Master Thesis

Scenarios for reducing the greenhouse gas emissions of the Dutch dairy sector

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Abstract

The Paris Climate agreement states that global temperature increase due to anthropogenic greenhouse gas emissions must be kept below 2 °C, with an effort to limit it to 1.5 °C. Agriculture and related land use change globally contribute to about 25% of anthropogenic greenhouse gas emissions. Within agriculture, livestock farming is the most important source of emissions. Especially raising ruminants produces high levels of GHG emissions, through enteric fermentation and low feed to food conversion rate. Dairy farming is an important sector in the Netherlands, with almost 2 million dairy cows and providing a livelihood for 30,000 people. GHG emissions levels are therefore likely high, but due to differences in allocation mechanisms in emission reporting, some analysis is needed to determine the *cradle to farm gate* emission of milk production in the Netherlands. The sector itself wants to reduce emissions with 20% in 2020 compared to 1990. However, this goal is not in alignment with the Paris agreement, so emissions will need to be reduced further. There are measures that can be taken on-farm to reduce the GHG emissions of a kg of milk. These measures cannot always be combined with each other, as they correspond with different types of farming. Therefore, there is a need for an overview of GHG reduction measures and how they can be combined. First, a literature review was conducted on the magnitude and sources of emissions from dairy farming in the Netherlands and potential mitigation measures. Secondly, interviews with experts in the dairy sector were held to improve information on the mitigation measures and to identify the participants views of the future of the dairy sector. These were used to develop three story-based scenarios in which mitigation measures were combined to reduce the emissions of milk production. It was found that the emissions of cradle to farm gate dairy production were 19.7 Mt CO_2-eq in 2015. Emissions should be reduced with 40% and 47% in 2030 compared to 1990 to comply with the Paris agreements targets of 2 °C and 1.5 °C respectively. If all measures of either the Unlimited Efficiency [1] and Limited efficiency [2] scenarios would be applied to all dairy farms in the Netherlands, both these targets would be met. The measures in the Nature-inclusive scenario [3] do not adequately reduce emissions. However, the Unlimited Efficiency [1] and Limited Efficiency [2] scenarios do have severe side-effects on other environmental indicators and animal welfare.

Keywords: milk production; greenhouse gas emissions; mitigation measures; scenarios; GHG footprint, Paris climate agreement

Acronyms

AFOLU	Agriculture, Forestry and Other Land Use
CBS	Cenraal Bureau voor de Statistiek (Office for National Statistics)
GHG	Greenhouse gas
Gt	Gigatonne
GWP	Global Warming Potential
FAO	Food and Agricultural Organization
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Analysis
NGO	Non-Governmental Organization
NIR	National Inventory Report
Mt	Megatonne
PBL	Planbureau voor de Leefomgeving (Netherlands Environmental Assessment Agency)
SOM	Soil Organic Matter
UNFCCC	United Nations Framework Convention on Climate Change

1 Introduction

1.1 Climate change

The Intergovernmental Panel on Climate Change (IPCC) stated in their latest assessment that anthropogenic greenhouse gas (GHG) emissions are “extremely likely to be the dominant cause” of the observed increase in global temperatures (IPCC, 2014). Climate change is identified to be one of nine important planetary boundaries, and one of the three boundaries that have been crossed (Rockström et al., 2009). Recently, evidence is emerging that some of Earth’s systems are moving outside of their stable state that lasted for more than 11.000 years: summer sea ice in the Arctic ocean rapidly reduces, mountain glaciers retreat and sea level rise is accelerating (Rockström et al., 2009).

In December 2015, 196 countries agreed to limit the increase of global temperatures to “well below 2 °C and to pursue efforts to limit the temperature increase to 1.5 °C”, in order to reduce the impact of climate change (UNFCCC, 2015a). To keep warming below 1.5 °C or 2 °C, a limited amount of greenhouse gases (GHG) can still be emitted. This is called the carbon budget (IPCC, 2014). When continuing 2010 levels of global emissions of 49 Gt CO_2-eq/year, the 1.5 °C carbon budget will be depleted in 2019 (Myhre et al., 2013). Assuming a linear reduction of GHG emissions from 2011 onward, carbon neutrality needs to be reached in 2027. The 2 °C target will be depleted in 2031 when emissions would remain equal to 2010 levels. When assuming a linear reduction from 2011 onwards, carbon neutrality should be reached in 2051.

Although the targets set in the Paris agreement are in line with science, inconsistencies remain between these targets and the national commitments of the individual countries (Rockström et al., 2017). Leading up to the Paris conference, countries submitted their Intended Nationally Determined Contributions (INDCs), which outline their post-2020 climate action. The INDCs of all countries are estimated to collectively cause a 2.6-3.1 °C warming (Rogelj et al., 2016). The INDC of the European Union has set a target of 40% reduction of GHG emissions in 2030 compared to 1990 levels (UNFCCC, 2015b). This reduction effort may not be enough to keep global temperature increase below 1.5 °C or 2 °C, and may therefore not be in line with the Paris accord (Van Vuuren et al., 2016). Setting reduction percentages for a country that are in line with the agreement requires dividing the global carbon budget among countries. The distribution depends on the choice of ‘principle of fairness’, which can for example allocate equal emission rights to every person on earth or may include historical emissions (du Pont et al., 2016). Choosing a principle of fairness therefore has a large impact on what can be considered an adequate or fair reduction potential for a country.

1.2 Greenhouse gas emissions from food production

Currently, production of food accounts for 10-12% (5.0-5.8 $GtCO_2eq$/year) of worldwide greenhouse gas emissions, when also including land use practices and land-use change -which are caused mostly by agriculture- this is increased with 4.3-5.5 Gt CO_2eq/year (9-11%). In total, emissions from agriculture are thus about a quarter of total global greenhouse gas emissions (Smith et al., 2014).

The Netherlands is the second largest exporter of agricultural products worldwide, although this includes re-export of imported goods (Ruijs & Jukema, 2017). The main export products are floriculture (12%), potatoes, fruits and vegetables (14%) and animal products (meat, dairy and eggs; 20%) (Ruijs & Jukema, 2017). Most of these are greenhouse gas intensive forms of production: the flowers and vegetables are grown in greenhouses heated with natural gas and animal products have a large carbon footprint per kg of products due to the low energy-conversion rate (Nijdam et al., 2012). Especially beef and dairy cattle emit relatively large amount of GHG’s, as cattle excretes CH_4 that is produced in their digestive system (Steinfeld et al., 2006).

In recent years, global warming has become a larger public issue in livestock farming after alarming reports from the United Nations and the popular documentary Cowspiracy (Steinfeld et al.,2006; Andersen & Kuhn, 2014), showing that a large proportion global GHG emissions are caused by agriculture. Emissions from livestock farming are especially high in non-CO_2 GHGs, which have a larger Global Warming Potential (GWP) than CO_2. Worldwide, the livestock sector is responsible for 37% of anthropogenic CH_4 emissions and 65% of N_2O emissions (Steinfeld et al., 2006). The GWP values for non-CO_2 gases have changed over time as knowledge about their effect on climate change has increased (Myhre et al., 2013). Due to the high amount of non-CO_2 gases released by milk production, using different GWP values can considerably affect the reported emissions. In total, the livestock sector is responsible for 18% of anthropogenic GHG emissions when calculating with a 100-year Global Warming potential (GWP) (Steinfeld et al., 2006). Considering the whole Agriculture, Land Use and Land Use Change sector (AFLULUC) is responsible for just under a quarter of total anthropogenic GHG emissions (Smith et al., 2014), livestock farming is the largest emission source in the worlds food production. Considering the dairy sector's substantial size in the Netherlands, it will be one of the larger emission sources within agriculture in the Netherlands.

According to the Dutch National Inventory Report (NIR) that reports GHG emissions to the United Nations, the agriculture sector produces 13.6% (25 Mt CO_2-eq) of the total greenhouse gas emission in the Netherlands (Coenen et al., 2016). This emission reporting method attributes some emissions produced during agricultural production to other sectors. For example, the energy used in stables for dairy production is attributed to the energy sector and not to the agricultural sector (Van den Pol et al., 2013). Moreover, only GHGs emitted in the Netherlands are included, and emissions in the production chain outside of the Netherlands are excluded, such as emissions from producing animal feed outside of Europe (Vonk et al., 2016). Therefore, the emissions effectively caused by agricultural production in the Netherlands are likely larger than 13.6%. Because of this registration procedure, it is not straightforward to estimate the total emissions of the dairy sector in relation to the total Dutch emissions.

Reijs et al. (2016) calculated the total emissions of milk production in the Netherlands to be 18.3 Mt CO_2-eq in 2015 using Life Cycle Analysis studies, including emissions abroad and those attributed to other sectors in the NIR system. Still, this number depends on what boundaries of the production system are chosen: in other words, what emissions are accounted to milk production and which not. Most current LCA studies do for example not consider emissions from land-use change (De Vries & De Boer, 2010). These computations should therefore be critically assessed on these boundaries.

Even though determining the total emissions from milk production in the Netherlands requires some more analysis, these emissions need to be reduced to meet the targets set in the Paris agreement. The Dutch agricultural sector has agreed with the government to reduce greenhouse gas emissions with 30% by 2020 compared to 1990 levels (Ministerie van Landbouw, Natuur en Voedselkwaliteit, 2008). The goal of the dairy sector itself is lower: a 20% reduction in 2020 compared to 1990. This goal was reached in 2011, but due to increases in production emissions have risen since then (Reijs et al., 2016). These reduction potentials are not enough to meet the Paris goals, so stricter goals need to be set (van Vuuren et al., 2016).

1.3 The Dutch dairy sector

The dairy sector is an important sector in the Netherlands in many ways. The characteristic Dutch view of the landscape is flat land comprised of wide pastures with peacefully grazing cows. Milk and its derived products have a central position in the average Dutch diet and are also famous export products, like the worldwide recognized Gouda cheese. The Netherlands are home to more than 1.7 million adult (productive) dairy cows and about 1.3 million young cows (CBS statline, 2017). The roughly 13 billion kg of milk produced by these cows on a yearly basis provide a living to 20,000 dairy farmers as well as to 10,000 workers in the dairy processing companies (CBS statline, 2017; Krebbekx et al., 2011). The worldwide demand for dairy products has been growing for a long time and is projected to grow further. The growth in demand is larger than the growth in production, especially in Asia, which will increase the imports of countries in this region (Krebbekx et al., 2011). The sector produces more than is consumed in the Netherlands, and exports the rest to the European and world market of a total value of 8 billion euro's in 2013, more than 1% of the total Dutch GDP (CBS, 2015). These exports comprised 66% of the total revenue of the Dairy Industry in 2013 (CBS, 2015).

For a long time, the market for dairy (and other agricultural products) in Europe has been dominated by interference from the government in the forms of restrictions to production and price regulation (Krebbekx et al., 2011). These protective measures have slowly but steadily been removed. Most notable is the abolishment of the milk quota system by the European Union in 2015. The milk quota system was originally introduced because more milk was produced in Europe than was consumed, resulting in the so called "butter mountains" and "milk lakes". This overproduction was a direct consequence of the subsidies on production from the Common Agricultural Policy of the EU. Overproduction was to be sold with subsidy on the world market. This became too expensive, and the milk quota was introduced to put a maximum on this production. In 2015 however, the milk quota system was abolished. This means that the sector will be more sensitive to free market dynamics (Krebbekx et al., 2011). To prevent too much industrialization of the sector, a new rule was introduced that makes it mandatory to purchase more land when a farmer wants to increase the number of cattle (Ramaker, 2015). Even though this measure may have limited the growth, milk production has still increased with 18% from 2007-2015 (figure 1.1). Moreover, for years there has been a trend in decreasing number of dairy farms and an increase in production per farm. It is projected that the average number of cows on a farm will increase from 60 (2013) to 100 or more in 2020 (CBS, 2015).

The large size and density of this industry and its growth also have drawbacks, especially to the environment. The environmental side effects are numerous: nutrient enrichment of surface and groundwater caused by surpluses of manure, acidification of the soil, loss of biodiversity and other sustainability issues such as increasing resistance to antibiotics, animal welfare and food safety (Van Calker et al., 2005).

This research will go into detail on only one of the environmental drawbacks: GHG emissions. Emission reduction can be achieved by applying a wide range of measures to the farm (Van den Pol et al., 2013). These are for example changes in diet of the cow, fermenting their manure or stimulating carbon sequestration in the soil. However, these measures cannot all be applied to every farm, as they sometimes need or promote very different types of farming.

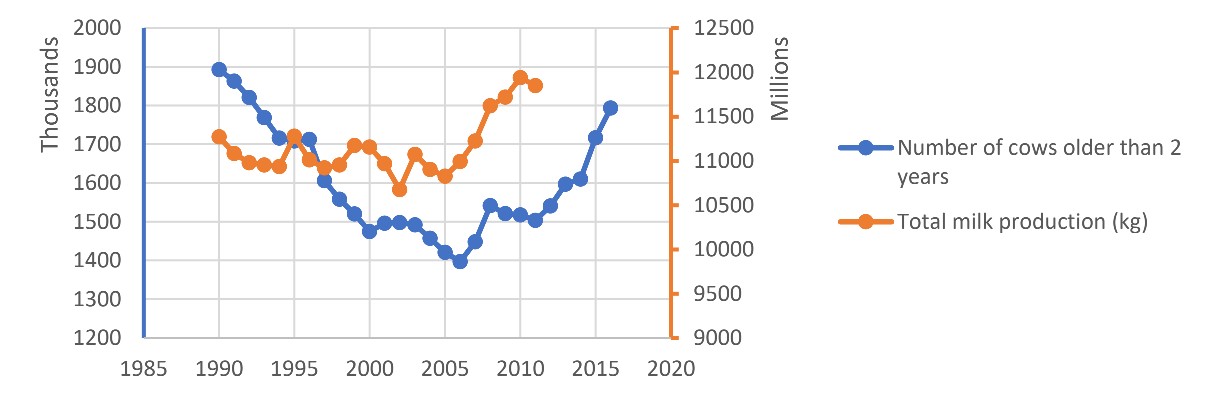

Figure 1.1 – Number of adult cows and yearly milk production of the Dutch dairy sector (CBS statline)

1.4 Problem definition and research aim

From the above, it follows that the problem is threefold. Firstly, the total amount of GHG emissions from dairy production in the Netherlands is uncertain and can vary among different methodologies used.

Secondly, the reduction target set for the sector by the Dutch government might not be in line with the Paris accord. Determining the reduction targets is complex and can yield different results when different allocation principles are used. Studying the reduction targets and the principles of fairness is therefore relevant.

Thirdly, there is no clear view from either the government or the sector itself in how they should reduce emissions in 2030 or beyond. There is ample literature and knowledge on different measures that can be taken to reduce GHG emissions on the farm level, but these have not yet been combined into prospects for the future.

From this it follows that the aims of this research project are:

1. To identify the sources of GHG emission in the dairy production process and the total emissions of the Dutch dairy sector;
2. To determine a fair GHG emission reduction target for the dairy sector;
3. To combine sets of measures into scenarios for the future of the sector and evaluate if these meet the reduction targets.

1.5 research questions and hypothesis

The three aims of this thesis will be addressed by the following main research question:

In which scenarios are the greenhouse gas emissions of the Dutch dairy sector in 2030 in line with the Paris agreement?

The main research question will be answered using the following sub questions:

1. What are the current and projected greenhouse gas emissions of the Dutch dairy sector?
2. What measures can be taken on the farm level to reduce GHG emissions and what is their reduction potential?
3. Which story-based scenarios will adequately reduce the dairy sector’s greenhouse gas emissions?

2 Methodology

2.1 Calculating the emissions of dairy production

The first sub question of this research (*what are the current and projected greenhouse gas emissions of the Dutch dairy sector?*) was answered through retrieving data from the literature. The product of this part of the research is an overview of the magnitude of the GHG emissions of the Dutch dairy sector and the specific parts of the production chain that create the emissions.

Data on the GHG emissions were retrieved from Reijs et al. (2016). They used Life Cycle Analysis studies to determine the GHG emissions of the average kg of milk produced in the Netherlands, and which specific parts of the production process are responsible for these emissions (Reijs et al., 2016). In the LCA, all emissions that arise from producing dairy from “cradle to farm-gate” are assigned to the production of dairy, and not to other sectors, to create a clear overview of all emissions caused by dairy production. Cradle to farm gate includes emissions produced by purchased goods, feed and electricity and the emission on the farm. Emissions from processing, packaging and transporting the milk are excluded. The cradle to farm-gate is a well-accepted method of calculating GHG-emissions from the production of a product (De Vries & De Boer, 2010).

Before this data can be used to calculate a GHG-footprint of the average kg of milk in the Netherlands, some further analysis was needed: firstly, a critical review of the emissions sources from milk production and whether these are included in the LCA studies used. Secondly, the time-horizon and values for the Global Warming Potential of CH_4 and N_2O were critically assessed and updated where necessary. These will be explained in section 3.1.

Subsequently, the total yearly GHG emissions of the Dutch dairy sector were calculated through multiplying the GHG-footprint with the yearly production of milk in the Netherlands, retrieved from CBS statline.

2.2 Identifying mitigation measures and their reduction potential

The second sub question (*what measures can be taken on the farm level to reduce GHG emissions and what is their reduction potential?*) was answered through conducting a literature review complemented by interviews with experts of the milk production sector. These interviews were also used for the development of the story-based scenarios.

2.2.1 Interviews

The goals of the interviews were to gather data on the perception and views of participants on the future of the dairy sector considering it needs to reduce GHG emissions, and on what reduction measures are appropriate to take within that view. Because of the intricate subjectivity of this data, a qualitative approach to the interviews is needed (Turner, 2010). A qualitative form of research allows to study the context, meaning and worldviews of the participants (Krauss, 2005).

Turner (2010) identifies 3 ways of conducting a qualitative interview: (1) the informative conversational interview, (2) the general interview approach and (3) the standardized open-ended interview. They differ based on the flexibility in which questions are asked and how. In the informative conversational interview (1), the interviewer does not have a fixed set of questions but asks questions based on the environment and situation, which are therefore highly flexible. In the general interview approach (2), there is a fixed set of questions, but the interviewer can ask more questions depending on the answers the participant gives. In the standardized open-ended interview (3), there is a fixed set of questions, on which participant can give an answer to the depth of their desire, but the interviewer does not deviate from the list.

