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- Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe
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- Rathenau Institute, The Hague

Contact:
Dr Leonhard Hennen (Co-ordinator)
Institut für Technikfolgenabschätzung und Systemanalyse; Forschungszentrum Karlsruhe
c/o Helmholtz-Gemeinschaft
Ahrstr. 45, D-53175 Bonn

Editors:
Martien Bokma-Bakker (ASG – WUR) and Geert Munnichs (Rathenau Institute).
Rathenau Institute
P.O. Box 95366
2509 CJ The Hague
The Netherlands
Tel: +31-70-3421542
Fax: +31-70-3633488
Email: info@rathenau.nl

Authors Part 1:
Marc Bracke (ASG – WUR), Kathalijne Visser-Riedstra (ASG – WUR), Femke Schepers (WU), Nanda Ursinus (WU), Harry Blokhuis (ASG – WUR, SLU), Marien Gerritzen (WU) and Ellen ter Gast (Rathenau Institute).

Authors Part 2:
Martien Bokma-Bakker (ASG – WUR), Geert Munnichs (Rathenau Institute), Aart Evers (ASG – WUR), Michel de Haan (ASG – WUR), Eveline van Mil (LEI – WUR), Kees van Reenen (ASG – WUR) and Frans Brom (Rathenau Institute).

Administrator: Jarka Chloupkova
Policy Department A - Economy and Science
Internal Policies Directorate-General
European Parliament
Rue Wiertz 60 - ATR 00K074
B-1047 Brussels
Tel: +32-2-2840606
Fax: +32-2-2849002
E-mail: jarka.chloupkova@europarl.europa.eu

Rue Wiertz – B-1047 Bruxelles – Tel: 32/2.284.38.12 Fax: 32/2.284.68.05
Palais de l'Europe – F-67000 Strasbourg – Tel : 33/3.88.17.25.79 Fax: 33/3.88.36.92.14

E-mail: poldep-esc@europarl.europa.eu

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EXECUTIVE SUMMARY

Animal welfare is a pressing public concern in the EU. At present, animal welfare status on-farm is usually inferred from external parameters, such as cage size or feeder space. This approach has serious limitations because the relation between such design parameters and animal welfare is not clear. Current research offers the possibility of assessing the welfare of animals more directly, in terms of their condition, health, performance and behaviour. This animal-based approach, although still work in progress, is very promising.

The STOA project 'Impact of Animal Welfare' investigates the potential for introducing a European system of on-farm assessment of animal welfare using animal-based indicators. Part 1 of the project describes the scientific and technological state-of-the-art with regard to animal-based welfare indicators and monitoring technology. Part 2 studies the socio-economic impact of introducing an animal-based welfare monitoring system on livestock production in EU Member States.

Animal-based welfare assessment

Current research efforts are focused on providing scientifically sound indicators to assess the welfare status of animals more directly on the farm in terms of their behaviour, physiology, performance and health. These animal-based indicators are seen as more sensitive to variations in both farm management and static system-design variables and provide a more reliable assessment of actual animal welfare.

Research initiatives into animal-based measures for welfare assessment include Semantic Modelling, Qualitative Behaviour Assessment, the Bristol University Assessment System of Animal Welfare, and the ongoing EU Welfare Quality project. The latter seems to be the most promising because of its encompassing nature covering the development of integrated sets of animal-based indicators, the provision of concrete measures which can be used by farmers to improve the welfare of their livestock, and the design of a welfare qualification system that can be used to inform consumers about the welfare quality of food products. Structured around the four Welfare Quality principles of good feeding, good housing, good health and appropriate behaviour, are 12 criteria, each covering a separate aspect of welfare with animal-based indicators for each type of animal. The conclusion is that standardized on-farm animal-based welfare assessment is becoming technically feasible.

The report also considers whether animal-based parameters could be used to establish a more humane way of killing animals during disease control but concludes further research is needed to establish the validity, reliability and feasibility of protocols designed for specific situations.

Automated measuring of on-farm animal welfare is a new and promising field with a number of potential advantages when compared to on-farm auditing. These include real-time recording, web-based information exchange, more objective measuring of parameters, and the avoidance of biosecurity risks associated with farm visits. An expert survey was held among leading European scientists and companies in the field of precision livestock farming to obtain information about the automated tools that currently exist and the R&D required to enable them to be implemented on-farm, in order to assess animal welfare according to the criterion of the Welfare Quality project.

The results show that at present, no cost-effective automated recording devices for animal-based welfare parameters are available on the market. Most of the current technologies have been developed for experimental research and need to be translated to low-cost and real-time algorithms for practical field use.

Socio-economic impact

In the second part of the report, the socio-economic issues related to the introduction of an animal-based welfare assessment system in EU Member States are explored. Because of the complexity of the subject, the study focuses on one livestock sector, dairy cows, and just two animal-based welfare indicators: clinical mastitis and severe lameness, for which different levels of welfare are constructed. The analysis is restricted to four countries: the Netherlands, Sweden, Italy and Austria. Because of these constraints, it is signaled that this is very much a pilot study that sketches out what factors should be taken into account.

The first issue addressed is economic: what costs and gains are involved in the introduction of an animal-based welfare monitoring system? In order to construct different welfare levels with regard to the prevalence of clinical mastitis and severe lameness in a herd, veterinarians were asked to draw lines between 'low', 'medium', and 'high' animal welfare. To move from a lower to a higher level of animal welfare, farmers have to take measures that enhance the welfare of their livestock. In order to model the possible economic impact of enhancing animal welfare, cost estimations have to be made with regard to concrete measures – in this example, measures that are relevant for the prevention of lameness and clinical mastitis. The compliance with these measures by typical farms in the Netherlands, Sweden, Italy and Austria and the estimated costs to comply with the 'missing' measures is then analysed. The analysis shows that the economic impact of introducing an animal-based welfare assessment in combination with achieving certain welfare levels varies among farms in EU Member States. For some, it will be a relatively steep climb to reach a higher welfare level for mastitis and lameness and may not be feasible within existing farm structures. Substantial welfare improving measures like outdoor grazing cannot be met in each situation. Furthermore, animal husbandry skills of farmers may vary widely, which could considerably affect the implementation of an animal-based welfare system.

Efforts to improve animal welfare should not just be associated with higher costs. Reducing mastitis and lameness levels can lead to financial benefits, like sustained milk yield and reduced health care costs. In the case of mastitis and lameness, these benefits largely compensate the expenditure required to reach a higher welfare level.

A broad variety of European and worldwide social and economic trends can directly or indirectly affect the feasibility (economic or otherwise) of implementing an animal-based welfare assessment and welfare enhancing measures in the dairy sector. The EU is currently the world's largest milk producer and second largest milk exporter. The liberalization and internationalization of the food market will have a strong impact on dairy farming within the EU, including EU plans to abolish the milk quota system by 2015. As a result of decreased protection, increased competition, increased production costs and greater fluctuations in milk prices, dairy farmers may be faced with a decline in farmer income, which implies less financial room for additional investment in animal welfare improving measures. With milk prices under pressure, farmers might focus on product differentiation including a more animal welfare friendly production system as an opportunity to distinguish themselves from those competing exclusively on price.

There is a strong tendency towards fewer but bigger farms and regional concentration as farmers use economics in scale to compensate for higher production cost. This could favourably affect animal welfare because large-scale farms might be better equipped to implement high-tech or automated animal-based welfare monitoring systems.

Supply chains within Europe are fundamentally retailer-driven and characterized by a relatively high concentration rate. Large retailers have become both the 'gateway' to the market, with suppliers having fewer alternatives routes; and the 'gatekeeper' for access to consumers and information about their preferences and purchasing behaviour. It is questionable whether they will be the catalyzing factor for changes in animal welfare. The results of the Eurobarometer public survey (2007) reveal an increased societal concern for how farm animals are treated, but consumer willingness to pay for animal-friendly products in the supermarket is still lagging.

Policy issues

The policy considerations that arise from this study are complex. In order to apply an animal-based assessment on a European scale, further research and development concerning welfare indicators, validation and automated monitoring is needed, which will require financial support. Furthermore, decisions have to be made on how encompassing an animal-based welfare monitoring system should be and whether all possibly relevant parameters should be included, or a more restricted range.

European citizens hold farmers primarily responsible for animal welfare. But farmers should be supported by institutional arrangements. One option is to leave the introduction of an animal-based monitoring system to the market. By linking product labelling to welfare levels, consumers may be stimulated to buy more animal-friendly products. A second option consists of the introduction of an EU-minimum standard regarding animal welfare, that all farmers within the EU must comply with. But what level of animal welfare should be regarded as minimum? A third option implies that the government encourages the introduction of an animal-based monitoring system and more animal-friendly food production, by financially supporting such a system. This option could mean that the EU-subsidies involved in Cross Compliance should be redirected.

The introduction of an animal-based monitoring system, however, may not be sufficient to accommodate public concerns. Public perceptions of animal welfare can diverge from a scientifically sound, animal-based assessment of animal welfare. The increase in farm scale does not necessarily affect the level of animal welfare, but could potentially fuel the – negative – public image of further industrialization of animal husbandry. This raises a fundamental question: what conditions should be met in order to foster public trust in farming practices?

GENERAL INTRODUCTION

Animal welfare is a pressing public concern in the EU. At present, animal welfare status on-farm is usually inferred from external parameters such as cage size or feeder space. This approach has serious limitations however, because the relationship between such design parameters and animal welfare is not clear and it is also influenced by an individual farmer's animal husbandry skills. Current research offers the possibility of assessing the welfare of animals more directly, in terms of their condition, health, performance and behaviour. This animal-based approach, although still work in progress, is very promising.

The STOA project 'Impact of Animal Welfare' investigates the potential for introducing a European system of on-farm assessment of animal welfare using animal-based indicators. Part 1 of the project describes the scientific and technological state-of-the-art with regard to animal-based welfare indicators and monitoring technology. It addresses the following questions: is it possible to define a set of validated animal-based indicators that can be used to monitor farm animal welfare? Is existing technology adequate for supporting an animal-based approach? What future R&D needs can be identified?

Part 2 of the project studies the impact of the introduction of an animal-based welfare monitoring system on livestock production in EU Member States. The following questions are addressed: is it possible to translate animal-based welfare indicators into overall welfare levels? What economic costs and gains are involved in implementing an animal-based assessment system? What policy issues arise? Because of the complexity of these subjects, the second part of the project focuses on dairy cows in four selected countries: the Netherlands, Italy, Sweden and Austria.

On January 28th 2009, the preliminary project results were presented to experts and EU stakeholder groups during a workshop at the European Parliament. This workshop was chaired by Mr Jorgo Chatzimarkakis, MEP and member of the STOA Panel. The project findings were commented upon by representatives from European Dairy Farmers (EDF), Eurogroup for Animals, European Dairy Association (EDA), and Dutch Food Retail Association (CBL). The results of the workshop have been incorporated in this report.

PART 1

SCIENTIFIC AND TECHNOLOGICAL STATE-OF-THE-ART

1 Introduction[1]

During the last fifty years, production efficiency and cost reduction have been the main drivers in the development of housing and management systems for farm animals. This one-sided focus on economic productivity is considered to be one of the main underlying causes of current animal welfare problems (Blokhuis, H.J. et al., 2000). However, animal welfare is becoming an issue of increasing significance for European consumers and citizens (Miele, M. and Parisi, V). Consumers' perception of food quality is determined not only by the overall quality of the end product but also by the welfare status of the animals from which the food has been produced (Harper, G.C. and Henson, S.J.). When it comes to buying animal-friendly products, the EU FAIR 98-3678 project (2001) suggests a 'barrier' for consumers is not the cost aspect but the lack of information about the welfare-friendliness of the production method. The results of the latest Eurobarometer public survey (2007) clearly support this view. In order to accommodate societal concerns about the welfare aspects of products, there is a pressing need for a reliable animal welfare monitoring system.

Animal welfare research is well developed in many EU countries. In a number of countries welfare monitoring systems are already in place or under development. Most of these systems are based on observations of the animals' *environment*, in particular on design measures known (or presumed) to affect animal welfare. This also applies to current EU welfare legislation, which strongly focuses on environment-based design measures. But the relationship between environment-based measures and animals' welfare status is not always clear, because of the impact of variable factors related to farm management as well as that of the animal itself (for example, variations between breeds). Current research efforts are increasingly focused on developing scientifically sound indicators to assess the welfare status of animals directly on the farm, in terms of their physiology, performance and health status. These *Animal-based welfare indicators* are expected to be sensitive to variations in both farming system management and static system-design variables (Blokhuis, H.J. et al., 2000).

In the following paragraph, a short overview is presented of the policy developments regarding animal welfare within the EU Member States and other countries. The following chapters describe the present understanding of welfare assessment in animal science (Ch.2); current initiatives for on-farm welfare assessment (Ch.3); a brief evaluation of the use of animal-based parameters during the killing of animals for disease control (Ch.4); and concludes with an overview of expert opinions on the potential for automated recording of animal welfare parameters (Ch.4).

[1] Part 1 of this report is based on the internal reports *Animal-based Indicators for On-Farm Welfare: State-of-the-Art* (March 2008) and *Expert Opinion on Automated Recording of Animal Welfare* (May 2008). Both reports are on request available at the Animal Sciences Group of WUR (marc.bracke@wur.nl).

1.1 Animal welfare policies

Along with issues like environmental pollution and food safety, animal welfare plays a major role in most public discussions about animal production. Since the early 1970s, the general public has become more aware of technological developments and related welfare problems in the animal production industry. In response, several countries have set up governmental committees to investigate the welfare of intensively kept livestock, for example the Brambell Committee in the United Kingdom (Brambell Committee, 1965) and the Husbandry and Animal Welfare Committee in the Netherlands (Anonymous, 1975). Their reports have covered a wide range of animal welfare problems and have stimulated discussion and research in this field.

In 1975, the Council of Europe drew up the European Convention for the protection of animals kept for farming purposes (Council of Europe, 1976). The framework of this convention gives principles for the keeping, caring and housing of animals including cattle, pigs, laying hens, sheep and goats. More recently the European Union has formulated legal requirements for the housing and management of laying hens, calves, pigs, and broilers. In countries outside Europe (e.g. USA, Canada, Australia, New Zealand, and Latin America), the debate has concentrated mostly on animal welfare in biomedical research. And although public debate on the welfare of farm animals is increasing in these countries (Global Conference on Animal Welfare – OIE initiative, 2004[2], Animal Welfare in Chile and EU, 2005[3], Animal Welfare Congress, 2007[4]), research on farm animal welfare is relatively limited. Scientific reviews prepared by the earlier Scientific Veterinary Committee (SVC), the Scientific Committee Animal Health and Animal Welfare (SCAHAW), and by the European Food Safety Authority (EFSA) have formed the basis for most current regulations.

Despite the advances in research, a key question remains: how to develop and implement animal-based indicators in order to assess animal welfare more appropriately. European legislation with regard to farm animal welfare usually takes the form of parameters describing the environment in which the animals are housed and managed. These parameters are known as environment-based parameters or 'means prescriptions', because they identify resources that are perceived as meeting welfare demands.

In order to determine whether welfare objectives have actually been met, animal-based indicators are needed. Animal-based indicators refer to parameters such as body condition, abnormal behaviour, and skin lesions, which are measured on the animal itself. Also known as 'goal prescriptions', they are presumed to more directly reflect the actual welfare state as intended by legal requirements. The incorporation of animal-based measures such as foot lesions, breast blisters and mortality, has played an important role in the relatively recent debates underlying the new Broiler Directive (adopted in May 2007; European Commission, 2005: GAIN report E35108). Further discussions on a transition from environment-based means prescriptions, towards animal-based goal prescriptions, are ongoing.

[2] http://ec.europa.eu/food/animal/welfare/international/2003_2073_3l_en.pdf
[3] http://ec.europa.eu/food/animal/welfare/seminars/sem_0905_proceedings.pdf
[4] http://ec.europa.eu/food/animal/welfare/seminars/programme_poster_aw_uruguay.pdf

In May 2004, the European Union launched an integrated project designed to provide practical science-based tools and strategies to assess and improve, the welfare of farm animals on a European scale: the Welfare Quality project. Forty-four institutes and universities from seventeen countries are involved. The Welfare Quality project aims to use primarily animal-based indicators (e.g. health and behaviour) for welfare assessment and environment-based measures (e.g. trough dimensions, cage size, and flooring) for identification of causes and possible solutions for welfare problems.

2 Animal welfare science

2.1 Introduction

Animal welfare science is a relatively young discipline which deals with the animal's welfare status from the animal's point of view. Unfortunately, we cannot ask animals how they feel, and there is no one single instrument (or thermometer) to directly measure the animal's welfare status. Scientists therefore have to rely on indicators that are related to disease, behaviour and stress-physiology. Most scientists accept that there are no major welfare problems when there is minimum mortality, low morbidity, little or no (risk of) injury, good body condition, the opportunity to perform species-specific activities (including social interactions, exploration and play), and the absence of abnormal behaviour, fear and physiological signs of stress, including suppression of immune responses (Anonymous, 2001).

Beyond this fairly common ground, however, there is a big scientific debate on how to define animal welfare. At one end of the spectrum are definitions that refer directly to measurable parameters of biological functioning such as survival, normal behaviour and physiology, and reproductive success. For example, Broom (1986) defined animal welfare as the state of an animal as regards its attempts to cope with its environment. At the other end, animal welfare is defined in terms of subjective emotional states such as hunger, pain, fear, frustration and pleasure (e.g. Dawkins, M.S., 1988, 1990; Duncan, I., 1996).

While there is still no complete agreement among scientists on how to define animal welfare, there is a considerable degree of consensus on how to assess it and sentience is accepted as a necessary condition. 'When people express concern about animal welfare, it is precisely the conscious experience of suffering that worries them most' (Dawkins, M.S., 1998). Non-sentient objects like machines, computers or plants do not have a welfare status, at least not in a sense that is relevant in a socio-political context (Stafleu, F.R. et al., 1996). In this report we will refer to 'animal welfare' as the animal's quality of life as it matters to the animals themselves.

Animal welfare science is a relatively young scientific discipline that deals with descriptive questions related to animal welfare. Although there is no universally agreed definition, there is a considerable degree of consensus among scientists on how to assess animal welfare.

2.2 The natural environment

The scientific assessment of animal welfare is ultimately based on the biological view that through natural selection, animals have evolved and adapted behaviourally and physiologically to live and survive in their natural environment. Some adaptations are common to most animals, such as locomotion, breathing and sleeping. Other adaptations are particular to a specific species, such as rooting in pigs and rumination in cattle. When animals can cope with environmental challenges using normal behavioural and physiological responses, they experience positive feelings. When animals cannot cope or adapt, they show signs of physiological or behavioural stress and experience negative feelings. The capacity to experience feelings has evolved throughout the course of evolution to enable the animal to deal with a variable environment.

Since studies have indicated that modern domestic animals still show their full behavioural repertoire when released into their natural environment (e.g. Stolba, A. and Wood-Gush, D.G.M., 1989; Wood-Gush, D.G.M. et al., 1990), the scientific study of animals in their natural environments helps to identify and understand the needs that are still important for animals kept under modern husbandry conditions. This means that a wide range of needs and related behaviour and physiology is relevant to assess the animal's overall welfare state.

This does not mean that the natural environment is the ideal environment for animal welfare. Free-ranging animals are not necessarily happy animals. Nature does not always provide optimal conditions: animals in the wild may suffer from disease, malnutrition, predation or harsh weather conditions. On-farm conditions are obviously usually controlled much better. Farm animals have been domesticated and are often well cared for and this by itself implies an important benefit for their welfare. However, this high level of human control over the animal's environment often ignores the need to perform natural behaviours such as rooting in pigs, grazing in cattle and nesting behaviour in poultry.

