feed intake. For example, the dairy cows consuming more protein supplements excrete more nitrogen (Kebreab *et al*., 2001).

- **Animal waste management system**: The method of managing the animal wastes determine the oxygen concentration and microbial community which have bearing on the emission rate of nitrous oxide. For nitrification, the optimal conditions imply that oxygen is available and pH is low. Increasing aeration initiates the nitrification-denitrification reactions, and hence makes release of N_2O possible. Nitrous oxide is a side-product which is produced in larger quantities Therefore, as fresh dung and slurry is highly anoxic and well-buffered with near neutral pH, it is expected that higher nitrification will occur. After the initial aerobic reaction, when conditions are suboptimal for nitrification, for example when oxygen is deficient, as in situations with high biological activity consuming oxygen, large amounts of N_2O is produced. A dry aerobic system of waste management may therefore provide a more conducive environment for N_2O emission than the waste managed in anaerobic lagoon and liquid system.

2. Estimates of Greenhouse Gas Emissions from Livestock

The primary focus of this section is to present the inventory of methane and nitrous oxide emissions from livestock and review the methodology used by various studies to estimate the emission rates of ruminants in India.

The global annual emission of methane from all sources has been estimated as 500-600 Tg[7]/year of which over 300 Tg/year comes from anthropogenic activities (IPCC 2001). The United States Environmental Protection Agency (USEPA) estimated that in 1990, global anthropogenic methane emissions were 277 to 477 Tg/year, with 354 Tg/year as the best estimate. EPA's aggregate estimate is similar to the Intergovernmental Panel on Climate Change's IS92a[8] estimate of 352 Tg per annum. Livestock farming has been found to be the most important anthropogenic activity that results in methane emissions.

As the methane emissions from livestock are attributable to two process viz. enteric fermentation and manure management, the discussion on inventory from these two sources is carried out in two sub-sections.

2.1 Enteric emissions:

Presenting a comprehensive summary of the methodology to derive methane emission rates from ruminants and the uncertainties contained therein, Crutzen *et al*. (1986) estimated that animals produced 72-99 Tg methane in 1983 from enteric fermentation, with an overall uncertainty of ±15% in their estimates. Broadly using the emission rates derived by Crutzen et al. (1986), an attempt was made by Lerner *et al*. (1988) to look into the geographical distribution of the emissions from the animal source as it is a crucial step in using the geographic variations in atmospheric methane to infer information about the global budget. The study found that in 1984 about half of the annual global emission of 75.8 Tg from enteric fermentation came from only five countries; viz. India (10.27 Tg), the erstwhile USSR (8.05 Tg), Brazil (7.46 Tg), the USA (6.99 Tg) and China (4.37 Tg). Species-wise cattle contributed 75%, buffaloes 8%, sheep 9% and goats 3% to the total emission. Simply on account of its enormous size of livestock population, India emerged as the largest contributor to livestock methane budg*et al*though the emission rate per animal in the country was much lower

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7 1 Tg = 10^{12} grams = 1 million tons

8 IS92a is one of the six scenarios used by IPCC to estimate future global emissions.

than in the developed countries. For instance, the annual methane production per animal was estimated to be 95 kg for the German dairy cows, nearly three fold higher than 35 kg for the Indian cattle (Crutzen *et al*., 1986).

The recent estimates of enteric methane emissions from the greenhouse gas inventory database of United Nations Framework Convention on Climate Change are given in Table 1 for the selected countries which have high production potential of ruminants. Estimates for India are not available in this database.

Table 1: Enteric Methane Emissions: Selected Countries

(Teragrams/year)

Countries	1990	2000
United States of America	6.1	5.9
Canada	0.8	0.8
Australia	3.1	2.9
New Zealand	1.5	1.4
Japan	0.3	0.3
Russian Federation	4.4	
France	1.5	1.4
Germany	1.3	1.0
United Kingdom	0.9	0.9
Poland	0.8	0.4
Italy	0.6	0.6
Netherlands	0.4	0.3
Austria	0.2	0.1
European Community	6.9	6.3

Source: **UNFCCC Greenhouse gas inventory database.** ***http://ghg/unfccc.int***

Emissions from Indian livestock: Estimates of enteric emissions from Indian livestock vary widely from 6.17 Tg/year to 10.3 Tg/year (Table 2). The high variability in the estimates of methane emission for a particular reference year (e.g. ALGAS study) clearly indicate that such wide variations are solely attributable to the differences in emission rates that are used to arrive at the total emissions. Even in case, where the reference year of studies differs (e.g. Lerner *et al*, Bandyopadhyay and ALGAS study) the variations of 10.27 Tg in 1984 to 6.17 in 1987 and 10.3 in 1990, are a result of differences in the emission rate as livestock population increased from 1984 to 1987 and then further to 1990. It is therefore critical to discuss the methodology used to arrive at those emission rates as the mitigation strategies can only be evaluated if there is a reliable knowledge of the emission rates.

Table 2: Different estimates for Methane Emissions from Indian Livestock

(Tg/year)

Year	Cattle	Buffalo	Sheep	Goat	Camel	Total
Lerner *et al*. (1988)						
1984	6.38	3.20	0.20	0.40	0.06	10.27
Bandyopadhyay *et al*. (1996)						
1987	3.3	1.73	0.81			6.17
Mitra (1996)						
1987 (Tier II methodology)	3.93	1.734	0.90			6.91
ALGAS (1998)						
1990 (Tier I methodology)	5.43 (1.33 for non-dairy & 4.10 for dairy)	3.96	0.26	0.53	0.06	10.3
1990 (Tier II)	3.93	1.734				7.5
USEPA (1994)						
1991	5.59	4.0	0.2	0.55	0.07	10.41
Singhal and Madhu Mohini (2002)						
1992						9.72
1994						10.07
Khan (1996)						
1994	5.80	2.40	0.20	0.50		8.9
Garg *et al*. (2001)						
1995						7.26
Singh (1998)						
1996	5.59	2.80	0.19	0.41		SUMM E9.0

IPCC guidelines for enteric emission inventory: In 1991 IPCC started its National Greenhouse Gas Inventories Programme (NGGIP) in close collaboration with the Organisation for Economic Cooperation and Development (OECD) and the International Energy Agency (IEA), to assess and develop methods and practices for national greenhouse gas inventories and disseminate information related to inventory methods and practices. The IPCC guidelines for national greenhouse gas inventories were first accepted in 1994 and published in 1995. In 1996 they were revised and published as “Revised IPCC Guidelines for National GHG Inventories”. IPCC recommends two approaches for inventory of methane from enteric fermentation, Tier I and Tier II (IPCC 1996a). In 2000, IPCC published a report on “Good Practice and Uncertainty Management” in response to the request from the UNFCCC to complete its work on uncertainty and prepare a report on good practice in inventory management. The Tier II method used to estimate methane emission from cattle was updated to improve the feed intake estimates and additionally, a Tier 2 method for sheep was proposed (IPCC 2000).

The Tier I is a simplified approach that relies on default emission factors drawn from previous studies (e.g. Gibbs and Johnson 1993 and Crutzen *et al*. 1986). The IPCC default emission factors for the Indian sub-continent are presented in Table 3 and the data (assumptions) used for arriving at these estimates is given in Appendix A.

Although IPCC gave the default emission rates for the Indian sub-continent as per the Tier I approach, it recommended the Tier II approach for estimating methane emissions from enteric fermentation from those countries with large livestock population, such as India. In contrast with the Tier I method, this approach required much more detailed information on the animal and feed characteristics and recommended the net energy system described in NRC (1989 and 1996) as the starting point for the estimates. The Tier II methodology for cattle as updated by IPCC (2000) is presented in Appendix B.

Using the Tier II approach (IPCC 1996a) the ALGAS study came up with 27% lower estimates of methane production from the Indian livestock for the year 1990 as compared to the Tier I methodology. Table 4 shows the emission rates estimated as per the Tier II methodology. As one can see from the comparison of the emission rates given in Table 3 and 4 that the differences in emission rates were particularly sharp for adult buffaloes, ranging from 55-80 as per IPCC default values to 26-39 as per Tier II methodology. The emission rates based on the Tier II methodology that are used by other researchers (Mitra 1996; Garg *et al*. 2000) also vary somewhat from each other, perhaps due the differences in aggregation of the rates across age groups. The emission rates worked out in the ALGAS study are age-wise and species wise but not sex-wise. The sex-wise differences are important for adult animals as the breedable females, particularly lactating animals are fed much better diet than the adult males specially in the regions where the importance of adult males as draft animals has declined due to mechanization of agriculture.

Table 3: IPCC default emission factors (Tier I) for Indian sub-continent

Animal category	Emission rate (kg/head/year)
Dairy cattle	**46**
Non-dairy	**25**
Adult female	31
Adult male	41
Young stock	17
Buffalo	**55**
Adult male	55-77
Adult female	57-80
Young stock	23-50
Sheep	**5**
Goat	**5**
Camels	**46**

Source: **IPCC, 1996a**

Table 4: Emission rates from Indian livestock (Tier II methodology)

Species	Age in months	Kg methane/animal/year
Buffalo indigenous	3.0-6.0	10.6
	6.0-12.0	15.4
	12.0-24.0	20.1
	24.0-36.0	22.6
	> 36.0	25.8
Improved	3.0-6.0	16.0
	6.0-12.0	27.2
	12.0-24.0	32.1
	24.0-36.0	36.0
	> 36.0	39.4
Cattle indigenous	3.0-6.0	72
	6.0-12.0	9.7
	12.0-30	16.1
	30.0-72.0	22.5
	> 72.0	20.1
Higher breeds	3.0-6.0	11.5
	6.0-12.0	24.1
	12.0-30	28.3
	>30	32.1
Ovine	<4	4.1
	4-8	4.7
	8-12	5.0
	12-48	5.7

Source: ALGAS, 1998

Uncertainties in methane inventory

The above discussion clearly brings out that there exist considerable uncertainties in the methane inventory from enteric fermentation in India largely due to uncertainties associated with the use of default emission factors. Assessing the uncertainty associated with its Tier I method, IPCC itself admits that "…Emission factors estimated using Tier I method are unlikely to be known more accurately than ± 30% and may be uncertain to ±50% (IPCC 2000).

In its Tier II methodology, recognizing that in evaluation of the feed-energy intakes for tropical cattle on the basis of net energy system described in NRC, potential biases may creep in (as the NRC relationships were developed based on analyses of the higher-quality feeds found in the temperate agricultural system and would be inappropriate for tropical countries where cattle consume relatively low-quality feeds), some adjustments were made in applying the same to tropical countries. However, the following methane conversion rates (MCR) have been recommended for the developing countries as per the rule of thumb:

- all dairy cows and young cattle are recommended to have a conversion rate of 6.0 percent (± 0.5%), which is equal to the rate recommended for all cattle (except feedlot cattle) in the developed countries.
- all non-dairy cattle, other than young stall-fed animals, are recommended to have a conversion rate of 7.0% (± 0.5%).
- Conversion rate for grazing cattle is 6.0% (± 0.5%).

These conversion rates that have been recommended for developing countries, in all likelihood may not be appropriate specifically for Indian conditions, as the animals fed with low quality diet produce much more methane compared to animals fed with good quality diet. Therefore, animals in India may produce more than the default value of 6 to 7 %. Kurihara *et al*. (1999) reported 10.5 % MCR of *Bos Indicus* cattle under tropical conditions. For the Tier 2 method IPCC associates an uncertainty of the order ±20% (IPCC 2000).

Emission estimates based on IPCC methodologies make the inventories transparent and comparable across nations. But the price for these comparable estimates has to be paid in the form of resulting high uncertainties in budget estimates if emission factors used are not representative of the actual conditions. In order to reduce the uncertainty in the

GHG estimations, the Ministry of Environment and Forests (MoEF), the implementing and executing agency of India's National Communication (NATCOM) to the UNFCCC, in collaboration with its facilitating agency Winrock International India, recently funded a project on 'Uncertainty reduction in methane and nitrous oxide gases emissions from livestock in India" (Singhal and Madhu Mohini 2002).

Interestingly, the emission rates for major categories of adult animals are in sharp contrast with the ones estimated by ALGAS study using Tier II methodology (Table 5) and are much more in line with Tier I emission rates. In this study, the emission rate for adult cross-bred animals ranges from 36 to 39 kg/head/year, while in the ALGAS study it was much lower at about 32 kg/animal/year. Similarly, the emission rate of adult indigenous cattle is about 37 to 40% higher than the ALGAS study. The differences between the two estimates are even sharper in case of buffaloes.