In this research the general interview approach (2) was used. This approach was chosen because the standardized open ended interview (3) did not provide enough space to deepen the interview on the specificities on the participant's case. The informative conversational interview (1) on the other hand requires observing the participant in the environment in which they act on this subject. This option would have been too time-consuming and impractical and would lead to biases due to the interpretive nature of this approach (Turner, 2010). The general interview approach (2) was used as this provided an adequate balance between the similarity of the interviews and the depth of the responses.

The participants were all asked the following questions:

- What does the Dutch dairy sector in the Netherlands look like in 2030 considering it needs to reduce GHG emissions?
- What measures can be taken to reduce GHG emissions?

Depending on their answers, follow-up questions could be asked. For example: when an interview participant mentioned a mitigation measure that deviated from literature sources, more explanation was asked. More often, follow-up questions were asked to get a clearer picture of the view of the participant on the future dairy sector, for example: what do you think the average farm in 2030 *should* look like.

Interviews were conducted with 7 experts from different organizations (table 2.1). These organizations represent most stakeholders in the dairy sector, so they will have other sets of knowledge and different views on what the dairy sector in the future will or should look like. They include farms, banks, political parties, NGOs, umbrella organizations and consultancy's. Contacts were derived through the network of Natuur & Milieu.

Table 2.1 – Interviewees and the organization they represent

Name	Organization name	Type of organization
Marijn Dekkers	Rabobank	Bank
Elbert Dijkgraaf	Staatkundig Gereformeerde Partij (SGP)	Political party
Eva Fransen	Commonland	NGO
Harry Kager	Land- en Tuinbouworganisatie (LTO)	Organization for agricultural entrepreneurs and employers
Carel de Vries	Courage	Innovation organization
Frank Verhoeven	Boerenverstand	Consultancy
Catharinus Wierda	De Fryske	Cheese manufacturer

2.2.2 Literature review

Additional to the interviews, a literature review was conducted to compose a list of measures that can be taken *on the farm level* to reduce the GHG emissions of a kg of milk. Only published literature that goes into detail about representative Dutch dairy farms and gives specific reduction potentials was used. The work of Van den Pol et al. (2013) was used as the main reference for the measures, because they used a panel of experts of dairy production in the Netherlands to review measures on the farm level to their GHG mitigation potential, cost-efficiency and applicability. From the report of Van den Pol et al (2013), this thesis only incorporated measures of which specific mitigation potentials could be found in the references and that specified the reductions separately for the three main greenhouse gases (CO_2, N_2O and CH_4), as this research aims to use updated versions of GWP for CH_4 and N_2O (section 3.1).

For some measures, the literature referenced in the report did not qualify to these conditions. For example: for the measure "increased milk production per cow", no exact figures were given for reduction of the separate greenhouse gases. In these cases, other published literature was used that did qualify to the above-mentioned conditions. Moreover, in the literature additional measures could be identified. If these met the previously mentioned criteria, they were included in this research. These sources were found through the network of Natuur & Milieu and internet searches. Reliability of grey literature were confirmed by supervisors from Natuur & Milieu.

No uncertainty in the reduction potential of the measures could be identified, even though it is most likely this will be present. Therefore, a reduction potential of 0.5 percent was set as a minimum for the reduction potential to be included in this research.

Section 3.2 gives an overview of all the potential measures, and explains how they result in a reduction of GHG emissions. Furthermore, the measures have been aggregated in a table which shows the reduction potential for which greenhouse gases and the base emissions from which this reduction was calculated. Of most measures the base emissions of a kg of milk were given in the corresponding literature. In the cases where no base emission was presented, the GHG-footprint of an average kg of milk in 2011 reported by Reijs et al. (2016) was used (with updated GWP), as this is also the reference emissions used in Van den Pol et al (2013).

Some of the measures are not singular, but an aggregated group of measures that all contribute to emission reduction through the same mechanism. For example, carbon sequestration is a set of measures on soil management aiming to increasing organic matter in the soil.

Some of the reduction measures not only reduce direct emissions from milk production, they can also reduce emissions from other users outside of the farm. For example: when the farm produces renewable electricity, it could produce more than what is needed on the farm. This excess electricity will then be used by for example a household, which could use it to replace electricity produced from fossil fuels, resulting in lower GHG emissions from that household. This reduction could then be counted as extra reduction for the farm that produces milk. This mechanism was mentioned by some interview participants (Agricultural umbrella organization, innovation network) and used in similar research (Weiske et al., 2006). However, the aim of this research was to identify how the direct GHG emissions of the dairy sector could be reduced. Therefore, compensation of emissions was not considered here, but compensation does have potential to contribute to climate mitigation targets.

2.3 Scenario development

2.3.1 Creating the scenarios from the interviews

The answers of the Interview participants were used to develop three story-based scenarios that have a different view of what an average farm and the sector will look like in 2030. Section 3.3.1 explains how the deviating answers from participants were used to create an axis system of views on which determine the base characteristics of the scenarios.

Subsequently, the measures following from the previous analysis were categorized in the scenarios. This categorization was based on by which interview participants they were (positively) mentioned: the measure was then included in the scenario corresponding with that participants view. If this was not possible, the measures were reviewed on their suitability with the story of the scenario by the authors best judgment.

Measures that were identified to have overlap were not included in any of the scenarios. When this occurred, the measure with the highest reduction potential was included and the one with the lower potential was excluded.

2.3.2 Calculating the emission reduction from these scenarios

From the combined list of measures for each scenario, the total reduction of GHG emissions of the scenarios could be calculated. The following assumptions were made in the calculations:

- It was assumed that the reduction potential found in the literature was applicable to all the farms in the Netherlands. The reduction potential for some measures are based on a specific farm or type of milk production of which the GHG-footprint is not the same as the average footprint. Therefore, the GHG-footprint is compared with the average footprint of a kg of milk from the Netherlands, and the reduction potential of the measure will be adapted by using a ratio. For example, when the base GHG footprint of a kg of milk on which the reduction potential of a measure is based is lower than the average GHG footprint, the measure will be more effective when applied to the average kg of milk.
- It was also assumed that the reduction potentials of the measures could be added, if these measures were not identified to have overlap.

Subsequently, the calculated total reduction potential of the scenarios will be compared to the emission reduction targets that follow from the Paris Climate agreement. An analysis was needed to determine a fair and adequate reduction target for the dairy sector in the Netherlands (section 3.3.4).

3 Results

3.1 The GHG emissions of the Dutch dairy sector

In this section, the first sub question will be addressed: *What are the current and projected greenhouse gas emissions from the Dutch dairy sector?* This section will first describe the Global Warming Potential values used in this report. Secondly, the sources of the GHG emissions of producing milk on the average Dutch farm will be described. Thirdly, the current and projected total GHG emissions in the Netherlands will be presented.

3.1.1 The GWP time-horizon and values for CH_4 and N_2O

In dairy production, most of the emitted GHGs are the non-CO_2 gases methane (CH_4) and nitrous oxide (N_2O) (Reijs et al., 2016). This is in contrast to the total global anthropogenic GHG emissions, where CO_2 makes up the majority of the emissions (IPCC, 2014). These three gases have a different effect on climate change per amount that is emitted. The Global Warming Potential (GWP) is used to compare these different effects on global warming between the gases. The GWP is based on two parameters of the GHGs: 1. The radiative forcing of the gas (the ability to trap heat in the atmosphere) and 2. The lifetime of the gas in the atmosphere. CH_4 has a larger radiative forcing than CO_2, but remains only for about 12.4 years in the atmosphere, where CO2 remains for up to 200 years (IPCC, 2013). Most of the global warming effect caused by methane is therefore within these 12.4 years while CO_2 contributes to climate change for a longer time. The GWP expresses the global warming potential of gases relative to CO_2 (therefore the unit is CO_2-equivalent per kg) on a specific time interval, usually 20, 100 or 500 years. The choice of time interval can have a large effect on the GWP. For relatively (compared to CO_2) short-lived gases such as CH_4 the GWP becomes higher when a lower time interval is chosen. For long-lived gases such as SF_6 the GWP becomes lower with smaller time intervals. For example: the GWP of methane on a 100-year time horizon is 34 CO_2-eq, while on a 20-year time horizon it is 86 CO_2-eq (IPCC, 2013). Since the Kyoto protocol in 1997, the GWP values with a 100-year time horizon have been used as a standard for comparing emissions among sectors and countries (Godal, 2003). Therefore, the GWP used in almost all LCA studies has a 100-year time horizon.

However, the effects of climate change are already noticeable and dangerous tipping points in the climate system may already be very close (Crowther et al., 2016). In that light, a 100-year time frame underestimates the effect of CH_4 on climate change, and therefore a shorter time-period might be necessary (Shine, 2009). By using the 100-year GWP, sectors that are intensive in short-lived GHGs - such as the dairy sector- have a much lower GHG footprint than when a 20-year time horizon is used (Howarth et al., 2011). Moreover, with each new IPCC report, the GWP values for CH_4 are updated, which so far has led to an increase from 21 kg CO_2-eq in the first IPCC report to a value of 34 kg CO_2-eq for a 100-year time horizon in the latest IPCC report (table 3.1). The LCA study used by the dairy sector in its sustainability report still uses the old value of 25 kg CO_2-eq for CH_4 (Reijs et al., 2016). When the CO_2 equivalence of CH_4 is updated to 34, the total emissions from a kg of milk increase from 1.24 to 1.48 kg CO2-eq (table 3.2). When the equivalence is further raised to 86 kg CO2 (the 20-year time horizon GWP) the carbon footprint of a kg of milk becomes 2.63 kg CO2-eq, an increase of 90 percent.

In this research, the GWP with a 100-year time-horizon will be used, as this is in line with international emission registration under the Kyoto protocol. All emissions presented in this report in CO_2-equivalence use the updated GWP values with a 100-year time horizon. Where this was not possible this is indicated.

Table 3.1 – The Global Warming Potentials (GWP) on a 100-year time-horizon in the IPCC synthesis reports of 2001, 2007 and 2013 (Boucher et al., 2001; Forster et al., 2007; Myhre et al., 2013). In this research, the 2014 values are used to update the GHG-footprint as presented in Reijs et al (2016), which uses the AR4 values.

GHG	IPCC AR5 (2013)	IPCC AR4 (2007)	IPCC TAR (2001)
CH_4	34	25	21
CO_2	1	1	1
N_2O	298	298	296

3.1.2 The sources of GHG emissions in producing milk

The following section will provide an overview of the sources of cradle to farm gate GHG emissions in the production of milk. Table 3.2 presents the sources of GHG emissions from an average kg of milk produced in the Netherlands.

Table 3.2 Greenhouse gas emissions in CO2-eq of one kg of milk of an average Dutch farm in 2015. First column with emissions uses 2007 values for the GWP of CH4, the second column uses updated (2013) values for GWP of CH4 (Reijs et al., 2016).

Source of GHG	GHG	Emissions (kg CO_2-eq/ kg milk)	Corrected emissions (kg CO_2-eq / kg milk)
Enteric fermentation	CH_4	0.51	0.69
Manure	CH_4	0.16	0.22
Manure and soil	N_2O	0.14	0.14
Energy use	CO_2	0.06	0.06
Total on farm		*0.87*	*1.11*
Purchased feed	CO_2 and N_2O[1]	0.29	0.29
Purchased fertilizer	CO_2 and N_2O[2]	0.06	0.06
Other purchasing	CO_2	0.02	0.02
Total off farm		*0.37*	*0.37*
Total		*1.24*	*1.48*

[1] Emissions from purchased feed are assumed to consist mostly of CO_2 (Hoogeveen, 2017).
[2] Emissions from purchased fertilizer are assumed to be composed of 50% CO_2 and 50% N_2O (Hoogeveen, 2017).

3.1.2.1 Producing feed and fertilizer

Feed production is a significant GHG source in the production chain of dairy. It arises from (artificial) fertilizers, land-use and land-use change. Especially maize demands a high input of nitrogen fertilizer. In the Netherlands, 252.000 ha are used to produce maize, 99.1% of which is used as animal feed (Steinfeld et al.,2006; de Rooij, 2011). Moreover, the food that is imported (soybean, rapeseed etc.) need fertilizers to grow, which are mostly supplied in the form of artificial fertilizers (Cavalett & Ortega, 2009). Furthermore, shipping the feed to the Netherlands results in CO_2 emissions.

Nitrogen fertilizers are manufactured with the Haber-Bosch process, which uses extremely high pressures and therefore requires large amounts of energy; approximately 1% of the world's energy is used to produce nitrogenous fertilizer (Smith, 2002). This results in the emission of CO_2 emissions when fossil fuels are used to produce the electricity. Fossil fuels used in producing the fertilizers may emit 41 Mt of CO_2 per year worldwide (Steinfeld et al.,2006).

3.1.2.2 Emissions from soil and fertilizer application

Besides the production of the fertilizer, applying it to the soil also results in GHG emissions. On average, only 50% of the nitrogen that is applied to the soil (either in organic or mineral form) is taken up by the plants (Steinfeld et al., 2006). Most of the remaining fraction is converted by bacteria to N_2 during denitrification, but also some N_2O is produced. This also occurs when urine and feces are applied to the soil, either produced during grazing or collected in stables and distributed over the land (Van den Pol et al., 2013).

3.1.2.3 Land use change

Greenhouse gas emissions can arise when land cover is changed, for example from forest to pasture or from pasture to arable land. These emissions come from the degradation of biomass and the loss in soil carbon. Estimating these CO_2 emissions is not straightforward, as it is difficult to know how much biomass is lost and over which time span this occurs. It is even more difficult to attribute this to one sector, such as the livestock sector (Steinfeld et al.,2006). This is partly due to indirect land-use change, where one sector can replace another sector on a piece of land, that second sector is then “forced” to move into forested area (Arima et al., 2011). For example: pasture in South America is changed into arable land for soybean production, the livestock farmer that used to have this pasture moves into forested area and clears that for pasture. Through this mechanism, the soy production is responsible for land-use change but may not be held responsible for it (Arima et al., 2011).

Worldwide, the emissions from land-use and land-use change are about as large as the other direct emissions from agriculture (Smith et al., 2014). A large fraction of the feed used in the dairy industry is imported from outside Europe. Some ingredients that might have caused land use change in their production are soy, which production is known to be at the expense of the Amazon rain forest, and palm kernels which are a residue after oil extraction of the African Palm seed, and is the lowest priced high protein feed (Carvalho et al., 2006; Arima et al., 2011). Palm oil is a leading cause in the deforestation of the Asian rainforest in Malaysia and Indonesia (Wicke et al., 2011). Since 2015, the Dutch Dairy industry only uses RTRS-certified soy in the cow’s feed, which respects valuable nature and human rights in its production (Reijs et al., 2016).

A form of land-use change in dairy farming is a widely-used practice to convert grassland to arable land every few years, which is followed by a loss of soil carbon to the atmosphere (Elferink et al., 2012). Soils are one of the largest (terrestrial) carbon reservoirs, and worldwide it is estimated to hold about 1100 to 1600 billion tonnes of carbon, twice the amount of carbon in the atmosphere (750 billion tonnes) (Sundquist, 1993). (Conventional) use of soil decreases the carbon content that is naturally present in the soil. The carbon disappears from the soil by aerobic breakdown due to tillage, due to harvesting and soil laying bare. In conventional yearly agriculture, not much organic material is added to the soil, as the yearly plants don’t take root so deep. Because permanent grassland is not tilled and provides a permanent cover, soil under grassland has a higher carbon content than arable soil (Elferink et al., 2012).

3.1.2.4 Oxidation of peat

Another form of land-use change in the Netherlands is oxidation of peat. The Netherlands has 109,000 ha of peatland that is used by the dairy sector (Elferink et al., 2012). Most of this peatland is used by dairy farms as peatland is often too wet for growing crops, but can be used as grassland if the natural water table is lowered. For centuries, the Dutch peatlands had a high water table. The top soil remained saturated with water throughout the year. This inhibited the oxidation of the peatland and the ground level only declined with a few millimeters a year. Since the 1960’s however, the groundwater table was lowered to enable modern production agriculture. This resulted in deeper penetration of air into the soil. In these aerobic conditions, the peat is oxidized, resulting in loss of peat and emissions of the greenhouse gases CO_2 and N_2O (Kwakernaak et al., 2010). Through oxidation, the peatland area in the Netherlands has decreased by 20% in the past 30 or 40 years; every year about 2000 ha of peatland is still lost in the Netherlands (Van den Akker, 2005). The estimated yearly GHG emissions from oxidizing peatland are 30 tonnes CO_2-eq per hectare. In total, 4.7 Mt CO_2-eq of GHGs

(4.2 Mt CO_2 and 1000 t N_2O) are emitted yearly. This is roughly the same emissions as two million cars and 2-3% of all the emissions of the Netherlands (Kwakernaak et al., 2010).

Peatland can be a net source of GHGs or a net sink. Dry peat oxidizes and emits CO_2 and N_2O, and adding extra fertilizers causes more N_2O emissions by adding easily degradable N. Wet peat emits CH_4 by anaerobic degradation of plant material, but also binds CO_2 in organic material (Kwakernaak et al., 2010). Comparative research has shown that restoring a peatland area to its natural state (high water table) results in a net sequestration of carbon (the CH_4 emissions in CO_2-eq are smaller than the sequestration of CO_2). It also shown that the lower the water table and the more intense form of agriculture, the higher the net emissions of greenhouse gases (Kwakernaak et al., 2010). Moreover, increasing global temperature will accelerate the oxidation and sinking of the peat soil as it is expected to cause warmer and dryer summers (Jansen et al., 2009).

3.1.2.5 On-farm fossil fuel and energy use

Energy use on farm only contribute to about 5% of the emissions of a kilogram of milk (table 3.2). These CO_2 emissions originate from using fuels for machinery (such as tractors) and the purchased electricity. For the machinery used on farm, generally diesel is used as a fuel.

3.1.2.6 Respiration and enteric fermentation

Just like all other animals, cows emit CO_2 through their breathing (respiration), but these emissions are not accounted for because they are part of a rapid carbon cycle where the plants take up the CO_2 from the atmosphere that is emitted by respiration from the animals. The emissions are considered equivalent to the absorption and are therefore not considered a net source under the Kyoto protocol (Steinfeld et al.,2006).

However, CO2 is not the only greenhouse gas emitted by cows through their breathing. In all ruminant animals, the large fore-stomach hosts archaea that ferment fibrous material into products that can be digested by the animal itself. A side product from this process (called enteric fermentation) is CH_4-gas, which the animal expels through its mouth and anus (Hristov et al., 2013). CH_4 is a much more potent greenhouse gas than CO_2, and therefore cannot be considered part of the natural fast-carbon cycle as respiration can (Steinfeld et al., 2006).

