A system analysis of the Dutch pork production sector

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A system analysis of the Dutch pork production sector: the performance of different scenarios for pig husbandry in the field of pork production, environmental impact and animal welfare

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1 SAMENVATTING

Er spelen momenteel twee belangrijke kwesties in de veehouderij. De eerste is de milieu-impact van de veehouderij. Vee heeft een grote invloed op meerdere milieuaspecten, bijvoorbeeld klimaatsverandering, eutrofiëring en de kap van regenwoud voor de productie van veevoer. De voorspelde stijging van de wereldbevolking, de hogere welvaart in ontwikkelingslanden en het groeiende aandeel van niet-herkauwers (zoals varkens) in de veestapel leiden hoogstwaarschijnlijk tot een toenemende milieu-impact van de veeteeltsector in de toekomst.
De tweede belangrijke kwestie is het dierwelzijn. In de afgelopen decennia is het aantal dieren per bedrijf explosief gegroeid. De Nederlandse burgers maken zich in toenemende mate zorgen over het dierwelzijn in de veeteeltsector.

De focus van deze thesis zal liggen op de productie van varkensvlees in Nederland. De vermeende hoge milieu-impact (MI) van de veeteelt en het lage dierwelzijn (DW) zullen worden onderzocht met behulp van de volgende centrale onderzoeksvraag:

> *Hoe verhouden verschillende scenario's voor de Nederlandse varkensvleessector zich tot elkaar op het gebied van varkensvleesproductie, milieu-impact en dierenwelzijn?*

Deze vraag wordt beantwoord door vijf scenario's voor de varkensvleessector in Nederland met elkaar te vergelijken. De scenario’s zijn: Conventioneel, Natuurlijk, Voedselafval, Biologisch en Megastal. De scenario's bestaan uit verschillende opties voor de productie van veevoer, huisvesting en transport. Het scenario Conventioneel is het referentie scenario. De andere scenario’s vertegenwoordigen elk een andere manier om de MI te verlagen en/of een goede invloed te hebben op het DW. Nadat de scenario’s zijn beschreven, zullen de prestaties van deze scenario's op het gebied van varkensvleesproductie, MI en DW worden vergeleken met het referentie scenario.

Uit de literatuur blijkt dat de productie van veevoer het meest doorslaggevend is voor de totale MI van de varkensvleessector. Om de MI van veevoer productie te verlagen, kan de productie het beste worden verminderd. Veranderingen in dieet (of overgaan op biologisch veevoer) leiden slechts tot lage of soms zelfs geen verbeteringen voor de MI. Voor het welzijn van dieren is het transport van levende dieren van groot belang. Transport is zeer stressvol voor varkens. Een andere optie om DW te verbeteren is om te streven naar een zonatuurlijke mogelijke omgeving voor de varkens, waarbij ze de optie hebben om een modderbad te nemen.

Twee van de scenario's zijn gunstig voor zowel MI als DW, maar zijn onrealistisch vanwege een lage varkensvlees productie. Het scenario Natuurlijk heeft geen MI en een zeer hoog DW. In dit scenario wordt er op wilde zwijnen gejaagd. Het scenario levert echter slechts twee worsten per persoon per jaar op. In het Voedselafval scenario zijn de varkens gehuisvest in de achtertuin en worden ze gevoerd met huishoudelijk voedselafval. Dit scenario blijkt ook niet realistisch te zijn vanwege de lage vlees opbrengst, die gelijk is aan drie porties varkensvlees per maand.

Een gelukkig varken dat buiten rondloopt en een modderbad kan nemen blijkt erg onrealistisch te zijn als alle burgers in Nederland hun huidige niveau van varkensvlees consumptie willen behouden. De milieu-impact van de varkensvleessector kan drastisch worden verlaagd wanneer er geen veevoer wordt geproduceerd. Dit leidt tot een lage (tot afwezige) productie van varkensvlees. Natuurlijk zou al het varkensvoer biologisch kunnen worden geproduceerd. Maar de biologische landbouw heeft net zoveel nadelen als de conventionele landbouw, hoewel deze nadelen in karakter verschillen. Over het algemeen kan dus gezegd worden dat zowel op gebied van MI als DW de enige echte oplossing is om een vegetarische levensstijl aan te nemen.

2 SUMMARY

There are two important issues associated with the livestock sector. The first is the impact the livestock sector has to the environment. Livestock imposes a great environmental impact on multiple aspects like global change, eutrophication and the clearing of rain forest areas for feed production. The predicted growth of the world population, the expected growth of prosperity in developing countries and forecasted higher growth of consumption of monogastric livestock implies that the current environmental impact of the livestock production sector will increase in the future.
The second important issue associated with livestock is the animal welfare. In the past decades, the number of animals per farm has grown explosively. Dutch citizens report concern with the welfare situation of livestock.

The focus of this thesis will be on the production of pigs' meat (pork) in the Netherlands. The alleged high environmental impact (EI) of livestock and the concerns of the Dutch citizens with animal welfare (AW) are both subjects that will be researched in this thesis. The main research question is:

> *How do different scenarios for the Dutch pork production sector relate to each other in terms of pork production, environmental impact and animal welfare?*

This question will be answered by composing five scenarios for the pork sector in the Netherlands. The scenarios are: Conventional, Natural, Food-waste, Organic and Mega farm. The scenarios consist of different options for feed production, housing and transport. The Conventional scenario is the reference scenario; the other scenarios each represent a different way to lower the EI and/or pressure on AW. After the scenarios are described, the performance of these scenarios on the field of EI and AW will be compared to the reference scenario.

From the literature it became obvious that the most decisive factor for EI is the feed production. In order to lower the impact of feed production, the feed production should be reduced. Changes in diet (or shifting to organic feed) lead to minor improvements for the EI. For animal welfare, transport of living animals is very important. The transport can cause severe stress in pigs. Another option to improve AW is to strive at a natural environment for the pigs, with an option to wallow. The main targets of the scenarios were therefore: feed, housing and transport.

Two of the scenarios are beneficial for both EI and AW, but are also unrealistic. The natural scenario has no EI and a very high animal welfare. In this scenario wild boar are hunted for their meat. The downside is that the resulting pork from this scenario is equal to two sausages per person per year. In the Food-waste scenario the pigs are housed in the backyard and fed household food-waste. This scenario also proved to be unrealistic because of the low meat productivity. The resulting pork from this scenario was equal to three servings of meat per month.

In general, scenarios score better on EI and AW simply by producing less pork. Happy pigs browsing around outside and taking mud baths are highly unrealistic if everyone wants to keep consuming as much pork as they do now. Even the Organic scenario does not come close to that ideal. And the scenarios that do come close are not producing enough pork to sustain in the demand. So the real solution for animal welfare would be to stop consuming pork.
The environmental impact from the pork production sector can be lowered drastically if the feed production is absent. In this thesis can be read that such a solution leads to low pork productivity. There is the option to produce all feed under organic management. But organic agriculture has just as many downsides as conventional agriculture, although they do differ in nature. As with maximizing animal welfare, the only real solution to lower the environmental impact from the pork production sector is to

3 INTRODUCTION

There are two important issues associated with the livestock sector. The first is the impact the livestock sector has to the environment. Livestock imposes a great environmental impact on multiple aspects like global change, eutrophication and the clearing of rain forest areas for feed production(FAO, 2009). The Food and Agriculture Organization (FAO) states that 18% of all anthropogenic greenhouse gas emission results from the livestock sector world-wide. Livestock world-wide is even responsible for 64% of all anthropogenic emissions of ammonia (Seinfield *et al.*, 2006). Livestock feed production uses 33% of all agricultural lands (FAO, 2009). In the future, the environmental impact of livestock is assessed to become even higher. The reason for the increasing environmental impact is the growing world population and a higher percentage of the world population that will be able to afford meat (Seinfield *et al.*, 2006). Especially the consumption of monogastric livestock (i.e. pigs, chickens) is expected to grow faster than the consumption of cattle (Seinfield *et al.*, 2006). The predicted growth of the world population, the expected growth of prosperity in developing countries and forecasted higher growth of consumption of monogastric livestock implies that the current environmental impact of the livestock production sector will increase in the future (FAO, 2009)

The second important issue associated with livestock is the animal welfare. In the past decades, the amount of animals per farm has grown explosively(CBS, 2011). Environmental and animal welfare organizations in the Netherlands spend increasingly more attention to the effect of the housing situation on animal welfare in the livestock sector(Ministerie EL&I, 2011). A quote from the campaign of *Milieu Defensie* (Environmental Defense) is: “Mega farm or mud bath? Animals belong in the meadow”. This quote is depicted in figure 3-1. Not only environmental and welfare organizations vocalize their concerns with the increasing scale in the livestock sector, also Dutch citizens express their worries in questionnaires(TNS NIPO, 2007). The Dutch government responded to the increased media attention for animal welfare with a public (online and in real live) debate about so-called *megastallen*, mega farms (Ministerie EL&I, 2011). Citizens, farmers, politicians and agricultural specialist were able to share their opinion and eventually the government could use the dialogue for decision making. But until this date, no specific decisions were taken on the field of the intensity and scale of animal housing.

Figure 3-1 - Advertisement by *Milieu Defensie* "Mega farm or mud bath?"

Not only is there a lot of media attention for mega farms, also meat and other animal products coming from conventional farms are struggling with a bad image. Animal welfare organizations try to make the consumers aware of the situation on conventional farms. They state that meat can only be as cheap as it is now, because of the poor health and welfare circumstances in the conventional system(Wakker dier, 2012). On top of the poor housing conditions, breeding has deteriorated the welfare situation according to these organizations. Farm animals are selected for the highest yield of milk or meat, which lead to unhealthy physical malformations in animals(Wakker dier, 2012). This conviction is shown in figure 3-2.