The NATCOM sponsored study has gone a step further than ALGAS study in working out not only age-specific but also sex-specific, and work-specific emission rates, and hence has been able to overcome one important limitation of the latter study. However, it has not been able to fulfil the need for region-specific emission rates as the animal and feed characteristics vary widely across regions in a so agro-climatically diverse country like India. Estimates of source magnitudes on a regional scale allow more focused and efficient mitigation strategies. There is thus a critical information gap in terms of regional emission factors in India. Nevertheless, in the absence of such estimates the present study resorts to the estimates made by Singhal *et al*. (2002) for looking into the potential of reducing methane emissions from Indian livestock.

Table 5: Recent Estimates of Enteric Emissions from Adult Bovine Animals

	Animal categories	**Emission Rate (kg/head/year)**
Crossbred cattle	Working males	36
	Females in milk	39
	Females dry	39
Indigenous cattle	Working males	33
	Females in milk	36
	Females dry	29
Buffaloes	Working males	66
	Females in milk	77
	Females dry	56

Source: **Singhal and Madhu Mohini, 2002**

2.2 Emissions from Manure management

Methane: The total global methane emissions from livestock manure management have been estimated as 9.3 Tg/year (Scheehle, 2002) of which the developed countries contribute about 52 %. The estimates of methane emissions from manure management in major dairying countries are presented in Table 6. Indian levels are 0.905 Tg/year in 1990 (ALGAS, 1998; Scheehle, 2002) rising marginally to 0.977 by 2000 (Scheehle, 2002). Both the studies have used IPCC Tier I default rates to arrive at these estimates. However, the methane emission factor from manure is much lower in India then the western counterparts due to differences in manure management practices. The cattle and buffalo manure is extensively used in the country as fuel and is largely managed in dry systems.

Nitrous Oxide: India's contribution to nitrous oxide emissions from manure management in 1990 is estimated to be 0.017Tg/year which is projected to increase to 0.022 Tg by 2020 (Scheehle, 2002).

Uncertainty: The uncertainties in the manure management emission factors have been explicitly recognized by the IPCC in its "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories". For its Tier I emission factors, IPCC candidly admits that since they are not based on country specific data, they do not represent accurately the manure management system characteristics for any given country and are highly uncertain as a result. In the Tier 2 methodology also, the reliability of emission rates is low due to uncertainty in the manure management usage data and in the equation used to calculate the emissions. In case of Nitrous Oxide, additional uncertainty arises in the nitrogen excretion data. The uncertainty ranges for the default nitrogen retention values provided by IPCC are as high as ± 50 percent**.**

Hence, further research work on the country specific basis needs to be carried out in this area to get reliable estimates of emissions from manure management.

Table 6: Methane Emissions from Manure management: Selected Countries

(Gigagrams/year)

Countries	1990	2000
United States of America	1,390	1,784
Canada	219	242
Australia	75	84
New Zealand	18	17
Japan	51	44
Russian Federation	500	
Germany	270	211
Italy	190	185
France	168	173
Netherlands	103	88
Austria	27	24
Poland	56	36
United Kingdom	111	105
European Community	1,576	1,577

Source: **UNFCCC Greenhouse gas inventory database. *http://ghg/unfccc.int***

3. Relevance of CDM for the Indian Livestock sector

3.1 International Climate Change Negotiations and evolution of CDM

The Intergovernmental Panel on Climate Change (IPCC) published its first report in 1990 and confirmed that climate change is a threat and it called for an international treaty to address the problem. Recognizing that the global nature of climate change calls for a cooperative and coordinated response by all countries, the United Nations General Assembly responded by formally launching negotiations on a framework convention on climate change and establishing an "intergovernmental Negotiating Committee" to develop the treaty. Negotiations to formulate an international treaty on global climate protection began in 1991 and were completed by May 1992, in the form of United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC was opened for signature in June 1992 during the UN Conference on Environment and Development, the Rio Earth Summit. The Convention aims at stabilizing atmospheric concentration of green house gases at a safe level that would prevent dangerous anthropogenic interference with the climate system. To achieve this objective, all countries have a general commitment to address climate change, adapt to its effects and report their actions to implement the convention. It came into force on 21 March 1994, and has been ratified by 196 countries.

The Convention divides countries into two groups: Annex I parties, the industrialized countries who have historically contributed the most to climate change, and non- Annex I Parties, which include primarily the developing countries, like India. The principles of equity and "common but differentiated responsibilities" contained in the Convention required Annex I parties to take the lead in returning their greenhouse gas emissions to 1990 level by the year 2000.

The Convention established the Conference of Parties (COP) as its supreme body with the responsibility to oversee the progress toward the aim of the Convention. At the first session of the COP in Berlin, it was decided that post-2000 commitments would only be set for Annex I parties. During the third COP held in December 1997 in Kyoto, Japan, an important milestone in the international climate change negotiations was achieved in the form of Kyoto Protocol. The Protocol is a legally binding set of obligations for 38 industrialized countries including 11 countries in Central and Eastern Europe to reduce their emissions of GHGs to an average of approximately 5.2% below their 1990 levels over the commitment period 2008-2012. The emission targets were specified in Annex B of the Kyoto Protocol and hence these countries are also referred to as Annex B countries.

The six gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and three industrial gases: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) which are not covered earlier by the Montreal Protocol that banned global chlorofluorocarbons. Each gas is weighted with its GWP factor (see above). The Protocol also established three cooperative mechanisms designed to help Annex B Parties reduce the costs of meeting their emissions targets by achieving emission reductions at lower costs in other countries than they could domestically. These mechanisms are:

a) *International Emissions Trading* which permits countries to transfer parts of their 'allowed emissions' (assigned amount units) between themselves.

b) *Joint Implementation (JI)* allows countries to claim credit for emission reduction that arise from investment in other Annex I countries. The ensuing reduction in emission are transferred as “emission reduction units” (ERUs) between the countries and can only accrue from 2008.

c) *Clean Development Mechanism:* In order to grasp reduction opportunities in the non- Annex B countries, the Kyoto Protocol instituted a mechanism called Clean Development Mechanism (CDM), defined in Article 12 of the Protocol. The CDM allows countries with emission targets to buy emission credits from projects in countries without targets and hence is of relevance for India, unlike the first two mechanisms mentioned above which are applicable to only Annex I countries. Under the CDM, an Annex I party is to implement a project that reduces greenhouse gas emissions (or subject to constraints, removes green house gases by carbon sequestration) in the territory of a non-Annex I party. The resulting certified emission reduction (CERs), can then be used by the Annex I party to help meet its emission reduction target. CERs are tradable under Article 3.12 of the Kyoto Protocol. Not only countries but companies as well, are allowed to invest and execute projects.

3.2 Relevance of CDM for developing countries:

The developing countries like India can benefit from this mechanism as the CDM can:

* attract capital for projects that assist a more prosperous but less green house gas-intensive economy;
* encourage and permit the active participation of both private and public sectors;
* provide a tool for technology transfer, if investment is channelled into projects that replace technologies which lead to high emissions and
* help define investment priorities in projects that meet sustainable development goals.

It has been envisaged that “the funding channelled through the CDM should assist developing countries in reaching some of their economic, social, environmental and sustainable development objectives, such as cleaner air and water, improved land-use, accompanied by social benefits such as rural development, employment, and poverty alleviation and in many cases, reduced dependence on imported fossil fuels. In addition to catalysing green investment priorities in developing countries, the CDM offers an opportunity to make progress simultaneously on climate, development, and local environmental issues. For developing countries that might otherwise be preoccupied with immediate economic and social needs, the prospect of such benefits should provide a strong incentive to participate in the CDM" (UNEP, 2003).

3.3 Coverage of CDM projects:

Apart from nuclear energy and deforestation avoidance, all other projects are eligible under CDM. Thus, India can attract projects in the livestock sector under CDM as the investments in this sector of non-Annex I countries can qualify for CDM credits.

Even if the methane emissions from this sector can be reduced by only 10% in the medium term from the current level of about 9-12 Tg/year, it would amount to an annual reduction of 18.9 to 25.2 million tons of CO_2 equivalent. A reduction of 5% in nitrous oxide emission can lead to reduction in 0.31 million tons of CO_2 equivalent.

Project eligibility: The two broad criteria stipulated under the Kyoto Protocol that CDM projects must satisfy are broadly classified as **additionality** and **sustainable development**.

Additionality: A project activity resulting in greenhouse gas emissions would be considered eligible under the CDM process if, as stated in Article 12.5, reductions in emissions are:

"additional to any that would occur in the absence of the certified project activity". The CDM projects must lead to "real, measurable, and long-term benefits related to the mitigation of climate change." The additional greenhouse gas reductions are calculated with reference to a defined "baseline". A baseline is a quantifiable business-as-usual scenario which is a critical aspect in the design of the CDM. A detailed discussion on the issue of baselines in the Indian livestock sector shall follow later in this chapter.

The "additionality" condition of the CDM projects has been an issue of intense debate and subject to several interpretations. The Marrakesh Accords include two direct statements on additionality :

"…….Emphasizing that public funding for clean development mechanism projects from Parties in Annex I is not to result in the diversion of official development assistance…..and is to be separate from and not counted towards the financial obligations of Parties included in Annex I. (UNFCC 2002:Decision 17/CP.7) and

"A CDM project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM project activity." (UNFCCC 2002:CMP.1 Art.43)

The financial additionally referred to in the first paragraph is relatively easy to establish and means that the investment under CDM project should ensure an increase in financial resources to developing countries and not a re-labelling of existing official development aid (ODA)- this means that ODA funded projects in the dairy sector will not be able to be labelled as CDM projects. It is the interpretation of the second paragraph which is more controversial. One group of experts interprets additionality as environmental additionality only, while the other group contends that environmental additionality is a necessary but not a sufficient condition, the additionality of the project itself (investment additionality) has to be proven in order to qualify for the CDM (Pearson *et al*., 2003; Greiner *et al*., 2003). The CDM Executive Board tends to lean towards the second interpretation as it asks project developers to apply a distinct additionality test.

Sustainable development: One important objective of CDM is to contribute to the sustainable development of the host country. Article 12.2 of the Kyoto Protocol says, "The purpose of the clean development mechanism shall be to assist Parties not included in Annex I in achieving sustainable development and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in achieving compliance with their quantified emission limitation and reduction commitments under Article 3" (UNFCCC 1997).

Although there are no common guidelines for the sustainable development criterion and the Marrakech Accord clearly states that "it is the host party's prerogative to confirm whether a clean development mechanism project activity assists it in achieving sustainable development", the criteria for sustainable development may be broadly classified as (Pembina 2003):

- Social criteria: The project improves the quality of life, alleviates poverty, and improves equity.
- Economic criteria: The project provided financial returns to local entities, results in positive impact of payments, and transfers new technology.
- Environmental criteria: The project reduces greenhouse gas emissions and the use of fossil fuels, conserves local resources, reduces pressure on the local environments, provides health and other environmental benefits, and meets energy and environmental policies.

Let us now address the issues of baseline and sustainable development in the context of the livestock sector in India, while the discussion on additionality issue be taken up in the next chapter after discussing the various strategies to reduce greenhouse gas emissions in the livestock sector.

3.4 Issue of Baseline in Indian Livestock sector:

Emission abatement through a project can only be calculated with respect to the emission level that would have existed had the project not been implemented. The construction of such a hypothetical state is known as the "baseline" of the project (Pearce 1995, p. 27). The issue of baseline would not have been a relevant one if the CDM host countries themselves had quantitative targets, as in case of other two flexible mechanisms under the Kyoto Protocol viz. Joint Implementation and Emission Trading. But in the absence of such targets for the non Annex I Parties, the credibility of the CDM depends upon the extent to which it reduces the GHG emissions and at the same time avoids overstatement of emission reductions.

The Subsidiary Body on Scientific and Technological Advice (SBSTA) of the UNFCCC states that "…The methodologies used in calculating the baseline scenario may be sector-specific, technology-specific or country-specific" (UNFCCC 1997). But this was applied to the pilot phase of cooperative projects and does not relate to the CDMs. The Marrakech Accords say that baselines should be project specific but in 2003 the CDM Executive Board's Methodology Panel started to develop sectoral baselines (e.g. electricity grid emission factors for renewable electricity generation projects). The sector specific baselines have been envisaged as good depiction of reality and quite accurate if indirect effects do not cross the sector boundaries (Michaelowa and Fages, 1999).

On the basis of the discussion in the previous chapter on the emission inventory from livestock sources in India, it can be concluded that baselines using aggregate emission rates at the national level cannot be accurate. The emission rates are influenced by both the livestock and feed characteristics, which vary widely across regions in an agro-climatically diverse country like India. The inter-regional variations in average productivity of animals and average availability of dry and green fodder per adult bovine (Table 7) is an indication of the differences in livestock characteristics and average feed intake of the animals (and hence emission rates) across regions.

