METHANE PRODUCTION AS A RESULT FROM RUMEN FERMENTATION IN CATTLE CALCULATED BY USING THE IPCC-GPG TIER 2 METHOD

FINAL REPORT

Feed Innovation Services (FIS)

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The Netherlands

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Authors:
W. Smink
W.F. Pellikaan
L.J. van der Kolk
K.W. van der Hoek (RIVM)

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Report by:
Feed Innovation Services (FIS)
P.O. Box 85
NL-5735 ZH Aarle-Rixtel
Tel. (+31) (0)492 388855
www.fisbv.nl

Authors:
W. Smink (smink@fisbv.nl)
W.F. Pellikaan
L.J. van der Kolk
K.W. van der Hoek (RIVM)

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SUMMARY

The Netherlands has to comply with the IPCC-GPG Tier 2 method concerning the calculation of the methane production resulting from rumen fermentation (including intestine) by cattle. At present, a preliminary calculation to the method is used. The aim of this study is to determine the methane production for all categories of cattle in the Netherlands during the period from 1990 till present with use of this calculation model.

The IPCC-GPG Tier 2 method starts with the need of an animal for nett energy required for maintenance, activity, growth, gestation and lactation. The gross energy intake and methane production are calculated from the required nett energy intake.

The data for these calculations include the number of animals per category, the weights, the growth, milk production and milk compound, the ration components and the digestibility of the ration components.

In the Netherlands, the total methane emission as a consequence of rumen fermentation by cattle in 2002 is calculated to be about 260,000 tons. In the period 1990-2002, the emission decreased by 16%. In 1990, cows in milk accounted for 61% of the total emission and for 64% in 2002. The methane production per dairy cow per year has increased from 102 to 113 kg. The higher emission factor (methane/animal/year) for dairy cows in 2002 is mainly a result from a higher milk production. In the period from 1990-2002, the methane production per animal for young stock, bulls for service, beef cattle and suckling cows has not significantly changed.

For the monitoring of the methane emission for dairy cows, an annual methane emission factor is proposed. For the other animal categories a review once every five years is recommended.

CONTENTS

INTRODUCTION

The Netherlands has to comply with the IPCC-GPG Tier 2 method as far as the calculation is considered of the methane production resulting from rumen fermentation (including intestine) by cattle. At present the data used are those calculated by Van Amstel et al. (1993). They used the formulas of IPCC-OECD, from a workshop in 1991. These formulas are now sometimes referred to as the precursors of the present IPCC-GPG Tier 2 method.

The aim of this study is to make a continuity calculation of the methane production during the period 1990 till present by using the IPCC-GPG Tier 2 method.

In order to achieve continuity calculation one has to set up activity data. The basic data are as closely as possible connected to the data used by the Working Group on Uniform calculations of Manure and Mineral Figures [Werkgroep Uniformering berekening Mest- en Mineralencijfers] (WUM). The basic data, but also the complementary data necessary for the calculation of the methane emission through IPCC-GPG have been critically looked at and have been explained. In the calculation of the IPCC-GPG Tier 2 method the digestibility of feed plays an important part. This aspect has received explicit attention, partly in connection with the changing compound of grassland products over the last 10 years. Next to this, it has been investigated in which way the methane emission in other countries with high productive dairy cattle is calculated.

The structure of this report is as follows.
In Chapter 1, the activity data are described (like number and cattle categories, weights, feed intake, milk production).
In Chapter 2, the results of the continuity calculation by means of the IPCC-GPG method are presented.
In Chapter 3, the selected values in the formulas of IPCC-GPG are extensively examined, and the results are discussed.
In Chapter 4, the most important conclusions are indicated.
Finally, in Chapter 5 the calculation of the methane emission in the near future is dealt with.

In the report the results over the years 1990, 1995, and 2000 till 2002 are described. In Appendices 5 en 6 the activity data and the calculated methane emission of all the years in the period from 1990 to 2002 are presented.

1 ACTIVITY DATA

In this Chapter, relevant activity data are given for the calculation of the methane production. As far as possible a distinction has been made between regions. For the division into relevant regions in the Netherlands and animal categories, the division used by the WUM is the starting point. The WUM employs a division into two regions, the East and the South of the Netherlands (high share of green maize in the feed ration) and the North and West of the Netherlands (low share of green maize in the feed ration). North West includes the provinces: Groningen, Friesland, Drenthe, Utrecht, Zeeland, Noord- and Zuid-Holland. East South includes the provinces Overijssel, Gelderland, Noord-Brabant, Limburg and Flevoland.

1.1 Numbers of animals

In the year 2001 a so-called foot and mouth disease-fmd [mkz] adjustment was applied. As a result from the culling and depopulation of the livestock buildings the number of animals counted at the agricultural census did not represent the average number of animals in that year. In order to reach an average number of animals anyway, the agricultural census was adjusted. In the following tables the numbers of animals per region are indicated.

Table 1.1 Number of animals in the region East and South of the Netherlands (source: Agricultural Census)

	1990	1995	2000	2001 incl. fmd-adjmt	2002
Cattle for breeding					
Female young stock under 1 yr	447,536	405,691	312,911	303,889	286,246
Male young stock under 1 yr	29,841	26,149	24,319	49,933	26,484
Female young stock, 1 yr – calving down	520,836	468,876	392,244	368,169	354,551
Male young stock, 1-2 yrs	17,989	18,512	16,659	15,768	18,052
Cows in milk and in calf	1,028,014	935,629	796,440	803,239	767,412
Bulls for service 2 yrs and over	4,658	4,560	5,828	6,198	7,466
Cattle for fattening					
Meat calves, for rosé veal production	508,622	74,332	122,344	125,647	126,046
Meat calves, for white veal production*		497,598	535,931	462,272	472,960
Female young stock under 1 yr	35,167	37,604	27,262	28,320	24,807
Male young stock (incl. young bullocks), under 1 yr	218,180	151,344	64,412	57,141	45,029
Female young stock, > 1 yr	61,649	70,965	41,112	40,769	38,174
Male young stock (incl. young bullocks) > 1yr	155,266	144,478	75,316	74,162	59,288
Fattening and suckling cows, 2 yrs and over	36,716	31,454	41,166	65,236	32,290
Suckling cows	37,734	59,384	61,425	36,652	60,377
Total cattle	3,102,208	2,926,576	2,517,369	2,437,395	2,319,182

*: For 1990 no distinction has been made between white veal and rosé veal calves. The Agricultural Census has covered the numbers rosé veal calves from 1995. Rosé veal calves stock raising started in the second half of the 1980's. In 1995, the share of rosé veal calves was 12.8% of the total number of veal calves. It is assumed that in the period 1987-1995, the share of rosé veal calves annually increased by 1.6%. Therefore, with regard to 1990 a share of 4.8% has been calculated.

Table 1.2 Number of animals in the region North and West of the Netherlands (source: Agricultural Census)

	1990	1995	2000	2001 incl. fmd-adjmt	2002
Cattle for breeding					
Female young stock under 1 yr	305,122	290,372	249,652	248,706	242,881
Male young stock under 1 yr	23,388	18,014	13,121	38,068	18,208
Female young stock, 1 yr – calving down	358,890	338,982	306,489	297,828	293,946
Male young stock, 1-2 yrs	16,646	14,606	9,669	11,051	13,491
Cows in milk and in calf	849,670	772,246	707,657	735,941	718,119
Bulls for service 2 yrs and over	4,104	4,114	4,582	4,784	6,666
Cattle for fattening					
Meat calves, for rosé veal production	92,963	11,471	23,484	25,303	25,987
Meat calves, for white veal production*		85,918	100,976	94,508	88,340
Female young stock under 1 yr	17,854	19,614	14,038	14,591	14,080
Male young stock (incl. young bullocks) under 1 yr	37,195	36,849	19,035	19,720	17,959
Female young stock, > 1 yr	37,840	44,053	20,612	20,278	20,391
Male young stock (incl. young bullocks) > 1yr	35,064	36,037	22,750	20,740	20,839
Fattening and grazing cows, 2 yrs and over	26,824	23,589	26,400	35,950	23,298
Suckling cows	18,255	31,754	34,406	22,964	35,007
Total cattle	1,823,815	1,727,619	1,552,871	1,590,432	1,539,212

*: See, remarks at Table 1.1.

1.2 Weights

With regard to the weights of the different animal categories the weights used by the Working Group on Uniform calculations of Manure and Mineral Figures (WUM) were followed for the calculation of excretion factors of minerals. The weight classes per animal category are indicated in the following table.

Table 1.3 Weights (in kg) per animal category

	1990 – 1993		1995		1999 - 2002	
	Initial weight	Final weight	Initial weight	Final weight	Initial weight	Final weight
Cattle for breeding						
Female young stock under 1 yr	43	310	43	310	43	320
Male young stock under 1 yr	43	310	43	310	43	400
Female young stock, 1-2 yrs	310	520	310	520	320	530
Male young stock, 1-2 yrs	400	680	400	680	400	680
Female young stock, 2 yrs and over	310	520	310	520	320	530
Cows in milk and in calf	520	600	520	600	530	600
Bulls for service 2 yrs and over	680	1100	680	1100	680	1100
Cattle for fattening						
Meat calves, for rosé veal production	43	230	43	310	43	336
Meat calves, for white veal production*	43	230	43	230	43	245
Female young stock under 1 yr	43	310	43	310	43	320
Male young stock (incl. young bullocks) under 1 yr	55	461	55	450	50	465
Female young stock, 1-2 yrs	310	520	310	520	320	530
Male young stock (incl. young bullocks), 1-2 yrs	461	609	450	637	465	640
Female young stock, 2 yrs and over	310	520	310	520	320	530
Male young stock (incl. young bullocks), 2 yrs and over	461	609	450	637	465	640
Fattening and grazing cows, 2 yrs and over	520	650	520	650	530	650
Suckling cows	520	650	520	650	530	650

*: See, remarks at Table 1.1.

1.3 Milk production characteristics and races

No average milk production figures are available per region. The national average values are indicated in Table 1.4. The milk production per day has been calculated by dividing the total milk production (source: Marketing Board for Dairy Products [Productschap Zuivel]) by the number of cows in milk and in calf and by dividing this again by 365 days. The results, which are indicated in Table 1.4, are used for the calculation of methane in Chapter 2.

Table 1.4 Milk production per cow and fat and protein content (Central Bureau for Statistics [Centraal Bureau voor de Statistiek; CBS])

	Milk production per cow (kg / yr)	Milk production per day (calculated)	Fat content (%)	Protein content (%)
1990	6050	16.58	4.38	3.41
1995	6580	18.03	4.40	3.48
2000	7416	20.32	4.38	3.47
2001 *)	7336	20.10	4.44	3.46
2001	7127	19.53	4.44	3.46
2002	7187	19.69	4.43	3.46

*): Number of cows in milk and in calf adjusted for fmd (used for further calculations).

In order to gain any insight into the differences between the races, the milk production data of the NRS are indicated in Tables 1.5 - 1.7. Here, a distinction has been made between black Holstein (HF) dairy cattle breed (Table 1.6) and the red Holstein including the MRIJ breed (Table 1.7). The information from Tables 1.5 – 1.7 has not been taken into consideration.

Table 1.5 Milk production per cow and fat and protein contents of the herd-book cows (NRS data, Annual characteristics 2002 CR Delta [Jaarkarakteristieken 2002 CR Delta])

	Milk production per cow (kg / year*)	Intercalving period (days)	Milk production per day (calculated from intercalving period)	Number of animals	Fat content (%)	Protein content (%)
1990	6897	-	-	1,071,159	4.38	3.45
1995	7304	391	18.68	1,018,248	4.44	3.48
2000	7999	400	20.00	1,002,539	4.33	3.45
2001	8092	402	20.13	962,745	4.38	3.45
2002	8070	405	19.93	995,527	4.39	3.46

*: year = intercalving period, the lactating and dry period between calving down.

Table 1.6 Milk production per cow and fat and protein contents of the black Holstein dairy breed. (NRS data, Annual characteristics 2002 CR Delta [Jaarkarakteristieken 2002 CR Delta])

	Milk production per cow (kg / year*)	Intercalving period (days)	Milk production per day (calculated from intercalving period)	Number of animals	Fat content (%)	Protein content (%)
1990	7122	-	-	739,220	4.42	3.43
1995	7584	394	19.25	708,218	4.44	3.46
2000	8222	404	20.35	761,035	4.30	3.43
2001	8311	405	20.52	740,115	4.35	3.43
2002	8270	408	20.27	778,664	4.34	3.42

*: Year = intercalving period, the lactating and dry period between calving down.

Table 1.7 Milk production per cow and fat and protein contents of the red Holstein dairy breed. (NRS data, Annual characteristics 2002 CR Delta [Jaarkarakteristieken 2002 CR Delta])

	Milk production per cow (kg / year*)	Intercalving period (days)	Milk production per day (calculated from intercalving period)	Number of animals	Fat content (%)	Protein content (%)
1990	6359	-	-	303,691	4.27	3.50
1995	6661	384	17.35	269,974	4.40	3.55
2000	7277	389	18.71	234,732	4.45	3.53
2001	7325	390	18.78	216,518	4.52	3.54
2002	7242	392	18.47	210,730	4.54	3.52

*: Year = intercalving period, the lactating and dry period between calving down.

