

**COWS AND CLIMATE CHANGE:  
CATTLE CH<sub>4</sub> EMISSIONS MITIGATION IN THE  
UNITED STATES.**

by  
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## ABSTRACT

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As the world turns to watch the events at the Third Conference of the Parties of the United Nations Framework Convention on Climate Change in December 1997, climate change is raising awareness also in the United States, the single largest emitter of greenhouse gases. The U.S. will be responsible for implementing mitigation strategies as a result of anticipated binding emissions reductions aimed at eventually meeting 1990 emissions levels. Carbon dioxide (CO<sub>2</sub>) has the greatest impact on global warming of the greenhouse gases, but one methane (CH<sub>4</sub>) molecule can absorb 21-25 times the radiative energy of one molecule of CO<sub>2</sub>. For this reason, a small reduction in CH<sub>4</sub> emissions could have the same effect as a large reduction in CO<sub>2</sub>. CH<sub>4</sub> emissions from cattle in the form of enteric fermentation and anaerobic decomposition of manure are responsible for 21 percent of anthropogenic CH<sub>4</sub> emissions in the U.S., and therefore form a substantial source of greenhouse gas emissions. This study examines the reduction potential of mitigation strategies for cattle CH<sub>4</sub> emissions in the U.S., and what impact this could have on domestic mitigation of greenhouse gases. The U. S. Environmental Protection Agency (EPA) has proposed technical, economic, and regulatory strategies that are expected to result in CH<sub>4</sub> emissions reductions. However, after close analysis of the options suggested, it does not appear as though the U.S. has the potential to reduce CH<sub>4</sub> emissions from cattle unless there is a substantial reduction in the size of the national cattle population. In addition, some reduction potentials have not been explained. An exploration of new options shows that while reduction of emissions may be possible with the implementation of strategies to change human demand for beef, in fact the only true reduction possibilities lie in recovering CH<sub>4</sub> from covered manure storage lagoons, or culling cattle herds. Although reducing CH<sub>4</sub> emissions from cattle should not be relied on as a significant option for greenhouse gas reduction in the U.S., looking internationally for opportunities for CH<sub>4</sub> reduction cannot be discounted. Finally, in depth studies such as this one should be done for all greenhouse gas sources and reduction strategies to identify the best areas for mitigating climate change.



## PREFACE

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*This section clarifies how I was introduced to studying CH<sub>4</sub> and cattle, as well as explaining the context in which I would like my thesis to be read and to whom it is addressed.*

In the fall of 1995, I witnessed the environmental and cultural effects of a national dependency on an animal. The nation was Botswana and the animal was the cow. A drought was plaguing Botswana during the time I was there, and a common sight was the burning of the numerous cow carcasses littering the countryside. The animals had died from lack of feed and water, because there were no resources available for them. The environmentalists secretly cheered for the disappearance of the animals, which had caused the direct and indirect loss of most of Botswana's wildlife.<sup>1</sup> However, the wet season of 1996 finally brought rains, and the cattle population expanded. The Government of Botswana was surely glad that their economy, heavily dependent on cattle, was once again healthy. Similarly, the cattle farmers were glad to see their incomes grow. The conservationists sulked.

Cattle are not only significant to Botswana but also to a multitude of countries in the rest of the world, whether they are poor or wealthy. Cattle have a worldwide impact on economies, diets and environments that cannot be compared with any other species. It is for this reason that I chose to study an aspect of the impact of cattle on the environment for my thesis. Recognizing the international dependency on cattle is fundamental, as no policies can be properly drawn up without such an understanding.

Superficial research of climate change issues showed cattle to have significance even in this arena. By examining the evidence more carefully, I came to realize that cattle could be great sources of CH<sub>4</sub> – a significant greenhouse gas that contributes to the effect of global climate change. I wanted to combine this fact and my familiarity with the other issues surrounding cattle. With the upcoming United Nations Climate Change conference in Japan in December 1997, climate change appeared as a *hot topic* in newspapers on a daily basis. Cattle and climate change together led to a study of CH<sub>4</sub> emissions from cattle in the U.S. and the possibility to reduce ruminant emissions.

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<sup>1</sup> Personal communication with conservationists, Maun, Botswana, fall 1995.

## Introduction

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*This section briefly introduces the current atmosphere surrounding greenhouse gas issues in the United States. The connection between cattle and CH<sub>4</sub> will be discussed, as will a brief background on climate change.*

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This study asks what impact cattle CH<sub>4</sub> emission mitigation could have on the reduction of greenhouse gases in the United States. Looking at the reductions strategies for CH<sub>4</sub> emissions is a large topic, and a broad comparison between different CH<sub>4</sub> sources would lead to vague and generalized information that would serve little purpose. Because each country and each economic sector has such disparate characteristics for greenhouse gas emissions, it is important to look at specific case studies. I have chosen to limit my analysis to examining CH<sub>4</sub> emissions from cattle in the U.S., and the feasibility of various CH<sub>4</sub> reduction strategies.

### 1.1. THE FRAMEWORK CONVENTION ON CLIMATE CHANGE AND THE UNITED STATES

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On Earth Day 1993, President Clinton announced the United States' commitment to reducing the emissions of greenhouse gases to 1990 levels by the year 2000.<sup>2</sup> This goal was initiated by the United Nations "Earth Summit" conference in 1992, at which time the other participating countries also agreed to the goal. Out of these discussions was born the United Nations Framework Convention on Climate Change (FCCC),<sup>3</sup> which holds its third Conference of the Parties (COP-3) in Kyoto, Japan in December 1997. However, progress for this meeting appears slow. In 1997, the total global greenhouse gas<sup>4</sup> emissions are far from returning to the emissions levels of seven years ago. This was officially documented for the U.S.

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<sup>2</sup> United Nations Framework Convention on Climate Change, *Executive Summary of the National Communication of the U.S.A.* UNFCCC, 25 July 1995.

<sup>3</sup> The UNFCCC is the "first binding international legal instrument that deals directly with climate change," according to the Information Unit on Climate Change (IUCC), United Nations Environment Programme, *Climate Change Information Kit*, January 1997.

<sup>4</sup> The *greenhouse effect* is actually the meteorological description of the process in which heat is trapped in the atmosphere during the day, similarly to the way that a greenhouse that stays warm by trapping heat. Sunlight enters a greenhouse easily but cannot radiate out through the glass and hence is "trapped." Many of the gases called "greenhouse gases" occur naturally in the atmosphere, and are necessary to keep the Earth warm. When the term is used in conjunction with the idea of global climate change, however, it indicates that excess amounts of the gases are being added to the atmosphere on a daily basis through anthropogenic activities. An increase in the concentrations of greenhouse gases is expected to exacerbate the *greenhouse effect*.<sup>4</sup> The major greenhouse gases are water vapor (H<sub>2</sub>O), CO<sub>2</sub>, CH<sub>4</sub>, tropospheric ozone (O<sub>3</sub>), nitrous oxide (N<sub>2</sub>O), chlorofluorocarbons (CFC) and hydrogenated chlorofluorocarbons (HCFC).<sup>4</sup>

in the review of the U.S. *Climate Action Report*, required by the FCCC from each country that has ratified the Convention.<sup>5</sup> This formal report allows international experts to comment and evaluate the extent to which greenhouse gas reduction in these countries is being implemented.<sup>6</sup> The comments on the U.S.'s most recent report criticized the U.S. for not having demonstrated appropriate efforts to reduce domestic greenhouse gas emissions.<sup>7</sup> The "Earth Summit +5" meeting was held at the United Nations headquarters in New York in June 1997 in preparation for the FCCC/COP-3. The U.S. was again heavily criticized by international environmental advocates who felt that the Clinton Administration was "not taking a firm enough stance in negotiations...aimed at setting binding targets for reducing greenhouse gases."<sup>8</sup> The need for domestic action is particularly important, as the U.S. is currently the greatest single emitter of greenhouse gases at 18 percent<sup>9</sup> of the global total. A recent U.S. conference in October 1997, sponsored by the White House, emphasized the need for the U.S. to take action.<sup>10</sup>

The U.S. is now looking to establish its position on the issue of what mitigation strategies to adopt and advocate at the upcoming COP-3. The complexity of the situation is built on the dilemma clearly stated at the White House conference: the U.S. will only take action with a guarantee that the domestic economy will remain intact. In addition, recent reports indicate that the Clinton Administration is advising the postponement of the date at which emissions levels should be at 1990 levels from 2000 to 2015.<sup>11</sup> While several European nations have been capable of advancements according to the 1992 Convention, the U.S. has not shown any emissions reductions and, in fact, is 4 percent above 1990 levels.<sup>12</sup> Through the advancement of technology, there is potential to have a large mitigation impact. It is important, therefore, to look at which greenhouse gas sources and strategies would be most effective to target for reduction and/or implementation in order to make the decision to implement them.

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<sup>5</sup> The United States ratified the Framework Convention of Climate Change on October 15, 1992, according to "Status of Ratification of the Convention of Climate Change," UNFCCC website.

<sup>6</sup> Articles 4.2 and 12 of the Framework Convention on Climate Change.

<sup>7</sup> UNFCCC, "Report on the in-depth review of the national communication of the United States of America," Publication No. FCCC/IDR.1/USA, 26 February 1996, UNFCCC website.

<sup>8</sup> Cushman, Jr., John H. "Europe Leaders Fault US at UN Environment Talks." *New York Times*, June 24, 1997. A6.

<sup>9</sup> UNFCCC, Addendum Two, FCCC/CP/1996/12/Add.2. UNFCCC website.

<sup>10</sup> White House Global Warming Conference at Georgetown University, October 6, 1997.

<sup>11</sup> Cushman, "Top Aides Urge Clinton to Ease Global Warming Emission Goal," *New York Times*, October 10, 1997.

<sup>12</sup> UNFCCC, Addendum Two, FCCC/CP/1996/12/Add.2. UNFCCC website.

## 1.2. WHY CH<sub>4</sub>?

A 1989 U.S. Environmental Protection Agency (EPA) report claims that “a 50 percent reduction target for livestock-related emissions would provide on the order of half the reductions needed to stabilize [atmospheric CH<sub>4</sub>] concentrations.”<sup>13</sup> The same report, however, also claims that “addressing emissions from one or two sources will not be sufficient to stabilize the abundance of CH<sub>4</sub> in the atmosphere” and advocates reducing emissions from all sources.<sup>14</sup>

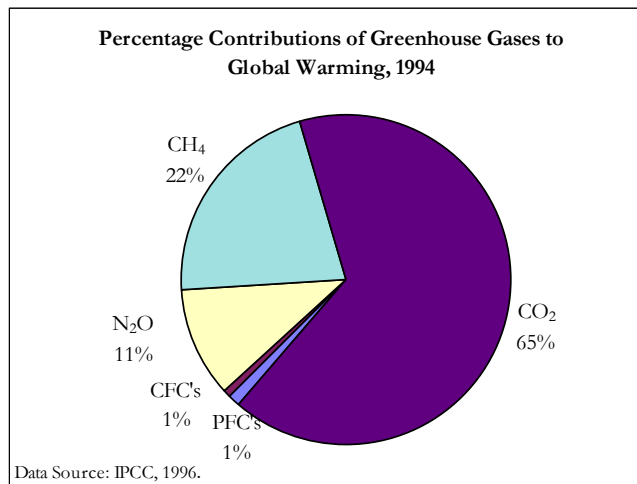
Further complicating the picture is the fact that the longer policymakers wait to make a move, the more severe that move will have to be. The EPA agrees that, due to CH<sub>4</sub>'s high potency and relatively short life in the atmosphere of 11 years, stabilization of CH<sub>4</sub> emissions will have rapid impact on mitigating potential climate change.<sup>15</sup> If it can be

affirmed that mitigation of cattle emissions has a significant impact on reducing atmospheric CH<sub>4</sub>, these actions will hopefully delay and/or reduce the effects of global climate change.

Currently, most research emphasizes the potential dangers of CO<sub>2</sub> (carbon dioxide) for climate change, since its emissions sources are numerous and well documented. In

fact, CH<sub>4</sub> is a more powerful and effective heat trapping gas. According to Table 1.1, CO<sub>2</sub> is in fact the least potent heat trapper among the greenhouse gases.<sup>16</sup> The Global Warming Potential (GWP) is an index to give a relative measure of the radiative effects of the various greenhouse gas emissions. According to the Intergovernmental Panel on Climate Change (IPCC), the index is defined as the “cumulative radiative

Figure 1. 1



<sup>13</sup> United States Environmental Protection Agency, *Reducing Methane Emissions from Livestock: Opportunities and Issues*, Office of Air and Radiation, EPA 400/1-89/002, August 1989. 14.

<sup>14</sup> EPA (1989) 1.

<sup>15</sup> United States Environmental Protection Agency, *Anthropogenic Methane Emissions in the United States: Estimates for 1990*, Report to Congress, Office of Air and Radiation (6202), EPA 430-R-93-003, April 1993. 1-2.

<sup>16</sup> National Academy of Sciences, *Policy Implications of Greenhouse Warming*, Committee on Science, Engineering

forcing between the present and some chosen time horizon caused by a unit mass of gas emitted now,

Global Warming Potential	
	<i>multiply by</i>
CO <sub>2</sub>	1
CH <sub>4</sub>	21
CFC-11 and -12	5400
N <sub>2</sub> O	290

Data Source: National Academy of Sciences, 1991.

expressed relative to that for some reference gas," which in most cases is CO<sub>2</sub>.<sup>17</sup> Table 1.1 shows a GWP for a 100-year time horizon. As knowledge of the current CH<sub>4</sub> budget is incomplete and uncertainties of future effects poorly known, understanding

the sources and effects of CH<sub>4</sub> becomes essential.<sup>18</sup>

CH<sub>4</sub> is a greenhouse gas because it is radiatively and chemically active and traps infrared radiation, raising the Earth's temperature. CH<sub>4</sub> is the second greatest contributor to global warming, as can be seen in Figure 1.2. CH<sub>4</sub> was estimated to contribute about 12 percent of the added warming from excess greenhouse gases in the 1980's,<sup>19</sup> and in 1994 was responsible for 22 percent.<sup>20</sup> Increased CH<sub>4</sub> abundance has also been found to cause a raise in tropospheric ozone (O<sub>3</sub>) and stratospheric water vapor (H<sub>2</sub>O) levels.<sup>21</sup> Atmospheric concentrations of CH<sub>4</sub> increased greatly over the period 1979-1991, as can be seen in Figure 1.1.<sup>22</sup> Overall, the past 20 years have shown a *decline in the rate* at which CH<sub>4</sub> is added to the atmosphere. In fact, the growth rate of atmospheric CH<sub>4</sub> concentrations was zero in the middle of 1992. Since 1993, however, the growth rate has returned to approximately 8 ppbv/yr,<sup>23</sup> and hence the cause for concern remains. The primary reason for a potential *increase* in the rate of CH<sub>4</sub> added to the atmosphere is

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and Public Policy, Washington, D.C., June 1991. 10.

<sup>17</sup> Intergovernmental Panel on Climate Change, *Climate Change 1995: The Science of Climate Change*, Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change, eds. J.J. Houghton, et al., Cambridge University Press, 1996. 21.

<sup>18</sup> Mitchell, John F.B. "The 'Greenhouse Effect' and Climate Change," *Reviews of Geophysics*, Vol. 27, No. 1, February 1989. 115-139.

<sup>19</sup> Houghton, J.T., et al. eds. *Climate Change*, Cambridge University Press, 1990, in Paul J. Crutzen, "Methane's sinks and sources," *Nature*, Vol. 350, 4 April 1991. 380-381.

<sup>20</sup> IPCC, *Climate Change 1995: The Science of Climate Change*. 434.

<sup>21</sup> EPA (April 1993) 1-2.

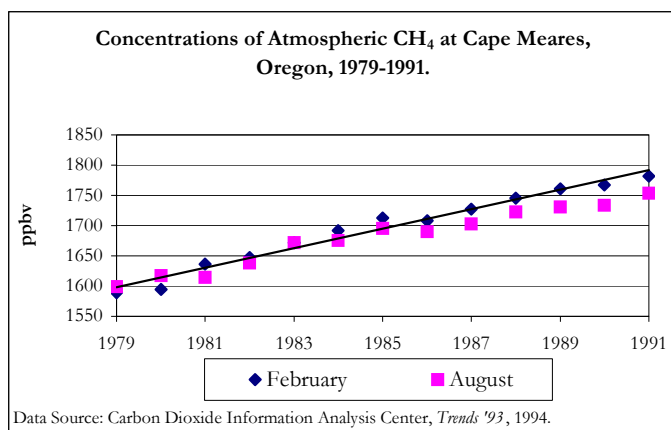
<sup>22</sup> Boden, Thomas A., ed., *Trends '93*, Carbon Dioxide Information Analysis Center, No. ORNL/CDIAC-65, Publication No. 4195, September 1994.

<sup>23</sup> Intergovernmental Panel on Climate Change, *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses*, Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change, eds. R.T. Watson et al., Cambridge University Press, 1996. 18.

Ppbv/yr = parts per billion per volume per year. Commentaries in *Science*, Vol. 252, p. 1496, describe the rate change to be from 18 ppbv/yr to 12-13 ppbv/yr.

the decrease in CH<sub>4</sub> sinks,<sup>24</sup> which react with CH<sub>4</sub> to form other compounds.<sup>25</sup> CH<sub>4</sub> sinks include the hydroxyl radical (OH), whose effect is to oxidize CH<sub>4</sub> in the troposphere and stratosphere,<sup>26</sup> an effect which has compelled Crutzen to call OH the *detergent of the atmosphere*, thereby lowering the concentration of CH<sub>4</sub>.<sup>27</sup>

Figure 1.2



The IPCC estimates that OH eliminates approximately 420-520 Tg of CH<sub>4</sub> a year. The total natural and anthropogenic amount emitted is 400-610 Tg/yr, and the net atmospheric increase is 28-37 Tg/yr.<sup>28</sup> Studies have shown that the rate of OH reaction with CH<sub>4</sub> is not as high as previously thought,<sup>29</sup> but this sink still contributes far more than the others, which are identified as soil uptake, at 30 TgCH<sub>4</sub>/yr, and transport into the stratosphere at 10 TgCH<sub>4</sub>/yr.<sup>30</sup> However, addition of CH<sub>4</sub> to the atmosphere reduces the concentration of OH, a reduction that will in turn reduce the rate of CH<sub>4</sub> removal because the reaction goes

<sup>24</sup> "Sinks" are chemical species that react with CH<sub>4</sub> to produce other gases, thereby eliminating the CH<sub>4</sub>.