Table 7: Regional variations in animal productivity and feed availability in India

Regions/States	Average milk yield per lactating animal (kg/day)@			Average Fodder availability per adult bovine (kg/day)#	
	Buffalo	Crossbred cows	Local cows	Dry Fodder	Green Fodder*
Northern Region					
Haryana	5.7	6.7	4.2	16.8	14.7
Himachal Pradesh	3.1	3.3	1.7	6.3	6.8
Punjab	6.2	8.7	2.8	15.9	16.7
Uttar Pradesh	3.9	6.0	2.1	9.4	5.1
Southern Region					
Andhra Pradesh	2.9	6.2	1.7	10.5	5.2
Karnataka	2.6	6.2	2.0	9.2	3.2
Kerala	5.5	6.2	2.4	1.8	2.5
Pondicherry	4.0	4.7	2.4	8.8	0.0
Tamil Nadu	3.7	5.8	2.4	13.9	5.5
Western Region					
Gujarat	3.9	8.0	2.9	7.8	16.0
Maharashtra	3.6	6.9	1.5	11.7	10.3
Rajasthan	4.1	5.3	2.8	8.0	6.4
Eastern Region					
Bihar	3.5	4.9	1.6	3.5	0.8
Orissa	1.8	3.9	0.5	2.4	2.4
West Bengal	5.8	7.2	2.1	9.0	0.8
North eastern Region					
Arunachal Pradesh		7.7	1.3	10.4	178.0
Assam	2.0	3.8	1.0	3.8	2.4
Manipur	3.2	6.5	1.4	4.4	7.6
Meghalaya	1.8	8.8	0.7	2.8	12.8
Mizoram		7.2	1.0	19.9	250.0
Central region					
Madhya Pradesh	3.0	5.7	1.3	9.6	10.7

@ Average of 1997-98 and 1998-99
# Fodder Production average 1997-2002
* includes yield from forests, permanent pasture and grazing lands, and cultivated area under fodder crops

Source: **Compiled from**

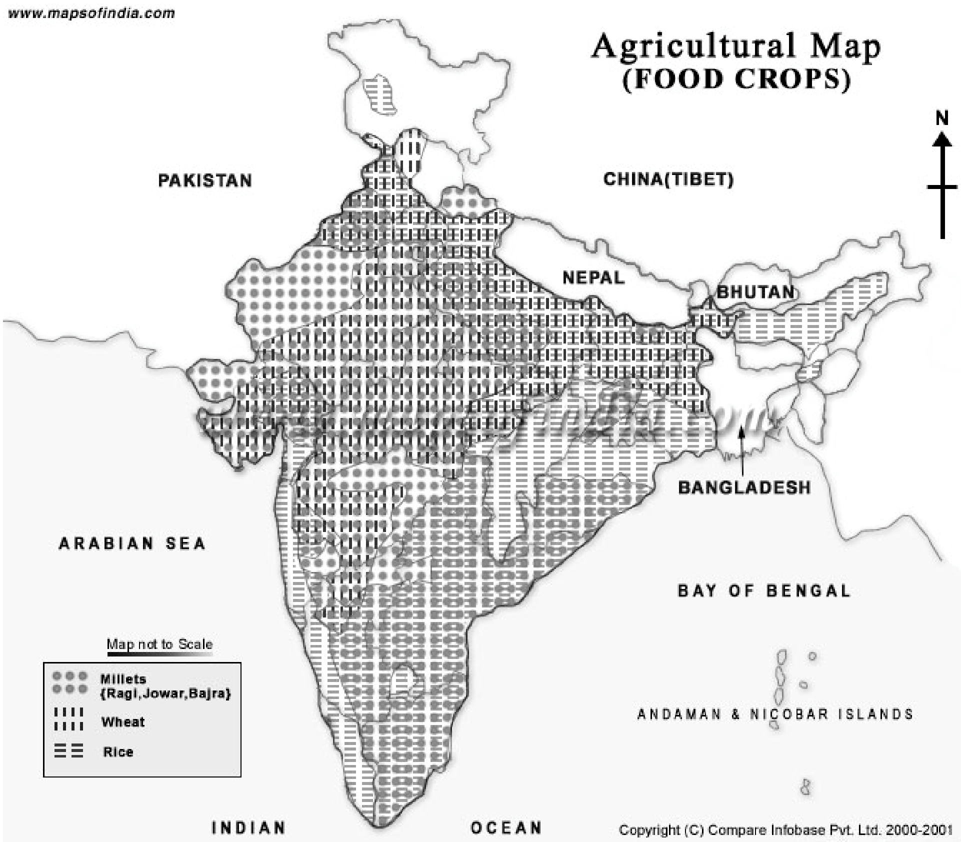
1) Basic Animal Husbandry Statistics 2002, Dept. of Animal Husbandry and Dairying, Ministry of Agriculture.

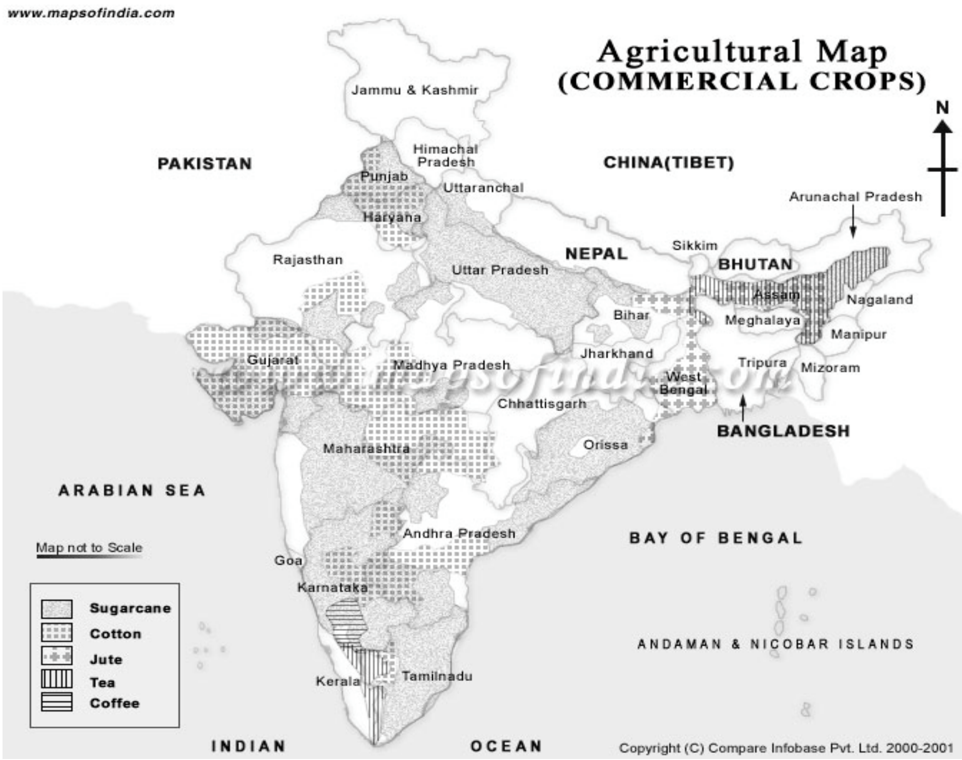
2) Lok Sabha Unstarred Question No.17, Dated 15.07.2002.

Besides the quantum, the type and quality of feed resources also vary across regions. Due to poor availability of pasture and grazing lands in India (only 3.4% of area in India is permanent pasture and grazing land), the animals either subsist on poor quality grasses available in the pastures and non-pasture lands or are stall-fed, chiefly on crop by-residues. The type of crop by- residues fed to animals depend on the cropping pattern of the region. A bird's eye view of the regional variations in cropping pattern in India can be taken from Map 2a & 2b. Experiments have shown that diet pattern have considerable influence on the methane emission from enteric fermentation. For instance, *in vivo* methane production studies on different ratios of berseem[9] and wheat/paddy straw indicated a decrease in methane production depending on the proportion of berseem in the diet (Singh 2001). Berseem is extensively used as green fodder during the winter months in the Trans-Gangetic Plain in the northern part of India while in the eastern part and southern part of the country there is general shortage of green fodder. Hence for arriving at the baseline from livestock sector, only regional emission factors should be used.

[9] a green fodder grown during the winter season

Map 2a: Regional Variations in Cropping Pattern in India





Map 2b: Regional Variations in Cropping Pattern in India

The other important aspect of "baseline" is the issue of static vs. dynamic baseline. A static baseline assumes that the same benchmark is used in estimating emission reductions over the entire project life. On the other hand dynamic baselines vary over time. The two concepts are illustrated with the help of following example:

Static baseline estimated for base level benchmark in say, year 2000 would be equal to

$$\textit{Emission rates (ER)}_{2000} \textit{ x livestock population}_{2000}$$

For the subsequent years, the base line could be, **either**

$$\textit{Emission rates (ER)}_{2000} \textit{ x livestock population}_{t+1} \text{ where t= base (e.g. 2000) } \textbf{or}$$

$$\textit{Emission rates (ER)}_{t+1} \textit{ x livestock population}_{t+1} \text{ (Dynamic baseline)}$$

As long as feeding patterns (or manure management practices for working out emissions from manure management) do not change over time both, the static and dynamic baselines will not differ. On the basis of practical field experience it can be safely said that the feeding patterns (and similarly manure management practices) do not change in relatively shorter time frame, say up to 10 years. So whatever changes in the baseline takes place over the life of CDM project would come from changes in livestock population.

Of the 520.6 million livestock population in India in 2002, 42.6% were cattle, 18.3% buffaloes, 23.8% goats ands 11.3% sheep (Table 8). The growth trends in the population of these four major species indicate a sharp decline in the rate of increase over the past three decades, from 1.7% during 1972-82 to 1.1% during 1982-92 and further to 0.9% in the last decade, 1992-2002. This indicates that there is a tendency towards stabilization of the livestock population in the long-run which is a positive aspect from the emissions perspective.

Table 8: Trends in Livestock Population in India

Species	**2002**
Nos. (in million)	
Cattle	221.9 (42.6)
Buffaloes	95.1 (18.3)
Sheep	58.8 (11.3)
Goats	124.0 (23.8)
Other	20.8
Total Livestock	520.6

Growth rates (%)	**1972-82**	**1982-92**	**1992-02**
Bovines (cattle+buffaloes)	1.06	0.96	0.93
Ovines (sheep + goat)	2.92	1.42	0.96
Bovines + Ovines	1.68	1.13	0.94

Figures in parenthesis are percentage share in total

Source: **FAOSTAT**

With the deceleration in the growth rate certain compositional shifts have also taken place in the livestock population which have implications for the emission levels and hence mitigation options:

- Cattle which constituted 75.7% of the bovine stock (cattle + buffaloes) in 1972, now accounts for only 70% of the same. In other words, the composition of bovine stock has shifted in favour of buffaloes. The buffaloes have higher methane emission rate from enteric fermentation.

- The declining share of cattle population largely comes about from the decline in the indigenous cattle population. Extensive dairy development efforts to improve the productivity of low-yielding indigenous cattle through hybridization of this zebu cattle with exotic breeds has increased the crossbred cattle population in the country from a negligible number in 1972 to over 16 million at present. The crossbred cattle also emit more methane than the indigenous cattle.

- Along with the shift in breed composition, the sex composition of bovines has also shifted, from males to females. The adult female bovines, particularly those in lactation have higher feed intake and consequently higher methane emission rate.

These compositional shifts in bovine population are guided by the economics of milk production and of alternate energy sources that can be used for farm operations. India is the home tract of very good cattle species like, Sahiwal, Tharparkar, Gir, Kankrej etc. but these are available in few numbers and most of our cattle is non-descript. The studies carried out on the comparative economics of milk production from buffaloes, crossbred and indigenous cows unambiguously indicate the buffaloes and crossbred cattle are more economic to the farmer, primarily due to their relatively much higher productivity than the local cows.

The importance of indigenous cattle further declined due to substitution of mechanical power for animal power in the agricultural operations. The Green Revolution made it imperative to replace relatively inefficient and time consuming draft animal power by mechanized pumpsets and tractors. This led to a decline in the requirement of male cattle used for work and of the female cattle to provide replacement stock of male off-springs.

With further rise in domestic demand for milk in India as a result of increasing per capita income, opening up of new vistas for exports of milk and milk products as a result of globalization and trade liberalization, and increase in the intensity of agricultural mechanisation the observed trends in composition shift will be re-enforced further.

The status of data availability for taking into account these complex compositional changes is however, not very encouraging. The FAO publishes the country level statistics on major species of livestock heads annually. But this does not provide species-wise break-up of the livestock numbers according to age, sex and breed of the animals. The Livestock Census which is conducted in India quinquennially by the Directorate of Economics and Statistics in the Department of Agriculture and Cooperation, Ministry of Agriculture provides such detailed classification at the district level. But there is a minimum seven to eight years lag in publication of results! This implies that appropriate models need to be developed for forecasting the livestock population, which take into account the dynamic changes in the demand for livestock products, comparative economics of production from alternate species, etc.