Figure 3-2 - Advertisement from the campaign of *Wakker Dier* called "Evolution of the kilo stunner"(Wakker dier, 2012)

The focus of this thesis will be on the production of pigs' meat (pork) in the Netherlands. The Dutch pork production sector is exemplar for a highly intensified and specialized sector. The development of the intensive pork sector started after the Second World War. Before the war, pigs were often used to ingest farm-waste and to convert it to a more valuable product: pork. Family food-waste, vegetable peels and agricultural surpluses were used to fatten the pig. By autumn, one or more pigs were slaughtered and the meat was preserved for later consumption. In the winter, the pickled meat was an important source of protein. After the war, technological progress and social developments caused structural changes in the whole agricultural sector. Farms started to specialize in one particular task: cultivating one crop or housing one species. By specialization, the efficiency of the production started to rise quickly(de Greef and Casabianca, 2009). At the same time, the specialization of the whole agricultural sector caused that the connection between the agricultural land needed for feed-crops and the location of the farm started to fade. It became possible to transport feed over great distances to the farms. The specialization not only caused a disconnection between agricultural land and the location of the pigs, but also a drastic growth of the number of pigs housed on one farm(CBS, 2011). Eventually, the Netherlands became one of the leading export countries of piglets, adult pigs and pork (PVV, 2012).Each year, the Netherlands exports 6 million piglets, 5 million adult pigs and 870 million kilograms pork, which is equal to 9.5 million pigs (PVV, 2012).

The Dutch system of pig fattening is very comparable to pig fattening in the whole western world. A sow gives birth after a pregnancy of three months, three weeks and three days (115 days). She delivers about 10 piglets, each weighing 1.4 kilogram. The piglets stay with their mother until they are four weeks old. Then they are transferred to another pen at the same farm with their siblings. The sow is placed in a separate pen with the other sows in anticipation of her next fertile period. The male piglets are usually castrated before they reach the age of seven days (Stichting Varkens in Nood, 2012). Castration of the boars (male pigs) is done in order to prevent the meat of having a specific 'boar taint'. Until 2009 this was done without any sedation, now it is done with sedation (CBL *et al.*, 2007). The ultimate goal is that castration will no longer be necessary by 2015; the boar taint will then be detected in the abattoir (CBL *et al.*, 2007). If pork is detected with boar taint, the meat is not suitable for human consumption, but it still can be used for i.e. pet feed. Next to castration, almost all piglets have docked tails and filed canine teeth (Stichting Varkens in Nood, 2012). Both interventions are carried out to prevent biting damage either to peers or to the mothers' nipples. The piglets stay at the nursery farm until they reach a weight of about 25 kilograms at an age of 70 days. Then they are transported to a specialized fattening farm. After a period of approximately 112 days in the fattening farm, the pigs reach the desired end-weight. The pigs are transported to the abattoir, where their lives will end.

3.1 Research questions

The alleged high environmental impact (EI) of livestock and the low animal welfare (AW) in the conventional livestock sector are both subjects that can be researched. The main research question of this thesis is: *How do different scenarios for the Dutch pork production sector relate to each other in terms of pork production, environmental impact and animal welfare?*
In order to answer that research question, sub questions are formulated:

1) *How does a pig get fattened in the current Dutch system?*

2) *Which factors (during the lifecycle from cradle to abattoir gate) are decisive for the environmental impact?*

3) *Which factors (during the lifecycle from cradle to abattoir gate) are decisive for the animal welfare?*

4) *What scenarios can be designed for pig fattening that lower the impact on the environment or/and increase the animal welfare?*

5) *What are the results of these scenarios on the field of pork production, environmental impact and animal welfare?*

3.2 Methodology

The research for this thesis will be in the form of a system analysis. In the first phase of the research, basic knowledge about the pork production system will be obtained from literature. In this phase, sub question one will be answered. In the second phase of the research, the environmental impacts and animal welfare implications of the pork production system are studied. This leads to the identification of the main decisive factors for both EI and AW in the pork production sector. Sub questions two and three will be answered in this phase of the research. When the pork production system is analyzed, five different scenarios will be designed. One of these scenarios will be the Conventional scenario, which will serve as a reference for the other scenarios. Each scenario will exist out of three parts: feed production, housing and transport. The scenarios are based on different scales that are possible in the pork production sector: from small scale, extensive pig husbandry ranging to large scale, intensive pig husbandry. A more elaborate explanation about the formation of the scenarios can be found in chapter 6.
In the last phase of the research the fifth sub question is answered. All scenarios are compared with the reference scenario. The results will be in the field of pork production, EI and AW. Feed production influences EI, housing influences mainly AW and transport influences both EI and AW. The results of the comparison are not qualitative, but relative to the Conventional scenario.
Finally, conclusions will be drawn and the main research question will be answered.

3.3 System boundaries

The pork production needed to provide for the current Dutch consumption is taken as a starting point. This translates to a certain quantity of pork, explained in the next chapter. Without any pork production, there would be no environmental impact or animal welfare issues. By taking a certain meat production quantity as a starting point, the resulting effects for environmental impact and animal welfare can be compared fairly. It has to be said that there are some scenarios that cannot meet the pork demand of the Dutch citizens. Therefore the pork production resulting from a scenario is taken into account as a factor to take into account when the scenarios are compared.

The whole pork production sector is taken into account from cradle to abattoir gate. Included in this research are: crop cultivation, feed production, transport of feed and manure, housing and transport to abattoir. Excluded are: parental animals, piglet phase, and water-use (direct and indirect).

3.4 Structure of the thesis

After the introduction, the first sub question will be answered in chapter 4. The second and third sub questions will be answered in the following chapter. The description of the scenarios (sub question four) can be found in chapter 6. The results of the comparison of the scenarios are in chapter 7. Eventually a conclusion and a discussion will be given in chapter 8 and 9.

4 SYSTEM DESCRIPTION

How does a pig get fattened in the current Dutch system?

In the introduction of this thesis, a short description of the life of a pig can be found. This chapter will give more details about the whole system. Furthermore, some definitions and numbers will be given that are used throughout the thesis.

In the Dutch system, the piglets are born at another location as the pigs are fattened. This means that the system is stratified. Almost all pigs in the Netherlands are raised in a stratified system. The research boundary used in this thesis lies at the entrance of the fattening farm. When a pig enters the fattening farm, the siblings are usually mixed with other pigs and placed in new groups of 10 to 20 animals. Each pig is entitled by law to a surface of 0.8 m^2(Rijksoverheid Nederland, 2012b)
(Rijksoverheid Nederland, 2012b).Up to 50% of the floor is slatted. The slatted floor allows the manure to fall down so it can be collected. The farmer is obliged to place at least one toy in each pen, usually a ball, a metal chain or a piece of rope (Rijksoverheid Nederland, 2012b).

After 112 days in the fattening farm, the pigs reach a weight of 115 kilograms and are ready to be slaughtered. In order to reach this weight, a pig requires feed with the energy equivalent of 300 EW (Elferink, 2009). EW stands for '*Energiewaarde varkens*' translated as 'energy value for pigs' (Centraal veevoederbureau, 2003). This comes down to approximately 250 kilograms of feed in the fattening period[1]. Lifestyle can affect the amount of feed needed to fatten a pig. The more a pig moves around, the more feed it needs to fatten (Lammers *et al.*, 2010). How much extra feed is needed, is calculated by Lammers et al. They found that a pig with outdoor access needs 3% extra feed. This corresponds to approximately 310 EW or 258 kilogram feed. These numbers will be used in this thesis if the feed requirement of a pig is discussed.

Pigs in the conventional system produce liquid manure. The amount of manure is given in m^3 when agricultural sources are used. Because of practical reasons, it will be given in kilograms in this thesis. Each pig space in the conventional fattening system represents a manure production of 1.1m^3 per year (Vermeij *et al.*, 2009). Per pig this is 0.34 m^3 and this corresponds with 340 kilogram manure. This number is assumed to apply to all pigs, even if they have a higher feed demand due to their lifestyle.
Manure is rich in nutrients and can therefore result in eutrophication of the local environment if the manure is spread over (agricultural) land.

When pigs reach the desired end-weight, they are transported to the abattoir. The abattoir is usually located in the Netherlands. Some adult pigs are sold to be slaughtered abroad (CBS, 2011). If abattoirs in the Netherlands are overbooked, some farmers send their pigs to abattoirs in Germany or Belgium (PVV, 2012).

[1]It is obvious that besides feed, water is also an input during the fattening phase. But since water is not within the research boundaries, it is neglected.

4.1 Definition: amount of pork from one pig

Each pig differs from other pigs when it comes to its' slaughter weight. During transport to the abattoir, pigs lose some weight due to the lack of feed, but also due to stress. It is assumed that each fattened pig weight 115 kilograms at the time of slaughtering. A part of this weight is not suitable for (human) consumption: the brain, guts, bones and blood (Hoste *et al.*, 2004). After these parts are removed, the carcass weight is assumed to be 90 kilograms(Hoste *et al.*, 2004). The farmer gets paid per kilogram for the carcass weight. When this carcass eventually reaches the consumer, only 50% of the weight is actually sold for consumption. The other 50% gets lost during the cutting process, due to cutting losses and evaporation(Hoste *et al.*, 2004). Part of this cutting loss is not suitable for human consumption, but is used in for example pet feed. Eventually only 45 kilogram pork from one pig is sold and consumed. This net weight is used when the meat productivity of a scenario is discussed and will also be used when the consumption of meat is discussed. (NB: when transport of living animals is discussed, the end life weight of 115 kilograms is used).

Dutch citizens consume 21 kilograms of pig meat each year (PVV, 2012). The total Dutch consumption of pork corresponds with 7.8 million fattening pigs per year. That number will be used as a reference in this thesis when the productivity of a scenario is calculated.