Feelings have evolved in the course of evolution to help an animal deal with a variable environment. Animal welfare, defined as the quality of life as perceived by the animals themselves, can be assessed by means of scientific observations. In particular, the study of animals in their natural environments can help to identify and understand needs that are still important for domesticated animals kept under modern husbandry conditions.

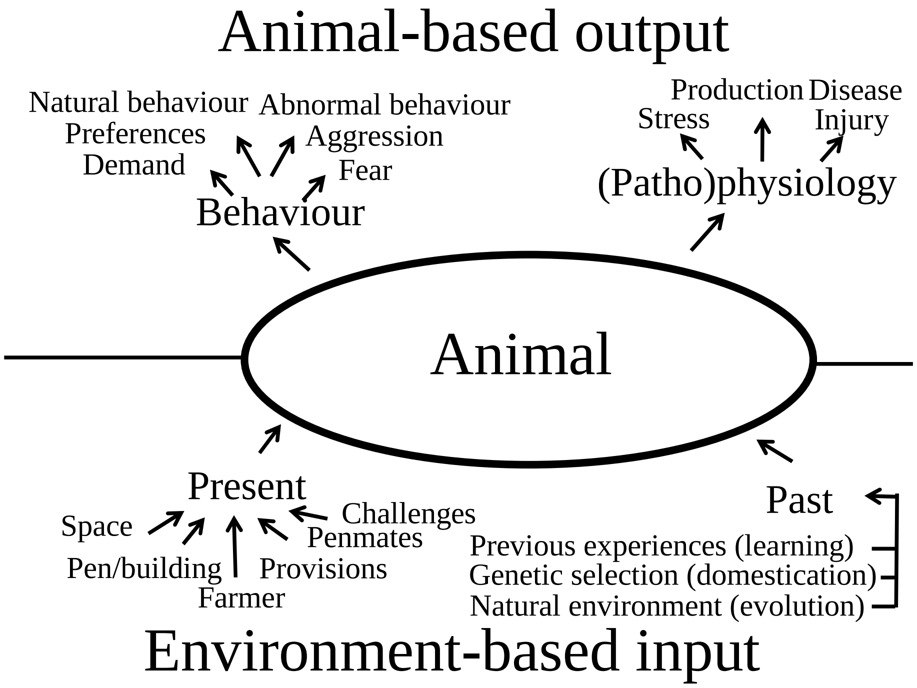
2.3 Coping with environmental challenges

From the current scientific point of view, animal welfare (feelings) and animal responses (behaviour and physiology) are part of biological control systems (needs). The animal's behaviour and physiology are functional mechanisms which help the animal to reduce any discrepancy between (its perception of) the environment and its internal 'setpoints' (motivations, needs). In other words: how to cope with environmental challenge. For example, a pig in a cold environment may perceive a discrepancy between its skin temperature and its ideal one, resulting in the activation of thermoregulatory behaviour (e.g. huddling) and physiology (pilo-erection, shivering). These coping mechanisms may or may not be successful. When animals successfully cope (e.g. by finding a warm resting area), good welfare may be maintained and positive feelings (or a reduction of negative ones) may result, but when they have difficulty or fail to cope (e.g. continued shivering), stress, enhanced disease risk and negative feelings may arise.

In any environment, the animal receives stimuli which may be regarded as 'input'. These include variables such as space allocation, farmer management and floor type. The animal compares the incoming stimuli with its needs, which are the products of evolution (as explained above), breeding and its previous life experiences (e.g. through learning and development). Cognitive processes such as learning are important for animal welfare, because 'smart' animals may find solutions for their welfare problems, but also because predictability has been shown to be particularly relevant for animal welfare. Animals that can predict stressful events show reduced symptoms of poor welfare (Weiss, J.M., 1972). In response to stimuli from the environment, animals may or may not exhibit behavioural and physiological responses: the animal-based 'output' that help the animal to cope with challenges.

These responses indicate the level of welfare and the extent to which an animal has succeeded or has failed to cope with challenges (e.g. abnormal behaviours, elevated stress hormones, certain vocalisations).

Figure 1: Relations between various kinds of environment-based input and animal-based output.



In order to achieve or maintain good welfare, animals have a range of specific needs that must be met in their environment, in order that they can not only perform behaviours for which they are motivated, but that also enable them to 'thrive' in good health. What animals need for welfare can be classified in terms of their main behaviours, including what has been called 'sickness behaviour' (Hart, B.L., 1988). A fairly comprehensive list of needs includes: (from Bracke, M.B.M. et al., 1999):

- Food and foraging (eating and searching for food; not feeling hungry)
- Water (drinking; not feeling thirsty)
- Rest (resting)
- Thermoregulation (e.g. huddling and panting; not feeling too hot/cold)
- Respiration (& other climatic conditions) (breathing)
- Health & (level of) injuries (sickness behaviour; not feeling ill or pain)
- Social contact (social behaviour)
- Reproductive behaviour
- Maternal behaviour
- Play (feeling joy)
- Exploration
- Safety (level of exposure to aggression and danger; not feeling fear)
- Movement/locomotion
- Elimination (voiding faeces and urine)
- Body care/comfort

These needs cover the full behavioural repertoire of the animals. The relevance of these needs obviously varies according to animal breed, season and age (e.g. play is more important for young animals than for adults). All needs must be considered when assessing welfare overall, because each one on its own could severely compromise welfare.

The environment provides stimuli which causally determine animal welfare ('input'). Behavioural and physiological responses reflect different levels of coping with environmental challenge and thus animal welfare. The animal's biological control systems constitute welfare needs, all of which must be considered when assessing welfare overall. Behaviour and physiology provide animal-based output parameters for animal welfare.

2.4 Current developments in animal welfare research[5]

The number of scientific publications on animal welfare has increased dramatically since 1990). These publications originate from all countries around the world with the majority published in European countries (46%) and North America (38%). Popular topics nowadays include animal welfare in relation to i) the individual animal ii) housing systems iii) society and iv) policy making. Within these areas Keeling (2007) identified the following trends:

i) Assessment of positive emotions (in addition to negative ones) by getting 'inside' the body and head of the animal. Multidisciplinary approaches (cf. Boissy, A. et al., 2007; Spruijt, B.M. et al., 2001; Harding, E.J. et al., 2004) and on-farm studies (Bracke, M.B.M., 2007a,b);

ii) Research into the epidemiological aspects of welfare under commercial conditions. Early work on welfare in relation to housing focussed on comparisons of different housing systems under controlled conditions, but this (more current) type of research shows how the stockperson and their management practices has a major effect on animal welfare (e.g. Dawkins M.S. et al., 2004; Boivin, X. et al., 2003). In the future, automated recording and remote monitoring may play an important role in this type of research;

iii) Social and economic aspects of animal welfare including consumers' willingness to pay, willingness of farmers to change and costs of welfare improvements. This work is increasingly done in collaboration with animal scientists;

iv) Decision support and risk assessment of animal welfare (Anonymous, 2001; Bracke, M.B.M. et al., 2004a, 2007a; De Mol, R.M. et al., 2004; EFSA, 2006b, 2007a,b).

These developments in animal welfare research are likely to indicate policy-making needs and thus are also relevant for addressing the issue of assessing on-farm welfare using animal-based indicators.

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[5] This paragraph is indebted to Linda Keeling's presentation at meeting of EFSA in November 2007 (see http://www.efsa.europa.eu/EFSA/EventsMeetings/efsa_locale1178620753812_EfsaScientificForumFoodSafetySummit.htm).

Current developments in animal welfare research indicate policy-making needs: a need for positive welfare indicators, detailed animal-based descriptions of farming practices, socio-economic information and technical decision support. These research trends are relevant for animal-based welfare assessment.

3 On-farm assessment under common production conditions

3.1 Intensive farming husbandry systems

In 2006, the FAO[6] estimated that there were 1.36 billion cattle, 0.99 billion pigs and 16.7 billion chickens worldwide. For Europe, the numbers were 128 million cattle, 192 million pigs and 1902 million poultry. The main husbandry systems and animal-based welfare indicators are described below for pigs, laying hens and broilers[7] which are the major intensively farmed species and which produce different commodities (meat and eggs).

Over 190 million *pigs* are reared annually for meat production in the European Union. Weights at slaughter differ markedly between countries (from 105–170kg live weight). Italy has a tradition of high carcass weights (Parma ham, for example), whereas countries like the UK, Ireland, Denmark, Greece and Portugal, slaughter much lighter pigs. Although some pigs are reared in extensive outdoor facilities, most pigs in the EU are raised indoors under intensive farming conditions. In the most intensive systems, three separate phases of rearing pigs for slaughter can be identified: farrowing, weaning, and the growing-finishing phase. There are different feeding and housing conditions for each of these phases. The gestation period of the sow is approximately 112 to 115 days. The average litter size in the EU is 11. After birth, piglets are nursed by their dams (farrowing sows, mostly confined in individual crates) for approximately 21 to 28 (in some member states, up to 35) days. At a young age, most piglets are tail docked to prevent tail biting problems at a later age, and most male piglets are castrated. After weaning, piglets are generally moved to - and mixed with - members of other litters in specially designed housing systems for weaners. After about 5-6 weeks, when the piglets reach approximately 25-30 kg live weight, the weaned pigs are moved on to accommodation designed to maximize growth until the pigs reach their slaughter weights. Housing design may vary according to factors such as outdoor climate, national legislation, economics, farm structure, ownership and tradition. Weaned and fattening pigs are typically housed indoors on partly slatted concrete floors. In organic production, straw is provided as well as more space and access to an outdoor area.

Laying hens are housed in a variety of systems. These systems can be categorised into three groups: conventional laying cages (battery cages), furnished cages (also called enriched cages) and non-cage systems. Battery cages are small enclosures with welded wire-mesh sloping floors. Hens are housed 4 or 5 to a cage with 550 cm^2 available per bird. There is no hen scratch or dust bathing substrate. The cage design provides only for feeding, drinking, egg collection, manure removal, insertion and removal of hens, and claw shortening. Furnished cages additionally provide some opportunity for the hens to express their natural behaviour, e.g. there is a perch, nest box, dust bath and/or some additional space (increased cage height). Each hen has 750 cm^2 available. There are various types of furnished cages designed for small groups (5-15 birds) or larger groups (40-60). There is a wide variety of non-cage systems which range from single-level systems to multilevel aviaries, with or without free-range facilities. Housing density is generally a maximum of 9 birds per square metre. One-level housing systems have a partly slatted or wired floor which is partly littered, and have laying nests.

[6] http://faostat.fao.org

[7] http://www.ciwf.org.uk/publications/reports/Welfare_of_Broiler_Chickens_in_the_EU.pdf

In aviary housing systems the birds live on different levels where the upper levels generally have a slatted or wired floor and the ground floor provides litter. Laying nests are also provided. Non-cage systems may provide outside access. In organic systems, for example, there is a maximum of 7 birds per square metre and birds are housed partly on slatted and wired floor with litter and laying nests. All birds have access to the outdoors. In organic systems with no beak trimming, there is a risk of feather pecking outbreaks. The classification of eggs (cage eggs, barn eggs, free-range) is subject to EC regulations (Commission Regulation, 1991).

Broilers (intensively reared chickens for meat production) are slaughtered at about 6 weeks of age when 2 kg, sometimes 3 kg, in weight, which is long before they have reached adulthood (4 months of age). This extremely fast growth is the result of intensive feeding and selective breeding methods - slaughter age has halved in the last 30 years. In the EU, intensively farmed broilers are housed indoors in large sheds in flocks of several thousand birds. The sheds are often windowless with artificial light, ventilation and temperature control systems. There is litter material (wood shavings, chopped straw, etc.) on the floor, and several rows of feeders and drinkers. In organic production, slower growing birds are used, more space is provided, as well as access to outdoors.

3.2 Translation of animal welfare research into on-farm assessment

On-farm welfare assessment involves the practical evaluation of animals' welfare status under commercial farm conditions. The main focus of experimental welfare studies has been to identify causal factors affecting animal welfare that can be measured from behaviour, (stress) physiology, production and health. In such studies, a high level of control is exerted over influencing factors, and experimental conditions allow for intensive and advanced measuring techniques. By contrast, there is a much more limited level of control over environmental factors in on-farm assessment other than the usual husbandry practices. Although the same animal-based parameters are used as in experimental studies, the practical conditions obviously limit the sort of measuring techniques that can be applied. On-farm assessment is thus affected by a number of difficulties and variables. For example, seasonal and climate factors can have a significant impact on both physical and behavioural measurements in livestock (e.g. Buckner, L.J. et al., 1998) and thus influence an assessment carried out at a specific point in time; potentially important factors such as animal histories may not be known in on-farm studies (Edwards, S.A., 2007). In addition, a farm herd is a large and diverse group of animals (e.g. containing animals of different age groups) compared to the uniform groups used in experimental studies.

On-farm assessment also tends to be more constrained in terms of time, budget, equipment and expertise when compared to the resources available for experimental studies. This may result in insufficient training for observers, for example, who do not allow enough time for animals to completely settle down during tests, and enable farmers to affect animal behaviour by adjusting climate control or providing some enrichment materials such as straw, to improve the outcome of the audit. A major limitation is also that many test parameters undertaken during experimental conditions are not feasible for on-farm assessment at present.

These include invasive measures such as continuous blood sampling to monitor levels of plasma corticosteroids (stress hormones); measures requiring specific equipment (e.g. video recording of detailed behavioural elements, heart rate monitors); and constraints for the analysis of too infrequent behaviours (e.g. play behaviour) or behaviours which occur at inconvenient times (e.g. disturbance at night due to blood mites in poultry).

Observers also need to be aware that their role in welfare assessment is distinct from a role as an advisor to improve animal welfare. Welfare assessment involves the comparison of different farms with respect to their level of animal welfare (what is the welfare status, and only that). Welfare improvement is focussed towards determining how welfare may be improved on a particular farm, by interpreting which environment-based parameters (e.g. space, flooring, etc.) causally affect the animal's behaviour and physiology, based on what is known mainly from experimental studies.

On-farm welfare assessment involves the practical evaluation of the animals' welfare state under commercial farm conditions. Scientific knowledge generated in the lab must be translated to these on-farm conditions since parameters taken under experimental conditions may not be feasible for on-farm assessment.

3.3 Initiatives for on-farm welfare assessment

In recent decades, several systems for assessing overall animal welfare have been developed throughout Europe. In Austria, for example, the 'animal needs index' (Tiergerechtheitsindex, TGI). This instrument is designed for assuring defined welfare standards in (mainly organic) livestock operations. The scoring of specified housing conditions leads to a sum total of points which is supposed to indicate the level of welfare (Bartussek, H., 2001). This index has been incorporated into Austrian legislation. In Germany, a related version of the TGI has been developed (Sundrum, A. et al., 1994). In the United Kingdom, the 'Freedom Food scheme' in which specific housing and management conditions must be met was developed by the RSPCA[8]. In the Netherlands, a 'decision support system for sows' aimed at the formalised transformation of scientific statements into overall welfare scores (Bracke, M.B.M. et al., 2002a, b). In France and Italy, specific tools for dairy cows (Capdeville, J. and Veissier, I., 2001; Tosi, M.V. et al., 2001).

Like most animal-welfare regulations and certification standards such as 'organic production', these systems have mainly been based on observations and evaluations of the environment, and the welfare-relevant resources available to the animals (see e.g. Keeling, L.J., 2005). However, the links between specific input measures and the animals' welfare status are not always clearly understood. Therefore, it is essential to verify the animals' welfare status using animal-based indicators.

There are two kinds of practical animal-based welfare methods for assessing on-farm welfare status. Firstly, screening in an abattoir for retrospective health and welfare indicators(e.g. Valros, A. et al., 2004; potential for a genomics/proteomics approach in the future). The other, more prevalent approach is population sampling on farms.

[8] www.rspca.org.uk

The most promising measurements in this respect include skin lesion scoring, body condition scoring, health indicators such as lameness and diarrhoea, and measuring of consequences of abnormal behaviours such as tail biting and feather pecking (Edwards, S.A., 2007).

Research into animal-based welfare assessment is increasing with larger companies in Europe developing activities towards assessing and controlling the welfare quality of their product chains (e.g. Swedish Milk, McDonald's Europe, KKM, IKB).

It is essential to integrate the most appropriate knowledge to develop, refine, standardize and calibrate welfare assessment systems. Relevant initiatives for using animal-based measures for welfare assessment include Semantic Modelling, Qualitative Behaviour Assessment, the Bristol University Assessment System of Animal Welfare and the Welfare Quality project.

3.3.1 Semantic Modelling

In Semantic Modelling, animal welfare is assessed on a scale from 0 (worst) to 10 (best), in a computer programme (decision support system). Its objective is to translate scientific knowledge into an overall welfare score to support ethical and political decision-making. To this end, a biological framework (Bracke, M.B.M. et al., 1999) and formal procedures have been developed, including pragmatic algorithms (for including weighting factors and measures of uncertainty) in order to calculate welfare scores. (Bracke, M.B.M. et al., 2002a; Bracke, M.B.M., 2008) Semantic models have been developed for pregnant sows (Bracke, M.B.M. et al., 2002a), laying hens (De Mol, R.M. et al., 2006), tail biting (Bracke, M.B.M. et al., 2004a), enrichment materials for pigs and models for dairy cattle and farrowing sows are being constructed. Models have been 'validated' by comparing model scores with expert opinion (Bracke, M.B.M. et al., 2002b; 2007a, b) and against empirical data (Bracke, M.B.M. et al., 2004b). Very high correlations have been found between overall model scores and international expert opinion ($r = 0.92$ for welfare in sow housing systems and $r = 0.97$ for welfare benefits of enrichment materials for pigs). All models contain benchmarking systems to support applications in practice and been designed to facilitate upgrading when new knowledge becomes available.

The first semantic model, SOWEL, was designed to show that, in principle, available scientific knowledge can be used to assess overall welfare (Bracke, M.B.M., 2001). Since its objective was to assess welfare at the housing system level, the SOWEL model was designed for use as a kind of cost-benefit risk assessment framework (Bracke, M.B.M. et al., 2008) that was used without actually going to farms to take animal-based measurements. In semantic modelling, scientific information, systematically collected and analysed in a database, has a central place. Since scientific information typically describes if-then relationships between environment-based and animal-based measures, the attributes in the model, by definition, are concepts that have both environment-based and animal-based components (as well as a needs/feelings-based component). That also closely relates to the underlying definition of animal welfare as the quality of life as perceived by the animal itself, as it implies that animal welfare and feelings have a functional role in relation to environment-based stimuli and animal-based responses.

From a semantic modelling perspective, animal-based measurements are highly valuable sources of information, when available, to assess welfare. However, animal-based measurements are no panacea for on-farm welfare assessment (Bracke, M.B.M., 2007b).

For example, it is not always true to say that an animal is in a poor welfare state with respect to the need for food if it has a poor body condition. A red deer stag may lose body weight dramatically during the rutting season without a substantial compromise to its welfare state. Poor welfare arises when an animal is losing body weight due to lack of food when it is known (or at least reasonable to assume) that the animal would have had a good body condition if food had been available.

Similarly, when 5% of pigs on a farm are suffering from tail wounds, it makes a big difference as to whether all animals are kept under intensive conditions in barren environments, or whether the same animals are kept in enriched conditions with high-quality provisions (of e.g. food, water and climatic conditions), all other things being equal. A final example illustrates the relevance of environment-based measurements even more clearly. Intensively farmed sows are sometimes kept in crates with very little space to move - they cannot even turn around - yet during routine farm auditing, only limited abnormalities may be detectable from these animals. Since available scientific knowledge shows that pigs are biologically 'programmed' to respond to stimuli, e.g. to explore, to avoid danger, to forage, to socially interact with conspecifics, to protect offspring and to perform species-specific behaviours such as wallowing and nest building, the simple observable fact that sows are kept in crates provides a very strong indication that their welfare is reduced. So while animal-based indicators do provide a most welcome and important new source of information, the role of environment-based information that has a clear scientific foundation, such as applied in existing animal welfare legislation, should not be overlooked when welfare is to be assessed objectively.