Therefore the informational requirements for establishing a high precision sectoral baseline in the livestock sector in India are quite substantial. But as has been explained in the following section that the voluminous information collected for such a sectoral baseline would also be suffice for working out the project–specific baseline from the same.

Project-related baselines:

In principle, a thorough test of additionality can only be done through derivation of project specific baselines that take into account the economics of the project. However, studies have indicated that project-specific guidelines have high transactions costs, which would make CDM projects less attractive (Michaelowa *et al* 2003). Another problem which could arise in project-related baselines is that they are most likely to be financed as part of the transaction costs by the investor, who could try to influence the outcome of the baseline study.

These two problems in calculating project specific baseline for the livestock sector can be taken care of by a sectoral baseline, provided the sectoral baseline has been calculated on the basis of regional emission rates and livestock population, taking a district as the smallest administrative unit. In other words, in working out such a sectoral baseline, since district specific emission rates would have to be worked out and these can be used along with the district livestock population for arriving at what can be called a "district-specific baseline." Depending on the districts covered by a prospective CDM project, these district-specific baselines can then be transformed into project-related baselines.

This would mean that once the sectoral baseline has been created on the basis of regional emission factors than no additional costs need to be incurred for arriving at project-related baselines, and investor bias will also be negligible. The dynamic baselines are also easier to work for the districts falling within the command area of a CDM project as the updated information on the livestock population for a particular district is more readily available at the district headquarters (through state or district animal husbandry departments or other such records) than for all the districts together through the central department.

3.5 Sustainable development in the Indian context:

India's concern for sustainable development in the scenario of climate change can be gauged from the statement made by the Indian Prime Minister during the COP-8 in New Delhi, "India is deeply committed to the goals of sustainable development" (Vajpayee, 2002). The development plan in India is structured in planning phases of five years. The development priorities, objective and strategies of the country are defined in the Five Year Plan document issued by the Indian Planning Commission. The current Tenth Five Year Plan (2002-07) has been prepared against a backdrop of high expectations arising from encouraging growth of 6.5% growth in GDP achieved during the previous two Plan periods, making India one of the ten fastest growing developing countries. Recognizing that economic growth cannot be the only objective for national planning and development objectives are to be defined not just in terms of increases in GDP or per capita income but in more broader terms of enhancement of human well-being, the 10^{th} Plan establishes specific and monitorable targets of development (Box 2) in addition to a 8% GDP growth target. The Plan also emphasised that 'environmental management and economic development are mutually supportive aspects of the same agenda" and that "sustainability is not an option but imperative".

Box 2

MONITORABLE TARGETS FOR THE TENTH PLAN AND BEYOND

• Reduction of poverty ratio by 5 percentage points by 2007 and by 15 percentage points by 2012;

• Providing gainful and high-quality employment at least to addition to the labour force over the Tenth Plan period;

• All children in school by 2003; all children to complete 5 years of schooling by 2007;

• Reduction in gender gaps in literacy and wage rates by at least 50 per cent by 2007;

• Reduction in the decadal rate of population growth between 2001 and 2011 to 16.2 per cent;

• Increase in Literacy rates to 75 per cent within the Plan period;

• Reduction of Infant mortality rate (IMR) to 45 per 1000 live births by 2007 and to 28 by 2012;

• Reduction of Maternal mortality ratio (MMR) to 2 per 1000 live births by 2007 and to 1 by 2012;

• Increase in forest and tree cover to 25 per cent by 2007 and 33 per cent by 2012;

• All villages to have sustained access to potable drinking water within the Plan period;

• Cleaning of all major polluted rivers by 2007 and other notified stretches by 2012.

Targets for the Livestock sector: The animal husbandry and dairying contributes about 6% to total gross domestic product (GDP). Livestock sector provides employment to almost 18 million people in principal (9.8 million) or subsidiary (8.6 million) status. Women constitute about 70 per cent of the labour force in livestock farming. The overall growth rate in the livestock sector has been steady at around 4.5 per cent. As the livestock sector contributes substantially to the GDP and employment and also as the ownership of livestock is more evenly distributed among landless labourers and marginal farmers, the progress in this sector will result in a more balanced development of the rural economy.

The sectoral development strategy in the Tenth Plan aims to give high priority to animal husbandry and dairying in the efforts for generating wealth and employment, increasing the availability of animal protein in the food basket and for generating exportable surpluses. The overall focus will be on four broad pillars viz. (i) removing policy distortions that is hindering the natural growth of livestock production; (ii) building participatory institutions of collective action for small-scale farmers that allow them to get vertically integrated with livestock processors and input suppliers; (iii) creating an environment in which farmers will increase investment in ways that will improve productivity in the livestock sector; and (iv) promoting effective regulatory institutions to deal with the threat of environmental and health crises stemming from livestock. The Tenth Plan target for milk production is set at 108.4 million metric tonnes envisaging an annual growth rate of 6.0 %. The main focus of the Plan is a transition from subsistence livestock farming to sustainable and viable livestock and poultry farming.

National sustainable development priorities: The formal institution for the approval of CDM projects was set up by cabinet approval in December 2003. However, prior to that, to provide guidance for the development of the CDM projects, the Indian administration released a set of guidelines with regard to the sustainable development that are still valid. The following aspects should be considered when designing CDM project activities in India (MoEF 2002):

Social well-being: The CDM project activity should lead to alleviation of poverty by generating additional employment, removal of social disparities and contributing to provision of basic amenities to people leading to improvement in their quality of life.

Economic well-being: The CDM project activity should bring in additional investment consistent with the needs of the people.

Environmental well-being: This should include a discussion of the impact of the project activity on resource sustainability and resource degradation, if any, due to the proposed activity; bio-diversity-friendliness; impact on human health; reduction of levels of pollution in general;

Technological well-being: The CDM project activity should lead to transfer of environmentally safe and sound technologies with a priority to the renewable sector or energy efficiency projects that are comparable to best practices in order to assist in up-gradation of the technological base.

The aspects of sustainable development that should be considered in a CDM project in livestock sector should be as follows:

1) Increase in Productivity of the animals:

Although India is the world's number one milk producing nation, producing 84.5 million tonnes annually, yet the productivity of the livestock is very low in India compared to the world average (Table 9). The rising demand for food from animal origin needs to be met by increasing the productivity levels rather than increasing the numbers. Any increase in numbers would increase the pressure on environment and accentuate the shortage of feed and fodder in the country, thus decreasing the productivity further. Unless the emission reduction strategies are accompanied by increase in productivity they will not be in consonance with the sustainable development of livestock sector.

Livestock farming is caught in a vicious trap of low productivity (Fig.3). As a result of the low productivity of animals, to be able to meet the demand for products, the farmers maintain a herd larger than the one that would be economically optimum in relation to the availability of feed resources. This further increases the pressure on resources and leads to still lower productivity levels. The increase in productivity levels will positively affect sustainable development also via an indirect channel of reducing the livestock numbers and hence easing the pressure on land, feed resources and environment, subject to the condition that total output does not decline. Increase in productivity resulting in an increased output will also lead to increase in employment in livestock enterprises for marketing and distribution of livestock products.

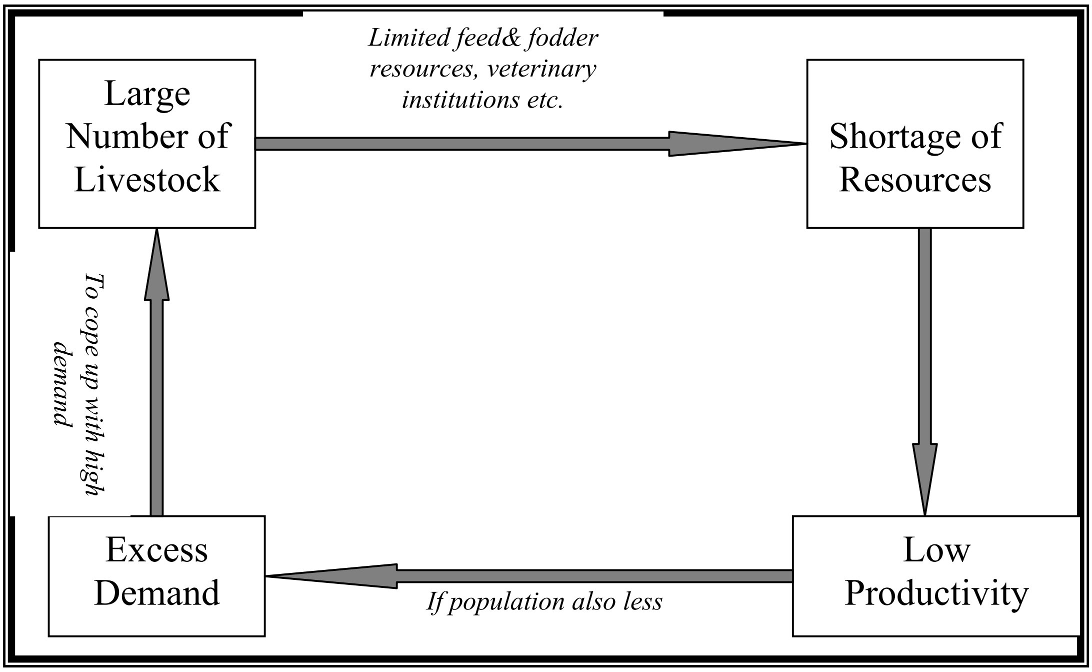
Table 9: Annual Productivity of cows: selected countries

(metric tonnes)

Countries	2002
USA	8.42
Canada	7.35
EU	5.76
Australia	4.90
Poland	3.96
Argentina	3.95
New Zealand	3.71
Russian Federation	2.75
India	1.01
World Average	3.15

***Source:* USDA, FAS, Dec. 2003.**

Fig. 3 Low Productivity Trap



From the implementation point of view also, it is important that mitigation options should have a built-in component of raising the productivity levels. Farmers are not aware and concerned about the environmental aspects of livestock farming. For a technology to be acceptable to them, the productivity increases should be obvious.

2) Increase in net income of producers:

Rise in productivity levels is a necessary but not sufficient condition for sustainable development unless accompanied by increase in net income of farm households, which implies that the incremental unit cost of production should be less than the incremental revenue generated from the additional unit of production. In India, more than 18 million farm families are dependent on livestock farming as their primary or secondary occupation. The distribution of livestock animals across farm categories (Table 10) shows that 68% of the milch animals and 87% of small ruminants (sheep and goats) are owned by the weaker sections of the society, viz. landless, marginal and small farmers. The increase in net income from livestock enterprises would be instrumental in poverty alleviation and reducing the disparities in income distribution among the farm households. This is in consonance with the socio-economic sustainable development indicators.

Table 10: Distribution of Livestock According to Size of Land Holding in India

(percent)

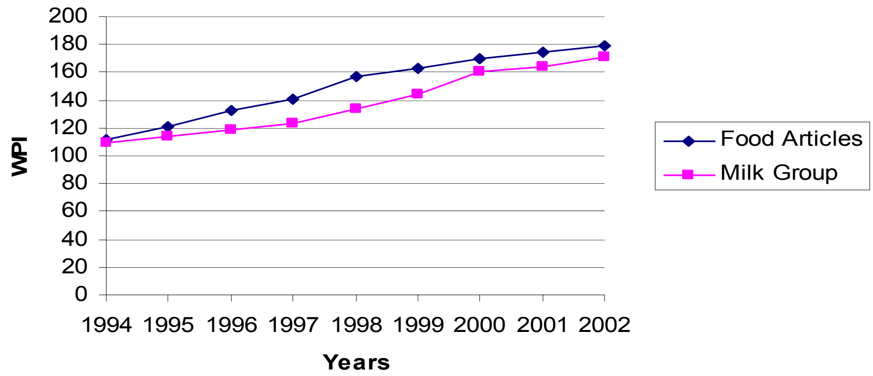
Category of land-holding	Milch animals	Sheep and Goats
Landless	3.2	13.6
Marginal (< 1 hectare)	43.4	64.1
Small (1-2 hec)	21.5	8.9
Semi-medium (2-4hec)	17.5	6.8
Medium (4-10hec)	11.0	4.4
Large (>10 hec)	3.4	2.2

Source: **Land and Livestock Holding Survey: 1992, National Sample Survey Organisation, India.**

3) Ensuring low cost of production:

From the producers point of view, an increase in net income can be achieved by increase in price of the products, but could be detrimental to the interest of the consumers. The milk and milk products account for 19% of the private final consumption expenditure on food articles and over the past three decades the growth in final consumption expenditure of food from animal origin has been faster than the corresponding growth in food items as a whole. Although in the past decade, the wholesale price index of milk group has increased lesser than the increase in the price index of food articles (Figure 4), yet a cost push pricing of milk would have a depressing effect on demand as the price elasticity of milk and milk products demand is greater than one i.e. they are substantially price elastic. The rising costs would not only depress domestic consumption but also hurt the international competitiveness of dairy industry. Presently, the ex-farm gate prices of milk in India are lower than that of the major players in the world dairy markets, except Australia and New Zealand. In the wake of the provisions of Agreement on Agriculture under WTO the Indian dairy industry envisages to make a place for itself in the world dairy markets, which will be seriously hampered if cost of production rises. The Tenth Plan document also emphasises that technology support in the sector is important not only for enhancement of productivity but also for reduction of cost at the same time. Therefore, rising cost, and a fall in demand occurring as a result of rise in prices would be detrimental to the overall development objectives of the sector.