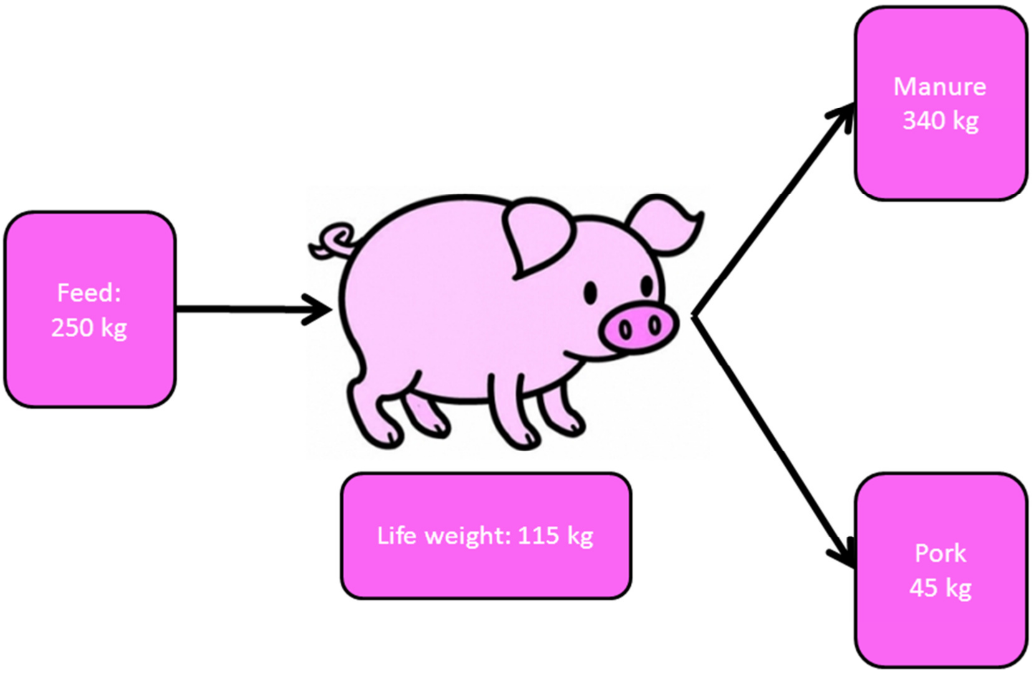

Figure 4-1 - Average pig in the Dutch fattening system

4.2 Definition: pig spaces

A *pig space* is a place in the barn that houses one pig at a time. Because the lifespan of a pig in the fattening phase is only 112 days, a pig space represents (365/112) 3.3 pigs a year. This can be made more insightful with an example. Take a farmer that has a barn with 2000 pig spaces. His productivity a year will be 6600 pigs. In this thesis, the capacity of a farm or system will be expressed in pigs (per year) in most situations. Only if relevant, the number of pig spaces will be used.

Table 4-1 – Summary of system assumptions

Number slaughtered of pigs/year	7.8 million
Live span pig in fattening phase	112 days
End life weight	115 kg
Amount of pork from one pig	45 kg
Amount of feed per pig	250 kg
Amount of manure per pig	340 kg

5 ENVIRONMENTAL IMPACT & ANIMAL WELFARE

Which factors (during the lifecycle from cradle to abattoir gate) are decisive for the environmental impact and animal welfare?

First, the second sub question will be answered: Which factors (during the lifecycle from cradle to abattoir gate) are decisive for the environmental impact? After that, the third sub question will be addressed: Which factors (during the lifecycle from cradle to abattoir gate) are decisive for the animal welfare?

5.1 Environmental impact

The environmental impact from the pork production sector is mostly studied with the use of the LCA methodology. For this thesis, literature about the pork production sector in developed countries is used. The method used for pork production is comparable in all developed countries, so it can provide basic knowledge about the Dutch pork sector.
The environmental impact from the pork production sector (till abattoir gate) is mainly caused by three parts within the sector. The first part is the feed production, in which crop cultivation has an important role. The second part is the housing of the pigs. The third part is the transport of feed and manure to and from the farm. The impacts of manure will be addressed in the last subsection. All three parts of the pork production sector have a different kind of impact on the environment.

5.1.1 Feed production

From multiple life cycle assessments of the pork production system one conclusion can be drawn: in the whole life cycle, feed production has the highest contribution to the environmental impact (Basset-Mens and Van Der Werf, 2005, Stern *et al.*, 2005, Strid Eriksson *et al.*, 2005, Halberg *et al.*, 2010, Lammers *et al.*, 2010). This applies even if different diet choices are made. Diet choices can influence the amount of environmental impact and the kind of impact, but whatever diet is chosen: the feed will always have the largest impact when looked at the pork production from cradle to abattoir gate.
Almost all literature used for this thesis describe the complete pork production (mostly till farm gate). So it is a bit complicated to pull out the feed production phase from the total pork production. Fortunately, most articles have separate sections about feed production, because it has such a large impact on the environment.

The largest part of the literature describes a comparison between conventional and organic pork production. Organic agriculture refers to a complete agricultural method that is different in many aspects from conventional or intensive agriculture. Basic principles of organic agriculture are: efficient use of local resources, no pesticides, herbicides or artificial fertilizers, no (synthetic) food or feed additives and no genetic modified organisms (GMOs).
The root of all organic agricultural practices is the importance of natural ecological processes. The goal of organic agriculture is to diminish the interference with nature. The rules of organic agriculture are the same worldwide. In the Netherlands the performance is monitored by a foundation called Skal (StichtingSkal, 2012).

In general, there are some things that can be said about organic crop cultivation. Organic management schemes have beneficial effects on the soil: the soil organic matter (SOM) increases on organic agricultural land and there is less leaching of nitrogen (N) compared to conventional agricultural land (Gomiero et al., 2011). A downside to the slow release of N by organic fertilizers is the difficulty to match the N-release to the N-need of the crop (Gomiero *et al.*, 2011). Organic agricultural land is often associated with a high biodiversity, which has multiple causes: there is no use of pesticides or herbicides and a landscape with organic plots is usually more diverse(Gomiero *et al.*, 2011). Crop rotation used in organic agriculture also contributes to the higher biodiversity (Gomiero *et al.*, 2011). Besides, organic plots are usually smaller. This leads to a higher diversity in a specific area.

There is a lot of discussion in literature about the energy use in the organic system. Because of the lack of synthetic fertilizers, the indirect energy use of organic agriculture is quite low (Gomiero *et al.*, 2011). But because of the lower yield per hectare, the energy use per kilogram crop yield is equal to or even higher than the energy use in a conventional management scheme (Gomiero et al., 2011). The yield from an organically harvested crop is between 20 to 40% lower than the yield from a conventionally harvested crop(Gomiero *et al.*, 2011).
It can be concluded from the review by Goimiero et al. that the fossil energy use per yield is comparable if not higher for organic systems than the energy use for conventional systems. And because of the lower yield per hectare, the land use of the organic system will always be higher than the land use in the conventional system, if one looks at the same productivity (expressed in e.g. kg). In short: organic agriculture uses few inputs, but the yield is lower than the yield of conventional agriculture. Therefore, the land-use of organic agriculture is higher when the same yield (e.g. in kg) is considered.

Besides the comparison between organic and conventional, a lot is written about the choice for a certain functional unit (FU). Basset-Mens et al. (2005) looked at the environmental impact of the pork production sector in France with respect to two functional units: per hectare and per kilogram pig. They concluded that organic agriculture (not only feed production, but the whole pork production chain till farm gate) uses more energy per kilogram, but less per hectare compared to the conventional scheme. Crop production is responsible for 74% (conventional) to 94% (organic) of all energy used in the whole pork production chain (Basset-Mens and Van Der Werf, 2005). The rest of the energy is appointed to the piglet phase, constructing and heating the building and the use of straw litter (Basset-Mens and Van Der Werf, 2005). Please note that the piglet phase is not included in the system boundaries of this research. Other authors drew the same conclusion: if the FU per hectare is used, organic agriculture has less EI compared to conventional. And if the FU per kg is used, conventional agriculture has less EI compared to organic.

Apart from the comparison between organic and conventional agriculture, it seems that local feed production can cause a lower EI. Strid Eriksson et al. discussed the EI of different feed choices and concluded that domestic feed production is beneficial to the environmental impact of the pork production system. 'Domestic' refers to feed production in the same country as the pork production. Especially the avoidance of imported soybean in the diet results in a lower environmental impact (Strid Eriksson *et al.*, 2005). Strid Eriksson et al. are convinced that within the pork production system, feed production is responsible for the highest share of environmental impact. Furthermore, they came to the same conclusion as Basset-Mens et al. concerning functional units: the crop yield per hectare influences the environmental impact. In general, a high yielding crop automatically has a low environmental burden (even if this means that there are more environmentally damaging inputs; Strid Eriksson *et al.*, 2005). Although organic agriculture is not mentioned in the research performed by Strid Eriksson et al., this could possibly mean that organic agriculture would have a high impact. This is due to the lower crop yield of organic agricultural methods.

5.1.2 Housing

In the housing phase the EI can be caused by (direct) energy use to heat the building and to provide fresh air. Also the building of the farm itself is often included in the EI of the whole pork sector. But both the direct energy use and the EI from the construction do not have a high contribution in the total EI. It is difficult to find data on housing of pigs only. If there are any, it usually handles the effect of up-scaling the number of animals on one farm. According to literature, there is little energetic advantage to increasing the amount of pigs on a fattening farm (Lammers *et al.*, 2010). If the number of pigs on the farm would double, the achieved energy saving is less than 0.3% (Lammers *et al.*, 2010). This saving is in direct energy used for processes like heating or cooling the building, construction and maintenance (Lammers *et al.*, 2010).