<sup>25</sup>EPA (1989) 6.

<sup>26</sup>EPA (1989) 6.

<sup>27</sup>Crutzen, 1991.

<sup>28</sup>IPCC in United States Environmental Protection Agency, Opportunities to Reduce Anthropogenic Methane Emissions in the United States, Report to Congress, Office of Air and Radiation (6202), EPA 430-R-93-012, October 1993. 1-4.

**Tg: 1 Teragram = 10<sup>12</sup> grams = 10<sup>9</sup> kilograms = 10<sup>6</sup> metric tons.**

*Note that these numbers do not sum, as they are estimates of the possible ranges.*

<sup>29</sup> Vaghjiani, G.L. and A.R. Ravishankara, *Nature*, Vol. 350. 529-531.

<sup>30</sup> Johnson, Kristen et al., "Measurement of Methane Emissions from Ruminant Livestock Using a SF<sub>6</sub> Tracer Technique," *Environmental Science and Technology*, Vol. 28, No. 2, 1994. 359-362.

both ways just as easily.<sup>31</sup> Because so few CH<sub>4</sub> sinks have been identified, scientists believe that in fact it makes sense to place most of the effort on quantifying and reducing the sources.<sup>32</sup>

### 1.3. WHY CATTLE?

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Anthropogenic sources of CH<sub>4</sub> are solid waste, coal, oil and gas production, wet rice agriculture, biomass burning, and liquid wastes, in addition to enteric fermentation in livestock and anaerobic decomposition of organic materials in livestock manure (Figure 1.3).<sup>33</sup> These sources make up 60-80% of current global CH<sub>4</sub> emissions.<sup>34</sup> Natural sources, which cannot be regulated, include wetlands, termites, freshwater lakes, oceans and a small contribution from enteric fermentation from ruminants other than commercial livestock (e.g. non-domesticated swine, goats, and buffalo). Domestic cattle have been calculated to contribute 29 percent of total anthropogenic CH<sub>4</sub> emissions to the atmosphere.<sup>35</sup> It seems clear, therefore, that the world has reason to be concerned about the link between ruminants<sup>36</sup> and global climate change.

Cultural dependence on cattle can be witnessed worldwide. Cattle are consumed as a large part of human diets in many countries, and also used as agricultural laborers. It is for this reason that making changes regarding cattle becomes difficult. While the evidence for the many impacts of cattle on the environment are clear and widely recognized, their current “benefits” and the existing dependence on them are a large barrier to any type of reduction in population sizes. Cultural attachment to cattle is not only prevalent in non-industrialized nations, as described in the Preface, but also seen in industrialized countries, such as the U.S. Figure 1.5 indicates that U.S. cattle consumption has remained relatively stable for the past

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<sup>31</sup>IPCC, Working Group II, 18.

<sup>32</sup>Johnson.

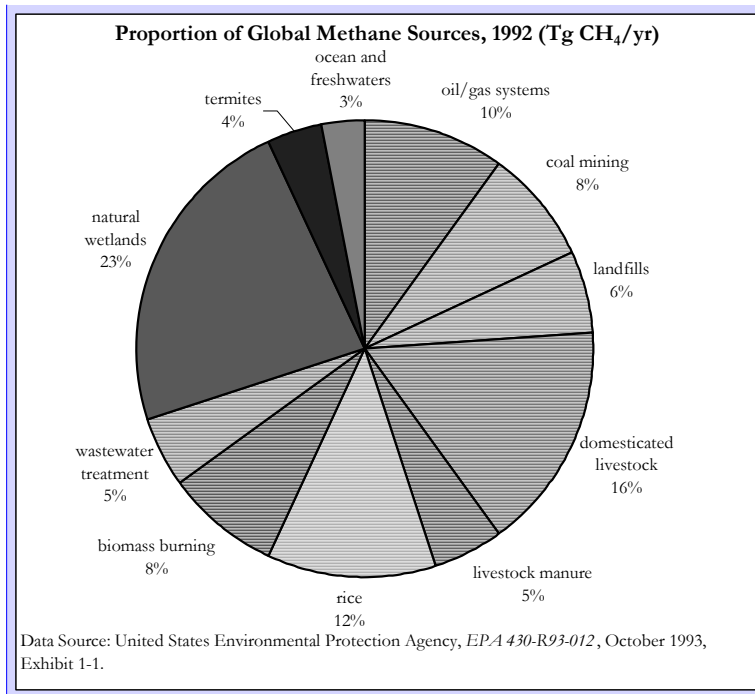
<sup>33</sup>World Resources Institute, *World Resources 1996-97*, New York: Oxford University Press, 1996. 332-335.

<sup>34</sup>Based on numbers from IPCC in EPA (October 1993) 1-4.

<sup>35</sup>United States Department of Energy, Energy Information Administration, *Mitigation of Greenhouse Gas Emissions: Voluntary Report*, EIA-1605EZ, electronic version last modified October 21, 1997.

<sup>36</sup>The term “ruminants” actually includes camels, buffalo, sheep and goats as well. Due to the nature of this paper, and the fact that beef and dairy cattle make up 95 percent of ruminants in the United States, I will consider ruminants and cattle to mean the same thing. In addition, cattle contribute approximately 70 percent of global CH<sub>4</sub> emissions from ruminant livestock, according to Johnson et al.

Figure 1.3



Comment [LS1]:

Table 1.2		
Global Methane Sources, 1992		
	Source	TgCH <sub>4</sub> /yr
<i>Anthropogenic</i>	oil/gas systems	50
	coal mining	40
	landfills	30
	domesticated livestock	80
	livestock manure	25
	rice cultivation	60
	biomass burning	40
	wastewater treatment	25
<b>Total</b>		<b>350</b>
<i>Natural</i>	natural wetlands	115
	termites	20
	ocean and freshwaters	15
<b>Total</b>		<b>150</b>
<b>Total</b>		<b>500</b>

Data Source: U.S. EPA, 1993.

26 years. While the total cattle population has fluctuated slightly, the size still remains between 100-120 million head of cattle as it was in 1970. The U.S. is still very much attached to beef, despite recent popularity and education about vegetarian diets.

Figure 1. 4

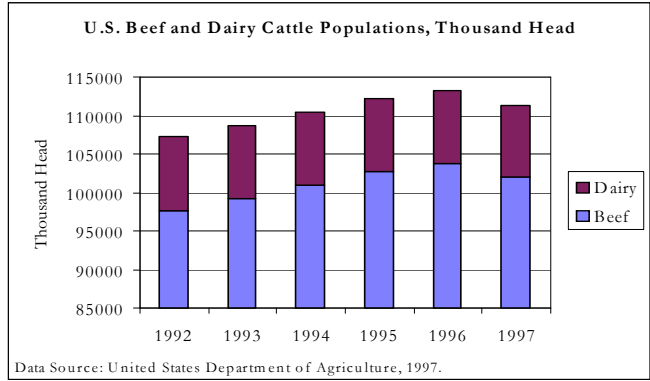
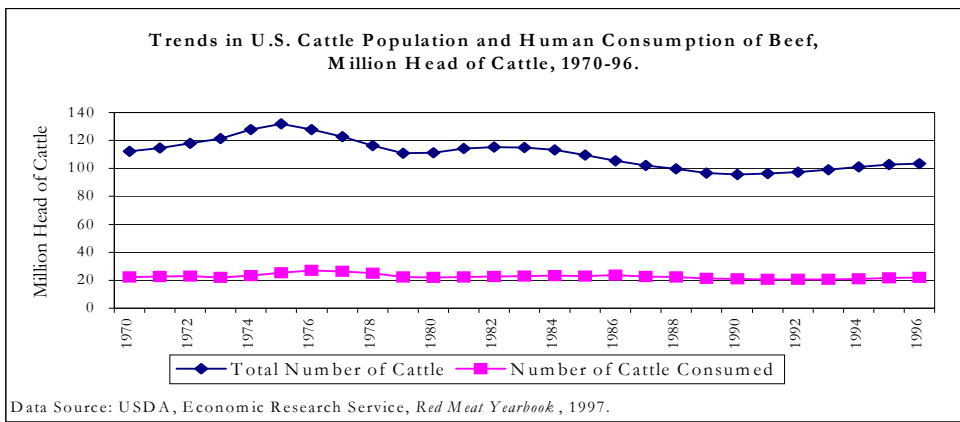


Figure 1. 5



The U.S. per capita beef consumption has declined only slightly since 1970 (Figure 1.6). A decrease is a logical change as the human population has necessarily grown, while the number of animals consumed has remained steady. However, the decline is not as great as would be expected from the population growth in the U.S. This can be explained by the fact that cattle carcass weight has in fact increased dramatically, as can be seen in Figure 1.7.

Figure 1. 6

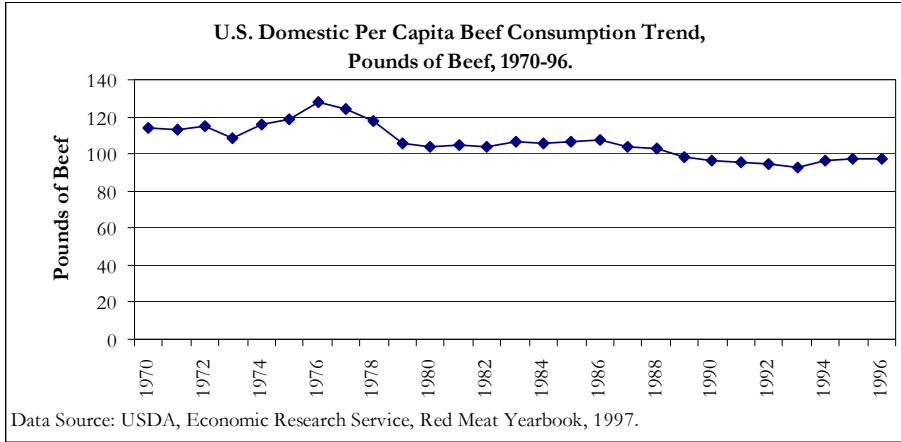
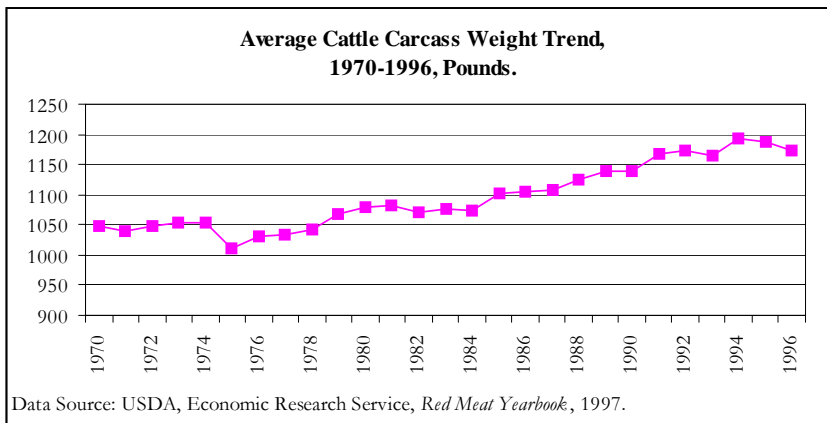


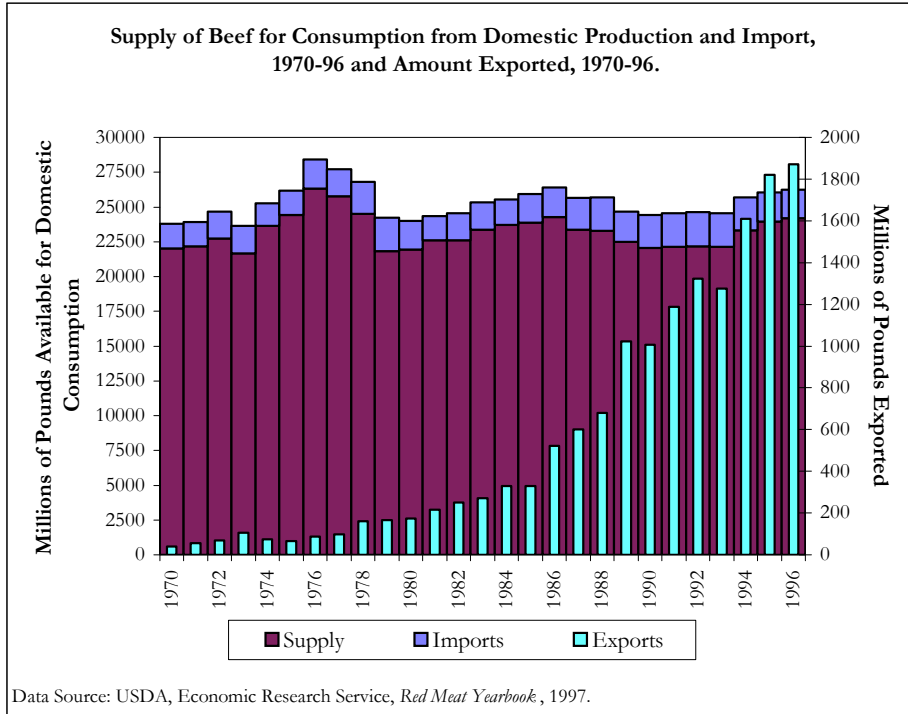
Figure 1. 7



While U.S. per capita beef consumption has decreased, beef exports have in fact increased. Since more meat is available, and approximately the same amount is being consumed in the U.S. as before, the excess is exported. This can be seen in Figure 1.8. The bars indicate the meat available for consumption (supply adjusted for demand) after the excess has been set aside for export. Some higher quality beef is imported from Canada, Australia and New Zealand. Lower grade beef is exported primarily to Japan, Mexico and Canada.<sup>37</sup>

<sup>37</sup> USDA, Economic Research Service, Red Meat Yearbook, 1997.

Figure 1. 8



The above figures demonstrate the importance of cattle to U.S. consumers. While some may think of images of cows blocking busy streets in developing countries as typical, and different from images in the U.S., in fact cattle are very much a part of American daily life as well. From a policy perspective, this also means that cattle mitigation is more strongly resisted. Cattle are a significant CH<sub>4</sub> contributor, through, and mitigation may soon be the only option.

#### 1.4. CH<sub>4</sub> PRODUCTION BY CATTLE

Enteric fermentation takes place in the rumen<sup>38</sup> of cows during digestion with the help of the naturally occurring methanogenic bacteria.<sup>39</sup> These bacteria are part of the primary mechanism producing CH<sub>4</sub> by converting fermentation products (principally carbon dioxide plus hydrogen or formate) to CH<sub>4</sub> (Table 1.3).<sup>40</sup>

Fermentation is a necessary part of digestion for cattle, as it enables them to digest coarse plant material which monogastric animals,

including humans, cannot digest.<sup>41</sup> However, the fermentative process results in the production of large amounts of gases that must be eliminated, otherwise the animals suffer from bloating. Due to the nature of the digestive system of cattle, more gas is produced than by digestion in simple-stomached animals. Ruminant digestion results in a 20 percent loss of the digestible energy from feed in the form of heat and CH<sub>4</sub>.<sup>42</sup> The process by which the gases are expelled is called *eructation* (belching).<sup>43</sup> Some of the gases are also absorbed by the blood, and later eliminated through exhaled air from the lungs.<sup>44</sup> U.S. CH<sub>4</sub> emissions

Figure 1. 9

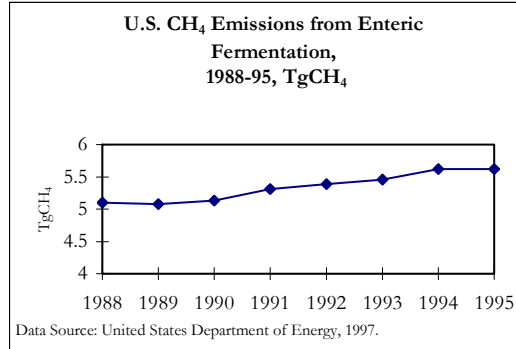
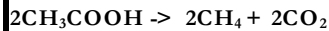
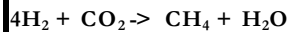


Table 1.3.

##### Fundamental Reactions for Enteric Fermentation



*two moles of acetic acid yield two moles of methane and two moles of carbon dioxide*



*four moles of hydrogen gas and carbon dioxide yield methane and water*

<sup>38</sup> The rumen is a large fore-stomach which is the dominant feature of the digestive system of cattle. The environment of the rumen is such that it can support high populations of microorganisms that ferment carbohydrates and other plant material. This is where conversion of hydrogen or formate and bicarbonate produce CH<sub>4</sub>.

<sup>39</sup> EPA (1989) 16.

<sup>40</sup> EPA (1989) 1.

<sup>41</sup> EPA (October 1993) 5-5.

<sup>42</sup> United States Environmental Protection Agency, *Improving Ruminant Production and Reducing Methane Emissions from Ruminants by Strategic Supplementation*, Office of Air and Radiation (ANR-445), EPA/400-1-91/004, June 1991. 47.

<sup>43</sup> Ensminger, M.S., *Animal Science*, Danville, Illinois: Interstate Publishers, Inc., 1991. 91.