Fig 4 : Wholesale Price Movement of Food and Milk Group
(base 1993)



Source: DGCIRS

4) Transfer of safe technologies:

Transferred technologies should not be detrimental to the health and genetic potential of the animals in the long-run. Some technologies increase the production in the short-run but in the long-run may harm the animals and also the produce from such technologies may not be considered safe for human consumption. Bovine somatotropin (bST) is an example of one such controversial biotechnology. Although bST can boost milk yield per cow significantly-doing in 1 year what it would take 10 to 20 years to achieve with current reproductive technologies -, concerns have been raised about its safety for humans and animals and the use of bST has been banned in several industrialized countries. It is imperative to ensure that there is no 'technological dumping' in the developing nations under the CDM projects.

In consonance with the guidelines proposed above, clearly defined questions towards a CDM project with a closed set of pre-defined answers could be formulated to be able to make a straightforward statement with respect to each of the issues raised above. The other approach to assure a measurable contribution to sustainable development for the implementation of a CDM project could be that of 'negotiated targets", whereby the project proponent discusses with the livestock farmers of the project area what additional contribution to their local development the proposed project shall deliver. Although concerns have been expressed that since this approach does not make any assessment of the sustainability of the project itself, theoretically, it is possible that a totally unsustainable project fulfils the negotiated targets requirements by agreeing on compensation measures that have been negotiated with the local community (Sutter, 2003). The possibility of these fears getting transformed into reality in the livestock sector are however ruled out since livestock farming is not only an crucial source of income but a way of living under the Indian setup.

To integrate the sustainability issues raised by the local stakeholders in the holistic approach to sustainability, multi-criteria assessment of CDM project is also possible (Sutter 2003), but further research needs to be carried out in this area to make it applicable to the livestock sector in the developing countries in general, and Indian conditions in particular.

4. Mitigation strategies for reducing greenhouse gas emissions

This chapter presents an overview of the various mitigation options for emissions from enteric fermentation and discusses these strategies from the point of view of the possibility of their application as CDM projects in India[10].

4.1 Options for reducing Enteric emissions:

The strategies for reducing methane emissions from enteric fermentation can be broadly focused in two main areas: 1) reducing livestock numbers and 2) improving the rumen fermentation efficiency. Another approach for reducing enteric emissions that has been suggested by some studies is improving the productivity of animals. However, this is actually a sub-category of the first approach as productivity improvement would result in reduction of total enteric emissions only if the amount of product is kept constant i.e. as productivity increases the animal numbers are decreased so that the total amount of product remains constant.

The option of decreasing livestock numbers may be economically desirable considering the feed and fodder shortage in the country with respect to the size of the bovine population, but may not be practically feasible until a) productivity levels increase substantially to break the vicious circle of low productivity discussed earlier and b) the

[10] The discussion on mitigation options is confined to enteric emissions because of two reasons. One, the options for reducing enteric emissions themselves lead to decline in methane from livestock manures. Secondly, a CDM project to reduce emissions from livestock manure management would not be viable in Indian conditions, as manure is managed under dry system leading to low emission rate per cattle head from manure. A project for using methane emitted from livestock manure as bio-gas for substituting traditional coal and wood as fuel in rural households comes under the ambit of non-renewable energy sector and is outside the project boundary of livestock sector, as such a practice is not actually reducing total methane emissions from livestock manure, rather it is using bio-gas as source of energy.

national policy on slaughtering of ‘economically unviable’ animals- particularly, cows- is not guided by the religious and social taboos on animal slaughtering in India. Unlike in EU, where the trends in animal numbers are dependent on both, the EU’s Common Agricultural Policy (CAP) and national policies; in the Indian context, a very complex set of socio-economic and religious factors influence such trends in animal population. Therefore, the option of mitigating methane production by decreasing animal numbers is outside the purview of CDM projects. Thus, we limit our focus on improving rumen fermentation efficiency as the plausible mitigation strategy.

Improving rumen fermentation efficiency

The growth of rumen microbes is influenced by chemical, physiological and nutritional components. The major chemical and physiological modifiers of rumen fermentation are rumen pH and turnover rate and both of these are affected by diet and other nutritionally related characteristics such as level of intake, feeding strategies, quality of fodder and fodder:concentrate ratios. The options for increasing rumen efficiency can meet the sustainable development criteria only if they do not lead to any adverse affect on the health of the animal. For instance, feeding ruminants on diets containing high levels of readily fermented non-structural carbohydrate has been shown to minimize methane production by reducing the protozoal population and lowering rumen pH. However, this can give rise to an overall depressed ruminal fermentation, which may lower the conversion of feed energy into animal product and may be detrimental to the animal's health. Using diets with extreme nutrient compositions is therefore not considered likely to be a successful or sustainable method to control methane (DGXI 1998).

The options identified to increase rumen efficiency without threatening the animal health can be classified as:

- improved nutrition through
    - feed additives,
    - strategic supplementation, and
    - dietary manipulation,
- changing rumen microflora by
    - adding specific inhibitors or antibiotics,
    - biotechnological manipulation and

- genetic engineering.

But several of these options are not commercially available technologies at present and so we concentrate only on those options which can be applied in the field conditions presently, while discussing the upcoming technologies in Appendix C.

Feed additives: A wide range of feed additives are available that can reduce rumen methanogenesis (Chalupa, 1980; Mathison *et al*. 1998) such as propionate precursors and ionophores.

Propionate precursors: Within the rumen, hydrogen produced by the fermentation process may react to produce either methane or propionate. By increasing the presence of propionate precursors such as pyruvate, oxaloacetate, malate, fumarate and succinate more of hydrogen is used to produce propionate. The dicarboxylic organic acids, fumarate and malate, have been suggested as potential hydrogen acceptors to reduce methane in the ruminants (Asanuma *et al*., 1999; Lopez *et al*., 1999; Carro *et al*., 1999).

Propionate precursors can easily be introduced as a feed additive for stall-fed animals receiving concentrates. For the grazing animals also, the propionate precursor malate could be fed by increasing the concentration of malate in forage grasses through plant breeding techniques. But not only considerable research is needed for such an endeavour, also its applicability to grazing animals shall remain limited to areas where animals feed on maintained pasture lands.

Broadly, the potential for methane reduction from increasing propionate precursors like malate in the diet of animals has been estimated up to 25% (ADAS, 1998).

Ionophores: The ionophores are known to inhibit methanogenesis and shift VFA (volatile fatty acids) patterns towards higher propionate. The main ionophores (monensin, lasalocid, salinomycin) in use have shown improved feed efficiency by reducing feed intake and maintaining weight gain or by maintaining feed intake and increasing weight gain. Monensin, an ionophore, inhibits methane *in vivo* by about 25% (van Nevel and Demeyer, 1995). The experiments conducted in India with monensin pre-mix showed that using this technique methane production can reduce by 20-30% depending on the diet of animals viz. 14-23% for animals fed at maintenance diet, 23-32% at medium production diet and 14-25% at high production diet (Singh, 1998).

Ionophores are extensively used in many segments of cattle industry like beef fattening. In EU and USA, its use has not been permitted in dairy cows because the product requires a withdrawal period. However, in many countries ionophores are approved for use in dairy cows. In India also, its use is not banned and hence it would not be in conflict with the sustainable development objective of the country. The lactation trials carried out with lasalocid did not show any significant impact of this ionophore on milk yield, while the milk yield of cows fed with monensin premix and monensin CRC (controlled release capsule) was found to go up by 4.5 to 6 % (McGuffey *et al* 2001).

Strategic supplementation: Strategic supplementation provides critical nutrients such as nitrogen and important minerals to animals on low quality feeds. The use of molasses/urea multinutrient blocks (MNBs) has been found to be a cost effective diet supplementation strategy with a potential to reduce methane emissions by 25 to 27% (Bowman *et al*., 1992; Robertson *et al*., 1994) and increase milk production at the same time.

Dietary manipulation: The substitution of low digestibility feeds with high digestibility ones tends to reduce methane production, as with the improvement in digestibility same level of production can be achieved through lesser feed intake and hence the enteric emissions are reduced. This point can be illustrated with the help of the following Table 11:

Table11: Effect of Feed Quality on Methane Emission of cows at the same level of milk production

Dry Matter (DM) digestibility (%)	55	65	75
Milk production (kg/d)	20	20	20
Feed intake (kg DM/d)	21.6	17.5	14.6
CH_4 emission (g/d)	309	296	285
g CH_4/kg milk	15.5	14.8	14.3

Source:* O'Hara *et al.

Benchar *et al*. evaluated the effect on methane production of a range of dietary strategies using a modelling approach and predicted that a reduction of 10 to 40% can be achieved this way. Methane production could be reduced by increasing feed intake (-7%), increasing the concentrate proportion of the diet (-40%), replacing fibrous concentrate with starchy concentrate (-22%), with the utilisation of less ruminally degradable starch (-17%), increasing the digestibility of forage (-15%), with legume compared to grass forage (-28%) and with silage compared to hay (-20%).

Experiments in India have shown that increasing the ratio of concentrate in the diet of animals from 25 to 75% decreased methane by more than 18% (Singh, 2001). Similarly, increased feeding of berseem (green fodder) also decreased the methane production by 20 to 30% depending on the ratio of berseem in diet. In case of feeding oat as green fodder with wheat straw diet/substrate, methane production was reduced by 8 to 23% (Singh, 2001).

Changing rumen microflora: Probiotics, the microbial feed additives contain live cells and growth medium. Probiotics based on *Saccharomyces cereisiae* (SC) and *Aspergillus oryzae* (AO) are widely used for increasing animal productivity. There are mixed reports as to whether these probiotic additives can reduce methane emissions. AO has been seen to reduce methane by 50% which was directly related to a reduction in the protozoal population (Frumholtz *et al*., 1989). On the other hand, addition of SC to an in vitro system reduced the methane production by 10% initially, though this was not sustained (Mutsvangwa *et al*., 1992).

Scope of applicability of the mitigation strategies in the Indian context

Of the several options discussed above only molasses-urea products (MUP) and concentrate feeding have actually been tested at field level in Indian conditions. In fact, one dairy feed project using the molasses urea products has already been underway in India[11]. Some experiments have also been conducted in India with monensin feed additives and the results have been quite encouraging. Each of tried options will now be

[11] In 1994, Applied Energy Systems Ltd. and TransAlta provided joint investment for an EnterpriseWorks project called India Dairy Project. The Project was proposed to be a part of the US Initiative on Joint Implementation (USIJI) which was to be one of the most comprehensive programs for AIJ activities, the precursor of CDM. EnterpriseWorks and its partners in India are working with local commercial enterprises to produce and market low-cost MUPs as a dairy cattle feed supplement that increases milk production and can also reduce methane gas emissions. Project activities are currently underway in five districts of Gujarat, a state in western India. The project was expected to contribute 569,966 tonnes of CO_2 reductions in 2005 (Salmon 2000). TransAlta hoped the project would receive future recognition as a CDM project and in its Sustainable Development Annual Report 2000, reports a contractual transfer of following CO_2 equivalent tones to TransAlta- 1996: 1000 t, 1997: 6000t, 1998: 12000t, 1999: 36000t, 2000: 117000t. The current status of the project is however, unclear.

discussed from the perspective of a potential CDM project in the livestock sector, highlighting the "additionality" criterion. A note of caution needs to be mentioned here clearly that the results obtained are based on broad aggregate assumptions and can vary substantially from region to region depending on a host of interactive local factors. We start with the projects that have been tested in the field conditions.

1) Strategic supplementation using molasses-urea products (MUP):

This technology is applicable to all the types of dairy and non-dairy animals who are on poor diet. The level of methane reduction and improvement in milk as a result of MUP supplementation will vary according to the composition of molasses, urea and other constituents in the block. The composition of a typical molasses/urea multinutrient block is given in Table 12 although the exact composition of the blocks will depend on local needs and available materials.