Enteric fermentation is the largest source of emissions from the production of milk, namely 41 percent of total GHG emissions in CO_2 equivalence (table 3.2). The amount of CH_4 emissions from enteric fermentation are dependent on the type of feed that is fed to the cows as well as the breed of cow (Van Middelaar et al., 2014).

3.1.2.7 Manure

CH_4 is also emitted through the manure of cows. The way of collecting and storing manure has a large influence on how much CH_4 is emitted. When the manure is held in liquid form (most of the time this is combined with the urine of the cows), more CH_4 is released (Verloop et al., 2013).

The amount of CH_4 emissions from manure is correlated with the energy content of the manure. Higher energy intake increases the CH_4 in the manure and produces a more liquid manure, which also results in more CH_4 emissions. On the other side, high energy feeds are more easily digestible and can cause a lower CH_4 emission in the enteric fermentation in the first stomach of the cow (Hristov et al., 2013). besides CH_4, manure also releases N_2O when it is applied to the soil (Verloop et al., 2013).

3.1.3 *The total emissions of the Dutch dairy sector*

From the GHG-footprint of a kg of average milk and the total amount of milk produced in the Netherlands in a year, the total “cradle to farm-gate” emissions were calculated (table 3.3). In 2015, the milk production was 13.3 million kg and the GHG-footprint of a kg of milk was 1.48 kg CO_2-eq per kg milk (with corrected GWP). Therefore, the total *cradle to farm-gate* emissions of the dairy sector were 19.7 Mt CO_2-eq in 2015.

The collaborative sustainability effort by the Dutch dairy sector, *De Duurzame Zuivelketen,* has set a target to reduce GHG by 20% in 2020 compared to 1990. This goal was reached in 2011, due to a reduction in the total number of cows in the Netherlands but a steady milk production (Reijs et al., 2016). Therefore, they changed their target to "climate neutral" growth from 2011 onward: total emissions should not increase above the 2011 level of 17.0 Mt CO_2-eq. However, emissions in 2015 were 16% higher than in 2011. This is mostly a result of an increased milk production, while the GHG-footprint of a kg of milk has not decreased since 2008 (Reijs et al. 2016).

The emissions in 1990 could not be updated to a new GWP, as no GHG-footprint specifying emissions in separate GHGs is given. Therefore, the emissions in 1990 are calculated as 20% higher than 2011 emissions, resulting in 20.4Mt CO_2-eq.

Table 3.3 – GHG-footprint of an average kg of milk (kg CO_2-eq/kg milk) and the total GHG emissions from the Dutch dairy sector (Mt CO_2-eq) in 1990, 2011 and 2015.

	1990	2011	2015
GHG-footprint (kg CO_2-eq/kg milk)	-	1.46	1.48
Total GHG emission (Mt CO_2-eq)	20.4	17.0	19.7

3.2 Measures to reduce GHG emissions on farm level

This section presents the list of measures that can be taken on the farm level to reduce GHG emissions. It combines information from the interviews and literature research.

Table 3.4 shows the measures that were mentioned by the interview participants, either positively or negatively. They do not include all measures that were identified through the literature research, but they do present an overview of what type of organizations are in favor of which type of measures

Table 3.4 – Measures identified in the interviews with experts, categorized in mentioned as positive or negative.

Measures that were mentioned as positive	*Mentioned by interviewees representing the following types of organizations*
Keep less young animals	Consultancy, NGO
Carbon storage in the soil	Consultancy, cheese manufacturer, agricultural umbrella organization
Increasing milk production per cow	Dairy innovation organization, political party
Generating renewable energy	Bank, agricultural umbrella organization, NGO
Genetic selection	Bank
Changes in diet	Bank
Mono-fermentation	Bank
Measures that were mentioned as negative	
Increasing milk production per cow	Consultancy, political party
Feed additives (Carel de Vries)	Innovation network

Table 3.5 lists the measures that can be taken on the farm level to reduce GHG emissions from milk production. The following section will describe their reduction mechanism. They are subdivided into 6 categories: the animal, fertilization, crop and soil management, feed, energy and additional measures.

Table 3.5 – Measures that can be applied on a dairy farm to reduce GHG emissions from milk production. The reduction potential of the measures is given in kg CO_2-equivalents, separately for the three main GHGs CO_2, CH_4 and N_2O and in total. Reduction is based on the average GHG-footprint of Dutch milk in 2011 (Reijs et al., 2016).

	CO_2	CH_4	N_2O	Total	Percentage reduction
GHG-footprint[1]	0.38	0.90	0.19	1.47	
Increase "animal sustainability"[2]	-	0.146	-	0.146	9.94%
Decrease Nitrogen fertilizer input by 50 kg per hectare[3]	0.012	0.010	0.023	0.045	3.1%
Separating solid and liquid manure[4]	-	0.044	0.003	0.047	3.2%
Sowing on current grass instead of re-sowing[3]	0.001	-	0.006	0.008	0.5%
Replace 2.5 kg of concentrate feed with 2 kg of grain[3]	0.058	0.038	0.002	0.098	6.69%
Methane-low concentrate feed[5]	-	0.045	-	0.045	3.1%
Nitrate food additives[6]	-	0.273	-	0.273	18.63%
Solar/wind energy[1]	0.060	-	-	0.060	4.09%
co-fermentation/ mono-fermentation[7]	-	0.204	-	0.204	13.90%
Less time in pasture[8]	-	-	0.082	0.082	5.57%
Water drains in peatlands[9]	-	-	0.010	0.010	0.68%
carbon sequestration in soil[10]	0.211	-	-	0.211	14.4%

Sources: 1. Reijs et al. (2016); 2. Van Laarhoven (2010); 3. Roetert (2009); 4. Verloop et al. (2013); 5. Smink et al. (2003); 6. Hristov et al (2013); 7. Schils et al. (2005); 8. Van den Pol et al. (2013); 9. Kwakernaak et al. (2010); 10. Elferink et al. (2012).

3.2.1 The animal

Increasing animal sustainability

The measures presented in this category in the report of Van den Pol et al. (2013) did not specify the reduction separately for the three main greenhouse gases, but only in CO_2 equivalents. These measures involved increasing the milk production per cow and reducing the number of calves held at the farm. A report by Valocon-Dairy presented the potential of reducing CH_4 emissions by increasing the "animal sustainability", which effectively will increase the milk production per year and the productive life span of the cows (Van Laarhoven, 2010). Fewer cows are needed because the production per cow has increased and less young cows are needed to replace older cows, as productive cows have a longer lifespan. Even though this will increase emissions per cow, total emissions are reduced as fewer cows and calves are kept.

The list of measures that can be taken is quite extensive. They often have a mutual relationship and interaction, and therefore the measures should be applied together to be effective. Appendix B.1 elaborates on some examples of measures that need to be taken, applied on the young animals and the adult ones.

If the measures presented in the report are applied, a reduction of the methane production of 15% can be achieved, resulting in the reduction of the GHG-footprint with 0.146 kg CO_2-eq (10%).

3.2.2 Fertilization

Lower Nitrogen fertilizer input with 50 kg per ha

This measure has a potential of reducing the greenhouse gas emissions of a kg of milk with around 0.05 kg CO_2-eq (4%). This is mostly due to decreased N_2O emissions from the grassland resulting from bacterial reformation of ammonia (NH_3) to N_2O (Roetert, 2009). This measure also reduces the CO_2 and CH_4 emissions: decreased energy use from producing the fertilizer reduces CO_2 emissions; CH_4 emissions are reduced because some of the roughage in the diet is replaced by more starchy foods as a consequence of lower grass production from lower fertilizer input (Roetert, 2009).

Separation of manure

On most dairy farms in the Netherlands, urine, feces and water are stored together. However, this slurry can be separated into a liquid and a solid part on the farm (Schröder et al., 2009). The liquid part can then be used to fertilize the grasslands of the dairy farm, while the solid part is transported from the farm to for example arable lands (Verloop et al., 2013). This decreases the volume and weight of the manure that is transported, which decreases the emissions from transporting the manure. Moreover, separating the liquid and solid part of the manure decreases its CH_4 emissions, but those are partly offset by increased energy use for separating the manure. Positive side effects can be seen in adding organic material to the soil. This is mostly present in the solid part of the manure, and when this is applied to arable soil (in which the organic matter content is on average lower than in grassland), it can increase the soil organic matter content, reducing GHG emissions from the manure. Verloop et al. (2013) stress that the potential for this measure is low (0.047 kg CO_2-eq/kg milk (2%) decline in emissions) and that the results are quite uncertain and based on laboratory experiments, which often do not correspond with actual emissions on farms.

The middle scenario B1/80 from Verloop et al (2013) for separating manure is used to calculate the reduction potential. This includes a reduction in the use of N fertilizer, because the liquid fraction of the manure is applied on the farm, which has a higher N efficiency, reducing the need to apply artificial fertilizer.

3.2.3 Crops and soil management

The report of Van den Pol et al. (2013) lists seven potential measures in this category, of which five are given a specific reduction potential. Of these five, four measures either have a lower reduction potential than 0.5% or the specific reduction potential was not retrievable through the referenced literature. For the measure of drainage pipes in peatlands, other source material was found, and an extra measure was found in other literature, namely storing carbon in the soil.

Sowing on current grass instead of re-sowing

On most farms, yearly about 10% of the grassland is sprayed with herbicides, after which new grass is sowed. Instead, seeds can be sowed in the existing grassland. This decreases emissions from the production of herbicides and less use of diesel for machinery. The reduction potential of this measure is 0.007 kg CO_2-eq per kg of milk (0.5%) (Roetert, 2009). Moreover, this measure has the potential to reduce the loss of soil carbon from re-sowing, but this is not considered in the calculated reduction potential.

Drainage pipes in peatland

Raising the water table in the peatland can reduce emissions from peat oxidation (Kwakernaak et al., 2010). This can be achieved without losing productive grassland by installing drainage pipes. Drainage pipes are horizontal pipes that are positioned in the peat below the water table. Due to limited infiltration capacity of the ditch walls and the soil, the evaporation from the pastures in the summer is faster than the maximum infiltration speed of the water. This lowers the water table in most of the pasture, increasing oxidation. Drainage pipes increase the water flow between the ditches and the soil, stabilizing the water table. An additional benefit is that the water flow the other way around it also increased, preventing too high water tables in winter that inhibit agricultural production. Drainage pipes would reduce soil subsidence by half, effectively reducing GHG emissions from oxidation in half as well (Kwakernaak et al., 2010).

Van den Pol et al. (2013) list adding drainage pipes as a cost-efficient method of reducing greenhouse gas emissions, although they do not provide a potential reduction of emissions when this measure is applied. This may be because no direct measurements have been executed on the effects of drainage pipes on GHG emissions, as this is a complicated procedure due to differences of emissions throughout the year and difficulties in closed chamber systems (van den Akker et al., 2010). However, empirical relationships between peat subsidence and CO_2 and N_2O emissions were found, and so subsidence rates can be used to estimate GHG emissions (Van den Akker et al., 2010; Kuikman et al., 2005). This method is also used for reporting the GHG emissions from peat to the UNFCCC. However, emissions factors are still uncertain, especially for the N_2O emissions.

The effect of drainage differs per type of peat soil. If there is a top layer of clay, subsidence rates are generally lower and drainage pipes can effectively eliminate the subsidence, as they can fully submerge the peat without submerging the top part of the soil. In peat without a covering layer of clay, even with drainage pipes the top part of the peat is exposed to air and will therefore oxidize and subside (Kwakernaak et al., 2010).

Here, we assume all ha of peat to be without clay layer, and that the implementation of drainage pipes will reduce emissions from the soil with 50%, as they also reduce the subsidence by 50% (van de Akker et al., 2010; Kwakernaak et al., 2010). Therefore, this measure reduces the CO_2 and N_2O emissions from peat soil (as accounted in the emissions of a kg of milk) by 50%. However, only the N_2O emissions from peat oxidation are considered in the GHG-footprint. The reduction potential is therefore 0.010 kg CO_2-eq/kg milk (0.68%).

Further raising the water table to natural levels would eliminate CO_2 and N_2O emissions, and will make the peatland a net GHG sink by adding more organic material to the peat (Kwakernaak et al., 2010). One interview participant (NGO) named this as an optional measure, where the peatland can then be used for paludiculture (growing inundated crops) such as cranberries. However, grass production (and thereby milk production) is no longer possible on inundated peatlands, therefore this measure is not considered here.

Carbon sequestration in the soil

Around 2,000 Pg of carbon are stored in terrestrial ecosystems globally, more than in the atmosphere (770 Pg). Of the terrestrial carbon pool, most carbon resides in the soil (1,500 Pg) (McCarl et al., 2006). In managed ecosystems worldwide, about half of all soil carbon has been lost to the atmosphere as CO_2 over the past two centuries due to human interference. By applying other management practices, this loss can now represent a possible carbon sink that can reduce atmospheric CO_2 levels (McCarl et al., 2006).

Grasslands typically have a high soil organic matter (SOM) content (Conant et al., 2001). The SOM can be increased by applying other management to the grassland. The effectiveness of the measures is highly influenced by biome type and climate (Conant et al., 2001). Therefore, to estimate the potential of carbon storage in grasslands in the Netherlands that is used by the dairy sector, a specific study about the Dutch situation is needed. Elferink et al. (2012) conducted a "quick-scan" research into the potential to store carbon in the soil of the Dutch dairy sector. Besides grasslands, this includes all the soils used by the sector, also for example soil used for production of maize by the farmers. The research does not include carbon storage in soils used to produce feed outside of the Netherlands. Elferink et al. (2012) conclude that there is a potential to store 2.5 Mt CO_2-eq per year when accounting for the applicability of these measures. If all the measures mentioned below are implemented to its maximum potential, and if the increase in SOM of these measures can be added without interfering effects than the effect could be as large as 4.9 Mt CO_2-eq/yr. Appendix B.2 elaborates on the individual measures needed to fulfill the potential of sequestration of 2.5 Mt CO_2-eq per year.

Sequestering 2.5 Mt CO_2-eq per year will compensate 0.211 kg CO_2 emissions per kg of milk (14%).

3.2.4 Feed

Nitrate food additive

Adding nitrate to the diet of a dairy cow can reduce CH_4 emissions from enteric fermentation by more than 30% (Hristov et al. 2013). Fermentation in the rumen (forestomach) results in production of excess hydrogen. This needs to be removed to efficiently continue further fermentation and microbial growth. Generally, this is removed by archaea who produce CH_4 and water from CO_2 and the excess hydrogen, almost 80% of this hydrogen is converted to CH_4 (Mills et al., 2001). One way to mitigate the production of CH_4 is to replace the chemical reaction with one where other, even beneficial, products are created from the hydrogen (van Zijderveld et al., 2010). A lot of additives have been tested with this point of view. So far, only nitrate seems to efficiently reduce CH_4 emissions (Hristov et al., 2013). There is however the danger of toxic effect of nitrite, which is formed within the reduction of nitrate to ammonia. Animals slowly increase their ability to reduce nitrite into ammonia, and can therefore consume more nitrate when exposed for longer periods of time (van Zijderveld et al., 2010).

The total reduction potential of this measure is 0.273 kg CO_2-eq per kg of milk (19%).

Interview participant Carel de Vries (Innovation network) has severe doubts about this measure as he says the sector should not become more dependent on multinationals than it already is, which would be the producers of these additives. Moreover, feeding nitrate will increase the ammonia emissions from milk production, a harmful side effect (see section 4.5).

Low-methane concentrate feed

Another option to reduce enteric CH_4 production is to reduce the amount of hydrogen gas produced in the forestomach. As most of the hydrogen is reformed to CH_4 by archaea, this will lower CH_4 emissions. The hydrogen itself is formed as a by-product when carbohydrates and proteins are fermented into volatile fatty acids (VFA) (Smink et al., 2003). Estimating the production of these acids by the fermentation of food is therefore a good indicator of CH_4 production. The production of the VFA's is dependent on the composition of the feed. Cellulose rich material for example, results in a higher acetic acid production in comparison with starch or protein. Fermentation of starch on the other hand consumes H_2 gas. For different components of feed (dissolvable sugars, starch, cellulose, protein etc.) the estimated production of VFA's is determined. This is used to estimate the H_2 and therefore CH_4 production in the enteric fermentation of the cow.

Changing the composition of a part of the feed, CH_4 emissions can be reduced by up to 35% (Smink et al., 2003). However, the price increases when the CH_4-reduction potential of the feed increases. A reduction in CH_4 emission of 5% can be achieved without (significantly) raising the costs of the feed. This measure results in a reduction of the GHG-footprint of milk of 0.045 kg CO_2-eq kg milk (3%).

Interview participant Frank Verhoeven (consultancy) would not soon apply measures that alter the CH_4 emissions from enteric fermentation, as he says they often negatively affect other aspects.

Replacing 2.5 kg of concentrate feed with 2 kg of grain

Replacing a part of the concentrate feed with grain can reduce CH_4 emissions from enteric fermentation (through the same mechanism as described with methane-low concentrate feed) and reduce CO_2 and N_2O emissions by a reduction in transport and soil emissions. The reduction potential of this measure is 0.098 kg CO_2-eq/kg of milk (7%).

3.2.5 Energy

Purchasing or producing renewable electricity

The production of renewable electricity can fully eliminate the GHG emissions from electricity use. Solar panels and wind energy are identified as the most efficient way to achieve this (Van den Pol et al., 2013). If these measures may not be technically possible, purchasing renewable energy will also effectively eliminate the CO2 emissions from electricity use. Therefore, the reduction potential here is 0.06 kg CO2-eq/ kg milk (4%).

Interview participant Carel de Vries (innovation network) thinks that farms can be a valuable addition to the renewable energy production in the Netherlands, and that the greenhouse gas emissions reduction from this, can be used as compensation for the carbon footprint of the dairy. Other interview participants mentioned producing renewable electricity positively as well (NGO, agricultural umbrella organisation, bank).

Co-fermentation or mono-fermentation of manure and maize

fermentation is the organic degradation of manure (and possibly co-fermentation materials, often maize) under anaerobic conditions. This produces biogas, which is comprised of mainly CH_4 and CO_2. The production of biogas is dependent on the potential of organic degradation of the organic material: fresh manure and plant material yield the best results (Oenema et al., 2015). Co-fermentation or mono-fermentation results in a GHG emission reduction by eliminating CH_4 emissions from manure storage. This measure therefore has a reduction potential of 0.204 kg CO_2/ kg milk (14%).