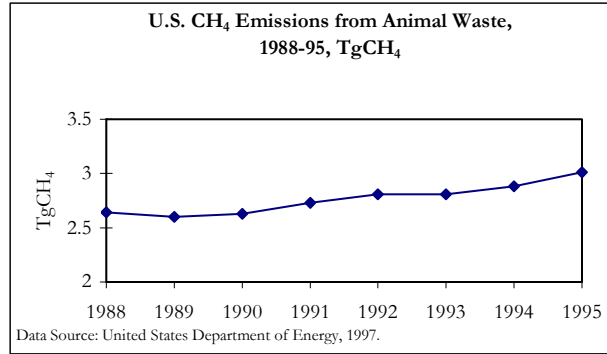
<sup>44</sup> Ensminger, 91.

from enteric fermentation have been estimated at 5.5 TgCH<sub>4</sub> in 1996, which is 18 percent of the total U.S. anthropogenic emissions.<sup>45</sup>

Anaerobic decomposition of manure from cattle also contributes to the overall CH<sub>4</sub> emissions, as the IPCC recently documented.<sup>46</sup> Despite the fact that these lagoons often include wastes from livestock other than cattle, one cow produces as much waste by volume as 16 humans over the same period of time.<sup>47</sup> U.S. CH<sub>4</sub> emissions from livestock manure have been estimated at 2.8 TgCH<sub>4</sub> in 1996, 9 percent of total U.S. anthropogenic emissions.<sup>48</sup>

Cattle therefore contribute 27 percent of total U.S. CH<sub>4</sub> emissions. As a result, cattle pose a threat to global climate

**Figure 1. 10**



change for several reasons. First, cattle populations are growing along with the demand for their products due to human population growth. In addition, livestock manure systems may soon be shifted to liquid based systems, which will create a problem, as liquid manure management systems are known to emit 80 percent of the total CH<sub>4</sub> emitted from livestock manure and 5 percent of the total anthropogenic CH<sub>4</sub> emissions.<sup>49</sup> As questions of which actions to take remains mostly unanswered, studies such as this one gain importance.

<sup>45</sup> Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1996*, DOE/EIA-0573(96), Office of Integrated Analysis and Forecasting, U.S. Department of Energy, October 1997.

<sup>46</sup> IPCC, Working Group II, 758.

<sup>47</sup> Ensminger, 242.

<sup>48</sup> Energy Information Administration, 1997.

<sup>49</sup> EPA (October 1993) 6-1.

## 1.5. APPROACH

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Below is the model used to arrive at the question: *what impact could a reduction of cattle CH<sub>4</sub> emissions have on greenhouse gas reduction in the United States?* It is a typical model for approaching environmental questions. The model is also chronologically linked, as it could be argued that the first part (*problem definition*) was the original task of the current environmental movement. In the second table, the question is fit to the model.

Table 1.4

<i>ENVIRONMENTAL PROBLEM SOLVING</i>
<b>1. Identification of the problem/issue</b>
<b>2. Identification of the source of the problem/issue</b>
<b>3. Identification of environmental and socioeconomic consequences of the problem/issue</b>
<b>4. Identification of alternative solutions and/or reduction methods which address the source and effect of the problem/issue</b>
<b>5. Implementation of solution/reduction method</b>
<b>6. Evaluation and analysis of solution/reduction method results in order to understand what methods work better than others -- leading to elimination of the methods that are not effective nor efficient</b>

The approach in this study follows the model below, in that it begins by looking at the greater context. In this case, global climate change is the issue of interest. The next section discusses CH<sub>4</sub> emissions as a source for climate change, and contextualizes the case study, the U.S., as one of the most significant CH<sub>4</sub> emitters globally. The source of interest, cattle, is examined as a significant producer of CH<sub>4</sub> in the U.S. Alternative solutions and reduction methods for cattle CH<sub>4</sub> mitigation are outlined and suggested. The known and potential results of these methods are shown, along with an analysis of the feasibility and viability of implementing these strategies in the U.S. as well as globally.

Table 1.5

<i>WHAT IMPACT COULD A REDUCTION OF CATTLE METHANE EMISSIONS HAVE ON GREENHOUSE GAS REDUCTION IN THE UNITED STATES?</i>
<ol style="list-style-type: none"><li><b>1. Global climate change which could warm or cool climates worldwide.</b></li><li><b>2. Excess amount of greenhouse gases (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, SF<sub>6</sub>, HCFC's, PFC's) in the atmosphere, primarily emitted from human activities.</b></li><li><b>3. Potential raised or lowered global temperatures, raised sea levels, unreliable conditions for agricultural purposes, wider distribution of tropical and other diseases.</b></li><li><b>4. Reducing CH<sub>4</sub> emissions from cattle, a substantial source of total anthropogenic CH<sub>4</sub>.</b></li><li><b>5. Identification and implementation of reduction methods for CH<sub>4</sub> emissions from cattle.</b></li><li><b>6. Examining mitigation options to find the most efficient, feasible and cost-effective option.</b></li></ol>

The analysis in this study will be carried out using the framework described in Table 1.5. While it is not expected that this study will be totally encompassing, due to limited access to data and information, the concluding recommendations will be based on a profound examination of the issue, and an analysis of calculations based on data from established sources. The hope is that this study will clarify the topic and investigate a source of greenhouse gas contribution where a potentially powerful solution may lie.

## Mitigation Approaches

This chapter briefly presents the United States attitude toward CH<sub>4</sub> emissions and the goals for CH<sub>4</sub> reduction. It then outlines the current technical, economic, and regulatory options available and implemented for reducing CH<sub>4</sub> emissions in the United States.

### 2.1. THE UNITED STATES AND CH<sub>4</sub>

The United States is home to over 100 million cows – 10 percent of the global total.<sup>50</sup> As the U.S. has almost 270 million human beings, 4.6 percent of the world total, the cow to human ratio in the U.S. is more than double what it is in the rest of the world, as can be seen in Table 2.1.

Table 2.1				
Cattle Numbers in Selected Countries, 1995				
	U.S.	Brazil	India	World <sup>a</sup>
Dairy Cattle (1000 head)	9461	17500	33000	135326
Beef Cattle (1000 head)	102755	148278	274155	1044181
Total Cattle (1000 head)	112216	165778	307155	1179507
<i>Percentage of World Total (%)</i>	<i>10</i>	<i>14</i>	<i>26</i>	
Human Population (millions)	263	167	862	5720
<b>Cow to Human Ratio</b>	<b>0.43</b>	<b>0.99</b>	<b>0.36</b>	<b>0.21</b>
a) Selected countries only				
Data Source: United States Department of Agriculture, <i>Dairy: World Markets and Trade 1996; Livestock and Poultry: World Markets and Trade</i> , 1997.				

Table 2.2					
Anthropogenic CH <sub>4</sub> Emissions, Selected Countries, 1991					
Percent and TgCH <sub>4</sub> /yr					
		U.S.	Brazil	India	World
Livestock	TgCH <sub>4</sub>	5.6	8.1	11.0	81.0
Total Anthropogenic CH <sub>4</sub>		27.0	9.9	33.0	270.0
	<b>% of total</b>	<b>21%</b>	<b>82%</b>	<b>33%</b>	<b>30%</b>
Percentage CH <sub>4</sub> from Livestock		7%	10%	14%	
Percentage Livestock CH <sub>4</sub> in Total		10%	4%	12%	
Data Source: World Resources Institute, <i>World Resources 1996-97</i> , 1996.					

<sup>50</sup> United States Department of Agriculture, *Dairy: World Markets and Trade*, Foreign Agricultural Service, FD 1-97, January 1997.

Tables 2.1 and 2.2 indicate that U.S. CH<sub>4</sub> emissions from enteric fermentation and animal waste make up 7 percent of the world's CH<sub>4</sub> emissions from ruminants, and 10 percent of the world's total anthropogenic CH<sub>4</sub> emissions from all sources. In 1990, approximately 15 percent of the world's total CH<sub>4</sub> emissions from livestock manure came from the United States.<sup>51</sup> Such a number is significant as the U.S. also maintains the world's largest economy, and therefore plays a crucial role in any international negotiations concerning greenhouse gases. According to the United Nations, the U.S., as an OECD Annex-I country, has a commitment to the international community to make greater efforts than countries in transition to a market economy. Unlike Annex-I countries, non-Annex-I countries are granted a certain degree of flexibility in terms of adhering to emissions reduction policies.<sup>52</sup> With the atmospheric concentration of CH<sub>4</sub> so much greater in the 1990's than ever before, the U.S. cannot simply be an observer and a contributor to the global CH<sub>4</sub> balance, it must be an actor. Measures for action have recently been discussed more seriously than ever before in the U.S., since the upcoming FCCC/COP-3 conference has inspired new national concern about climate change, as evidenced by the increased amount of news coverage on global warming.<sup>53</sup>

Currently, U.S. farmers are not legally required to control CH<sub>4</sub> from enteric fermentation.<sup>54</sup> In fact, according to the Energy Information Administration, there were no CH<sub>4</sub> reduction projects for enteric fermentation reported in 1995.<sup>55</sup> Other agricultural sources of CH<sub>4</sub> emissions are, however, being addressed voluntarily. In 1995, there were 58 CH<sub>4</sub> reduction projects, 39 of which relied on recovering CH<sub>4</sub> to generate electricity. These 58 projects reduced CH<sub>4</sub> emissions in 1995 by 1.1 Tg, up by 7 projects from 1994.<sup>56</sup> Although these efforts are moving in the right direction, a problem still exists in that the emissions reductions are indirect. Direct mitigation options, for example reducing cattle numbers or rumen chemistry, are unpopular and/or poorly understood. Should binding emissions targets be implemented as a result of FCCC/COP-3, the U.S. will be faced with the necessity to implement the options currently available. Without total awareness of the effects of CH<sub>4</sub> mitigation programs, reduction potential cannot be predicted well. An assessment of the efficiency of the currently known mitigation methods prior to their

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<sup>51</sup> EPA (October 1993) 6-43.

<sup>52</sup> UNEP, *Climate Change Information Kit*, January 1997.

<sup>53</sup> This evidence was found primarily from articles in the *New York Times* in October 1997.

<sup>54</sup> Personal communication with Mark Orlic, Office of Air and Radiation, USEPA, May 1997.

<sup>55</sup> USDOE, EIA.

implementation will provide the U.S. with more confidence about an issue that is already not thoroughly understood – global climate change.

## 2.2. CH<sub>4</sub> MITIGATION

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The IPCC estimates that Annex-I countries can reduce 21 percent of global CH<sub>4</sub> emissions from ruminants through mitigation.<sup>57</sup> The EPA holds that these emissions can be reduced 12-22 percent in the U.S. by the year 2000.<sup>58</sup> An identification of the actual CH<sub>4</sub> reduction quantities from each strategy cannot be applied prior to a thorough analysis of the various areas where reduction can take place, as well as an assessment of other factors that must also be considered, such as the ethics of any option.

### 2.2.1. OPTIONS FOR CH<sub>4</sub> MITIGATION

CH<sub>4</sub> mitigation can be possible from many directions and by manipulating many related forces. The most direct way to reduce CH<sub>4</sub> emissions from cattle in the U.S. is to reduce the cattle population size. Cattle are an important source of nutrition in the U.S., both for their meat and the many dairy products that have become staple items in most homes. Therefore, reducing the number of animals is only possible if it does not adversely affect American diets, and if acceptable substitutes protein sources can be found. CH<sub>4</sub> reduction from the animals allows the populations to remain at their current levels, while CH<sub>4</sub> emissions per cow are reduced. There are some direct, technical solutions that focus on manipulating the methanogenic process in the animals' rumens. Technical options are based around biochemical engineering for ways to reduce CH<sub>4</sub> production in the rumen through methanogenesis manipulation,<sup>59</sup> or to increase beef or dairy productivity of an individual animal, hence reducing CH<sub>4</sub> production per unit of cattle product. Another way to reduce emissions per cow is by way of altering the productivity per animal. By increasing milk or beef quantities produced with the same size herd, CH<sub>4</sub> emissions are reduced per unit of product. Economic instruments in the form of taxes and permits allow incentives for CH<sub>4</sub> reduction which may not already be present. Regulatory options may also be useful.

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<sup>56</sup> USDOE, EIA.

<sup>57</sup> IPCC Working Group II, *Technologies, Policies and Measures for Mitigating Climate Change*, IPCC Technical Paper I for the United Nations Framework Convention on Climate Change, November 1996. 11.

<sup>58</sup> EPA (October 1993) 5-1.

<sup>59</sup> Methanogenesis manipulation changes the fermentation process within the rumen to reduce the amount of CH<sub>4</sub> resulting from the digestive reactions (see Table 1.2).

Finally, the U.S. could reduce its CH<sub>4</sub> emissions through the collaboration in programs such as Joint Implementation (JI), an international strategy for global reduction of greenhouse gases through cooperation between developing and developed countries. Once an identification of the various sources of reduction measures has been established, an evaluation of the potential reduction possibility of each of the strategies is the next step.

The strategies are presented here with those currently suggested by the EPA first, followed by an explanation of human consumption manipulation and finally alternative strategies, variations on those options suggested by the EPA and IPCC.

### **2.3. TECHNICAL MITIGATION OPTIONS**

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Technical mitigation strategies are attractive as they can function by reducing CH<sub>4</sub> directly from its source. Such options include diet manipulation through hormone supplementing, and raising the quality of the feed. The other option that reduces CH<sub>4</sub> emissions is actually an indirect consequence of increasing cattle productivity. The technical solutions for increasing milk amounts produced by an individual animal, for example, reduces CH<sub>4</sub> by reducing the amount of cattle needed to produce the same amount of milk.

The technical approaches for emissions from waste are variations of CH<sub>4</sub> recovery for use as on-site fuel sources, or in some cases to sell to a utility. The CH<sub>4</sub> recovery strategy makes up the greatest proportion of CH<sub>4</sub> reduction programs currently being implemented for agriculture as well as for other sources.<sup>60</sup>

#### **2.3.1. METHANOGENESIS MANIPULATION**

For minimal emissions of CH<sub>4</sub> from an individual animal, the rumen nutrient environment needs to be well balanced. One of the problems with rumination is that fermentation of the feed results in a 20 percent loss as heat and CH<sub>4</sub> of the digestible energy in the feed.<sup>61</sup> The more efficient the digestion process, the less excess CH<sub>4</sub> is produced. As discussed in Chapter 1, ruminant digestion is more inefficient than monogastric digestion and therefore large quantities of CH<sub>4</sub> are produced. The IPCC states that a

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<sup>60</sup>The most frequently reported method of reducing CH<sub>4</sub> emissions was by recovering CH<sub>4</sub> for energy." USDOE, EIA, "Projects Reported" chapter from *Mitigation of Greenhouse Gas Emissions: Voluntary Reporting*, October 21, 1997.

<sup>61</sup>EPA (1991) 47.

better quality diet has the potential to reduce the amount of CH<sub>4</sub> produced by an individual animal by providing a better nutrient balance in the rumen.<sup>62</sup> Controlling CH<sub>4</sub> emissions from ruminants is possible through the manipulation of the methanogenic process, the chemical reaction forming CH<sub>4</sub> in the rumen of the animals. Chemical additives reduce CH<sub>4</sub> emissions because they allow a greater proportion of the diet to pass to the lower digestive tract. The microbial cells found in the lower intestines do not participate in methanogenesis, as these cells are lost in feces.<sup>63</sup> Reducing the frequency or intensity of the methanogenic process will reduce the amount of CH<sub>4</sub> emitted through eructation. This can be done by three ways: (1) chemically modifying the environment of the rumen so that less CH<sub>4</sub> results from the digestive reactions, (2) increasing the efficiency of digestion so that less CH<sub>4</sub> per unit of feed is emitted by supplementing the diet, and (3) treating the ingested feed with special compounds which will suppress the CH<sub>4</sub> quantities resulting from digestion of the feed. All three processes minimize fermentative digestion and often are all accomplished through the implementation of one strategy.<sup>64</sup>

The chemical manipulation of the rumen that most directly cuts CH<sub>4</sub> emissions is the addition of halogenated compounds, such as *chloral hydrate*, to the rumen. This action can almost entirely inhibit CH<sub>4</sub> production. Unfortunately, this method has been shown to not work well in the long run, as the microbes appear to adapt to the compound.<sup>65</sup> *Ionophores*, another halogen compound, is also used to reduce methanogenesis directly. The use of ionophores has been found to reduce rumen efficiency, which can raise CH<sub>4</sub> emissions, methanogenesis manipulation through ionophores may not be the most effective way to reduce CH<sub>4</sub> emissions either.<sup>66</sup> However, ionophore treatment is the only currently commercially available supplement that directly reduces methanogenesis.<sup>67</sup> *Elimination of rumen protozoa* is another method that has been identified as probably the best way to control methanogenesis. In a study with sheep, the digestibility of the straw diet was increased by 18 percent after protozoa had been removed from the rumen.<sup>68</sup> Protozoa ingest and digest bacteria and decrease the protein to energy ratio in the nutrients

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<sup>62</sup>United States Environmental Protection Agency, *Methane Emissions and Opportunities for Control, Workshop Results of Intergovernmental Panel on Climate Change*, Office of Air and Radiation (ANR-445), EPA/400/9-90/007, September 1990. D-16.

<sup>63</sup>EPA (1991) 54.

<sup>64</sup>EPA (1991) 13.

<sup>65</sup>EPA (1991) 54.

<sup>66</sup>EPA (1991) 54.

<sup>67</sup>EPA (October 1993) 5-14.

<sup>68</sup>EPA (1991) 45.

absorbed and decrease the efficiency of utilization of feed.<sup>69</sup> This method can be used together with maintaining the rumen in a “defaunated state” to reduce methanogenesis by increasing microbial cell outflow from the rumen (i.e. displacing the microbial cells into the lower intestines.) This would reduce CH<sub>4</sub> emitted per unit of carbohydrate fermented by around 25 percent. However, the method is not ideal either, as scientists are currently unclear on the process for removing the protozoa without endangering the animals.<sup>70</sup> The IPCC believes that options for altering the microbial conditions of the rumen should be investigated further in the realm of better feeds, and feed combinations, feed treatments and bio-engineering. They emphasize the necessity of an exploration of propionate production<sup>71</sup> in the rumen and defaunating the rumen (removing protozoa).<sup>72</sup> Increased propionate production, or microbial cell yield relative to acetate production, has been shown to decrease methanogenesis by 10 to 80 percent.<sup>73</sup> This is perhaps the best possibility for reducing methanogenesis directly.

The next way to reduce methanogenesis is to increase digestive efficiency, which has as a secondary effect on reduction of methanogenesis. The EPA classifies diets meeting the requirements for efficient microbial growth in the rumen as a baseline necessity for efficient rumination. A diet lacking in nutrients necessary for microorganism growth will yield low microbial cell amounts relative to the volatile fatty acids (VFA) which results in increased CH<sub>4</sub> generation per unit of feed consumed.<sup>74</sup> One option is to provide the cows with molasses/urea multinutrient block licks (MUB) which provide the necessary nutrients in an easily consumed and simply administered manner. Urea increases the efficiency of fermentative digestion in the rumen by stimulating digestion during food intake. The treatment ensures sufficient nutrients in balanced amounts.<sup>75</sup> Urea supplements can channel twice as much (15 versus 7 percent) of the digestible energy into CH<sub>4</sub>.<sup>76</sup> MUB’s are only difficult to use in the sense that the intake is difficult to monitor, since the animals ingest the nutrients at their own initiative. Currently the popularity of this option is based on the fact that it requires little maintenance. Therefore, some animals may ingest large quantities and some may not ingest any at all. Other options to increase microbial protein availability

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<sup>69</sup> EPA (1991) 45.

