CRANFIELD UNIVERSITY AT SILSOE

TIAGO PELLINI

REGULATORY IMPACT ASSESSMENT OF THE IMPLEMENTATION OF THE IPPC DIRECTIVE TO THE PIG INDUSTRY IN ENGLAND AND WALES

INSTITUTE OF WATER AND ENVIRONMENT

PhD THESIS

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Regulatory Impact Assessment of the implementation of the IPPC Directive to the pig industry in England and Wales

Supervisor: Professor Joe Morris

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For Liliam and Antônio

ABSTRACT

The Directive 96/61/EC on Integrated Pollution Prevention and Control (IPPC) is an important element of the EU strategy of sustainable development. IPPC imposes environmental regulation upon industries considered to have high potential for pollution, including the intensive rearing of pigs. Having its origins in the environmental regulation of the manufacturing and processing industries, the application of IPPC to the agricultural sector justifies particular attention and support. The required use of Best Available Techniques (BAT) offers a particular challenge to the sector.

This thesis develops and applies a framework for the assessment of the impact of IPPC on the pig industry in England and Wales. Three case study pig installations are used to compare changes in performance between 'without' and 'with' IPPC situations. Particular attention is paid to the impact of IPPC on capital and operating costs, and on commercial viability. This is set against the environmental benefits obtained. The validity of the predictions based on the case studies for the pig industry as a whole are assessed by means of a sectoral postal survey of pig producers and a workshop with key stakeholders.

The case study analysis confirmed that design and operation of animal housing and waste management systems are the most critical factors for IPPC introduction. Significant environmental improvements are possible by applying BAT to pig installations, especially through the reduction of ammonia emissions. Estimated abatement costs ranged between £3 and £6 per kg of ammonia abated. The total compliance costs for existing installations were substantial, at levels unlikely to be absorbed by the margins, but compliance with IPPC is expected to have a relatively lower financial impact for new installations. There is a risk that the current approach to BAT may not ensure a completely integrated approach to environmental protection. Notwithstanding this, the IPPC regime represents a significant step towards the internalisation of externalities caused by intensive pig production. IPPC is likely to reinforce and guide the structural change and technological innovation in this sector to more efficient and environmentally responsible production systems.

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ABBREVIATIONS AND ACRONYMS

AB Pigs	Assured British Pigs
ADAS	Agricultural Development and Advisory Service
(the) Agency	Environment Agency for England and Wales
ALARA	As Low as Reasonably Achievable
ALARP	As Low as Reasonably Possible
BAT	Best Available Technique
BATNEEC	Best Available Technique Not Entailing Excessive Cost
BPEO	Best Practicable Environmental Option
BREF	Best Available Techniques Reference document
BSE	Bovine Spongiform Encephalopathy
CAC	Command-and-control (policy instruments)
CAP	Common Agricultural Policy
CCLA	Climate Change Levy Agreements
CE	Cost Effectiveness
CEA	Cost-Efficiency Analysis
COGAP	Code of Good Agricultural Practice (Air, Soil and Water) produced by the UK Ministry of Agriculture, Fisheries and Food (MAFF)
DEFRA	Department of Environment and Rural Affairs (replacing DETR and MAFF from April 2002)
DETR	UK Department of Environment, Transport and Regions
DSR/PSR	Driving force (Pressure) – State - Response model
DPSIR	Driving force- Pressure – State – Impact – Response model
DoE	Department of Environment
ECETOC	European Chemical Industry Ecology and Toxicology Centre
EEA	European Environment Agency
EIA	Environmental Impact Assessment
EIPPC	European Commission's IPPC Bureau
ELV	Emission Limit Value (for pollutants)
EMAS	Eco-Management and Audit Scheme
ENDS	Environmental Data Service
EPA	Ireland's Environmental Protection Agency
EP OPRA	Environmental Protection Operator Performance and Risk Appraisal
EQS	Environmental Quality Standard
EU	European Union
FAO	United Nations Food and Agriculture Organisation
FWMP	Farm Waste Management Plan
FYM	Farmyard manure
GBR	General Binding Rules
InfoMil	Dutch Centre for Environmental Information and Certification
IPC	Integrated Pollution and Control
IPPC	Integrated Pollution Prevention and Control (Directive)
LEAF	Linking Environment and Farming (Audit)
LNV	Dutch Ministry of Agriculture, Nature Management and Fisheries

(cont.)