3.2.6 Other measures

Reduce the daily time spent in the pasture

Reducing the time spent in pastures can reduce between 2 and 19% of emissions, differing per type of soil, where peaty soil has the highest potential and sandy soil the lowest. During grazing, hotspots of N_2O emissions occur on places where urine and feces are deposited, as they contain a high amount of N (Van den Pol et al., 2013). When the grazing time is reduced, more of the excrement is deposited in the stables, where it can be collected and stored, reducing N_2O emissions. Moreover, this measure increases the amount of stable manure applied to the soil and reduces the need for artificial fertilizers (Schils et al., 2006). Even though emissions thus vary depending on the type of soil, Van den Pol et al. (2013) estimated the emission reduction for the average Dutch farm if they apply the following measure: cows will graze 5 hours less every day and receive 4 kg dry matter though concentrated feed extra in the period in which they normally go outside. The reduction potential of this measure is set at 0.081 kg CO_2-eq (6%) (Van den Pol et al., 2013).

The literature referenced by Van den Pol et al (2013) for this measure did not specify the reduction in the three main GHGs separately. But as the reduction is here almost fully accounted to N_2O emissions reduction, it is assumed that the reduction number stated in Van den Pol et al. (2013) is fully an N_2O reduction.

3.3 Three scenarios for reducing GHG emissions of the Dutch dairy sector

This section will answer the third sub question: *Which sets of measures combine into story-based scenarios that will adequately reduce the dairy sector's greenhouse gas emissions?* First, it will be explained how the axis system on which scenarios are placed was identified from the interviews. Second, the story-based scenarios will be described and matched with the reduction measures presented in the previous section. Then, a fair GHG reduction target for the dairy sector will be identified. Subsequently, the total reduction potentials from these scenarios is calculated.

3.3.1 Identifying scenarios from the interviews

A diversity of views of the future of the dairy sector can be identified among the participants. The primary difference in views that comes forward is that between the intensification and the extensification of the current dairy farming practices.

Participants from the Innovation network, political party, agricultural umbrella organization and the bank all stated that the dairy sector should focus on increasing efficiency and through that can achieve emission reduction. For example: Carel de Vries (innovation network) states that the farmers that use their nutrients more efficiently (and therefore cause less eutrophication) also have a lower carbon footprint of milk, because they use the nutrients more efficiently and therefore need less fertilizer and feed per kg milk. He also thinks extensification is not a guarantee for cleaner agriculture: increasing efficiency is the way to go in protecting the environment. If the goal is to have clean farms, policies must steer on emissions per unit product and quality of the environment and not on number of cows per hectare.

On the other side participants representing an NGO, consultancy and cheese manufacturer state that the current trend toward intensification should be reversed. They are in favor of a more extensive approach toward milk production. Catharinus Wierda (cheese manufacturer) states that farms that are more intensive have higher risks in the system such as higher manure surpluses. All three state that a focus on GHG emissions per kg milk will lead to the wrong stimuli; there should be a focus on looking at decreasing the input and output of the system: such as import of feed and export of manure. Moreover, intensive forms of dairy farming result in soil degradation, losing a lot of carbon which is often not accounted for in these footprints. Moreover, Eva Fransen (NGO) says that an intensive form of dairy farming on peatland as is customary now is not sustainable and that this system should be made more extensive.

These two diverging views can therefore be represented on an axis of intensive to extensive (horizontal axis in figure 3.2).

Subsequently, a second division in views can be identified: either focusing on GHG emissions as the main issue or also including other sustainability and environmental effects of milk production. This distinction is mainly seen in answers from participants who are in favor of increased efficiency on the first axis: some find efficiency is the only goal that should be strived toward while others think other environmental and animal welfare effects should be critically assessed. For example: Elbert Dijkgraaf (political party) states that the most important reason for the relatively high CO_2-footprint of Dutch milk is animal welfare: farmers are afraid to ask to much of their cows. This inhibits an increase in efficiency which could significantly lower emissions.

This divide can best be seen in the measures they propose: participants form the agricultural umbrella organization and political party propose mainly measures that do not have (large) impacts on other sustainability indicators such as animal welfare, but focus more on stable systems, carbon sequestration and artificial fertilizers. Other participants (innovation network, bank) focus more on measures that target the animal itself: increasing its milk production, reducing enteric fermentation and genetic selection or manipulation.

Therefore, the second axis represents the opposite views of integrative sustainability versus a focus on GHG emissions per kg of product (figure 3.2).

This divide between integrality and focusing on GHG emissions only occurs with a focus on intensive farming practices as no option for a view of focusing on GHG emissions while promoting extensive farming practices were found. This can be attributed to the participants who favor extensive agriculture put more value in nature and animal welfare, which then automatically becomes a more integral view of sustainability. Moreover, two participants (NGO, consultancy) state that by focusing on reducing GHG emissions [per kg of product], the sector is automatically pushed toward intensification, resulting in negative effects on other sustainability indicators such as biodiversity, soil quality, land use and nutrient loading.

On this axis system, the scenarios can be identified. First through de horizontal axis: intensive or extensive? Then through a second choice of integral or focused. On the extensive side, the Nature-inclusive scenario was identified, which holds an extensive view of the dairy sector which aims to be sustainable among a wide range of sustainability indicators. On the intensive side two scenarios were identified: both see dairy farming becoming more intensive in the future, where the Unlimited efficiency scenario is most extreme in intensification and barely considers other environmental and animal welfare aspects. The limited efficiency scenario focuses on efficiency as well, but has limits in how far measures can go in terms of other environmental effects and animal welfare.

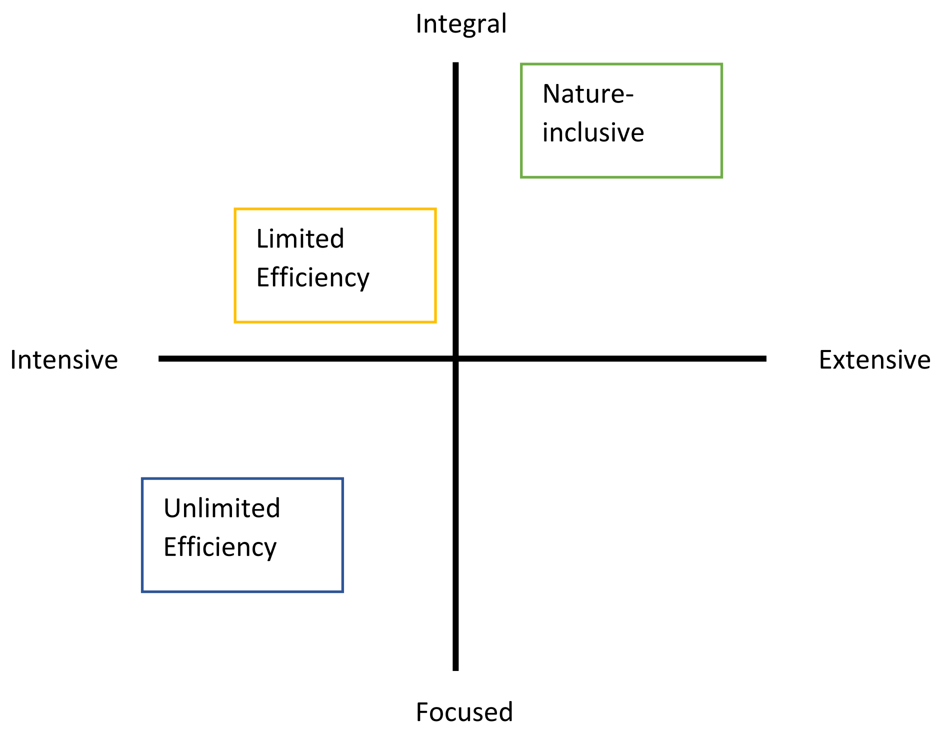

Figure 3.2 – The three scenarios expressed in their positions on the axes intensive/extensive and integral/focused. The intensive/extensive axis represents a view of intensive farming practices where emissions reduction is achieved through efficiency increase, and extensive farming practices where emission reduction is attempted on using the land that is available in a nature-conscious manner where there are fewer cows per ha of land. The integral/focused axis represents the way other sustainability facets are addressed in the scenario: is it focused on solely reducing greenhouse gas emissions or does it account for other sustainability factors as well?

3.3.2 The story-based scenarios

In the following section the scenarios will be described in story form. Subsequently, the identified reduction measures will be matched with the scenarios, from which a reduction potential will be calculated.

The scenarios in story form

1. ***Unlimited Efficiency***

In the Unlimited Efficiency scenario, the Dutch dairy sector will produce milk with a considerably higher efficiency. This is achieved by an intensification of farming practices. No longer will there be small family held farms with 80 cows, but the average company will have more than 500 animals. Most of the cows don't go outside, as keeping them inside enables a nearly closed system where CH_4 emissions from the manure can be captured and utilized for energy production. Animal welfare is only regarded when it reduces the efficiency of milk production. Other environmental problems such as ammonia (NH_4^+) emissions are approached similarly to the GHG emissions: by creating a closed system, the emissions to the environment are limited.

The animals in the large stables create a lot of manure, which is first used to extract energy (biogas) and processed into mineral fertilizer, which is then transported to arable land in the Netherlands and abroad. CH_4 emissions from enteric fermentation are decreased by changing the diet of the cows from cellulose-rich material to more easily digestible sugars and starches, which will also increase their milk production. Adding nitrate and other food supplements will further decrease the CH_4 emissions from enteric fermentation. To keep the animals from receiving toxic levels of nitrate, their intake is strictly monitored.

2. ***Limited Efficiency***

Like in the Unlimited Efficiency scenario, the Limited efficiency scenario will achieve a reduction in GHG emissions mostly by increasing the efficiency of the milk production, likewise with an intensification of the farming practices. The limited efficiency scenario does consider other social and sustainability aspects in its goal to increase efficiency however. The size of the average farm is increased, but they will remain family owned businesses that can manage more animals due to increased automation, but instead of one large farm, the animals will be divided among several locations, because smaller stables and herds are more socially accepted. The milk production per cow it not increased to its full potential, as farmers are worried that this might put too much stress and pressure on their animals. The diet of the cows consists mostly of grass and maize produced from the land of the farm, but is supplemented with concentrate feed that is imported. The fraction of easily digestible feed and residual flows such as wheat grass will increase.
Moreover, the cows will graze outside for a few hours a day, as the cultural historic view of the Dutch grassland areas includes grazing cows. Their daily time in the pasture is decreased from its current levels however, as the importance of manure processing for energy purposes is increased, and grazing cows emit more N_2O than stable-held cows.

GHG emissions are partly compensated by applying management practices on grassland and arable land that increase carbon sequestration in the soil, even though this will slightly increase the workload of the farmer.

3. ***Nature-inclusive***

In the Nature-inclusive scenario, the Dutch dairy sector will adapt itself so it makes the best use of the landscape and aims to produce milk under natural circumstances to reduce the environmental footprint. It does not seek to increase efficiency of the milk production. The size of the farms will be small and family held. Farmers will receive a "fair" price for their milk, which increases when they adopt more nature-inclusive measures. The cows can always go outside to graze. The pastures are managed so that they will sequester more carbon. These practices will be more extensive than in the other scenarios and will also focus on capturing carbon in existing biomass, such as silvopasture practices. The pasture will also contain a mix of grasses, herbs and clover species which will reduce the need for fertilizers and which might increase the nutritional value of the milk and benefit the overall health of the cows. Cows are mostly fed grass because their natural use is to convert grass -indigestible for humans- and turn it into valuable food. Producing feed on arable land would compete with production of food directly fit for human consumption.

The dairy farms in the peatland will adapt their farming practices to the land. A higher water table is managed by switching to a smaller breed of cow. Some parts may be inundated to allow other crops will be grown there, which can serve as protein-rich feed for animals, as food for humans or as isolation material.

3.3.3 Measures in the scenarios

Table 3.6 shows the measures identified in section 3.2 and in which of the three story-based scenarios they are included. The following section will describe why the measures are included in the scenarios as presented in table 3.6.

Table 3.6 – The reduction measures included in the three story-based scenarios.

Measure	***1. Unlimited Efficiency***	***2. Limited Efficiency***	***3. Nature-Inclusive***
Improving animal sustainability	X	X	
Decrease Nitrogen fertilizer input by 50 kg per hectare			X
Seperate solid and liquid manure	X	X	
No more re-sowing		X	X
Sowing on current grass instead of re-sowing		X	X
Replace 2.5 kg of concentrate feed with 2 kg of grain	X	X	
Nitrate food additives	X		
methane-low concentrate feed	X	X	
Solar/wind energy	X	X	X
co-fermentation/ mono-fermentation	X	X	
Less time in pasture	X	X	
Water drains in peatlands	X	X	X
carbon storage in the soil		X	X

Improving animal sustainability is matched with both the efficiency scenarios because the measure is focused on increasing the milk production per cow, the productive live span of the cows and reducing the number of young cows kept at the farm, which all benefit efficiency. The measure is not matched with the Nature-inclusive scenario because the increased milk production per cow might reduce animal welfare levels (Van der Schans & Rougoor, 2017). In the Nature-inclusive scenario, farmers may adopt some of the practices from this measure, such as increasing the healthy life span of the cow and reducing the number of young cows. No specific reduction potentials were calculated for such a combination of practices.

Decreasing Nitrogen input by 50 kg per hectare is matched with the Nature-inclusive scenario, because it will reduce the productivity of the grassland, and thereby the efficiency of the milk production. Nature-inclusive farmers will improve the nitrogen fertilization of their grasslands by sowing clover species in the grass, which will also benefit biodiversity.

Separating manure in solid and liquid fraction is matched with both the Efficiency scenarios, because it will reduce greenhouse gas emissions while producing energy. It is not matched with the Nature-inclusive scenario because cows need to be kept indoors for the manure to be collected and processed.

Sowing on the current grass instead of re-sowing is matched with the Nature-inclusive and Limited Efficiency scenario, because the measure will reduce the use of (and emissions from) herbicides while the impact on production is small. This measure does not fit in the unlimited technology scenario because it will reduce the grass production and thereby the efficiency.

Replace 2.5 kg of concentrate feed with 2 kg of grain. This measure is included in the Efficiency scenarios because it will reduce emissions from enteric fermentation and from a higher efficiency in growing grain than other typical concentrate feed while not reducing the milk production. This measure is not included in the Nature-inclusive scenario because in that view cows will be fed mostly with grass and the goal is to use only cows for their added value in digesting grass and prevent them from competing with food fit for human consumption.

Nitrate food additives in the diet of the cows is only used in the Unlimited Efficiency scenario as it is a cost-efficient way of reducing emissions of enteric fermentation. The Limited Efficiency scenario does not include this measure because it would reduce the social acceptability of the sector and the risks of toxicity are perceived as too large.

Methane-low concentrate feed will be adopted by both the Efficiency scenarios, because it is only a small change from the currently used mix of concentrate feed. Moreover, a reduction in CH_4 emissions from enteric fermentation might also point to a higher efficiency in digestion of the feed and thereby increasing milk production (Hristov et al., 2013).

Producing solar or wind energy is included in all scenarios, as it is cost-efficient and does not have any negative effects on other sustainability aspects. There might be a preference for solar energy over wind for the Limited efficiency scenario and Nature-inclusive scenario, because of the perceived negative effects on the scenery caused by wind turbines (Wolsink, 2007).

Fermentation of manure (co- or mono-fermentation) is included in the Efficiency scenarios, because it can create renewable energy and reduces CH_4 emissions. The measure is not included in the Nature-inclusive scenario because the animals need to be kept indoors to collect the manure.

Less time in pasture is excluded in the Nature-inclusive scenario, because in that scenario the time in pasture would sooner be increased instead of decreased. This measure is included in the Efficiency scenarios, where the Unlimited Efficiency scenario the time in pasture could be eliminated whereas in the limited efficiency scenario cows will still graze about one hour per day because of societal acceptance of the sector.

Water drains in peatlands will be included in all three scenarios because it reduces emissions and increases the productivity of the grassland due to an improved and stabilized distribution of water. Moreover, it decreases the oxidation and land degradation of peatland.

3.3.4 Overlap between measures

Some measures will have overlap because they address the same process through which GHGs are emitted. Below follows a list of measures who were identified to have overlap with one another. The measures with the lower reduction potential were then excluded from the scenarios.

Separating solid and liquid manure and *mono- or co-fermentation of manure.* For the fermentation of manure, the "slurry" manure from the stables is collected and fermented in its totality (with or without extra fermentation material such as maize). In the measure separating manure, this slurry is separated, and emissions are reduced by a decrease of transport of manure, reduced need of nitrogen fertilization on the land, and lower CH_4 emissions from storage of manure. These emissions will also be reduced when fermentation is applied, because the weight of the manure decreases when fermented and CH_4 emissions of storage are used to produce biogas. Therefore, the reduction potential of separating manure might be effectively zero when combined with fermentation. These two measures can therefore not be combined in one scenario. The measure mono- or co-fermentation is included over separating solid and liquid manure in the Limited Efficiency and Unlimited Efficiency scenarios.

Replacing 2.5 kg of concentrate feed with 2 kg of grain and *methane-low concentrate feed*. Both these measures reduce CH_4 emissions from enteric fermentation. The measure methane-low concentrate feed achieves this by changing the composition of the concentrate feed. If subsequently a part of this concentrate feed is replaced with grain, this interferes with the reduction potential. Therefore, the reduction potentials of these two measures cannot be combined. The measure methane-low concentrate feed has the lower reduction potential and will therefore be excluded from the Limited Efficiency and Unlimited Efficiency scenarios.

3.3.5 A fair reduction target for the Dutch dairy sector

One of the aims of this research was to assess if the GHG reduction from applying the measures in the scenarios will be enough to meet the 1.5 °C and 2 °C targets set in the Paris agreement in 2030. Because there are these two targets, the reduction potentials from each will be compared with two targets following from the Paris agreement: one where the reduction meets the requirements for 1.5°C and one where it meets the 2°C target.