In the period from 1990-2002, the share of the black dairy breed (HF) increased. The paddle black dairy breed consists for 80% of HF animals and for 20% of an HF/FH cross. Two-thirds of the paddle red animals are a MRIJ/HF cross, a quarter HF paddle red and less than 10% is MRIJ.

1.4 Feed intake

In the following table (1.8) the feed intake of the different animal categories is indicated. Like the animal weights, the feed intake data have been taken from the WUM. The basic data for the years 1990, 1995 and 2002 are presented in Table 1.9.

Table 1.8 Feed intake of the different animal categories in 1990, 1995 and 2002 (WUM data)

		Feed intake (kg dm /day)		
		1990	1995	2002
East and South of the Netherlands				
Cattle for breeding				
201	Female young stock under 1 yr	4.3	4.4	4.1
203	Male young stock under 1 yr	4.3	4.4	5.0
205	Female young stock, 1-2 yrs	7.7	7.8	7.2
207	Male young stock, 1-2 yrs	8.6	9.2	8.7
209	Female young stock, 2 yrs and over	7.7	7.8	7.2
211	Cows in milk and in calf	14.9	15.5	16.7
213	Bulls for service 2 yrs and over	8.6	9.2	8.7
Cattle for fattening				
216	Meat calves, for rosé veal production		4.6	4.7
214	Meat calves, for white veal production	1.7	1.8	2.0
217	Female young stock under 1 yr	4.3	4.4	4.1
219	Male young stock (incl. young bullocks) under 1 yr	4.6	4.9	5.1
221	Female young stock, 1-2 yrs	7.7	7.8	7.2
223	Male young stock (incl. young bullocks), 1-2 yrs	9.5	9.3	8.9
225	Female young stock, 2 yrs and over	7.7	7.8	7.2
227	Male young stock (incl. young bullocks), 2 yrs and over	9.5	9.3	8.9
228/229	Suckling cows (incl. fattening and grazing cows 2 yrs and over)	9.2	9.2	9.4
North and West of the Netherlands				
Cattle for breeding				
201	Female young stock under 1 yr	4.3	4.5	4.1
203	Male young stock under 1 yr	4.3	4.5	5.0
205	Female young stock, 1-2 yrs	7.7	7.9	7.3
207	Male young stock, 1-2 yrs	8.6	9.2	8.7
209	Female young stock, 2 yrs and over	7.7	7.9	7.3
211	Cows in milk and in calf	14.8	15.5	16.6
213	Bulls for service 2 yrs and over	8.6	9.2	8.7
Cattle for fattening				
216	Meat calves, for rosé veal production		4.6	4.7
214	Meat calves, for white veal production	1.7	1.8	2.0
217	Female young stock under 1 yr	4.3	4.5	4.1
219	Male young stock (incl. young bullocks) under 1 yr	4.6	4.9	5.1
221	Female young stock, 1-2 yrs	7.7	7.9	7.3
223	Male young stock (incl. young bullocks), 1-2 yrs	9.5	9.3	8.9
225	Female young stock, 2 yrs and over	7.7	7.9	7.3
227	Male young stock (incl. young bullocks), 2 yrs and over	9.5	9.3	8.9
228/229	Suckling cows (incl. fattening and grazing cows, 2 yrs and over)	9.2	9.3	9.4

In the period from 1990-2002, the feed intake of most of the animal groups has not significantly changed with the exception of cows in milk. There are hardly any differences between the two regions regarding the animal categories.

Table 1.9 Feed intake by the different animal categories per region in 1990, 1995 and 2002

Section Agricultural Census	1990							1995							2002						
	Artificial milk 1)	Wet concentr.	High Protein concentr.	Other feed concentr.	Green maize	Grass silage + hay	Meadow grass	Artificial milk 1)	Wet concentr.	High Protein concentr.	Other feed concentr.	Green maize	Grass silage + hay	Meadow grass	Artificial milk 1)	Wet concentr.	High Protein concentr.	Other feed concentr.	Green maize	Grass silage + hay	Meadow grass
	kg/cow	kg dm/cow	kg/cow	kg/cow	kg dm/cow	kg dm/cow	kg dm/cow	Kg/cow	kg dm/cow	kg/cow	kg/cow	kg dm/cow	kg dm/cow	kg dm/cow	kg/cow	kg dm/cow	kg/cow	kg/cow	kg dm/cow	kg dm/cow	kg dm/cow
East and South of the Netherlands																					
Cattle for breeding																					
201 Female young stock under 1 yr	354	0	0	318	227	679	313	354	0	0	318	222	730	303	200	0	0	299	194	626	371
203 Male young stock under 1 yr	354	0	0	318	227	679	313	354	0	0	318	222	730	303	200	0	0	275	575	575	395
205 Female young stock, 1-2 yrs	0	0	0	235	144	1292	1158	0	0	0	235	140	1388	1120	0	0	0	219	126	1219	1101
207 Male young stock, 1-2 yrs	0	0	0	297	0	2880	0	0	0	0	297	0	3094	0	0	0	0	297	0	2925	0
209 Female young stock, 2 yrs and over	0	0	0	235	144	1292	1158	0	0	0	235	140	1388	1120	0	0	0	219	126	1219	1101
211 Cows in milk and in calf	0	166	579	1215	1402	878	1374	0	211	783	1343	1494	736	1314	0	229	371	1502	2030	1463	694
213 Bulls for service 2 yrs and over	0	0	0	297	0	2880	0	0	0	0	297	0	3094	0	0	0	0	297	0	2925	0
Cattle for fattening																					
216 Meat calves, for rosé veal production	0	0	0	0	0	0	0	73	234	372	604	487	0	0	52	164	153	849	604	0	0
214 Meat calves, for white veal production	679	0	0	0	0	0	0	679	0	0	0	37	0	0	722	0	0	43	37	0	0
217 Female young stock < 1 yr	354	0	0	318	227	679	313	354	0	0	318	222	730	303	200	0	0	299	194	626	371
219 Male young stock (incl. young bullocks) < 1 yr	41	142	624	0	969	0	0	30	125	679	0	1059	0	0	35	198	220	441	1060	0	0
221 Female young stock, 1-2 yrs	0	0	0	235	144	1292	1158	0	0	0	235	140	1388	1120	0	0	0	219	126	1219	1101
223 Male young stock (incl. young bullocks), 1-2 yrs	0	682	1076	0	1825	0	0	0	936	956	0	1603	0	0	0	838	0	1020	1481	0	0
225 Female young stock, 2 yrs and over	0	0	0	235	144	1292	1158	0	0	0	235	140	1388	1120	0	0	0	219	126	1219	1101
227 Male young stock (incl. young bullocks) 2 yrs	0	682	1076	0	1825	0	0	0	936	956	0	1603	0	0	0	838	0	1020	1481	0	0
228/229 Suckling cows (incl. fattening and grazing cows, 2 yrs)	0	0	0	640	0	2606	3506	0	0	0	640	0	2800	3992	0	0	0	460	0	2992	3482
North and West of the Netherlands																					
Cattle for breeding																					
201 Female young stock under 1 yr	354	0	0	257	0	932	347	354	0	0	257	0	1001	336	200	0	0	244	0	854	409
203 Male young stock under 1 yr	354	0	0	257	0	932	347	354	0	0	257	0	1001	336	200	0	0	275	575	575	395
205 Female young stock, 1-2 yrs	0	0	0	157	0	1520	1158	0	0	0	157	0	1633	1120	0	0	0	146	0	1435	1101
207 Male young stock, 1-2 yrs	0	0	0	297	0	2880	0	0	0	0	297	0	3094	0	0	0	0	297	0	2925	0
209 Female young stock, 2 yrs and over	0	0	0	157	0	1520	1158	0	0	0	157	0	1633	1120	0	0	0	146	0	1435	1101
211 Cows in milk and in calf	0	166	0	1795	296	1703	1618	0	211	0	2125	460	1406	1681	0	229	98	1775	770	1965	1421
213 Bulls for service 2 yrs and over	0	0	0	297	0	2880	0	0	0	0	297	0	3094	0	0	0	0	297	0	2925	0
Cattle for fattening																					
216 Meat calves, for rosé veal production	0	0	0	0	0	0	0	73	234	372	604	487	0	0	52	164	153	849	604	0	0
214 Meat calves, for white veal production	679	0	0	0	0	0	0	679	0	0	0	37	0	0	722	0	0	43	37	0	0
217 Female young stock under 1 yr	354	0	0	257	0	932	347	354	0	0	257	0	1001	336	200	0	0	244	0	854	409
219 Male young stock (incl. young bullocks) < 1 yr	41	142	624	0	969	0	0	30	125	679	0	1059	0	0	35	198	220	441	1060	0	0
221 Female young stock, 1-2 yrs	0	0	0	157	0	1520	1158	0	0	0	157	0	1633	1120	0	0	0	146	0	1435	1101
223 Male young stock (incl. young bullocks), 1-2 yrs	0	682	1076	0	1825	0	0	0	936	956	0	1603	0	0	0	838	0	1020	1481	0	0
225 Female young stock, 2 yrs and over	0	0	0	157	0	1520	1158	0	0	0	157	0	1633	1120	0	0	0	146	0	1435	1101
227 Male young stock (incl. young bullocks), 2 yrs	0	682	1076	0	1825	0	0	0	936	956	0	1603	0	0	0	838	0	1020	1481	0	0
228/229 Suckling cows (incl. fattening and grazing cows, 2 yrs)	0	0	0	640	0	2606	3506	0	0	0	640	0	2800	3992	0	0	0	460	0	2992	3482

1) In kg powder or in kg whole milk.

2 RESULTS OF METHANE PRODUCTION

The methane production resulting from rumen fermentation in cattle has been calculated by means of the IPCC-GPG Tier 2 methodology (IPCC, 2000) for two regions in the period 1990-2002. Through this methodology, a calculation is made of the energy needed for maintenance, growth, milk production, activity, mobilisation body reserve, gestation and labour. Based on this need a gross energy intake is calculated. From the gross energy the methane production is calculated with a conversion factor (usually 6% of the gross energy). For the basic data the figures collected by the WUM were followed as closely as possible. These are reported in Chapter 1. In order to be able to calculate the methane production by means of the formulas of IPCC-GPG, also various complementary data are required.
In Chapter 3.1 the complementary data are discussed as well as the relevance of the precision of the basic and complementary data in the formulas used. The most relevant results from the calculations are presented in Chapter 2.

In the following tables the most relevant results from the calculations are reproduced. Indicated are the calculated gross energy intake, the calculated dry matter intake (Table 2.1), the methane production per animal per year or the emission factor (Table 2.2) and the total methane production per animal category (Table 2.3).
It has been decided to join together a number of animal groups, which were dealt with separately by the WUM. The following animal groups of the WUM have been joined together:

<u>Cattle for breeding:</u>

“Female young stock, 1-2 years” and “Female young stock, 2 years and over”.

<u>Cattle for fattening:</u>

“Female young stock, 1-2 years” and “Female young stock, 2 years and over”
“Male young stock (incl. young bullocks), 1-2 years” and “Male young stock (incl. young bullocks), 2 years and over”
Suckling, fattening and grazing cows.

At the beginning the calculations were carried out for the two distinguished regions North West and East South. It appeared from the results that there were minimal differences between both regions (See further, 3.2.2.). For this reason it has been decided that no distinction would be made as to region and that the starting point would be the national average for all animal categories.

Table 2.1 Calculated gross energy intake (GE) in MJ/d and dry matter intake (DMi) in kg /d.

	1990		1995		2000		2001		2002	
	GE	DMi	GE	DMi	GE	DMi	GE	DMi	GE	DMi
Cattle for breeding										
Female young stock < 1 yr	85.7	4.6	85.7	4.6	88.3	4.8	88.3	4.8	88.3	4.8
Male young stock < 1 yr	73.7	4.0	73.7	4.0	92.8	5.0	92.8	5.0	92.8	5.0
Female young stock 1 yr – calving down	130.8	7.1	130.8	7.1	132.5	7.2	132.5	7.2	132.5	7.2
Male young stock 1-2 yr	140.1	7.6	140.1	7.6	140.1	7.6	140.1	7.6	140.1	7.6
Cows in milk and in calf	258.8	14.0	268.4	14.5	291.6	15.8	289.0	15.7	287.5	15.6
Bulls for service > 2 yr	159.0	8.6	159.0	8.6	159.0	8.6	159.0	8.6	159.0	8.6
Cattle for fattening										
Meat calves, rosé veal	90.4	4.9	90.4	4.9	96.1	5.2	96.1	5.2	96.1	5.2
Meat calves, white veal	62.6	3.4	63.5	3.4	67.6	3.7	67.6	3.7	67.6	3.7
Female young stock < 1 yr	85.7	4.6	85.7	4.6	88.3	4.8	88.3	4.8	88.3	4.8
Male young stock + young bullocks < 1 yr	102.0	5.5	99.7	5.4	102.7	5.6	102.7	5.6	102.7	5.6
Female young stock > 1 yr	123.5	6.7	123.5	6.7	125.1	6.8	125.1	6.8	125.1	6.8
Male young stock + young bullocks > 1 yr	151.4	8.2	151.0	8.2	152.7	8.3	152.7	8.3	152.7	8.3
Suckling cows (incl. fattening and grazing)	163.9	8.9	163.9	8.9	164.2	8.9	164.2	8.9	164.2	8.9

Table 2.2 Emission factor (kg methane/animal/year) per animal category

	Emission factor methane				
	1990	1995	2000	2001	2002
Cattle for breeding					
Female young stock < 1 yr	33.73	33.73	34.75	34.75	34.75
Male young stock < 1 yr	29.00	29.00	36.53	36.53	36.53
Female young stock 1 yr – calving down	51.49	51.49	52.16	52.16	52.16
Male young stock 1-2 yr	55.15	55.15	55.15	55.15	55.15
Cows in milk and in calf	101.94	105.64	114.83	113.73	113.19
Bulls for service > 2 yrs	62.59	62.59	62.59	62.59	62.59
Cattle for fattening					
Meat calves, rosé veal	35.59	35.59	37.82	37.82	37.82
Meat calves, white veal	16.42	16.66	17.73	17.73	17.73
Female young stock < 1 yr	33.73	33.73	34.75	34.75	34.75
Male young stock + young bullocks < 1 yr	40.13	39.25	40.43	40.43	40.43
Female young stock 1-2 yrs and over	48.61	48.61	49.23	49.23	49.23
Male young stock + young bullocks > 1 yr	59.57	59.43	60.08	60.08	60.08
Suckling cows (incl. fattening and grazing)	64.51	64.51	64.61	64.61	64.61

The methane emission factor for cows in milk is the highest, and it increased by about 11-12 kg in the period 1990-2002. This is mainly a result from a higher milk production. The changes in cows in milk with regard to weight, growth, number of days in pasture and digestibility of the ration slightly influence the emission factor. The calculated methane emission factor for male young stock is increased in 2000 as a result of an altered body weight. The calculated methane emission factor for white veal calves is increased in the period 1990-2002 as a result from a higher growth and the intake of some dry roughage in the

ration. The methane emission factors for the other animal categories stayed (almost) unaltered.
In Table 2.3, the total methane production per animal category is presented. For this aim, the emission factors have been multiplied with the number of animals in the animal category and year concerned.