Up-scaling is also researched by Dutch agricultural research agencies, but they concentrated mainly on the economics. And in the Netherlands the picture is quite clear: pig fattening farms have a higher profitability if the amount of animals on the farm is increased. This has two reasons. The first reason is that the technological improvements of the previous decennia make it possible to handle a larger amount of pigs with the same amount of labor (Lammers *et al.*, 2010, Berkhout and van Bruchem, 2011). Multiple processes are automated, like feeding the pigs and cleaning the manure from the barn. The second reason is the lower turnover for pork and the higher prices for feed, energy and other costs associated with the fattening of pigs (Berkhout and van Bruchem, 2011). In the context of increased costs, it is often cost-efficient to increase the production. Especially if this increased production can be realized with the help of automation instead of manual labor. The up-scaling in the pig sector in the Netherlands results mostly in a farm with more pigs, but without any changes in the operational processes (Berkhout and van Bruchem, 2011). This means that after up-scaling it can still be a family-run farm, sometimes with additional labor forces in the form of contractors.

5.1.3 Transport

From an EI perspective, only the transport of feed and manure will be assessed. The actual EI of transport is not quantified in this thesis. Instead, the mileage per scenario will be calculated. This is compared among scenarios. A higher mileage will mean a higher impact from transport. The kind of EI from transport is mostly the emission of greenhouse gasses (GHG) and the depletion of natural resources.

5.1.4 Manure

The average farmer in the Netherlands would store the manure until the storage capacities are reached. After that, the manure will be transported to another place for processing or the farmer can choose to use the manure directly on agricultural land as fertilizer. Since most pig farmers do not possess any agricultural land, the manure is collected in most cases. A few basics of the Dutch manure legislation are covered below.

If a farmer decides that the fresh manure will be used to fertilize crops, specific laws regulate the spread of the fresh manure. For each hectare of agricultural or grass land the maximum supply of liquid pig manure corresponds with the application of 140 kilogram nitrogen (N) per year (Rijksoverheid Nederland, 2012a). According to that maximum, there can be 35 pigs per hectare outside in a year. This comes down to 11 pig spaces. For each pig, an area of 910 m^2 would be needed to spread the manure within the limits of the Dutch government. When pigs are housed outside, eutrophication is a large environmental threat because the space available outside is often a lot smaller than 910m^2 per pig.

Only the possible eutrophication impacts caused by the manure from pigs that are housed outside are taken into account in this thesis. This means that when the pigs are housed inside, manure is not mentioned. So manure is only mentioned when the pigs are housed outside and there is a possibility that manure leaks into the soil.

5.2 Animal welfare

It is very difficult to objectively research the welfare of an animal. Humans tend to observe animal behavior within an anthropomorphic context. Generally, it can be assumed that an animal is happy when it is not hungry or thirsty, does not experience pain, stress or discomfort and expresses natural behavior (Temple *et al.*, 2011). Animal welfare can be measured by behavioral observation or by measuring stress hormone levels in the blood (Temple *et al.*, 2011). An environment in which an animal can display its' natural behavior is best for animal welfare (Temple *et al.*, 2011).
Pigs are highly motivated to explore their surroundings and to interact with group mates (Temple *et al.*, 2011). Behavior like tail biting, extreme fear of humans and apathetic behavior is assumed to be abnormal for pigs. When pigs display abnormal behavior, it is assumed that the perceived welfare by the pigs is low (Temple *et al.*, 2011). Abnormal behavior is often observed under conventional animal husbandry conditions (Zimmerman *et al.*, 2006, Temple *et al.*, 2011). This is not surprising, since a conventional husbandry system does not correspond with the natural environment the animal has evolved to. Of course, most livestock species are selectively bred to become more adjusted to their life among humans. Still, in general they feel more comfortable in a surrounding that is more natural than a barren pen with a slatted floor (Averós *et al.*, 2010, Temple *et al.*, 2011).

5.2.1 Housing

In a meta-analysis of 45 articles about pig welfare under intensive husbandry conditions, Averós*et al.* (2010) came to some interesting conclusions. Before going into details about these conclusions, some knowledge about natural pig behavior is essential. As was mentioned before, it is important to know that pigs are very active animals that are continuously inclined to explore their surroundings. The more inactive behavior (lying down, sitting still) they show, the less attractive their environment is and this creates an unnatural situation. Unnatural situations lower animal welfare. The first thing that Averós et al. conclude is that enlarging the space allowance per pig has positive influences on animal welfare. This conclusion is shared by other authors (Temple *et al.*, 2011). A more remarkable conclusion is that the provision of bedding material in the pen, like straw or other litter materials reduces the negative effects of a larger group size or smaller space allowance (Averós *et al.*, 2010). This is shown by an increased amount of time spent exploring the surroundings and the reduced negative social interaction when bedding material is present (Averós *et al.*, 2010). The last conclusion Averós et al. draw is that the presence of toys, especially partly ingestible and deformable toys, enhances the welfare of pigs. Toys are required by law, but there is no regulation about the complexity of the toys (Rijksoverheid Nederland, 2012b).

Outdoor access can also be part of the housing conditions. Pigs have problems maintaining a constant body temperature (Temple *et al.*, 2011). Therefore, indoor temperature conditions are always kept as constant as possible in order to enhance pig welfare. Outside, a pig can control its' core temperature by wallowing (taking a mud bath; Temple. Next to body temperature regulating, wallowing has a role in preventing the attachment of parasites in the skin of the pigs. In the conventional housing system, there is no outside access for the pigs. In the organic system there is outside access, but (almost) never the possibility of taking a mud bath. This is because the outside access has a concrete floor in most cases (Stichting Skal, 2012). More about the differences in housing conditions are explained in the next chapter.

5.2.2 Transport

Practically all pigs in the Netherlands are transported twice in their lifetime: once as piglets to a fattening farm and the second time to the abattoir. The pigs have to undergo journeys that often take one whole day. During transport, animals are crowed in a small space and have no access to water or feed (Halberg *et al.*, 2010, Nielsen *et al.*, 2010). Both journeys have a different impact on the life of the pig and therefore they are treated separately.

Many studies concentrate on the impact of transport on pigs at a young age. These studies are mostly conducted by taking blood samples before, during and after the transport. The presence of stress hormones in the blood can give a clue about the physical state of the animal. This physical information can be translated to welfare. Stress hormones like adrenaline and cortisol are often present in high concentrations during or right after a transport (Nielsen *et al.*, 2010). The presence of a stress hormone implies that the animal is under stress en thus its' welfare is being compromised. During the transport of piglets, researchers often observed piglets that were vomiting (Nielsen *et al.*, 2010).

Figure 5-1 - Transport of pigs abroad

The other moment of transport is at the end of the pigs' life. At the time of this journey, the pigs are fattened to a certain weight. This weight can (in combination with the transport) cause health problems. Examples of these problems are broken bones (especially in the paws) and severe bruising (Nielsen *et al.*, 2010). In general, fattened pigs are more susceptible to diseases and other health issues (Nielsen *et al.*, 2010). The sudden change of environment can trigger health issues to emerge. As with the piglets, fattened pigs show elevated cortisol levels during and right after transport (Nielsen *et al.*, 2010). During non-invasive research through observation, inactive behavior is seen for weeks after the journey (Villarroel *et al.*, 2011b). This indicates compromised welfare, because pigs are very explorative of nature (Averós *et al.*, 2010, Villarroel *et al.*, 2011a). If transport distances are above 100 km, mortality during the journey can increase to above 0.7% (Nielsen *et al.*, 2010). This might seem a small proportion. But the farmer has invested a lot of resources in that pig in order to fatten it. For the farmer, each dead animal during the journey is a great loss. During longer distances, almost all pigs tend to lose weight (Nielsen *et al.*, 2010). This is also a financial problem for the farmer, as his reward for the pigs will be calculated according to slaughter weight.

Especially during long journeys it is difficult to keep the humidity and temperature in the truck constant (Villarroel *et al.*, 2011b). Although maximum or minimum values will never be exceeded, the changes in temperature and humidity are very stressful for animals (Villarroel *et al.*, 2011b). As stated before, pigs have trouble maintaining their body temperature. Large and rapid fluctuations in temperature and humidity will compromise animal welfare.

6 DESCRIPTION OF SCENARIOS

What scenarios can be designed for pig fattening that lower the impact on the environment or/and lower the impact on animal welfare?

In this chapter, the fourth sub question is answered: *What scenarios can be designed for pig fattening that lower the impact on the environment or/and lower the impact on animal welfare?* For each scenario, three separate factors are important: feed production (decisive for EI), housing (decisive for AW, but contributes also to EI) and transport (EI, transport of living animals AW). For all three factors, multiple management options are possible. Each scenario will have its' own composition of management options in the field of feed production, housing and transport. When the pigs are housed outside in the scenario, the possible eutrophication effect of manure is also assessed.

First of all, a reference scenario will be designed. This scenario models the current situation on farms in the Netherlands. After that, four other scenarios will be made. The scenarios will range from small scale, extensive pig husbandry ranging to large scale, intensive pig husbandry. Each level of intensity holds different pros and cons for EI and AW. Besides that, the general public opinion was also important in determining which scenarios would be designed. General ideas like "organic pig husbandry is beneficial to animal welfare and has a low environmental impact" and "a mega farm is the worst-case scenario for animal welfare" are widespread in the society (TNS NIPO, 2007). In the next chapter, it will become obvious whether or not these sorts of ideas actually are agreed upon by science. A short explanation of the choice for these specific scenarios will be given below.

The scenarios will be (in order of appearance in this chapter):

- *Conventional scenario(reference)*
  This scenario reflects the average conditions in the Dutch pork sector.
- *All-natural scenario*
  In this scenario, pork is obtained by hunting of wild boar. This scenario reflects the prehistoric hunting and gathering culture. The wild boar are not held at a farm, but live in all forested areas of the Netherlands. This scenario reflects the ideal image that most people have in mind when they think about happy pigs: pigs that can browse around in the mud and can forage on acorns in the field.
- *Food-waste scenario*
  Instead of normal pig feed, pigs are fed with household food-waste. Pigs live in a backyard, to avoid transport of the food-waste. This scenario reflects a pre-war situation. People held pigs as a cheap way to convert waste into meat.
- *Organic scenario*
  Instead of normal pig feed, organic feed is used. Housing rules also differ for organic pig housing. This scenario is (like the Conventional scenario) a situation that is used at the present day in the pork production sector. The public opinion about organic farming is very positive, both on the field of AW and EI (TNS NIPO, 2007).
- *Mega farm scenario*
  In this scenario, all pork will be produced in a few mega farms. These mega farms are large enough to house their own abattoir. This scenario reflects a future in which the intensity in the animal husbandry sector is even higher as it is today.