In semantic modelling, animal welfare is typically assessed on a scale from 0 (worst) to 10 (best), in a computer-based decision support system. It proposes to use available scientific information together with information about both animal-based indicators and environment-based resources to make the best possible assessment of farm animal welfare.

3.3.2 Qualitative Behaviour Assessment[9]

The qualitative assessment of behaviour approaches the animal as a whole (Wemelsfelder, F. et al., 2001; Wemelsfelder, F., 2007). It originates from early behaviour and psychology studies in which an animal's individuality is seen as a basis for doing behavioural observations. Famous scientists like Jane Goodall have used a form of Qualitative Assessment for describing the personality profiles of individual animals.

Compared to classical ('quantitative') applied ethological studies, qualitative assessment uses more subjective terms such as 'confident', 'nervous', 'calm' or 'excitable' to express welfare. Scientists may use such terms in studies of animal personality and temperament, to denote quantitative variables, but, wary of anthropomorphism, are reluctant to do so in studies of animal welfare. However, it has been argued that qualitative welfare assessment may have a stronger observational foundation than is currently recognized, and may be of use as an integrative welfare assessment tool. Validation of qualitative assessment has been done using 'Free-Choice-Profiling', a methodology which leaves observers free to select their own descriptive terminology.

[9] This paragraph is indebted to comments received from F. Wemelsfelder.

This assessment method has consistently found relatively high levels of inter- and intra-observer reliability in pigs, dairy cattle, poultry and sheep when animals were assessed individually and at group level (e.g. Rousing, T. and Wemelsfelder, F., 2006). With pigs, dairy cattle and sheep (not tested in poultry), these assessments were found to be correlated to quantitative behaviour measures, both under experimentally controlled and on-farm conditions. Significant correlations (up to r = 0.8) with physiological measures (heart rate, heart rate variability) were found for individual pigs under a variety of experimentally controlled test conditions (e.g. open field, human interaction, food maze). These results support the biological validity of Qualitative Behaviour Assessment. Digital manipulation of videos showing individual pigs demonstrated that the environmental background in which these pigs were observed did not unduly bias the assessors' qualitative judgement of the animals' behaviour. This independence of background is important when animals are assessed under varying housing conditions during on-farm visits.

Qualitative assessments have also been incorporated in the pilot protocols of the Welfare Quality project (see 3.3.4), for example in the protocol for laying hens. In these programs, assessors are instructed to observe the animals for at least 20 minutes, assessing behavioural expressions such as confident, relaxed, depressed, bored, insecure, content, energetic, friendly and happy. Such an assessment is considered complementary to the more conventional welfare quality quantitative measures, particularly for assessing positive emotions. Qualitative Behaviour Assessment provides a relatively cheap and quick scan of welfare but it is important to combine this approach with more specific quantitative assessments of behaviour to provide feedback to the farmer on the underlying causes for observed disturbances of welfare.

> The qualitative assessment of behaviour reflects a 'whole animal' approach and uses subjective descriptors such as 'confident', 'nervous' and 'calm'. Such an assessment is considered complementary to the more conventional quantitative measures taken in Welfare Quality, especially for assessing positive emotions.

3.3.3 The Bristol University Assessment System for Animal Welfare[10]

The Royal Society for the Prevention of Cruelty to Animals (RSPCA) Freedom Food standard is a farm assurance and food labelling scheme which uses an independent audit of welfare related measures designed to achieve higher standards of animal welfare on farms and address consumer demand for higher welfare product. The Freedom Food scheme requires members to adhere to welfare standards set by the RSPCA in association with species-specific working groups. These groups include producers, industry experts, veterinary surgeons and animal welfare scientists. The RSPCA has developed standards for cattle (dairy and beef), poultry (layers and broilers), pigs, sheep, turkeys, ducks and salmon. Farms applying for membership of the Freedom Food scheme receive a copy of the relevant standards and are inspected by Freedom Food assessors. Farms that comply with the standards receive a certificate and are monitored annually. The Freedom Food mark seen on eggs, dairy, meat, poultry and salmon products means the animals involved have been reared, handled, transported and slaughtered to the standards devised and monitored by the RSPCA.

[10] This paragraph is based on Weeks, C. and Butterworth, A. (2004), and Webster, A.J.F. et al. (2004).

The RSPCA Freedom Food scheme tends to examine environmental provisions in their standards rather than using animal-based welfare parameters. To evaluate the impact of the scheme on animal welfare, the RSPCA commissioned research from the University of Bristol. To this end, researchers developed animal-based welfare recording protocols for each species to evaluate the Freedom Food scheme using animal-based parameters. For example, measurements taken at flock level to assess welfare in layers include calmness, flight distance, response to a novel object, signs of ill health, aggression, feather pecking, feather loss and comb colour. Measurements taken at the level of the individual bird included weight and body condition, beak trimming, plumage, injuries and overall state.

An important conclusion from the work has been that welfare problems and priorities for action are specific to individual farms. Lameness in dairy cattle, for example, occurred at high levels on both Freedom Food farms and on non Freedom Food farms. Imposing a disinfecting foot-bathing routine on farms, as prescribed by the scheme, does not necessarily lead to a reduction of lameness in cattle. Each farm's lameness problem has specific causes and needs to be managed and treated at a local level. And because the Freedom Food standards are largely environment-based (e.g. housing conditions), while the University of Bristol Assessment was animal-based (i.e. behaviour, physical conditions and health records), it was possible for a farm to comply fully with the Freedom Food scheme and yet nonetheless perform poorly according to the Bristol University Assessment protocol. In other words, despite the fact that a Freedom Food scheme assessment can involve more than 400 questions (almost entirely related to environment-based husbandry provisions), it may still fail to identify important welfare problems.

Bristol University has developed welfare recording protocols for each farmed species to evaluate the Freedom Food scheme using animal-based parameters and found that environment-based measures alone are not sufficient to assess overall welfare.

3.3.4 The Welfare Quality project

The Welfare Quality project is a European program which aims to develop reliable systems for assessing the welfare status of farm animals using animal-based measures and to accommodate the information requirements of consumers (Blokhuis, H.J., 2004). Within the Welfare Quality project, European research groups are being integrated to build on European research strengths and to realise societal and policy objectives. The project will deliver its systems and protocols for different farm animal species in 2009.

One of the main objectives of the Welfare Quality project is to develop sets of indicators to assess the actual welfare state of farm animals in terms of their behaviour, health and physiology. Environment-based measurements are also taken on the farms, not for welfare assessment per se, but for identifying causes of poor welfare and for proposing remedial measures (feedback to the farmer). A basic starting point in the Welfare Quality project is that animal-based parameters are more valid for welfare assessment. This relates to the view that animal welfare is the property of an individual animal, and that animal-based measures can include the effects of variations in the way the farming system is managed (role of the farmer) as well as specific system-animal interactions.

According to the Welfare Quality project, a comprehensive assessment of animal welfare must address scientific, political and societal aspects and take into account the different biological needs of the animals (science), the five freedoms as formulated by the Farm Animal Welfare Council (1992; politics) and the natural behaviour of animals (society). Based on existing scientific literature and following discussion among scientists, 12 areas of concern have been identified. These are presented in Table 1 as 12 welfare criteria.
Each criterion covers a separate aspect of welfare, which encompasses all potential areas of concern, while at the same time, keeps the total number of criteria to a minimum. Several indicators contribute to each criterion. To further reduce the number of items and enhance understanding by the general public, the 12 criteria have been grouped into four welfare principles:

- Are the animals properly fed and supplied with water?
- Are the animals properly housed?
- Are the animals healthy?
- Does the behaviour of the animals reflect optimised emotional states?

For each of the main farm species there are around 20-30 indicators that are currently applied in practice. These are nearly all animal-based indicators, but for some welfare criteria there are at present no valid animal-based parameters available. For example, ‘absence of prolonged thirst’ is very difficult to assess using parameters like skin turgor and plasma mineral concentrations, and it is therefore currently assessed directly using environment-based parameters related to ‘water availability’ (e.g. drinker space).

The measures have already been studied within the Welfare Quality project for validity, repeatability and feasibility. Further selection of parameters and fine-tuning will take place after the results of current on-farm trials. Given the successful operation of the assessment systems, it should then be possible to award a grade or certificate to the farm or farmer.

Table 1: Overview of the main, illustrative indicators used in the Welfare Quality project for pigs and poultry, grouped according to welfare principles and criteria. Indicators in italics are described in the text below. The table based is on Veissier, I. and Evans, E. (2007b).

Welfare principle	**No.**	**Criterion**	**Fattening pigs**	**Broilers**	**Laying hens**
Good feeding	1	Absence of prolonged hunger and thirst	*Body condition scoring*	Feeder space*	Feeder space*
	2	Absence of prolonged thirst	Water supply (number of drinkers, flow rate)*	Drinker space*	Drinker space*
Good housing	3	Comfort around resting	Pressure injuries	*Clinical inspection: feather cleanliness*	*Clinical inspection: feather cleanliness*
	4	Thermal comfort	Percentage of animal shivering	Percentage of animals huddling (cold) or panting (hot)	*Percentage of animal huddling*
	5	Ease of movement	Total pen space, stocking density	Gait score, stocking density	
Good health	6	Absence of injuries	*Skin Lesions,* lameness score	*Lameness score, breast blisters, lesions on feet and hocks*	*Clinical inspection: foot pad injuries*
	7	Absence of disease	Respiratory problems (coughing, sneezing), enteric problems	*Clinical inspection: total plumage, eyes, nose, respiratory problems*	*Clinical inspection: total plumage, skin, comp, eyes, nose, respiratory problems*
	8	Absence of pain due to management procedures	Castration, tail docking		*Clinical inspection: beak trimming severity, beak shape*
Appropriate behaviour	9	Expression of social behaviours	*Biting wounds (tail, ear)*	Aggressive behaviours	Aggressive behaviours
	10	Expression of other behaviours	*Biting wounds (tail, ear);* Qualitative assessment#	*Novel object test;* Qualitative assessment#	*Novel object test;* Qualitative assessment#
	11	Good human-animal relationship	*Human approach fear test*	*Touch test*	*Touch test or husbandry test*
	12	Absence of general fear	Reluctance to move during loading		

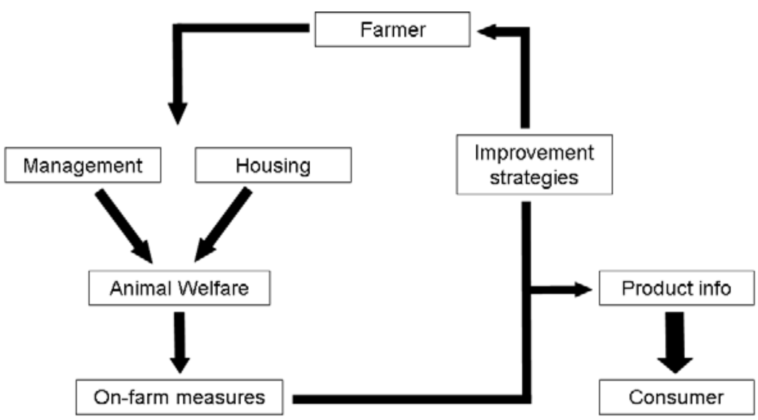
* These are in fact environment-based parameters. They were selected because no feasible animal-based parameters for on-farm application were available. # See also paragraph 3.3.3.

To address consumer concerns and allow for the clear marketing and profiling of product, the Welfare Quality project is analysing ways of converting welfare-related measures into information that can be easily communicated and understood by the consumer. Such an information standard, with several grades or levels, could provide assurance about welfare issues and production conditions to both consumers and retailers. The feedback of information to the farmer to improve welfare is also being studied. With appropriate and adequate responses to on-farm management, this should facilitate ongoing improvements in welfare. Hence, Welfare Quality systems are designed as information feedback systems that are capable of learning and which can evolve with time.

Standardized welfare assessment involving animal-based measures taken on-farm may require an independent entity to manage and upgrade the systems in operation and to provide a processing infrastructure, for example a European Animal Welfare Centre. This is an important step in order to protect the integrity and the standardized use of an up-to-date animal-welfare assessment system.

The main roles of on-farm assessment systems described above are schematically illustrated in Figure 2. In the following paragraphs illustrations are presented of animal-based indicators for welfare assessment in animals kept for different purposes (pigs and broilers kept for meat; laying hens kept for egg production).

Figure 2: Schematic representation of how information about animal welfare is used to provide improvement strategies (via the farmer) and for consumer assurance.



After Blokhuis et al., 2003

The European integrated Welfare Quality project aims to develop reliable systems for assessing the welfare status of farm animals using animal-based parameters, and for informing the consumer. Environment-based parameters are not used for welfare assessment, unless no alternative is available, but are used for giving advice on potential improvements to animal welfare.

Fattening pigs[11]

Body condition scoring indicates how thin or fat an animal is and the level (or absence) of hunger. The most precise method to measure body condition is by measuring backfat depth. This is measured ultrasonically in the region of the last rib, 65 mm from the mid-line (Yang, H. et al., 1989). Another relatively quick and easy method is by visual and tactile evaluation, where a 5 or 6 point scale is used (Patience, J. and Tacker, P.A., 1989; ITP, 2000). A score of one is given for a pig that has a very prominent emaciated shape of the back and has dull and long hairs and abscesses. A score of six is given to a pig with a very large concave shape of the back which shows many folds of fat.

Skin lesions are injuries of the skin, indicating pain (and perhaps associated fear). Skin lesions can be a consequence of the social environment (fighting during feeding and mixing) or of the physical environment (inappropriate design of facilities; Velarde, A., 2007a). Skin lesions may be recorded at the farm as well as in the slaughterhouse. Several protocols have been developed for on-farm use, giving scores for different regions of the pig's body, such as head/neck, flanks, legs, back and hindquarters. For each region, the number of lesions is observed as well as the nature (scratch, open wound, blotch, etc.), the size, the depth and state of the lesion (fresh/healed). For the observation of skin lesions in the abattoir, pigs are usually evaluated as whole animals. Photographically documented scales are commonly used with 1 to 4 or 5 point scales (Meat and Livestock Commission, 1985; Barton-Gade, P.A. et al., 1996).

Tail biting, ear biting and cannibalism are recognized as major welfare problems, especially in relation to the pigs' frustrated motivation to explore and forage (i.e. search for food, Fraser, A.F. and Broom, D.M., 1990). Both tail and ear biting are known to be affected by many factors such as absence of rooting materials (e.g. straw and peat), slatted floors, diet (e.g. salt and protein), breed, feeding competition, and stocking density (Bracke, M.B.M. et al., 2004a,b; EFSA 2007a). The level of tail biting is also considerably affected by tail status: the level of tail biting often increases once a tail has been bitten in a pen and is losing blood, leading to what is called an outbreak of tail biting. The level of tail biting is determined using clinical inspections and predefined categories of observation. For example, tail biting may be recorded using tail length (5 categories), damages (3 categories) and blood (4 categories) using a score sheet illustrated with pictures (Zonderland, J.J. et al., 2003; reprinted in Bracke, M.B.M., 2007a).

Pigs may show *fear* of humans, which is modified by positive and negative experiences with handlers (Spoolder, H.A.M., 2007). A standard but time-consuming measuring method is the so-called human-approach fear test, which may be performed in a separate room or in the home environment of the pigs. The observer enters the enclosure and stands opposite the entrance. The pig is allowed several minutes to approach the human. Recorded measures include the time taken by the pig to come within 0.5 m of the observer, the total time spent in this area, and the time taken to the first physical interaction with the observer and the number of physical contacts (Hemsworth, P.H. et al., 1994).

[11] Information based on (internal) documents supplied by Velarde (IRTA, January 2008) and Velarde, A. and Geers, R., 2007b.

Broilers[12]

In the Welfare Quality project, one of the animal-based parameters applied to broilers is a *touch test*, which is used to test a combination of fear, ease of movement and curiosity. This test is also a *human-approach fear test*. The observer approaches a group of birds in a non-cage system and squats for a moment, counting the number of birds at arm's length. An attempt is made to touch the birds, which is followed by another bird count.

Another test, which is designed to indicate the level of motivation to explore and fear towards objects, is the *novel object test* in which a coloured stick is put on the floor. Birds within a distance of 30 cm from the novel object are counted every 10 seconds for 2 minutes.

In broilers, special attention is paid to *lameness*. For this indicator, birds are temporarily gathered in small groups and individually examined with respect to mobility on a predefined point scale.

Clinical scoring is performed with the help of the farmer, who picks up the birds while the observer assesses feather cleanliness, body condition, breast blisters and lesions on feet and hocks. Inspection of the eyes, nose and respiratory distress is used to detect further pathological symptoms.

Laying hens[13]

The on-farm assessment for laying hens in the Welfare Quality project is very similar to that for broilers. This is because the underlying biology is very similar, even though the end product is different (eggs vs meat).

As a consequence, the *novel object* and *touch* tests are applied to laying hens in much the same way as they are to broilers. In addition, a *husbandry test* is performed in cage systems. In this test (which is also a human-approach fear test, like the touch test) the observer walks down a corridor in a hen house with battery cages (hands hanging alongside their body while looking at the food trough so as to avoid direct eye contact) at a distance of 60 cms from the front of the cage row. A cage at a minimum distance of 1.5 m and with at least 3 heads poking through the front wire-mesh, is selected. While walking down the corridor, the observer counts the number of heads poking out of the selected cage before reaching the edge of the cage (measure 1) and when passing the edge of the cage (measure 2). While walking on, the next cage is selected, and so on, until 10 cages have been tested.

The percentage of *huddling* birds is scored at different points in a barn and at different time points during a farm visit. Huddling percentage indicates thermal stress and ease of movement, and is scored in levels ranging from no huddling to all bird huddling.

For *clinical inspection,* birds are picked up from all areas of the hen house following a standardised procedure. Each bird is inspected systematically from the front to the rear, on the dorsal and ventral side. The keel bone is palpated by running two fingers along the keel bone to determine deviations from a straight line.

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[12] Information based on an interview with A. Butterworth (University of Bristol, Clinical Veterinary Science, January 2008).

[13] Information based on (internal) documents supplied by T. Fiks (WUR-ASG, 2008).

T bird is also scored on a check sheet for total plumage, skin of the rear body, skin of the comb, footpads and beak. The beak, for example, is scored for beak trimming severity (1-3) and for beak shape (1-2).

At present, most indicators used in the Welfare Quality project assessments are measured by an observer during a farm visit. Examples include body condition scoring, skin lesion scoring, human-approach fear tests and clinical observations, all conducted in a standardized way and expressed quantitatively.

3.4 Towards overall welfare assessment

The approaches described in the previous paragraphs provide different methods for integrating animal welfare measurements. Semantic modelling proposes formalised procedures using combined animal and environment-based attributes based on systematic analysis of scientific literature; qualitative assessment proposes direct, intuitive evaluation' the Bristol Scheme avoids overall assessments altogether; the Welfare Quality project is developing mathematical multicriteria algorithms.

Each of these routes has major advantages and disadvantages. For example, without overall scores it may be very difficult, perhaps even impossible, to inform consumers. Since welfare itself is a continuous variable, an expression of overall welfare may require a continuous scale (e.g. Bracke, M.B.M. et al., 2002a). However, whilst problematic from a scientific point of view (e.g. Mendl, M., 1991), an expression of welfare in discrete levels may have practical advantages. If welfare is to be regulated in the market or when political objectives must be formulated, discrete levels and cut-off points are probably necessary. Information for consumers (certification/labelling) must be easily understandable, and retail (business-to-business trade) may also require a limited number of welfare classes.