Table 2.3 Total methane emission in millions kg per animal category, per year

	Methane emission				
	1990	1995	2000	2001	2002
Cattle for breeding					
Female young stock < 1 yr	25.388	23.479	19.551	19.204	18.389
Male young stock < 1 yr	1.543	1.281	1.368	3.215	1.633
Female young stock 1 yr – calving down	45.294	41.594	36.443	34.736	33.823
Male young stock 1-2 yrs	1.910	1.826	1.452	1.479	1.740
Cows in milk and in calf	191.413	180.417	172.713	175.056	168.147
Bulls for service > 2 yrs	0.548	0.543	0.652	0.687	0.885
Cattle for fattening					
Meat calves, rosé veal	1.028	3.053	5.515	5.708	5.749
Meat calves, white veal	9.401	9.722	11.295	9.874	9.954
Female young stock < 1 yr	1.788	1.930	1.435	1.491	1.351
Male young stock + young bullocks < 1 yr	10.249	7.387	3.374	3.108	2.547
Female young stock 1-2 yrs and over	4.837	5.591	3.039	3.005	2.883
Male young stock + young bullocks > 1 yr	11.338	10.728	5.891	5.701	4.814
Suckling cows (incl. fattening and grazing)	7.711	9.430	10.557	10.389	9.754
Total for The Netherlands	312.449	296.981	273.283	273.655	261.668

In the period 1990-2002 the total methane emission decreased by 16%. For the most relevant category, cows in milk and in calf, the decrease was 12%.

3 APPLIED BASIC VALUES AND DISCUSSION ON RESULTS

3.1 Calculation of the methane emission by using the IPCC-GPG Tier 2 methodology

In this Chapter, the different formulas will be considered which are applied for the calculation of the methane emission per animal category. Here, the different suppositions made for the situation of the Netherlands will be considered, and it will be explained how these suppositions came into being. These formulas have been applied for all animal categories in cattle (breeding and fattening).

3.1.1 Nett energy for maintenance

The formula for the calculation of nett energy for maintenance is as follows.

$$\mathbf{NEm = Cf_i * (weight)^{0.75}}$$

NEm:	Nett energy for maintenance (MJ/day)
Cf_i:	Coefficient for the calculation of the nett energy for maintenance. The IPCC gives the following coefficients: - Non lactating cattle : 0.322 - Lactating cattle : 0.335
Weight:	Living weight of the animal in kg

Important aspects with regard to weights of animals :
- For the average weights per animal category the weights used by the WUM were taken as a starting point (See, Table 1.3). For the calculation of the excretion factors of minerals the WUM uses initial and final weights per animal category.
- The average weight per animal category has been calculated by taking the arithmetic mean of initial and final weight per animal category. The average will be slightly different, but will hardly influence the calculated methane emission.
- No data are known on differences in animal weights between the two regions.

For the years 1990-1993, 1995 and 2000 till 2002 the average calculated weights per animal category are presented in the following Table.

Table 3.1 Calculated average weights (kg) of the different animal categories (CBS / WUM)

	1990 -1993	1995	2000-2003
Cattle for breeding			
Female young stock under 1 yr	176.5	176.5	181.5
Male young stock under 1 yr	176.5	176.5	221.5
Female young stock, 1 yr–calving down	415.0	415.0	425.0
Male young stock, 1-2 yrs	540.0	540.0	540.0
Cows in milk and in calf	560.0	560.0	565.0
Bulls for service 2 yrs and over	890.0	890.0	890.0
Cattle for fattening			
Meat calves, for rosé veal production	136.5	176.5	189.5
Meat calves, for white veal production	136.5	136.5	144.0
Female young stock under 1 yr	176.5	176.5	181.5
Male young stock (incl. young bullocks) < 1 yr	258.0	252.5	257.5
Female young stock, 1 yrs and over	415.0	415.0	425.0
Male young stock (incl. young bullocks), > 1 yr	535.0	543.5	552.5
Suckling, fattening and grazing cows	585.0	585.0	590.0

3.1.2 Nett energy for activity

The formula for the calculation of the nett energy for activity is as follows.

$$NE_a = C_a * NE_m$$

NE_a: Nett energy for activity (MJ/day)
C_a: Coefficient for the required activity of the animal for the intake of feed. The IPCC gives the following division.

Table 3.2 Division of IPCC with regard to the C_a coefficients

Situation	Definition	C_a
Shed	Animals are kept on a small surface where they use little energy for their feed intake	0
Pasture	Animals are kept in areas with a good feed supply; average energy required for feed intake	0.17
Vast areas	Animals graze on vast areas and use a lot of energy for their feed intake	0.36

With regard to the situation in the Netherlands estimations were made of the C_a for the different animal categories; these are reproduced in Table 3.3.
The coefficients lie between 0 and 0.17. The difference between a factor 0 (100% in shed during the whole year) and 0.17 (100% pasture during the whole year) on the methane production in cows in milk is limited (100% pasture is 3% higher). The selection of coefficients for the animal categories was made on the basis of the share of meadow grass in the total ration that has been calculated by the WUM. With regard to young stock until 1 year, other female young stock, other male young stock and suckling cows, fattening and grazing cows it has been calculated that the percentage of meadow grass is, on average 21, 41, 0 and 52% respectively. There is little difference between 1990 and present. In cows in milk the share of meadow grass compared to the complete ration decreased in the last decennium. It therefore has been decided to calculate the factor for each year.

Table 3.3 Selected C_a coefficients for the different animal categories in the Dutch situation

Animal category	C_a coefficient
Cattle for breeding	
Female young stock under 1 yr	0.036
Male young stock under 1 yr	0.036
Female young stock, 1 yr – calving down	0.070
Male young stock, 1-2 yrs	0
Cows in milk and in calf	0.046/ 0.043/ 0.027/ 0.034/ 0.029*
Bulls for service 2 yrs and over	0
Cattle for fattening	
Meat calves, for rosé veal production	0
Meat calves, for white veal production	0
Female young stock under 1 yr	0.036
Male young stock (incl. young bullocks) < 1 yr	0
Female young stock, 1 yr and over	0.070
Male young stock (incl. young bullocks), > 1 yr	0
Suckling, fattening and grazing cows, 2 yrs and over	0.088

*: Based on the share of feed intake made up by meadow grass. This is:
1990: 27% (0.27 x factor 0.17 = 0.046)
1995: 25%
2000: 16%
2001: 20%
2002: 17%

3.1.3 Nett energy for growth

The formula for the calculation of the nett energy for growth is as follows (IPCC, 2000):

$$\mathbf{NE_g = 4.18 * \{0.0635 * [0.891 * (BW * 0.96) * (478/(C*MW))]^{0.75} * (WG * 0.92)^{1.097}\}}$$

NE_g:	Nett energy for growth, MJ/day
BW:	Living weight of the animal in kg
C:	Coefficient (0.8 for female cattle; 1.2 for male cattle)
MW:	Adult weight (final weight) of the animal, in kg
WG:	Daily growth, in kg/day

The data of the WUM have been taken as a starting point for the different weights. The daily growth per animal category has been calculated by dividing the difference between initial and final weight by 365 days. For cows in milk and in calf, by considering an initial weight of 520 or 530 kg and a final weight of 600 kg, the growth calculated is 70-80 kg spread over about 3 years. The total (growth) course chosen is based on the data reported by Heeres-van der Tol (2001). The choice for the period of time for the growth courses of breeding bulls, meat calves and suckling cows (incl. fattening and grazing cows) has also been made based on the study by Heeres-van der Tol (2001). What has been chosen for is a calculated average weight. This may possibly be too low. However, the “error” made is not big. Using an average weight of 575 kg instead of 565 kg leads to a calculated methane production in cows in milk, which is 0.6% higher.

3.1.4 Mobilized nett energy

At the beginning of the lactation high productive cows in milk lose weight. The formula for the calculation of the mobilized nett energy is as follows.

NE_{mob} = 19.7 * weight loss

NE_{mob}:	Nett energy by weight loss (mobilized), MJ/day
Weight loss:	Weight loss in kg per day For the weight loss of high productive dairy cattle under the circumstances in the Netherlands an annual weight loss of 50 kg at the beginning of the lactation was considered.

IPCC indicates that this factor only needs to be considered if the feed intake is measured during a limited period. Therefore, this is not applicable to the situation in the Netherlands.

3.1.5 Nett energy for lactation

The formula for the calculation of the nett energy for lactation is as follows (IPCC, 2000).

NE_l = kg milk / day * (1.47 + 0.40 * fat percentage)

NE_l:	Nett energy for lactation, MJ/day
Kg milk/day:	Average milk production/day. For this aim, the average milk production per year (See, Table 1.4) has been divided by 365 days
Fat percentage:	Fat percentage in the milk (for fat percentages in the Netherlands, see, Table 1.4)

3.1.6 Nett energy for gestation

The formula for the calculation of the nett energy for gestation is as follows (IPCC, 2000).

$NE_p = C_{gestation} * NE_m$

NE_p :	Nett energy for gestation (MJ/day)
$C_{gestation}$:	Coefficient gestation (0.10 for cattle)

3.1.7 Relation with digestible energy

For the calculation of the gross energy intake the following relations have to be calculated (IPCC, 2000).

a. Relationship between available energy for maintenance and absorbed digestible energy.

$$NE_{ma}/DE = 1.123 - (4.092 * 10^{-3} * DE) + [1.126 * 10^{-5} * (DE)^2] - (25.4/DE)$$

b. Relationship between available energy for growth and absorbed digestible energy

$$NE_{ga}/DE = 1.164 - (5.160 * 10^{-3} * DE) + [1.308 * 10^{-5} * (DE)^2] - (37.4/DE)$$

DE: Digestible energy expressed as a percentage of the gross energy

For the DE values of different feeds under the Dutch circumstances the following presuppositions were made (Table 3.4).

Table 3.4 Estimation of the DE (digestible energy in % of gross energy) of different feeds

Feed	Estimated DE value (%)
Artificial milk	90
Feed concentrate	80
Grass silage	72
Green maize	72
Meadow grass	79

Conversion digestible organic matter to digestible energy

The Dutch Feed Tables do not contain any coefficients for digestible energy (=DE). For products, however, a digestion coefficient for organic matter (=dcOM [vcOS]) has been determined. A calculated DE has been chosen based on the digestibility of organic matter. The digestion coefficients for organic matter for meadow grass, grass silage and green maize of the Laboratory for Soil and Crop Testing, BV [Bedrijfslaboratorium voor Grond- en Gewasonderzoek (Blgg)] in Oosterbeek have been used as a basis for the estimation of the DE values. The DE of feed concentrate and artificial milk is estimated on the basis of practical feed compounds, the total consumption of mixed feed raw materials (data WUM) and data of the CVB Table (2003) for individual feed concentrate raw materials. The height of the digestion coefficient of energy strongly influences the calculated methane production through the IPCC method. The height of the digestibility of mixed feed raw materials as presented in important foreign feed tables (NRC, AFRC and INRA) are sufficiently in conformity with the Dutch ones. In the Netherlands, calculations are carried out with the dcOM [vcOS], not with the digestion of energy. In a study including whether digestion tests carried out by different institutes it appeared that the dcOM [vcOS] is higher compared to the dcGE (or DE value). This difference is on average 1 – 3%-units for feed concentrate raw materials and 2 – 4%-units for roughage (Deaville et al., 1994). As to grass silage an adjustment has been made of 4%. With regard to green maize and fresh grass an adjustment has been made of 3%. Appendix 1 deals extensively with the differences and similarities between the Dutch and foreign feed tables.