(continued ABBREVIATIONS and ACRONYMS)

MAFF	Ministry of Agriculture, Food and Fisheries (now DEFRA)
MLC	Meat and Livestock Commission
NPA	National Pig Association (UK)
NFU	National Farmers' Union (UK)
NVZ	Nitrate Vulnerable Zone
NSPPS	National Survey of Pig Production Systems
OECD	Organisation for Economic Co-operation and Development
OPRA	Operator and Pollution Risk Appraisal
PPC	Pollution and Prevention Control: reference to national instruments enacting IPPC in England and Wales (1999 Act and 2000 Regulations)
RIA	Regulatory Impact Assessment
RSPCA	Royal Society for Prevention of Cruelty to Animals
SFIR	Standard Farming Installation Rules and Guidance
SRI	Silsoe Research Institute
TWG	Technical Working Group for BREF Note
UN/ECE	United Nations Economic Commission for Europe
UK	United Kingdom
VROM	Dutch Ministry of Environment
WID	Waste Incineration Directive

GLOSSARY AND TERMINOLOGY

Best Available Technique (BAT): 'the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for ELV designed to prevent and, where it is not practicable generally to reduce emissions and the impact on the environment as a whole [...] subject to economic and technical viability.' (IPPC Directive: OJ, 1996).

Environmental Limit Value (ELV): the mass, concentration or level of an emission which may not be exceeded over a given period (DETR, 2000a).

Environmental Quality Standard (EQS): refer either to 1) a requirement which must be fulfilled at a given time by a given environment as set in EC legislation (as defined by IPPC regulations); or 2) a domestic requirement or objective which may be relevant in the determination of BAT (DETR, 2000a).

IPPC Directive: Directive EC/61/96 being implemented in all European Union member-states from the end of October 1999. Its purpose is to achieve prevention and control of pollution arising from the range of activities listed in Annex 1 of the Directive. It lays down measures designed to prevent, or where that is not practicable, to reduce emissions to air, land and water from these activities, including measures concerning waste. This is being done in order to achieve a high level of protection of the environment taken as a whole.

Installation: an IPPC installation is defined as: 1) a stationary technical unit where one or more activities listed in Part 1 of Schedule 1 to the PPC Regulations and 2) any other location on the same site where any other directly associated activities are carried out which have a technical connection with the activities carried out in the stationary technical unit and which could have an effect on pollution. For an intensive livestock unit, the installation comprises the building or buildings in which the animals are housed will be the stationary technical units. Although the fields are not part of the stationary technical unit, directly associated activities to pig production such as a slurry handling system will be part of the installation and, therefore, subject to the permitting process. (Source: DETR (2000a) *IPPC: A Practical Guide).*

Manures: refers to both solid manure (farmyard manure or FYM) and liquid manure (slurry).

Member-States: countries within the European Union (currently they are 15, namely: Belgium, Denmark, Germany, Greece, Spain, France, Ireland, Italy, Luxembourg, the Netherlands, Austria, Portugal, Finland, Sweden and the UK).

Operator: an operator is, in relation to an installation or mobile plant, the person who has control over its operation (Source: DETR (2000a). *IPPC: A Practical Guide).*

Permit: written decision granting authorisation to operate an installation under IPPC.

Regulator: is the competent regulatory authority for IPPC, which for England and Wales is the Environment Agency.

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CHAPTER 1

INTRODUCTION

1.1 THE CONTEXT OF THIS RESEARCH

The concept of sustainable development, which aims to harmonise the economic, social and environmental dimensions of development strategy, is now a key feature of policy making in the European Union (EU) (EEA, 1998 and 1999). As result of EU Directives, member states are obliged to regulate economic activities which use or impact on natural resources and the environment.