Current EU legislation formulates just two levels of animal welfare: below legal minimum standards and above minimum standards. Organic production is widely believed to be meeting high welfare standards and is often considered as a 'third' (higher) standard. However, organic production is not high welfare by definition. For example, some organic farms have problems with damaging behaviours (e.g. feather pecking in poultry) or predation of animals in outdoor runs. Also, organic farmers are reluctant to use effective treatments such as antibiotics, and this attitude may increase welfare problems for animals suffering from disease. There may also be a need to identify welfare levels both below and above levels obtained in organic production (e.g. because of a market and/or societal demand for it).

One of the first systems to define different levels of animal welfare was the TGI (Tiergerechtheitsindex, i.e. animal needs index) scoring system. In this system, mainly applied in organic production, points are assigned to mainly environment-based welfare parameters. The points are added up to give a total number of points that describes the level of animal welfare within (politically defined) limits of welfare classes.

In the Welfare Quality project, it is recognised that producers and consumers may demand different types of information. Farmers may be particularly interested in technical details and how to improve welfare; consumers may be more interested in overall welfare levels and a guarantee that the information provided is reliable.

The Welfare Quality project approach is to develop a product information system in which information about the different animal-based parameters as measured on the farm is integrated. The project relies primarily on expert opinion and multicriteria evaluation rules to do this integration, first from parameter scores (often classified in a limited number of levels) to criteria scores, then from criteria scores to scores for the different principles and then to an overall welfare classification.

In the Welfare Quality project the following four categories to express overall welfare have been proposed:

- Not classified (below legal requirements)
- Acceptable
- Enhanced
- Excellent

This system is still being discussed and borders between the different grades are not definitively set.

Current EU legislation may be regarded as formulating two levels of animal welfare: below legal and above minimum standards. Organic standards are often considered as a 'third' (higher) level but 'organic' is defined by environment-based criteria and is not high-welfare by definition. Welfare should be preferably be based on animal-based measures and certified independently. An expression of overall welfare in different welfare levels is needed in relation to political decision-making and especially when welfare is to be regulated in the market (through providing welfare information to consumers). To this end, Welfare Quality is presently developing a system with four grades.

3.5 Conclusions

Standardised on-farm welfare assessment using animal-based parameters is becoming technically feasible. It is a very promising approach, but still work in progress. When comparing the various initiatives, the Welfare Quality project is the most promising because it produces overall welfare scores, information to support farm management in making welfare improvements and a system of welfare classes to inform consumers. Furthermore, a large number of European Member States are already involved in the project. The Welfare Quality project is therefore used as a starting point for the next phase of this study.

Standardized on-farm welfare assessment using animal-based parameters is becoming technically feasible.

4 Use of animal-based parameters during killing for disease control

4.1 Introduction

The use of animal-based parameters for on-farm welfare assessment does not only apply under normal farming conditions. In order to control the spread of disease, large numbers of animals need to killed on farms and these procedures have raised considerable societal concern[14]. Can animal-based parameters be used to guarantee or establish a more humane way of killing animals during disease control, and if so, how?

Control of highly contagious diseases in farm animals is laid down in international guidelines and legislation (EU Council Directive, 2005; OIE, 2003; Galvin, J.W. et al., 2005). Control measures should be effective, e.g. stop the disease from spreading as quickly as possible, and should be acceptable for humans and animals, e.g. safe to apply and with minimal harm to animal welfare. With a primary focus on disease control and humane safety, animal welfare is addressed only in general terms and not in more specific guidelines. At present, there are no animal-based protocols for on-farm welfare assessment during emergency killing, but they could almost certainly be developed from existing research experience.

Emergency killing may involve the slaughter of individual animals (e.g. cattle and pigs) that are killed sequentially by lethal injection, captive bolt or electrocution. It may also involve killing animals in groups (e.g. pigs or poultry) using gas containers, electrocution lines, whole house gassing or gas-foam (under research). Compared to killing in abattoirs, killing for disease control is normally done on the farm without the usual meat quality considerations. Hence, toxic drugs (by lethal injection) and high electrical currents can be applied, provided human safety aspects are respected.

Welfare assessment during killing primarily relates to when animals lose consciousness prior to death. As a result, indicators used to assess normal husbandry practices are of little value. Animal-based parameters to assess unconsciousness and death have been developed for application in research to evaluate stunning and killing methods used in abattoirs and during emergency killing. Main parameters are loss of posture (LOP), cornea reflex, somatosensory evoked potentials (SEP), brain activity (EEG) and heart activity (ECG) (reviewed in EFSA, 2004; EFSA, 2006). Most of these parameters are not suitable for routine on-farm application, because they are invasive techniques requiring surgery (e.g. SEP, EEG, ECG), or because the recording equipment is too difficult to disinfect. Even parameters like loss of posture or cornea reflex that may seem readily applicable, may not be feasible, perhaps because emergency killing is performed under time pressure (to stop the spreading of the disease as soon as possible) and because human-animal contact may be limited. When large numbers of birds are killed simultaneously in containers or in a barn or when animals pose a biosecurity risk for humans (e.g. Avian Influenza) it may not be possible to touch or even see the animals to monitor animal-based parameters such as loss of posture and cornea reflex.

[14] A related issue concerns ethical issues arising from the killing of wildlife for disease control and environmental issues (Littin, K.E. and Mellor, D.E., 2005).

On the other hand, in many cases at least some of these parameters can be used (e.g. when individual cattle or pigs are killed sequentially) and it is conceivable that remote monitoring devices or other measures such as recording vocalisations can be developed to assess welfare under practical conditions in the future.

Thus, animal-based parameters as used in research to assess consciousness are not readily applicable for routine on-farm application and require further research. When considering protocols to protect animal welfare during emergency on-farm killing, a distinction can be drawn between the pre-killing phase, the killing phase and the post-killing phase.

4.2 Pre-killing phase: catching, moving, handling and restraint

Before animals are killed, they may have to be taken from their home pen, moved, and restrained to enable adequate killing. Improperly restrained animals may escape or hamper killing (e.g. through insufficient injection volume or inadequate electrical shocks). Catching and handling can easily lead to considerable stress (poor welfare), inhibiting loss of consciousness and thereby lengthening the period of suffering.

Note that the ('environment-based') killing method itself may also have a considerable effect, such as on the amount of handling required. In whole-house gassing situations for poultry, for example, the animals remain in their home environment. This prevents catching and handling stress altogether, and could potentially contribute more to improving welfare than can be achieved using animal-based measures to reduce stress in individual killing procedures.

Suggested animal-based parameters for application during the pre-killing phase include:

- Escape attempts
- Vocalisations
- Injuries
- Handling and restraining durations

4.3 Killing phase: unconsciousness and death

This phase starts when killing treatments are applied. Some of the same animal-based parameters as described above can be used (e.g. escape attempts, injuries and vocalisations). Loss of consciousness can be assessed using parameters such as 'loss of posture' and cornea reflex. Uncontrolled muscle spasms may pose a welfare risk when they occur before loss of consciousness, because they may be painful and can cause injury. It should be noted however, that muscle spasms seen after electrical stunning and killing are not indicative of reduced welfare, because they occur after loss of consciousness.

Unconsciousness can be expected when animals show full loss of posture (i.e. they don't move their limbs and they don't try to lift their heads). Qualified personnel (e.g. a veterinarian) may be required to ascertain death (e.g. using a combination of parameters such as cornea reflex, auscultation of heartbeat and observation of prolonged absence of breathing).

Suggested animal-based parameters for application during the killing phase include:

- Muscle spasms
- Loss of posture
- Cornea reflex
- Breathing
- Heart beat

4.4 Post-killing phase: removal, registration and evaluation

In the post-killing phase animals are loaded, moved or transported for destruction. When animals regain consciousness in this phase, animal welfare may be seriously compromised. Therefore, it is important that sufficient precautionary measures have been taken to avoid animals from regaining consciousness, e.g. by ascertaining irreversible unconsciousness/death in all animals by qualified personnel in the preceding phase, and by allowing sufficient time to elapse before animals are moved for destruction. In addition, continued monitoring of animals during this phase may be required to ascertain that animals really did not regain consciousness. Furthermore, the (animal-based) information collected during this and the preceding phases must be processed in order to assess welfare and to be able to formulate strategies to improve welfare in the future. Since improved animal welfare may conflict with economic and biosecurity considerations, it may require considerable research effort to determine exactly if and how welfare can be improved by using animal-based measures.

4.5 Conclusions

On-farm killing of animals during disease control is likely to continue to raise animal welfare concerns. Handling, killing and animals regaining consciousness can in principle be monitored using animal-based welfare parameters. These parameters, however, which mainly focus on states of consciousness, differ considerably from the parameters used to assess normal husbandry procedures. Further research is needed to establish the validity, reliability and feasibility of protocols designed for specific situations. For example, when using gas containers, whole house gassing and gas-foaming, animals cannot be observed during the killing process. For these situations new parameters and techniques such as (telemetric) measuring techniques, may have to be developed.

During disease control, large numbers of animals may have to be killed on farms. These procedures have raised considerable societal concern. Animal-based indicators could be developed to assess and improve farm animal welfare during killing for disease control. This will require different parameters from those used to assess normal husbandry conditions, because killing primarily involves assessing whether an animal has lost consciousness or is dead.

5. Automated recording of animal welfare

5.1 Introduction

As shown in the previous chapters, standardised on-farm welfare assessment using animal-based indicators is becoming technically feasible, particularly due to research being conducted in the European Welfare Quality project. At present most parameters in the project are measured by auditors during farm visits. Compared to on-farm auditing, automated recording of animal-based parameters has a number of potential advantages. Firstly, automated recording is less time consuming than on-farm auditing. Secondly, recordings could be made in real-time, on a more continuous basis. Thirdly, information could be managed using databases and methods of web-based information exchange, reducing the need to send specialized personnel out to farms. Fourthly, existing parameters such as body temperature, skin lesions and activity of the animals can be measured more objectively. Fifthly, automated recording may enable new parameters, such as heart rate (variability) and plasma cortisol (stress hormone) levels, to be incorporated in the welfare assessment scheme. Finally, automated recording may be able to solve some methodological problems such as animal disturbance and biosecurity risks associated with farm visits. Essentially, automated recording may increase repeatability and feasibility of large scale assessment and ultimately reduce costs.

The field of automated recording of animal-based parameters is relatively new. Some electronic tools are currently available to farmers (e.g. individual recognition in dairy cattle and sows at the concentrate feeder, automatic weighing of broiler chickens). But most tools and research are focusing on research goals (often developed for laboratory animals) or production-related parameters, instead of welfare parameters. The available technology is not yet ready for on-farm use and the expertise seems to be fragmented.

In order to get a better overview of the current and future possibilities of automated and/or remote recording of animal-based welfare parameters, an expert survey has been held among leading European scientists and companies in the field of precision livestock farming. They were asked what automated recording tools already exist and what research and development (R&D) is necessary to implement automated recording of animal-based parameters on-farm in order to assess animal welfare according to the criteria as defined in the Welfare Quality project. The scientists and companies were contacted by e-mail and asked to provide a short description of their own expertise, available products, and problems and solutions with respect to assessing and certifying (overall) animal welfare.

In total we contacted 21 scientists and companies, of which 16 responded (9 scientists and 7 companies: see Annex 2). This chapter describes a compilation of the expert contributions. A draft version has been sent to all respondents for clarification and verification.

5.2 Tools for automated welfare assessment

The results of the expert consultation on automated recording of animal-based parameters to assess animal welfare are presented below according to the 12 welfare criteria as defined in Welfare Quality project (see 3.3.4). The results show that there may be potential for automatic recording of animal-based parameters for most welfare criteria. However, at present, there are no cost-effective automated recording devices for animal welfare available on the market.

Absence of prolonged hunger

There is one device under development that will directly measure whether or not there is absence of prolonged hunger in dairy cows (IceScore vision platform from IceRobotics). With a camera and associated software, the IceScore sensor can determine the body condition score (BCS) of dairy cattle, i.e. how thin/fat the cows are. If many cows within a farm have a low BCS, it can be concluded that the cows are hungry according to the Welfare Quality criteria. IceRobotics mentions that it intends to release the IceScore sensor for automated body-condition scoring using proprietary vision technology to research institutes in 2009 and to commercial dairy farmers in 2010. This device is developed for dairy cattle, but perhaps the technology may also be made applicable to other farm animal species.

Another product from IceRobotics, the IceSampler, can take blood samples from free-ranging cows automatically at set intervals. The cows are fitted with a protective backpack and blood is collected through a sampling line connected to a catheter in the cow's jugular vein. From a sample, several blood parameters (e.g. glucose concentration) could be measured and used as an indicator for hunger. Human interference and expertise is needed to apply the sampler (insert catheters, remove the samples from the device) and to analyse the blood. Like many other products discussed in this report, it should be clear that this product is designed especially for use in scientific research and that application for on-farm welfare assessment is doubtful and will in any case take a considerable research effort to overcome all kinds of practical problems and to reduce costs.

Nielsen mentioned the RuminAct (Milkline), which records rumination activity. This technology could potentially be used as a measure for absence of hunger in ruminants (cattle, sheep, and goats). Validation research, for accurately measuring rumination activity, is currently being undertaken. Limitations as to its on-farm application have not been specified, other than that further research will be needed.

Several devices could indirectly measure the absence of prolonged hunger by indicating the position of animals within a housing system, e.g. the frequency and duration of animal visits to the food area (eYenamic from Fancom, real time positioning system mentioned from Blip Systems and IceTag3D from IceRobotics). eYenamic uses roof-mounted cameras to determine the positions of animals and is available for pigs and laying hens. The real time positioning system is based on Bluetooth technology and is still under development. The IceTag3D is a three-dimensional motion sensor with a very high sample rate, which has recently been released in Denmark for application in the research community to monitor animal activity, including lameness, but could perhaps be modified to record how often a cow visits a feeding area. However, validation is needed to determine what feeder visits mean for welfare, i.e. how different farm animal species react to hunger (e.g. does hunger mean animals will visit the feeders more or less?).

Many automated feeding systems on the market record feeder visits of farm animals carrying transponders. Where available (i.e. when automated feeders are present on the farm), the information from such systems could be extremely valuable for welfare assessment, not only to assess the level of feeding, but also for measuring other aspects of animal welfare such as the presence of disease, since ill animals often refuse to feed. Nielsen mentions research in Denmark which is currently investigating whether the Joker calf Milk feeder can be used in the early detection of disease.

While existing automated systems (e.g. for feeding and milking) provide several potential welfare parameters, further research is needed as to how this information could actually be used: how it could contribute to welfare assessment on the (automated) farm, but also how data could be compared across farms (e.g. with farms that do not have such automated systems).

Absence of prolonged thirst

As mentioned above, devices such as real time positioning systems, IceTag3D, eYenamic and transponder-based systems (e.g. automated feeders) could be used for measuring the absence of thirst by detection of visits to drinking areas. Again, validation is needed to determine how different farm animal species react to thirst (is there a change/difference in frequency and duration of visits to the drinking areas?). Again, in theory the IceSampler could be used to measure the level of dehydration in blood samples, but it is unlikely that this will ever become a reality in on-farm welfare assessment.

Comfort around resting

Animals should be able to rest comfortably. The animal-based parameters proposed in Welfare Quality vary between species. For example, in pigs, pressure injuries are recorded; in poultry and cattle, cleanliness is observed; in dairy cattle, lying postures and the time taken to lie down are recorded. Thus different technologies are probably required for these different parameters, and also perhaps, for different species.

For cleanliness, which indicates reduced resting comfort, no tools have been suggested by the respondents. IceRobotics states that it may be difficult to design a cost-effective tool and suggests that recordings of cleanliness may need to rely on manual measurement.

Two devices were mentioned for measuring 'lying down' behaviour: IceTag3D (IceRobotics) and biomotional analysis (FBI Science). The first can measure the total lying down time, and could potentially also measure the time it takes for the cows to lie down. The second technique, biomotional analysis, could be used to record movement patterns of the body of a single animal, and hence give information about the ease with which animals lie down.

Furthermore, the IceScore vision sensor could be adapted to monitor the sleeping position of cows and view when their hindquarters are lying over the edge of the sleeping platform.
As explained earlier, the frequency and duration of animal visits to a specified area (in this case the resting area) can be recorded (e.g. eYenamic and the real time positioning system).
None of these systems are ready for routine application in on-farm welfare assessment.

Thermal comfort

The MaGiiX rumen bolus (from MaGiiX, USA; mentioned in the contribution from IceRobotics) is a “passive” sensor which only provides a temperature reading when the animal passes a fixed panel reader. Another device was mentioned that can measure body temperature of pigs: TemPlanT (from TeleMetronics biometry). This is an implant that can indicate whether or not animals are within their thermal neutral zone. It is wireless and fitted with radio-frequency identification (RFID) transponders for identification of the animals. The first tests were promising and, with the proper financial support, may be ready for large scale use in two to four years. Perhaps in the future it can also be used for other farm animal species.

Ease of movement

As mentioned before, the biomotional analysis technology (FBI Science) can accurately record movement patterns of the body of a single animal, and thereby potentially give an indication of the ease with which the animal moves. There are two further devices that can (potentially) measure the activity of animals, eYenamic (Fancom) and TemPlanT (Telemetronics biometry) that have been mentioned before. eYenamic uses a camera-based system to give an indication of the activity level of animals in a certain area of the housing system and is already applicable to pigs and laying hens. TempPlanT is an implant that primarily measures body temperature, but it can be extended with a 3D accelerator for measuring body activity of individual animals.

The location of animals within their housing system can also be recorded. FBI Science is developing a system that can track animals within their enclosure to measure roaming behaviour with the help of already existing RFID transponders. This measures their activity indirectly. The IceTag3D (IceRobotics) can measure where a cow is located, since the sensor within the device is triggered every time the cow passes a wireless trigger station. In this way it is possible to keep track of cows moving to and from an outdoor area.

Absence of injuries

Injuries may have a considerable impact on animal welfare andmay take diverse forms, ranging from lameness to skin lesions. It will probably be difficult, if not impossible, to develop a device that can detect all types of injuries in the different farm animal species. Yet some devices can measure a certain kind of injury on a single species. The IceTag3D (IceRobotics), for example, is currently undergoing field trails to develop an algorithm for early identification of lameness in dairy cattle - a major welfare problem among dairy cows. The IceScore sensor (IceRobotics) could potentially be enhanced to provide an automated locomotion scoring capability by analysing walking gait, head movement, and the arching of a cow’s back, which are also indicators of lameness. Furthermore, the biomotional analysis (FBI Science) could potentially indicate lameness in animals.

Perhaps one of the most promising tools for automated recording of injuries is described in the contribution by Ingrid de Jong, who is developing video imaging of foot pad lesions in broilers at the slaughterhouse. Perhaps this technique could be adapted to measure lesions on carcasses (pig and chickens) as well.

Absence of disease

There are several devices that can potentially measure some symptoms of disease: body temperature (TemPlanT, TeleMetronics biometry), blood measures (IceSampler, IceRobotics), activity (IceTag3D, IceRobotics), tissue alterations (Ultrasonography, Wójtowski), EEG and ECG (Neurologger, NewBehaviour, see 'Absence of pain' below), heart rate and oxygenation recorder (Blip Systems, mentioned by Birte Nielsen), and respiration and hearth rate (ultra-wideband radar, OT Solutions). The TemPlanT system is an implant measuring body temperature in pigs and can be used to detect fever and thus give information on the health status in pigs. The IceSampler could be used to take blood for measuring e.g. white blood cell counts or acute phase proteins to detect activation of the immune system. The motion-sensor of the IceTag3D could perhaps be used to detect reduced activity in diseased animals. Ultrasonography was suggested for application to assess udder and teat health of goats and sheep, but it does require skilled human personnel to take and interpret the measurements.