Relationship N-fertilization and digestibility of grassland products

Due to changes in legislation on the use of fertilizer the N-fertilization level on grassland has gone down over the last 15 years. A literature study has been carried out to gain insight into the consequences thereof in relation to the compound and the digestibility of grass and grass silage. The object of this study was mainly the research carried out in the Netherlands in the period 1990 till present. On the basis of literature data the relations between the digestion coefficient of the organic matter (dcOM [vcOS]) on the one hand and crude protein (RP) and cell walls (NDF) on the other hand are presented in a number of Figures in Appendix 2. From these studies it appears that generally a negative relationship exists between the RP and the NDF content in grassland products, and a positive relationship between the RP and the dcOM. This has been determined in tests in which the influence of the N-level on the digestibility has been studied (See, Appendix 2).
In the period from 1990 - present the average RP content in grassland products actually decreased as well. However, the decrease of the RP content in this period has not carried much weight on the digestibility. It therefore seems not justified to apply different dcOM

values on grassland products between 1990 and present. Over the whole period, the dcOM for grass silage was about 76%. The DE value has therefore been estimated to be 72% (4% adjustment).

The data of the feed intake are presented in Table 1.9. The results of the calculated DE value in the rations are presented in Table 3.5.

Table 3.5 Calculated DE values of the different animal categories in 1990, 1995 and 2002

		DE (%)		
		1990	1995	2002
Cattle for breeding				
201	Female young stock under 1 yr	75	75	75
203	Male young stock under 1 yr	75	75	75
205	Female young stock, 1-2 yrs	75	75	75
207	Male young stock, 1-2 yrs	73	73	73
209	Female young stock, 2 yrs and over	75	75	75
211	Cows in milk and in calf*	73/72	73/73	72/71
213	Bulls for service 2 yrs and over	73	73	73
Cattle for fattening				
216	Meat calves, for rosé veal production	78	78	77
214	Meat calves, for white veal production	90	89	89
217	Female young stock under 1 yr	75	75	75
219	Male young stock (incl. young bullocks) under 1 yr	75	75	75
221	Female young stock, 1-2 yrs	75	75	75
223	Male young stock (incl. young bullocks), 1-2 yrs	76	76	76
225	Female young stock, 2 yrs and over	75	75	75
227	Male young stock (incl. young bullocks), 2 yrs and over	76	76	76
228/229	Suckling, fattening and grazing cows, 2 yrs and over	76	76	76

*: Value of region North West/ South East. Because of a digestion depression at a relatively high feed level, an adjustment has been made for cows in milk of minus 4 units. The estimation of 4% at 2.5 times maintenance leads to a good estimate. (McDonald et al., 1995).

The applied DE values are equal for all 3 years, with the exception of cows in milk and meat calves. The lower share of meadow grass can explain the lower DE in 2002 and in the East South region in cows in milk.

3.1.8 Gross energy

The formula for the calculation of the gross energy is as follows (IPCC, 2000).

GE ={[(NEm + NEmob + NEa + NEl + NEp)/(NEma/DE)] + [NEg / (NEga/DE)]}/ (DE/100)

GE: Gross energy, MJ/day

From the gross energy intake the daily dry matter intake can be calculated. For this aim the gross energy intake is divided by the energy density of the ration (18.45 MJ/kg dm).

DMi = GE / 18.45

DMi: Calculated dry matter intake per animal/day

3.1.9 Emission factor

The formula for the calculation of the emission factor is as follows (IPCC, 2000):

$$\mathbf{EF = (GE * Y_m * 365\ days/year) / 55.65\ MJ/kg\ CH_4}$$

EF: Emission factor, kg methane / animal / year
GE: Gross energy intake, MJ / animal / day
Y_m: methane conversion factor; fraction of the gross energy in the ration, which is converted into methane

For the value of the methane conversion factor under Dutch circumstances the values given by the IPCC (2000) are taken as a starting point. With regard to developed countries, the following subdivision is made for the estimation of the methane conversion factor.

Table 3.6 Methane conversion factors for developed countries (IPCC, 2000)

	Y_m
Cattle fed with more than 90% feed concentrate	0.04 ± 0.005
Other cattle which does not belong to the first category	0.06 ± 0.005

The methane conversion factor used is 0.04 for white veal calves and 0.06 for all other categories. Zijderveld and Van Straalen (2004) have indicated that a conversion factor of 0.06 can be applied to the Dutch situation. The height of this conversion factor strongly influences the calculated methane production, since the application of 0.055 instead of 0.06 will already result in a decrease of the methane production by 10 kg per year for one milk cow. This is similar to around 10%.

3.2 Discussion on results

3.2.1 Trends 1990 - 2002

In the period 1990-2002, the total calculated methane emission of cattle (calculated through the IPCC-GPG Tier 2 method) decreased by around 16%. This decrease is for the largest part due to a decrease of the number of animals by 25%.

In 2002, 85% of the total methane production originated from cattle for breeding. The production of methane by the group cows in milk and in calf is 65% of the total. From 1990 onward the number of cows in milk and in calf decreased by about 20%. The calculated decrease of the total methane production for cows in milk and in calf amounts to around 12%. The emission factor (kg methane per animal per year) for cows in milk was about 102 kg in 1990, about 106 kg in 1995, and about 114 kg in the years 2000-2002. In the years 2000-2002 there were no big differences in milk production and methane emission factor of cows in milk. Compared to 2000 this even seems to have decreased in 2002. According to the calculations of the IPCC-GPG Tier 2 method, the calculated methane emission factor of cows in milk and in calf increased with more than 10% in the period 1990-2002. This increase is a logical result from a higher milk production. In order to realize this higher milk production through the IPCC-GPG Tier 2 method a higher dry matter intake is calculated (14.0 kg in 1990; and 15.8 kg in 2000-2002). In relation to 1990 the milk production per cow increased

by 20%. Compared to 1990, in the years 2000-2002, the methane production of the cows in milk and in calf went down by 6-7% per litre produced milk.
In the period 1990-2002 there was a change of the ration. The share of green maize increased. The amount of consumed grassland products per cow remained the same, but the share of meadow grass in it became smaller. Green maize and grass silage have a lower DE value than meadow grass (See, Table 3.4). With a shift from meadow grass to more green maize according to the IPCC-GPG Tier 2 calculation the gross energy intake per cow will also increase and therefore the methane emission per cow.

The methane emission factor of the other animal categories hardly changed over the period 1990-2002.

3.2.2 Differences between regions and influence of feed

The WUM works with two regions, namely the East and South of the Netherlands (relatively high share of green maize in the ration) and the North and West of the Netherlands (relatively low share of green maize in the ration). The total calculated methane emission in the East-South region is 145,000 ton of which about 80% is produced by cattle for breeding and 20% by cattle for fattening (See, Appendix 4). In the North-West region more than 90% of the calculated methane emission is produced by cattle for breeding.

The calculated methane emission factor for all animal categories is in both regions almost identical. This is a result from the fact that:
- An equal milk production is calculated;
- No differences in body weight are utilized;
- The calculated digestible energy coefficients (DE%) when rounding off to whole percentages, are identical in almost all the cases.

The calculated dry matter intake of the animals in the regions is identical in almost all the cases. This is well in conformity with the actual differences within the animal categories between the regions, as utilized by the WUM. The WUM, however, makes a division in regions mainly because of different N-contents in the supplied basic rations (because of a different share of green maize and grass silage).
The influence factor feed on the calculated methane production through IPCC-GPG is only indirectly present in the form of the estimation of the digestible energy value (DE in % of GE). The influence factor DE strongly influences the height of the calculated methane emission. In order to be able to give a good estimation of this, also compared to other countries, there has been carried out a study that is described in Appendix 1. The height of the chosen DE value conforms well to other feed tables with regard to the same mixed feed raw materials.

The increase of the share of green maize and the share of feed concentrate in mainly the North-West region influences the methane production, too. In this report this is not being dealt with. The influence factor feed has, inter alia, recently been described in a study within the ROB programme of Novem (Smink et al., 2003).

3.2.3 Estimations of the methane production per animal

The methane emission factor (in kg methane per animal per year) is presented in Table 2.2. A quick comparison with the present emission factors shows the following picture:

- The present methane emission is estimated through the IPCC-GPG Tier 2 method on about 113 kg per year for cows in milk. For 1990, a value of 102 kg has been calculated. This value is at the same level as the 102 kg for 1990, which has been indicated by Van Amstel et al. (1993).

- The methane emission factor for young stock for breeding until 1 year is about 29-36 kg in the period from 1990 to 2002. This value is 35-40% lower than the one calculated by Van Amstel et al. (1993). Both the calculated feed intake (Table 2.1) and the actual feed intake (Table 1.8) are 4-4.5 kg dm per day. The calculated feed intake and methane emission factor equals about 30-35% of the values in cows in milk and in calf.

- The methane emission factor for male animals for breeding and the female animals for fattening (suckling, fattening and grazing cows) is 30-40% lower in the present way of calculating in comparison to the values indicated by Van Amstel et al. (1993). The dry matter intake calculated by us conforms well to the values of the WUM for these animal categories.

- The methane emission factor for meat calves is divided into rosé and white veal calves. For the white veal calves a methane conversion factor of 4% was applied, because the share of roughage in the ration is less than 10%. However, more than 90% of the ration consists of milk powder and will in principle pass through the rumen via the oesophagus. Probably, the methane production as a result from rumen fermentation is still highly overestimated.

Table 1 of Appendix 3 contains an overview of methane emission factors for cows in milk and in calf in some countries with high productive dairy cattle. The emission factors calculated in this report have been used for the Netherlands. Both for the basic year 1990 and for the year 2002 the Dutch methane emission factor, expressed in grams of methane per litre produced milk, is not incongruous.

From the calculation methodology described in this report it is remarkable that an increase of green maize in the ration does not lead to a decrease of the methane emission factor per cow. The methane emission factors for cows in milk in the East and South of the Netherlands with relatively much green maize in the ration are higher than those for cows in milk in the North and West of the Netherlands with relatively little green maize in the ration (See, Table 2 in Appendix 4). The reason for this is that according to Table 3.4 green maize has a lower DE value than meadow grass and that the methane conversion factor of 6% is applied in both rations (irrespective of the share of maize silage). The influence of a relatively larger share of feed concentrate and green maize in the ration on the methane conversion factor therefore deserves to get more attention.

4 CONCLUSIONS

The most important conclusions are indicated briefly below.

The total calculated Dutch methane production as a result from rumen fermentation in cattle was 312,449 ton in 1990; it decreased to 261,668 ton in 2002. This means a decrease by about 16%.

Cattle for breeding (milk production) accounts for around 85% of the methane production. The methane production by cows in milk and in calf is around 64% of the total methane production by rumen fermentation in cattle.

In the period 1990-2002, the calculated methane emission factor for cows in milk and in calf through the IPCC-GPG Tier 2 method increased by 10%, whereas in the period 2000-2002, the calculated methane emission per animal consolidated or even slightly decreased.

The methane production per kg of milk in the period 2000-2002 is 6-7% lower compared to the year 1990.

The WUM works with two different regions based on the differences in basic ration for cows in milk. Calculation of the methane emission factor by using the IPCC-GPG Tier 2 method does not lead to clear differences between the two regions.

Decreasing the N-fertilization in the period from 1990 till present has resulted in lower CP-contents in grassland products. The decrease of the crude protein contents in the last decennium has not affected the dcOM and consequently, not the dcGE (or DE%) either.

The DE value selected strongly influences the calculated methane production. A workable alternative for calculating the dcGE (or DE value) is to apply the dgOM [dcOS] as applied in the Netherlands, with an adjustment (decrease) of 2-4%.

The new methane emission factors are remarkably lower than the values used to date, in particular with regard to young stock, male cattle for breeding and female cattle for fattening.

Points of improvement

Within the calculation methodology as described in this report a shift from meadow grass to more green maize in the ration entails an increase of the gross energy intake and consequently a higher methane emission per cow. An effect of a larger share of green maize and feed concentrates on the decrease of the methane conversion factor has not been considered. It is advisable that more attention be paid to this when a future review of the calculation methodology will be carried out.

5 FUTURE PROTOCOL RUMEN FERMENTATION IN CATTLE

The calculation of the methane emission as a consequence of rumen fermentation is based on the IPCC-GPG Tier 2 methodology. This methodology starts from the total gross energy intake by the animal for its maintenance, growth, milk production, activity, mobilization body reserve, gestation and labour. From the total gross energy the methane production is calculated with a conversion factor.

The zoo technical numbers necessary to be able to calculate the gross energy intake are collected annually by the WUM (Working Group on Uniform calculations of Manure and Mineral figures) for the annual calculation of the mineral excretion of productive livestock. By applying these figures there will be consistency between the mineral excretion and the methane production.

Although all input variables in the IPCC formula for gross energy intake are in principle year specific, it is here suggested that only the variables be adjusted that influence the emission significantly. Furthermore, it is proposed to use a fixed emission factor per period of 5 years, for animal categories with minor annual fluctuations in the methane production, in other words: an emission factor for 1990 and a review thereof in 1995, 2000, 2005 etc.

In concrete terms this entails the following.