<sup>70</sup> EPA (1991) 59.

<sup>71</sup> Propionate production is a process that removes protozoa.

<sup>72</sup> EPA (1990) D-16.

<sup>73</sup> EPA (1991) 54.

<sup>74</sup> EPA (1991) 46.

<sup>75</sup> EPA (1991) 60.

to ruminants eating forage based diets includes supplementing *their diets* with urea and sulfur (see below for treatment with these compounds) or supplementation with slowly degraded protein to provide the rumen microbes with peptides and amino acids. A method that is rarely utilized, since it is barely feasible, is to increase rumen digesta turnover, meaning to lower the residence time of digestion, thereby lowering bacteria maintenance requirement which lowers CH<sub>4</sub> production because more nutrients are utilized by the animals for functions other than bacteria maintenance.<sup>77</sup>

Increasing the efficiency of digestion can also be achieved through the direct treatment of the feed to inhibit methanogenesis by altering the chemical composition of the feed such that the CH<sub>4</sub> producing reaction does not occur to the same extent. Digestibility of feed can be raised by adding strong alkali compounds to the straw diet. The most common alkali used is sodium hydroxide. There are several issues with this treatment, however, primarily due to the fact that this strategy is expensive and also produces large quantities of sodium since the ions simply accumulate. Ammonia, hydrochloric acid with sulfuric acid, or sulfur dioxide can also be used as treatment to improve the digestibility of straw. The greatest potential for increasing digestibility of straw is a treatment that combines ammonia and sulfur dioxide.<sup>78</sup> This can increase digestibility by 80-90 percent. Large amounts of sulfur have the effect of reducing feed intake that can slow down growth and reduce productivity, and perhaps in the long run fail to change CH<sub>4</sub> emissions. Also, treatment of cereal straws with ammonia has been found to increase CH<sub>4</sub> per kilogram of straw.<sup>79</sup>

### 2.3.2 PRODUCTIVITY MANIPULATION

The EPA believes that “improving livestock productivity so that less CH<sub>4</sub> is emitted per unit of product is the most promising and cost effective technique for reducing emissions in the U.S.”<sup>80</sup> If the rate of conversion of feed energy to CH<sub>4</sub> by the animal is held constant, improving feed efficiency can reduce CH<sub>4</sub> emissions per unit of product since feed intake per unit of product is reduced.<sup>81</sup> A 20 percent improvement in production rates would reduce CH<sub>4</sub> emissions by 8 percent for dairy and 12 percent for

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<sup>76</sup> EPA (1991) 65.

<sup>77</sup> EPA (1991) 54.

<sup>78</sup> EPA (1991) 62.

<sup>79</sup> Gomes, W.R., *Use of Bovine Somatotropin in Dairy Production*, New Technology Collection, National Dairy Database, June 1992.

<sup>80</sup> EPA (October 1993) 5-2.

beef cattle per unit produced.<sup>82</sup> Further, increased production per animal, and/or turnoff at an earlier age will have a much greater effect on total CH<sub>4</sub> production than reduction of methanogenesis in digestion of individual animals.<sup>83</sup> Increasing efficiency of feed utilization may not increase productivity because inhibiting or eliminating methanogens does not automatically increase the feed energy accessible to the animal.<sup>84</sup> It is therefore important to examine the options for productivity manipulation.

The general approach for increasing productivity is to decrease the amount of CH<sub>4</sub> emitted per unit of product produced from beef and dairy cattle. This in itself may not alter the total CH<sub>4</sub> quantities, as the individual animals are still emitting the same amount of CH<sub>4</sub>. It is therefore *essential* that animal numbers also decrease with an increase in productivity. If the market demands a certain amount of milk or beef, then the productivity of the animals can be adjusted to yield that amount and then the rest of the animals can be eliminated. Animal numbers can however only be decreased if human or market requirements for the products are saturated.<sup>85</sup> Should the conditions be right, therefore, productivity increases should be able to reduce CH<sub>4</sub> emissions. Productivity may be enhanced through the use of various substances whose effects are (1) to improve feed digestion efficiency and increase milk yield or edible meat quantities per cow and (2) to accelerate growth of the animals so they will produce more at a younger age, spending fewer years consuming and emitting CH<sub>4</sub> without producing offspring or reducing the time before beef cattle can be slaughtered.

Many of the strategies described in 2.3.1. can also be applied to increasing productivity, as more efficient digestion raises productivity. Further options include reducing the maintenance requirement per unit of product.<sup>86</sup> This can be accomplished by increasing the reproductive efficiency of the animals, which significantly dilutes the maintenance requirements of the breeding herd.<sup>87</sup> Improving feed conversion efficiency for production so that the efficiency level is above that of maintenance (the level of feed intake required to support the basic metabolic necessities for the animal) allows a greater growth rate

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<sup>81</sup> EPA (October 1993) 5-14.

<sup>82</sup> EPA (1993) 5-14.

<sup>83</sup> EPA (1991) 59.

<sup>84</sup> EPA (October 1993) 5-14.

<sup>85</sup> EPA (1991) 59.

<sup>86</sup> EPA (October 1993) 5-2

<sup>87</sup> EPA (1990), D-16.

to remain efficient.<sup>88</sup> It is important that productivity not be increased at the expense of the feed-to-energy conversion efficiency. Increasing the size of beef cattle can be done through the use of anabolic steroids that have been effective in increasing the rate of weight gain while improving feed conversion efficiency. Steroids redirect the energy used to deposit fat in the animal to the deposition of protein, hence allowing the animal to add protein more quickly and efficiently.<sup>89</sup> The IPCC emphasizes that increased productivity will be an effective CH<sub>4</sub> reducer because it will reduce the size of the animal population necessary to produce a given level of product.<sup>90</sup>

A controversial substance currently being used to increase productivity of cattle is known as bovine Somatotropin (bST). BST is a naturally occurring growth hormone found in cattle, which has been isolated to use for increasing milk production in dairy cows. Used on its own, however, bST does not change the efficiency with which feed energy is used for maintenance of milk synthesis.<sup>91</sup> For this reason, bST is added to feed with a higher than usual energy content, which allows milk production to be more efficient. BST dilutes the maintenance requirements of individual lactating cows and thereby reduces the size of the herd necessary to support the lactating cows.<sup>92</sup> It has been projected to reduce CH<sub>4</sub> emissions by 9 percent if adopted nationally. Research has shown that bST can increase milk production by 15 to 40 percent.<sup>93</sup> The controversy arises because many consumers fear that bST will affect humans through the consumption of the milk produced with the hormone, but Gomes insists that bST has no effect as it is inactive in humans.<sup>94</sup> Efficient fermentative digestion achieved through the use of protein supplements will also shorten the lifespan of the animals while they produce the same amount of CH<sub>4</sub> and product as previously. This has been shown to lower the amount of CH<sub>4</sub> emitted from 250g CH<sub>4</sub> per liter of milk to 40-80g. Increasing the growth rate of beef cattle has proved a reduction of CH<sub>4</sub> to a fifth of the quantity without treatment.<sup>95</sup> According to a 1991 report by the EPA, improving the reproduction rates of cattle is the most important action for any productivity increases.<sup>96</sup> Diet supplements can reduce the age of the first

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<sup>88</sup> EPA (October 1993) 5-2.

<sup>89</sup> EPA (1993) 5-14.

<sup>90</sup> EPA (1990), D-16.

<sup>91</sup> EPA (1993) 5-19.

<sup>92</sup> EPA (1990), D-16.

<sup>93</sup> Gomes.

<sup>94</sup> Gomes.

<sup>95</sup> EPA (1991) 14.

<sup>96</sup> EPA (1991) 38.

calving from 5 to 2-3 years.<sup>97</sup> Supplementation with a protein meal and urea can provide a better balance of nutrients to the animal and increase live-weight gain and efficiency of feed utilization in young animals, pregnant ruminants and lactating animals. In addition, this supplementation decreases the age of puberty, increases conception rate and decreases the intercalving interval in mature cows (the time between calving for a cow) from 24 to 12-15 months.<sup>98</sup> This means that there will be less time when the animals are only producing CH<sub>4</sub> and no product. During young years the animals have 100 percent CH<sub>4</sub> to product ratio, meaning that they are entirely inefficient. Shortening this time will mean that the ratio of overall CH<sub>4</sub> emissions to product output also decreases. Improving the reproductive efficiency reduces the brood herd size needed to sustain a given population of animals.<sup>99</sup> Also, the EPA estimates that the time required for replacement of draft animals can be reduced by 50 percent. It follows that this strategy can more than double the current milk production by increasing the number of cows in the national herd who are lactating at any one time. Growth rate can be doubled through raising the quality of forage by supplementing it with nutrients because animals with high quality diets grow much more efficiently. Because animals on low quality diets also produce the same amount of CH<sub>4</sub> per kilogram of live weight as animals who are eating high quality diets, increasing growth rate would mean less time spent before reaching slaughter or calving age, less CH<sub>4</sub> would be emitted in waste.

### 2.3.3. TECHNICAL OPTIONS FOR EMISSIONS FROM WASTE

In 1993, there were 22 projects to recover CH<sub>4</sub> from dairy, swine and poultry manure management systems in the U.S. Fifteen biogas digesters were producing fuel from the manure of about 9000 dairy cattle, preventing around 0.001 Tg of CH<sub>4</sub> from being emitted into the atmosphere.<sup>100</sup> In 1995, the project number had increased to 41, all but two of which use the recovered CH<sub>4</sub> to generate electricity.<sup>101</sup> Reducing CH<sub>4</sub> emissions from cattle waste is more easily done than for enteric fermentation, as there is a greater incentive since the reduced CH<sub>4</sub> can be used as an on site fuel source. CH<sub>4</sub> emissions captured from livestock manure<sup>102</sup> depend on the manner in which the waste is collected and stored. One manure

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<sup>97</sup> EPA (1991) 15.

<sup>98</sup> EPA (1991) 60.

<sup>99</sup> EPA (1990), D-16.

<sup>100</sup> EPA (April 1993) 6-16.

<sup>101</sup> USDOE, EIA, "Projects Reported."

<sup>102</sup> The terms *manure* and *waste* are used to mean the same thing here.

collection technique offers a complete elimination of CH<sub>4</sub>. Since the majority of the CH<sub>4</sub> collection in the U.S. is not of this zero-emissions sort, the EPA looks primarily to CH<sub>4</sub> gas recovery for various purposes as the most effective method of reduction. In fact, the only true option for mitigating the emissions from animal waste is to convert the CH<sub>4</sub> released from manure into energy. It is important to look at the different methods used for this, which vary according to the manure collection technique.

Options for collecting manure from livestock are summarized in the table below:

<i>MANURE COLLECTION TECHNIQUES</i>	
Pasture/Rangeland:	Animals grazing on pasture not part of manure management systems. Manure is not managed at all, simply left where it is deposited.
Daily Spread:	Manure is collected in solid form (with or without the bedding), by for example scraping, and then stored until it is of the consistency such that it can be applied to fields on regular basis.
Deep Pit Stacks:	For animals that are kept on a cage floor manure is allowed to collect in solid form under the cages. It is then collected once a year, or less often. The manure stays dry.
Drylot:	This option only works in dry climates where animals are kept on unpaved feedlots. Here the manure is allowed to dry until it is periodically removed. Upon removal it is spread on fields.
Anaerobic Lagoon:	Systems are usually characterized by automated flush systems using water to transport manure to treatment lagoons, usually greater than six feet deep. The manure resides in the lagoon for periods ranging from 30 – 200 plus days depending on lagoon design and other local conditions. The water from the lagoon is often recycled as flush water. Lagoon water may be used for irrigation on fields with the treated manure providing fertilizer value.
Liquid/Slurry:	Large concrete lined tanks built into the ground. Manure stored in tank for six or more months until it can be applied to fields. Water must usually be added to manure so that it can be more easily handled as a liquid. This reduced the total solid concentration to less than 12 percent. Slurry systems may or may not require addition of water
Solid Storage:	Manure is collected through scraping, etc and stored in bulk for months until disposed.
Pit Storage:	Like pit stacks, but the length of the storage time varies from less than or longer than one month.
<p><b>Sources:</b> U.S.EPA, <i>Anthropogenic Methane Emissions in the United States: Estimates for 1990</i>, Report to Congress, USEPA Office of Air and Radiation, EPA 430-R-93-003, April 1993.  U.S.EPA, <i>Global Methane Emissions from Livestock and Poultry Manure</i>, USEPA Office of Air and Radiation, EPA/400/1-91/048, February 1992.</p>	

The collection technique that emits virtually no CH<sub>4</sub> is *daily spread*.<sup>103</sup> In the U.S., 1/3 of the daily manure is managed by being spread directly on cropland, and another third is managed as liquid. The most common liquid systems are the *pit storage*, *anaerobic lagoons* and *liquid/slurry* techniques. Liquid systems keep manure in oxygen-free environments (anaerobic conditions) which promote CH<sub>4</sub> production.<sup>104</sup> These systems are responsible for approximately 60-80 percent of the total CH<sub>4</sub> emissions from livestock manure in the U.S.<sup>105</sup> The solid based collection systems include *pasture/range*, *drylots*, *solid storage*, as well as *daily spread*, accounting for the other 20 percent of CH<sub>4</sub> emissions. In solid systems, CH<sub>4</sub> production is minimal because the anaerobic conditions leading to CH<sub>4</sub> production are not present.<sup>106</sup> Low-CH<sub>4</sub> emitting

<sup>103</sup> EPA (April 1993) 6-11.

<sup>104</sup> EPA (April 1993) 6-11.

<sup>105</sup> EPA (April 1993) 6-16.

<sup>106</sup> EPA (October 1993) 6-22.

solid management options are not viable everywhere, as humid climates would not be suitable for drying the manure.

The two viable options for CH<sub>4</sub> recovery currently being implemented in the U.S. are *covered lagoons* and *manure digester* alternatives: *plug flow digesters* and *mixed tank digesters*.<sup>107</sup> Covered lagoons simply place a floating cover over the anaerobic lagoon where the manure is stored. This method allows the CH<sub>4</sub> to be completely recovered. The method is being implemented throughout the U.S., although it is most applicable in warm climates, and naturally easiest where CH<sub>4</sub> is already collected in liquid form.<sup>108</sup> The digesters are more practical in that they can be used in most climates. *Plug flow digesters* (also called *complete mix digesters*<sup>109</sup>) use the solid manure to produce CH<sub>4</sub>. The process begins by placing an expandable cover over a trough in which CH<sub>4</sub> is added on a daily basis. At each addition of CH<sub>4</sub>, the new *plug* of manure pushes the old mass down the trough. Inside the trough the manure decomposes anaerobically and produces CH<sub>4</sub>, which is collected. The decomposed and stabilized manure is extracted from the other end of the tank.<sup>110</sup> Mixed tank digesters also work by having manure added on a daily basis. The manure is mixed inside the closed tank where it remains for 20-30 days, decomposing anaerobically, before being removed. The resulting CH<sub>4</sub> is recovered as for the other systems.<sup>111</sup> The energy recovered from these systems can be practical for on-farm uses such as refrigeration of milk and heating of hot water to wash cows, and electricity generation for both on-farm use and to sell to utilities.<sup>112</sup> Other on-farm uses include internal combustion engine, chiller or boiler and space heater powering.<sup>113</sup>

Solid-based systems, although more effective than liquid-based systems, contribute to water pollution because the manure is generally not isolated or contained. Many states are requiring farms to control the water runoff from these systems by switching to liquid-based systems.<sup>114</sup> This will mean an increase in CH<sub>4</sub> emitted as liquid systems emit more than solid systems, when CH<sub>4</sub> recovery systems are put in place. It is estimated that the fraction of dairy manure that will be placed in lagoons without cover

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<sup>107</sup> EPA (October 1993) 6-22.

<sup>108</sup> EPA (April 1993) 6-27.

<sup>109</sup> EPA (October 1993) 6-22.

<sup>110</sup> EPA (April 1993) 6-27.

<sup>111</sup> EPA (April 1993) 6-27.

<sup>112</sup> EPA (April 1993) 6-27.

<sup>113</sup> EPA (October 1993) 6-42.

<sup>114</sup> EPA (April 1993) 6-24.

will go from 11 percent to 32 percent by the year 2000, and consequently, animal-waste related emissions could increase 65-90 percent.<sup>115</sup>

Fortunately, criteria developed by the EPA for evaluating the system effectiveness have shown covered lagoon systems to offer the best opportunity for CH<sub>4</sub> reduction. This is based also on the fact that lagoons are the most common system. In addition, these systems are technically feasible in most parts of the country. An important point to make, since covered lagoons are primarily useful in warm climates, is that most of the lagoon systems are currently found in the southern U.S.<sup>116</sup> Finally, these covered lagoons are economically advantageous over digesters because they do not require large amounts of capital, and CH<sub>4</sub> can be collected and hence reduced at low costs.<sup>117</sup>

#### **2.3.4. OTHER TECHNICAL OPTIONS**

A strategy for reducing future CH<sub>4</sub> emissions is to develop breeding animals that are low CH<sub>4</sub> emitters through genetic manipulation.<sup>118</sup> There is genetic potential in for improving characteristics such as milk production, growth rates and ease of reproduction.<sup>119</sup> The resulting increases in production levels have the possibility of reducing CH<sub>4</sub> emissions per unit of product, if coupled with improved management and feeding of the animals. For this reason, genetic material from high-producing cows has systematically been introduced in many developing countries. As of 1993, opportunities for accelerating selective breeding for the purpose of reducing CH<sub>4</sub> emissions had not fully been evaluated by the EPA.<sup>120</sup> The existing methods, such as crossbreeding in developing countries, genetic improvement in dairy cattle, transgenic manipulation (the transfer of genetic material from one species to another) and improved reproduction still have to show more evidence of effectiveness to be considered CH<sub>4</sub> reducers.<sup>121</sup>

#### **2.4. ECONOMIC AND REGULATORY OPTIONS**

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<sup>115</sup> EPA (April 1993) 6-26.