The wireless heart rate and oxygenation recorder (Blip systems) is based on pulse oximetry in which a source of light, originating from a probe, is placed at a thin part of the animal's skin (in humans a finger is used). The light is partly absorbed by haemoglobin depending on whether it is saturated or not saturated with oxygen. By measuring the absorption of the light, the processor can compute oxygenation. The oximeter requires pulsatile, arterial flow and produces a graph of the quality of flow. The computer within the oximeter is capable of distinguishing pulsatile flow from other more static signals (such as tissue or venous signals) to display only the arterial flow. This device is not yet on the market, but a prototype has been developed. Further development is necessary particularly concerning the attachment of the sensor to the animal, as well as showing the relevance of this parameter for routine farm-animal welfare-assessment.

Finally, ultra-wideband radar may provide an interesting technology for welfare (health) assessment as it can be used to detect minute motions such as respiration rate and heart rate (variability). The radar can automatically detect periods when the animal is motionless and perform the measurements.

It is clear that progress is being made with respect to the automated recording of a number of disease symptoms. Some of these symptoms may also be used for assessing other aspects of welfare (e.g. heart rate may be used to assess pain, fear and human-animal relationships; temperature may be used to assess thermal comfort). While separate systems may be used to record separate symptoms, automatic recording of overall disease status, like overall welfare, will probably remain problematic, and may well require a human operator/auditor/assessor using some kind of expert (or decision support) system that takes a wider range of measures as input, some of which may have been recorded automatically.

Absence of pain induced by management procedures

One device was mentioned that could give an indication of pain/stress perceived by animals, called the Neurologger (NewBehaviour). This is a small device attached to an animal that (usually) has implanted electrodes to measure EEG or ECG. Comparing normal conditions with EEG and ECG levels during management (e.g. transport and slaughter) procedures, could perhaps give an indication of stress and pain perceived by the animals. The device is currently operational for research purposes in mice and has been tested on giraffes.

Furthermore, devices like the IceTag3D, which measures activity in cows, could give an indication of an animal being in pain by highlighting abnormal behaviour, when these were (known to be) valid indicators of pain. Also, bimodal wireless sensors were suggested by Nielsen as potentially useful for recording pain sensitivity. Considerable R&D can be anticipated before such tools are ready for routine on-farm welfare assessment.

Expression of social behaviours

Tracking animals' social behaviours can potentially be measured with several devices: PhenoTyper (Delta Phenomics), EthoVision (Noldus) and IceTag3D (IceRobotics). The first can only be used to measure behaviour of small animals, like rats and rodents, because the animal needs to be placed inside the PhenoTyper. EthoVision is a digital imaging processing system, using video cameras and video tracking of one or more animals, and can detect behaviours. It is currently not applicable on-farm, especially not in enclosures with a large group of animals (e.g. thousands of broilers). The IceTag3D is a tool that can monitor individual cow behaviour. Further research is needed to make this tool applicable to the assessment of social behaviours.

Expression of other behaviours

The systems mentioned under the welfare criterion 'Expression of social behaviours' could potentially be used for measuring other behaviours (e.g. exploration, foraging and play). Recording the time near enrichment materials (e.g. in pigs) may indicate levels of play directed at these objects.

Good human-animal relationship

This welfare criterion cannot be measured directly and is not mentioned by any of the companies or scientists as a principle that can be measured by their (or others') technology. However, some systems like UltraVox (Noldus, measuring vocalisations in rodents), wireless heart rate and oxygenation recorder (Blip Systems, mentioned by Nielsen) and ultra-wideband radar (OT Solutions) could perhaps also be used to measure fear or stress in animals provided the presence or absence of a human could simultaneously be detected.

Absence of general fear

This welfare criterion has not been mentioned explicitly by the respondents, but activity measures (flight), physiological measures (body temperature, ECG) and blood sampling are in principle applicable to this final welfare criterion.

Complementary issues

In addition to devices which can measure parameters linked to one of the welfare criteria, there are some other systems that are complementary to these devices such as the wireless sensor network (Ipema and Lokhorst). This wireless sensor network transfers information, but cannot measure the animal-based parameter itself. Animals have sensors on their body, or implants under their skin, which measure a certain parameter (e.g. heart rate, body temperature). However, these measurements need to be sent to a computer where they can be processed and analysed. Each sensor needs to send its information to the computer and should also be able to send it over a large distance. This may be impractical in some cases, e.g. when cows are located on pasture. This is where the wireless sensor networks can be of help.

A sensor can send its information to another sensor that is closer to the central computer and again to another sensor until it reaches the computer. In this way the sensors remain smaller and more energy-efficient than when they have to send the information to the computer directly. In addition to developing specific tools for assessing welfare aspects, there are a number of other needs for automation. These include (centralised) processing of information, integration of information from different sensors and integration into an assessment of overall welfare. In the more distant future perhaps, there may also be a need to automatically generate advice to the farmer as to how to improve welfare on his farm. These points have not been addressed in the contributions received.

5.3 Research and development issues

The expert survey has identified a wide range of problems and needs for further research. In order to realize the objective of automated monitoring of animal welfare, a lot of research still needs to be done. The main problems identified are related to economics, energy requirements, further technological developments, research focus, validation and social issues. The main points are summarised below.

Economics

Cost was identified as a major problem for the application of automated tools for farm animal welfare assessment by several contributors (Fancom, NewBehaviour, FBI Science, IceRobotics, TeleMetronics biometry). NewBehaviour pointed to the typically low profit margins in the farming industry and the role of policy makers (e.g. to consider legislation on the subject). Others pointed to a need for consumer responsibility and farmer interest in animal health and productivity as opportunities to cover costs (e.g. IceRobotics).

Costs are commonly perceived as a major obstacle, but solving technical problems (energy requirements and other technological developments) may actually have priority for research in the near future in order to show that automated recording can really fulfil its promise of more objective and valid welfare assessment.

Energy requirements

In most wireless sensor systems, energy management is a problem, especially when sensors must continue working throughout the animal's lifetime. This is the main problem for GPS systems. Also, several contributors noted that GPS cannot be used inside housing systems (Ipema and Lokhorst; NewBehaviour). There may be alternatives. In wireless sensor networks, for example, it is expected that wireless sensors in the future will carry software on board for the analysis of recorded information, which will not only reduce the communication frequency need but also reduce energy requirements.

Further technological developments

Several items listed for R&D will require further technological developments. For example:

- New sensors, electronics, software, model-based algorithms and user interfaces need to be developed (Fancom B.V.);
- In wireless sensor networks (Ipema and Lokhorst), the loss of information packages is an important research item;
- FBI Science identifies the following issues: further reduction of the size of the RFID sensors (transponders) and antennas for achieving adequate recognition of animals close to check-points; integration of different parameters such as body temperature or heart rate, and the integration of information in a central database;
- IceRobotics identifies a need for standardisation of sensor measures to facilitate bench-marking;
- Data abundance is a major technological problem especially in relation to video imaging: 'The problem is not data collection, but data mining, data analysis, and the interpretation of the data.' (Delta Phenomics). This is specified in the contribution from Noldus who noted that animals (pigs, broilers) touching each other may become one object for the vision system, requiring advanced contour-analysis and modelling of the animal's specific shape; specific posture changes (e.g. switching from standing to lying in pigs) may be difficult to detect and active shape models can help to resolve this; when animals are kept in large groups (50 or more pigs or broilers, as is often the case, esp. in broilers) than individual tracking will become practically impossible.

> "Further research is needed to develop and manufacture quality and cost-efficient PLF [Precision Lifestock Farming]-based products, in particular with respect to new sensors, electronics, software, model-based algorithms and user interfaces. Most of the current technologies for automatic monitoring of animal-based parameters are developed for experimental research and need to be translated to low cost, and real-time algorithms for practical field-use." (Fancom B.V.)

Research focus

Research focus ranges from life-long automated recording (e.g. Telemetronics biometry; Ipema and Lokhorst) to using automated recording to support measurements taken during a farm audit for certification, as this would 'more easily be universally applicable and with consistency across farms and across national boundaries' (IceRobotics). In general, exchange of information between people working on automated welfare assessment is likely to benefit mutual understanding and reaching common goals.

Many companies and activities are focussing specifically on laboratory animals (e.g. NewBehaviour) and on the application of technology for research purposes, rather than farm animals and use in commercial conditions. Perhaps more importantly, the focus is often not on animal welfare but on other (e.g. medical, production) aspects. One exception may be the validation research done on video imaging of foot pad lesions in broilers (De Jong), which was conducted specifically for welfare assessment in the Welfare Quality project.

However, here too, the prototype system needs further upgrading and must be prepared for commercial use. A tool validated for one species may require substantial R&D before it can be made applicable in another species. Technological expertise also needs to be combined with expertise on different species of farm animals and with specific expertise on welfare assessment and certification. Although such multidisciplinary collaboration is not always easy, the 'translation' of existing knowledge on laboratory animals and research settings to the case of monitoring of farm animal welfare is definitely a promising area for future investigation, given proper coordination and research focus.

Validation

Validation of the technologies and the parameters they measure is necessary. There may be a need for additional R&D to develop the measuring method itself (showing that a sensor really measures what it is supposed to measure, e.g. body temperature), but there is also considerable need for welfare validation, i.e. to determine what the parameter tells us about animal welfare. This is because measuring techniques are generally not developed for application in farm animal welfare but rather for laboratory animals in experimental/research settings. For example, it remains to be proved that the frequency and/or duration of visits by an animal to a feeding area are a valid indicator of hunger; it is not enough to simply show that hungry animals have altered feeder-visit patterns. It also requires a wider investigation into potentially confounding factors and how these can be taken into account, to derive an accurate assessment of hunger from recorded feeder-visit patterns (and other measures).

Further research is also needed as to how this acquired information can actually be used. How it can contribute to overall welfare assessment on a farm, but also how farms (including those without automated systems) can be compared and what action should be taken where a is a farm cannot afford to implement such systems.

Social issues

Poor farmer perception of the scale of welfare issues is identified as a potential problem by IceRobotics. In addition to external audits by independent third parties, they suggest using 'objective sensor-based welfare audit systems to highlight realities to the farmer'. They also identify a need for demonstration and training for farmers to get acquainted with the new technologies.

Other technologies raise other problems: database systems may raise concerns over the privacy of information; implants in themselves may pose a risk for animal welfare (surgical implantation) and initiate food quality problems (if implants end up on the consumer's plate). Another example is provided by De Jong who has measured foot pad lesions in broilers in abattoirs. This research raises both ethical (societal) and methodological questions. There has been concern in the Netherlands because the lesions were measured at the abattoir, instead of on-farm when the birds were still alive and could benefit from welfare improvements. Furthermore, De Jong tried to validate the system in comparison to human (veterinary) observation but it remains to be seen whether humans should be 'the golden standard'. The more welfare assessment that becomes established by hand-recording first, the more human-observation becomes a 'standard' that is increasingly difficult to replace with automated techniques (compared to de novo introduction). The implementation of automated recording techniques may be hampered if it has to wait welfare assessment, based primarily on human observations, has been developed at the European level.

A co-evolution where the value of automated recording is recognised from an early start may benefit the objective of standardised monitoring of farm-animal welfare, which includes sensor development, integration of welfare-relevant information (overall welfare assessment), automated labelling and certification, tracking and tracing and perhaps even (automated) generation of advice as to how animal welfare on the farm may be improved.

> "To assess animal welfare it will be necessary to measure a set of parameters. It should first be studied which parameters are indicative of welfare AND can be measured quickly and at low costs either on-farm or at the slaughter plant. Thereafter, a system of feedback to the farmer, linked with management advice, should be developed to improve on-farm welfare. When such a system is available, commercial products should be certified with respect to the welfare of the animal on-farm. Automatic systems to measure animal welfare will contribute to a low-cost and easily applicable system of monitoring animal welfare." (Ingrid de Jong).

5.4 Conclusions

Automated measuring of on-farm animal welfare is a new and promising field, especially with respect to solving issues like recording frequency, measurement objectivity, biosecurity and costs. A variety of welfare parameters could be measured using automation technology, but this requires existing technologies to be 'translated' for farm animal welfare use. Most technologies currently in use have been designed for laboratory settings and need to be translated to a routine and on-farm application. Table 2 summarizes potential (existing and under development) automated tools related to the twelve Welfare Quality welfare criteria.

More importantly, technologies need to be validated for welfare assessment. Several large companies and scientists who develop technologies that could be used for monitoring of farm-animal welfare, responded to our request to specify available tools and R&D issues. Whether or not automated on-farm monitoring of animal welfare will actually become a reality, will largely depend on policy decisions at various levels (research coordination, national level, European level). Many R&D issues urgently need to be addressed, ranging from solving technical difficulties to performing validation studies and dealing with social barriers that may be associated with automated recording. A clear priority setting and an integrated, multidisciplinary approach with a European-wide focus seems to be essential.

> "The use of wireless technology to identify and to monitor animal health and welfare is very promising; it has the potential to become the most powerful innovation in pig husbandry for the next decades." (Gerard van Essen, Telemetronics Biometry B.V.)

Table 2: Potential tools for on-farm automated welfare assessment.

WQ welfare criterion	**Potential automated tools available for:**
Absence of prolonged hunger	Body condition scores Blood sample parameters free ranging cows as hunger indicators Recording of rumination activity Real time positions of animals in the housing system (food area) Recording feeder visits in automated feeding systems
Absence of prolonged thirst	Real time positions of animals (drinking area) Blood samples: dehydration
Comfort around resting	Recording of lying time and biomotion (movement patterns of the body) Recording of sleeping positions Real time positioning (lying area)
Thermal comfort	Rumen bolus with temperature reading Implant for body temperature measuring in pigs
Ease of movement	Recording of biomotion Activity measurement via sensors, implant or camera-based Real time positions in the housing system
Absence of injuries	Early identification of lameness in cows (sensor) Video imaging of foot pad lesions in broilers
Absence of disease	Several devices for recording of body temperature, blood measures, activity, tissue alterations (ultrasonic), EEG and ECG, heart rate, respiration. White blood cell counts
Absence of pain induced by management procedures	EEG and ECG recording Activity recording
Expression of social behaviour	Video recording
Expression of other behaviours	Video recording
Good human-animal relationship	(Not measurable directly) Indirectly via heart rate, recording of fear and stress
Absence of general fear	Recording of activity, physiological parameters and blood sampling

To guide future R&D, we recommend using a matrix evaluating proposed tools in relation to the welfare measures and welfare criteria on one axis, and the R&D issues on the other axis. This matrix (see Table 3) describes for each proposed tool its stage of development (i.e. its need for further technological developments, including energy requirements); research focus (applicability to farm animals); validity for welfare assessment (including the link to existing welfare measures); socio-ethical issues (e.g. biosecurity risks) and economic feasibility.

Table 3: Example matrix of welfare requirements and issues for directing future R&D (research and development). A, B, C: Example tools for automated recording of (aspects of) farm animal welfare. All rated on a scale from --- to +++ with respect to their present achievement and potential.

Welfare criteria	**Tool**	**Stage of development**	**Research focus**	**Validity**	**Socio-ethical issues**	**Economics**
Absence of prolonged hunger	A	++→+++	Lab → Cattle	+ →+	++	-- → --
Absence of prolonged thirst						
Comfort around resting						
Thermal comfort	B	+→++	Lab→Pigs	+ →+++	--	+ →+
Ease of movement						
Absence of injuries						
Absence of disease						
Absence of pain due to management procedures	C	--→ +	Lab. Animals	- →+	--	--- → -
Expression of social behaviours						
Expression of other (natural) behaviours						
Good human-animal relationship						
Absence of general fear						

Response to R&D questions from our contributors was diverse, ranging from conceptual (e.g. Ipema and Lokhorst) to more tangible products (e.g. IceTag by IceRobotics, video imaging of foot pad lesions by De Jong). Some 'solutions' provide opportunities to incorporate potentially new welfare measures that have not been feasible by hand-recording , e.g. ultra-wide band radar to allow measurements of heart rate and respiration from OT Solutions. Others provide an automated alternative to a manual activity (e.g. the IceScore from IceRobotics which could replace manual body condition scoring). While finding automated solutions for existing welfare measures is a first priority, future R&D should keep an eye open, not only for new welfare measures, but also for more creative applications in previously unexpected areas.

As indicated, many aspects of animal welfare are addressed by at least some recording device, but all need further research to meet major challenges of combining expertise to validate systems, making them available for on-farm application in different species of farm animals, to jointly assess overall welfare, and at acceptable cost levels. The matrix described above can help focus R&D needs.

PART 2

IMPACT OF ANIMAL-BASED WELFARE ASSESSMENT

6 Introduction

The findings of Part 1 of this study suggest that the Welfare Quality project, in comparison to other approaches, has the most promise for on-farm welfare assessment although it is not complete yet. There is a lot of ongoing research on feasible indicators and integrated welfare levels, and it is to be expected that even after the project is finished, many research questions will remain. Nevertheless, it is still useful to explore now the potential for introducing an animal-based welfare assessment system in EU Member States.

The following questions arise when considering implementing such a system: Is it possible to translate animal-based welfare indicators into overall welfare levels and a corresponding marketing labelling system, in order to inform consumers about the welfare quality of food products? What economic costs and gains are involved in implementing an animal-based monitoring system? What policy issues should be taken into account when considering implementation?

Because of the complexity of the subject, which involves gathering knowledge from very different disciplines, this study focuses on one livestock sector: the dairy sector. This is particularly relevant for several reasons. The welfare of dairy cattle is becoming a more prominent topic within EU policy: the European Food Safety Authority (EFSA) is currently compiling a report on the welfare of dairy cows and it is likely that an EU Directive on the welfare of dairy cows will follow soon.[15] Data concerning the dairy sector is plentiful and accessible: the Welfare Quality project indicators for dairy cattle have recently been tested on 90 EU farms. Furthermore, the International Farm Comparison Network (IFCN) for dairy cattle has proved to be a useful source of economic data and welfare indicators in EU member countries.

The analysis is largely restricted to four countries: the Netherlands, Sweden, Italy and Austria. By selecting these countries, we have tried to achieve diversity in farm production systems, diversity in societal perception of animal welfare and geographical diversity. The selected countries are also all members of the IFCN network, so economic data of their dairy cattle is available. (Poland was initially one of the selected countries, but the necessary economic data was not obtainable. Instead, the analysis has been expanded to include Austria.)

In the following chapters, we will firstly discuss the economic impact of implementing an animal-based monitoring system and improving the level of animal welfare in the EU. Then we turn to the possible effects of a number of relevant socio-economic trends at meso and macro level in the areas of trade, the production chain and public opinion. We conclude with an overview of policy issues that arise when considering implementing an animal-based welfare monitoring system in the EU Member States.

[15] www.thedairysite.com/articles/1627/tackling-dairy-cow-welfare-issues/print

Before going into these findings, two further points should be made. First of all, the introduction of an animal-based welfare assessment system is not just a matter of implementing a new, more precise method of assessing animal welfare. An underlying – more or less implicit – purpose of the implementation of such a system is to enhance the general level of animal welfare within the EU.

A second point concerns the status of the findings as described in the following chapters. When it comes to estimations on economic costs, the effects of developments on the world market, or the influence of public concerns, the findings of this study should be considered as qualitative and indicative. The second part of this study, should be considered a *pilot* study, with findings that sketch out what factors should be taken into account when considering the implementation of an animal-based welfare monitoring system in the EU.