The United Kingdom (UK) was one of the first EU members to implement a national scheme under the 1990 Environmental Protection Act (HMSO, 1990) to limit the environmental impact of particular industrial operations through Integrated Pollution Control (IPC). The IPC regime to control pollution arising from industrial activities has now been replaced by the Council Directive 96/61/EC (OJ, 1996), which sets up EU legislation on Integrated Pollution Prevention and Control (IPPC). This was enacted in England and Wales in August 2000 under the Pollution Prevention and Control (PPC) Act 1999 and Regulations 2000 (HMSO, 1999 and 2000).

The scope of IPPC is more comprehensive than IPC and relates to the prevention and control of pollution from activities instead of processes. Under IPPC, any installation at which a listed activity takes place above specified size thresholds, where relevant, must be subject to regulation (Emmott and Haigh, 1996). It adopts a wide definition of 'pollution' addressing issues such as noise, odours and vibration, and gives special consideration to waste minimisation, energy efficiency and resource conservation.

The IPPC Directive extended environmental regulation to a range of activities not previously regulated by IPC. The intensive rearing of pigs and poultry are among the newly regulated sectors. With respect to pigs, IPPC applies to installations with more than 2,000 fattening pigs or 750 places for breeding sows. New or substantially modified pig units above the threshold must comply with IPPC from August 2000, whereas the sector as a whole (including existing pig installations falling into the IPPC size threshold) will be phased in by 2007. It is mandatory under IPPC to obtain a permit awarded by the competent regulatory authority to operate such installations. This is the Environment Agency in England and Wales. Also, operators are required to use Best Available Techniques (BAT) to prevent pollution (Environment Agency, 1999a and 2001a; EIPPCB, 2001).

The principles of the IPPC Directive have their origins in the environmental regulation of the manufacturing and processing industries. Application to the agricultural sector justifies particular attention and support. According to MAFF (1998a) 'the development of indicators [to measure environmental performance and determine pollution risk] for agriculture is not as straightforward as for other sectors since its impacts tend to be complicated, diverse and liable to substantial local variation'.

Although the application of the IPPC Directive to the pig sector is justified in terms of reducing environmental risks (Environment Agency, 1998; DETR, 1998), it is likely to have important economic implications in terms of costs for the industry, especially during the initial adoption period (IFI, 1999). It is also likely, as a consequence of BAT, to encourage convergence of technology and practice, with possible implications for the structure and competitiveness of the industry. However, IPPC requires that the proportionality principle should apply whereby the regulatory burden imposed on industry should be in proportion with the environmental risks to be controlled (DETR, 1999). It is difficult to determine the 'correct' degree of regulation for the newly regulated sectors until the environmental risks and the costs and benefits of regulation have been ascertained.

The IPPC regulatory burden is associated with costs of applying for a permit, charges on application, maintenance and surrender of a permit, and the compliance costs of meeting the requirements of the permit (DETR, 2000a). In this respect, IPPC is likely to impact on the size and composition of production costs. It could mean changes in operating costs with respect to labour, raw materials, utilities, and time spent on record keeping and environmental management (FRCA, 1997). Depending on existing circumstances and practices on a particular installation, IPPC could also mean additional capital expenditure on buildings, fixed plant and equipment for animal housing, feeding, and waste management. However, while BAT may involve additional costs associated with adoption of techniques to avoid or abate pollution, it can offer potential benefits associated with reduced use of raw materials and energy, and reduced waste.

While IPPC is distinguished by its 'integrated' approach for the newly regulated industries, these industries are in many cases already subject to environmental and related regulations. IPPC needs to incorporate or build on these where possible to ensure consistency, avoid duplication and reduce where possible the regulatory burden. The main UK standards and obligations that are likely to interact with IPPC for intensive animal rearing include those pertaining to water quality and groundwater protection, Environmental Impact Assessment (EIA) and Animal Waste Directives and, of course, animal welfare regulations, which have been a major driving force for change in the pig industry in recent years. Non-statutory instruments such as voluntary schemes have also been driving significant changes in the pig sector and must be taken into account when implementing IPPC.