At the end of the chapter, two summary tables can be found that focus on EI and AW.

6.1 Conventional scenario

The scenario conventional is modeled to resemble the average conditions in the Dutch pork sector. An average pig farm in the Netherlands fattens approximately 6000 pigs a year and is managed by one farmer and some hours per week extra help (CBS, 2011). Most of the time this extra help is arranged within the family (wife, brother, father, son), but sometimes labor is hired from a contracting firm.

Feed production

Dutch pig feed mainly consists of wheat, barley and soybean (Basset-Mens and Van Der Werf, 2005, Strid Eriksson *et al.*, 2005). This feed is mixed by feed companies, often in the Netherlands, but sometimes abroad. Almost all the inputs are imported. This means that the crop cultivation is located far away from the actual pork production. Impacts are manifested at the location of the feed production, which is in this case abroad.

To keep the model simple and straightforward, it is assumed that all the ingredients for the feed are imported. The feed itself is mixed in a factory near the import harbor and after that, transported to the farms. See for more details appendix A.

Every pig in this scenario needs 250 kilograms of pig feed. The exact composition does not really matter for the results on EI.

Housing

The housing conditions for the Conventional scenario are mentioned in the system description (chapter 4).

Transport

Feed and manure are transported in trucks, with a loading capacity of 3200 kilogram (van Schijndel, 2012). In general, a farmer receives a truck of feed once a week. The feed is stored at the farm in silos. Manure is stored in spaces beneath the floor of the barn. If that capacity is not large enough, it is stored elsewhere on the farm till the manure collecting truck arrives. The manure is collected on average twice a month per farm.

Transport of feed and manure is assumed to be always needed on a farm; most pig farmers do not have any agricultural land to spread the manure over. It is assumed that feed is transported from one of the three Dutch harbors to the farm. The truck returns to the harbor empty. Manure is collected with separate trucks that will pick up the manure at the farm and transport it to one of the three Dutch harbors. Although in reality, the manure will probably be transported to another location (either a farmer with agricultural land or a digester), but to keep the model simple it is assumed that the manure is collected in the harbor. An empty manure truck returns to the farm again. Note that the transport of feed and manure are two separate lines. All the details of the transport model can be found in appendix A.

6.2 Natural scenario

Our pre-historic ancestors already did it: they ate wild boar. In this scenario, wild boar are hunted and consumed by Dutch citizens. The wild boar live in their natural environment (forested areas) and no inputs are used.

The Dutch government assigned two areas for harboring wild boars: National Parks The Hoge Veluwe and De Meinweg (Vossestein, 2008). Both areas have a strict limit for the number of wild boars, but despite the allowed hunt both limits are exceeded by great numbers (Vossestein, 2008). The limit for the Netherlands in total is set at about 1000 wild boars, while records

Figure 6-1 - Wild boar

about actual numbers vary between 3000 and 4000 boars (Vossestein, 2008). There is enough feed available for the population to survive at such high levels, and the wild boars are also observed outside the two allowed areas. The high numbers of wild boars cause all kinds of problems in the surroundings of these national parks, like traffic accidents due to crossing boars and damage to agricultural crops (Vossestein, 2008).

Feed production

In the Natural scenario, there is no feed production for the boar. The boar will feed on products naturally available in the Dutch forested areas like mushrooms, acorns and fruit.

Housing

Housing will be provided by nature, just like the feed. But how many wild boars could live in the Netherlands and what would be a sustainable way of harvesting? This can be calculated by taking the limit set for the National Park the Hoge Veluwe and extrapolate that for all forest areas of the Netherlands. The total forested area in the Netherlands is obtained with data from the Dutch bureau for statistics. The limit for the number of wild boar in *De Hoge Veluwe* is used to calculate the number of animals that could theoretically live in all forested area in the Netherlands. The result of this extrapolation can be seen in table 6-1.

Table 6-1 – Wild boar level at the Hoge Veluwe and an extrapolation for all forest area in the Netherlands (via the wild boar density in the Hoge Veluwe; CBS (2011))

	Area (hectare)	Number of wild boar in area
De Hoge Veluwe	5500	860
All forest area in the Netherlands	344700	55152

Now that the maximal total number of wild boar in the Netherlands is known, it is possible to calculate the 'sustainable yield'. Sustainable yield refers to a method to hunt the boar in such a way that the population stays at the same level in time. M. Vossenstein (2008) describes how this could be accomplished in the current Dutch wild boar population. According to his study of the wild boar population at the Hoge Veluwe, the current limit for the amount of boar is too low. Because there is an abundance of space and feed, the birth rate will rise drastically if the population limit is maintained. The birthrate is predicted to rise to 11.6 piglets per sow per year. If the limit of 860 boar at the Hoge Veluwe is maintained, each year 4000 boar will have to be shot to maintain the population. Note that with a birthrate of 11.6 the number of piglets per year will be almost 5000. Approximately 25% of the shot boars will have to be adults; the rest will be piglets of that year.

Adult boars are suitable for human consumption and the number of shot adults is used to calculate the meat availability from this option. The number of shot adults can be extrapolated as shown in table 6-2. Note that the 'Wild boar population' is the population target at the end of the hunting season. The population will grow immensely during the spring because of the high amount of piglets.

Table 6-2 Number of adults shot/year according to Vossenstein (2008). Second row shows an extrapolation of the number of adults shot/year for the hypothetical wild boar population in the Netherlands.

	Wild boar population	Number shot/year	Number of adults shot/year
De Hoge Veluwe	860	4000	1000
Netherlands	55152	256521	64130

Transport
Transport is assumed to be absent in this scenario. There is no need for feed transport, since the forest can provide the wild boar with enough feed. Manure that is released in the forest does not have to be collected and transported. Furthermore, the wild boar are shot before they are transported. So no transport of living animals occurs in this scenario.

6.3 Food-waste scenario

Feed production has the highest contribution to the EI of all processes during the life cycle of the pork production. It is interesting to see how the feed production could be changed in order to minimize the EI. One option is to feed the pigs with food-waste. This is actually something that rural inhabitants of the Netherlands did before the Second World War. They kept one or two pigs to convert all the farm and kitchen waste into pork.
Food-waste is an issue of discussion in the Dutch media(Voedingscentrum, 2012). Although the exact claims differ, Dutch citizens waste about 45 kilograms of food per year(Voedingscentrum, 2012). By feeding pigs with household food-waste, two problems can be solved simultaneously. First, there is no longer any need for feed production for the pork sector. This would reduce the EI of the whole sector. Secondly, feeding pigs with food-waste would offer a sustainable solution for the waste. It no longer has to be collected and transformed to for instance compost or energy. Although these applications of food-waste are potentially very useful, using the waste as feed would be the most sustainable option. Waste is used to produce food, which closes a part of the food-cycle.

Feed production
Food-waste does offer one challenge; not all food-waste is suitable for consumption by pigs. Meat should be abandoned from their diets, because it increases the risk that harmful prions will accumulate in their tissue (Geels, 2009). The prions can affect humans that consume the infected meat. This is actually what happened with cows during outbreaks of BSE (Bovine spongiform encephalopathy). For this scenario, it is assumed to leave out all meat.

First, an inventory of the amount of food-waste per household had to be made. According to the *Voedingscentrum*(Nutrition Center) each Dutch inhabitant produces on average 42 kilogram food-waste a year, excluding meat. All the different groups of food that end up in the food waste (and that are suitable for a pigs' consumption) are listed in the first column of table 6-3. In the second column, the waste is expressed in kilograms per year. Now that an inventory of all groups present in food-waste is made, it is time to assess the nutritional value of the food-waste. This was achieved by using food tables provided by the *Voedingscentrum*. The food groups have to be further specified to foodstuffs in order to obtain their nutritional value. The specification in foodstuffs is shown in the third column. So for the group "dairy" demi-skimmed milk was used to look up the caloric value, and so on. The nutritional value unit kcal is used in human consumption, while the unit EW is used in pigs' consumption. So each kcal value had to be turned into an EW equivalent. This was done by using a feed table provided by the *Centraal Veevoederbureau* (Central Feed Office). If the foodstuff mentioned in the third column could not be found in the feed table, the most similar product was chosen. For some of the products, no EW value was mentioned at all. For these products, the EWs are calculated by using the Kcal/EW ratio of know products as a reference. These products are listed with an * in the fifth row of table 6-3. The last column provides the total EW value of the food-waste per capita per year.

Table 6-3 shows that each person in the Netherlands produces on average 42 kilogram food-waste with an energetic content of 25.2 EW.

Table 6-3 - Food-waste per capita per year in the Netherlands.

Foodstuff[1]	Kilogram waste/ year[2]	Specification of used product[3]	kcal/100 gram[4]	EW/kg[5]	Total: kg x EW[6]
Dairy	15	Demi skimmed milk	47	*0.2	3.0
Bread	10	Wheat bread	239	1.0	10.0
Vegetables	5	Average	30	0.1	0.5
Fruit	4	Apple	50	0.2	0.8
Potato	3	Boiled potato	76	0.3	0.9
Biscuits/cake	2	Biscuit	481	*2.0	4.0
Oil and fats	1	Olive oil	900	3.8	3.8
Cheese	1	Gouda cheese	377	*1.6	1.6
Eggs	1	Boiled egg	148	*0.6	0.6
Total	**42**				**25.2**

1, 2, 3 and 4: Obtained from the *Voedingscentrum* (2012).
5: Partly obtained from the *Centraal Veevoederbureau* (2003). Authors own calculations are marked with a *.
6: Authors own calculations.