CATTLE for BREEDING	
Female young stock < 1 yr	fixed emission factor, readjustment every 5 years
Male young stock < 1 yr	fixed emission factor, readjustment every 5 years
Female young stock 1 yr to calving down	fixed emission factor, readjustment every 5 years
Male young stock 1 – 2 yrs	fixed emission factor, readjustment every 5 years
Cows in milk and in calf	annual emission factor
Bulls for service > 2 yrs	fixed emission factor, readjustment every 5 years
CATTLE for FATTENING	
Meat calves, rosé veal	fixed emission factor, readjustment every 5 years
Meat calves, white veal	fixed emission factor, readjustment every 5 years
Female young stock < 1 yr	fixed emission factor, readjustment every 5 years
Male young stock + young bullocks < 1 yr	fixed emission factor, readjustment every 5 years
Female young stock 1 yr and over	fixed emission factor, readjustment every 5 years
Male young stock + young bullocks > 1 yr	fixed emission factor, readjustment every 5 years
Suckling cows, incl. fattening and grazing cows > 2 yrs	fixed emission factor, readjustment every 5 years

With respect to the calculation of the annual emission factor for cows in milk and in calf, the compound of the ration and the digestibility, the annual milk production and the share of meadow grass in the ration are of special interest. These numbers are taken from the WUM. The digestibility of the ration components, expressed per kg feed product, has no annual variation and these values have been presented in this report. Other required activity data are: the number of animals in the different animal categories, the milk production and milk compound, and the animal weights.

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Appendix 1 Inventory of feed raw materials in a number of countries with high productive dairy cattle.

In this part, the quality data of a number of feed raw materials as published by the CVB (2003) are compared with data sets, which are the basis for the feed valuation systems as utilized in North America (NRC, 2001, 1978), England (AFRC; Alderman and Cottrill, 1993) and France (INRA; Sauvant et al., 2004). The aim of the investigation is to find out the digestion coefficients of the organic matter (dcOM) as applied by the CVB relate to the digestion coefficients of organic matter or of the digestible energy (dcOM or dcGE) determined by the NRC, AFRC and INRA. Dry feed concentrate raw materials are appropriate for comparing results of digestion between different systems, because there will be expected a relatively limited effect on the digestibility between regions.

NRC:

In the NRC system, the sum of the digestible quantity of energy coming from individual nutrients is expressed in units "Total Digestible Nutrients" (TDN) (NRC, 2001; Guyer, 1996). In practice this means that the TDN is equated with the digestion coefficient of the digestible energy (dcGE).

AFRC:

In the English system the energy valuation is expressed in metabolisable energy (ME). For the relation between ME and DE (loss of energy via urine and CH_4) a fixed number is taken (ME/DE = 0.86). The DE calculated from this can be expressed in percentages as opposed to the gross energy (GE). However, in the AFRC-publication there is no information on the GE-values. To this end, the table values as published by the INRA (2004) have been taken over.

INRA:

In the publication "Tables of composition and nutritional value of feed materials" of the INRA information is given on the dcOM and the dcGE as well as the GE.

In Table 1 the background data used for the calculations are presented.
In Figure 1 the digestion coefficients from the CVB are compared with those of the NRC, the AFRC and the INRA.

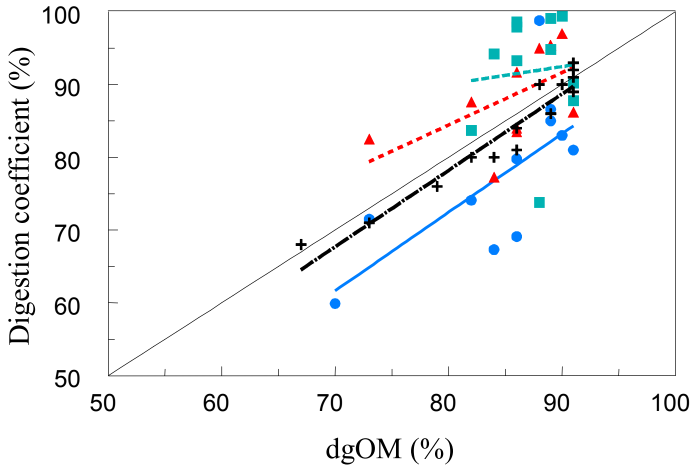

Figure 1. Relation between the dcOM (CVB) and the TDN (NRC;), dcGE (NRC;), dcGE (AFRC;) and dcGE (INRA;) or a number of mixed feed raw materials.
The regression coefficients are given below:

dcOM vs. TDN (NRC):	Ey = -13.95 + 1.08x	$R^2 = 0.45$
dcOM vs. dcGE (NRC):	Ey = 26.87 + 0.72x	$R^2 = 0.30$
dcOM vs. dcGE (AFRC):	Ey = 70.88 + 0.24x	$R^2 = 0.01$
dcOM vs. dcGE (INRA):	Ey = -5.77 + 1.05x	$R^2 = 0.91$

From Figure 1 it clearly appears that the dcGE-data of the INRA (+) resemble the dcOM-values of the CVB the most. Compared to the TDN (●) the dcOM gives higher values with a direction coefficient equal to 1, which indicates a difference in level between CVB and NRC. With respect to the dcGE (NRC, ▲) a slightly lower dcOM was attained. With regard to the AFRC data a major variation was found where the dcGE (AFRC) gives on average higher values than the calculated dcOM. The dcGE for AFRC has been calculated by us from the given ME. Probably, the dcGE for AFRC is overestimated at the selected presuppositions. INRA gives both the dcOM and the dcGE. When the dcOM (CVB) data of the raw materials are compared with those of the INRA, then the two appear to be almost exactly equal (Table 1). In Figure 2 the relationship between the dcOM and the dcGE is presented on the basis of the INRA-table values.

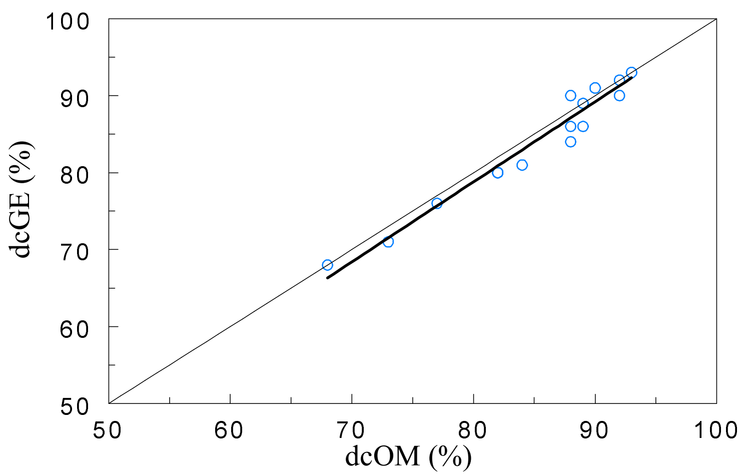

Figure 2. Relationship between the dcOM and the dcGE on the basis of INRA-data.
Ey = -4.40 + 1.04x $R^2 = 0.95$

The linear data show that generally compared to the dcGE slightly higher coefficients are found for the dcOM. The equation demonstrates that the dcGE can be deduced with high precision from the dcOM. At a dcOM of 80% the calculation can be drawn that rounded off dcGE must be 79% (-4.4 + 1.04 * 80). In research with hamel digestion tests carried out by different institutes, it appeared that the dcOM is higher compared to the dcGE. This difference is on average 1-3%-units for feed concentrate raw materials and 2 – 5%-units for roughages. With respect to grass silage, an adjustment has been chosen of 4% and with respect to green maize and fresh grass 3%.
These coefficients for digestible energy constitute the input-data for the IPCC equations as mentioned in paragraph 3.1.7.

Table 1. Digestion coefficients of a number of feed raw materials[1].

NAME	CVB	INRA			NRC		AFRC	
	dcOM %	dcOM %	dcGE %	GE MJ/kg	TDN %	dcGE [2] %	ME MJ/kg	dcGE [2] %
Beet pulp sugar <100	86	84	81	15.2	69.1	83.5	12.8	97.9
Beet pulp sugar 100-150	86	84	81	15.1	69.1	84.0	12.8	98.6
Citrus pulp	86	88	84	15.7	79.8	91.7	12.6	93.3
Peas	90	92	90	15.8	83.0	97.0	13.5	99.4
Lupins CFat<70 CP<335	91	89	89	18.3			14.2	90.2
Lupins CFat<70 CP>335	91	90	91	18.8			14.2	87.8
Maize	89	89	86	16.2	85.0	95.4	13.8	99.1
Maize gluten feed CP>240	82	82	80	16.4	74.1	87.6	11.8	83.7
Palmseed flakes CF>220	67	68	68	18.2				
Rapeseed expeller	79	77	76	17.1				
Soybeans heated	88	88	90	20.8	98.8	95.0	13.2	73.8
Soya hulls CF>310	84	82	80	16.3	67.3	77.3	13.2	94.2
Soybean meal CF<50	91	93	93	17.2				
Soybean meal CF>70	91	92	92	17.3				
Soyb. meal CF 50-70 CP<440	91	92	92	17.1				
Soyb. meal CF 50-70 CP>440	91	92	92	17.3	81.0	86.2		
Tapioca Starch 575-625	84							
Wheat	89	88	86	16.8	86.6	95.4	13.7	94.8
Wheat bran	73	73	71	16.4	71.5	82.5		
Sunflowers meal CF 160-200	70				59.9		9.6	

[1]. dcOM = digestion coefficient OM; dcGE = digestion coefficient GE; GE = gross energy; TDN = total digestible nutrients; ME = metabolisable energy
[2]. dcGE calculated by us on the basis of GE-values as given by INRA.

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Appendix 2 Digestible energy of grassland products as a function of the protein content and other quality characteristics

The height of the calculated methane production calculated according to the IPCC directive is dependent of the height of the digestibility. By changes in the legislation on fertilization the N-fertilization level on grassland decreased over the last 15 years. A literature study has been carried out to gain an insight into the consequences of the decrease in relation to the compound and the digestibility of grass and grass silage. This study mainly focuses on research carried out in the Netherlands during the period from 1990 till present. On the basis of literature data the relations between the digestion coefficient of the organic matter (dcOM), on the one hand and the crude protein (CP) and cell walls (NDF), on the other hand have been illustrated in a number of figures.

Figure 1 shows the relations between the CP and NDF as reported by Gosselink (2004), Valk (2002), and Van Vuuren (1993). Based on these data the following regression equations have been formulated:

Valk:	477 – 0.044x	$R^2 = 0.003$
Van Vuuren:	473 – 0.313x	$R^2 = 0.466$
Gosselink (grass):	674 – 1.077x	$R^2 = 0.413$
Gosselink (clover):	580 – 0.596x	$R^2 = 0.665$

The data of Valk have a big spread so that there is no connection illustrated between the CP and NDF. The data of both Van Vuuren and Gosselink show a clear connection between CP and NDF and the combined data of the three authors present a clear relationship where a higher CP-content is connected with a lower NDF-content.

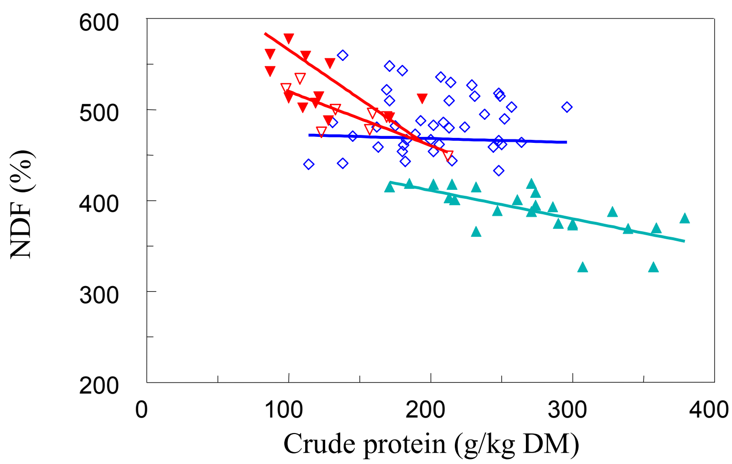

Figure 1. Relation between CP and NDF according to observations by Valk (2002; ◊), Van Vuuren (1993; ▲) and Gosselink (2004; red clover, ∂ ; rye-grass, ▼)

Figure 2 shows the relation between the CP and the dcOM as reported by Gosselink (2004), Valk (2002), Nevens and Reheul (2001) and Van Vuuren (1993). A number of regression equations are presented:

Valk:	77.6 + 0.013x	$R^2 = 0.04$
Van Vuuren:	82.1 + 0.006x	$R^2 = 0.06$
Gosselink (grass):	52.4 + 0.157x	$R^2 = 0.68$
Gosselink (clover):	43.0 + 0.146x	$R^2 = 0.78$

It is noteworthy in these data that, the more the CP-contents decrease (< 150 to 200 g/kg) the more the spread in the dcOM increases and the dcOM shows a tendency to lower values. With CP contents > 150 g/kg the spread in dcOM seems to diminish and there is no noticeable influence of CP on the digestion coefficients. The tests carried out by Nevens and Reheul on extensive parcels or parcels in transition to extensive parcels have generally low CP contents (120 g/kg) with a clearly lower dcOM. However, on the extensive grasslands other than rye grasses were found which in part explains the lower dcOM.
The data of Valk and Van Vuuren in particular suggest that, if the CP contents of grass do not reach a level lower than 150 g CP/kg the height of the dcOM will slightly or not be influenced. Earlier work published by Korevaar (1986) confirms this.