<sup>116</sup> EPA (October 1993) 6-43.

<sup>117</sup> EPA (October 1993) 6-43.

<sup>118</sup> EPA (1991) 38.

<sup>119</sup> EPA (July 1993) 6-33.

<sup>120</sup> EPA (July 1993) 6-33.

<sup>121</sup> EPA (July 1993) 6-34.

There are substantial opportunities for the use of market forces to reduce CH<sub>4</sub> emitted from cattle. However, such policies are difficult to implement because of product price fluxes. The following strategies focus on cleaning up the inefficiencies caused by lack of communication and organization in the dairy and beef industries. While economic incentives drive both the dairy and beef-related CH<sub>4</sub> emission reduction opportunities, they also drive Joint Implementation (JI).<sup>122</sup> The use of JI for reducing CH<sub>4</sub> emissions will be further examined later in this chapter.

#### 2.4.1. DAIRY MARKET OPPORTUNITIES

Many regions of the developed world, including the United States, produce more milk than they sell to consumers or the market.<sup>123</sup> This excess production also causes unnecessary CH<sub>4</sub> to be emitted, which could be eliminated through a decrease in production. Maintenance of a supply-demand balance over the long term is important in order to limit CH<sub>4</sub> emissions from this sector.<sup>124</sup> Since predicting dairy product demand is difficult, the easiest method for attempting to use the market to reduce CH<sub>4</sub> emissions is to focus on changing the use of fat as a pricing gauge.<sup>125</sup> As of right now, fat content in dairy products is what sets the value for the farmers. This means that dairy farmers are paid more for their milk if it contains more fat.<sup>126</sup> Because consumer preferences are tending toward products of the low-fat or nonfat variety, whole milk products are not in as much demand. Excess fat in dairy products is equivalent to excess CH<sub>4</sub> production, as it takes energy for the animals to produce the fat, which translates into CH<sub>4</sub> emissions.<sup>127</sup> By emphasizing protein instead of fat production, CH<sub>4</sub> emissions per unit of milk produced would decline because energy requirements to synthesize fat will not be as high when protein is emphasized.<sup>128</sup> This happens due to a reduction in feed intake per unit of milk produced. Although this effect has not yet been quantified, it would most probably result in less than a 5 percent reduction in emissions per unit of product produced.<sup>129</sup>

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<sup>122</sup> Joint Implementation is a strategy that allows a developed country or a company within that country to receive emissions reduction credits for sponsoring greenhouse gas reductions in a developing country.

<sup>123</sup> EPA (April 1993) 6-37.

<sup>124</sup> EPA (October 1993) 5-27.

<sup>125</sup> EPA (April 1993) 6-38.

<sup>126</sup> EPA (October 1993) 5-29.

<sup>127</sup> EPA (October 1993) 5-29.

<sup>128</sup> EPA (October 1993) 5-31.

<sup>129</sup> EPA (October 1993) 5-31.

#### 2.4.2. BEEF MARKET OPPORTUNITIES

Direct government intervention to maintain an “orderly market” for the beef industry does not exist as it does for the dairy market.<sup>130</sup> However, the U.S. beef industry is in the process of being re-oriented toward a “Value Based Marketing System” which is meant to reduce the inefficiencies traditionally associated with beef production.<sup>131</sup> The result of these inefficiencies is excess fat production, producing excess CH<sub>4</sub>. As for dairy products, the removal of this excess body fat is what drives the strategy. Consumers do not desire high quantities of fat on their meat.<sup>132</sup> The new production system would therefore be more closely tied to the consumer, providing objective meat grading.<sup>133</sup> The existing beef grading system does not adequately identify tender and palatable low fat beef.<sup>134</sup> The EPA holds that the implication on CH<sub>4</sub> emissions of the new marketing system could be “substantial.”<sup>135</sup>

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<sup>130</sup> EPA (October 1993) 5-32.

<sup>131</sup> EPA (April 1993) 6-38.

<sup>132</sup> EPA (April 1993) 6-38.

<sup>133</sup> EPA (April 1993) 6-38.

<sup>134</sup> EPA (October 1993) 5-32.

<sup>135</sup> EPA (October 1993) 5-32.

FIRST SUMMARY TABLE OF MITIGATION STRATEGIES.

TYPE	NAME	ADVANTAGES	DISADVANTAGES
METHANOGENESIS MANIPULATION	chloral hydrate supplements	directly cuts CH <sub>4</sub> emissions	microbes adapt to compound
	ionophore supplements	only commercially available treatment	reduces methanogenesis, also reduces rumen efficiency, more emissions
	elimination of rumen protozoa	digestibility increases, reduced CH <sub>4</sub> emitted per unit carbohydrate 18%	scientists do not know how to do this without endangering the animals
	elimination of protozoa combined with defaunation	reduces CH <sub>4</sub> emitted per unit of carbohydrate 25%	
	molasses/urea multnutrient block licks	provide nutrients to increase digestion efficiency 7-15%	difficult to monitor, animals ingest nutrients at own initiative
	urea, sulfur supplements	increase digestive efficiency	not feasible
	slowly degraded protein supplements	increase digestive efficiency	not feasible
	strong alkali compounds added to straw diet	increases digestibility of straw	expensive strategy, pollutes if SO <sub>2</sub> used
ammonia and sulfur dioxide treatment of straw diet	increases digestibility by 80-90%	reduces growth rate, indirectly increasing CH <sub>4</sub> emissions -- ammonia been found to increase CH <sub>4</sub> per kg straw	
PRODUCTIVITY MANIPULATION	steroids	animal can add more protein at a faster rate.	not popular with consumers
	bovine Somatotropin (bST)	more efficient milk production, increase production 40%	reduces CH <sub>4</sub> emissions per unit of product
	protein supplements	lower amount of CH <sub>4</sub> emitted per unit of product 16-32%	
CH <sub>4</sub> RECOVERY FROM WASTE	covered storage lagoons	collect all CH <sub>4</sub> produced simple	can only be used in warm climates
	manure digesters	can be used in all climates	causes ground water pollution from runoff and leaching
GENETIC MANIPULATION	breeding in favor of characteristics such as high milk production, growth rates or ease of reproduction	can reduce CH <sub>4</sub> emissions per unit of product	not been fully evaluated by EPA for CH <sub>4</sub> reduction potential
MARKET CHANGES	change importance of using <i>milk fat</i> as price gauge for milk to using protein levels	excess fat in milk production means excess CH <sub>4</sub> production, less fat means less CH <sub>4</sub>	small effect on CH <sub>4</sub> reductions
	re-orienting beef industry toward less excess body fat by changing the meat grading system to emphasize low fat beef	less excess fat means less excess CH <sub>4</sub> production	not currently being enforced, only suggested.

## 2.5. MANIPULATING HUMAN DEMAND

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While manipulating CH<sub>4</sub> production in the rumen to meet the desired emissions levels is stated above as the most effective biological approach to reducing emissions, in fact eliminating cattle is *truly* the most direct approach. There would be practically no need for cattle if humans stopped consuming beef products. Changing attitude and behavior of consumers is extremely difficult, and substantial research has been done on the issue.<sup>136</sup> It is not the role of this thesis to propose social research methods, nor suggest psychological approaches to manipulate consumers so that they reduce their intake of milk, cheese, steaks and other cattle products. However, it is important to recognize the impact of consumer attitude and behavior on demand, as these forces also have an impact, therefore, on supply (see Figures 1.5-1.7). The main strength of manipulating human demand is that it can lead to reductions in the cattle population size, which translates into an impact on CH<sub>4</sub> emissions.

CH<sub>4</sub> emissions are only one of the many harmful effects of cattle on the environment. Cattle also cause land degradation, desertification, inefficient resource and land use, and pollution. By reducing the number of cows, the extent of these environmental problems will also be reduced. It is also important to recall the effects of eliminating cattle on other greenhouse gas emissions. In fact, both CO<sub>2</sub> and N<sub>2</sub>O are emitted as a result of activities related to cattle, such as packaging and transport of cattle products, the use of manure as fertilizer, keeping the animals warm during winter, and maintaining power for the farm or ranch.<sup>137</sup> The greenhouse gases emitted by the activities discussed here are not addressed further in this research, as it is difficult to quantify and assess the total impact of cattle the environment and on greenhouse gases. However, clearly the elimination of a portion of the cattle population would be capable of reducing these inputs as well.

### 2.5.1. BEEF CONSUMPTION TRENDS

Per capita beef consumption in the United States can be seen in Figure 1.6. The relatively constant levels, remaining around 20 million head of cattle per year, suggest that, dependent only on

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<sup>136</sup> See for example Paul Stern “Energy Conservation as if People Mattered: Lessons from Behavioural Research,” from *Consumer Behaviour and Energy Policy*, 1986; *Values, Beliefs and Emergent Social Objects: The Social-Psychological Construction of Support for the Environmental Movement*, National Science Foundation, United States; as well as Folke Ölander and John Thøgersen. “Understanding Consumer Behaviour as a Prerequisite for Environmental Protection.” *Journal of Consumer Policy* 18: 345-385, 1995.

quantities of consumption by Americans, the number of cattle kept in the U.S. for the primary purpose of human consumption has not changed over the past 26 years, although export has increased because the amount of meat produced has increased. In fact, the average carcass weight increased almost 150 lbs. (13 percent of the mean weight over time) between 1970 and 1996.<sup>138</sup> Several factors can explain this increase. First, the fact that cattle are now primarily on feedlots rather than rangeland is important because feedlot feed quality is higher, and therefore the animals can convert more energy into product. Following this, because animals are larger, more people can be fed from one animal. Figure 1.6 shows that per capita beef consumption has decreased since 1970 by 15 percent. This indicates that the American population is consuming less beef per person, but more people are eating beef, logical since there are more people in the U.S. now than in 1970. Despite this, CH<sub>4</sub> emissions from cattle have remained on an upward trend, even as productivity has increased. Without a conscious effort to raise productivity in order to reduce CH<sub>4</sub> emissions, therefore, no CH<sub>4</sub> reductions will occur. Again, raising productivity is only capable of reducing CH<sub>4</sub> emissions immediately if fewer animals are in demand.

### **2.5.2. PROSPECTS FOR CHANGING HUMAN DIET**

Manipulating milk and, particularly, beef prices in ways other than those suggested above could provide strong forces for mitigating CH<sub>4</sub> emissions. The U.S. has 0.43 cows per capita, twice as much as the rest of the world, at a ratio of 0.21 to one (see Table 2.1.). In addition, the U.S. has an average standard of living much above that of many other countries in the world. This means that lowering the supply of beef to American consumers is in fact possible without reducing the survival probability of the people. This would result in changing the diet of Americans. Subsidizing other meats, or providing education to the general public on the social and health benefits of eating less or no meat are options that could have an effect on beef consumption. Beef cattle emit 2.7 times more CH<sub>4</sub> than dairy cattle (see next chapter), and dairy products are generally less easily replaced than beef products, the emphasis on changing diet should be placed on moving away from beef.

## **2.6. ALTERNATIVE STRATEGIES**

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<sup>137</sup> IPCC, *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change*, 1996.

<sup>138</sup> USDA, Economic Research Service, *Red Meat Yearbook*, 1997.

The alternative strategies presented here result partly from methods recommended by the IPCC, but also from examining cattle management practices. Though the benefit of improving cattle management is much more difficult to quantify, as there are many variables, several aspects of this area can be improved. Strategies to reduce CH<sub>4</sub> emissions that have not currently been examined in the U.S. include options that are often discussed in conjunction with greenhouse gas reduction on a much larger scale. Taxes, permits and regulations are strategies that can be applied directly to mitigating CH<sub>4</sub> from cattle. Subsidies to encourage herd reduction and/or low CH<sub>4</sub> or CH<sub>4</sub> reducing practices may also have a large impact on cattle management.

### 2.6.1. TAXES AND PERMITS

Taxes could be powerful tools for mitigating cattle CH<sub>4</sub> emissions because of their effectiveness. Cost of mitigation is often the first factor considered by those implementing strategies. Economic instruments for mitigation are generally considered “more cost-effective than other approaches to limit greenhouse gas emissions.”<sup>139</sup> Using taxes to discourage excess CH<sub>4</sub> emissions is the primary goal in this case, although the additional benefits exist. For example, tax revenues can be used to finance subsidies or technology for CH<sub>4</sub> reduction. Taxes can be placed on CH<sub>4</sub> emissions when emissions are above a certain level, or simply per unit emissions, to create an incentive for farmers to reduce emissions directly, and also on product consumption in order to discourage demand.

Although *permits* are in fact not necessarily dependent on economic forces, they can be used in a similar manner to taxes, by acting as an incentive for reducing CH<sub>4</sub> emissions. Permits could be granted depending on supply and demand of beef or milk, meaning that farmers could be allowed to breed animals/emit CH<sub>4</sub>, based on the extent of supply saturation of cattle products. This could potentially act as an incentive to eliminate some herds, reducing total cattle numbers. Permits might be more effective than taxes in achieving specified emissions targets, but taxes provide greater certainty of control. A tradable permit system, between farms could also be introduced. For a tradable permit system to work well, competitive conditions must exist in the permit and product markets.<sup>140</sup> Permits allowing emissions from

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<sup>139</sup> IPCC, Technical Paper I, 6.

<sup>140</sup> IPCC, Technical Paper I, 70.

cattle are difficult to specify as, again, monitoring CH<sub>4</sub> emissions is difficult and changing or manipulating emissions from individual animals is even more difficult if the effect needs to be immediate.

### 2.6.2. REGULATIONS AND SUBSIDIES

Since the ultimate goal is to find a solution to reducing CH<sub>4</sub> that can be applied quickly in order to avoid the potential onset of the effects of climate change, regulations may be an appropriate mitigation option. Regulations in this case could be in the form of limits to how many animals can exist in the U.S., or even how many animals one rancher can own. In addition, because feed quality has an effect on the amount of CH<sub>4</sub> emitted, set nutrients levels in feed should be regulated. There could also be regulations determining how manure is to be collected and stored, so that any liquid systems are covered lagoons, and dry systems are plugflow or mixed tank digesters. Because these types of systems are so much more efficient than any other manure storage system, regulating their implementation is a simple method for reducing CH<sub>4</sub> emissions from animal waste. Without further technological advances, these systems could abate the most amount of CH<sub>4</sub> from manure possible to abate.

To ensure the adherence to these regulations, subsidies could be used. However, providing farmers and ranchers with a monetary incentive to reduce CH<sub>4</sub> emissions implies that there is a high cost to reducing CH<sub>4</sub> emissions, which will mean that opportunities to reduce will most likely otherwise be avoided. Subsidies are good for initiating action, but problematic as they redirect emphasis of mitigation away from CH<sub>4</sub> reduction. If greenhouse gas reduction is not the ultimate reason for mitigation, these gases may be emitted from other simultaneous practices without being considered a problem. Also, subsidies are currently used in some countries to encourage activities that *emit* greenhouse gases, and therefore the implementation of other subsidies to *reduce* greenhouse gases could be difficult to justify.<sup>141</sup> Despite this fact, subsidies could be useful for financing CH<sub>4</sub> mitigation technology research, or if no other options work.<sup>142</sup>

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<sup>141</sup>IPCC, Technical Paper I, 69.

<sup>142</sup>IPCC, Technical Paper I, 69.

### 2.6.3. OTHER OPTIONS

While chemical and economic manipulation may *potentially* work to reduce CH<sub>4</sub>, there are a few simpler steps that can help improve efficiency. These include maintaining proper veterinary care, appropriate sanitation and ventilation of living quarters, sufficient nutrition and comfort for the animals. Under such conditions animals will digest feed more efficiently.<sup>143</sup> Such steps should especially be taken in countries or areas where nutritional supply does not meet demand, because in developed countries improvements in animal performance have led to reductions in overall animal numbers and therefore reductions in CH<sub>4</sub> emissions.

Finally, culling cattle remains an option in the U.S. This could happen without regard to change in consumer demand. In fact, during the recent “Mad Cow Disease” scares in the United Kingdom, culling animals was announced as an option for abating the threat to humans for contracting the disease. CH<sub>4</sub> emissions from cattle can also be considered a threat to human health, since climate change has been expected to facilitate the spreading of diseases.<sup>144</sup> Despite the fact that CH<sub>4</sub> production in the rumen can be mitigated, therefore *directly* approaching mitigation relative to the other options, this and all other options are simply ways to *indirectly* deal with the problem. The only truly direct option is to reduce the polluters, in this case by culling cattle herds.

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<sup>143</sup>EPA (October 1993) 5-26.

<sup>144</sup> from the White House Conference on Global Warming, October 6, 1997.

## 2.7. INTERNATIONAL ISSUES

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Lack of effectiveness of the ruminant CH<sub>4</sub> reduction strategies in the U.S. can be due to poor techniques and lack of education for farmers and ranchers, but also the fact that the balance between beef and dairy productivity and emissions may possibly have reached its most efficient level, according to CH<sub>4</sub> experts in the EPA<sup>145</sup>. CH<sub>4</sub> emissions from cattle remain a problem, however, and therefore it is important to see what the opportunities are elsewhere in the world. The use of Joint Implementation programs is a way to fund CH<sub>4</sub> reduction projects emissions in other countries where the cost for such strategies is lower than in the U.S., while giving the U.S. credit for the reductions.<sup>146</sup> JI involves several countries in a technical cooperation to meet the goals of the 1993 Convention.<sup>147</sup> The process is built on one country, or a firm in that country, sponsoring emission reduction actions in another country, in addition to the first country's other reductions. The first JI projects were piloted after the COP-1/FCCC meeting in the spring of 1995.

According to the IPCC, JI is a cost-effective method for developed countries to fund greenhouse gas emission reduction projects in other countries while helping meet local development needs.<sup>148</sup> In addition, JI is considered a *first step* toward establishing an international tradable quota system for greenhouse gases, which does not exist as of yet. Technology transfer in exchange for other services and tradable quotas<sup>149</sup> can also be options for mitigation on the international level. In some cases the technology developed for the sponsoring country may not fit the needs or address the issues present in the developing country. Allowing international trade of emission quota, could be effective while reducing the cost of achieving compliance with national emissions limits, regardless of their initial allocation. Each country would be expected to reduce its emissions, or to purchase quota from other countries, so that the sum of these two was not more than national emissions limits.<sup>150</sup> Under an international tradable quota system, participating countries could use whatever domestic policies available to achieve compliance. So

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<sup>145</sup> Personal communication with Mark Orlic, Office of Air and Radiation, USEPA, January 1996.