Housing

In this scenario, pigs are fed food-waste. In order to make that logistically possible, the pigs have to be housed near the origin of the food-waste. Food-waste has to be consumed right after it is left over from the human consumption(Voedingscentrum, 2012). Furthermore, about 12 people are needed to provide for one pig. This follows from the need to consume feed with an equivalent of 310 EW (assumed that a pig fed with food-waste will be housed on a larger area than a conventional pig). So a logistically easy way would be to locate the housing somewhere in residential areas. People with a (large) backyard could house pig(s) there and neighbors can bring their food-waste to the pig.

Figure 6-2–A pig can be held as a pet.

For this type of housing, there are no regulations or rules. With the help of information from hobbyists that hold their own pigs in the backyard, a backyard housing system is proposed that is used in the food-waste scenario. First of all, pigs can never be housed alone. This would seriously compromise their wellbeing, as pigs are group animals (Temple *et al.*, 2011). A second condition is that there has to be a dry and warm shelter available on the lot (Vereniging het Nederlandse Bonte Bentheimer Landvarken, 2012). A third condition is that there has to be enough space to move around, about 4 m^2 per pig would be sufficient (Vereniging het Nederlandse Bonte Bentheimer Landvarken, 2012). The shelter has to be large enough to house two pigs lying down, which is easily achieved. The fourth condition is a strong fence around the meadow. Pigs are exploring animals and they will plow the entire garden if they are not restricted to a certain area. The fifth and last condition is that there has to be water available at all times.
Pigs are naturally very clean animals, and they will deposit their manure in a specific area if their surroundings are clean (Vereniging het Nederlandse Bonte Bentheimer Landvarken, 2012). It is important that the responsible household removes the manure from the meadow once a day. In this way, the pigs will keep deposing their manure at that specific location. It also prevents heavy odors from the manure and the (further) leaking of nutrients into the soil.

Transport
In this scenario, only the transport of manure is needed. Feed is supplied by the local citizens. The manure can be scooped into crates that can be picked up once a week.
The possibilities for the transport from a backyard is different compared to the conventional transport of manure. Assumed that these backyards lay in residential areas, heavy trucks are not suitable. The transport should be performed with delivery vans in that case, which have a maximum loading capacity of 1600 kilograms. Please note that a delivery van has a different (lower) environmental impact per kilometer than a truck. But because of the lower loading capacity of the delivery vans, the impact per kilogram will be higher.
Besides transport of manure, living pigs have to be transported to and from the backyard in this scenario.

6.4 Organic scenario

Feed production and housing under organic circumstances differ from conventional. For both feed production and housing, strict regulations are set up that apply to all organic agriculture world-wide. In this scenario, it is explained how the feed production, housing and transport would be affected by housing all pigs under organic circumstances.

Feed production
Some of the assumptions for the conventional feed production method correspond to the assumptions for the organic feed production method. It is assumed that the pig feed in the Organic scenario enters the Netherlands through one of the harbors. Besides that, literature values for the environmental impact of feed production are used.
An assumption for this scenario is that the energy content per kilogram of the organic feed is the same or at least comparable with the energy content of the conventional feed. This means that the same amount of feed is needed to fatten a pig in this feed production scenario as in the conventional feed production method. Organic pigs do need some extra feed, because they have more space to move around. In the system description it can be found that an active pig would need feed with the equivalent of 310 EW in order to reach the desired end-weight(Elferink, 2009, Lammers *et al.*, 2010).

Housing
The amount of space a pig has in an organic system is minimal 1.3 m^2 per pig, compared to minimal $0.8m^2$ in the conventional system. There has to be outdoor access, but that outdoor space may have a concrete floor. So in practice, even pigs in the organic system cannot enjoy a mud bath. Virtually all organic fattening farms have outdoor access with a concrete floor. Only sows and piglets are usually held outdoors in the organic system, but the parental animals and piglets fall outside the system boundary of this research. Inside the pen of the fattening pigs, litter material should cover the floor. Up to 30% of the floor can be slatted (compared to the 50% in a conventional barn). The tails of the piglets cannot be docked, their teeth not filed and the boars are not castrated. Per pen there have to be two toys, which is one more than in the conventional housing.

Transport
The transport model for the Organic scenario is comparable to the transport model for the Conventional model. The only difference is that the amount of feed transported is 3% higher (per pig and in total).
As is the case in the Conventional scenario, living pigs are transported twice: to an organic fattening farm and to an abattoir. In the Netherlands there is only one big organic abattoir and several smaller ones (Vion Food Group, 2012). In that way, there is no mixing up of conventional and organic pigs at the abattoir.

6.5 Mega farm scenario

In the last scenario that is modeled, all pigs in the Netherlands are housed in mega farms. There is one condition that determines the size of the mega farm: there has to be an in-door abattoir. In order to make this feasible, a fixed amount of slaughters per week have to be performed here. This is explained under housing.

Feed production

The feed production (and the amount of feed) is exactly the same as in the Conventional scenario.

Housing

The housing conditions in the Mega farm scenario resemble the housing conditions of the Conventional scenario. There is only one thing that differs: the amount of pigs present at one farm. The total amount of pigs at the farm is calculated with the help of the minimum amount of slaughters per week in order to run a feasible abattoir. This is achieved by looking at the smallest, conventional abattoir in the Netherlands. This abattoir handles 25,000 slaughters per week(Vion Food Group, 2012). Extrapolation to a year leads to 1.3 million pigs per year or 400.000 pigs spaces.

Figure 6-3 - Artist impression of a mega farm

Transport

In this scenario, there will be no transport of living animals. Furthermore, it is assumed that these mega farms are located strategically in the Netherlands to avoid massive transport movements of feed and manure. Manure processing could be located at the site and feed transport would be almost eliminated if this mega farms would be located near the harbor, since this is the location where the feed arrives. For simplification reasons, it is assumed that all (truck) transport is absent in this scenario.

6.6 Summary tables of all scenario properties

Table 6-4–Environmental criteria for all scenarios

	Feed production?	Housing?	Transport feed and manure?
Conventional	Yes	Yes	Yes
Natural	No	No	No
Food-waste	No	Backyard	Yes
Organic	Yes (organic)	Yes	Yes
Mega	Yes	Yes	No

Table 6-5 Welfare criteria for the scenarios

	Area per pig in m^2	Outdoor access?	Mud pool?	Straw bedding?	Transport living pigs?
Conventional	0.8	No	No	No	Yes
Natural	60,000	Yes	Yes	-	No
Food-waste	4.0	Yes	Yes	-	Yes
Organic	1.3	No	No	Yes	Yes
Mega	0.8	No	No	No	No

7 IMPLICATIONS OF THE SCENARIOS

What are the results of these scenarios on the field of pork production, environmental impact and animal welfare?

The goal of this thesis is to see how the different scenarios relate to each other. This gives a deeper understanding of the current system and the relationships that there possibility are between pork production, EI and AW. This is done by examining the outcome of scenarios concerning feed production, housing and transport. Each specific scenario provides benefits for EI or/and AW compared to the Conventional scenario. The scenarios are arranged from small scale, extensive agriculture to large scale, intensive agriculture. Another way of looking at it could be that the scenarios are arranged in a historical order: the Wild boar scenario reflects a pre-historic way of obtaining pork meat. The other end is the Mega farm scenario, which reflects an option for pork production in the future. Each level of intensity holds different pros and cons for EI and AW, and besides, people have a different opinion towards all levels of intensity. For the meat productivity, the consumption of the Dutch citizens is taken as a starting point. If the scenario cannot sustain in that quantity of pork, the quantity which it can provide is calculated.

The conventional scenario is a reference scenario and the results of all scenarios are compared to that scenario. Therefore, all results will be qualitative (e.g. higher or lower, more or less) instead of an exact value. The only exception is the transport of feed and manure, which is modeled in excel and results in a mileage. But the EI resulting from this mileage is not quantified, rather the distances are compared and the EI is assessed based on the comparison.

7.1 Conventional scenario

Feed production

Conventional feed production requires high inputs of synthetic fertilizers, pesticides and so on. These high inputs cause local environmental impacts, like acidification, eutrophication, and toxicity (which reduces biodiversity on site). On the other hand, conventional agriculture leads to high yields. If one looks at the EI per kilogram (either per kilogram crop yield or per kg end-product, pork), conventional agriculture has quite a low EI. When the EI is assessed for the FU per hectare, the EI is quite high. So this means that there is a high EI at the location of the feed production (which is situated abroad in this scenario).

Housing

Conventional housing is the minimum required for AW by law. Despite that, many pigs are observed in the conventional system that express abnormal (social) behavior. Especially the transport is very stressful for the pigs and therefore very bad for AW. Furthermore, castration, teeth filing and tail docking prevent the pigs to express certain kinds of natural behavior.

Transport

A transport model was designed with help op Excel. The result from this transport model is a distance of 3.6 kilometer per pig. The model is further explained in appendix A.
Besides transport of feed and manure, there is transport of living pigs which compromises AW.

7.2 Natural scenario

In the Natural scenario the nature provides for the pork. The only intervention is to allow a higher number of wild boar to settle in the Netherlands. A natural situation is always the best for animal welfare.

Assuming that the carrying capacity of the natural ecosystems of the Netherlands can handle the proposed amount of boars, there is no EI from this scenario. Besides the absent feed production, no transport of feed and manure will be necessary.
The same goes for housing. The wild boar will use the forest to provide shelter in the night. The boar will not be castrated and their teeth will not be filed nor their tails docked. There is no transport of living animals. So the Natural scenario is the best option for AW.