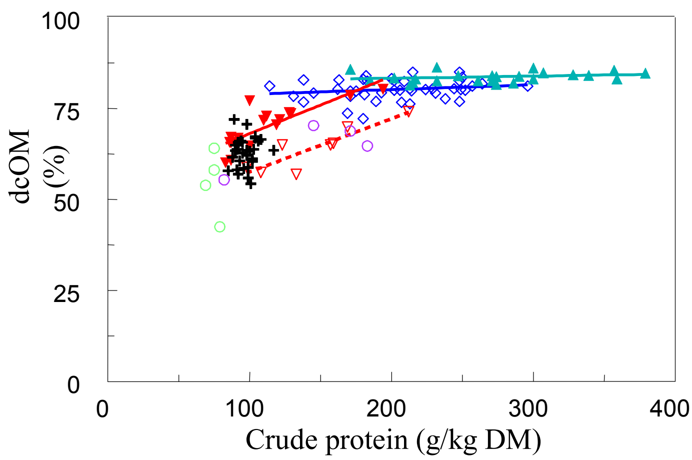

Figure 2. Relation between CP and dcOM according to observations by Valk (2002; ◊), Van Vuuren (1993; ▲), Gosselink (2004; red clover, ∂ ; rye-grass, ▼), Nevens and Reheul (2001; grasslands +; grassland extensive, O; grassland intensive, O)

In Figure 3, the relation between the NDF and the dcOM is presented on the basis of the data of Gosselink (2004), Valk (2002) and Van Vuuren (1993). In this case, all the authors found a clear relationship between NDF-content and dcOM, which is in line with the expectations.

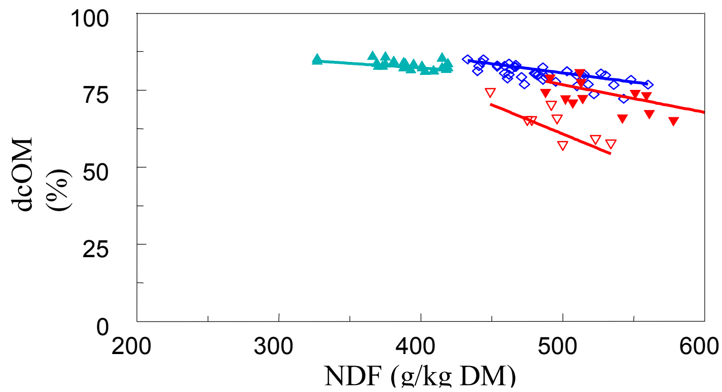

Figure 3. Relation between NDF and the dcOM according to observations by Valk (2002; ◊), Van Vuuren (1993; ▲), and Gosselink (2004; red clover, ∂ ; rye grass, ▼).

Next to these literature data an investigation has been made into the changes in the relation between the dcOM, on the one hand and Protein content and cell walls on the other hand during the last decennium. For this aim, the mean was taken based on the data of the Laboratory for Soil and Crop Testing, BV [Bedrijfslaboratorium voor Grond- en Gewasonderzoek (Blgg)] in Oosterbeek (period 1990 – 2003). No information is available regarding the number of observations per data set, but it may be assumed that certainly with regard to the fresh grass analyses, the number of analysed samples is significantly lower than the number of analysed grass silages.

In Figure 4, the course of the CP-content in grass and grass silage during this period of time is presented. The average analysis results of fresh grass show a tendency of a decreasing CP-content with an average CP of 25.7% in 1999 to 22.5% in 2003. With respect to the grass silage a similar tendency is found, but the effect is less strong at a greater variation (from 20.1% in 1990 to17.2% in 2003).

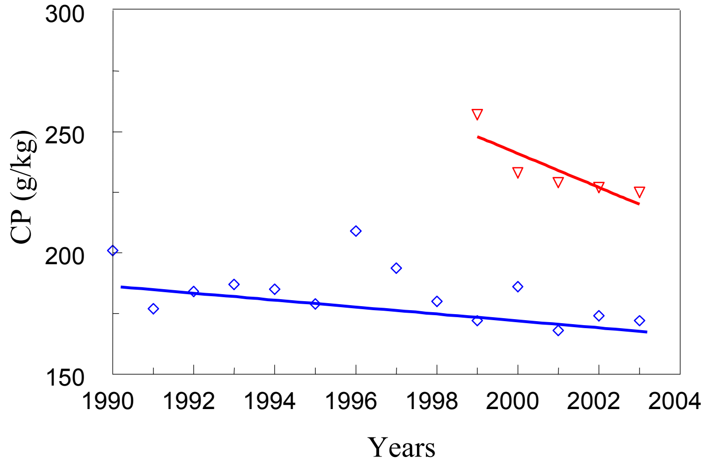

Figure 4. Course of the crude protein content in grass and grass silage from 1990 till 2003.

Figure 5 reflects the course of the dc-OM in grass and grass silage from 1994 till 2003.

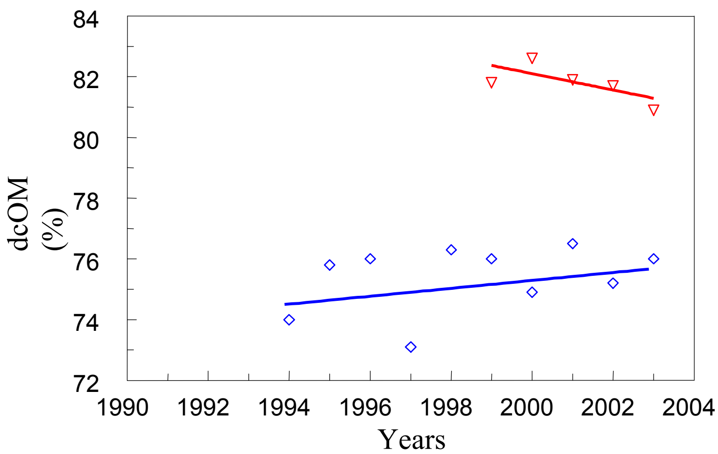

Figure 5. Course of the dcOM content in grass and grass silage from 1994 – 2003.

The dcOM of grass silages has slightly increased from 1994. The incline of the regression line is for a large part steered by the low observations in 1994 and 1997. After an adjustment for these points it can be supposed that the dcOM of grass only slightly changed during the period 1994 – 2003. Although from 1999 the fresh grass demonstrates a tendency to lower dcOM-values, the maximum difference between the highest and the lowest dcOM-observation is less than 2 %-units (80.9 – 82.6%).

Figure 6 reflects the course of the NDF (cell walls) and the relationship of the ADL/NDF (lignification of the cell wall fraction) in grass silages from 1999 to 2003.

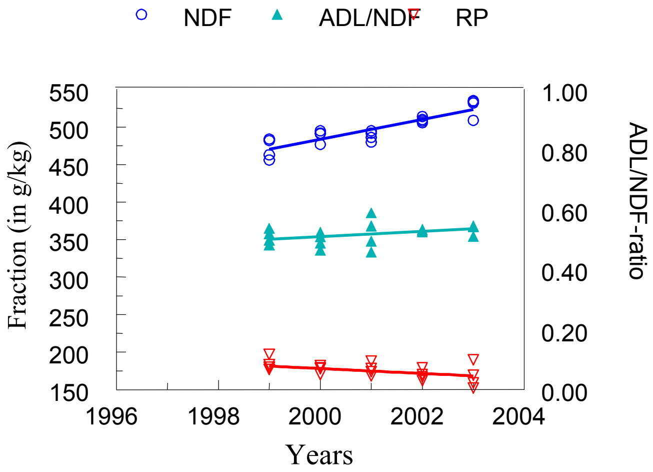

Figure 6. Course of the NDF, CP and the ADL/NDF-ratio of grass silages from 1994 till 2003.

This Figure clearly illustrates that there is a tendency to a lower CP-content in the grass, which is combined with an increase in NDF. The share of lignine in the cell wall fraction however seems to have increased relatively less quickly, and less lignification of the cell walls results in a higher digestibility.
Although the CP in grass silage seems to diminish and the NDF increases, the effect on the dcOM seems to be low. Although these trends may be observed from 1999 it is questionable whether this will continue in the same way. Given the minimal trend in change of the dcOM it now seems to be realistic to take the digestion coefficients for the GE (dcGE) on the basis of the present dcOM as a starting point. In this way the dcOM is adjusted to dcGE as described in Appendix 1.

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Appendix 3 Overview IPCC calculation rumen fermentation in other countries with high productive dairy cattle

The IPCC directives for the calculation of the methane emission as a result from rumen fermentation take the total gross energy intake by ruminants as a starting point. From this the methane emission is calculated with a so-called methane conversion factor. For this purpose the IPCC directives contain a number of formulas through the application of which the energy need for maintenance, growth, milk production, activity, mobilization body reserve, gestation and labour can be calculated. The Tier 1 method starts from a fixed methane emission factor per animal based on fixed code numbers for milk production, growth, etc. The Tier 2 method starts from the same formulas, but it uses country specific code numbers for milk production, growth etc. This Appendix presents a concise overview on how other countries with high productive dairy cattle calculate the methane emission. The information is taken from the National Inventory Reports 1990 – 2002 of these countries. Finally, a Table is presented for these countries with high productive dairy cattle with data on the milk production per cow and the matching methane emission, expressed both in kg CH4 per dairy cow and in grams CH4 per litre produced milk.

AUSTRALIA
National Greenhouse Gas Inventory 2002 (date of publication, April 2004) indicates that the energy intake of dairy cattle is calculated according to the *Feeding Standards for Australian livestock, Ruminants 1990*, edited by SCA, Standing Committee on Agriculture, CSIRO Australia. The methane conversion factor is calculated according to the well-known formula of Blaxter and Clapperton (1965). This formula takes into consideration the digestibility of the feed and the relation total feed level compared to the maintenance need.
The National Inventory Report gives a cumulative value for dairy cattle, a group that includes cows in milk, young stock and bulls for service. The Report does not provide any insight into the share of these categories separately.

CANADA
Canada's Greenhouse Gas Inventory 1990 – 2001 (date of publication, August 2003) takes a Tier 1 approach for dairy cattle. In the coming years a switch will be made to a Tier 2 approach. Both for 1990 and for 2001 a methane emission factor of 118 kg CH4 per dairy cow is applied; this value is derived from USA calculations.

DENMARK
Denmark's National Inventory Report 1990 -2002 (date of publication, June 2004) bases on a Tier 2 approach of the methane emission of dairy cattle. The energy intake is calculated according to Danish standards and then multiplied by a methane conversion factor of 6%.

GERMANY
The German calculations are extensively documented in the *Nationaler Inventarbericht 2004 – Berichterstattung unter der Klimarahmenkonvention der Vereinten Nationen – Teilbericht für die Quellgruppe Landwirtschaft,* Landbauforschung Völkenrode Sonderheft 260, edition 2003. The methane emission of cows in milk is calculated with regression formulas of Kirchgessner et al. (1991), for the other cattle the default Tier 1 values are applied.

FRANCE
The French calculations are documented in two documents, both published by CITEPA. These are: *Inventaire des émissions de gaz à l'effet de serre en France*, date of publication, December 2003, and *Organisation et méthodes des inventaires nationaux des émissions atmosphériques en France*, Draft Report, April 2004. The methane emission factors for cows in milk are based on regression formulas similar to the ones applied by Germany, whereas for the other cattle categories the default Tier 1 values have been applied.

NEW ZEALAND
New Zealand's Greenhouse Gas Inventory 1990 – 2002 (date of publication April, 2004) indicates that one calculates the energy intake of cattle according to Australian Feeding Standards. Subsequently, a methane conversion factor of 6,5% for cattle is applied. Just like with Australia a cumulative figure is presented for dairy cattle and the Inventory does not give any information on cows in milk separately.

UK
UK Greenhouse Gas Inventory, 1990 to 2002, date of publication April, 2004, indicates that the energy intake of dairy cattle is calculated in conformity with IPCC directives Tier 2 approach. Furthermore, a methane conversion factor of 6% is applied. The energy required for activity during grazing, is multiplied with a factor 0.43, because dairy cattle grazes only part of the year.

USA
Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2002, date of publication, 15 April 2004, reports that the energy intake of dairy cattle is calculated in accordance with the Tier 2 approach of IPCC. The calculation is made with a methane conversion factor lower than 6%. Furthermore, with regard to the energy for activity during grazing it is taken into consideration, that the dairy cattle only grazes part of the year. Since a cumulative number is used for dairy cattle the code numbers for energy intake of cows in milk and the matching methane conversion factor cannot be derived. On the other hand, it is possible to derive from the Inventory the methane emission factor for cows in milk.

Methane emission per dairy cow and per litre of milk
Table 1 gives information on the milk production per cow and the matching methane emission with regard to the above mentioned countries of which the data on cows in milk are available. Among these countries, only Canada takes a Tier 1 approach for cows in milk. When having a closer look at the countries with a Tier 2 approach, one will notice that, in all countries in the period 1990 to 2002 the methane emission per cow increases and that the methane emission per litre produced milk goes down. The Table also shows that the Dutch methane emission factor for cows in milk conforms reasonably well to the factors applied by other countries. At presenting the data of all countries in Table 1 in a graph it then appears that at an increasing milk production per cow the methane emission per cow also increases and that the methane emission per litre produced milk decreases (See, Figure 1).

Table 1. Methane emission by cows in milk as a result from rumen fermentation in some countries with high productive dairy cattle, for the years 1990 and 2002. Source: National Inventory Reports; data for The Netherlands from this study.