Table 12: Typical Compositions of Molasses/Urea Multinutrient Blocks

Ingredient Amount	(%)	Function
Molasses	40-60	Palatability and Energy
Urea	4-15	Ammonia Source
Lime	8-10	Binding Agent
Mineral/Vitamins	1-15	Nutrient Supplements
Wheat/Rice Bran	20-30	Soluble Protein

Sources: **Leng, 1991; Saadullah, 1991**

The following assumptions are used to work out the cost of this option:

a) The average quantity of the product consumed by an adult animal is 400 g/day and by heifers 300g/day.

b) The cost of producing one kilogram of the product is taken as Rs.5.00. The ex factory cost of the molasses urea product produced in the India Dairy Project (called Pashu Poshak) during 1998-99 worked out to be Rs.4.3 at the then exchange rate[12] (Bundick *et al*., 2000). Considering the increase in price level the current cost is taken as Rs.5.00 per kg.

d) The methane reduction per animal is taken as 11%.

[12] at the current exchange rate it is equal to Rs.4.5

e) Milk yield of animals is assumed to increase by 10% from the existing average lactation yield of 1.8 litres/day for local cows (270 days lactation length) and 4.0 litres/day for buffaloes (280 day lactation length).

f) The selling price of cow milk is Rs.8/litre and buffalo milk is Rs.9/litre.

g) Cost of technology is not worked out for crossbred animals as they are not really fed poorly because of the high asset cost of the animals and their higher milk potential.

f) Quantification of benefits other than decrease in methane production and increase in milk production have not been attempted (e.g. the impact of improved digestibility on work performance of adult male, growth of heifers etc.), the actual net cost of the option may therefore, be still lower than arrived here.

The gross cost of the methane abatement ranges from €73/t CO_2 to €157/t CO_2 for the lactating animals, being lower for the buffaloes than the local cows (Table 13) and €103/t CO_2 to €192/t CO_2 for the other animals. In case of dairy cows, due to increase in milk production the net cost comes down to €73/t CO_2 from the gross cost of €157/t CO_2. For the milch buffaloes the value of increased milk production more than compensates for the cost of MUP and offers a positive return of €28/t CO_2.

Table 13: Economics of MUB supplementation projects

Type of animals	Annual cost of supplement-ation (Rs.)	Annual Methane Emission (kg/head/year)	Annual Reduction @11%	Gross Cost of reduction €/t CO_2	Value of increased milk production @10% (Rs.)	Net cost of reduction €/t CO_2
Milch:						
Local cow	730	36	3.96	156.7	389	73.3
Buffalo	730	77	8.47	73.2	1008	-27.9
Heifer:						
Local cow	547.5	22	2.42	192.4		
Buffalo	547.5	37	4.07	114.4		
Adult male:						
Cattle	730	34	3.74	165.9		
Buffalo	730	55	6.05	102.6		

The estimates arrived at here are in consonance with those arrived at by the ALGAS study on Bangladesh (ALGAS, 1998). Taking a 25% methane reduction potential of MUB technology the study arrives at \$2.8/kg (equal to €2.3/kg) of methane abated as the incremental gross cost of the option while the net financial benefit per kg methane reduction for this option came to be \$2.3 (= € 1.92). If instead of 11% reduction we assume 25% reduction then our gross cost also ranges from €0.7/kg CH_4 to €1.8/kg CH_4.

2) Dietary manipulation through increasing concentrate feeding:

In the early 60s, from a survey of more than 12000 Indian households on the diets of animals it emerged that on an average less than 500 grammes of concentrate was fed to dairy animals per day (Table 14). For the non-dairy animals the quantity was even lower. Over the years an increase in the proportion of the concentrate in the livestock feed has been observed (Table 15). But even the existing proportion of 7.5% concentrate is not sufficient to cater to the recommended nutritional requirement of 40% concentrate and 60% roughage on dry mater basis for the Indian cattle. For high milk producing dairy animals the concentrate to roughage ratio is still higher at 50:50. Further, the increase which has taken place in the level of concentrate is far from uniform across species and regions. Across regions, the trend of increased concentrate feeding is limited in the areas where as a result of better market opportunities and commercialization, producers have the incentive to switch from subsistence oriented supplementary livestock rearing to market oriented pattern, while across species it is limited to the lactating and pregnant animals particularly, the high yielders.

Table 14: Feeding of cattle and buffaloes in India in the 1960s

Class of animal	Type of animal	Amount of feed fed/animal/day in kg fodder		
		Dry[2]	Green[2]	Concentrates[1]
In milk	Cow	3.5	4.4	0.3
	Buffalo	5.9	6.8	0.8
Dry	Cow	2.8	2.8	0.1
	Buffalo	4	4.3	0.1
Adult	Cattle	3.7	5	0.3
Males	Buffalo	5.4	6.5	0.2
Young	Cattle	1.5	1.6	Negligible
Stock	Buffalo	1.7	1.6	Negligible

Source: **Amble *et al.*, 1965 (p. 231)**

Table 15: Composition of livestock feed in India (%)

Item/Period	1950-51	1970-71	1981-82	1995-96
Dry Fodder	59.7	57.8	46.8	35.4
Green Fodder	37.7	40.2	50.6	57.0
Concentrates	2.5	2.1	2.6	7.6

***Source:* Birthal *et al*., 2001**

Assumptions used to work out the cost:

a) The average concentrate fed per day to lactating local cows, crossbreds and buffaloes is 1kg, 2.5 kg and 2 kg., respectively. The other animals are fed concentrate at the rate of 500g per day.

b) The cost of concentrate supplements is Rs.6 per kg.

c) Mitigation strategy involves doubling of the concentrate level for dairy animals and increasing it by 200% per day for other animals as they are under-fed in terms of concentrate.

d) For the reduction of methane we take a conservative estimate of 15%.

e) The partial elasticity of milk yield with respect to concentrate feeding at the average level is assumed to be: 0.1, 0.5 and 0.4 for local cattle, crossbred cattle and buffaloes.

f) Milk yield of animals is assumed to increase by 10% from the existing average lactation yield of 1.8 litres/day for local cows (270 days lactation length) and 4.0 litres/day for buffaloes (280 day lactation length).

g) The existing milk yield of lactating crossbred cow is taken as 6.5 litres/day (305 day lactation length) and price of milk as Rs.8/litre. The yield and milk price assumptions for local cattle and buffaloes are same as in the previous option.

The gross and net cost of the option is presented in Table 16. The results indicate that except for the crossbred animals which can cover the cost of increased feeding, for all the other animals the incremental cost is more than the incremental returns to farmers.

Table 16: Concentrate feeding

Type of animals	Annual cost of additional concentrate fed (Rs.)	Annual Methane Emission (kg/head/year)	Annual Reduction @15%	Gross Cost of reduction €/t CO_2	Value of increased milk production (Rs.)	Net cost of reduction €/t CO_2
Milch: Local cow	2190	36	5.4	344.8	389	283.6
Buffalo	4380	77	11.6	322.5	4032	25.6
Crossbred cow	5475	39	5.9	795.8	7930	-356.8
Other animals	2190	35	5.3	354.7		

3) Feed additive Ionophore monensin.

The third option which we consider is the addition of feed additive monensin sodium salt.

Assumptions:

a) Methane reduction potential for animals on maintenance ration: 20%

Medium production ration: 30%

High production ration: 22%

b) Indigenous animals are assumed to be on maintenance ration, buffaloes on medium production ration and crossbred animals on high production ration.

c) 100mg of monensin is fed to each animal daily.

d) The increase in milk yield is 5%.

e) The available information on price of monensin shows a extremely high range:

1) The cost of pure monensin sodium salt in India is Rs.10000 for 5gm, i.e. € 36,000/kg monensin.

2) The monensin premix is manufactured by Elanco Animal Health, USA under the brand name Rumensin, which contains 200g monensin sodium salt per kilogram of Rumensin. The price of this product in Germany is €7.40/kg. The reasons for this huge gap in the prices of pure monensin sodium salt and monensin premix is not known. Monensin premix has never been imported by India. The cost estimates using both these prices are shown in Table 17. The cost estimates as per the cost of Rumensin show an annual expenditure of only Rs.15 per animal and substantial net returns. The gross cost of methane abatement is only €0.55-1.82/t CO_2 equivalent and the net cost is negative. But with the pure chemical even if the dose is reduced to half the abatement cost is phenomenally high.

Table 17: Cost of Ionophore Feed additive

Type of animals	Annual cost of ionophore	Annual Methane Emission (kg/head/year)	Annual Reduction	Gross Cost of reduction €/t CO_2	Value of increased milk production (Rs.)	Net cost of reduction €/t CO_2
Monensin premix (Rumensin)						
Local cow	15	36	7.2	1.77	389	-44.15
Buffalo	15	77	23.1	0.55	4032	-147.87
Crossbred cow	15	39	8.6	1.48	7930	-784.44
Other animals	15	35	7.0	1.82		
Pure Monensin sodium salt						
Local cow	36500	36	7.2	4310.75	389	4264.83
Buffalo	36500	77	23.1	1343.61	4032	1195.19
Crossbred cow	36500	39	8.6	3617.41	7930	2831.49
Other animals	36500	35	7.0	4433.92		

4) Propionate precursors and Probiotics:

The cost of these options were estimated as follows in Europe (DGXI, 1998):

Mitigation Measure	€/t CO_2 equivalent
Propionate Precursors:	
Dairy cows	130
Non-dairy cattle	270
Probiotics:	
Dairy cows	259
Non-dairy cattle	540

However, these two technologies of propionate precursors and probiotics have not been tested in the field conditions in India so working out the cost of these options will be somewhat conjectural. Albeit, in any case, their cost is unlikely to be lower in India as the methane reduction per animal would be lower in India than the EU due to lower emission rate of animals.

From the cost estimates of various options the following important conclusions can be drawn:

1) Of all the technological options considered, the use of ionophore additives is the most cost-effective technology provided monensin premix is used and it is as effective as the pure monensin sodium salt in methane abatement.
2) The cost of MUB, the second less expensive option in India is also lower than the methane abatement cost from enteric emissions using similar technology in other developing country Bangladesh.
3) The abatement cost per ton of CO_2 equivalent methane using Monensin premix and MUB technology in India is lower than the similar abatement cost using Propionate precursor and probiotics in EU.

4.2 "Additionality" of the Mitigation options:

The Government of India in its interim approval criteria for CDM projects lists three additionality criterion: viz., emission additionality, financial additionality and technological additionality. The mitigation options discussed above clearly fulfill these three conditions but if the additional condition of "investment additionality " is taken into account then the options become non-additional in instances where the net cost of methane reduction is negative, as a positive net returns (or negative net costs) imply that the project is commercially viable without the CDM route. However, this argument should not hinder the prospects of CDM projects in dairy sector as there are several barriers to application of these options at the field level, as discussed hereinafter, because of which they are not commercially attractive. Hence without the financial and technical inflows via CDM projects it is absolutely unlikely that such mitigation strategies will ever be implemented in the Indian conditions in the medium term.

4.3 Key constraints and possible responses for potential CDM projects

There are a number of constraints in implementing the enteric methane mitigation strategies at the field level. These barriers which include, technical, financial, informational, policy and institutional issues are discussed as under along with possible responses to these constraints.

Technical issues

Access to farmers for implementation and monitoring: The livestock holdings are widely scattered in India with the average herd size of 2-3 adult animals on marginal and small holdings (less than 2 hectare) and 4-5 adult animals on medium and large holdings (above 2 hectares). The commercial farms owning large herds of 50 animals or more are relatively very few in number and are either concentrated in peri-urban areas of larger cities or are location specific in some states like Punjab, Haryana, Rajasthan etc.

Therefore, to access the small-scale farms for implementation of the mitigation option and their subsequent monitoring for estimation of the CER generated under a CDM project is a difficult task. This requires a good extension network and close contact with producers. The country has a extensive network of extension services for transfer of technologies in the agriculture and allied sectors. Although the efficacy of this network has often been subject to criticism yet, in the animal husbandry and dairying there are several examples of effective extension services in their outreach to the farmers. For example, the milk producer co-operatives in Gujarat and the multinational dairy product companies like Nestle, Smithcline Beecham etc. have developed close contacts with the farmers in their milk shed areas by providing them useful livestock extension services on a continuous basis. Also, the non-government organizations like Self-Employed

Women's Association (SEWA) have access to women's groups involved in dairy production and Bhartiya Agro Industrial Foundation (BAIF) also have strong liaison with the farmers because of their research and development programmes in the livestock sector. The National Dairy Research Institute, with its headquarters in Karnal in Northern India, has been the hub of extension service activities among the livestock farmers through its Operation Research Programme (ORP), Institution Village Linkage programme (IVLP), Krishi Vigyan Kendra (KVK) etc. The cost of extension services per CDM project will vary according to the type of extension agency involved and the project size.