The natural scenario looks perfect: it is the best option for both EI and AW. There is one disadvantage: this scenario results in a very low meat productivity. With 64130 adult boars shot each year (see previous chapter), the meat consumption of every Dutch citizen will have to decrease to almost zero. Wild boars reach an adult weight of about 115 kg. This is the same as a common pig. The composition of meat and fats in a boars' body might be different than in a common pig. But to simplify the calculations, it is assumed that eventually the same proportion of the carcass is suited for consumption. This would lead to 45 kilograms of meat per boar. Each year, there will be 64130 x 45 = 2.9 million kg boar meat. Per person, this translates to 175 grams. This is the equivalent of two sausages a year.

7.3 Food-waste scenario

The most decisive for EI in the pork production sector is the feed production. Lowering the feed production would directly cause a lower EI of the total sector (till abattoir gate). The food-waste scenario has the goal to eliminate the feed production completely by substituting it with household food-waste. To avoid the collection and transport of household food-waste, the pigs are housed in pairs in the backyard of citizens.

Feed production

Feed production is absent. Household food-waste is used. Because pigs are housed in the backyard, they have more space to move around than a conventional pig. Therefore, they have to consume the equivalent of 310 EW in order to reach the desired end-weight. A simple calculation shows that there are 12 people needed to feed a pig. Two pigs are housed together at one location. These two pigs have to be fed by 24 people that live nearby the location of the pigs.
The current population of the Netherlands is 16.7 million people (CBS, 2011). If they all would collect their food-waste to feed pigs, 1.3 million pigs could be fed. It is assumed that there are enough backyards available to house the pigs. These 1.3 million pigs are not sufficient to supply the current Dutch consumption of meat per person. The availability of pork per capita will drop with almost 85% to 3.5 kilograms a year. Assuming that one serving of pork weights 100 gram, 3.5 kilogram pork would amount to approximately three servings of meat per month.

Housing

The pigs have more freedom to move around and there is the possibility to take a mud bath. There is no direct necessity for tail docking and teeth filing, because the pigs are housed in pairs. But despite these advantages, there are several disadvantages. The first is the uncertainty whether a regular household can take care of two pigs. The meadow should be cleaned from feces and the pigs have to be fed regularly. Also, it is the owners' responsibility to try to diminish the chances of the pigs getting bored. If the owners cannot succeed, these pigs will score low on AW despite the space and mud bath.
The manure of the pigs is likely to cause eutrophication. The pigs are living together on a relative small plot that does not meet the requirements of under which manure spreading is allowed.

Transport
Because the pigs are housed in residential areas, the actual delivery picking up of manure has to be done with delivery vans. This is modeled with the help of Excel, and the specifications are mentioned in appendix A. The outcome of the model is a distance of 44 kilometer per pig (from which 95% with a delivery van and 5% with a truck).
Besides transport of feed and manure, there is transport of living pigs which compromises AW.

7.4 Organic scenario

Organic meat has increased in popularity during the last few years(Ministerie EL&I, 2012). If asked in questionnaires, people especially stress the importance of the welfare conditions of organic housing(Ministerie EL&I, 2012). Furthermore, organic feed production has the image of being better for the environment than conventional agriculture. Is it really true that organic pork production results in less EI and a better AW compared to conventional?

Feed production
Organic feed production uses lower inputs of artificial fertilizers, pesticides and so on than conventional agriculture. Therefore the EI per hectare is lower. These low inputs result in a low productivity, so the crop yield per hectare is virtually always 20-40% lower if organic agriculture is used. This causes the EI per kg end-product (pork) to be higher compared to conventional agriculture. The land-use of organic feed production is estimated to be twice the land-use of conventional feed production(Basset-Mens and Van Der Werf, 2005). So if the same amount of feed is provided to the pigs in the Organic scenario as in the Conventional scenario, twice as much land has to be used.

Housing
The housing rules for organic husbandry provide the pigs with (a little) more space, outdoor access and more toys. Besides that, the pigs are not castrated, nor will their teeth be filed or tails docked. This is beneficial for the AW.
But these benefits for AW can be put in perspective. Compared to the housing used in the Conventional scenario, there are not that many (big) differences. The pig has somewhat more space, but it is still not much compared to more natural housing situations. Besides that, there is no possibility for the pigs to take a mud bath. Simply put: the pig is still housed in a very unnatural environment which will definitely compromise its' welfare.

Transport
The transport model for the Organic scenario is very similar to the transport model of the Conventional scenario. The only difference is the extra feed that has to be transported because of the higher space allowance of the pigs. The outcome of the model is nevertheless the same as for the Conventional scenario: 3.6 kilometer per pig. Details of the transport model can be found in Appendix A.
Living pigs are transported in this scenario. This compromises the AW, similar to the transport in the Conventional and Food-waste scenarios.

7.5 Mega farm scenario

The horror scenario of all welfare organizations is the Mega farm. According to Dutch legislation, a farm is considered mega when 7500 fattening pigs are housed(Gies *et al.*, 2007). The megafarm from this scenario counts 400,000 pig spaces and proposes an even greater threat to welfare. But is this really true? And what is the EI from a mega farm?

Feed production
First of all, the feed production is exactly the same as in the Conventional scenario. So the EI from the feed production is equal to the Conventional scenario.

Housing
Pigs are housed under the same conditions as in a conventional farm. Although there are in total more pigs present at the farm, they will probably not notice the presence of their peers. The pigs can be divided over multiple sections in the building that are sealed from each other to prevent noise disturbances and the spreading of pathogens.

How large would such a barn be? Every pig has at $0.8m^2$ of surface in this barn. To make a quick calculation, it is assumed that the total area per pig would be $1m^2$ (including space between pens, storage facilities and so on). So a farm this size should at least have a total area of 400,000 m^2. A barn in the Netherlands is allowed to have two stories at maximum(Gies *et al.*, 2007). So the total area of 400,000 m^2would result in a two-storied barn with a surface area of 200,000 m^2. This boils down to a building of approximately 450m x 450m. In figure 7-1 the dimensions of such a mega farm are placed in the city center of Groningen to get an idea of how large such a building would be. With a production of 1.3 million pigs a year, six such mega farms would be enough to provide in the pork consumption of the Netherlands.

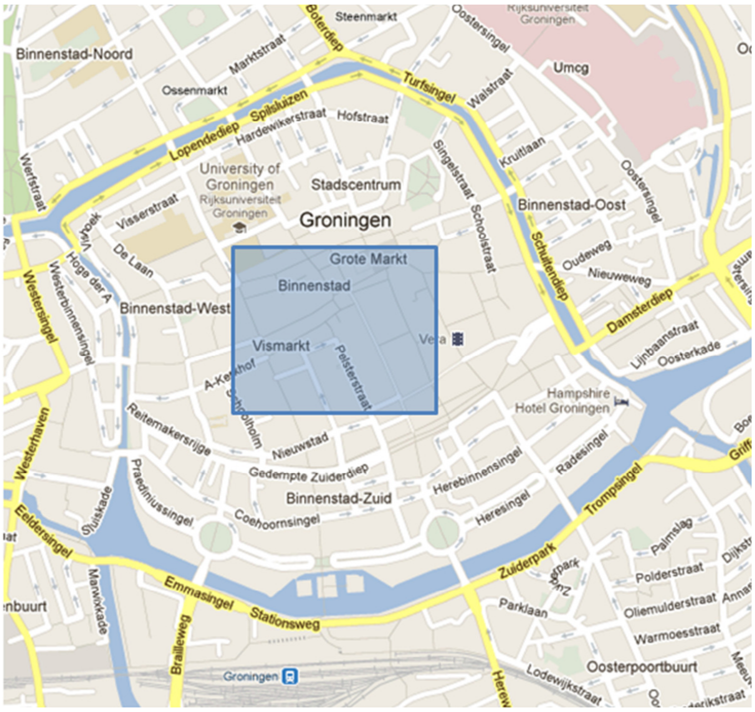

Figure 7-1 - Example of a mega farm with dimensions 450m x 450m on a map of the city center of Groningen

Transport
It is assumed that all transport is absent in the Mega farm scenario. The Mega farm is located near the import harbor. Manure is assumed to be processed in the direct proximity of the farm.
Transport of animals will be absent as well, since the abattoir is located in-doors.

The EI of this scenario is comparable with the Conventional scenario, but without any EI from transport. The AW for this scenario has one large benefit compared to the Conventional scenario: there is no transport of living pigs necessary.

7.6 Summary table: how do the scenarios perform?

Table 7-1 - Summary of the system characteristics EI, AW and Meat production. Red (--) worst score, green (++) highest score

	Environmental impact	Animal welfare	Meat production
Conventional	--	--	++
Natural	++	++	--
Food-waste	+	+	-
Organic	--	-	++
Mega	-	-	++

An explanation of the scores is given in Appendix B.

8 CONCLUSION

The main goal of this thesis was to answer the question: *How do different scenarios for the Dutch pork production sector relate to each other in terms of pork production, environmental impact and animal welfare?* In this chapter, conclusions will be drawn from the results. These conclusions will be divided in an environmental impact part and an animal welfare part. After that, the conclusions on both fields are put together and the main research question will be answered. As *Milieu Defensie* put it in their campaign*: Mud bath or mega farm?*

Environmental impact
The first and most important conclusion concerning EI is that the feed production is the most important factor determining the environmental impact during the pig fattening from cradle to farm gate. This means that the feed production phase has the most potential when it comes to lowering the EI for the whole life cycle. The Mega farm scenario has the exact same EI from feed production as the Conventional scenario. In the Organic scenario the feed production method is altered and in the Food-waste and Natural scenario, feed production is absent.