	Canada	Denmark	Germany	France	The Netherlands	UK	USA
1990							
Milk production litre/cow/year	5808	6231	4699	4723	6050	5204	6705
Methane emission Kg CH4/cow	118	109.5	94.3	98.8	101.9	103.9	114
Methane emission g CH4/litre milk	20	18	20	21	17	20	17
2002							
Milk production litre/cow/year	7348	7525	6216	6043	7187	6529	8451
Methane emission kg CH4/cow	118	118.0	102.7	103.3	113.2	121.2	116
Methane emission g CH4/litre milk	16	16	17	17	16	19	14

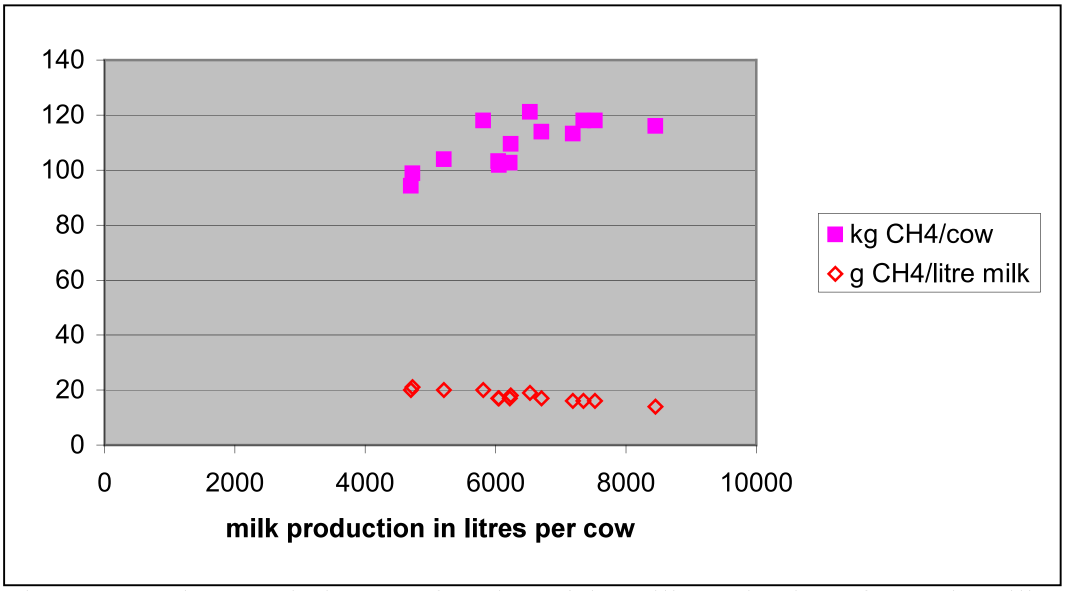

Figure 1. Methane emission as a function of the milk production of cows in milk. Data are taken from Table 1.

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Appendix 4 Results; division per region

Table 1 Calculated gross energy intake (GE) in MJ/d and dry matter intake (DMi) in kg /d.

	1990		1995		2000		2001		2002	
	GE	DMi	GE	DMi	GE	DMi	GE	DMi	GE	DMi
East and South of the Netherlands										
Cattle for breeding										
Female young stock < 1 yr	85.7	4.6	85.7	4.6	88.3	4.8	88.3	4.8	88.3	4.8
Male young stock < 1 yr	73.7	4.0	73.7	4.0	92.8	5.0	92.8	5.0	92.8	5.0
Female young stock 1 yr – calving down	130.8	7.1	130.8	7.1	132.5	7.2	132.5	7.2	132.5	7.2
Male young stock 1-2 yrs	140.1	7.6	140.1	7.6	140.1	7.6	140.1	7.6	140.1	7.6
Cows in milk and in calf	261.2	14.2	268.4	14.5	294.4	16.0	289.0	15.7	290.2	15.7
Bulls for service > 2 yrs	159.0	8.6	159.0	8.6	159.0	8.6	159.0	8.6	159.0	8.6
Cattle for fattening										
Meat calves, rosé veal	90.4	4.9	90.4	4.9	96.1	5.2	96.1	5.2	96.1	5.2
Meat calves, white veal	62.6	3.4	63.5	3.4	67.6	3.7	67.6	3.7	67.6	3.7
Female young stock < 1 yr	85.7	4.6	85.7	4.6	88.3	4.8	88.3	4.8	88.3	4.8
Male young stock + young bullocks < 1 yr	102.0	5.5	99.7	5.4	102.7	5.6	102.7	5.6	102.7	5.6
Female young stock 1-2 yrs and over	123.5	6.7	123.5	6.7	125.1	6.8	125.1	6.8	125.1	6.8
Male young stock + young bullocks > 1 yr	151.4	8.2	151.0	8.2	152.7	8.3	152.7	8.3	152.7	8.3
Suckling, fattening and grazing cows > 2 yrs	163.9	8.9	163.9	8.9	164.2	8.9	164.2	8.9	164.2	8.9
North and West of the Netherlands										
Cattle for breeding										
Female young stock < 1 yr	85.7	4.6	85.7	4.6	88.3	4.8	88.3	4.8	88.3	4.8
Male young stock < 1 yr	73.7	4.0	73.7	4.0	92.8	5.0	92.8	5.0	92.8	5.0
Female young stock 1 yr – calving down	130.8	7.1	130.8	7.1	132.5	7.2	132.5	7.2	132.5	7.2
Male young stock 1-2 yrs	140.1	7.6	140.1	7.6	140.1	7.6	140.1	7.6	140.1	7.6
Cows in milk and in calf	256.4	13.9	268.4	14.5	288.9	15.7	289.0	15.7	284.8	15.4
Bulls for service > 2 yrs	159.0	8.6	159.0	8.6	159.0	8.6	159.0	8.6	159.0	8.6
Cattle for fattening										
Meat calves, rosé veal	90.4	4.9	90.4	4.9	96.1	5.2	96.1	5.2	96.1	5.2
Meat calves, white veal	62.6	3.4	63.5	3.4	67.6	3.7	67.6	3.7	67.6	3.7
Female young stock < 1 yr	85.7	4.6	85.7	4.6	88.3	4.8	88.3	4.8	88.3	4.8
Male young stock + young bullocks < 1 yr	102.0	5.5	99.7	5.4	102.7	5.6	102.7	5.6	102.7	5.6
Female young stock. 1-2 yrs and over	123.5	6.7	123.5	6.7	125.1	6.8	125.1	6.8	125.1	6.8
Male young stock + young bullocks > 1 yr	151.4	8.2	151.0	8.2	152.7	8.3	152.7	8.3	152.7	8.3
Suckling, fattening and grazing cows > 2 yrs	163.9	8.9	163.9	8.9	164.2	8.9	164.2	8.9	164.2	8.9

Table 2 Emission factor (kg methane/animal/year) per animal category

	Emission factor methane				
	1990	1995	2000	2001	2002
<u>East and South of the Netherlands</u>					
Cattle for breeding					
Female young stock < 1 yr	33.73	33.73	34.75	34.75	34.75
Male young stock < 1 yr	29.00	29.00	36.53	36.53	36.53
Female young stock 1 yr–calving down	51.49	51.49	52.16	52.16	52.16
Male young stock 1-2 yr	55.15	55.15	55.15	55.15	55.15
Cows in milk and in calf	102.79	105.64	115.84	113.73	114.22
Bulls for service > 2 yrs	62.59	62.59	62.59	62.59	62.59
Cattle for fattening					
Meat calves, rosé veal	35.59	35.59	37.82	37.82	37.82
Meat calves, white veal	16.42	16.66	17.73	17.73	17.73
Female young stock < 1 yr	33.73	33.73	34.75	34.75	34.75
Male young stock + young bullocks < 1 yr	40.13	39.25	40.43	40.43	40.43
Female young stock 1-2 yrs and over	48.61	48.61	49.23	49.23	49.23
Male young stock + young bullocks > 1 yr	59.57	59.43	60.08	60.08	60.08
Suckling, fattening and grazing cows > 2 yrs	64.51	64.51	64.61	64.61	64.61
<u>North and West of the Netherlands</u>					
Cattle for breeding					
Female young stock < 1 yr	33.73	33.73	34.75	34.75	34.75
Male young stock < 1 yr	29.00	29.00	36.53	36.53	36.53
Female young stock 1 yr-calving down	51.49	51.49	52.16	52.16	52.16
Male young stock 1-2 yrs	55.15	55.15	55.15	55.15	55.15
Cows in milk and in calf	100.91	105.64	113.69	113.73	112.09
Bulls for service > 2 yrs	62.59	62.59	62.59	62.59	62.59
Cattle for fattening					
Meat calves, rosé veal	35.59	35.59	37.82	37.82	37.82
Meat calves, white veal	16.42	16.66	17.73	17.73	17.73
Female young stock < 1 yr	33.73	33.73	34.75	34.75	34.75
Male young stock + young bullocks < 1 yr	40.13	39.25	40.43	40.43	40.43
Female young stock 1-2 yrs and over	48.61	48.61	49.23	49.23	49.23
Male young stock + young bullocks > 1 yr	59.57	59.43	60.08	60.08	60.08
Suckling, fattening and grazing cows > 2 yrs	64.51	64.51	64.61	64.61	64.61

Table 3 Total methane emission in million kg per animal category per year and per region

	Methane emission				
	1990	1995	2000	2001	2002
East and South of the Netherlands					
Cattle for breeding					
Female young stock < 1 yr	15.096	13.685	10.875	10.561	9.948
Male young stock < 1 yr	0.865	0.758	0.888	1.824	0.967
Female young stock 1 yr – calving down	26.816	24.141	20.458	19.202	18.492
Male young stock 1-2 yrs	0.992	1.021	0.919	0.870	0.996
Cows in milk and in calf	105.669	98.838	92.261	91.355	87.651
Bulls for service > 2 yrs	0.292	0.285	0.365	0.388	0.467
Cattle for fattening					
Meat calves, rosé veal	0.869	2.645	4.626	4.751	4.766
Meat calves, white veal	7.949	8.290	9.504	8.198	8.388
Female young stock < 1 yr	1.186	1.268	0.947	0.984	0.862
Male young stock + young bullocks < 1 yr	8.756	5.940	2.604	2.310	1.821
Female young stock 1-2 yrs and over	2.997	3.450	2.024	2.007	1.879
Male young stock + young bullocks >1 yr	9.250	8.586	4.525	4.455	3.562
Suckling, fattening and grazing cows > 2 yrs	4.803	5.860	6.628	6.583	5.987
Total region East and South	185.539	174.768	156.625	153.489	145.786
North and West of the Netherlands					
Cattle for breeding					
Female young stock < 1 yr	10.292	9.795	8.676	8.643	8.441
Male young stock < 1 yr	0.678	0.522	0.479	1.391	0.665
Female young stock 1 yr – calving down	18.478	17.453	15.985	15.533	15.331
Male young stock 1-2 yrs	0.918	0.806	0.533	0.609	0.744
Cows in milk and in calf	85.743	81.579	80.452	83.701	80.495
Bulls for service > 2 yrs	0.257	0.257	0.287	0.299	0.417
Cattle for fattening					
Meat calves, rosé veal	0.159	0.408	0.888	0.957	0.983
Meat calves, white veal	1.453	1.431	1.791	1.676	1.567
Female young stock < 1 yr	0.602	0.662	0.488	0.507	0.489
Male young stock + bullocks < 1 yr	1.493	1.446	0.770	0.797	0.726
Female young stock 1-2 yrs and over	1.840	2.142	1.015	0.998	1.004
Male young stock + bullocks > 1 yr	2.089	2.142	1.367	1.246	1.252
Suckling, fattening and grazing cows > 2 yrs	2.908	3.570	3.928	3.806	3.767
Total region North and West	126.910	122.213	116.659	120.165	115.881
Total of The Netherlands	312.449	296.981	273.283	273.655	261.668

Appendix 5 Milk production and ration classification numbers of dairy cattle of all years through from 1990 until 2002

Table 1 Milk production per cow and fat content

Year	Milk production per cow (kg / year)	Milk production per day (calculated)	Fat content (%)
1990	6050	16.58	4.38
1991	6090	16.68	4.43
1992	6140	16.82	4.41
1993	6270	17.18	4.46
1994	6405	17.55	4.43
1995	6580	18.03	4.40
1996	6626	18.15	4.43
1997	6803	18.64	4.41
1998	6827	18.70	4.40
1999	7034	19.27	4.34
2000	7416	20.32	4.38
2001 *)	7336	20.10	4.44
2001	7127	19.53	4.44
2002	7187	19.69	4.43

*): Number of dairy cows adjusted for fmd (utilized for the calculations)

Table 2 Ration classification numbers from 1990 for the South East (SE) and the North West (NW) region in the housing (stable) and grazing (grass) periods.