The IPPC Directive goes beyond the traditional scope of environmental regulation and therefore poses a challenge to the newly controlled industries. Given the complex nature of the IPPC implementation process, it is very important to achieve constructive liaison between regulator and operators. This is particularly the case where industries are characterised by very diverse, relatively small and medium sized operators such as in the pig sector.

1.2 Aim and objectives

In the context of the new regulatory processes applied to intensive livestock, the broad aim of this research is to develop a framework for assessing the economic and environmental impacts of the implementation of the IPPC Directive in the pig sector in England and Wales with a view to inform policy management.

The specific objectives seek answers to the following research questions:

I) What is the current financial and environmental performance of intensive pig production systems?

II) What are the relevant indicators for assessment of the impacts of IPPC on the pig industry?

III) How does IPPC relate to other statutory instruments and to voluntary agreements that apply to the pig production and associated activities?

IV) What are the impacts of IPPC on the financial and environmental performance of the UK pig industry, including impacts on business viability and affordability?

V) Is the current policy design of IPPC appropriate for its application to the pig sector? What are the processes whereby stakeholders interact to influence the IPPC implementation in this newly regulated industry? What are the likely responses of the pig industry to IPPC?

A key element of the research purpose is to develop an analytical framework to address these research questions, drawn on secondary data, the findings of detailed case study enquiry and a target survey of pig producers.

1.3 Structure of the Thesis

This thesis is structured as follows. The scope, aims and objectives of the research are defined in Chapter 1 (Introduction). Chapter 2 confirms the purpose and boundary of the study and, by definition of study topic, reviews the specific research issues and possible ways of approaching the research objectives. Chapter 3 describes methods used for data gathering and analysis. This is followed by presentation of summary results for three case study pig units in Chapter 4. Chapter 5 discusses the results from a postal questionnaire survey of pig producers likely to be affected by IPPC within the National Pig Association (NPA) membership. It also reports on the discussion of preliminary results from this research in a workshop with key stakeholders. Finally, Chapter 6 contains the conclusions and recommendations drawn from this research.

CHAPTER 2
IPPC DIRECTIVE AND THE PIG INDUSTRY

This chapter presents the origins of the IPPC Directive and how this relates to the broader context of EU and UK policy frameworks on Sustainable Development. The chapter also describes the principles, concepts and instruments by which the Directive is applied to the pig sector. Relationships and conflicts with other mandatory and voluntary instruments are explored. The pig industry in UK is described in terms of structure of units, predominant production systems and market aspects (prices and competitiveness). The chapter goes on to outline how stakeholders take part in policy implementation process. Information already available on the regulatory impact of IPPC on the pig sector is reviewed, determining the approaches that have been used to date and identifying possible gaps in knowledge. Having identified challenges and opportunities posed by IPPC to the pig sector, the research questions are revisited to confirm their validity and identify possible approaches to answer them.

2.1 IPPC DIRECTIVE AND SUSTAINABLE DEVELOPMENT

The purpose of the Council Directive 96/61/EC (IPPC Directive) is to achieve protection of the environment as a whole based on integrated prevention and control of pollution arising from listed activities. It is explicit in the text of the Directive that implementing environmental protection through IPPC is expected to support the objectives of competitiveness of industries and Sustainable Development within the Community policy framework.

This section aims to define the underlying principles of Sustainable Development and the emphasis they are being given in the Directive. Following this, a critical view of principles of the IPPC Directive is presented. Recent developments in UK environmental policy are examined, seeking to differentiate IPPC from the previous control of industrial pollution, Integrated Pollution Control (IPC). Subsequently, the instruments and other relevant aspects of the implementation of IPPC Directive to the pig industry in England and Wales are critically reviewed.

2.1.1 The broad context of IPPC: definition and principles of Sustainable Development

The concept of sustainability was developed as an attempt to reconcile the potentially conflicting objectives between economic development and protecting the environment. In its route to development, society seeks to achieve improvement in economic welfare. The environment has, from an economic standpoint, three main functions, namely, to provide resources (renewable and non-renewable), to act as a sink for waste and to provide environmental goods and services (Turner *et al.*, 1994). Therefore, the intensity of the economic activity is often directly related to pressures on the environment, with negative impacts in the form of declining of natural resources, pollution and damage to ecosystems.