7 Economic impact

In order to make a rough estimation of the economic impact of implementing an animal-based monitoring system in the EU – and improving the general level of animal welfare – several stages must be taken into account. Firstly, animal-based welfare indicators have to be translated into integrated welfare levels, so that relevant parties like farmers, retailers, legislators and consumers can be appropriately informed as to the overall welfare quality of farm animals. Secondly, welfare enhancing measures that farmers can use to achieve a higher level of animal welfare need to be identified. Finally, the economic costs of taking these farming measures, as well as the costs of implementing an animal-based monitoring system, need to be estimated.

7.1 Constructing welfare levels

The assessment system currently under development in the Welfare Quality project includes a wide range of various animal-based indicators for dairy cattle (see Annex 1). The level of welfare on a given farm is estimated following the integration of these indicators with a quantitative type of multicriteria evaluation. This method involves the integration of individual indicators into sub-criteria; the integration of sub-criteria into criteria; and, finally the overall assessment (Botreau, R. et al., 2007). In this hierarchical approach, a total of 12 sub-criteria are defined, each encompassing multiple indicators. The indicators are mainly animal-based, complemented by a few environment-based ones, because animal-based indicators cannot be found for all sub-criteria (Veissier, I. and Evans, E., 2007). In the final integration step, four criteria are constructed from the 12 sub-criteria, each with a score between 0 and 100. These four criteria are: good housing, good feeding, good health, and appropriate behaviour. Thus, the level of welfare of a single farm can be expressed as a profile consisting of four scores. The Welfare Quality project aims to aggregate the four welfare criteria into an overall assessment by comparing farms or abattoirs to reference profiles that define welfare classes (e.g. from zero to three stars).

In this study, the analysis has been confined to a limited number of *single* animal-based indicators with different levels of welfare constructed from these indicators. It is obviously necessary to interpret the project findings with this limitation in mind.
The choice of animal-based indicators to assess the animal welfare levels of dairy cows is driven by the impact of the indicator on the welfare of dairy cows as well as by the availability of scientific information about underlying risk factors related to dairy cow housing and management. As a result, two animal-based indicators are analyzed: i) the percentage of clinically lame cows in a herd; ii) the percentage of cows in a herd with clinical mastitis. Both lameness and mastitis have a significant impact on dairy cattle welfare.

In order to determine welfare levels concerning the prevalence of lameness and clinical mastitis in a herd, a number of Dutch veterinarians were asked to define a 'low', a 'medium' and a 'high' level with respect to the prevalence of lameness and clinical mastitis in herds in Europe. (We also consulted Italian and Swedish veterinarians, but we did not receive a response.) A prevalence below the low level is assumed to be associated with a high welfare level of the herd; a prevalence between the low and the high level was assumed to be associated with an in intermediate welfare level; and a prevalence higher than the high level was assumed to be associated with a low welfare level.

According to the estimates of the veterinary experts, low, medium and high welfare levels for the combined lameness and mastitis indicators have been defined as presented in the table below.

Table 4: Low, medium and high herd welfare levels, based on herd prevalence of lame cows, and herd prevalence of cows with clinical mastitis.

Prevalence → Mastitis / Lameness ↓	> 40%	15-40%	< 15%
> 25%	WELFARE LEVEL LOW		
15-25%		WELFARE LEVEL MEDIUM	
< 15%			WELFARE LEVEL HIGH

To clarify the table: herds with both a mastitis prevalence of more than 40% and a lameness prevalence of more than 25 % are considered to have a low welfare status, whereas herds with less than 15% lameness and less than 15% mastitis have a high welfare status.

According to (not published) detailed information from the agricultural research institute in France (INRA), if more than 25% cows on a farm are clinically lame, the welfare score for lameness is below 20 (on a scale from 0 to 100). A score of 25 % lameness is thus considered to be a critical welfare limit. These findings correspond with the findings of the consulted veterinarians in this study.

7.2 Welfare enhancing measures

In order to move from a lower to a higher level of animal welfare, farmers have to take measures that enhance the welfare of their livestock. The animal-based approach gives farmers the freedom to choose welfare enhancing measures that best fit their overall farm management. However in order to model the possible economic impact of enhancing animal welfare, cost estimations have to be made with regard to concrete measures. The following paragraphs provide details of measures identified as controlling risk factors related to housing and management underlying lameness and clinical mastitis in dairy cows.

7.2.1 Clinical mastitis

For clinical mastitis, the following five measures to control risk factors have been identified (Elbers, A.R.W. et al., 2007; Barkema, H.W. et al., 1999a,b; Sato, K. et al., 2008; Steeneveld, W. et al., 2008):

1. Disinfection of maternity area after every calving. The room must be cleaned (complete removal of manure, straw, etc.), and disinfected with a disinfecting agent (e.g., Halamid);
2. Disinfection of cubicles at least once a month. Removal of any substrates, and disinfected with a disinfecting agent (e.g., Halamid);
3. Regular replacement of stall bedding (at least once a week);
4. Sufficient grazing time for milking cows. The milking cows must graze at least 150 days/year for 8 hours;
5. Separation area for infected cows. A separate area is available to separate infected cows from healthy ones, with a physical barrier, e.g. a concrete, wooden or steel wall.

Given the nature of the available information in scientific literature, it is not possible to reliably estimate the effect of each of these measures on the herd prevalence of cows with clinical mastitis. For the current exercise, we are assuming that each individual measure will decrease the herd prevalence of cows with clinical mastitis by 5%. Furthermore, effects are assumed to be additive, i.e. significant interactions between measures to control risk factors are assumed to be absent.

7.2.2 Lameness

The following seven measures to control risk factors in lameness have been identified in scientific literature (Somers, J.G.C.J. et al., 2003, 2005a,b,c; Cook, N.B. et al., 2004; Cook, N.B. 2003, 2004; Amory, J.R. et al., 2006; Holzhauer, M. et al., 2006, 2008; Espejo, L.A. et al., 2006; Barker, Z.E. et al., 2007; Espejo, L.A. and Endres, M.I., 2007; Platz, S. et al., 2008; Norring, M. et al., 2008; Onyiro, O.M. et al., 2008a,b; Onyiro, O.M. and Brotherstone, S., 2008):

1. Cow mattresses in cubicles. In every cubicle, a cow mattress is available;
2. Sand in cubicles. Sand is used as bedding material for cubicles during the entire period when cows are present in the stable;
3. Cubicles larger than 115 * 230 cm, and no brisket board is present;
4. Slatted floor with manure scraper. The stable is equipped with a slatted floor and an automatic manure scraper automatically cleans the floor several times a day;
5. Straw yard. When in the stable, cows can walk and lay down freely on straw bedding without cubicles;
6. Grazing milking cows. The milking cows must graze for at least 150 days/year for 8 hours;
7. Transition cows are housed in a specific stable. For 3 weeks prior to calving and 3 weeks after (transition period), cows are housed in a specific stable.

The effects that different measures have on controlling risk factors related to herd prevalence of severe lameness, are indicated in scientific literature. The percentage of cows within a herd with a locomotion score of 3 on a 3-point scale, or locomotion score 4 or 5 on a 5-point scale, for example. These estimates are mostly based on comparisons with the control treatment (e.g no mattress in cubicle; no sand in cubicle; cubicles smaller than 115 * 230 cm, brisket board present; solid concrete floor without automatic manure scraper; slatted or solid concrete floor; zero-grazing). The effect of providing transition cows with a special housing and management is estimated by veterinarians who have been consulted. The effects, in terms of a decrease of the herd prevalence of severe lameness, of each measure are estimated as follows:

Measures to control risk factors for lameness		Estimated effect on herd prevalence
1.	Cow mattresses	5%
2.	Sand in cubicles	15%
3.	Cubicles > 115 * 230 cm, no brisket board	10%
4.	Slatted floor with manure scraper	10%
5.	Straw yard	20%
6.	Grazing milking cows	20%
7.	Special housing transition cows	10%

The effects of measures to control risk factors related to lameness are assumed to be additive (as they are for clinical mastitis). It should be noted that for the current exercise we only took risk factors into consideration that could be readily explored in an economic context. Additional sets of relevant risk factors for lameness and mastitis that do not comply with this latter condition include genetic and nutritional factors which require a more elaborate and sophisticated modelling approach outside the remit of this study.

Table 5: Selected measures for risk control and estimated effects on prevalence rates for lameness and clinical mastitis.

Selected measures for clinical mastitis	**Estimated lowering effect on herd prevalence***	**Selected measures for lameness**	**Estimated lowering effect on herd prevalence**
Disinfection of maternity area	5%	Cow mattress in cubicle	5%
Disinfection of cubicles (once a month)	5%	Sand bedding in cubicle**	15%
New cubicle bedding (every week)	5%	Minimum size cubicle (115x230 cm), no brisket board	10%
Access to pasture (lactating cows)	5%	Slatted floor combined with automatic manure scraper	10%
Separation area for infected cows	5%	Deep litter area with straw (no cubicles)	20%
		Access to pasture (150 days a year; 8h/day)	20%
		Separation area around calving	10%

* The scientific literature did not reveal reliable estimations of the effects of the risk factors on herd prevalence of clinical mastitis. We assumed that each factor decreases herd mastitis prevalence by 5%.

** Not applicable in combination with slatted floors in walking area.

Access to pasture turns out to have a positive effect on both the prevention of lameness and the prevention of mastitis.

The measures to control risk factors are used in the following paragraphs to estimate the costs of reaching the highest welfare level concerning lameness and mastitis for typical farms in the four selected countries. But first some details will be presented of the farm structure and dairy production in the selected countries.

7.3 Characteristics of selected countries

In order to obtain a rough indication of the economic consequences of welfare enhancement regarding lameness and mastitis, for each of the selected countries the following information was gathered via the IFCN network: i) the average number of cows, housing type, bedding type, access to pasture, floor types and labor costs per hour of a *typical* dairy farm; ii) yes/no compliance with the selected measures (risk factors); and iii) associated costs. This information has been combined with data on cost price structures of the selected countries (IFCN Dairy Report, 2008). Table 6 shows some characteristics of the four selected countries with respect to farm type and milk production.

Table 6: Characteristics of dairy production and typical farm structure in the four selected countries.

Milk production facts per country	**Netherlands**	**Italy**	**Sweden**	**Austria**
No. of dairy farms	21000	60000	8000	50000
Average farm size (cows)	65	35	50	12
Quota (mill tons)	11.5	11	3.3	3.2
Farm characteristics of a typical farm	**NL-65**	**IT-133**	**SE-50**	**AT-25**
Region	East	Lombardia	Skåne, Hörby	Mühlviertel
Kind of farm	Family farm	Family farm	Family farm	Family farm
No. of cows	60	133	54	25
Farm description of the typical farm				
Total agricultural land[1] (ha)	40	54	80	30
Land used for dairy enterprise[2] (% of total agr. land)	100%	100%	70%	100%
Stocking rate[3] on total ha	1.64	2.46	0.63	0.85
Total labour input[4] (labour unit)	1.3	4.3	1.9	1.8
Family labour input (% of total labour)	93%	56%	90%	100%
Other enterprises[5]				forestry
Dairy specific data of the typical farm				
Milk yield (kg ECM[6]) / cow)	8400	8800	9500	6800
Milk production (t ECM)) (quota)	545	1176	475	170
Replacement rate (%)	30%	29%	39%	30%
Age of first calving (months)	24	27	27	28

1) Without forest und other land

2) Incl. setaside

3) No. of cows / total agricultural land

4) Hired and family labour input for the whole farm (1 unit = 2100 hours)

5) Other than crop and dairy

6) ECM = Energy corrected milk (4% fat, 3.3 % protein)

A striking difference is the *average* farm size in Austria compared with the other three countries: 50,000 typically small farms with an average of 12 cows per farm. The overall average farm size in the other selected countries is between 35 and 65 cows per farm. The *typical* Italian farm has the largest amount of cows per farm: 133 cows compared to 65 cows or less in the other countries. The typical farms in the selected countries are all characterized as family farms.

However, the percentage of family labour input in Italy is substantially less than in the other selected countries (only 56%). Sweden and Austria have a relatively small stocking density per hectare. Austrian dairy farms have the lowest average milk yield per cow per year.

7.4 Costs estimations welfare enhancement

According to the data received from the IFCN contact persons, typical country farms in the Netherlands and Sweden have an average farm size of 60 and 54 dairy cows, respectively, which are held in cubicle sheds with straw or sawdust bedding and slatted walking floors and with access to pasture. A typical country farm in Italy has an average farm size of 133 dairy cows, held in cubicle sheds with straw or sawdust bedding, but with solid walking floors and no access to pasture. A typical farm in Austria has an average size of 25 dairy cows, held in tied-up housing systems on concrete floors with straw.

The prevalence rates of clinical mastitis and lameness on typical farms in Sweden, Italy and Austria are unknown. We only know the average prevalence rates for Dutch dairy farms. Thus we lack insight in the actual welfare levels of typical farms with respect to mastitis and lameness. However, knowledge about the compliance of typical farms with measures for risk control is available. Based on this knowledge, estimations have been made about possible costs involved in animal welfare improvements. With regard to cubicle stables, nine relevant measures related to mastitis and lameness have been selected.[16] In calculating the costs to achieve a higher welfare level, we assume that the highest welfare level for mastitis and lameness can only be reached if all these nine risk measures are dealt with. Table 7 shows the welfare enhancing measures, the compliance of standard farms in the Netherlands, Sweden, Italy and Austria, as well as the estimated costs. Annex 3 gives a more detailed description of the costs as estimated by the contact persons of the selected countries.

[16] Deep litter is not applicable in cubicle stables; mattresses and sand bedding in cubicles are not simultaneously applicable; sand bedding is not applicable in combination with slatted floors in the walking area.

Table 7: Compliance with measures for risk control on typical farms in the selected countries and estimated costs to achieve the highest welfare level.

	The Netherlands	Sweden	Italy	Austria
Average number of dairy cows:	60	54	133	12
Type of farm:	Cubicles, slatted walking floors	Cubicles, slatted walking floors	Cubicles, solid floors	Tied-up, concrete floor with straw
Labor costs per hour:	€23	€19	€12	€12 - €18
Compliance with measures (yes +/no -): *Mastitis* Disinfection of maternity area Disinfection of cubicles (ones a month) New cubicle bedding (every week) Access to pasture (lactating cows) Separation area for infected cows *Lameness* Cow mattresses in cubicles Minimum size cubicle, no brisket board Slatted floor with automatic manure scraper Access to pasture (150 days/year; 8h/day) Separation area around calving	 + - (€23) + + - (€10) - (€15) - (€ 7) + + +	 - (€11) - (€37) + + + + + + + - (€19)	 - (€4) - (€39) + - (€np)* + - (€25) + +*** - (€np)* - (€7)	 - # - no cub # + + - (€10) - no cub # + - tied-up # + - tied-up #
Estimated costs to reach the high welfare level	**€55**	**€67**	**Not possible*** (**€75**)**	€10
Total costs per cow per farm per year	€4.000	€4.000	€3.700	€5.700
% Increase of overall costs	1,6%	1,7%	(2,0%)	0,2%

* Compliance with access to pasture is supposed to be not feasible. By our definition; the highest welfare level can thus not be reached.

** Estimated total costs for all measures the Italian standard farm does not comply with.

*** Italian typical farms are equipped with a solid floor with anti-slip diamond-shaped design profile and automatic manure scraper. This is believed to have an equal effect on animal welfare as slatted floors with a manure scraper.

All these measures improve the welfare level on farms with cubicles but are not applicable on farms with a tied-up system

The typical Swedish farm complies with six out of nine risk factors, with a presumed accumulated effect of 60% reduction in lameness and mastitis (see Table 7). The typical Dutch farm complies with five risk factors with a presumed accumulated effect of 55% reduction in lameness and mastitis. The typical Italian farm complies with four risk factors with a presumed accumulated effect of 30% reduction in lameness and mastitis. The typical Italian farm uses stables with cubicles but, unlike Dutch and Swedish farms, in combination with solid walking floors and no access to pasture. In Italy, access to pasture is considered less feasible because of the domination of maize and lucerne silage as the main feed crops in the dairy sector. These crops (determined by climatic conditions) are the most productive feed crops and it explains the zero-grazing system in the Po Valley. Given our assumptions of a high welfare level, i.e. compliance with *all* selected welfare measures, this implies that an Italian typical farm would not be able to achieve the highest welfare level for lameness and mastitis. This is not to say that higher welfare levels funded on a wider variety of animal-based indicators are not feasible for dairy farms in the Po Valley.

The estimated costs of achieving the highest level of welfare for lameness and mastitis are higher for Swedish typical farm than for the Dutch one. This may seem at odds with the ranking of the standard Swedish farm, since a Swedish farm needs to apply fewer measures than a Dutch farm in order to reach the higher level. However, it can be explained by the costs per action that each country has to carry out, which varies between countries.

Austria is the only selected country where typical farms are equipped with a tied-up housing system. In tied-up systems, only four out of the nine risk factors for cubicle stables are applicable. The standard Austrian farm complies with three of these risk factors: new straw bedding every week, minimum sizes of cow stands and access to pasture. They don't comply with the measure of supplying a separation area for infected cows, a measure that is estimated to lead to a 5 % reduction of mastitis prevalence. From the available 45% reduction by applicable measures the Austrian farm realizes up to 40%. Austrian tied-up farms probably already have or can easily reach (with small costs) a high welfare level concerning lameness and mastitis.

Reducing mastitis and lameness levels should not just be associated with costs for enhancing measures, but also with certain benefits. These include sustained milk yield, reduced costs for health care and reduced labour costs. In the Dutch case, these benefits could add up to €100 per prevented clinical case of lameness (Dijkhuizen, A.A., 1992; Dijkhuizen, A.A. et al., 1995) and up to €260 per prevented clinical mastitis case (Enting, H. et al., et al., 1997). In the Netherlands, the average clinical mastitis prevalence is estimated at 30% and the average lameness prevalence at 20% of the total number of cows per herd. (According to Table 4, a Dutch average farm is thus considered to have a *medium* welfare level.) Based on these numbers, a typical Dutch farm with 60 cows will have on average 18 cows with clinical mastitis and 12 cows with severe lameness. At herd level, this represents associated costs of €4,680 for mastitis and €1,200 for lameness giving a total of €5,880 for an average herd of 60 cows.

To reach the highest welfare level for lameness and mastitis according to our definition, a typical Dutch farm should halve the herd prevalence for clinical mastitis from 30% to 15% and reduce the prevalence of lameness from 20% to 15%, This would reduce the herd costs for clinical mastitis by €2,340 and severe lameness by €300 i.e. a total cost reduction of €2,640 per year for a herd with 60 dairy cows or €44 per dairy cow per year.

In Table 7 we have estimated that for a typical Dutch farm to reach the highest welfare level concerning lameness and mastitis, the cost is €55 per cow per year. So the reduction in costs for fewer outbreaks of mastitis and lameness already largely compensates for the expenditure required to reach the highest welfare level. This compensation of costs by benefits is obvious in cases of welfare reducing *diseases*. The financial benefits of other welfare enhancing measures concerning positive feelings or more natural dairy cow behaviour, for example, are more difficult to quantify.

7.5 Monitoring costs

At this moment, it is difficult to see the animal-based welfare assessment and monitoring system of the future. A lot of questions remain unanswered. Which animal-based welfare indicators will be included in the assessment? Will it function as a mandatory monitoring system (public legislation); a private quality system only mandatory for its own members; or will it remain a completely voluntary system designed as a tool for farmers for on farm welfare assessment? And what kind of automation will be used to facilitate measuring the animal-based welfare indicators?