Van Vuuren et al. (2016) developed three approaches to calculate the necessary emission reduction for the EU and the Netherlands based on the Paris climate agreement. These are:

1. To stay within the 2°C target with more than 66% chance (*well below 2*°C), assuming there will be 200 Gt CO_2 "negative emissions" after 2050;
2. To stay within the 2°C target with more than 66% chance (*well below 2*°C) without assuming negative emissions;
3. To stay within the 1.5 °C target with more than 50% chance with 350 Gt CO_2 negative emissions.

In this research, approaches 2 and 3 are used as a base for the reduction targets for the Dutch agriculture. For the 2°C version the 2nd approach was chosen because the technology to achieve negative emissions is not without controversy (such as biofuel to CCS; Van Vuuren et al., 2016). For the 1.5 °C target there is no scenario without counting on a large amount of negative emissions, because achieving this target without negative emissions is considered unreachable (Van Vuuren et al., 2016).

The remaining GHG's that can be emitted within these targets can be expressed as the carbon budget (IPCC, 2014). This worldwide carbon budget can be divided among countries and among sectors within these countries. Worldwide there is discussion about how the carbon budget should be divided among the countries (Van Vuuren et al., 2016). The allocation is dependent on the principle of fairness, but there is not yet consensus among scientists, countries and NGOs as to which principle is most 'fair'. Principles that are proposed are based on for example (historical) responsibility for emissions, the capacity of a country to contribute to reductions and cost-effectiveness (Höhne et al., 2014). The minimum reduction percentage for the EU in 2030 to keep to the 2°C target is 36%, according to studies with different interpretation of the principle of fairness (du Pont et al., 2016). Van Vuuren et al (2016) determined the emission reduction targets based on of every person in the world having right to an equal amount of emissions in 2050. This is only one of the criteria and does for example not consider economic ability and historic emissions, but it is the most widely used allocation mechanism. For the EU, this results in a reduction percentage of 61% and 53% for respectively the 1.5 and 2°C targets, higher than the target set by the EU itself of 40% reduction in 2030 compared to 1990 (Van Vuuren et al., 2016; European Commission, 2016). For the Netherlands, this results in an emission reduction target in 2030 of 47% and 40% compared to 1990 for respectively the 1.5 and 2°C targets (table 3.7).

Table 3.7 – Carbon budget (in Gt CO_2-eq) from 2020 onward and the GHG emission reductions relative to 1990 in 2030 and 2050 (Van Vuuren et al., 2016). It should be noted that the 1.5°C budget counts on negative emissions in the future whereas the 2°C does not.

Target		1.5°C	2°C
Chance of meeting target		50%	66%
With/without negative emissions		With negative emissions	Without negative emissions
Global budget		540 Gt-CO_2	640 Gt CO_2-eq
EU28 reduction	2030	61%	53%
EU28 reduction	2050	>100%	95%
Netherlands reduction	2030	47%	40%
Netherlands reduction	2050	>100%	95%

The European Union divides its 40% target among sectors. There is a distinction between ETS and non-ETS sectors. The European Emission Trading System (EU-ETS) is a 'cap and trade' system, meaning that a 'cap' on the total amount of emissions is set, and that the companies that are covered by the system can trade emissions allowances within the cap. Currently, 11,000 heavy energy-using installations are covered by the system, which covers about 45% of the GHG emissions from the EU (European Commission, 2017). The other 55% of emissions are emitted by the so-called non-ETS sectors: transport, agriculture, buildings, waste etc. In total, the European Union has agreed to reduce GHG emissions by at least 40% by 2030 compared to 1990 (both ETS and non-ETS). They specified that the non-ETS sectors should reduce emissions by 30% in 2030 compared to 2005 as their contribution to the overall target (European Commission, 2016). This contribution is thus lower for these sectors than for the ETS sectors. For the non-ETS sectors an allocation for different members of the EU was proposed, that accounted for a fair distribution of reduction efforts. The Netherlands were appointed a 36% reduction in 2030 compared to 2005 for non-ETS in the Effort Sharing Regulation proposal (Daniëls et al., 2016). Europe-wide the emission reduction for ETS sectors is 43% in 2030 compared to 2005 (European Commission, 2017). In this research, the distinction between ETS and non-ETS and the subsequent allocation of reduction efforts between those sectors was not used, because this is based on a 40% reduction for the European Union in 2030 (compared to 1990), which is not in line with the Paris agreement (Vuuren et al. 2016). This research uses the 40% and 47% reduction for the Netherlands compared to 1990 for respectively the 1.5 and 2°C targets. It is assumed here that all sectors in the Netherlands must contribute equally to reduction efforts, because the distribution between ETS and non-ETS cannot be translated to the reduction targets identified by Van Vuuren et al. (2016). Therefore, the dairy sector must reduce GHG emissions by 40% and 47% in 2030 compared to 1990 for respectively the 1.5 and 2°C targets.

3.3.6 *Reduction potentials of the scenarios*

Tables 3.8–3.10 show the potential to reduce the GHG emissions of an average kg of milk from the three scenarios when all the measures included in them are combined. The Unlimited Efficiency scenario [1] can reduce the GHG-footprint of a kg of milk by 59%, the Limited Efficiency scenario [2] by 55% and the Nature-inclusive scenario [3] by 23%.

It follows from the Paris climate agreement that the Dutch dairy sector will need to reduce its GHG emissions in 2030 compared to 1990 by 40% or 47% to keep to the 1.5 and 2 °C targets respectively.

If all measures in the scenarios would be applied to all the dairy farms in the Netherlands, this effectively means that the reduction potentials for the GHG-footprints are also the reduction percentages for all the cradle to farm gate emissions from Dutch dairy production. When assuming that the milk production will remain equal to the 2015 level of 13.3 billion kg, the reduction potentials compared to 1990 of the scenarios 1, 2 and 3 are 62%, 58% and 27% respectively (table 3.11).

From this it follows that the emission reductions from the Unlimited Efficiency scenario [1] and the Limited Efficiency scenario [2] are consistent with both the targets following Paris agreement in 2030, whereas the Nature-inclusive scenario [3] is inadequate for both.

Tables 3.8 – 3.10 The measures included in the three scenarios and their reduction potentials. The tables present the GHG-footprint of milk in total and separate GHGs from an average kg of milk produced in the Netherlands in 2011 (with updated GWP; Reijs et al., 2016). The reduction potentials are given separately for the greenhouse gas emissions. The amount of reduction is calibrated to be applied to the average GHG-footprint of a kg of milk in the Netherlands (see section 2.2). All units are in kg CO_2-equivalents with a GWP for CH_4 of 34 and for N_2O of 298.

Table 3.8 – The measures included in the Unlimited Efficiency Scenario [1] and their reduction potential.

	CO_2	***CH_4***	***N_2O***	***Total***	***Percentage reduction***
GHG-footprint	0.38	0.90	0.19	1.47	
Increase "animal sustainability"	-	0.146	-	0.146	9.94%
Replace 2.5 kg of concentrate feed with 2 kg of grain	0.058	0.038	0.002	0.098	6.69%
Nitrate food additives	-	0.273	-	0.273	18.63%
Solar/wind energy	0.060	-	-	0.060	4.09%
co-fermentation/ mono-fermentation	-	0.204	-	0.204	13.90%
Less time in pasture	-	-	0.082	0.082	5.57%
Water drains in peatlands	-	-	0.010	0.010	0.68%
Total reduction of GHG-footprint	**0.12**	**0.66**	**0.09**	**0.87**	**59%**

Table 3.9 - The measures included in the Limited Efficiency Scenario [2] and their reduction potential.

	CO_2	***CH_4***	***N_2O***	***Total***	***Percentage reduction***
GHG-footprint	0.38	0.90	0.19	1.47	
Increase "animal sustainability"	-	0.146	-	0.146	9.9%
Sowing on current grass instead of re-sowing	0.001	-	0.006	0.008	0.5%
Replace 2.5 kg of concentrate feed with 2 kg of grain	0.058	0.038	0.002	0.098	6.7%
Solar/wind energy	0.060	-	-	0.060	4.1%
co-fermentation/ mono-fermentation	-	0.204	-	0.204	13.9%
Less time in pasture	-	-	0.082	0.082	5.6%
Water drains in peatlands	-	-	0.010	0.010	0.7%
carbon sequestration in soil	0.211	-	-	0.211	14.4%
Total reduction of GHG-footprint	**0.330**	**0.388**	**0.100**	**0.818**	**56%**

Table 3.10 – The measures included in the Nature-Inclusive Scenario [3] and their reduction potential.

	CO_2	***CH_4***	***N_2O***	***Total***	***Percentage reduction***
GHG-footprint	0.38	0.90	0.19	1.47	
Decrease Nitrogen fertilizer input by 50 kg per hectare	0.012	0.010	0.023	0.045	3.1%
Sowing on current grass instead of re-sowing	0.001	-	0.006	0.008	0.5%
Solar/wind energy	0.060	-	-	0.060	4.1%
Water drains in peatlands	-	-	0.010	0.010	0.7%
carbon storage in the soil	0.211	-	-	0.211	14.4%
Total reduction of GHG-footprint	**0.284**	**0.010**	**0.039**	**0.333**	**23%**

Table 3.11 – The reduction potentials for the Unlimited Efficiency scenario [1], Limited Efficiency scenario [2] and the Nature-inclusive scenario [3]. The GHG-footprints in the scenarios are based on the combined reduction potentials in the measures included in them (table 3.8-3.10). The total GHG emissions are the result of the multiplication of the footprints with a production of 13.3 kg of milk, the amount of production in the Netherlands in 2015 (Reijs et al., 2016).

	1990	2011	2015	Scenario 1	Scenario 2	Scenario 3
GHG-footprint (kg CO_2-eq/kg milk)	-	1.46	1.48	0.59	0.642	1.127
Total GHG emission (Mt CO_2-eq)	20.4	17	19.7	7.847	8.5386	14.9891
Reduction 2030 compared to 1990 (%)				62	58	27

4 Discussion

The main research question was: *In which scenarios are the greenhouse gas emissions of the Dutch dairy sector in 2030 in line with the Paris agreement?* This question was answered by focusing on three aspects: 1) Identify the magnitude of emissions and potential reduction points, 2) aggregate available data on measures to reduce GHG emissions and 3) combine these measures into scenarios and calculate their total reduction potential. The data reveal that in the Unlimited Efficiency [1] and Limited Efficiency scenarios [2], the targets set in the Paris agreement will be met if all the measures are applied before 2030. The reduction potential of the Nature-inclusive scenario [3] is inadequate.

4.1 Current and projected GHG emissions of the dairy sector

The first sub question of this research was: *What are the current and projected greenhouse gas emissions of the Dutch dairy sector?* I found that the current GHG emissions of a kg of milk in the Netherlands are 1.48 kg CO_2-eq/kg milk and the total emissions of the dairy sector are therefore 19.7 Mt CO_2-eq pet year. Moreover, the emissions are likely to rise further, because the sector itself wants to increase production, while the emissions of a kg of milk have not decreased since 2008 (Reijs et al., 2016).

The total emissions of the dairy sector are larger than presented by the dairy sector itself (16.4 Mt CO_2-eq; Reijs et al., 2016). This difference is caused by the updated GWP value for CH_4. Using this new GWP value repeats the finding that the emissions of the dairy sector are substantial. In comparison: the annual GHG emissions of all traffic and transport in the Netherlands are around 35 Mt CO_2-eq (CBS, PBL & Wageningen UR, 2017).

The goal of the sector is to reduce emissions to 2011 levels which were 20% lower than in 1990, while maintaining growth (Reijs et al., 2016). They argue that this can be achieved by reducing emissions per kg of milk, as the top 5% of farms produce below this threshold. They acknowledge that this is no easy task, regarding the stabilized GHG-footprint of milk and point to the need of financial incentives to increase efficiency. A recent report from PBL projected that CH_4 emissions from agriculture will increase with 6% in 2030 due to an increase in the number of dairy cows and milk production per cow. N_2O emissions are expected to decrease with 3% mostly because daily grazing time for cows will decrease (Velthof et al., 2016). This shows that current policies and trends likely will not lead to a reduction in emissions.

The data that could be retrieved from the literature on the GHG emissions of milk production was lacking in quality and transparency. No specific system boundaries for the *cradle to farm-gate* calculations of the GHG-footprint of milk were presented by Reijs et al. (2016). Instead, the authors refer to a variety of methods used to calculate emissions from different sources but fail to explain how this influenced the results. This results in uncertainty about what emissions are included in the GHG-footprint. For example, it appears that CO_2 emissions from peatland oxidation are most likely not included in the GHG-footprint. This can be seen in the difference between the GHG-footprint from milk production on peatland and non-peatland. The former's larger value is caused by higher N_2O and CH_4 emissions (Hoogeveen, 2017). No CO_2 emissions from the soil appear to be included, whereas approximately 90% of emissions from peatland oxidation are in the form of CO_2 (Kwakernaak et al., 2010). Attributing the CO_2 emissions from peat oxidation would add 4 Mt of CO_2 emissions to dairy production in the Netherlands, an increase of 20%.

Furthermore, no information was retrievable about the uncertainties in the calculations of the GHG-footprint. While the uncertainties in measurement of CH_4 and N_2O emissions from grazing cows might be as high as 50% (A. Hensen, personal communication, May 10, 2017). In short, the quality of the data is lacking and could be improved. When done so, it is likely that the emissions from the dairy sector might be somewhat higher than reported now.

4.2 The reduction measures

The second sub question of this research was: *what are the possible methods to reduce GHG emissions of the dairy sector*. This part of the research resulted in an aggregated list of 13 measures. All of them were retrieved from literature that was thoroughly checked on credibility and the underlying sources. The list presented in this research can therefore be considered a complete list of measures that are thoroughly tested on their applicability and their reduction potential.

For all three scenarios, it goes that the measures included in them are not yet applied to most farms. For example, in 2015, only 3.5% of the electricity used in the dairy sector was produced by solar and wind-energy on the farms (Reijs et al., 2016); drainage pipes are applied on only a small fraction of peatland used for grass production (van den Akker et al., 2010) and co-fermentation is applied by 90 farms, 0.05% of the total number of dairy farms in the Netherlands (CBS, 2012). The reduction potentials of the measures are based on the average GHG-footprint of milk and thus account for the farms on which they are already applied.

Still, not every measure can technically be applied to every farm, and the technical feasibility should be reviewed for every farm specifically in future research. However, some potential barriers and chances can already be identified. For example, installing solar panels is considered an easy measure and applicable on almost all stables, and results in extra income for the famer (Van den Pol et al., 2013). The installation of wind turbines is more difficult, as permits are needed and the turbines can cause severe disturbance to people living close by (Van den Pol et al., 2013).

The final list of measures is shorter than the list of Van den Pol et al. (2013), which is the most recent and complete list of measures specifically aimed at the Dutch dairy farms. Not all the measures presented there are incorporated in this research as some of them had too much overlap and some had too little reduction potential to have any impact. On the other hand, some measures were added to the list from other sources, such as water drains in peatland and carbon sequestration. This made the list more coherent and more complete at the same time.

The precise reduction potential of the measures should be considered with caution, because the magnitudes of the uncertainties were not retrievable form the literature. The individual measures should therefore be interpreted as calculated estimations of reduction per kg of milk. Still, it is useful to combine measures in such a way as is done in this research, as it provides a view of the order of magnitude in which emissions can be reduced by applying a certain combination of measures. However, more research is needed to increase the reliability of the reduction potentials.

There are large differences in cost-effectiveness between the measures. Most of the measures presented here are cost-efficient (see also Van den Pol et al., 2013). Mono- of co-fermentation of manure, installing water drains in peatland and carbon sequestration can be costly measures however. For an average dairy farm the investments for a co-fermentation installation are around €630,000 (Schils et al., 2006), even though this can be somewhat reduced by partnerships between farmers, it will not be cost-effective. The costs of Installing water drains are high with €200 to €300 per hectare (Van Hardeveld et al., 2014). The costs of carbon sequestration are not yet clear, and depend on which types of management are applied. Increasing the soil organic matter can increase productions and reduce costs of applying these management practices.

Still, there may be more reduction measures available that are not included in this research. For some potential measures, no literature is yet available with their calculated reduction potentials, such as the genetic selection and manipulation of cows to reduce emissions from enteric fermentation or of growing paludiculture in peatlands as a protein rich animal feed. Moreover, considering the types of measures, there seems to be a focus in research on measures that require further intensification, which leads to this type of measure being relatively well presented in this research as well. On the other hand, a recent report specifically going into detail about nature-inclusive measures did not reveal any new measures that would fit on the extensive/integral side of the axis system (Erisman et al., 2017). Yet, the authors indicate that more research is needed in the concept of nature-inclusive agriculture and measures that can be taken within it.

4.3 The scenarios

The third sub question of this research was: *which story-based scenarios will adequately reduce the dairy sector's greenhouse gas emissions?* Three scenarios were identified in this research: Unlimited Efficiency [1] Limited efficiency [2] and Nature-inclusive [3]. If all the measures in scenario 1 and 2 would be applied to all dairy farms in the Netherlands, the sectors emissions would be in line with the Paris agreement in 2030 (with both the 1.5 and 2 °C targets).

The fair GHG reduction percentages for the dairy sector that are in line with the Paris agreement that were identified in this research are on the lower end of the spectrum, because it uses the principle of fairness of equal emission rights per person (Van Vuuren et al., 2016). Considering the historic emissions of the Netherlands and the dairy sector and the economic capabilities, it could be argued the fair reduction target should be higher. It is important that the EU will decide on an effort sharing approach, and translates this to reduction efforts for countries and sectors, because then sectors know how much they should reduce their GHG emissions and can subsequently take action.

The research approach of combining single reduction measures into scenarios -and thereby aiming to calculate the total reduction potential- has not been applied to Dutch dairy farms. Therefore, it is important to assess what pathways other literature sources take in reducing GHG emissions of milk production. Smith et al. (2008) assessed the worldwide GHG mitigation potential for agriculture. The potential mitigation measures for milk production focus on reducing enteric CH_4 emissions through feed additives and feeding practices and increasing the productivity of the cow. These measures were identified in this research as directing to an intensive form of farming, especially dietary additives were seen by the interview participants as something which directs (too much) towards industrialization of the sector. The IPCC includes a wider range of measures: they range from extensive-focused measures (rewetting peatlands and carbon sequestration under grassland) to intensive-focused measures (dietary additives such as nitrate and higher productivity of a cow) (Smith et al., 2014).