In the Organic scenario, the environmental inputs of artificial fertilizer, pesticides and GMOs are lower than in the Conventional scenario. But because of a low turnover, the EI per kilogram pork is higher than in the Conventional scenario. Organic agriculture needs about twice as much land compared to conventional agriculture to produce the same amount of crops.
The scenario Food-waste brings two difficulties. The first one is the meat productivity of the scenario. Using all food-waste in the Netherlands would imply that every citizen has can consume three portions of pork per month, which is 85% less than the current consumption. There is simply not enough food-waste to sustain the current consumption of pork.
Lastly, the Natural scenario. This scenario has practically no EI. How attractive that might sound, the pork produced in this scenario is negligible. In this scenario, the pork production is equal to two sausages per person per year.

Besides the feed production, housing and transport cause a small part of the environmental impact. The environmental impact for housing is assumed to be neglectable. Although the EI from transport is small compared to the EI from feed production, transport is quantified for all scenarios by making a model. There is no transport in the Natural scenario and the Mega farm scenario. The transport models for the Conventional scenario and Organic scenario have comparable outcomes. The Food-waste scenario does lead to a high increase in the mileage per pig. Although only manure is transported in that scenario, the housing of the pigs in urban areas causes a higher mileage per pig. The reason behind this is that trucks cannot enter urban areas so delivery vans are used for the transport.

Animal welfare
There are two different factors that influence the welfare of a pig: the housing and transport. If one looks at housing, a natural environment is the most beneficial for AW. Therefore, the Natural scenario scores very high on welfare. The next best thing is the housing in the backyard in the Food-waste scenario. In the backyard, a pig has more space than in a conventional barn and the possibility of taking a mud bath.
In the public opinion, organic housing is seen as beneficial for the welfare of pigs(TNS NIPO, 2007). But in practice, the pigs only have little extra space compared to a conventional barn. Although they have outdoor access, they do not have the possibility of taking a mud bath. Organic husbandry has a very good image among Dutch citizens, but the actual situation is less beneficial for AW then assumed.
The housing in the Mega farm scenario is comparable to the housing in the Conventional scenario. Although there will be more pigs at one farm, the pigs will not come in contact with all of their peers.

Instead, they will be housed in a pen similar to the pens in the Conventional scenario. This means that the welfare resulting from the housing will be equal to the perceived welfare in the Conventional scenario.

Transport is very stressful and influential in a pig's life. All scenarios need transport of living pigs except for the Natural and Mega farm scenario. In the Natural scenario the pigs are killed by hunters before they are transported for further processing. In the Mega farm scenario the abattoir is located in the mega farm. In all other scenarios, transport towards the abattoir is unavoidable and this lowers the animal welfare.

Answer to the main research question

In general, scenarios score better on EI and AW simply by producing less pork. Happy pigs browsing around outside and taking mud baths is highly unrealistic if everyone wants to keep consuming as much pork as they do now. Even the Organic scenario does not come close to that ideal. And the scenarios that do come close are not producing enough pork to sustain in the demand. So the real solution for animal welfare would be to stop consuming pork.

The environmental impact from the pork production sector can be lowered drastically if the feed production is absent. In this thesis can be read that such a solution leads to a low pork productivity. There is the option to produce all feed under organic management. But organic agriculture has just as many downsides as conventional agriculture, although they do differ in nature. As with maximizing animal welfare, the only real solution to lower the environmental impact from the pork production sector is to adopt a vegetarian lifestyle.

If people want to keep their consumption of pork at the same level, then housing pigs in mega farms might not be such a bad idea. Because all transport is avoided, there is no EI from transport. The pigs are not transported alive, which increases the perceived animal welfare compared to pigs in the Conventional scenario.

9 DISCUSSION

The research that is performed for this thesis looked for the causes of the high environmental impact of the pork producing sector. The pork producing sector is exemplar of all livestock sectors, although details of course differ between sectors. The FAO states that livestock has a large contribution to the world wide environmental impact caused by humans and that the environmental impact will only grow in the future. In this thesis it is concluded that the feed production has the largest share in causing the environmental impact. And because there is no pork production without feeding the pigs, the environmental impact is inevitable. Except when citizens are willing to consume less pork or even become a vegetarian. It does not seem very plausible that every citizen in the Netherlands is willing to give up their consumption of pork. In that regard, the FAO is right in its' claim that the environmental impact from the livestock sector will only grow in the future.

The animal welfare story is intertwined with the environmental impact story. Happy pigs live outside in a very natural environment and are free to take a mud bath. They are not transported alive, since this compromises the animal welfare. But these happy pigs would also cause a lot of eutrophication of the soil, because of their manure. And although it was not studied for this thesis, it is thinkable that the supermarket-price of these happy pigs would probably be very high. The history of the livestock sector proofs that intensifying the sector increased the efficiency and more pork could be produced while the costs remained similar. Extensifing the sector would therefore mean a loss of efficiency what would imply higher costs.
In other words: the happy pig ideal is not very realistic. Although there are possibilities to produce pork from a happy pig, there are always drawbacks. Take the Food-waste scenario for example. In this specific scenario there is a very low meat productivity. Although it is not studied for this thesis, it is imaginable that caretaking by (untrained) citizens could cause problems with animal welfare. If the citizens neglect the pigs, the animal welfare level will drop drastically. And the environmental impact side of the Food-waste scenario cannot be ignored either. The transport per pig increased enormously due to the poor logistics in urban areas and the manure of the pigs would probably cause eutrophication.

For both the issues EI and AW the best option seems to stop the consumption of pork. And that this is not a realistic option in the current society is obvious. The other scenarios (Conventional, Organic and Mega farm) show possibilities that all have their own benefits and disadvantages. All three scenarios can provide in the pork demand of the Netherlands and at this moment the conventional and organic system are both present in the Netherlands. A mega farm housing 400,000 pigs is not yet build anywhere in the world. Despite that, there are plans to build farms this size. These farms will be located in Russia, but owned by Dutch entrepreneurs (Wakker dier, 2012). So a farm housing more than 400,000 pigs will be realistic in the nearby future. A farm this size would alter the labor market for pig farmers enormously. In the current pork production sector most farms are family-run. Mega farms with in-door abattoirs cannot be owned by one family, but will probably be owned by a pork processing company. There will be many people working in this factory-like farm. The mega farm will have enormous dimensions and operate 24 hours a day. This is the total opposite of the previously described socially-embedded ideal of pig management.

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11 APPENDIX A – TRANSPORT MODEL

For all transport models made for the three feed options (conventional, organic and food-waste) there are some general assumptions. These will be explained here, along with the method of calculation for each option.

First assumption is the distance from the harbor to the farm. To calculate these distances, each province of the Netherlands was assigned a harbor. The average distance from a harbor to the mid-point of the province was used to determine the distance. This was done with help of Google Maps. It is assumed that every province has an equal amount of farms and thus an equal amount of transport movements. Table 11-1 shows the assigned distances and the average distance for each trip.

Table 11-1 - Provinces with assigned harbors and corresponding distances from harbor to farm

Harbor	Province	Distance to 'farm' in km
Eemshaven		
	Groningen	35
	Drenthe	70
	Friesland	85
	Overijssel	150
Rotterdam Europoort		
	Zuid Holland	35
	Noord Holland	90
	Utrecht	90
	Braband	100
	Gelderland	130
	Flevoland	150
Vlissingen		
	Zeeland	35
	Limburg	200
Average distance		97.5

Assumptions for the conventional, organic and food-waste models are listed subsequently in table 11-2 and 11-3.

Table 11-2 - Assumptions for conventional and organic transport model

Total pigs/year in the system	7.8 million
Capacity of a truck	32000 kilogram
Distance to a farm (two way)	97.5 * 2 = 195
Amount of feed per pig	250 kilogram (conv.) and 258 kg (organic)
Amount of manure per pig	340 kilogram

The transport model for the feed option food-waste is more complex. It is assumed that the pigs live from local food-waste and are housed (in pairs) in a backyard. The manure is scooped into crates by the care-takers and these crates are picked up by delivery vans. These delivery vans go to a central location where the crates with manure are transferred to a truck. The trucks will cover the same distance as the trucks in the previous two models (195 kilometer for a two way trip). The delivery vans are assumed to make rounds with a distance of 200 kilometer. During these rounds, they can collect the manure of 80 households. Every household will be visited twice (rounded) a week by a delivery van.

Table 11-3 - Assumptions for the food-waste transport model

Total pigs/year in the system	1.3 million
Amount of manure per pig	340 kilogram
Capacity of a truck	32000 kilogram
Capacity of a delivery van	1600 kilogram
Amount of manure/week/household	42.2 kilogram
Content of one crate	20 kilogram manure
Amount of crates per van	80
Distance of one round trip with van	200 kilometer
Distance with truck	195 kilometer

12 APPENDIX B –THE SCORES FOR THE SCENARIOS

The scores for table 7-1 are determined as following:

Conventional scenario

- *Environmental impact*
  High per hectare, low per kilogram end product. Overall high environmental impact, -- score.
- *Animal welfare*
  Least beneficial for welfare, -- score.
- *Meat productivity*
  Can provide in the current consumption, ++ score.

Natural scenario

- *Environmental impact*
  Absent, ++ score.
- *Animal welfare*
  Natural environment is best for welfare, therefore ++ score
- *Meat productivity*
  Almost no meat productivity, -- score.

Food-waste scenario

- *Environmental impact*
  Almost no impact, + score.
- *Animal welfare*
  More space, but no educated caretakers, + score.
- *Meat productivity*
  Low meat availability (but higher than from Natural scenario), - score.

Organic scenario

- *Environmental impact*
- High per kilogram end product, low per hectare. Overall high environmental impact, -- score.
- *Animal welfare*
  Some improvements in housing conditions compared to Conventional, - score.
- *Meat productivity*
  Can provide in the current consumption, ++ score.

Mega scenario

- *Environmental impact*
- High per hectare, low per kilogram end product. Overall high environmental impact, -- score.
- *Animal welfare*
  Same as conventional, but without the transport, - score.
- *Meat productivity*
  Can provide in the current consumption, ++ score.