A possible response to the problem of access to the fragmented livestock holdings is to initially take up mitigation projects in the areas where these organizations are effective. Since they have been working closely with the livestock farmers they can be powerful partners in the implementation of abatement strategies and also their subsequent monitoring which is a critical component of CDM project. The claimed success of India Dairy Project and its proposed replication in not only other parts of the country but also other developing countries like Bangladesh, Uganda, Tanzania and Zimbawe by Global Livestock Group Inc. (parent company EnterpriseWorks) should show the way to get over the barrier of access to farmers in India.

Also, the strengthening of extension services in animal husbandry and dairying has received special attention in the Tenth Plan. The Plan proposes to treat livestock extension separately from crop-related extension and it would be driven by technology transfer. As women play an important role in animal husbandry activities, deployment of women extension workers is also proposed to be encouraged so that they can work as links between farmers, the animal husbandry department and workers of NGOs.

Inadequate field testing of technologies: The response of mitigation strategies may vary across regions due to location specific factors like animal and feed characteristics. Inadequate field testing of the technologies can cause substantial difference in ex-ante assessment of CER generation and actual CERs generated after the application of the same.

To overcome this problem it is imperative to ensure field testing and proper use of the technology. This may increase the transactions cost of the project as the R&D phase will precede the implementation phase of the project but nevertheless, it is crucial for the success of the project. The field testing of the mitigation options will not only decide the emission reduction potential of the technology in a particular region it will also ensure proper use of the technology for its acceptance by the farmer. For instance, in Gujarat, the molasses urea blocks developed by hot process did not gain wide acceptance by farmers because the block was difficult to use, attracted many flies, and could cause sickness and even death from urea toxicity in animals that bit off chunks of it. The blocks developed by the cold-process were an improvement over the earlier ones but had several other problems. The cold-process hemispherical blocks were served in a cylindrical metal bowl and helped prevent overeating but it did not make the product any easier to use. The farmers used to break up the blocks into half-kilogram portions, crumbling the solid blocks into a mash and mixing it with the animal's normal dry-fodder rations. By observing farmer behaviour, the R&D team of Appropriate Technologies India developed the granular, or mash, form of the MUP which had high farmer acceptance (Bundick *et al.* , 2000).

Financial issues

Lack of capital with farmers: The feed cost comprises of about 60% of the cost of milk production. But the farmer incurs out of pocket expenses largely for the purchase of concentrates only, as dry fodder comes from home grown crop by-residues. Green fodder is also cultivated by the farmer or animals graze on land for which no license fee is paid in most instances. For the concentrate mixture the farmers generally use the customary preparations made by them rather than the purchased compound livestock feed. Several ingredients in these customary preparations also do not require any cash outflow since at times they are available on the farm households as the semi-processed agricultural produce from farmer's field. Therefore even if a particular feed type increases the net returns of the farmers after a period of time, he is not in a financial position to buy it in the first instance, or substitute it with those feeds for which he is not incurring any out of pocket expense.

The credit availability through micro-finance institutions and Self –Help Groups for the purchase of improved feed would be instrumental in overcoming this critical barrier. In addition, what is required is effective marketing, the use of incentives and promotional campaigns. For the milk co-operative society members the purchase of the feed can be linked into the cooperative milk-collection and payment system.

Direct economic incentives lacking for non-dairy animals: The farmer guided by the profit motive can incur higher gross cost for the dairy animals but for the non-dairy animals, particularly the males since benefits of feeding ration which reduce methane emissions will be less obvious to farmers, the adoption of the technology will be hampered. But that of course does not imply that sufficient CER cannot be generated from a dairy project and hence CDM route should not be used, as the female population (i.e. dairy animals) are themselves in sizeable numbers which can be targeted. In addition, there are possible ways to get over this barrier as discussed below.

Use of locally available feeds and fodder in the production of methane mitigating rations should be promoted, such that farmer finds a market for his home grown produce and can use the improved rations in lieu of home grown feed stuffs. Technological innovations to make the benefits (other than methane reduction) more obvious in non-dairy animals. Create awareness of farmers about the climate change, its impact on their production systems and their responsibility to prevent the same.

Socio-cultural issues

Cultural taboos on rearing animals for meat: The benefits of feeding ionophores to non-dairy animals can be substantial if these animals are reared for meat purposes. But due to cultural considerations they are seldom raised for this purpose at the farm house-holds.

Response: The animals for meat purpose can be raised commercially provided the government policy in this regard solely guided by "religious considerations" does not prove any hindrance to it. It should be explicitly recognized by the policy makers, that in the scenario of rapidly declining demand for male animals for draft purposes in several parts of the country due to mechanization, there is an urgent need to find an economic way for the disposal of the male calves. Raising them commercially for meat purposes is a far better option from both, the economic and environmental perspective, as the farmer can then fetch a good price for them.

Poor extension outreach to women: The women are carrying out most of the work related to livestock activities. However, due to socio-cultural reasons, the extension programs may facilitate communication with men, but overlook women's dominant role in livestock management which would be detrimental to the implementation of the mitigation options.

Response: The sex ratio of extension agents should be balanced so that rural women can be an integral part of the implementation process.

Institutional issues

No Capacity Building in the Agriculture sector: CDM is a complex undertaking that currently is only understood by a very limited number of individuals from research and consultancy companies, mainly from industrialized countries. The expansion of the pool of individuals understanding CDM is key to a successful implementation of CDM projects. Hence, capacity building is a pre-requisite to a successful formulation of the CDM project. The CDM capacity building efforts in India started in 1999, but the intensified efforts in this direction took off only from 2003. A national Strategy Study (NSS) on Clean Development Mechanism has been initiated in India to assess the issues and opportunities presented by potential international markets of GHG credits through the CDM and to evaluate processes and methodologies to facilitate implementation of CDM in India. However, the agriculture sector- of which dairy is a part- has totally been left out of these capacity building efforts.

The scope of NSS should be widened to include the dairy sector within its fold since this a potential area where there exist opportunities for prospective CDM projects.

Thus, we see that there is a host of barriers which need to be overcome for attracting projects under CDM in the dairy sector.

5. Research and Policy Imperatives

We see four critical research/policy issues emerging in the area of CDM in the dairy sector in India:

- ***Assessment of baseline using disaggregated level data***

  An appropriate baseline being the first step in design and formulation of CDM project, research needs to be carried to work out the total enteric emissions at the district level and the regional emission factors for the purpose of identifying the 'hot spots' for CDM projects in the dairy sector.

- ***Assessment of cost-effective regional animal nutrition strategies for methane reduction***

  The pilot testing of the alternate mitigation options in various regions id another important area of research which is imperative to identify cost efficient region specific animal nutrition strategy for methane reduction. Such a research activity is a critical step in arriving at the realistic estimates of CERs from a potential CDM project.

- ***Assessment of transactions cost for potential CDM project***

  Transaction costs consist of pre-operational costs and implementation costs (i.e. costs spread out over the entire crediting period). Pre-operational costs include direct expenses for search, negotiation, validation, and approval. Implementation costs are incurred for monitoring, certification and enforcement. An assessment of transactions cost of CDM project in the dairy sector in India along with two research imperatives outlined above would ascertain the quantity and price of CERs generated by a CDM project in dairy sector.

- ***Initiation of Capacity Building Efforts in the Indian Livestock Sector***

  Addressing the research issues can not be transformed into a CDM project in practice unless complemented by CDM capacity building in the livestock sector. The dairy sector has the potential to attract projects under CDM. As has been mentioned earlier that even a 10% reduction in enteric methane emissions in India are equal to 19 to 25 million tons of CO2 credits annually. However, given the vast size of the country, a single project cannot cover the entire ruminant population to achieve these reductions. Nevertheless, even small scale CDM projects in the sector – covering a group of agro-climatically analogous districts[13], have the potential to generate reasonable CERs to make the project viable. For instance, in Haryana, a state in Northern India known for dairying, six districts in the irrigated eastern zone of the state having similar livestock and feed characteristics, have the total adult cattle and buffalo population of 1.3 million. The methane reduction potential even with the modest coverage of 10 to 25 percent of the adult animal population in this area ranges from 45.1 to 112.6 million kg of CO_2 equivalent annually.

Thus, given the potential of CDM in the Indian dairy sector, concerted research and policy efforts are required to transform this potential into the actual CDM projects in the dairy sector.

[13] agro-climatically analogous districts would have broadly similar livestock and feed characteristic

Appendix A

Data for Estimating Enteric Fermentation Emission Factors for Indian Subcontinent

Animal type	Weight (kg)	Weight Gain (kg/day)	Feeding situation	Milk (kg/day)	Work (hrs/day)	% Pregnant	Digestibility of feed (%)	CH4 Conversion (%)
Dairy Cattle	275	0	Stall-fed	2.5	0	50	55	6
Non-dairy cattle								
Mature Females	125	0	Stall-fed	0.6	0	33	50	7.5
Mature males	200	0	Stall-fed	0.0	2.74	0	50	7.5
Young	80	0.1	Stall-fed	0.0	0.0	0	50	6.0
Buffalo								
Adult males	350-550	0.0	Stall-fed	0.0	1.37	0	55	7.5
Adult Females	250-450	0.0	Stall-fed	2.70	0.55	33	55	7.5
Young	100-300	0.15	Stall-fed	0.0	0.0	0	55	7.5

Source: **IPCC, 1996**

APPENDIX B
UPDATED TIER 2 METHODOLOGY FOR ESTIMATING ENTERIC EMISSIONS

IPCC recommends using the net energy system from the NRC (1984, 1989, and 1996) to estimate feed energy intakes for cattle. The following information is required to estimate feed energy intakes:

Maintenance: Maintenance is the feed energy required to keep the animal in equilibrium, i.e., there is no gain or loss of energy in the body tissues (Jurgens, 1988). For cattle, net energy for maintenance (NE_m) has been estimated to be a function of the weight of the animal raised to the 0.75 power (NRC, 1984):

EQUATION 1

$$NE_m \text{ (MJ/day)} = 0.322 \bullet (\text{weight in kg})^{0.75}$$

NRC (1989) recommends that lactating dairy cows be allowed a slightly higher maintenance allowance:

$$NEm \text{ (MJ/day)} = 0.335 \bullet (\text{weight in kg})^{0.75}$$

Feeding: Additional energy is required for animals to obtain their food. Grazing animals require more energy for this activity than do stall-fed animals. The following energy requirements are added for this activity based on

EQUATION 2[14]

$$NE_{activity} = C_{activity} \bullet NE_m$$

Where $C_{activity}$ is a coefficient with a value of 0 percent for confined animals in pens and stalls (no additional NE_m is expended), 17 percent for animals grazing on good quality pasture, and 37 percent for animals grazing over very large areas.

Growth: The energy requirements for growth can be estimated as a function of the weight of the animal and the rate of weight gain. The method used to estimate the energy requirements for growth relies on shrunk body weight data. Shrunk body weight is the weight of the animal after a one-night-fast, and is 96 percent of live weight (NRC, 1996). If data on shrunk body weight are not available, use live weight data and multiply it by 0.96 to convert it to shrunk body weight.

Based on the NRC (1996) formula for steer growth, the following equation is recommended:

[14] Previously called NE_{feed}, the name was changed to $NE_{activity}$ per discussion at the IPCC meeting in February 1999

EQUATION 3[15]

$$NE_g \text{ (MJ/day)} = 4.18 \bullet \{(0.0635 \bullet 478/(C \bullet FSBW))^{0.75} \bullet (0.96 \bullet SWG)^{1.097}\}$$

Where:

C: a coefficient with a value of 1 for steers and replacement heifers, 0.8 for feedlot heifers, and 1.2 for bulls (NRC, 1996).

FSBW: the observed final shrunk body weight (mature weight in kg) at average body condition (e.g., a body condition score of 5 on a scale of 1 to 10). FSBW is an observed value, and varies by breed, sex, and country. Because the FSBW varies by country, each country is responsible for estimating the average FSBW at average body condition for each breed by sex. Although data on FSBW are generally not published, estimates of FSBW for each breed by sex are generally available from livestock specialists and farmers. Table 8 provides examples of mature weights for females illustrated by those used as standard reference weights in Australia (Subcommittee on Agriculture (SCA), 1990). Additional examples of mature weights are available in Jenkins and Ferrell (1997).

SWG: the observed shrunk weight gain (kg/day).