<sup>146</sup> However, one of the main disadvantages of Joint Implementation currently is that in fact the sponsoring country is not granted credits for reducing emissions.

<sup>147</sup> IPCC, Technical Paper I, 71.

<sup>148</sup> IPCC, Technical Paper I, 72.

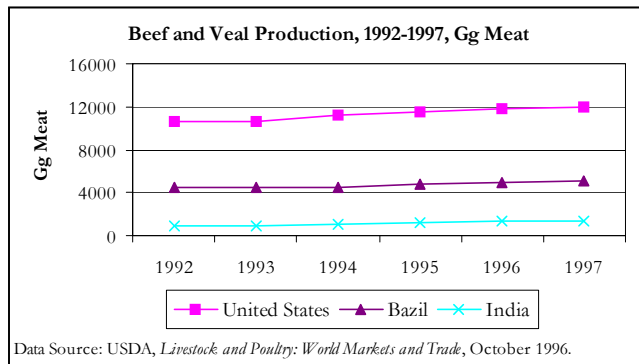
<sup>149</sup> Tradable quotas are when a country that does not emit its allotted amount of greenhouse gas is allowed to sell this share to another country.

<sup>150</sup> IPCC, Technical Paper I, 70.

far this has only been done on a small scale with CFC emissions. For this reason, it is important to further evaluate the effect of these options. Trading emissions, quotas or technology are approaches that are anticipated to be the focus at FCCC/COP-3.

Socioeconomic considerations may often prevent reduction in animal numbers in developing countries, as this may reduce the standard of living for those dependent on cattle products. Alternative sources of income would in this case have to be provided along with the CH<sub>4</sub> reduction program.<sup>151</sup> Such economic issues must be assessed and understood prior to the consideration of CH<sub>4</sub> reduction programs internationally. Despite this, any strategy for improving livestock production must consider implications for global climate change, no matter what country or what economic situation.<sup>152</sup>

**Figure 2. 1**



<sup>151</sup>EPA (1991) 20.

<sup>152</sup>EPA (1991) 37.

Figure 2. 2

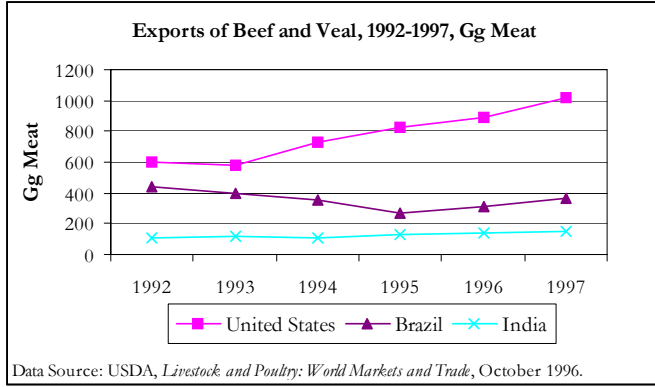


Figure 2. 3

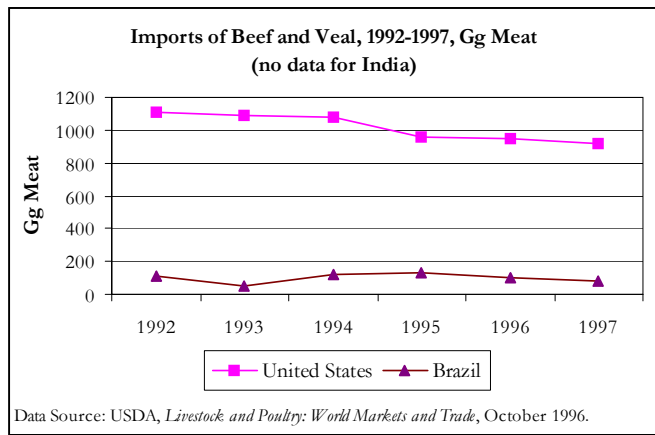
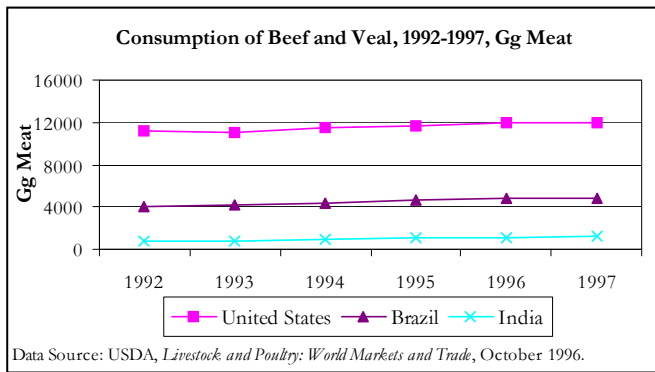
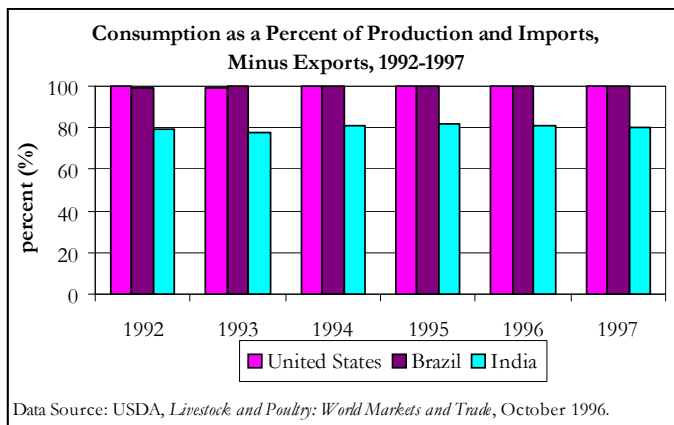


Figure 2. 4



In the U.S. the cattle industry is well supported by high demand for products, and subsidies from the government. However, in other countries this may not be the case (see Figures 2.1-2.5). Placing a tax on either the farmer or the consumer could be harmful here.<sup>153</sup> Climate change policy must therefore always be considered in the context of existing economies.<sup>154</sup> While emissions reductions could be profitable, as well as effective in developed countries in both the long and short term, such outcomes are not necessarily possible in developing countries. In applying economic instruments to limit greenhouse gas emissions at the international level, equity must be considered. The U.S. and other Annex-I countries would be responsible for reducing cattle numbers and methanogenesis, while developing countries approach the problem by raising the quality of the feed, and improving cattle management. Animals in developing countries are often grazing on poor quality rangelands and therefore producing more CH<sub>4</sub> per unit of feed consumed. If higher quality feed is provided, through technology transfer for example, these emissions would be substantially reduced. However, the method of manipulating methanogenesis may be more applicable in developed countries with large automated feedlots where each animal can be physically reached, and individual diets controlled.<sup>155</sup>

Figure 2. 5



Global food requirements must be satisfied in addition to the implementation of CH<sub>4</sub> mitigation methods. Farmers must also accept the agricultural technologies supplied. Certain goals need to be met for

<sup>153</sup> IPCC, Technical Paper I, 69.

<sup>154</sup> IPCC, Technical Paper I, 69.

<sup>155</sup> EPA (April 1993) 6-24.

any international mitigation program: (1) sustainable agricultural production must be achieved, or even enhanced, (2) net profits or other benefits must go to the farmer, and (3) the agricultural products must be accepted by the consumers in the country.<sup>156</sup> However, the current expectation is that there will be higher reductions in national emissions for industrialized countries, and slower rates of emissions growth for developing countries. The theory advocates distributing the burden equitably among Annex-I countries. This has been the cause of the previously mentioned debate in the U.S. because the fear is that developed countries will be the only ones to carry the burden.

<i>SECOND SUMMARY TABLE OF MITIGATION STRATEGIES</i>		
<b>TYPE</b>	<b>DESCRIPTION</b>	<b>EFFECTS</b>
<b>MANIPULATION HUMAN CONSUMPTION OF CATTLE PRODUCTS</b>	Subsidize alternative meats or protein products.	Lower demand and therefore population size of beef and dairy cows.
	Lower supply of beef.	Reducing consumption, and thereby lower the number of cattle.
	Provide education to the general public on the social and health benefits of eating less or no meat.	Lower demand for beef.
<i>Taxes</i>	Tax CH <sub>4</sub> emissions per unit of emission, or above a certain emission level.	Increase awareness of CH <sub>4</sub> production by cattle, educate about the importance of reducing emissions.
<b>PERMITS</b>	Grant product making permits depending on supply and demand balance for cattle products.	Limit excess production, lead to eventual reduction in cattle populations.
	Grant permits allowing CH <sub>4</sub> emissions.	
<b>REGULATIONS</b>	Limit how many cows are allowed in the U.S., and/or per rancher.	Reduce national cattle population size.
	Set nutrient levels for animals.	Efficient digestion, lowered CH <sub>4</sub> production.
<b>SUBSIDIES</b>	Subsidize farmers to help enforce regulations.	
<b>PROPER CARE</b>	Maintain proper veterinary care, sanitation, ventilation in living quarters, sufficient nutrition, comfort for the animals	Efficient digestion, lowered CH <sub>4</sub> production.
<b>CULLING</b>	Culling herds for CH <sub>4</sub> reduction, without regard to other factors.	Reduced CH <sub>4</sub> emissions.
<b>JOINT IMPLEMENTATION</b>	developed country sponsoring CH <sub>4</sub> emissions reductions in developing country	US already has relatively low CH <sub>4</sub> per unit of product, can help improve cattle management techniques in other countries

<sup>156</sup> IPCC, Technical Paper I, 70.



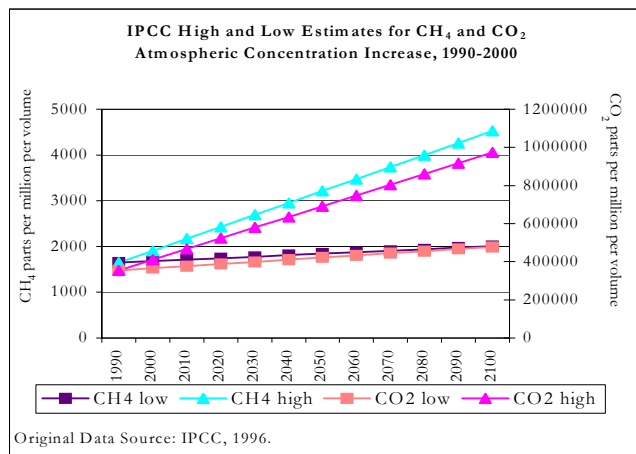
## Emissions Changes from Reduction Methods

The following chapter presents calculations based on data of U.S. CH<sub>4</sub> emissions from beef and dairy cattle in attempt to show the effects of the reduction strategies presented in the previous chapter.

### 3.1. RESULTS WITHOUT MITIGATION

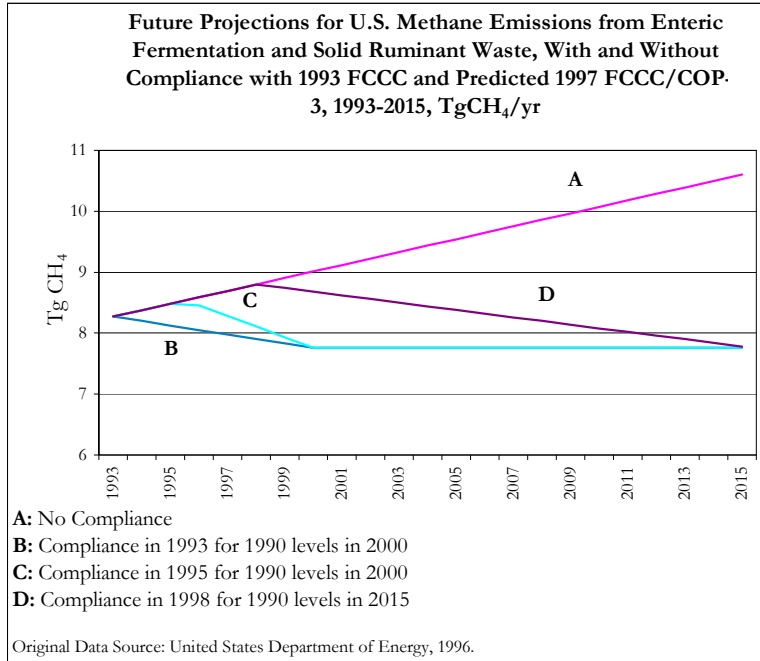
By looking at CH<sub>4</sub> data and the constraints associated with various mitigation strategies presented in the previous chapter, some evidence of the potential strength of the CH<sub>4</sub> reduction strategies should be clear. Current trends show increasing CH<sub>4</sub> emissions and atmospheric concentrations (Figure 1.2). Predictions of CH<sub>4</sub> concentrations without any mitigation have been made by the IPCC. Calculations are presented here based on those predictions for atmospheric concentrations of CO<sub>2</sub> and CH<sub>4</sub> (Figure 3.1). The range of suggested increases for CO<sub>2</sub> is 35 to 170 percent, and for CH<sub>4</sub> it is 22 to 175 percent.<sup>157</sup> In addition, calculations have been made based on potential linear increases for U.S. CH<sub>4</sub> emissions from enteric fermentation, and waste from cattle, originally reported by the United States Department of Energy. The reductions that were needed in the U.S. for compliance with 1993 FCCC agreements to reduce greenhouse gas emissions to 1990 levels by 2000, beginning in 1993 and 1995 can be seen in Figure 3.2, as can the reductions needed for a return to 1990 levels by the year 2015, beginning in 1998.

Figure 3. 1



<sup>157</sup> IPCC, *Climate Change 1995: The Science of Climate Change*. 23.

Figure 3. 2



The above figures indicate that significant changes will have to be made in the U.S. in the future, should no mitigation be implemented at this time. Figure 3.2. shows the result of the fact that little action was taken after the 1993 FCCC. Had action been taken in 1993, or even 1995, the amount to reduce would have been less than it is now in 1998. For this reason, the following section presents the effects of the previously suggested reduction methods, and the next section indicates how these effects can be applied to the data for Figures 3.1 and 3.2.

### 3.2. ORIGINAL DATA SOURCE

In order to fully assess the potential impact of the reduction methods outlined in the previous chapter, it is necessary to perform calculations. Using data from the United States

	Low	High	Index	Percent
Dairy	1.2	1.8	1	27
Beef	3.2	4.8	2.7	73

Data Source: USEPA, 1990.

Department of Energy's Energy Information Administration and extending this to 2000 allows a better view of what the magnitude of

effects of the methods. For the purpose of this study only a selection of emissions reduction scenarios are calculated, mostly due to lack of available data. The data are divided into beef and dairy cattle proportions, based on the information from the USEPA, which is presented in Table 3.1. Here, the USDOE/EIA data for both beef and dairy cattle has been divided into their respective emissions proportions to analyze each separately. Emissions from dairy cattle contribute 27 percent of the total, and beef cattle contribute 73 percent.

### 3.2.1. METHANOGENESIS MANIPULATION

The following figures show the changes possible by altering the process of methanogenesis in the rumen of beef and dairy cattle. The figures indicate that various reductions, expected from the implementation of several different CH<sub>4</sub> reduction strategies, have the potential to affect emissions substantially. The methanogenesis manipulation techniques suggested by the EPA are in some cases only ideas, or developed technology that has yet to be tested on actual animals. The reduction percentages suggested are, similarly, often calculated values that have not been observed. The data in Figures 3.3 and 3.4 are those on which the rest of the calculations are based.

Figure 3. 3

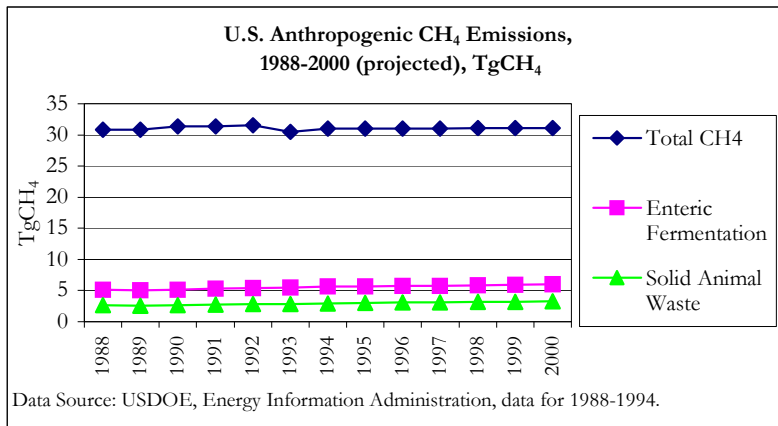
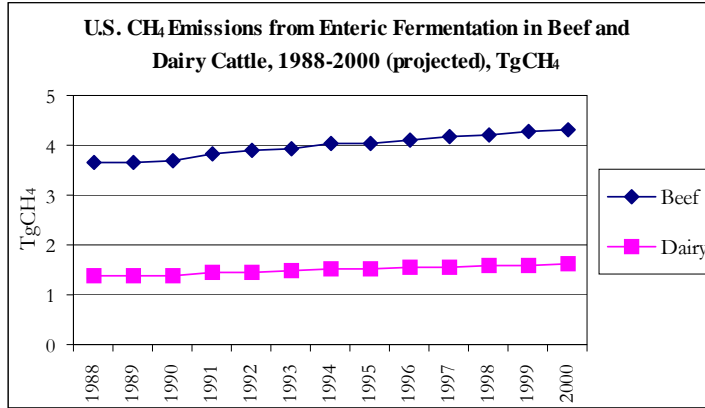


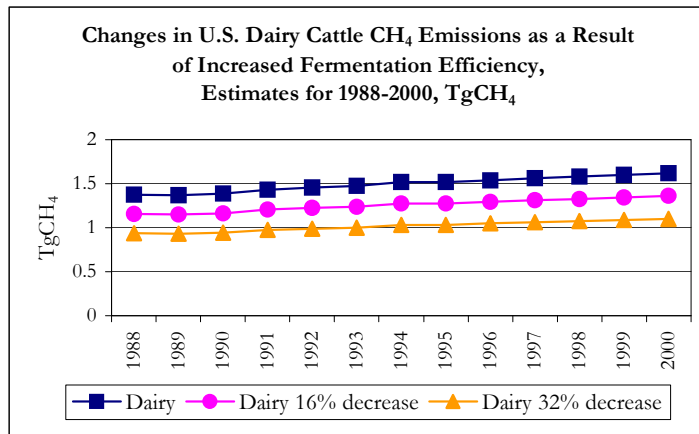
Figure 3.3 shows the original data from 1988-94, projected to 2000.