Sustainable Development was defined by the 1987 World Commission on Environment and Development report (WCED, 1987) as development that "seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future". This report (*Our Common Future*, often referred as the Brundtland Report) in many respects provided the foundations for integrated pollution control. Brundtland argued that the independent and fragmented work by institutions responsible for environmental protection at that time were incompatible with the integrated and interdependent nature of new challenges and issues facing them (Clinch, 2001). This identifies the very origin of the IPPC Directive, which was set to provide an enabling framework to address the issue of protection of the environment as a whole within EU member-states.

2.1.2 Environmental policy and instruments in the UK

The environmental policy in the United Kingdom[1] is increasingly dependent on the environmental policy framework of European Union (EU). The Fifth Environmental Action Programme of the EU - *Towards Sustainability* - was adopted in 1992 and sought to integrate environmental concerns into other policy areas in order to achieve Sustainable Development. DETR (1999) states that 'Sustainable Development requires

[1] The PPC Act 1999 and Regulations 2000 apply to England and Wales. However, it will sometimes be referred here to UK or British level following different sources of information used.

international co-operation on matters such as trade, relief of global poverty and environmental problems' and stresses the high level of influence of the European Union in the UK current policies.

Other spheres of international agreements are also influencing the UK policies on the environment, such as the Kyoto Protocol[2] on reduction of emissions to air for the Organisation for Economic Co-operation and Development (OECD) countries. Also ammonia emissions as a source of acidification have received particular attention in recent years and a protocol for reduction of this gas has been convened (UN/ECE, 1999).

The establishment of the *British Government Panel on Sustainable Development* and the *Round Table on Sustainable Development* in the 1990s represented, according to DETR (1999), substantial progress towards bringing environmental issues, considered until then of marginal importance, into the core of governmental political criteria. The panel was established to offer independent advice on strategic issues arising from the Government's Sustainable Development Strategy and other post-Rio reports (climate change, bio-diversity and forestry). For instance, in its third edition, discussing the impacts of agriculture on bio-diversity, the panel argued for a reform of the Common Agricultural Policy (CAP), with redirection of funds from agricultural commodity support to direct environmental payments. Moreover, it was argued that CAP should be replaced in the long-term by an "European Rural Policy of which a central objective would be to promote sustainable development, including sustainable farming, in rural areas" (DETR, 1997a). These ideas have been highlighted again in the recent published high level report to Government on the Future of Farming and Food by the Policy Commission (Cabinet Office, 2002).

An important milestone in the development of the current domestic environmental policy framework was the Environment Act 1995. Jewell & Steele (1996) state that the

[2] The EU members-states have agreed, under the Kyoto Protocol 1997, to take on a reduction target of 12.5% of greenhouse gases emissions having 1990 as a base (DETR, 1998). Agriculture, Forestry and Land Use sector is estimated to contribute with an overall release of 12% of the UK greenhouse gas baseline.

1995 Act "*is not limited to the reorganisation, and concentration, of regulatory functions but gives statutory recognition to 'sustainable development' as the new principal aim of domestic environmental law and policy*". The Environment Act 1995 created the environment agencies in the UK, which now have the duty to apply the IPPC Directive[3]. It also determines that costs related to requirements by the environmental protection authority to a regulated industry or activity need to be identified in terms of the resulting social and environmental benefits (Environment Agency, 1996). Therefore, the Agency is required to consider economic impacts of its policies.

The UK Government strategy for sustainable development (*A Better Quality of Life*, DETR, 1999) advocates that a more sustainable economy fulfils conditions such as: to make better use of resources and permanently promote efficiency in production and use of goods and services, to have stakeholders working together to achieve long term change, and to be stable and competitive. Additionally, the strategy identified the main areas of concern about management of the environment by the UK government as being: the achievement of major cuts in greenhouse gases emissions without compromising energy supply; improvement of air quality; protection of freshwater resources and water quality; protection of sea waters health and productivity; soil conservation and enhancement; landscape and wildlife protection; reduction of the spreading of persistent or diffuse pollutants and improvement of waste management; and, support international liaison to address global environmental problems. The Government gives a commitment to achieve environmental objectives, taking into account socio-economic criteria[4]. Later in this chapter (section 2.4.3) there is a discussion on the use of sets of indicators to design and evaluate sustainable agriculture policies and their links with IPPC.