	1990		1990	1991		1991	1992		1992	1993		1993
Dairy cows	SE stable	NW stable	mean stable	SE stable	NW stable	mean stable	SE stable	NW stable	mean stable	SE stable	NW stable	mean stable
Grass silage / hay	778	1387	1054	926	1556	1211	573	1289	896	698	1531	1074
Maize silage	807	196	531	741	147	472	1054	237	686	1033	257	683
Wet concentrate	100	100	100	74	74	74	57	57	57	47	47	47
Concentrate standard	497	1077	759	486	1072	751	632	1141	861	533	1088	784
High protein concentrate	579		317	586		321	510		280	554		304
Total housing	2761	2760	2761	2813	2849	2829	2826	2724	2780	2865	2923	2891
	grass	grass	grass	grass	grass	grass	grass	grass	grass	grass	grass	grass
Meadow grass	1374	1618	1484	1541	1753	1637	1692	2027	1843	1645	1702	1671
Grass silage / hay	100	316	198	100	170	132	100	17	63	100	329	203
Maize silage	595	100	371	409	100	269	159	100	132	378	100	252
Wet concentrate	66	66	66	49	49	49	38	38	38	32	32	32
Concentrate standard	718	718	718	715	715	715	761	761	761	725	725	725
High protein concentrate			0			0			0			0
Total grazing	2853	2818	2837	2814	2787	2802	2750	2943	2837	2880	2888	2884
Total year	5614	5578	5598	5627	5636	5631	5576	5667	5617	5745	5811	5775

Table 2 continued

	1994		1994	1995		1995	1996		1996	1997		1997
Dairy cows	SE stable	NW stable	mean stable	SE stable	NW stable	mean stable	SE stable	NW stable	mean stable	SE stable	NW stable	mean stable
Grass silage / hay	782	1378	1052	636	1209	895	669	1146	887	599	1137	843
Maize silage	945	355	678	882	360	646	889	441	685	926	424	699
Wet concentrate	74	74	74	127	127	127	81	81	81	179	179	179
Concentrate standard	525	1148	807	493	1275	847	634	1099	846	631	1102	844
High protein concentrate	623		341	783		429	663	198	451	617	146	404
Total housing	2949	2955	2952	2921	2971	2944	2936	2965	2949	2952	2988	2968
	grass	grass	grass	grass	grass	grass	grass	grass	grass	grass	grass	grass
Meadow grass	1211	1620	1396	1314	1681	1480	1495	1422	1462	1263	1754	1485
Grass silage / hay	100	383	228	100	197	144	22	522	250	100	165	129
Maize silage	837	100	504	612	100	380	484	100	309	716	100	437
Wet concentrate	50	50	50	84	84	84	54	54	54	119	119	119
Concentrate standard	765	765	765	850	850	850	865	865	865	832	832	832
High protein concentrate			0			0			0			0
Total grazing	2963	2918	2943	2960	2912	2938	2920	2963	2940	3030	2970	3003
Total year	5912	5873	5894	5881	5883	5882	5856	5928	5889	5982	5958	5971

Table 2 continued

	1998		1998	1999		1999	2000		2000	2001		2001	2002		2002
Dairy cows	SE stable	NW stable	mean stable	SE stable	NW stable	mean stable	SE stable	NW stable	mean stable	SE stable	NW stable	mean stable	SE stable	NW stable	mean stable
Grass silage / hay	803	1351	1055	885	1316	1086	984	1557	1254	1032	1593	1299	1063	1547	1297
Maize silage	937	537	753	987	533	775	1025	517	786	1064	559	823	989	539	771
Wet concentrate	153	162	157	134	142	138	163	163	163	152	152	152	157	157	157
Concentrate standard	602	1170	863	529	1075	783	758	1186	959	860	1168	1007	913	1186	1045
High protein concentrate	666	166	436	654	172	429	537	109	336	437	128	290	371	98	239
Total housing	3161	3386	3264	3189	3238	3212	3467	3532	3498	3545	3600	3571	3493	3527	3509
	grass	grass	grass	grass	grass	grass	grass	grass	grass	grass	grass	grass	grass	grass	grass
Meadow grass	775	1262	999	1149	1399	1266	781	1234	994	949	1567	1244	694	1421	1045
Grass silage / hay	404	544	468	200	656	412	300	547	416	350	328	340	400	418	409
Maize silage	949	180	595	793	182	508	990	282	657	839	192	531	1041	231	649
Wet concentrate	88	80	84	77	70	74	75	75	75	70	70	70	72	72	72
Concentrate standard	731	662	699	682	618	652	594	594	594	594	594	594	589	589	589
High protein concentrate			0			0			0			0			0
Total grazing	2947	2728	2846	2901	2925	2912	2740	2732	2736	2802	2751	2778	2796	2731	2765
Total year	6108	6114	6111	6090	6163	6124	6207	6264	6234	6347	6351	6349	6289	6258	6274

Appendix 6 Methane emission of all years from 1990-2002

Table 1 Number of animals per animal category, per year

	1990	1991	1992	1993	1994	1995	1996
Cattle for breeding							
Female young cattle < 1 yr	752,658	760,636	720,342	687,326	687,442	696,063	703,237
Male young cattle < 1 yr	53,229	59,044	53,905	49,573	47,841	44,163	57,182
Female young cattle 1 yr – calving down	879,726	907,854	892,867	836,109	802,884	807,858	804,949
Male young cattle 1-2 yrs	34,635	37,628	39,297	31,957	33,034	33,118	37,203
Cows in milk and in calf	1,877,684	1,852,165	1,775,259	1,746,733	1,697,868	1,707,875	1,664,648
Bulls for service > 2 yrs	8,762	9,899	8,547	8,551	7,975	8,674	9,229
Cattle for fattening							
Meat calves, rosé veal*	28,876	39,784	51,018	62,996	77,226	85,803	100,394
Meat calves, white veal	572,709	581,834	586,713	593,214	612,290	583,516	577,196
Female young cattle < 1 yr	53,021	65,551	61,436	63,009	63,144	57,218	55,575
Male young cattle + young bullocks < 1 yr	255,375	275,383	244,178	233,479	226,539	188,193	147,553
Female young cattle 1-2 yrs and over	99,489	121,882	127,823	128,765	121,131	115,018	97,145
Male young cattle + young bullocks > 1 yr	190,330	211,036	212,514	198,417	191,875	180,515	150,622
Suckling, fattening and grazing cows > 2yrs	119,529	139,375	145,978	156,459	146,462	146,181	146,384
Total The Netherlands	4,926,023	5,062,071	4,919,877	4,796,588	4,715,711	4,654,195	4,551,317

	1997	1998	1999	2000	2001	2002
Cattle for breeding						
Female young cattle < 1 yr	651,019	615,834	596,635	562,563	552,595	529,127
Male young cattle < 1 yr	46,785	41,830	37,653	37,440	88,001	44,692
Female young cattle 1 yr – calving down	821,891	756,995	714,018	698,733	665,997	648,497
Male young cattle 1-2 yrs	31,632	27,586	25,331	26,328	26,819	31,543
Cows in milk and in calf	1,590,571	1,610,630	1,588,489	1,504,097	1,539,180	1,485,531
Bulls for service > 2 yrs	8,198	8,141	10,278	10,410	10,982	14,132
Cattle for fattening						
Meat calves, rosé veal	100,948	101,267	118,397	145,828	150,950	152,033
Meat calves, white veal	603,171	609,724	634,257	636,907	556,780	561,300
Female young cattle < 1 yr	47,669	42,362	45,977	41,300	42,911	38,887
Male young cattle + young bullocks < 1 yr	137,053	115,106	97,465	83,447	76,861	62,988
Female young cattle 1-2 yrs and over	76,482	70,377	63,990	61,724	61,047	58,565
Male young cattle + young bullocks > 1 yr	150,714	137,870	120,619	98,066	94,902	80,127
Suckling, fattening and grazing cows > 2yrs	144,502	145,362	152,581	163,397	160,802	150,972
Total The Netherlands	4,410,635	4,283,084	4,205,690	4,070,40	4,027,827	3,858,394

* The Agricultural Census provides the numbers of rosé veal calves from 1995. The rosé veal breeding farming started in the second half of the 80-ies. In 1995 the share of rosé veal calves was 12.8% of the total number of veal calves. It is assumed that over the period from 1987 to 1995 the share of rosé veal calves annually increased by 1.6%. Therefore, the share for 1990 was calculated to be 4.8%.

Table 2 Methane emission factors (in kg methane/animal/year) per animal category per year

	1990	1991	1992	1993	1994	1995	1996
Cattle for breeding							
Female young cattle < 1 yr	33.73	33.73	33.73	33.73	33.73	33.73	33.73
Male young cattle < 1 yr	29.00	29.00	29.00	29.00	29.00	29.00	29.00
Female young cattle 1 yr – calving down	51.49	51.49	51.49	51.49	51.49	51.49	51.49
Male young cattle 1-2 yrs	55.15	55.15	55.15	55.15	55.15	55.15	55.15
Cows in milk and in calf	101.94	101.69	102.48	103.53	105.24	105.64	106.21
Bulls for service > 2 yrs	62.59	62.59	62.59	62.59	62.59	62.59	62.59
Cattle for fattening							
Meat calves, rosé veal	35.59	35.59	35.59	35.59	35.59	35.59	35.59
Meat calves, white veal	16.42	16.42	16.42	16.42	16.42	16.66	16.66
Female young cattle < 1 yr	33.73	33.73	33.73	33.73	33.73	33.73	33.73
Male young cattle + young bullocks < 1 yr	40.13	40.13	40.13	40.13	40.13	39.25	39.25
Female young cattle 1-2 yrs and over	48.61	48.61	48.61	48.61	48.61	48.61	48.61
Male young cattle + young bullocks > 1 yr	59.57	59.57	59.57	59.57	59.57	59.43	59.43
Suckling, fattening and grazing cows > 2yrs	64.51	64.51	64.51	64.51	64.51	64.51	64.51

	1997	1998	1999	2000	2001	2002
Cattle for breeding						
Female young cattle < 1 yr	33.73	33.73	33.73	34.75	34.75	34.75
Male young cattle < 1 yr	29.00	29.00	29.00	36.53	36.53	36.53
Female young cattle 1 yr – calving down	51.49	51.49	51.49	52.16	52.16	52.16
Male young cattle 1-2 yrs	55.15	55.15	55.15	55.15	55.15	55.15
Cows in milk and in calf	107.11	109.22	110.91	114.83	113.73	113.19
Bulls for service > 2 yrs	62.59	62.59	62.59	62.59	62.59	62.59
Cattle for fattening						
Meat calves, rosé veal	35.59	35.59	35.59	37.82	37.82	37.82
Meat calves, white veal	16.66	16.66	16.66	17.73	17.73	17.73
Female young cattle < 1 yr	33.73	33.73	33.73	34.75	34.75	34.75
Male young cattle + young bullocks < 1 yr	39.25	39.25	39.25	40.43	40.43	40.43
Female young cattle 1-2 yrs and over	48.61	48.61	48.61	49.23	49.23	49.23
Male young cattle + young bullocks > 1 yr	59.43	59.43	59.43	60.08	60.08	60.08
Suckling, fattening and grazing cows > 2yrs	64.51	64.51	64.51	64.61	64.61	64.61

Table 3 Total methane emission in million kg per animal category per year

	1990	1991	1992	1993	1994	1995	1996
Cattle for breeding							
Female young cattle < 1 yr	25.388	25.658	24.298	23.185	23.189	23.479	23.721
Male young cattle < 1 yr	1.543	1.712	1.563	1.437	1.387	1.281	1.658
Female young cattle 1 yr – calving down	45.294	46.742	45.970	43.048	41.338	41.594	41.444
Male young cattle 1-2 yrs	1.910	2.075	2.167	1.762	1.822	1.826	2.052
Cows in milk and in calf	191.413	188.345	181.920	180.832	178.676	180.417	176.799
Bulls for service > 2 yrs	0.548	0.620	0.535	0.535	0.499	0.543	0.578
Cattle for fattening							
Meat calves, rosé veal	1.028	1.416	1.815	2.242	2.748	3.053	3.573
Meat calves, white veal	9.401	9.551	9.631	9.738	10.051	9.722	9.616
Female young cattle < 1 yr	1.788	2.211	2.072	2.125	2.130	1.930	1.875
Male young cattle + young bullocks < 1 yr	10.249	11.052	9.799	9.370	9.092	7.387	5.791
Female young cattle 1-2 yrs and over	4.837	5.925	6.214	6.260	5.889	5.591	4.723
Male young cattle + young bullocks > 1 yr	11.338	12.572	12.660	11.820	11.430	10.728	8.951
Suckling, fattening and grazing cows > 2yrs	7.711	8.991	9.417	10.093	9.448	9.430	9.443
Total The Netherlands	312.449	316.870	308.064	302.448	297.698	296.981	290.224

	1997	1998	1999	2000	2001	2002
Cattle for breeding						
Female young cattle < 1 yr	21.960	20.773	20.126	19.551	19.204	18.389
Male young cattle < 1 yr	1.357	1.213	1.092	1.368	3.215	1.633
Female young cattle 1 yr – calving down	42.316	38.975	36.762	36.443	34.736	33.823
Male young cattle 1-2 yrs	1.745	1.521	1.397	1.452	1.479	1.740
Cows in milk and in calf	170.370	175.920	176.182	172.713	175.056	168.147
Bulls for service > 2 yrs	0.513	0.510	0.643	0.652	0.687	0.885
Cattle for fattening						
Meat calves, rosé veal	3.592	3.604	4.213	5.515	5.708	5.749
Meat calves, white veal	10.049	10.158	10.567	11.295	9.874	9.954
Female young cattle < 1 yr	1.608	1.429	1.551	1.435	1.491	1.351
Male young cattle + young bullocks < 1 yr	5.379	4.518	3.825	3.374	3.108	2.547
Female young cattle 1-2 yrs and over	3.718	3.421	3.111	3.039	3.005	2.883
Male young cattle + young bullocks > 1 yr	8.957	8.193	7.168	5.891	5.701	4.814
Suckling, fattening and grazing cows > 2yrs	9.322	9.377	9.843	10.557	10.389	9.754
Total The Netherlands	280.885	279.612	276.480	273.283	273.655	261.668