Other published literature also focuses mostly on technical measures such as feed additives and manure management, some also including carbon sequestration in the soil (Weiske et al., 2006; Herrero et al. (2016), Bellarby et al., (2013) and Havlík et al. (2014). These authors call for sustainable intensification of the livestock sector as the best pathway to reduce emissions. The FAO report Livestock's Long Shadow also notes that worldwide, most GHG emissions from the livestock sector are emitted due to extensive farming practices (Steinfeld et al., 2006). Even though this argues from a point of the global average in intensity of farming (which is already relatively high in the Netherlands), they also promote more technical mitigation measures such as vaccinating cows to reduce methanogens, which would fit into the Unlimited Efficiency scenario [1].

Van den Pol et al (2013), who specifically studied Dutch dairy farming systems, formed a package of mitigation measures from their overview of potential mitigation measures. In this they focus on measures that fit in the Unlimited and Limited efficiency scenarios, such as nitrate feed additives, increase production per cow and manure fermentation.

In short, almost all available scientific literature focuses on (sustainably) intensifying the livestock sector to reduce its GHG emissions. The scenarios Unlimited Efficiency and Limited Efficiency therefore appear to be the direction in which the scientific community is leading the sector. It must be noted however that almost all sources also promote a reduction of consumption of animal products to reduce emissions.

The high representation of the Efficiency scenarios in literature also shows that there are few alternatives to the measures included in them. This can also be seen in the absence of measures that exclusively belong to the nature-inclusive scenario. Even though this scenario was well represented in the views of the interview participants, it does not seem to be a distinct pathway that will lead to a reduction in the greenhouse gas emissions of milk production; it is a more critical view on what measures are considered good and appropriate.

The difference between extensive and intensive forms of dairy farming in actual classified forms of farming is comparable with the separation between conventional farming and organic farming. Organic dairy farming has strict criteria that protect the environment and animal welfare. Cows must be able to go outside for at least 120 days a year, artificial fertilizers are not allowed but clover and manure are used to fertilize grassland and the feed must be at least 60% roughage (grass, hay and maize) (Voedingscentrum, 2017). Organic dairy farming can therefore be placed in the integral-extensive quarter of the axis-system, just as the nature-inclusive scenario [3].

The Unlimited Efficiency and Limited Efficiency scenarios can thus be compared with conventional farming. The difference between the two scenarios can be described by the herd size on the farm: the more intensive the form of agriculture, the higher the herd size and the higher the risks of spillovers to other environmental factors. The Unlimited efficiency scenario [1] can therefore be represented by mega-farms as such that can be found in the US. In the US, more than half of the cows live in farms with more than 1000 cows (McDonald & Newton, 2014). In the Netherlands, the average herd size is much smaller (79 versus 144 in 2012) and the 100 largest farms have an average herd size of 500 cows (CBS, 2017). The average conventional farm in the Netherlands therefore fits in the Limited Efficiency scenario [2].

Although the approach of combining measures into scenarios is novel, we can compare the calculated reduction potential with other sources. Weiske et al. (2006) assessed the GHG mitigation potential for European milk production by combining measures into one package. These measures are: optimizing lifetime and efficiency of dairy cows, frequent manure removal, biogas production and improved manure application techniques; measures focused on the efficiency-side of mitigation measures. Weiske et al. (2006) found that emissions per kg of milk in conventional (i.e. non-organic) dairy farms could be reduced with about 75% (from 1.45 to 0.36 kg CO_2-eq per kg of milk; old GWP values used). This high reduction value is for a great part attributed to the production of biogas and its replacement of fossil fuel use elsewhere that is counted as compensation. When off-farm fossil fuel use reduction was excluded, the emission reduction was 39% percent (from 1.45 to 0.88 kg CO_2-eq per kg milk). This is a lower potential than that of scenarios 1 and 2, because it includes fewer measures.

Van den Pol et al. (2013) estimate a 14-25% possible reduction of cradle to farm gate GHG emissions on dairy farms if 90% of their proposed measures are adapted to the farms where this is possible. This would only result in minor costs as 40% of the measures are cost-efficient, and some even increase a farmer’s income. This reduction potential is low in comparison to the scenarios here, especially considering that most measures included in the calculations of Van den Pol et al. (2013) include measures categorized here on the intensive side of the axis-system, which is identified to have a higher reduction potential. This difference can be explained by their method of scaling: a panel of experts judged which measures were applicable on which type of farms (which type of soil they are on, technical applicability etc.) and how measures interacted with each other (i.e. lowered their combined potential). Unfortunately, no precise overview of calculations was given. The authors argue that this would not be desirable as it would create a false sense of objectivity and precision, where the experts' judgements are not considered completely objective and accurate.

The lower reduction potentials calculated in other research shows that the results from this thesis should be considered carefully. The relatively high reduction potentials do not account for the realistic applicability of the measures as this was not in the scope of this research. The reduction potentials therefore need to be considered as maximum potentials, where a realistic application will be lower.

4.4 Future steps for the dairy sector

Some mitigation measures were placed in all the scenarios. These can be seen as no-regret measures because stakeholders with different worldviews are most likely in favor of applying these measures. These measures are: Wind or solar energy and drainage pipes in peatland. These can therefore be promoted throughout the dairy sector regardless of which scenario is considered most favorable.

From the interviews, some lines of intervention on how to get to a reduction of GHGs could be identified, and these were different for each scenario. The first choice for policies will be on how to steer towards reduced GHG emissions: Three options fitting with the three scenarios were identified from the interviews: 1. regulating the GHG-footprint of a kg of milk. 2. regulating the GHG-footprint while limiting the maximum number of animals allowed on the farm and 3. regulating the GHG-footprint per hectare of land. The first two options will promote an intensification, with a limitation in the second option while the third favors more extensive forms of production.

Coupled to this policy tool is the so-called land bound farming (grondgebondenheid), which is incorporated in a law that will go into effect on January 1st 2018 (RVO, 2017). It is introduced to prevent dairy farms to grow without acquiring new land. With that, it is a stop on the Unlimited Efficiency scenario, which would lead to farms with a high number of cows to increase the efficiency of production. Land bound farming does not automatically steer toward the Nature-inclusive scenario however: the number of cows per ha of land is calculated through their phosphate excretion, thus the amount of phosphate that is allowed to be excreted directly influences the number of cows per hectare. With this, the government can steer toward the desirable stocking density. Therefore, it is not a policy tool specifically suitable for steering to one of the scenarios, but can be used to fit either of the scenarios by changing the allowed phosphate excretion.

In all scenarios, but especially in the Unlimited and Limited efficiency scenarios, the cost-effectiveness of measures will be a barrier for implementation. This can be overcome by incorporating the GHG-emissions from milk production in the emission trading scheme of the EU. The IPCC identified this as an effective pathway of mitigating emissions, where a price of 100 USD/tCO_2-eq would make expensive measures such as restoring peatlands cost-efficient (Smith et al., 2014). Measures in this research that can benefit from this are mono- or co-fermentation, carbon sequestration in the soil and installing water drains in peatland. Moreover, the measures that are already cost-efficient will become more profitable with a (higher) carbon price, which will increase the chance of their adaptation.

Another possible option for policies is to focus on reducing the production of milk and the number of cows in the Netherlands. Interview participant Harry Kager (agricultural umbrella organization) thinks that reducing production does not actually result in lower emissions unless consumption of dairy products is reduced, as otherwise production is replaced to other countries, where production is likely less efficient. This was repeated by other interview participants. Elbert Dijkgraaf (political party) thinks that we should educate people about the footprint of their food, so that they are aware of this when they make a choice in what to buy. Herrero et al. (2016), Bellarby et al., (2013) and Havlík et al. (2014) note that the economic potential of mitigation measures is only 10% of the technical potential and state that the most effective pathway to reduce emissions is by reducing the production of animal products (especially beef and dairy) through a reduction of their consumption.

4.5 Other environmental impacts

This research aimed to identify the GHG emissions of dairy production in the Netherlands and methods to reduce these emissions. Besides GHG emissions, dairy production also causes other environmental problems. Although it was not an aim of this research to quantify these, they should be considered when deciding on pathways for the future of the sector. Dairy farming impacts the environment in numeral ways: it impacts land use, soil, water, air and biodiversity (European Commission, 2000).

Biodiversity is pressured by dairy farming mainly through deforestation and intensification of land use (Steinfeld et al., 2006). Deforestation by Dutch dairy farming is currently mostly caused by foreign production of feed. This is link is strong in Latin America, where the cropland area for large-scale soybean production has doubled between 1994 and 2004 (Steinfeld et al., 2006). The Dutch dairy sector tries to limit their impact on deforestation by soy production trough purchasing RTRS-certified soy (Round Table on Responsible Soy) (Reijs et al., 2016). Organic farming uses less of these protein-rich feed crops by feeding the cows more roughage (Voedingscentrum, 2017). Traditional grazing on the other hand has positively affected biodiversity in pastures throughout Europe (Rook et al., 2004). However, when these pastures became more intensively managed, by sowing a single species of grass and managing it through the “cut and carry” system, biodiversity severely decreased (Steinfeld et al., 2006).

Water is affected by dairy farming both through water use and water pollution. To produce an average kg of milk in the Netherlands, 462 L of water is needed (Mekonnen & Hoekstra, 2010). This high-water use is caused by the low feed-conversion rate of cows and their own large drinking water requirement of 44 L a day (Steinfeld et al., 2006). More intensive forms of production use less water than a grazing (extensive) system (Mekonnen & Hoekstra, 2010). Most of this used water returns to the environment together with the rainwater on the pastures. Waste water and water that has been in contact with manure or fertilizers contain a considerable amount of nutrients, heavy metals, pathogens and drug residues (Steinfeld et al., 2006). In the EU, there are strict rules as to how much manure can be applied to the soil to reduce the nutrient loading of run-off water (Reijs et al., 2016). The Netherlands receive exemption from this rule through a higher allowed amount of manure/ha than other member states of the EU (European Comission, 2014). Nitrate loading is in some areas in the Netherlands 50% higher than the guidelines prescribe, although this is the result of all fertilizer and manure application in the Netherlands and not solely of dairy cow manure (Van Dam, 2017). When discharged to coastal waters these excess nutrient flows cause “dead zones” in marine areas (Broekema & Kramer, 2014). Organic production results in a lower eutrophication potential per kg of milk than conventional production due to lower (artificial) fertilizer application rates (De Boer, 2003).

Ammonia emissions from manure management and manure application on the soil contribute to terrestrial acidification and air pollution (Broekema & Kramer, 2014). Ammonia emissions from dairy farming were 23% higher in 2015 than the target set by the sector in 2020 (Reijs et al., 2016). This ammonia is transported through the air and deposited on the soil throughout Europe, affecting nature areas through acidification and nutrient loading (Steinfeld et al., 2006). Ammonia emissions are approximately the same per kg of milk for organic and conventional farming (De Boer, 2003).

Organic (extensive) dairy farming thus seems to have lower impacts on other environmental issues than conventional (intensive) farming, mainly on biodiversity, water pollution and eutrophication. No difference was found in the ammonia production between the two farm types. It is also found that GHG emissions in extensive farming systems are generally higher per kg of milk than conventional intensive systems (De Boer, 2003; Thomassen, 2008). This is also repeated by this research, as the reduction potential for the Nature-inclusive scenario [3] is lower than for the Efficiency scenarios [1,2].

4.6 Animal welfare

Another area on which dairy farming has an impact is on animal welfare. The scenarios deal differently with this issue; the higher a scenario is placed on the integral axis, the more it is concerned with animal welfare.

The life of a dairy cow is not an easy one. She gives birth her first calf when she is 2 years old, after which she starts to lactate (Wakker Dier, 2017). Per year she produces about 8000 liters of milk (Reijs et al. 2016). Every year the cow is inseminated, to give birth to a calf to keep up the milk production. Some of the calves are raised to be milk cows but most (including the males) are transported to be slaughtered for their meat (Wakker Dier, 2017).

The high production levels lead to several diseases, 7 out of 10 cows suffers from paw inflammation and 4 in 10 from udder inflammation, a problem increased by selection on productive cows and by less grazing time (Wakker Dier, 2010). Removal of the cows is often necessary because of reduced fertility and problems with their feet and udders (Reijs et al., 2016). Before she is slaughtered, the average dairy cow in the Netherlands reaches an age of 5.5 years, in which she gives birth to 3.5 calves (Hogenkamp, 2015). To milk the cows, the calves are generally separated from their mothers within the first 24 hours after birth (Flower & Weary, 2001). Bonding occurs between the calves in the first few hours after birth however, and this separation causes severe stress in cows which results in behaviour of calling, movement and placing the head outside the pen (Flower & Weary, 2001).

Due to the focus on efficiency and the intensive farming practices, the Unlimited Efficiency scenario [1] and to a lesser extent the Limited Efficiency scenario [2] would lead to a decrease in animal welfare. in the Nature-inclusive scenario [3] animal welfare is an essential point and will therefore likely lead to an increase in animal welfare compared to current levels.

5 Conclusion

This research was set up to answer the following research question: *Through which scenarios can the Dutch dairy sector reduce its greenhouse gas emissions to meet the reduction targets of the Paris agreement?* This research aimed to 1) provide an overview of the current state of GHG emission of the Dutch dairy sector, 2) create a list of measures that could be taken to reduce these emissions and 3) combine sets of measures into scenarios for the future of the sector and evaluate if these meet the reduction targets.

The research aims and main research question were divided into three sub questions. The first sub question was: *What are the current and projected greenhouse gas emissions of the Dutch dairy sector?* It was found that the cradle to farm-gate emissions of the Dutch dairy industry were 19.7 Mt CO_2-eq in 2015. From 1990 to 2011 emissions decreased, but have since increased again. The goal of the sector itself is to grow without increasing emissions, but as the GHG-footprint of a kg of milk has not decreased since 2008, it is therefore likely that total emissions will continue to increase as production grows. It was also identified that by using the most recent Global Warming Potential (GWP) values, the GHG-footprint of a kg of milk is 19% higher (1.48 kg CO_2-eq/kg milk) than was reported by the sector itself.

The second sub question was: *What are the possible methods to reduce the carbon footprint of the Dutch dairy sector?* A literature review and interviews with experts from the dairy sector yielded a list of 13 (aggregated) measures that can be applied on the farm level to reduce the GHG-footprint of a kg of milk. Their individual reduction potentials range from 1% to 19%. This study only included reduction measures of which their reduction potential was available from literature. There are however more promising measures that can be taken to reduce GHG emissions, their potential needs to be researched before they can be widely implemented.

The third and final sub question was: *Which sets of measures combine into story-based scenarios that will adequately reduce the dairy sector's greenhouse gas emissions?* This question was answered through identifying different views of the future of the sector among experts from a wide variety of organizations involved in the dairy industry. Three scenarios were identified, which are differentiated in their inclination toward either intensification or extensification of the sector and the focus on GHG emissions or a more integral view of sustainability. They are: 1. Unlimited efficiency, 2. Limited Efficiency, and 3. Nature-Inclusive. The scenarios have a total GHG-footprint reduction potential of 59% 56% and 23% respectively compared to the average GHG-footprint of an average kg of milk produced in the Netherlands in 2011. If the measures in the scenarios are applied to every farm in the Netherlands, this would result in total reduction of cradle to farm gate emissions from Dutch dairy production compared to 1990 by 62%, 58% and 27% respectively for scenarios 1, 2 and 3. Scenarios 1 and 2 could therefore meet the reduction targets following from the Paris Climate agreement for limiting global warming to 1.5 or 2°C. Scenario 3 would not be sufficient to meet the 2°C target, for which at least a 40% reduction in 2030 needs to be achieved.

The Limited Efficiency scenario [2] relates most to the current conventional dairy farming system in the Netherlands and is the focus of most research. The Unlimited Efficiency scenario [1] corresponds most to the mega-farms as for example seen in the US and the Nature-Inclusive scenario [3] approaches the organic farming system. It was identified that the Nature-inclusive scenario [3] would be most beneficial for other environmental aspects such as water pollution, biodiversity and air quality and for animal welfare, and the Unlimited Efficiency scenario [1] would impact these aspects the most.

Directing the sector through policies to one of the scenarios could be achieved by the choice of regulation of the emissions. Corresponding with the respective scenarios these options are: 1. Regulating the GHG-footprint of a kg of milk. 2. Regulating the GHG-footprint while limiting the maximum number of animals allowed on the farm and 3. Regulating the GHG-footprint per hectare of land.

The theoretical reduction potential for all three scenarios is most likely higher than the economic and technical potentials as interaction between reduction measures and their technical applicability were not quantified in this research. Therefore, to adequately reduce greenhouse gas emissions, the option to reduce the total production of milk in the Netherlands (alongside a reduction in consumption) should also be considered.

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Appendix A

Interviews with experts:

Harry Kager (LTO)

Carel de Vries (Courage)

Catharinus Wierda (De Fryske)

Elbert Dijkgraaf (SGP)

Marijn Dekkers (Rabobank)

Eva Fransen (Commonland)

Frank Verhoeven (Boerenverstand)

Harry Kager

Harry Kager is werkzaam bij ZLTO en LTO Nederland als specialist bodem en water. Hij is programmaleider van het onderwerp Energie & Klimaat van de Duurzame Zuivelketen en heeft daardoor veel kennis over hoe de melkveehouderij sector zelf, en de overkoepelende organisatie LTO, de toekomst van de melkveehouderij ziet en haar bijdrage aan het verminderen van broeikasgasemissies.

Hoe kan volgens u de melkveehouderijsector tot broeikasgasreductie komen?

De Carbon footprint kan naar de 1 kg co2 per kilo melk (nu 1.24 kg; Reijs et al., 2016). Met systeemaanpassingen kan dat nog lager door bijvoorbeeld een ander stalsysteem: nu wordt er gebruik gemaakt van koeienroosters waaronder drijfmest opgevangen kan worden. Daarbij komt veel methaan en ammoniak vrij. Dit kan vervangen worden door een stalsysteem waarbij mest direct wordt verwijderd, en vervolgens urine en mest gescheiden worden. Als koeien in de wei lopen gebeurt het scheiden van urine en mest automatisch. Stallen worden gebouwd met het plan dat ze er 30 jaar staan, dus het is zaak om daar snel op aan te pakken. Je moet hier wel integraal naar kijken, niet alleen sturen op broeikasgassen, maar ook dierenwelzijn en ammoniakuitstoot meenemen.