If implemented as a mandatory system within EU Member States, some kind of periodic on-farm assessment of welfare indicators by an independent controller will be necessary. In the Welfare Quality project, the time spent per control is estimated up to 4 hours. The costs per control in that case could be up to €320 (if in the Netherlands). The annual cost will depend on the number of independent on-farm assessments that are considered necessary, with one per year a minimum standard. In addition, the farmer will be required to interpret the scores of indicators that are incorporated in the welfare assessment that is applied on the farm. It is very likely that further automation of indicator measurement will be necessary in order to make this effort feasible. Farmers who strive to reach higher welfare levels might need to be supported by farm advisors (i.e. veterinarians) to select and perform welfare enhancing measures for their specific farm situation. This will cost approximately €130 per month (Dutch situation).

In Part 1 of this report, the state-of-the-art concerning automated recording of welfare has been presented. We have concluded that a variety of welfare indicators could potentially be measured using automation technology. However, most existing technologies have been designed for laboratory settings and need to be translated to routine and on-farm application. Costs will obviously depend on the precise applications being implemented. Equipping stables with real-time video recording, for example, requires an investment of about €1,000 per video system; applications for activity measurements via sensors or implants could cost €150 per cow (excluding registration facilities); cell counts in blood samples for mastitis prevention may cost €5 per cow.
We can conclude that the implementation of animal-based on-farm welfare assessment will certainly imply further costs which are related to the kind of monitoring system applied. At this moment, it is not possible to give a substantiated estimation of these costs or the level of automation possible. Applications of automated welfare assessment may vary between farm types and member states, and depend on the existing state of technology on the farm and the farmer's individual husbandry skills and entrepreneurship.

7.6 Conclusions

This brief analysis, with welfare indicators restricted to lameness and mastitis, shows that the economic impact of the introduction of an animal-based welfare assessment in combination with achieving certain welfare levels will vary among farms in EU Member States. For member states with a relatively low compliance with welfare enhancing measures, it will be a relatively steep climb to reach higher welfare levels. As a consequence, high welfare levels concerning mastitis and lameness might not always be feasible within existing farm structures:
substantial welfare improving measures like outdoor grazing cannot be met in each situation. For farms with a relatively high compliance with the defined welfare enhancing measures for lameness and mastitis, like the small standard farm in Austria with tied-up housing and access to pasture, the effort required for reaching the highest welfare level for lameness and mastitis will be minimal.

The implementation of an animal-based welfare system can thus be a competitive advantage or disadvantage for certain farm types. The necessary investments and related costs of achieving higher welfare levels concerning lameness and mastitis range in our example from 0,2% up to approximately 2,0 % of the total operating costs of the farm (depending on the actual farm welfare level with respect to lameness and mastitis).

We can expect there to be substantial financial benefits associated with improved welfare, especially in the case of cattle diseases with a high impact on animal welfare, like lameness and mastitis. It is important to keep these benefits in mind and communicate them to farmers, in order to support thoughtful consideration concerning welfare management. With a broader spectrum of animal-based welfare indicators taken into account, costs can be expected to increase further, whereas the financial benefits will not be easy to quantify.

In our brief analysis, only costs concerning welfare enhancing measures with respect to lameness and mastitis are included. Costs related to the monitoring system itself are not taken into account. At this moment, it is impossible to make a thorough estimation of these costs. Applications of automated animal-based welfare monitoring, granted that such a system might become implemented, may greatly vary between EU Member States, also depending on the current state of farm technology, farmer skills and entrepreneurship.

8 Socio-economic trends

A broad variety of European and worldwide trends and developments in social and economic areas can directly or indirectly affect the feasibility of implementing an animal-based welfare monitoring system and welfare enhancing measures in the dairy sector. In the following paragraphs, relevant trends and developments at meso and macro level are described from the perspective of dairy farmers, dairy companies, retail organizations, and consumers. In addition, corresponding threats and opportunities for the implementation of an animal-based monitoring system and animal welfare improvements are identified. In the next chapter, the policy issues will be discussed that stem from these trends, threats and opportunities, which are relevant when introducing an animal-based approach in the EU.

8.1 Relevant trends for dairy farmers

For dairy farmers within the EU, there are several trends and developments likely to impact the feasibility of the implementation of an animal-based welfare monitoring and related welfare enhancing measures. These trends are:

◊ ***Relaxation and abolition of the milk quota system in 2015***

In 2007, the European Union put forward concrete proposals to liberalize and eventually abolish the milk quota system in the EU by 2015. In its CAP Health Check proposal,[17] the European Commission argues that the dairy quotas are no longer valid as the EU is now facing a growing demand for high value products, especially cheese and fresh dairy products. The European Commission has suggested a gradual increase in quotas to allow a smooth transition to market-oriented dairy policy and a 'soft landing' for the sector before the quota system expires on 31 March 2015. Milk quotas have been in place in EU Member States since 1984.[18]

◊ ***Decreasing protection of the EU market from foreign markets and competition***

Since 2000, there has been a steady cutback of price support for the dairy sector. Since 2003, the aims of EU dairy policy has been to decrease price distortions between the EU and world dairy markets through successive reductions in milk intervention prices, to increase competitiveness and market orientation, and to give the industry an incentive to produce more value-added products.[19] The increasing demand for dairy products from Asia, the Middle East and South America, have ensured a good milk price for European dairy farmers, especially during 2007. Consequently, EU export subsidies have been cut back to zero. But with the declining prices for farm goods since late 2008, the EU has recently re-introduced export subsidies for some dairy products (butter, cheese, and milk powder) after two years of suspending the payments. As a consequence of the cutback of price support, milk prices will become more volatile.

[17] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0722:FIN:EN:PDF.

[18] With the exception of France, where milk quotas were introduced only a few years ago.

[19] Commission of the European Communities, 2007.

◊ ***Strong tendency towards large scale farming***

There is a strong tendency towards fewer but bigger farms and regional concentration. This tendency towards large-scale farming is a response to increasing international competition following the liberalization and internationalization of the dairy market. Farmers are using economies of scale to compensate for higher production costs. Herd sizes are predicted to grow at three times the rate of previous years. (Isermeyer, F. and Lutter, M., 2008).

◊ ***Increasing production costs due to societal demands***

EU dairy farmers are increasingly confronted with additional legislation and demands for higher production standards in response to societal issues. These relate to the environment (manure legislation, CO2 and methane emissions), animal health, animal welfare and food safety. This results in higher production costs.

◊ ***Fall in direct public payments (CAP)***

There is an increasing tendency in current EU policy propositions to relate farmer income support to environmental services and animal welfare (2nd Pillar). In 2013, the EU will be reconsidering the system of farmer income support. Criteria for income support are likely to be changed at that time and might offer an opportunity for supporting further welfare improvements by farmers.

Liberalization and internationalization are having a strong effect on dairy farming within the EU. According to Zijlstra (2008), the abolition of milk quotas will lead to a 2- 3 % increase in total EU milk production, according to various model studies. At the same time EU milk prices are estimated to decrease between 5% and 15%. EU regions with a combination of advantageous scores for entrepreneurship, profitability, competitive positioning of a processing industry and favourable soil production potential, like the North Sea region and the Po Valley, are likely to see an increase in their milk production. EU regions with unfavourable scores for entrepreneurship, profitability and competitive strength of their processing industry, will probably not increase their milk production. These are South European and certain East European countries.

Increased milk production within the EU and other countries could lead to downward price adjustments. In addition, liberalization and internationalization will in time result in a levelling of EU and world market prices. The European dairy sector is expected to be less protected from price fluctuations as a result of WTO agreements (which are currently still pending). As a consequence, European dairy farmers will experience larger fluctuations in the milk price than before. The milk prices for European dairy farmers will become more susceptible to international developments in production and demand, and thus to milk price fluctuations.

Feed prices can also be expected to fluctuate more (as a result of the growing interest in first generation biofuel production out of maize, soybeans and rapeseed), resulting in increased uncertainty and fluctuations in farmer income.

The EU-27 is currently the world's largest milk producer and the second largest milk exporter. In 2006, the EU-27 accounted for 25% of global milk production. Overall, in dairy regions worldwide, there is an increase in production. but EU production is decreasing, whereas production in North America, Oceania, Latin America, Asia and Africa is steadily growing (Isermeyer, F. and Lutter, M. 2008).

Worldwide demand for milk and milk products is growing faster than the increase in production. Growth in dairy product demand is predominantly driven by Asia, the Middle East and South America. However, it is unlikely that the export markets with the fastest growing demand are willing to pay a premium for dairy products that are produced with extra animal welfare in mind. Generally speaking, countries in North-Western Europe and North America tend to care more about animal welfare than Asian, South American and African economies.

Existing price mechanisms in animal-based product chains are not always helpful for the improvement of animal welfare (Ingenbleek, P. et al., 2006). The spot markets in particular, lack incentives to improve animal welfare, and instead contain incentives to minimize the costs of animal welfare. The freer market, growing worldwide demand for dairy products, and current higher milk prices could seduce dairy farmers to leave a cooperative and to sell their milk on the spot market. However, preliminary results of Isermeyer and Lutter (2008) indicate that farmers prefer partnerships with one or two milk processing plants. In their survey, 95% of responding EU dairy farmers who are members of European Dairy Farmers preferred a strong relationship with just one milk processing plant and 4% had two trading partners in 2008. It is implied that this situation is sustainable for the future.

According to Isermeyer and Lutter (2008), European dairy farmers expect an increase in land rents by 30% in the run up to 2013, as a result of competitive land claims (e.g. production of rapeseed for biodiesel and other agricultural and non-agricultural activities) resulting in additional costs of 0.8ct/kg milk. It is uncertain how this will influence cow access to pasture.

Threats and opportunities

The following economic consequences of the above mentioned trends for EU dairy farmers can be identified:

- As a result of increased competition, increased costs and greater fluctuations in milk prices, dairy farmers in several member states may be faced with a *decline in farmer income*, which implies less financial room for additional investments in animal welfare improving measures;
- Farmers will face *higher production costs* as a result of additional societal demands concerning environment, welfare, health and animal welfare;
- With milk prices under pressure, several farmers might focus on *product differentiation* including a more welfare-friendly production system, as an opportunity to distinguish themselves from colleagues who compete exclusively on price. The fact that most European farmers say they prefer strong partnerships with one milk processing plant, might also support welfare improvements. The latter creates an opportunity for implementing certain welfare standards by dairy processing companies, thereby pushing farmers towards compliance;
- The EU is predominantly producing for its home markets. Around 89% of the EU dairy products (especially fresh products) are traded within the EU. The other 11% is destined for third countries (Zijlstra, J., 2008). Product differentiation may therefore offer new opportunities for dairy products in the EU market;
- Improving animal welfare goes together with *reducing animal health costs*. For dairy farms this is a real opportunity, as severe welfare problems often happen to be health problems (lameness and mastitis for instance);

- In general, public opinion tends to perceive large-scale farming as adversary to *animal welfare*, and as a sign of increasing industrialization of farm animal husbandry. The difficulties big farms face in providing access to pasture for dairy cows may further increase public criticism of farming practices. In a country like the Netherlands, the public demand for access to pasture for dairy cows is rather strong. On the other hand, animal welfare may also benefit from the trend towards large scale farming, because it increases opportunities for automated practices on farms and automated welfare monitoring;
- Policy propositions to reconsider farmer income support as provided by the Common Agricultural Policy (CAP) might create opportunities for further implementation of welfare enhancing measures on farms.

One remaining issue should be mentioned here. Entrepreneurship and cattle management capabilities (husbandry skills) vary between farmers and between EU Member States, and could considerably affect the implementation of an animal-based welfare system. Progressive entrepreneurs might consider a welfare system as an opportunity for product differentiation and extra income possibilities. Dairy farmers in regions or countries in which management skills still need improvement, are unlikely to be enthusiastic about implementing a welfare monitoring system. For that reason, animal-based welfare monitoring seems more likely to be implemented in Western than in Eastern European countries.

8.2 Relevant trends concerning dairy companies and retail organizations

Several trends with respect to dairy companies and retail organizations may directly or indirectly influence the feasibility of an animal-based welfare approach. The following trends can be considered to be relevant:

◊ ***Concentration and consolidation among dairy companies***

In recent decades, the domestic-oriented cooperative dairy industry has become more internationally focused. Several co-operatives are already global players. Dairy companies are also expanding their activities to Eastern European and international markets. Due to a global shortage in milk, strategic access to sufficient milk supply has become more important. Mergers and acquisitions between dairy companies might affect whether dairy farmers continue co-operative membership or sell milk on the spot market.

◊ ***Consolidation of retail organizations and the rise of discounters***

The European retail sector is characterized by a relatively high concentration rate. Supply chains are now fundamentally retailer-driven (Fox, T. and Vorley, B., 2004). Large retailers hold two key positions: they have become the main 'gateway' for suppliers who now have fewer options for seeking a route to market; and they are 'gatekeepers' for access to consumers and information about their purchasing behaviour and preferences. Supermarkets are working with fewer preferred suppliers, driven by their desire to guarantee a certain standard of quality and chain transparency (Hingley, M.K., 2005; Fox, T. and Vorley, B., 2004). In addition, discount retailing is on the rise in Europe and traditional supermarkets are beginning to embrace the discount model to lower their costs and satisfy consumer demands for cheaper goods. Lastly, there is a growth in own-brand labels as a resource for strengthening customer loyalty (Burt, S.L., 2000), and a as a result of fierce price competition and a preference to control the supply chain (Planet Retail, 2007).

◊ ***Strategies oriented towards high added-value products***

The European market for dairy products is largely saturated. Competition strategies focus on quality and added-value dairy products. A recent trend is that more consumers are willing to pay more for taste experience and for products with a clear provenance (Arla Foods, 2007).

Threats and opportunities

The following consequences of the above mentioned trends concerning dairy companies and retail organizations can be identified:

- Mergers between dairy companies with a dominant production focus may have a downward effect on the milk prices, leaving farmers with little room for enhancing animal welfare, whereas mergers with a marketing focus leave room for good milk prices and opportunities for welfare investments in relation with product differentiation;
- If consumers consider animal welfare as an extra quality option, the trend towards value-added products might suggest willingness to pay for improved animal welfare. It might be an opportunity to link animal friendliness to other quality attributes;
- Price mechanisms in the farm-to-retailer chain may create a barrier for acceptance of animal-friendly production methods (Ingenbleek, P. et al., 2006). Price mechanisms are linked to governance structures, ranging from spot markets to fully integrated chains. Improvement of animal welfare is more likely to be realized in fully integrated chains than in spot markets, which are focused on low costs;
- A system that markets animal welfare to consumers needs to be supported by retailers, because of their 'gatekeeper' role with respect to consumers. Retailers have access to consumer information and consumer demands. At the same time, they can decide what kinds of products are offered to consumers, at what price and against which conditions. The question is whether retailers choose to be a catalyzing factor in implementing a system that improves animal welfare. This will depend on the extent to which a system of animal welfare will support their customer-oriented strategies. Market conditions have a strong influence on that. According to Ingenbleek et al. (2006), price wars are not the end of improving sustainability, including animal welfare, but rather a delaying factor;
- Retailers have an important influence on the purchasing behaviour of consumers. Hence price decisions by retailers significantly affect the consumers' price perception (Ingenbleek, P. et al., 2006). An important driver in pricing behaviour by retailers is competition on price and quality. Sustainable and 'ethical' products are increasingly used strategically, to attract customers to a supermarket or to improve store image. The market share of animal-friendly products may benefit from this. Leveraging extra demand for animal-friendly products in the mainstream, however, can be adversely affected by creating high margins in a limited segment of customers.

8.3 Consumer perceptions and public concerns

The following trends with regard to consumer behaviour and public concerns are relevant in relation to the subject of animal welfare enhancement:

◊ ***Societal concern for animal welfare***

Animal welfare is a pressing public concern in the EU Member States. The results of the Eurobarometer public survey (2007) underline the importance of animal welfare in the public mind. Below we summarize these results with regard to the EU-25 and the four selected countries, the Netherlands, Sweden, Italy and Austria.

The Eurobarometer survey shows an increased societal concern for how farm animals are treated. Citizens of the four selected countries find it very important that the welfare of farm animals is protected (all above 7.5 on the 10-point scale, with Sweden on 9) and the majority of European citizens wish to be better informed about the way farm animals are kept. This desire is particularly strong in many Mediterranean states, such as Italy.

A vast majority of European citizens stresses the need for further animal welfare improvement in their country (EU-25: 77%; Austria 72%; Italy 76%; the Netherlands 71% and Sweden 68%). Most of the responding EU citizens hold farmers primarily responsible for the welfare of their livestock but also (72%) believe they should be compensated for higher production costs that result from improved welfare standards. After farmers, veterinarians and government regulators are seen as those most responsible for assuring food products have been produced in an animal-friendly way.

◊ ***Need for transparency***

Consumers and citizens increasingly demand transparency regarding animal welfare matters, food safety and origin of products. Many EU citizens (54%) find it hard to obtain information on product sourcing. Consumers' preferred means of identifying welfare quality is through labelling (39%), with an almost similar percentage having a preference for communication through a logo on the product (Eurobarometer, 2007).

◊ ***Higher value-added products***

Consumer lifestyles are leaning towards higher value-added products. Reasons to buy animal welfare-friendly products are related to the fact that these products are considered to be healthier and of a better quality, supplemented by a concern for the happiness and health of farmed animals (Eurobarometer, 2007). Convenience, high quality, health, slow food, organic and regionally produced products are all factors gaining ground with consumers.

◊ ***Consumer willingness to pay***

Consumers and citizens are showing increasing concern for the welfare of farmed animals yet their willingness to pay for enhanced animal welfare in the supermarket is still lagging. There is a gap between the 'ethical principles' of citizens and their purchasing behaviour as consumers. At present, the number of consumers that can be considered 'responsible buyers' is relatively small. In general, the market share of 'ethical products' (organic, fair trade, animal welfare friendly) tends to be stuck somewhere between 1% and 3%, in spite of a growing societal disapproval of 'unethical' ways in which some products are produced.

In scientific literature, several causes are mentioned that provide some explanation for this ‘ethical gap’: (i) a pervading sense of powerlessness, felt by many consumers, in terms of making a real difference to the world through their consumption choices; (ii) lack of coordinated ranges of easily available ethical products priced for mass-market consumption. The premium price on many ‘ethical’ products has effectively excluded many consumers; (iii) Up to now, ethical goods are not often supported by extensive marketing and therefore are less effective in building competitive brand presence; and (iv) the fact that in reality, there is a very complex series of connections between consumer awareness, concern and action that are shaped by many internal (personality, attitudes) and external (peer group, competitive marketing attention) influences (Nicholls, A. and Opal, C., 2005).

Animal welfare improvement is of considerable public concern in the EU but at the same time, consumers’ willingness to pay a higher price for more animal welfare-friendly products is generally lacking. So what alternative arrangements can be thought of to improve the level of animal welfare in Europe, without charging it to the consumer’s bill?

9 Policy issues

In this concluding chapter an overview is presented of the policy issues related to the introduction of an animal-based welfare monitoring system in the EU. A draft version of the policy issues were presented at the workshop in the European Parliament, in which politicians, experts, and stakeholder groups participated. The results of the workshop discussion are incorporated in this chapter. Before going into the policy issues, the main 'promises' of an animal-based approach should be outlined.