The strategy also argues that more sustainable production should be promoted by the government through the following actions (DETR, 1999): raising awareness of the potential for increased efficiency through best practice programmes; minimum

[3] The new bodies are the 'Environment Agency for England and Wales' (the 'Agency') and the 'Scottish Environment Protection Agency' (SEPA).
[4] '(...) environmental improvements must reinforce social and economic objectives; acting proportionally – not every environmental improvement will be justifiable when all sustainable development objectives are take into account.' (*A Better Quality of Life*, DETR, 1999).

standards to eliminate processes or products with unacceptable environmental impacts or to provide a baseline for improvements; producer responsibility initiatives, getting producers to share responsibility for what happens at the end of products' lives; partnership along the supply chain to help suppliers to make improvements; commitment by business to assess impacts and see targets (encouraging action by individual firms and trade associations to use sustainable management systems, such as EMAS and ISO 14001; and environmental report by companies to demonstrate business commitment to improvement in environmental performance and to communicate with stakeholders. The strategy implies that different instruments are necessary to achieve better environmental performance of businesses. Regulation can be identified among them, in form of setting up *minimum standards* for processes or activities. As explained in the following section, this is the remit of the IPPC regime.

The DPSIR (Driving force-Pressure-State-Impact-Response) framework represents a systems analysis view of the relationship between the environmental systems and the human systems (EEA, 1999). The simplification provided by the DPSIR helps to describe relationships between origins and consequences of environmental problems, which is particularly useful from a policy point of view. *Pressures* by economic and social activities change the *state* of the environment determining *impacts*. The latter generates social *responses* that feed back on the system changing driving forces, reducing pressures or directly affecting the state or impacts with curative actions. In this context, the IPPC Directive can be identified as a *response* to pressures and impacts posed by industrial and intensive agriculture activities.

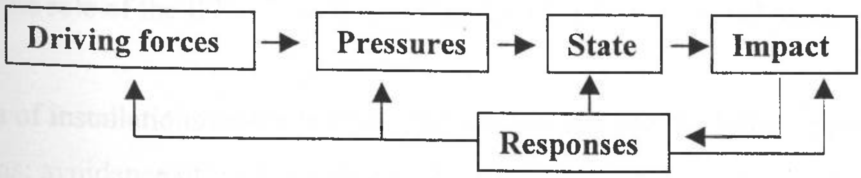

Figure 2. 1 – The DPSIR model
Source: EEA (1999) *Environmental indicators: typology and overview*, p.6.

2.1.3 The Integrated Pollution Prevention and Control (IPPC) Directive

Council Directive 96/61/EC (OJ, 1996) sets up EU legislation on Integrated Pollution Prevention and Control (IPPC). This was enacted in England and Wales in August 2000 under the Pollution Prevention and Control Act 1999 and its provisions given by the Pollution Prevention and Control (England and Wales) Regulations 2000 (HMSO, 1999 and 2000). Installations prescribed in the directive will be phased into the new regime on a sectoral basis up to the year 2007.

IPPC is a major new item of EU environmental law that introduces a requirement to apply a permitting regime for certain industrial activities, to attain a high level of protection of the environment taken as a whole (Emmott, 1999a). The Directive replaces the medium-by-medium approach of earlier EU legislation with an integrated, multimedia philosophy. It applies to larger industrial installations and, in the case of intensive rearing of pig, will apply depending on threshold capacities. New or substantially changed installations came under IPPC control in October 1999, while existing installations must phase before 2007.

Backes and Betlem (1999) affirm that 'indeed, the fundamental new element of the IPPC Directive - compared to the previous compartmentalised EC environmental law – is the attempt to bring together the emissions to the air, water, soil, the production of waste, the use of energy and the other environmental effects in order to achieve the best solution on the balance'. Nevertheless, Emmott (1999b) argues that the term used in the Directive, 'fully co-ordinated', does not mean in fact 'integrated'. In practice, the use of the former term could, according to authors such as Winter (1999) and Macrory (1999), diminish the role of the IPPC Directive within the EU environmental policy framework.