Andere maatregelen die genomen kunnen worden zijn bijvoorbeeld warmteterugwinning uit melk, om die warmte vervolgens te gebruiken in het woonhuis. Dit zou flink uitgerold kunnen worden. Daarnaast zou er een heel groot programma moeten komen om CO_2 opslag in de bodem en landschapselementen (bomen) te vergroten. Ook is het heel goed mogelijk om waar nu aardgas gebruikt wordt dat te vervangen door biobrandstoffen. Een ander belangrijk traject is kunstmest. Kunstmest zorgt voor veel uitstoot. Volgens Europese regelgeving mag er maar een bepaald aantal deel van maximaal nutriënten op het land uit dierlijke mest gehaald worden (70%), de rest wordt dan aangevuld door kunstmest. Er is goed argument is voor die regel. De regel kwam voort uit het idee dat dierlijke mest eerder uitspoelt naar het milieu, maar tegenwoordig kan er ook van dierlijke mest "kunstmest" (lees: minerale mest) worden gemaakt. Landbouw zonder stikstof kunstmest is mogelijk als het mag van de regels (als dus meer stikstof uit dierlijke bronnen gehaald mag worden).

Denk je dat de veestapel moet krimpen om tot een voldoende reductie te komen?

Het is niet zo dat de veestapel nu groter is dan ooit. In periode 1990-2011 verminderde het aantal koeien, nadat in 1984 na invoering melkquotum daalde het. Nu is het in 2015 weer afgeschaft en is het aantal koeien weer iets gestegen, maar nog niet boven het niveau van voor 1984.

Voor de landbouw heeft de EU een doel van 50% reductie in 2050 t.o.v. 1990. De EU roadmap zegt ook 50% reductie van niet-CO2. Ik denk niet per se dat de melkveestapel moet krimpen maar wel de verantwoordelijkheid moet nemen voor CF verlagen, lukt dat niet dan komt het aantal dieren in de knoop. Stel wij gaan die koeien niet meer houden, dan gaat die melk gaat toch ergens geproduceerd worden omdat de vraag niet daalt. Dit gebeurt dan waarschijnlijk in een land met hogere uitstoot per kg melk. De consumptie zou sturend moeten zijn. Als ik mijn productie aanpas gaat de prijs omhoog.

Carel de Vries

Carel de Vries is programmadirecteur bij Courage, de innovatieorganisatie van de melkveesector, opgericht door LTO Nederland en de Nederlandse Zuivelorganisatie NZO. Hun visie is het creëren van een gezonde Nederlandse melkveehouderij met toegevoegde maatschappelijke waarde. Carel de Vries heeft ruim ervaring in de zuivelsector, en het duurzaamheidsvraagstuk daarin. Zo heeft hij gewerkt als ontwikkelaar van het duurzaamheidsprogramma van FrieslandCampina en was hij manager van experimentele zuivelboerderij van de Wageningen universiteit.

Hoe ziet volgens u de toekomst van de melkveehouderij eruit als die tot reductie van broeikasgasemissies moet komen?

De productie van dierlijke eiwitten draagt aan aanzienlijk bij aan de productie van broeikasgassen. Voor Nederland is het wel van belang om een splitsing te maken tussen vleesveehouderij en melkveehouderij. Vleesveehouderijen in VS en Ierland en etc. zijn inefficiënt (melkveehouderij is in ieder geval in Nederland veel efficiënter). In Nederland is bijna geen rundvleesproductie, allemaal melkvee. Klimaat technisch gezien is het meest efficiënte om rundvlees te zien als een bijproduct van de melkveehouderij. Daarvoor moeten we naar een vleesconsumptie toe die niet hoger is dan de bijproductie van de melkveehouderij. Voor de melkveehouderij zit daar een kans. Nu worden koeien als ze versleten en mager aan het einde van hun melkcarrière geslacht, daardoor is de kwaliteit van het vlees veel lager. Het grootste deel van dit vlees gaat naar de gehaktballen, frikandellen en honden- en kattenvoer, niet zo snel naar biefstukken etc. DWDD University heeft zich een keer geweid aan een kok in de hoofdrol over rundvlees. Hij zegt dat het beste vlees komt van een melkkoe die aan het eind nog is vetgemest. Vroeger hadden we in Nederland dubbeldoelkoeien (koeien voor zowel melk als vlees). Nu is het heel erg gespecialiseerd naar melkproductie ten koste van vleesproductie.

Probleem: carbon footprint van vlees uit VS hebben wíj geen last van. Een koe wordt CO_2-intensiever als je hem ook voor vlees gaat houden, er moet dus wel compensatie zijn voor minder vlees van elders. Er moet dus een toedelingssystematiek komen die kloppend is en kan sturen op dit soort maatregelen.

Ik begin altijd even te zeggen dat in het hele klimaatdossier dat een koe hetzelfde wordt behandeld als een vrachtauto. Kern van het klimaatprobleem is dat wij fossiele brandstoffen verbranden en daardoor broeikasgassen naar de lucht gaan. Een koe gebruikt (in principe) geen fossiele brandstoffen maar verwerkt (geüpcycled) gras naar hoogwaardige voeding (gras en overblijfselen uit voedingsindustrie). Komt geen fossiele brandstof aan te pas. Maar het is natuurlijk wel zo dat hij methaan uitstoot bij vertering van die stoffen. Maar dat is eigenlijk een soort kort cyclische uitstoot van de CO_2 opgenomen door gras en andere voeding.

Welke maatregelen kunnen er genomen worden op bedrijfsniveau om tot broeikasgasreductie te komen?

Wij zijn nu bezig met de all-electric farm. Alles werkt dan dus op elektriciteit en allemaal met op het bedrijf opgewekte elektriciteit. Dit is dus een fossil-free farm. Alleen indirect worden er nog fossiele brandstoffen gebruikt door de gebouwen en machines die geproduceerd worden en overblijfselen van voedsel. Wat is dan een bijdrage van zo'n bedrijf aan het klimaatprobleem? Is dat dan dezelfde als de uitlaat van een vrachtwagen of rokende schoorsteen?

Hoe kan je nou van een melkveehouderij de Carbon footprint reduceren. CF van Nederlandse melk is ongeveer 1.24 kg Co2/kg melk. Als wij willen voldoen aan het scenario klimaat neutrale groei (red. scenario van de Duurzame Zuivelketen) dan moet die carbon footprint eigenlijk terug met 25% naar 1 kg Co2 per kg melk. Hoe kan een boer dat op zijn bedrijf minimaliseren. Dat kan hij allereerst door bijvoorbeeld de gewasproductie op zijn percelen te verhogen. Meer voer van eigen land is minder voer aan de kopen is hogere efficiëntie, naarmate er minder extern voer in die koe komt (daar kleeft zoveel carbon footprint aan). Ook een efficiëntere koe scheelt heel veel, een verhoging van de efficiëntie van het bedrijf is een hogere benutting van de grondstoffen dan daalt per kilo melk de carbon footprint. Dat is een route daar kan je heel ver mee komen, het is ook een route die heel logisch is (ook voor de boer omdat efficiëntie verhogen). Zie bijvoorbeeld het vruchtbaar-kringloop achterhoek project, waar 300 boeren werken aan kringlooplandbouw (met LTO, Rabobank, FrieslandCampina, provincie Gelderland, Vitens). Sinds vorig jaar werken we daarbij ook aan de carbon footprint (Universiteit Wageningen, FrieslandCampina). Wat we zien na de berekeningen is dat de boeren die het minst het milieu belasten qua waterkwaliteit (die hun nutriënt-verliezen het meeste hebben gereduceerd), dat zijn ook de boeren die het best scoren op de carbon footprint. Het verminderen van uitlekken van grondstoffen betekent dat de boer de benutting verbetert. Door die efficiëntie produceren ze een maximale hoeveelheid melk en daardoor reduceert ook die carbon footprint van die melk. Onze conclusie is dat via het spoor van de benutting van de nutriënten de carbon footprint automatisch wordt gegarandeerd. Scherpe doelstellingen met waterkwaliteit en oppervlaktewater gaan dus automatisch leiden tot een forse reductie van de carbon footprint van een liter melk. Mijn visie is dat dat stap 1 van de route is. Stap 2 is dan nog dat het teveel aan carbon footprint van een liter melk compenseren met elektrische productie (netto producenten van elektriciteit). Dat is voor mij de route om de landbouw future-proof te maken. Ik ben heel erg tegen additieven voor voeding om methaanemissies uit pensfermentatie te verminderen door manipulatie stofwisseling van de pens. Ik wil niet nog weer opnieuw zo'n sector afhankelijk maken van grote multinationals.

De boer die bij ons het beste scoort (hoge productie, 80 koeien) die heeft de afgelopen 5/6 jaar de puntjes op de i gezet. Hoe zo gezond mogelijk groeien, en hoe de koeien gezond houden en daardoor geven ze meer melk. Hoe krijg ik mijn bodem nou vruchtbaarder en daarmee gewasproductie verbeteren? Hij heeft een fosfaatoverschot van -30 kilo/ha stikstof overschot ook zo klein dat hij schoon grondwater heeft. En zijn carbon footprint is ook nog eens laag.

Er zit één addertje onder het gras: bv partijen als natuur & Milieu. Hij heeft het over de carbon footprint van een kilo melk (is hij voor) maar N&M zou dus opsturen naar CF per hectare bijvoorbeeld. Wat je dus moet voorkomen is dat je veel te veel beesten krijgt. Hoeveelheid dieren moet je beperken en eventuele groei van dieren moet je aan strikte randvoorwaarden voldoen. Ik ben altijd tegen keiharde structuurgrenzen, uiteindelijk is dat de doof in de pot omdat je ontwikkeling en vernieuwing houdt. Ik ben wel voor de begrenzing van de productie maar dan de meeste ruimte bieden van degenen die het het beste doen.

Ik ben wel voorstander van carbon footprint per productie-eenheid omdat je dan aanstuurt om de efficiëntie op peil te krijgen wat ook goed is voor het milieu. We hebben een x aantal mensen op deze aardbol die gevoed moeten worden en die kiezen een bepaald productiepatroon (kan je niet heel veel aan doen). Dus als je accepteert dat we dierlijke eiwitten willen eten dan is efficiëntie de belangrijkste route volgens hem.

Productie kan naar het buitenland toe verschuiven als je de productie hier verminderd, wat zorgt voor meer co2 uitstoot. Wat is rol voor NL? Niet de wereld voeden maar misschien wel de voedselproductiemethodes (circulair!) ontwikkelen, onze ambitie moeten zijn om een wereldvoedsellaboratorium te worden. Binnen allerlei voorwaarden is efficiëntie gewoon de toekomt, maar dat moet wel aan randvoorwaarden milieu voldoen. Binnen die randvoorwaarden is efficiëntie gewoon altijd het beste. Daarmee ben je het meest circulair bezig. Als dat je missie is moeten we ook met besturingsmodellen sturen op efficiëntie en verbetering van benutting.

Hij wil wel naar grondgebondenheid (hoe ga je dat dan definiëren? Welk getalletje ga je er dan aanhangen?) met altijd ruimte voor ontwikkeling voor verschuiving van dingen. Wat we nu grondgebonden vinden kan over 20 jaar heel extensief over komen. Als we dat zo opzetten dat hij mee kan bewegen met ontwikkelingen. Nu al heel veel verschil tussen boeren met hoeveel productie ze grondgebonden zijn.

Je moet niet het klimaatprobleem aangrijpen om structuurbeleid te voeren. Structuurbeleid moet je op zich voeren. Niet klimaat gebruiken om weerzin tegen koeien te gebruiken, want dat is nooit effectief.

Extensivering is géén garantie voor schoon, intensieve bedrijven kunnen net zo schoon zijn als extensieve bedrijven. Als je schoon wil blijven moet je niet sturen op koeien per hectare maar niet op stikstof per hectare. Kwaliteit van milieu, diergezondheid en biodiversiteit. Dit krijg je niet automatisch op sturen van kwantiteit. 50% koeien eruit en je hebt alle problemen opgelost is dus niet waar.

Catharinus Wierda

Catharinus Wierda ziet zichzelf als expeditieleider in duurzame zuivel. Hij houdt zich onder andere bezig met natuur-inclusieve landbouw: hoe kan daar een marktpotentieel voor gevonden worden? Zo heeft hij een kaasmerk ontwikkeld waarin ruimte voor de natuur centraal staat in de productie, met een speciale nadruk op duurzame werkwijzen en dierenwelzijn en weidevogelbescherming.

Hoe ziet de melkveehouderij in de toekomst eruit, en hoe vindt u dat deze eruit zou moeten zien?

In Nederland moeten we streven naar natuur-inclusieve landbouw. In Nederland moeten we een slag verder dan efficiëntie. Deze is nog niet genomen en daardoor verslechtert het imago van de melkveehouderij. Ik vind dat de melkveehouderij al veel eerder duurzaamheidskeuzes had moeten maken, dat moet nu dus nog steeds. Daarin moeten met grondgebondenheid gewerkt worden, dit komt ten goede van de biodiversiteit en het milieu. Hoe intensiever het bedrijf (aantal dieren per hectare) hoe groter het risico in het systeem wordt. Hierdoor wordt bijvoorbeeld het mestoverschot op een bedrijf steeds groter, hier zijn veel problemen mee, het transport wordt strenger gevolgd dan chemisch afval. Die 'mestcowboys' doen maar wat (mesttransporteurs verdienen goudgeld), dit komt door perverse prikkels: boeren intensiveren omdat het economisch gezien het meest aantrekkelijk is. Door (het niet oplossen van) het mestprobleem komen ze niet aan bij nieuwe problemen (duurzaamheid, biodiversiteit, soja, klimaat).

Ik vind ook dat het systeem van melkveehouderij niet klopt. De kern moet zijn grondgebondenheid (de melkveehouderij is nu niet grondgebonden). Als je grondgebonden om weidegang in stand te houden. Dan hoeven ze dus geen mest te transporteren, hebben meer ruimte om de koeien naar buiten te doen. Weidegangpremie van FrieslandCampina moet steeds hoger om te competitief te zijn met intensivering. Intensivering is de bron van dat er voor duurzaamheid geen ruimte is. Grond is duur, is intensiveren op klein stukje grond heel aantrekkelijk. Een oplossing zou dus zijn om grondgebondenheid in te voeren. Zonder dit gegeven is de basisvoorwaarde niet geregeld en kunnen er ook geen oplossingen komen.

Als je naar de klimaatimpact van een bedrijf kijkt moet je kijken naar de input en output. Een intensief bedrijf presteert het beste op CO_2 per kilogram melk. In hoeverre is de uitstoot van ver weg verbouwde soja meegenomen, en de (uitstoot van) de bodemdegradatie die daarbij komt kijken? Dichtbij hebben we ook te maken met bodemdegradatie, vooral door ploegen. Koolstofopbouw is veel hoger in grasland, dus er moet meer gevoerd worden met gras dan met maïs, dit is ook nog eens veel beter voor de bodem. Ik wil het liefst toe naar een footprint model waar dit in meegenomen wordt. Voor melkveehouderij is het nog interessanter om de discussie voor een goede carbon footprint aan te gaan, om op die manier niet met een instrument te zitten waarin intensiveringen worden beloond.

Weidegang zou ook nog eens kunnen leiden tot minder methaanuitsoot. Omdat het mengen van urine en mest kan zorgen voor meer methaanuitstoot. Het is belangrijk om te kijken naar uitstoot per hectare en niet per koe of per liter melk. Mooie indicator om aan te werken. Een bedrijf wat meer koolstofopslag kan doen heeft misschien een iets lagere productie per koe en verliest het daar dus weer.

Op welke manier kan de melkveehouderij duurzaam worden? Specifiek: Wat zijn de kaders en randvoorwaarden

Als er meer gras in rantsoen wordt gedaan heb je al veel meer eiwit in het dieet. Hierdoor hoef je minder krachtvoer te importeren, wat de uitstoot ten goede komt. Grassfed milk moeten we in Nederland ook krijgen. Er is in het verleden veel meer mais gekomen omdat het gras te hoog bemest werd, nu is het gras minder bemest. Het effect was hoe meer stikstof je in het gras stopt hoe meer eiwitten die de koe niet kan benutten, daarom moest er mais bij voor de kortere energie. Mais wordt nog steeds geteeld omdat het een hele hoge opbrengst heeft per hectare, maar gronden worden steeds armer door de teelt van mais. Er is weinig aandacht voor opbouw organische stof. In Flevoland komen ze er nu achter dat ze opbouw van organische stof nodig is en dat ze de bodem sinds ontginning hebben uitgeput.

Energieverbruik weet ik niet veel van. Boeren willen geen zonnepanelen op het dak. Die zorgen voor spanningselementen en koeien kunnen daar soms gek van worden. Omdat ze op blote voeten op nat beton lopen.

Elbert Dijkgraaf

Elbert Dijkgraaf zit namens de SGP in de tweede kamer. SGP is al enkele jaren bezig om de aandacht voor de landbouw te vergroten. Landbouw zit in zijn portefeuille. Hij constateert dat ze stemmen krijgen van boeren die niet per se tot hun achterban horen, maar dat ze op hen stemmen door de aandacht die ze aan landbouw geven.

In het partijprogramma van de SGP zijn ze onder andere vóór co-vergisting. Biologisch als uitgangspunt voor duurzaamheid.

Hoe kan volgens u de melkveehouderij in Nederland tot voldoende broeikasgasreductie komen, wat zijn de meest kansrijke maatregelen daarin?

Ik ben geen techneut, als politicus moet ik me niet zo zeer bezighouden met de technische kant. Is er überhaupt een prikkel nodig? Op het moment dat je minder CO_2-emissies hebt per liter melk moet je eerst de vraag stellen, heeft de boer niet sowieso al de prikkel om het meest efficiënt te werken? Ik was in Israël in Januari, daar haalde ze uit één koe 14.000 kg melk per jaar (red. in Nederland gemiddeld 8000 kg per jaar). Daarbij is de CO_2-emissie per liter melk is NL op 3 of 4 in de wereld, Israël en de Verenigde Staten zijn daarin efficiënter. Als je tegen Nederlandse boeren zegt: dat moet je ook doen, willen zij dat helemaal niet omdat ze dan teveel van de koe vragen. T.o.v. het gemiddelde in NL kan je nog wel 40% meer melk krijgen, maar ben je dan niet te veel een machine aan het maken van die koe? Vorig jaar augustus was ik in Ethiopië, daar hadden ze koeien geïmporteerd, de melkproductie was 3000 kg, er zit dus een factor 5 tussen Ethiopië en Israël. Dat zit hem in twee dingen: fok van de dieren en de optimalisatie van het voer. Dan kan je heel veel doen, als je die productie verhoogt, kan je emissies reduceren. De vraag waar ik nog niet uit ben, boeren willen een goed inkomen en dus efficiëntie, maar boeren gaand aar heel anders mee om, welzijn is voor die boeren daarin heel belangrijk.