TABLE 8

EXAMPLES OF MATURE WEIGHTS AT 25 PERCENT BODY FAT FOR AUSTRALIAN FEMALE CATTLE

Cattle Breeds	Females
Chianina	700
Charolais, Maine Anjou, Simmental	650
Angus, Blonde d'Aquitane, Brahman, Brahman x Hereford, Hereford, Murray Grey, Limousin, Lincoln Red, Friesian, South Devon	550
Beef Shorthorn, Dairy Shorthorn, Devon (Red), Galloway, Red Poll	500
Ayrshire, Guernsey, AMZ, Sahiwal	450
Jersey	400
Source: SCA (1990).	

Weight Loss: When an animal loses weight, a portion of the energy in the lost weight is mobilized and used by the animal for maintenance.

For lactating dairy cows, approximately 19.7 MJ of NE is mobilized per kilogram of weight loss. Therefore, the energy mobilized is calculated as follows (NRC, 1989):

EQUATION 4

$$NE_{\text{mobilized Lactating Dairy Cows}} \text{ (MJ/day)} = 19.7 \text{ MJ/kg} \bullet \text{(weight lost in kg/day)}$$

[15] The equation for NE_g is an updated equation that includes a mature weight scaling factor.

For other cattle, the amount of energy mobilized through weight loss is calculated by inserting the amount of weight lost (kg/day) as a positive number into Equation 3 as SWG, and calculating NE_g. The mobilized energy is then 80 percent of this value with a negative sign (NRC, 1996):

EQUATION 5

$$NE_{mobilized} = NE_g \bullet -0.8$$

Lactation: Net energy for lactation is expressed as a function of the amount of milk produced and its fat content (NRC, 1989):

EQUATION 6

$$NE_l \text{ (MJ/day)} = \text{kg of milk/day} \bullet (1.47 + 0.40 \bullet \text{Fat \%})$$

At 4.0 percent fat, the NE_l in MJ/day is about 3.1 · kg of milk per day.

Draft Power: Various authors have summarized the energy intake requirements for providing draft power (e.g., Lawrence, 1985; Bamualim and Kartiarso, 1985; and Ibrahim, 1985). The strenuousness of the work performed by the animal influences the energy requirements, and consequently a wide range of energy requirements have been estimated. The values by Bamualim and Kartiarso show that about 10 percent of NE_m requirements are required per hour or typical work for draft animals. This value is used as follows:

EQUATION 7

$$NE_w \text{ (MJ/day)} = 0.10 \bullet NE_m \bullet \text{hours of work per day}$$

Pregnancy: Daily energy requirements for pregnancy are presented in NRC (1996). Integrating these requirements over a 283-day gestation period yields the following approximate equation:

EQUATION 8

$$NE_{required} \text{ (MJ/283-day period)} = 35\text{MJ/kg} \bullet \text{calf birth weight (kg)}$$

Using the approximate calf birth weight as a function of the cow's weight, the NE required for pregnancy is estimated to be about 10 percent of the cow's annual NE_m requirement.

EQUATION 9

$$\text{Calf birth weight (kg)} = 0.266 \bullet (\text{cow weight in kg})^{0.79}$$

Therefore, a factor of 10 percent of NE_m is added to account for the energy required for pregnancy for the portion of cows giving birth each year, as shown in the following equation.

EQUATION 10

$$NE_p \text{ (MJ/day)} = 0.10 \bullet NE_m \text{ (MJ/day)}$$

Based on these equations, each of the net energy components for each of the cattle categories can be estimated from the activity data collected on weight in kilograms; feeding situation; weight gain (or loss) per day in kilograms; milk production in kilograms of 4 percent fat-corrected milk; number of hours of work performed per day; and portion that give birth.

These net energy requirements must be translated into gross energy intakes. Also, by estimating the gross energy intake, the net energy estimates can be checked for reasonableness against expected ranges of feed intake as a percentage of animal weight. To estimate gross energy intake, the relationship between the net energy values and gross energy values of different feeds must be considered. This relationship can be summarized briefly as follows:

- Digestible Energy = Gross Energy – Faecal Losses.
- Metabolisable Energy = Digestible Energy – Urinary and Combustible Gas Losses.
- Net Energy = Metabolisable Energy – Heat Increment.
- Net Energy = Gross Energy – Faecal Losses – Urinary and Combustible Gas Losses – Heat Increment.

The quantitative relationship among these energy values varies among feed types. Additionally, the values depend on how the feeds are prepared and fed, and the level at which they are fed. For the purposes of this method, simplifying assumptions are used to derive a relationship between net energy and digestible energy that is reasonably representative for the range of diets typically fed to cattle. Gross energy intake is then estimated using this relationship and the digestibility data collected. Given the digestibility of the feed, a general relationship between digestible energy and metabolisable energy can be used as follows (NRC, 1984):

Given the digestibility of the feed, a general relationship between digestible energy and metabolisable energy can be used as follows (NRC, 1984):

EQUATION 11

Metabolisable Energy (ME) = 0.82 ● Digestible Energy (DE)

Equation 11 is a simplified relationship; larger (smaller) methane conversion rates would tend to reduce (increase) the coefficient to values below (above) 0.82.

NRC (1984) presents separate quantitative relationships between metabolisable energy and net energy used for growth versus net energy used for other functions. Using Equation 11, the NRC relationships can be re-arranged to quantify the ratio of NE to DE, as follows:

EQUATION 12

$$NE/DE = 1.123 - (4.092 \bullet 10^{-3} \bullet DE\%) + (1.126 \bullet 10^{-5} \bullet (DE\%)^2) - 25.4/DE\%$$

EQUATION 13

$$NEg/DE = 1.164 - (5.160 \bullet 10^{-3} \bullet DE\%) + (1.308 \bullet 10^{-5} \bullet (DE\%)^2) - 37.4/DE\%$$

Where:

NE/DE: the ratio of net energy consumed for maintenance, lactation, work, and pregnancy to digestible energy consumed;

NE_g/DE: the ratio of net energy consumed for growth to digestible energy consumed; and

DE%: digestible energy as percentage of gross energy, expressed in percent (e.g., 65%).

Given the estimates for feed digestibility and equations 12 and 13, the gross energy intake (GE in MJ/day) can be estimated as follows:

EQUATION 14

$$GE = \{[(NE_m + NE_{mobilized} + NE_{activity} + NE_l + NE_w + NE_p)/ (NE/DE)] + NE_g/(NE_g/DE)\} / (DE\%/100)$$

The proper interpretation of this equation used to estimate Gross Energy Intake (GE) in megajoules per day (MJ/day) is as follows:

- $(NE_m + NE_{mobilized} + NE_{activity} + NE_l + NE_w + NE_p)$ is the total net energy intake required for maintenance, feeding, lactation, work, and pregnancy.
- (NE/DE) is a function that relates NE intake for maintenance, feeding, lactation, work, and pregnancy to digestible energy intake. The total NE intake for these metabolic processes divided by this {NE/DE} function produces an estimate of digestible energy intake.
- NE_g is the net energy intake required for growth.
- $\{NE_g/DE\}$ is a function that relates NE intake for growth to digestible energy intake. The NE intake for growth divided by this $\{NE_g/DE\}$ function produces an estimate of digestible energy intake.

The sum of the two numerator terms produces an estimate of total digestible energy intake. DE% is the digestibility of the feed in percent (e.g., 65%). Dividing the total digestible energy intake by DE%/100 produces an estimate of the total gross energy intake.

To check the estimate of daily gross energy intake from Equation 14, the estimate can be converted in daily intake in kilograms by dividing by 18.45 MJ/kg. This estimate of intake in kilograms should generally be between 1.5 percent and 3.0 percent of the animal's weight.

To estimate the emission factor for each cattle type, the feed intake is multiplied by the methane conversion rate.

EQUATION 15

$$\text{Emissions (kg/yr)} = [\text{Intake (MJ/day)} \bullet Y_m \bullet \text{(365 days/yr)}] / [\text{55.65 MJ/kg of methane}]$$

Source : IPCC Good practice guidance and uncertainty management in national greenhouse gas inventories - 2001

Appendix C

Upcoming techniques for methane reduction from enteric fermentation

Several techniques are in research stage such as: hexose partitioning; an immunogenic approach, genetic engineering and bacteriocins.

Hexose partitioning**:** In hexose partitioning, by varying diet, it may be possible to manipulate the amount of the feed carbohydrate going directly into microbial growth as opposed to fermentation. Theoretical studies have shown that increasing the quantity of microbial cells leaving the rumen per unit of carbohydrate consumed may have a large effect on the overall methane production (Beever, 1993). Using this theoretical basis, it has been shown that for an average dairy cow the annual methane production could be reduced by 36% (DGXI 1998). However, the technology is still under experimentation to investigate, *in vitr*o carbohydrate sources that provide improved hexose partitioning so that this information can be used to design diets with enhance hexose partitioning.

The cost of implementing the option is likely to be minimal as the overall effect would be increased productivity which would offset any additional feed costs associated with the option but at present no reliable cost or performance data are available**.**

Immunogenic approach**:** A team of researchers at Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia have made an application for a world wide patent under the following title: *Immunogenic preparation and method for improving the productivity of ruminant animals.* The patent describes a method of improving the productivity of a ruminant animal by administering to the animal an immunogenic preparation effective to invoke an immune response to at least one rumen protozoan. The removal of one species of protozoan from the rumen will invoke the improvements in productivity associated with defaunation (improved protein:energy ratio of the nutrients available for absorption). It is also believed that by modifying the activity of the rumen protozoan, there will be an indirect effect on the activity of methanogens, due to their commensal relationship with rumen protozoa. Therefore, by reducing the protozoal population, there may be a corresponding effect on the production of methane. The patent also proposes that a vaccine could be prepared directly incorporating antigens from one or more species of methanogenic bacteria as well as the protozoa. This would further reduce the production of methane by animals.

Data from this work are not yet published but it is anticipated that methane production could be reduced by as much as 70%. The long term prospects of this approach are not yet available but areas to be considered are the longevity of the immunisation and whether other species of protozoa and methanogens will increase their populations to compensate for those species where immunisation has taken place.

If this option develops successfully, it could be applied to the whole ruminant population. The costs associated with the approach could be high initially due to the monopoly associated with patents. The increased protein utilisation associated with defaunation would mean reduced emissions of ammonia and increased animal productivity.

Genetic engineering: Suggestions have also been made about the potential use of genetic engineering viz. recombinant deoxyribonucleic acid (DNA) technology to modify the fermentation characteristics of rumen micro-organisms (Armstrong and Gilbert, 1985). Progress in this direction has been made in the study of rumen methanogens (Weil et al 1989). Application of further biotechnology techniques would enable the quantification and identification of the methanogenic species present. Once developed, these could be further used to regulate the expression of specific genes in these methanogens which may provide additional means of altering ruminal methane production.

However, increased opposition to the release of genetically engineered organisms into the environment from several quarters, the field application of this technology may not be acceptable to most countries.

Bacteriocins: Bacteriocins are antibiotics, generally protein or peptide in nature, produced by bacteria. Callaway et al (1997) used the bacteriocinnisin which is produced by *Lactococcus lactis*, to produce a 36% reduction of methane production *in vitro*. Further research is on to evaluate the efficacy of bacteriocins.

Other techniques: Other techniques to inhibit methanogen growth and methane are the use of inhibitors, mevastatin and lovastatin (Miller and Wolin 2001). Also certain microbes in the rumen are known to promote reactions that minimise methane production and it may be possible to introduce such microbes directly as feed supplements. Such microbes include acetogens and methane oxidisers.

Acetogens are bacteria that produce acetic acid by the reduction of carbon dioxide with hydrogen, thus reducing the hydrogen available for reaction to produce methane (methanogenesis) (Demeyer and de Graeve, 1991). Although this reaction is theoretically possible in the rumen, populations of acetogens in the rumen of adult ruminants are low and a methane producing reaction tends to dominate.

Investigations are currently on to devise practical solutions for the survival of acetogenic bacteria in the rumen and hence the displacement of methanogenic bacteria. This would not only decrease methane production, but would also increase the efficiency of ruminant production. An alternative approach would be to screen a range of acetogenic bacteria for their activity in rumen fluid and to introduce the acetogens into the rumen as a feed supplement on a daily basis. If successful, this option has the potential to eliminate or reduce methane emissions from ruminants to a minimum. Emissions of ammonia may also be reduced as a result of more efficient carbohydrate fermentation which requires nitrogen. The option would again be applicable to all ruminants receiving supplements on a controlled and regular basis.

Methane oxidisers could also be introduced as direct-fed microbial preparations. The oxidation reaction would compete with the production of methane, which is a strictly anaerobic process. Methane oxidisers from gut and non-gut sources could be screened for their activity in rumen fluid *in vitro* and then selected methane oxidisers could be introduced into the rumen on a daily basis in a manner analogous with current feed supplements. If successful, this option has the potential to reduce methane production in the rumen by a minimum of 8% (ADAS, 1998).

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