Figure 3. 4



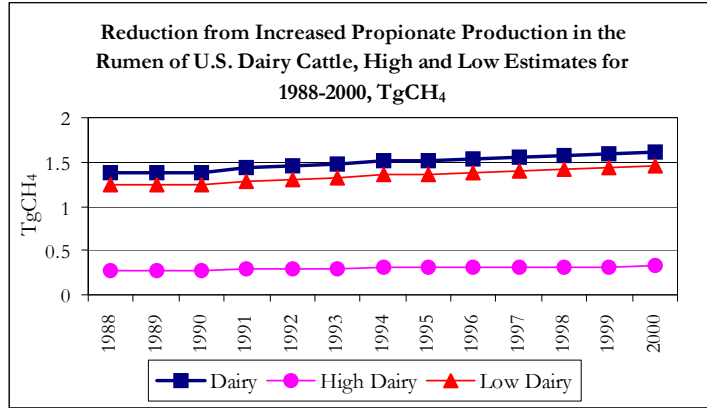
Beef cattle emissions are 2.7 times those of dairy cattle, as is shown in Table 3.1. In Figure 3.4 this can be seen more clearly. By applying the reductions possible, as seen in the First Summary Table in Chapter 2, the following figures display what emissions from dairy and beef cattle would have been since 1988, had the reductions been applied then.

Figure 3. 5



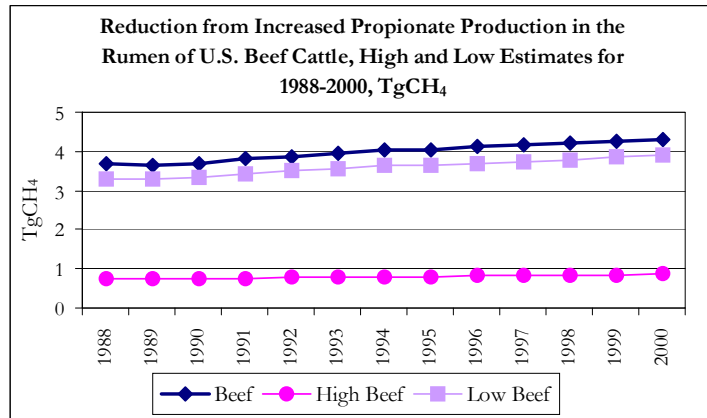
Increased fermentation efficiency, which is the possible outcome of several suggested methods, could provide a 16-32 percent decrease in CH<sub>4</sub> emissions from dairy cattle.

Figure 3. 6



Inducing an increase in propionate production in the rumen of beef and dairy cattle is also a method that can increase the efficiency of digestion, thereby reducing the CH<sub>4</sub> emissions. The decrease in emissions can be seen in Figures 3.6 and 3.7.

Figure 3. 7



### 3.2.2. PRODUCTIVITY MANIPULATION

The figures in this section show the changes in emissions caused by increases in productivity.

With different methods, CH<sub>4</sub> emissions change differently.

Figure 3. 8

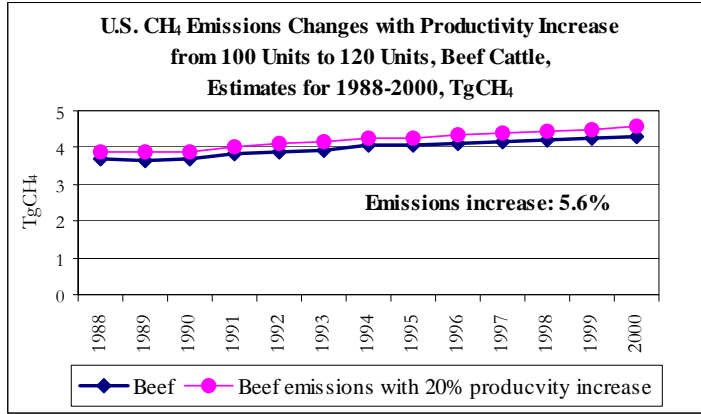
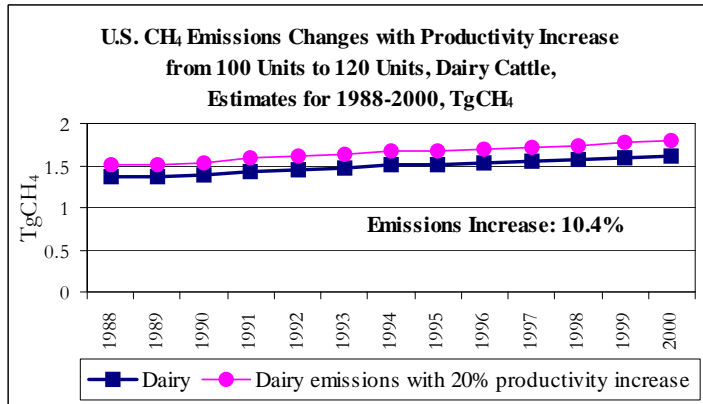


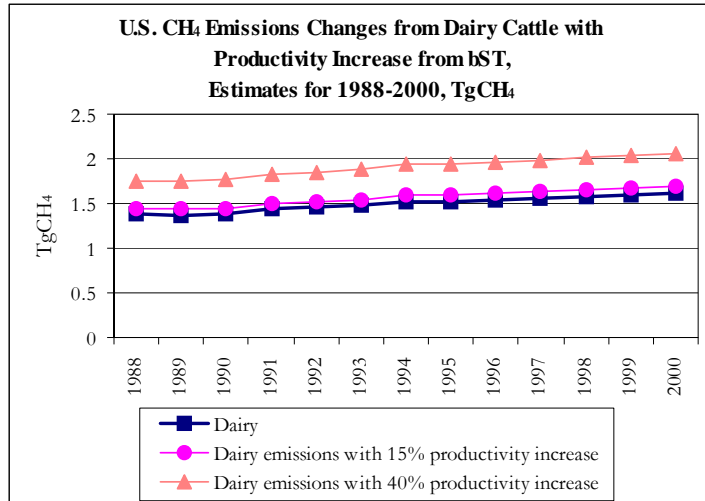
Figure 3.8 shows the effects of increasing productivity by 20 percent, which is calculated by creating an index of 100 for the current level of productivity, and increasing it to 120. Despite the fact that emissions per unit of product decrease, total emissions increase by 5.6 percent.

Figure 3. 9



Similarly as for Figure 3.8, emissions per unit of product decrease. Total emissions also increase here, by 10.4 percent.

Figure 3. 10



Again, in Figure 3.10 it can be seen that an increase in productivity has the effect of increasing CH<sub>4</sub> emissions. Productivity increases need to be accompanied by a decrease in U.S. cattle population size. Alone, culling cattle could be effective at reducing CH<sub>4</sub> emissions. In fact, productivity increase to reduce CH<sub>4</sub> emissions can be seen as a misleading concept. In order to reach 1990 levels in 2000, over 16 million head of cattle would have to be culled. This is 15 percent of the U.S. 1997 herd, as can be seen in Figure 3.11.

Figure 3. 11

Number of Cows to Reduce to Reach 1990 Emissions Levels by 2000 for Cattle CH <sub>4</sub> Emissions in the United States.	
1995 emissions rate:	7.69E+08 TgCH <sub>4</sub> /head of cattle
Projected emissions in 2000 without compliance:	9.012 TgCH <sub>4</sub>
Difference with 1990 emissions levels:	1.252 TgCH <sub>4</sub>
Number of cows to be reduced to reach 1990 emissions levels:	
	$1.252\text{TgCH}_4 / 7.69\text{E}+08\text{TgCH}_4/\text{head}$
	<b>=16 279 772 cows</b>
	<b>=15 percent of 1997 herd</b>

### 3.3. EVALUATION OF RESULTS

Reductions in CH<sub>4</sub> emissions are possible with an increase in fermentation and digestion efficiency. Productivity increases, however, are not capable of producing CH<sub>4</sub> reductions on their own. Cattle culling must be an element of these CH<sub>4</sub> mitigation strategies, therefore. Figure 3.2 shows that the CH<sub>4</sub> emissions reductions needed to meet 1990 levels were 10 percent in 1995 and 6 percent in 1993. In 1998, the reduction needed from the current emissions is 13 percent. While reductions of 6 to 13 percent appear possible according to the predicted data, the feasibility of implementing these mitigation strategies may not always exist. The next chapter looks at the effectiveness and potential of these strategies.

## Analysis and Discussion

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*This chapter evaluates the potential and barriers to the key reduction strategies currently suggested in the United States, and discusses areas in which policymakers should look for further reduction options. An analysis of the data presented in the previous chapter accompanies throughout.*

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### 4.1. EVALUATION OF MITIGATION APPROACHES

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The mitigation strategies presented in Chapter 2 represent the results of previous and current research efforts in the United States on the subject of reducing CH<sub>4</sub> emissions from cattle. The success of these mitigation strategies is a necessity if the U.S. is considering enforcing CH<sub>4</sub> mitigation from cattle as a way to reduce greenhouse gases.

In summary, the U.S. currently proposes:

1. mitigating CH<sub>4</sub> production directly in the rumen and thereby manipulating CH<sub>4</sub> emitted per animal;
2. manipulating CH<sub>4</sub> emitted per unit of product;
3. manipulating the cattle product market via price strategies;
4. genetically engineering cattle to produce more beef and milk and therefore less CH<sub>4</sub> per unit of product; and
5. sponsoring reducing CH<sub>4</sub> emissions in another country, rather than in the U.S.

This study also proposes:

1. manipulating human demand for cattle products;
2. taxing CH<sub>4</sub> emissions;
3. taxing product consumption and/or production;
4. regulating cattle product manufacturing;
5. regulating cattle population size; and
6. culling cattle herds.

### 4.2. EFFECTIVENESS OF STRATEGIES – POTENTIAL AND BARRIERS

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#### 4.2.1. TECHNICAL OPTIONS

As with any pollution problem, emissions from the source should be reduced first. The processes that reduce CH<sub>4</sub> production in the rumen are therefore theoretically the best way to reduce the problem. Changing the internal microbial processes of the rumen is desirable as it attacks the source of the CH<sub>4</sub> directly and lowers emissions per cow. However, an examination of the First Summary Table in Chapter 2,

and the calculations in Chapter 3 suggest that reductions in CH<sub>4</sub> emissions are not currently feasible through the manipulation of the methanogenic process. The options for enteric fermentation mitigation are problematic, as certain processes have been shown to generate more CH<sub>4</sub>. It is possible that hormone and feed supplements can increase the *efficiency* of the growth of microbes needed for methanogenesis, which means less CH<sub>4</sub> production for that process.<sup>158</sup> However, any nutrient required in the growth of microorganisms will also thereby increase CH<sub>4</sub> generation per unit of feed consumed.<sup>159</sup> Despite the fact that *microbial growth efficiency* will reduce methanogenesis per unit of feed digested, increased nutrient demand will reverse this gain and the result will be an increase in CH<sub>4</sub> production per animal.<sup>160</sup> The EPA has discovered that the overall effects of chemical additives, which primarily increase the efficiency of fermentative digestion by decreasing methanogenesis per unit of carbohydrate degraded in the rumen, to be problematic. According to a 1991 report, methanogenesis per animal may also be *increased* through the higher digestion rates.<sup>161</sup>

The more attractive option to the EPA is to increase beef or milk productivity of each individual animal, which indirectly reduces CH<sub>4</sub> contributions by creating lower emissions per unit of product. This method is more attractive to the EPA because, for one, it has a self-contained incentive for farmers. With greater productivity per animal, the same amount of milk or beef can be produced with fewer animals, hence with less cost to the farmers. However, the largest barrier to the implementation of this strategy is that reducing cattle numbers must be a prerequisite if CH<sub>4</sub> emissions are to be reduced. Without a cap on the cattle population, emissions would theoretically remain at constant levels, and the only CH<sub>4</sub> reductions would be per unit of product, as can be seen in Chapter 3. Since the ultimate goal is to reduce atmospheric CH<sub>4</sub> concentrations to stop the potential impact of global climate change, a reduction in emissions per unit of product is not a significant measure. In fact, Figures 3.9 to 3.11 show that increasing productivity greatly increases CH<sub>4</sub> emissions if population size reduction does not accompany the strategy. While there is little mention of this necessity in EPA studies, cattle carcass weight has increased significantly over the past years, and yet the amount of cattle consumed has remained stable. This indicates that an increase in productivity per animal could create an incentive to reduce the number of animals needed to meet the

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<sup>158</sup>EPA (1991) 17.

<sup>159</sup>EPA (1991) 46.

<sup>160</sup>EPA (1991) 59.

demand. Therefore the long-term effect could be a small reduction in CH<sub>4</sub> emissions and cattle populations.

Emphasizing productivity, however, focuses the efforts away from reducing CH<sub>4</sub> emissions. The potential problem with such an approach is that it may also encourage beef consumption. Increasing productivity is a way to meet the demand for cattle products. Without the demand for cattle there would be less excess CH<sub>4</sub> emissions. By increasing cattle productivity, demand for the products is assumed to be rising. In order to raise demand, the beef industry might attempt to raise demand for American beef elsewhere in the world, which is actually occurring, judging by Figure 1.8. According to the EPA, however, increased production per animal and turnoff at an earlier age could theoretically have a much greater effect on total CH<sub>4</sub> production than reduction of methanogenesis in digestion of individual animals.<sup>162</sup> Unless otherwise controlled, however, farmers could easily enjoy increased productivity while not reducing their herds. And since *reducing CH<sub>4</sub> emissions per product does not reduce overall CH<sub>4</sub> emissions*, the only way raising productivity would be helpful for controlling greenhouse gas emissions, therefore, would be if the number of animals were also reduced. Furthermore, CH<sub>4</sub> emissions per unit of product in the U.S. is (already) generally much lower than in other countries.<sup>163</sup> Increasing productivity is therefore not the place for the U.S. to look for ways to reduce emissions.

#### 4.2.2. ECONOMIC AND REGULATORY OPTIONS

Reducing CH<sub>4</sub> emissions by manipulating the milk and beef pricing gauges has been shown to have only a small effect on reducing CH<sub>4</sub> emissions. In fact, this approach may not be viable unless a change in consumer behavior, such as a decrease in the consumption of milk, and especially beef, takes place. Table 3.1 shows that beef cattle emit 2.7 times the quantities of CH<sub>4</sub> that dairy cattle emit. This indicates that any economic approaches should focus on reducing beef consumption. The strategies suggested in 2.4.1. and 2.4.2. do not attempt to do this directly, and therefore should not be implemented.

A tax as an instrument to directly mitigate the amount of CH<sub>4</sub> emitted may also be difficult to implement. First, monitoring emissions is difficult because it cannot effectively be done unless each

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<sup>161</sup>EPA (1991) 59.

<sup>162</sup>EPA (1991) 60.

<sup>163</sup>EPA (October 1993) 5-13.

animal is placed in a chamber, such as the one described in Appendix III.<sup>164</sup> Monitoring would have to take place on a consistent basis, for all cattle herds nationwide. The tax amount would be dependent on the amount emitted, and not being able to monitor this amount would make the tax impossible. In addition, small herds that emit quantities below the taxable level could potentially be emitting more CH<sub>4</sub> per animal, unless emissions are taxed per animal. This would be even more difficult unless better methods for measuring emissions quantities are established. Similarly, a tax system would be relatively useless if it didn't also prevent participation in any activities that indirectly increase greenhouse gas emissions.<sup>165</sup>

Without strict regulations to enforce active efforts to reduce CH<sub>4</sub> emissions, cost and ease of implementation of mitigation options are almost as important as the actual amount of CH<sub>4</sub> reduced. Eventually those responsible for the cattle, i.e. farmers and ranchers, will have to *choose* their method of CH<sub>4</sub> reduction, creating an incentive based system. A problem with using economics as an incentive for CH<sub>4</sub> reduction is that economic changes may potentially imply further regulatory changes, causing a delay in implementation and approval. Economic options necessitate training and education for farmers, as the information available to them currently is limited.<sup>166</sup>

#### 4.2.3. WASTE OPTIONS

CH<sub>4</sub> mitigation options for waste emissions are evaluated not only in terms of quantity of CH<sub>4</sub> reduced, but also technical feasibility on farms, consistency with current practices, and opportunity for profitable operation.<sup>167</sup> Based on these criteria, covered anaerobic lagoons are considered the best option. As explained in Chapter 2, liquid systems are not entirely ideal for reducing CH<sub>4</sub> emissions from manure, as dry systems can reduce a greater percent of the emissions. However, since the ultimate goal is to have greatest reductions possible while satisfying other criteria, and since the most attractive option for farmers will be the easiest one to implement, liquid systems will be the most popular. This is important if mitigation is incentive based, because liquid management systems have the greatest potential for profitability of all the options for anaerobic digestion of cattle manure.

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<sup>164</sup> IPCC, Technical Paper I, 70.

<sup>165</sup> IPCC, Technical Paper I, 71.

<sup>166</sup> EPA (October 1993) 5-46.

<sup>167</sup> EPA (October 1993) 6-42.

Furthermore, liquid based systems will be most common as a result of environmental regulations. As mentioned in Chapter 2, the threats of groundwater pollution from other manure storage facilities have caused a decision in the U.S. to shift the disposal of livestock manure to anaerobic lagoons in order to comply with the U.S. Clean Water Act (CWA).<sup>168</sup> Uncovered liquid based manure storage systems are the source of 80 percent of the CH<sub>4</sub> emitted from animal waste.<sup>169</sup> The emissions from cattle manure may therefore increase significantly over the next decade unless the lagoons are covered and the CH<sub>4</sub> collected properly.<sup>170</sup> The use of CH<sub>4</sub> recovery for these lagoon storage facilities is dependent on potential environmental regulations, as well as energy prices, the amount of energy recovered (which depends on the size of the farm, the number of animals in the herd) and the cost of the recovery system. Because of these factors, recovering CH<sub>4</sub> emissions from anaerobic decomposition should be regulated to be effective.