Operators of installations under an IPPC permit have to fulfil the following basic obligations: avoidance of waste production in accordance to Directive on Waste (71/442 and 91/156), waste recovery or its safe disposal, efficient use of energy, land and raw material, prevention of accidents and restoration of the site to a satisfactory state (Emmott and Haigh, 1996). The definition of pollution in IPPC is quite broad, covering 'direct and indirect introduction as a result of human activity of substances, vibrations, heat or noise into the air, water or land which can be harmful to human health or the quality of the environment, result in damage to material property, or impair or interfere with amenities or other legitimates uses of the environment' (Emmott and Haigh, 1996). IPPC goes further than previous mandatory instruments in defining the environmental impacts of economic activities. Emmott and Haigh (1996) suggest that as IPPC involves the installation where a prescribed activity is carried out as a whole (they define it as *source-based* approach), instead of the traditional process-by-process based approach (focus on components or phases) of previous regulations, it should allow comprehensive assessment of integrated activities using techniques such as mass balances and life cycle analysis.

According to the Agency (Environment Agency, 1999a), the most important features of the IPPC regulation are:

- the use of Best Available Technique (BAT) by operators to prevent pollution;
- the award of permits to operate installations to which regulations apply;
- an application process for a permit, which requires information on the physical, technical and managerial aspects of the unit;
- a public register where all relevant information on the unit regulated by IPPC should be available to the public (i.e. application, permit, regulators decision and monitoring); and
- subsidiarity, whereby local issues can determine most appropriate measures for the implementation of EU and national guidelines.

Best Available Technique (BAT) means, according to the IPPC Directive (OJ, 1996), 'the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole'. However, a more practical concept is derived from the verbatim definition of BAT as given in Article 2 of the Directive: *Best* means 'more effective in achieving a high general level of protection on the environment as a whole'; *Available* means ' developed at a scale which allows the implementation in the relevant industrial sector, under economically and technically viable[5] conditions' and *Techniques* include 'both the technology used and the way the installation is designed, built, maintained, operated and decommissioned'.

The UK was the first EU member to implement a national scheme based on limiting the environmental impact of certain industrial operations, under the name 'Integrated Pollution Control' (IPC), which was introduced by the 1990 Environmental Protection Act (HMSO, 1990). The prescribed processes under the IPC are required to use the 'Best Available Techniques Not Entailing Excessive Cost' (BATNEEC) to prevent, minimise or render harmless the release of any substances – or the 'Best Practicable Environmental Option' (BPEO) where a process is likely to involve releases into more than one medium, that is, air, soil and water (Emmott & Haigh, 1996).

The BAT concept had previously attached the term of 'Not Entailing Excessive Cost (NEEC)', and the UK representation during the discussion of the Directive would rather have retained BATNEEC in the final text. In the end, it was decided to use the term BAT, which was based on the German concept for those techniques described as 'state-of-the-art'. However, the description of 'available' given by the IPPC Directive, namely 'developed to a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into account the costs and advantages that are reasonably accessible to the operator', means that, as Emmott (1999b) points out, '...little difference can be observed between the requirement of BAT and the concept of BATNEEC [as used in the UK under IPC]'.

Emmott (1999a) identifies BAT as the key performance requirement in IPPC, as they will determine the requisites to setting permits conditions. Emission Limits Values (ELV)[6] for pollutants that are likely to be released in significant quantities by the

[5] Costs and advantages are taken into consideration in determining BAT. However, it is explicitly state that the techniques do not necessarily have to be used or originated from the Member State to be accessible.
[6] ELV is the mass, concentration or level of an emission which may not be exceeded over a given period (DETR, 2000a).

installations will be based on BAT. Environmental Quality Standard (EQS)[7] would not be provided by BAT alone, though. According to Skea and Smith (1998), the issue on how BAT, ELV and EQS relate was rather contentious among member-states representations doing the draft stage of the Directive. In the final version of this regulation, a more technology-based approach has prevailed rather than an environment-based (emission-based) one.