9.1 Promises

The assessment of animal welfare is currently inferred from external parameters. Accordingly, animal welfare legislation is directed at the enforcement of legally prescribed means, such as cage size or feeder space. Farmers do – or do not – comply with these regulations. In contrast with this current approach, an animal-based welfare monitoring system promises the following:

- An animal-based approach measures animal welfare more directly. Therefore, it can include the animal welfare effects of factors like farm management that have thus far been excluded. As a consequence, an animal-based approach could provide a more reliable assessment of the actual animal's welfare;
- By integrating the assessment of welfare indicators into a welfare qualification system consisting of different classes – that in turn may be linked to corresponding market labels – it becomes possible to provide farmers, retailers, legislators as well as consumers, with more adequate information on the welfare quality of food products. This may contribute to the awareness and knowledge of farmers and other parties in the food chain on the welfare of farm animals. Moreover, this may meet the consumer need for more transparency;
- An animal-based system creates more flexibility for farmers. Firstly, an animal based system is directed at reaching a certain level of animal welfare, without prescribing what precise measures a farmer should take in order to enhance animal welfare – which is contrary to the current situation. Secondly, an information system consisting of different welfare classes makes it possible to reward extra efforts by farmers to improve animal welfare. Both aspects further a more animal-friendly market dynamic. And both aspects may function as an appeal to farmer skills and expertise;
- An animal-based system can stimulate animal welfare enhancement by suggesting to farmers concrete measures by which they can actually improve the welfare of their livestock.

These promises still have to be fulfilled. In order to develop a comprehensive and validated animal welfare monitoring system, a lot of work still needs to be done. This *pilot study* only sketches the outlines of such a system, focusing on the case of dairy cows and (only) two welfare indicators (lameness and clinical mastitis). Nevertheless, the results of the study already make it possible to clarify relevant policy issues that should be taken into account when considering the introduction of an animal-based approach in the EU.

9.2 Policy issues

Research into the potential for introducing a European system of animal-based welfare monitoring generates policy issues at many levels, related to the scientific and technological state-of-the-art, the efforts to construct animal-based welfare levels, the costs of achieving higher levels of animal welfare and underlying economic and societal trends. It hardly needs saying that these policy issues need further political reflection and debate.

1. An animal-based welfare monitoring system is still a work in progress. Systems of animal-based welfare indicators are in development and need to be validated and made available for (automated) on-farm application with regard to different species of farm animals. A lot of research and development still needs to be done and if it is to be applied on a European scale, further support by policy makers will be required.

2. Decisions have to be made on how complete or encompassing an animal-based welfare monitoring system should be. According to the participants at the workshop, such a monitoring system should meet all relevant requirements as expressed in the five freedoms (freedom from hunger and thirst; freedom from discomfort; freedom from pain, injury or disease; freedom to express normal behaviour; freedom from fear and distress). Animal welfare should not be compromised by taking only a selection of parameters into account. This raises the question as to whether all possibly relevant indicators should and could be included. According to the Welfare Quality project, for dairy cattle alone, nineteen welfare indicators should be monitored (see Annex 1). Is such an encompassing approach workable? Or does it suffice to restrict the welfare assessment to a fewer number of relevant based parameters?

3. What animal welfare levels should be constructed? Where to draw the line between 'low', 'medium' and 'high' welfare – or, following the Welfare Quality project, between 'not classified', 'acceptable', 'enhanced' and 'excellent'? In this report, the expert opinion of a small group of veterinarians has been used to draw lines between 'low', 'medium' and 'high' levels of animal welfare with regard to lameness and clinical mastitis. This effort should be considered as a first attempt to define these levels and as a starting point for further discussion. It is obvious that it will be far more complicated to define boundaries between welfare classes when more animal-based welfare indicators are included.

4. Who bears prime responsibility for animal welfare? The state, the retail sector, the farmers, the consumer? According to the Eurobarometer survey, most European citizens are in favour of improving animal welfare, and hold farmers primarily responsible for this. Thus, public opinion is putting pressure on the farming sector. At the same time, citizens believe that farmers should be supported by veterinarians and government regulations and should be financially compensated for their efforts to enhance animal welfare. Taken together, these public views point to the need for an institutionally embedded system to enhance animal welfare. The question is then, what governmental or market arrangements can be thought of to provide such institutional requirements.

5. *One option* would be to leave the introduction of an animal-based monitoring system to the market. By linking product labels to welfare levels, consumers may be stimulated to buy more animal-friendly products. This option might benefit from the economic trend that consumers are more interested in buying higher value-added products. At the same time, one should keep in mind that the market share of 'ethical' products tends to be stuck somewhere between 1% and 3 %. But much also depends on the role retailers play as both the 'gateway' for suppliers and the 'gatekeeper' for consumers. They control shelf space and influence buying patterns through advertisements and promotional activities. When in comes to the market, what responsibility do retailers have when it comes to selling animal-friendly products? At the workshop in the European Parliament, further labelling of animal-friendly products was disputed. It was considered that the introduction of another product label would lead to further consumer confusion. Contrary to the findings of the Eurobarometer survey (2007), several participants at the workshop suggested that instead of having to choose in the supermarket for more or less animal-friendly products, consumers would prefer a general improvement of animal welfare in the whole food chain.

6. *A second option* is the introduction of a EU-minimum animal welfare level that all farmers within the EU should comply with. Meeting higher standards of animal welfare (than the bare minimum) could remain optional, and could be left to the market. But what level of animal welfare should be regarded as minimum? If the 'medium' level as defined by the veterinarians in this study were to be chosen as the minimum (prevalence of lameness between 15 and 25 %; prevalence of clinical mastitis between 15 and 40 %), many European farmers would not currently be meeting this standard. If the status quo were to be chosen as the EU-minimum, the general level of animal welfare cannot be expected to improve much. Thus, the introduction of a EU-wide legal minimum will be complicated by existing differences between European regions. Generally speaking, meeting higher welfare standards requires higher husbandry skills and appropriate knowledge. Farmers in Western European generally possess more of these skills and expertise than farmers in East European countries. The introduction of a EU-welfare minimum could be further complicated by competitive disadvantages for farmers who produce for the world market. However, since most European farmers produce for the EU-market, the effects of these disadvantages might be limited. And despite these competitive disadvantages, the EU might choose to be a frontrunner with respect to animal-friendly food production.

7. *A third option* implies that the government promotes the introduction of an animal-based monitoring system and a more animal-friendly food production, by financially supporting such a system. Farmers who succeed in meeting the highest welfare level, could be financially rewarded on the basis of national or EU subsidies. This option could mean that the subsidies involved in Cross Compliance, being part of the Common Agricultural Policy, could be redirected. At present, farmers who do *not* respect general EU-requirements with regard to animal welfare, can face cuts in their financial support. A policy that r*ewards* farmers who succeed in meeting higher levels of animal welfare would possibly stimulate a more animal-friendly dynamic.

8. The tendency towards large-scale farming seems to be inevitable. Economic trends such as the abolition of the milk quota system, the liberalization of the market, and increasing production costs, all contribute to this tendency. Increased production costs are partly due to societal demands relating to environmental quality, food safety and animal welfare: both the introduction of an animal-based monitoring system and the improvement of animal welfare performance will generally raise production costs. The increase in scale that results from these trends, in the case of dairy cows, could have a twofold effect. On the one hand, large-scale farms generally will be better equipped to implement a high tech animal-based welfare monitoring system. On the other hand, an important animal welfare measure like access to pasture becomes more difficult to realize when the number of animals per farm increases. The discussion at the workshop made clear that farm size is not necessarily at odds with improving animal welfare in general, or with welfare enhancing measures as access to pasture in particular. But in order to meet (higher) animal welfare standards, big farms require better management and higher qualified farmer skills.

9. The development of an animal-based monitoring system is motivated to a great extent by the need to accommodate public concerns with respect to animal welfare. But the implementation of such a system, though, will not necessarily lead to (more) public acceptance. Public perceptions of animal welfare can diverge from a scientifically sound, animal-based assessment of animal welfare. The increase in farm scale is not necessarily adverse to animal welfare, but could potentially fuel the – negative – public image of further industrialization of animal husbandry. This may lead to increased public criticism of farming practices. This negative perception may stem from romantic images of traditional, ‘natural’ farming – for instance as showed in commercial advertisements for food products. But it is far too easy to depict all forms of public criticism as ‘merely romantic’. Accommodating public concerns may require more than introducing an animal-based monitoring system. When product labelling does not meet the public demand for more transparency, but instead leads to increased confusion (see policy issue 5), the question remains unsolved what conditions should be met in order to foster public trust in farming practices.

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Annex 1 Welfare criteria for dairy cattle (Welfare Quality)

Welfare principles		Welfare criteria	Measures
Good feeding	1	Absence of prolonged hunger	On farm: Body condition score (% too fat or too thin animals)
	2	Absence of prolonged thirst	On farm: Water supply (number of water bowls, flow rate, cleanliness, functioning of bowls)
Good housing	3	Comfort around resting	On farm: Time needed to lie down Percentage of animals colliding with housing equipment when lying down Percentage of animals lying with hindquarters on edge Cleanliness scores (udder, flank and upper and lower legs)
	4	Thermal comfort	
	5	Ease of movement	On farm: Presence of tethering Access to outdoor loafing area and/or pasture
Good health	6	Absence of injuries	On farm: Lameness score (lameness prevalence) Integument alterations (hairless patches, lesions/swellings, overgrown claws)
	7	Absence of disease	On farm: Respiratory disorders (coughing, sneezing, nasal discharge, ocular discharge, increased respiration) Enteric disorders (diarrhoea) Reproductive disorders (milk somatic cell count, vulvar discharge) Other parameters (mortality, culling rate)
	8	Absence of pain induced by management procedures	On farm: Routine mutilations (dehorning, tail docking, procedure, age, use of anaesthetics/analgesics)
Appropriate behaviour	9	Expression of social behaviours	On farm: Incidence of agonistic behaviours
	10	Expression of other behaviours	On farm: Qualitative behaviour assessment
	11	Good human-animal relationship	On farm: Avoidance distance at feeding place Avoidance distance in the home pen

Annex 2 Expert survey on automated welfare monitoring

Responding scientists

Daniel Berckmans

Daniel Berckmans works at the Catholic University of Leuven at the department project Measure, Model & Manage Bioresponses (M3-BIORES). The focus of the research is to integrate dynamic responses of living organisms in the monitoring and control of biological processes.

Marcella Guarino

Marcella Guarino works at the University of Milan at the department of Veterinary Sciences for Animal Health and Food Safety.

Jörg Hartung

Professor Jörg Hartung is director of the Institute of Animal Hygiene, Animal Welfare and Behaviour of Farm Animals at the University of Veterinary Medicine Hanover. His main focus is on the understanding of the environmental stressors around farm animals and preventing measures.

Bert Ipema

Bert Ipema works at the Animal Sciences Group of Wageningen University and Research Centre. His focus is on information and knowledge systems, agricultural buildings and agricultural equipment, technology and animal husbandry.

Ingrid de Jong

Ingrid de Jong is an animal welfare scientist working at the Animal Sciences Group at Wageningen University and Research Centre and focuses on poultry and rabbit welfare.

Kees Lokhorst

Kees Lokhorst works at the Animal Sciences Group at Wageningen University and Research Centre. His focus is on animal production systems, integrated production systems, information and knowledge systems, organisational science, and poultry.

Berry Spruijt

Berry Spruijt is head of the division of Ethology and Welfare of the department of Animals, Science and Society at Utrecht University.

Christopher Wathes

Christopher Wathes is Professor of Animal Welfare at the Royal Veterinary College, University of London and head of the Centre for Animal Welfare. He is a bio-physicist, whose research concerns the environmental biology and management of farm animals.

Jacek Wójtowski

Jacek Wójtowski works at the Department of Sheep, Goat and Fur Animals Breeding at the August Cieszkowski Agricultural University.

Responding companies

Fancom BV
Fancom BV develops and produces total solutions for climate control, feeding systems, biometrics and data management for the pig and poultry production sectors.

FBI Science GmbH
FBI Science GmbH develops products for human and animal experimental research. They are specialised in the analysis and diagnosis of animal behaviour, development of procedures and products for behaviour analysis and investigational procedure as well as the implementation of databases.

IceRobotics
IceRobotics develops sensor technologies. Currently their products are mainly used by scientists, but in 2009 they will be releasing full production systems for use by commercial livestock farmers.

NewBehaviour AG
NewBehaviour AG develops products that can automatically assess animal behaviour. These can be divided into two main categories: assessment of behaviour in the laboratory, and animal tracking and ecology in the field.

Noldus Information Technology
Noldus Information Technology develops instrumentation and software packages for the collection and analysis of behavioural data.

OT Solutions
OT Solutions has developed a prototype which provides accurate measurements of physiological parameters of small freely moving laboratory animals such as mice, rats or guinea pigs.

TeleMetronics biometry
TeleMetronics biometry BV develops implantable telemetric (wireless) implants that enable the monitoring of on-line physiologic parameters such as body temperature, heart rate and body acceleration.

Annex 3 Information about costs estimations

Country				Netherlands			
Typical farm							
Average number of cows on typical farm: Type of cow stable: Type of bedding: Grazing: Walking floor: Price labour/hour (€):				60 Cubicles (cutted) straw/sawdust Yes Slatted 23			
Mastitis	Common?	Investment per cow (€)	% costs of investment[20]	Hours extra labour/cow	Extra yearly costs material / other per cow	**Total costs per cow (€)**	Remarks
1. Disinfection maternity area	Yes						
2. Disinfection cubicles monthly	No			1	0,27	**23**	4 hours cleaning whole stable/month, 900 ml Halamid sol./3 m² (1 cubicle)
3. Replacement bedding weekly	Yes						
4. Grazing milking cows	Yes						
5. Separation area infected cows	No	100	10%			**10**	
Lameness							
1. Cow mattress in cubicles	No	100	15%			**15**	

[20] Interest, depreciation, maintenance, insurance

2. Sand in cubicles	No	330	14%		11	**57**	Stable cheaper but more maintenance (investment "0"), small shovel (investment € 20.000), sand cheaper than straw (- € 3), contracted work removing and spreading sand (€ 14)
3. Cubicles larger than 115*230 cm, no brisket board	No	70	10%			**7**	
4. Use a slatted floor with manure scraper	Yes						
5. Deep litter (straw, no slatted floor)	No	-325	10%		250	**219**	(Negative investment) and extra costs straw (1770 kgs/cow)
6. Grazing milking cows	Yes						No extra costs, higher income grazing
7. Separation of cows around calving	Yes						Separation room for calving

Country	Sweden						
Typical farm							
Average number of cows on typical farm:	54						
Type of cow stable:	Cubicles						
Type of bedding:	(cutted) straw/sawdust						
Grazing:	Yes						
Walking floor:	Slatted						
Price labour/hour (€):	19						
Mastitis	Common?	Investment per cow (€)	% costs of investment[21]	Hours extra labour/cow	Extra yearly costs material / other per cow	**Total costs per cow (€)**	Remarks
1. Disinfection maternity area	No			0,5	1,2	**11**	Virkon S desinfection soulution, 120 euro for 5 kg, 10g/ 1 L water, 0.3 L / m2, 16 m2
2. Disinfection cubicles monthly	No			1,8	2,5	**37**	Virkon S desinfection soulution, 120 euro for 5 kg, 10g/ 1 L water, 0.3 L / m2, 2,88 m2
3. Replacement bedding weekly	Yes						
4. Grazing milking cows	Yes						
5. Separation area infected cows	Yes						
Lameness							
1. Cow mattress in cubicles	Yes						

[21] Interest, depreciation, maintenance, insurance

2. Sand in cubicles	No						Not possible on slatted floor
3. Cubicles larger than 115*230 cm, no brisket board	Yes						120*240 is most common
4. Use a slatted floor with manure scraper	Yes						
5. Deep litter (straw, no slatted floor)	No						Not possible on slatted floor
6. Grazing milking cows	Yes						
7. Separation of cows around calving	No	0		1		**19**	It is common to keep the dry cows in a separate group but not the newly calved cows. This measure does not need higher investment but better planning.

Country				Italy			
Typical farm							
Average number of cows on typical farm: Type of cow stable: Type of bedding: Grazing: Walking floor: Price labour/hour (€):				133 Cubicles (cutted) straw/sawdust No Not slatted 11.77			
Mastitis	Common?	Investment per cow (€)	% costs of investment [22]	Hours extra labour/cow	Extra yearly costs material / other per cow	**Total costs per cow (€)**	Remarks
1. Disinfection maternity area	No			0,2	1,2	**4**	In most Italian dairy farms calving cows are housed in collective straw bedded maternity pens, in which complete disinfection is not feasible after every calving. In this case it is feasible to use a bedding conditioner like Prosanex to reduce environmental bacteria and to control environmental mastitis. With 5 calving cows present in the collective maternity pen and an average occupation

[22] Interest, depreciation, maintenance, insurance

							period of 7 days we estimate 350 g of Prosanex per cow per week and an extra labour input of 30 min/week (costs of Prosanex 1,8 €/kg). To get best disinfection, an alternative solution is construction of at least 5 single maternity pens (investment costs) and the use of liquid disinfectant products like Halamid or Delegol NF Bayer (1% solution, cost 7,4€/l).
2. Disinfection cubicles monthly	No			0,5	32,8	**39**	In most Italian dairy farms cubicles are floored with straw and a dry manure layer 20-30 cm deep which is quite difficult and costly to remove and to renovate for monthly disinfection. Italian veterinarians usually suggest to apply

							Prosanex powder 350 g/cubicle*week during bedding replacement: extra labour 75 min/week, costs of Prosanex 1,8 €/kg. An alternative solution to get best disinfection is to renovate the cubicles, to fill them with concrete in order to have a proper impermeable flooring to be cleaned and disinfected with disinfectant solutions like Halamid or Delegon.
3. Replacement bedding weekly	Yes						
4. Grazing milking cows	No					**0**	Not feasible in Italy
5. Separation area infected cows	Yes						
Lameness							
1. Cow mattress in cubicles	No	125	20%			**25**	Not common, but their use is increasing
2. Sand in cubicles	No						Not feasible economically because sand is too expensive in

							Italy and destroys manure pumps
3. Cubicles larger than 115*230 cm, no brisket board	Yes						
4. Use a slatted floor with manure scraper	Yes						
5. Deep litter (straw, no slatted floor)	No	500	10%		102	**152**	Sloped bedded floor has been envisaged here for Italy as a renovation of a cubicle housing system, because a sloped bedded floor does not require a stable enlargement (1825 kg of straw per cow per year)
6. Grazing milking cows	No					**0**	Not feasible
7. Separation of cows around calving	No	7	10%	0,5		**7**	Common is to keep the dry cows separated as well as the fresh calved cows up to 3 months after calving ending up with 3 groups. This strategy will create at the end 5 groups

							of cows (two extra subgroups). We counted extra labour for extra group milking and separation of cows. Moreover, extra investments in four separation gates (4+4+2,5+2, 5=13 meters of €72 per meter)

Country				**Austria**			
Typical farm							
Average number of cows on typical farm: Type of cow stable: Type of bedding: Grazing: Walking floor: Price labour/hour (€):				12 tied up with chains Concrete floor with straw Yes tied up, so no walking floor 12,5 € for family workers, 15-18 € for employed persons			
Mastitis	Common?	Investment per cow (€)	% costs of investment[23]	Hours extra labour/cow	Extra yearly costs material / other per cow	**Total costs per cow (€)**	Remarks
1. Disinfection maternity area	No						Measure for stable with cublicles
2. Disinfection cubicles monthly	No						Measure for stable with cublicles
3a. Replacement bedding weekly (tied up)	Yes						
3b. Replacement bedding weekly (cubicles)	Yes						
4. Grazing milking cows	Yes						
5. Separation area infected cows	No	100	10%			**10**	
Lameness							
1. Cow mattress in cubicles	Partly						
2. Sand in cubicles	No						Measure for stable with cublicles

[23] Interest, depreciation, maintenance, insurance

3. Cubicles larger than 115*230 cm, no brisket board	Yes						
4. Use a slatted floor with manure scraper	No						Measure for stable with cublicles
5. Deep litter (straw, no slatted floor)	No						There are only few farms with deep litter
6. Grazing milking cows	Yes						
7. Separation of cows around calving	No						Measure for stable with cublicles