Barriers to CH<sub>4</sub> recovery systems include lack of information. This can lead to mechanical and operational problems, biological restrictions from geographical differences,<sup>171</sup> and economic and regulatory obstacles. For example, a small farm will generally not find CH<sub>4</sub> recovery economically sensible, since the quantity of CH<sub>4</sub> collected will not provide a significant amount of power relative to the needs of the farm. Larger farms may be able to recover enough CH<sub>4</sub> to run certain processes or machinery. Dairy farms in the U.S. generally have fewer than 500 cows each. At current electricity prices, CH<sub>4</sub> collected from the manure would therefore not be profitable. Despite these problems, however, there are opportunities for overcoming the barriers. Information can easily be made available to the farmers so that technical difficulties do not hinder the proper operation of the systems. Just as for enteric fermentation, economics could have a significant influence on the mitigation options used. Raising the price of electricity could be the solution to creating a demand for CH<sub>4</sub> collection, which would result in the livestock industry being a more efficient and environmental one. An energy tax would also help reduce CH<sub>4</sub> emissions, as relatively small increases in energy prices have been shown to have a large effect on the amount of CH<sub>4</sub> recovery that takes place.<sup>172</sup>

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<sup>168</sup>EPA (October 1993) 6-2.

<sup>169</sup>EPA (October 1993) 6-2.

<sup>170</sup>EPA (October 1993) 6-1.

<sup>171</sup>Some systems function worse in certain climates, for example.

<sup>172</sup>EPA (October 1993) 6-43.

#### 4.2.4. INTERNATIONAL OPTIONS

International options may be among the most successful for a reduction in cattle CH<sub>4</sub> emissions, primarily as the issue in a global one, and therefore worldwide collaboration is fundamental. Joint Implementation may be the most readily available of these options, as it is currently under discussion in the international policy community.

Other international options that need to be considered include monitoring global beef demand and supply so that excess meat does not get manufactured and end up in storage or stock houses, not getting used. Product that will not be consumed domestically should be redistributed to those countries where food supplies are not able to meet demand. Also, in countries where cattle are in competition with wildlife for land and resources, such as many African nations, farming of native animals to replace beef should be advocated. For example, in Botswana, farming ostriches has been shown to be both profitable and healthier as the meat is much lower in cholesterol.<sup>173</sup> The native species are adapted to the conditions resulting from the semi-arid climate, and therefore do not have the same death rate as cattle in droughts.<sup>174</sup> This can be practiced globally, and avoid many other environmental harms associated with cattle.

#### 4.2.5. HUMAN CONSUMPTION MANIPULATION

The IPCC estimates that Annex-I countries can reduce 21 percent of global CH<sub>4</sub> emissions from ruminants through mitigation,<sup>175</sup> and the EPA estimates that U.S. CH<sub>4</sub> emissions can be reduced 12-22 percent in the U.S. by the year 2000.<sup>176</sup> However, these statements are made based on indirect reduction strategies. The analysis has shown that in fact many of the options currently discussed do not work, and if they *can* work, the technology is not available or possible. With these concerns in mind, it is almost possible to forget the most obvious way to reduce CH<sub>4</sub> emissions, which is to cut the source: cattle. By culling cattle, the U.S. could easily meet 1993 Convention levels for CH<sub>4</sub>. Culling beef cattle would be the most convenient and effective way to achieve the reductions, as equivalent substitutes for beef exist. Changing human beef and dairy consumption or culling animals could have significant additional benefits

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<sup>173</sup> Personal communication, Maun, Botswana, fall 1995.

<sup>174</sup> Personal communication, Maun, Botswana, fall 1995.

<sup>175</sup> IPCC Working Group II, *Technologies, Policies and Measures for Mitigating Climate Change*, IPCC Technical Paper I for the United Nations Framework Convention on Climate Change, November 1996. 11.

<sup>176</sup> EPA (October 1993) 5-1.

apart from CH<sub>4</sub> emissions reduction. One benefit is health improvement from better diets caused by reduced beef consumption.

Overall, strategies apart from culling cattle populations cannot be declared effective after analysis. Not only is the technology insufficient, but the direction of the approach is also invalid for numerous reasons. Reducing cattle populations in the U.S. is the most direct and the best way to reduce CH<sub>4</sub> emissions. Despite their potential to address the issue in a similarly direct manner, international options must be considered with regard to justice issues. The U.S. has plenty of food for its inhabitants, as well as a wealthy cattle industry. It is certainly in the U.S. where beef should be reduced, from both the supply and the demand sides.

### 4.3. CONCLUSIONS

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#### 4.3.1. RECALLING THE ORIGINAL QUESTION

The original question was *what impact could a reduction of cattle CH<sub>4</sub> emissions have on reducing greenhouse gases in the United States?* I followed Table 1.5 in order to answer this question. My research began with a hope that reducing CH<sub>4</sub> emissions from cattle would prove to be an effective and viable option for countries to employ in order to meet binding greenhouse gas emissions targets. Through analysis of the issue, I also wanted to assess the overall effectiveness of various mitigation strategies proposed by the EPA. I wanted to see how these strategies were applied, and what the results were. Finally, therefore, I wanted to examine whether these strategies could provide an opportunity for the United States to reduce anthropogenic CH<sub>4</sub> emissions. Should this have been shown to be so, I wanted to see whether these strategies could be applied internationally. The most effective strategy was identified -- culling the U.S. beef cattle population, as the rest of the options were shown to be technologically impossible, ineffective, or otherwise infeasible.

#### 4.3.2. REMARKS

*“CH<sub>4</sub> is an attractive target for greenhouse controls, in part because its relatively short lifetime in the atmosphere – about ten years – allows the atmosphere to respond rapidly to cutbacks.”<sup>177</sup>*

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<sup>177</sup> Science, Vol. 525, June 1991, p. 1496.

Reduction of anthropogenic CH<sub>4</sub> emissions should continue to be advocated. However, mitigation of cattle emissions does not contribute to climate change avoidance to the extent where it is worthwhile. After the analysis in the previous chapters, there are three reasons to explain this conclusion. First, many of the reduction methods described in Chapter 2 are not effective for reducing emissions. The current options have not been shown to have a large effect on reducing CH<sub>4</sub> from cattle, as the emissions are still rising. Similarly, the United States is approaching the issue with an attitude that the market cannot be used as a tool to mitigate emissions. The current strategies considered by the EPA are chosen in an assumption that demand for beef and human diets are inflexible factors, and are not the most effective options for reducing CH<sub>4</sub> emissions. The effects of the strategies suggested in the second part of Chapter 2 would be considerably greater than those proposed by the EPA. However, enforced reductions in the U.S. will most likely not be significant anyway unless animals are culled, as cattle product industries are reaching their most efficient and total consumption is remaining constant. Despite this, every little bit helps. Those options that are simplest and least costly should be implemented, regardless of their total effectiveness. Opportunities to reduce CH<sub>4</sub> internationally still exist, as many countries have not reached the U.S. level of efficiency, and these options should be further investigated and discussed.

My hope is that this analysis has opened the issue for new thought and can serve as a springboard for an evaluation of all anthropogenic greenhouse gas sources. The most significant conclusion to be drawn from my research is that studies such as this one should be done for all anthropogenic greenhouse gas sources and mitigation strategies. The largest source and most effective and feasible mitigation options should be targeted, and money for research to develop new technologies and reduction methods should be placed there. While cattle CH<sub>4</sub> emission reduction technology clearly has several flaws, the amount of reductions possible might also be insignificant compared with those available for other sources of CH<sub>4</sub>. It is therefore not worthwhile to devote more resources to CH<sub>4</sub> mitigation from cattle. For all analyses, the factors that need to be taken into account are: cost of technology, implementation and capital needed; ease of implementation; maintenance effort necessary; effect and effect relative to other strategies. For U.S. cattle CH<sub>4</sub> emissions, the result of this equation is not encouraging.

#### 4.4. RECOMMENDATIONS

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My anticipated recommendation was going to be that policymakers advocate reducing greenhouse gas emissions by mitigating CH<sub>4</sub> from cattle. Instead, I suggest the following steps be taken:

1. *The U.S. should focus its money and research effort elsewhere* – There are other CH<sub>4</sub> sources that are likely to have simpler or less costly mitigation methods.
2. *A complete analysis, such as this one, should be done for all reduction methods so that it is possible to evaluate fully where the most cost-efficient and powerful reductions are* – This would show where the U.S. should begin reducing.
3. *An analysis including all greenhouse gases emitted due to cattle should be completed* – this would give an idea of the total impact of cattle on the environment, and include all greenhouse gas emissions due to effects such as land degradation, and all fossil fuels used to produce beef and milk.
4. *An evaluation of the benefits due to joint implementation should be conducted specifically for reduction of CH<sub>4</sub> emissions from cattle.*
5. *A reduction in emissions by recovering CH<sub>4</sub> from anaerobic decomposition is simple and effective and therefore covered lagoons or plugflow and mixed digesters should be mandated.*
6. *Reducing the U.S. cattle population has numerous significant benefits for other environmental problems and should therefore be considered seriously* -- reducing cattle numbers could be combined with raising native animals as alternatives to beef and providing better quality feed for the remaining cattle.



# Appendix I

## *TERMS AND ACRONYMS*

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Annex-I Countries	Countries considered industrialized by the OECD: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States.
ATI	Appropriate Technology International
CFC	Chlorofluorocarbon
CH <sub>4</sub>	Methane
CO <sub>2</sub>	Carbon Dioxide
COP-1, 2, 3	Conference of the Parties, first, second and third sessions
EIA	Energy Information Administration
EPA/USEPA	United States Environmental Protection Agency
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
IUCC	Information Unit on Climate Change
N <sub>2</sub> O	Nitrous Oxide
OECD	Organisation for Economic Co-operation and Development
PFC	Perfluorocarbon
SF <sub>6</sub>	Sulfur hexafluoride
Tg	Teragrams = 10 <sup>12</sup> grams = Megatonnes = 10 <sup>6</sup> metric tons
Gg	Gigagrams = 10 <sup>9</sup> grams
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
USDOE	United States Department of Energy
WRI	World Resources Institute
ppm	parts per million
ppmv	parts per million per volume
ppb	parts per billion
ppbv	parts per billion per volume



## Resources, Websites and Contacts

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These sources are primarily for those interested in studying this issue further. All of the Data Sources are fully cited in the References section, the names of the organizations and the publications are given here to simplify the search. The contacts are those people who were most resourceful for me, and while I do not suggest contacting them without specific questions to ask them, I found them all very understanding and interested in my work.

### DATA SOURCES

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The following sources were indispensable for collecting the data for this study. In some cases there are explicit data tables that can be downloaded in different formats using Adobe Acrobat, and in some cases there are data tables or text with data inserted.

- World Resources Institute, *World Resources 1996-97* and on-line data tables.
- EPA publications.
- DOE/EIA website.
- USDA Economic Research Service, *Red Meat Yearbook*.
- UNFCCC website.
- USDA publications.
- IPCC Working Group I and II publications.

### CONTACTS

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<p>Mark Orlic, Methane Branch Office of Air and Radiation United States Environmental Protection Agency Washington, D.C. (202) 233-9043</p>	<p>Michael Gibbs Ruminant Methane Specialist ICF Kaiser (818) 509-3186</p>
<p>Rod Livingston Appropriate Technologies International (202) 463-8476 <i>works on projects to apply Joint Implementation in developing countries.</i></p>	<p>Charles Wilbur Economist USDA <a href="mailto:cwilbur@mailoce.oce.usda.gov">cwilbur@mailoce.oce.usda.gov</a></p>
<p>Lawrence A. Duewer Economic Research Service USDA (202) 694-5172 <i>responsible for the data in the Red Meat Yearbook.</i></p>	<p>Vikram Bakshi Data Analyst ICF Kaiser</p>

### WEBSITES (AS OF DECEMBER, 1997):

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<http://www.ipcc.ch>

World Resources Institute:  
<http://www.wri.org>  
<http://www.wri.org/wr-96-97/96tocful.html>

United States Department of Agriculture, *Red Meat Yearbook*:  
<http://www.mannlib.cornell.edu/data-sets/livestock/94006/>  
<http://www.econ.ag.gov/Prodsrvs/dataproduct.htm>

United States Department of Agriculture  
<http://www.usda.gov/nass/>

Joint Implementation:

<http://www.ji.org>  
United Nations Framework Convention on Climate Change:  
<http://www.unfccc.de/>  
United States Department of Energy, Energy Information Administration:  
<http://www.eia.doe.gov/>  
National Resource Development Council  
<http://www.nrdc.org/>  
United States Climate Action Network  
<http://www.igc.org/climate/Eco.html>

## Appendix III

### *CH<sub>4</sub> MEASUREMENTS AND UNCERTAINTIES*

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#### CH<sub>4</sub> ATMOSPHERIC CONCENTRATION UNCERTAINTIES

CH<sub>4</sub> concentrations in the atmosphere dip in the beginning of the decade.<sup>178</sup> Many scientists and policymakers have attempted explanations for this dip, but no evidence to support the theories has been found. According to Sherwood Rowland at U.C. Irvine, there was an increase in the cattle population after the Second World War, which is tapering off.<sup>179</sup> This would cause a decrease in CH<sub>4</sub> emissions. In addition, cattle numbers have not dropped substantially in the past 26 years (Figure 1.4). The small decrease observed in cattle numbers is not capable of causing this dip in CH<sub>4</sub> emissions and atmospheric concentrations, especially since there has not been a decrease in cattle CH<sub>4</sub> emissions. Another proposed solution is that there has not been a direct reduction in CH<sub>4</sub> emissions, but an increase in a CH<sub>4</sub> sink. For example, increased O<sub>3</sub> levels in the troposphere could reduce CH<sub>4</sub> levels in the atmosphere.<sup>180</sup> Rapid economic turnover in the former Soviet Union and Eastern Europe, where there have been large known CH<sub>4</sub> gas leaks, could have led to significant changes in total global emissions. Economic change may have affected fossil fuel use in such a way that leaks were reduced.<sup>181</sup> However, it is unlikely that such a change could have taken place so quickly, therefore not showing evidence in the data.<sup>182</sup> An event which lowered global average temperatures by 0.7K in the Northern Hemisphere in 1992 was the eruption of Mount Pinatubo in 1991, which released small particles, known as *aerosols*, into the air. A change in temperature from aerosols would affect the amount CH<sub>4</sub> emitted by reducing CH<sub>4</sub> emissions from natural wetlands, although Rudolph admits that this would be extremely difficult to quantify. In fact, a reduction in temperature has been shown to reduce CH<sub>4</sub> sinks, which would mean that there would not be a dip

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<sup>178</sup> Rudolph, J., "Anomalous Methane," *Nature*, Vol. 368, 3 March 1994. 19-20.

<sup>179</sup> In Johnson, Kristen et al., "Measurement of Methane Emissions from Ruminant Livestock Using a SF<sub>6</sub> Tracer Technique," *Environmental Science and Technology*, Vol. 28, No.2, 1994. 359-362.

<sup>180</sup> Johnson.

<sup>181</sup> Rudolph..

in CH<sub>4</sub> emissions quantities, but rather a peak.<sup>183</sup> However, a dip in atmospheric CO<sub>2</sub> concentrations in 1992 has also been seen at Mauna Loa. These two events could be related.<sup>184</sup>

#### CH<sub>4</sub> DATA COLLECTION AND UNCERTAINTIES

When discussing CH<sub>4</sub> quantities, it is necessary to recognize that, just as for any greenhouse gas, the accuracy of the data is not guaranteed. It is therefore important to understand how the scientists are collecting, analyzing and using the data.

The following two techniques are based on assessing the relationship between energy intake and CH<sub>4</sub> production by placing individual cows in a respiration chamber for several days.<sup>185</sup> CH<sub>4</sub> quantities emitted from cattle are assessed based on how small the CH<sub>4</sub> amount expired is to the amount of feed energy lost in other forms. When cattle are fed high quality diets, a factor also increasing their growth rate without the use of hormone supplements, the amount of CH<sub>4</sub> lost from eructation is reduced. The first way to measure the effectiveness of diet on CH<sub>4</sub> emissions from an individual animal is to place the animal in a respiration calorimetry chamber for some days.<sup>186</sup> This process monitors the amount of CH<sub>4</sub> emitted, while also calculating the energy intake and the partitioning of the intake between the various metabolic pathways.<sup>187</sup> To help the understanding of this method, a model was developed to attempt to simulate rumen fermentation.<sup>188</sup> The model provides estimates of CH<sub>4</sub> formed and emitted from the microbial fermentation in the rumen.<sup>189</sup> The microbial fermentation is dependent not only on the microbes found in the rumen, but also on the chemical characteristics of the diet, which explains why the direct approaches for CH<sub>4</sub> mitigation include raising the quality of the diet or treating the feed with chemicals to increase the nutrient levels. A significant barrier to the dependence on respiration chambers is the fact that such an environment is artificial. It has not yet been established to what extent the knowledge acquired in this space can be applied the outside environment.<sup>190</sup> Such chambers are expensive to maintain, and financially

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<sup>182</sup> Rudolph.

<sup>183</sup> Rudolph.

<sup>184</sup> Rudolph.

<sup>185</sup> Johnson.

<sup>186</sup> Johnson.

<sup>187</sup> Johnson.

<sup>188</sup> Johnson.

<sup>189</sup> Johnson.

<sup>190</sup> Johnson.

supporting research with them can only be done if the resulting information can be applied to a real-world situation.

The second method for measuring the amount of CH<sub>4</sub> emitted is through a device called a *tracer*, which places a small amount of sulfur hexafluoride (SF<sub>6</sub>) in the rumen, and measures CH<sub>4</sub> and SF<sub>6</sub> concentrations around a cow's mouth and nostrils. By measuring a gas whose original quantity is known, it is possible to assess the amount of dilution of gases near the animal's mouth. Johnson et al. believe their findings show that the tracer method is efficient and simple, and will provide a better way to reduce the uncertainty in the ruminant contribution to the global CH<sub>4</sub> budget.

Currently uncertainties in data for CH<sub>4</sub> are similar to those for the impact of greenhouse gases on global warming, and even the future effects of global warming. While research has been done on CH<sub>4</sub> emissions data, as described above, the relative impact of CH<sub>4</sub> emissions from cattle is difficult to quantify.



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