Ziet u dan geen potentie meer in efficiëntie?

Qua klimaat is efficiëntie dus een goede, maar als boeren dat dus omwille van dierenwelzijn niet willen is dat lastig.

Hoe ziet het toekomstbeeld van de Nederlandse melkveehouderij sector eruit? Hoe vindt u dat die eruit moet zien in de toekomst?

Ik zou wel meer onderzoek willen naar het effect van verhoogde productie op het dierenwelzijn van die koe, als je dat opgelost hebt kun je volgens mij naar minder CO_2-emissies. Wat ik een beetje bij boeren proef is dat je dan misschien niets hoeft te doen. Dan moet je nog wat dingen doen in termen van voorlichting etc. Dierenwelzijn speelt terecht een hele grote rol, want het is geen machine.

Vind u het een optie om de veestapel te laten krimpen als de reductie niet genoeg is?

Dit vind ik onnozel omdat de vraag niet verminderd, dus dan vererger je het probleem omdat productie naar het buitenland wordt verplaatst waar de uitstoot per kg melk dus vaak hoger is.

Hoe kan de politiek daarin sturen? Moeten ze op vraag sturen?

In termen van voorlichting kan je daar veel aan doen, mensen informeren over footprint is altijd goed, dan weten ze wat ze kiezen.

Wat vindt u van grondgebondenheid?

Ja, maar dat ligt er erg aan hoe je dat definieert. Als elk melkveebedrijf mest op eigen grond mest moet afgeven, maak je het erger, want dan moet kunstmest op akkers. Binnen een straal van 30 km zou wel goed zijn, want dan sluit je eigenlijk de regionale kringlopen. Daarbij speelt nog één element mee: fosfaat in mest. Wij hebben een overschot, terwijl er wereldwijd een tekort is. Mest die wij overhebben zouden we dan kunnen verwerken naar fosfaatkorrels om dat te exporteren, dan is er minder fossiele fosfaat nodig.

Optie om binnen Europa alleen veevoer te halen?

Hoe regionaler hoe beter, maar komt niet altijd zo uit met de prijs. Als dat niet klopt is het geen rationele keuze.

Marijn Dekkers

Hoe ziet volgens u de toekomst van de melkveehouderij in Nederland eruit, die broeikasgassen moet gaan reduceren?

Wat ik zie is dat het een heel uitdagend doel is om de BKG-emissies terug te brengen, zal niet alleen in Nederland zijn, maar andere landen zullen hogere uitdagingen hebben, omdat Nederland over het algemeen veel efficiënter is dan andere landen hierin.

Hoe kan volgens u de melkveehouderij in Nederland tot voldoende broeikasgasreductie komen, wat zijn de meest kansrijke maatregelen daarin?

Oplossingen kunnen zijn: de opwekking van energie (wind of zon), genetische aanpassingen of selectie bij het vee, het aanpassen van het dieet. In Nederland vrij actueel is mono-vergisting: er zijn van mono-vergisting nog relatief weinig/geen gegevens in het economisch klimaat in Nederland dat er een positieve businesscase gedraaid kan worden. Of de sector moet ervoor kiezen om samen voor de mono-vergisting te betalen, om collectief het voordeel van hebben. Co-vergisting is ook een hele uitdagende, die is wel iets makkelijker om mee te rekenen. Bij mono-vergisting kan je beter grootschalig toepassen, veel mest van veel boeren bij elkaar vergisten.

Vind u het een optie om de veestapel te laten krimpen als de reductie niet genoeg is?

Aan die knop kun je altijd draaien, maar dan heeft het geen nut om alleen naar Nederland te kijken. De vraag is er wereldwijd, dus als je minder vee neemt, maar of daar het totale akkoord dan mee gehaald wordt vraag ik me dan af.

Hoe ziet volgens Rabobank de boerderij er in 20 jaar uit?

Collectiviteit van prijzen wordt belangrijk, ik zie geen steeds verder dalende melkprijs. Er zullen nog wel steeds familiebedrijven zijn, maar deze zullen wel wat groteren bedrijven met ongeveer 200 koeien worden, dat wordt dan zonder extra arbeid behaald door meer automatisering maar wel steeds met aandacht voor de duurzaamheid. Er zal behoud van weidegang zijn, en de levensduur van de koeien zal verhoogd worden. Er is zorg voor de maatschappelijke inpassing in de omgeving: de genen die echt door willen groeien zullen dan misschien naar meerdere locaties gaan, in plaats van één hele grote locatie met meer dan duizend koeien. Ook inpassing als gevolg van hoe bouw ik mijn stallen, hoe leg ik mijn groeisingels aan, koeien naar buiten?

Genetische selectie/aanpassingen bij het vee, u zei daar wat over, maar die optie ben ik nog niet tegen gekomen, kunt u daar wat meer over vertellen?

Ik sprak een Nieuw-Zeelandse veearts: er zijn genetische verschillen tussen (soorten) koeien en hoeveel methaan ze uitstoten. Dit zal dus in de toekomst nog een optie kunnen zijn, maar ik ben hier nog geen specifieke getallen over tegen gekomen.

Eva Fransen

Eva Fransen werkt bij Commonland, een organisatie die gemeenschappen helpt om hun land te restaureren. Ze dragen bij aan de “Bonn Challenge”, een wereldwijde poging om 150 miljoen hectare van de wereldwijd gedegradeerde en ontboste landen te herstellen voor 2020. Eva Fransen houdt zich bezig met het Nederlandse veenweidegebied, wat door huidige landbouwpraktijken inklinkt waardoor jaarlijks vele hectare van dit unieke landschap verloren gaan. Hiervoor heeft ze vanuit Natuur & Milieu bij allerlei adviesgroepen m.b.t. melkveehouderij aan tafel gezeten. De basis van haar advies is dat duurzaamheid integraal is, en dus moet zoeken naar oplossingen die op alle facetten van duurzaamheid helpen.

Hoe kan de melkveehouderij minder broeikasgassen uitstoten?

Het veenweidegebied is hierin heel belangrijk. Het heeft een grote CO2 footprint in verschillende fases van de productie, ook landgebruik. Als melkvee op veengrond gehouden wordt heb je dus al een grotere CO_2 afdruk dan op bijvoorbeeld zand- of kleigrond. De emissies uit veenweide bedragen 4.2 Mt CO_2 equivalenten per jaar. ter vergelijking is dat twee miljoen auto's. Daarnaast is ook de manier van bemesten en de soorten meststoffen die toegepast worden belangrijk. Kunstmest heeft hoge uitstoot in productiefase. Ook de methaanuitstoot van de koe verschilt per type voedsel. Je zou alle verschillende bronnen in en diagrammetje moeten zetten en dan bekijken: hoe kunnen we maatregelen treffen die niet te veel (negatieve) impact hebben op andere gebieden.

Zonnepanelen op het dak van stallen kunnen een goede maatregel zijn, ééntje die ik al vaak zie en waar de boeren tevreden mee zijn.

Bij de input van krachtvoer en kunstmest kan je kijken of je dat kan verminderen, meer naar een systeem gaan van grondgebondenheid en eigen voer telen. Een andere optie minder jongvee aanhouden, waarvoor je de melkkoe dus langer kan aanhouden. Eerste twee jaar geeft die koe geen melk. Die verhouding kan je verbeteren door de koe ouder te laten worden. Dan moet je dus meer kalfjes slachten of vetmesten of vervoeren, ook hoge footprint!

Veenweidegebied: veen verdwijnt naarmate waterpeil daalt en het grotere deel droog houdt. Veenweidegebied is helemaal niet geschikt voor intensieve veeteelt. In Friesland 90 cm onder bodem, NH 60 cm. Je kan het waterpeil naar 30 cm brengen en dat zorgt voor halvering broeikasgassen, maar dan kan je niet zo intensief koeien houden. Dan moet je minder grote/zware koeien gaan houden. Experimenten om het helemaal nat te houten (waterpeil helemaal omhoog) en dan om andere gewassen (lelies en cranberries). Zij zijn bezig om met een project om azolla (eiwitrijk) te telen, en die gaat hij dan aan zijn kippen voeren om soja te vervangen. De gedachte hierbij is dat je moet klein beginnen om te kijken hoe het werkt.

Veenweide-emissies worden heel vaak niet meegenomen. Afgelopen jaar is afgesproken dat het wel in de nationale metingen moet komen. Er komt al steeds meer aandacht voor maar staat meestal niet in studies van blonk etc. Er zijn onderzoeken die aangeven dat de carbon sink in veenlandschappen nog groter is dan het Amazonegebied.

Frank Verhoeven

Welke maatregelen kunnen er op bedrijfsniveau genomen worden om de broeikasgasemissies te verminderen?

Ruwvoer zorgt voor meer methaanemissie, maar door meer krachtvoer te geven stuur je de verkeerde kant op, omdat juist de toegevoegde waarde van een koe is dat die gras kan omzetten in waardevolle voeding. Intensief houden wordt dan "beloond" door een lagere carbon footprint. Omdat je met carbon footprint aanstuurt op meer melk per koe (= meer krachtvoer) maar ook minder jongvee (wat verder wel goed is).

Maar methaan staat wel laag op het "prioriteitenlijstje" van Boerenverstand, omdat het moeilijk is om daarmee in te grijpen en de maatregelen waarmee je dat kan doen op andere gebieden veel negatieve effecten hebben. Minder jongvee telt heel hard. Organische stof in de bodem opslag is ook een hele belangrijke.

Discussie wordt altijd heel veel op methaan gefocust, en dan komt de hoogproductieve koe altijd goed uit (is dus niet goed). Leidt de verkeerde kant op. Eigenlijk is klimaat ook one-issue en moet je ook kijken naar alle andere milieuaspecten zoals biodiversiteit, bodemkwaliteit, hoeveelheid landgebruik, N en P etc.

Mijnkringloopwijzer.nl kan je de kringloopuitrekening downloaden die elke boer moet invullen. Met die BEX berekening mag een boer dat gebruiken om meer N en P op eigen land kwijt te kunnen.

Het is vooralsnog heel moeilijk om harde kerngetallen te krijgen voor koolstofopbouw in de bodem.

Het is belangrijk om de klimaatdiscussie op de bodem gefocust te krijgen: geen scheuren van gras en bodemontwatering (in veenweide). Minder vee is sowieso gunstig (vooral sturen op jongvee). Voorkomen om productie omhoog per koe te sturen. Koe varken en kip worden een uitwisseling voor klimaat. Hij denkt dat melkvee dan wint omdat het veruit de economische sterkste sector van NL is. Melkveebedrijven hebben het publiek mee (in vergunningen) en een efficiënt georganiseerde sector. Varkens en kippen zullen dan weg gaan naar het buitenland. Dierenwelzijnssterren lopen aan tegen meer ammoniak en fosfaatplafonds.

Voorbeeld: er is een mesttekort in Zeeland (de mest halen ze uit Brabant). Zou je dan niet meersterren-concepten juist wél toelaten om meer ruimte te bieden aan die sectoren. Overheden zijn aan het zoeken nu naar duurzame concepten om daar ruimte aan te geven en niet aan niet-duurzame concepten. Dit concept is aan het slagen: er zijn steeds minder conventionele melkveehouderijen en er komen steeds meer duurzame concepten. Nederland zal keuze maken voor duurzame productie en dan heeft melkvee zoveel voor op andere veehouderij-sectoren omdat het draagvlak groter is (aaibaarheid sector) en tegelijk moet het oppassen dat het niet megabedrijven worden, maar er wordt al hard ingezet op weidemelk. Het is ook gewoon een kwestie van keiharde business: toegevoegde waarde moet gecreëerd worden om een plekje in de markt te houden, bijvoorbeeld door weidemelk etc.

Externe voeding is belangrijk voor broeikasgasemissies, evenals het aanhouden van minder koeien. Elke prikkel (beleid) stuurt meestal aan op intensivering, ook bij de ammoniakwetgeving.

Grondgebondenheid is wel een belangrijke maatregel. Hele grote lobby uit het zuiden om het tegen te houden terwijl 9 van de 10 boeren er geen probleem mee hebben. Bijvoorbeeld ZLTO is er fel tegen (intensieve melkveehouders uit het zuiden).

Appendix B

B.1 Measures included in Animal Sustainability

Measures regarding young animals:

- Optimize the feeding and caretaking in the first 6 months to utilize the growth potential of the young animals to its full potential. This has a large influence on the eventual milk production when the calf grows up.
- Improve the housing of the calves; they need ample room to move around and good living conditions overall, this will influence their growth positively.
- An early selection of redundant calves. As less calves need to be kept at the farm to replace adult cows, selecting the calves early will reduce emissions from the calves and offers room to pick the healthy cows that will grow up to be productive ones.
- The use of a "meat breed" for reproduction. If dairy cows that are not likely to contribute to the animal sustainability with their genes (the ones that aren't healthy or have low milk production) are inseminated with the sperm of a bull of a meat breed, it guarantees that the calf will be sold off early on.
- Regular check-ups on the growth and development of the young animals can lead to a more suitable feeding strategy which can result in being fertile on a younger age, and with that reduce the breeding period.

Measures regarding productive cows

- Measures in the transition phase (the 30 to 60 days before giving birth to a calf) are the most important measures to increase animal sustainability. These include better hygiene around the time of giving birth, optimize the diet after the first 120 days after giving birth and optimize the healthcare in the weeks after giving birth.
- Prevent health problems of the udders and problems with the legs during the lactation period. These are related to the diet, hygiene, housing and breeding.
- Improve reproduction by optimizing diet, housing and draft detection in the stable.
- Focus in the breeding on improving the genetic basis of the qualities that improve animal sustainability.

B.2 Measures included in Carbon Sequestration

No ploughing
This can be applied to all the maize production fields from the dairy sector. Until 2011 these measures had barely been applied. Ploughing reduces SOM as deeper soil is brought to the surface, where it is in contact with air, where it is broken down to CO_2. Therefore, ceasing ploughing will increase the soil organic matter.

Agroforestry or silvopasture
Agroforestry is a land use system where growing crops or raising cattle is combined with planting trees. There are different forms of agroforestry applicable to the Netherlands: 1) planting hedges around pasture, 2) alley cropping, where rows of trees are combined with rows of yearly crops, 3) riparian buffers, where a vegetation buffer is planted next to a ditch with the foremost reason protecting water quality from nutrient runoff and 4) silvopasture, which is a combination of grassland with sparsely

planted trees. This system results in a higher net production per hectare, and can reduce heat and wind stress for animals. On the long term however, it might reduce the grass production through shadow of trees. Elferink et al. (2012) estimate that agroforestry can be applied on 5% of the pasture area. This is a relative low estimate compared to the technical potential, as they only consider easily adaptable versions of agroforestry that do not drastically change the way of operating, for example planting hedges around pastures.

Supplying soil with organic matter
An effective way of increasing the SOM is by applying organic fertilizer to the soil in the form of manure or compost. The increase in SOM is dependent on the starting situation, the amount that is applied, the stability and the composition of the fertilizer. Therefore, Elferink et al (2012) state that making an estimation for increasing SOM for this measure is difficult, but they nevertheless estimate the carbon sequestration potential to be 1.53 t CO_2/ha per year. However, for an increase in SOM there needs to be an increase in available organic fertilizers in the dairy industry. This measure can be applied on all the land used by the dairy farmers. There is however the risk of over-fertilizing which can increase eutrophication, but the amount of available fertilizers is a limiting factor here.

Biochar is also mentioned as an effective way of adding carbon to the soil, biochar is charcoal made from biomass via pyrolysis. Biochar's potential in set to 1.045 t CO_2-eq/year.

Managed grazing
When cows graze in a pasture, they trample part of the grass in the soil, which increases SOM. Therefore, grassland that is grazed has a higher SOM than grassland that is mowed. The disadvantage of grazing is that it somewhat reduces the production of the grass. Either to intensive or to extensive grazing therefore results in low SOM, where in intensive grazing production losses are too high from trampling and in too extensive systems there is not enough trampling. A grazing system in which the cattle is regularly moved between pastures yields the highest results. Fortunately, this form of grazing is common in the Netherlands, although only 75% of the cows have access to pastures. Therefore, there is still room for improvement on some of the farms. The potential of this measure is estimated to be 0.913 t CO_2-eq/yr.

Measures with potential for carbon sequestration in the soil that are not considered here:

Land use change
Changing the use of the soil, the SOM can either increase or decrease. For example, when changing a nature area into agricultural land, a portion of the SOM is lost. The other way around can also be achieved by turning agricultural land into nature area. Switching to a different form of agriculture can also increase the SOM. For example, changing arable land (where e.g. maize is grown for feed) to grassland will increase SOM (although methane emissions from enteric fermentation will rise when a higher fraction of grass is incorporated in the diet). In theory, all arable land used to grow feed can be turned to grassland, increasing the fraction of grass incorporated in the feed. Elferink et al (2012) expect that most farmers will not be inclined to change arable land to grassland. They estimate the potential on 162,000 ha (the total land used for maize production) to be suitable for this measure. Based on that the sequestration of CO_2 in the ground is 465,000 t CO_2-eq/yr, if all the 162,000 ha of maize land is converted to grassland.

Woody crops replacing milk production.
This measure can include growing trees for production of paper, wood or bio-energy. This measure is not considered because there is no surplus of land on which this can be applied, and applying this measure will result in replacing the corn or grassland to somewhere else if milk production is not decreased, and the sector is not currently thinking of reducing production (Reijs et al., 2016).

Managing grassland

This measure aims to improve the use of grassland to increase production and therefore SOM. It concerns using of heavy machinery on the land, intensive grazing, and grassland renewal. The former two cause soil compaction. This results in a lower water and root permeability of the soil, which decreases the SOM. This can be reduced by “airing” the grassland, in which holes are made into the ground mechanically. Plant roots can use these holes for root growth. However, to much airing causes the organic matter to degrade, releasing CO_2.

Grassland renewal is originally being done by “ripping” the grass and re-sowing the grass. This results in a loss of SOM. Legally, how often and when the grass sod may be ripped is restricted. Re-sowing instead of ripping the grassland is also possible and will retain more of the SOM. Elferink et al (2012) could not retrieve specific numbers on either of these two processes, therefore they are not considered in the calculation.