The PPC Act 1999 and Regulations 2000 are statutory instruments designating the Environment Agency for England and Wales (referred simply as 'the Agency' from now on) as responsible for the monitoring and enforcement of IPPC regulations in England and Wales. Local authorities share some of these duties regarding odours and noise (for Part A(2) and Part B activities, as defined in DETR, 2000a).

The use of BAT may potentially return benefits attributable to cleaner technology which uses less raw materials, generates less waste and is more energy efficient. The Directive determines that BAT ought to be assessed in terms of the costs and benefits it delivers, including social and environmental ones (Emmott & Haigh, 1996). This is consistent with the duty placed on the regulator under the Environment Act 1995 to consider the benefits and costs of its regulatory actions (Environment Agency, 1996).

In general terms, bringing an industry under IPPC regulation involve, to the regulated party, costs associated with: applying for a permit, complying with a permit, and surrender of the installation. Besides compliance costs, other identified challenges to the implementation of the Directive are its application to sectors without previous mandatory environmental rules and its comprehensiveness. 'IPPC regime is broader than IPC because IPPC brings in new sectors that have not previously been regulated in this integrated way…[and] …is deeper, introducing new factors to be taken into account [namely, raw material use, energy efficiency and site restoration after ceased activity]' (Environment and Industry, 1999).

[7] EQS has two meanings, depending on the context, namely: 1) a requirement which must be fulfilled at a given time by a given environment as set in EC legislation (as defined by IPPC regulations); or 2) a domestic requirement or objective which may be relevant in the determination of BAT (DETR, 2000a).

IPPC has the opportunity to integrate environmental and business needs. Many aspects of its requirement may be regarded as good business practice and should support environmental management systems already in place in some sectors (Environment and Industry, 1999). However, the underlying concept of *win-win* opportunities to promote both economic activity and environmental protection is controversial (see critics to the so-called Porter's model in O'Connor and Spash, 1999). That is to say, in most cases technological innovation implies additional costs that can compromise financial performance at least in the short term. Moreover, the emphasis of IPPC is clearly on environmental protection, as shown in the following extract: 'IPPC is broader and deeper approach [for environmental protection] than the present systems [and] … the result should be cleaner air, rivers and groundwater, fewer dangerous chemical being released to the environment, less waste to landfill sites, better use of raw materials, less noise pollution and less contamination of land … a better environment for us all' (Environment and Industry, 1999). IPPC promotes the internalisation of existing external costs. This is likely to increase costs to polluters through the application of 'polluter pays' principle. It is possible, however, that cleaner less polluting technologies can offer efficiency gains in the medium to long term, especially in a policy framework which consistently applies 'polluter pays' principle.

The IPPC Directive requires a flow of technical information among the member states in order to determine BAT. This is implemented through Technical Working Groups (TWG) responsible for the compilation of the BAT Reference documents (BREF Notes) for each sector subject to regulation. BREF Notes are being produced by the European Commission IPPC (EIPPC) Bureau in Seville, Spain. According to the Agency (IFI, 1999) the industry regulated by IPPC may expect the information coming from these BREF Notes (that is, the resultant BAT) to affect decisions on new investments and changes in major processes. It should also affect their relationships with trade organisations that are likely to act to influence BAT in accordance with membership interests.

Although IPPC implementation is expected to raise standards of environmental protection, as pointed out by Peters (1999), at EU level there is no harmonisation of instruments for reducing the emissions from installations below the IPPC thresholds.

Having described IPPC in a broader context of environmental policy at national and European level, it is necessary now to identify the characteristics of its implementation to intensive pig installations, which is one of the prescribed activities regulated by the Directive and focus of this research.

2.2 IPPC AND THE PIG INDUSTRY

2.2.1 IPPC requirements for the pig sector

The intensive rearing of poultry and pigs is captured within IPPC regulation. This includes installations with more than 40,000 places for poultry, 2,000 fattening pigs or 750 places for breeding sows. The principles of the IPPC Directive have their origins in the manufacturing and processing industries and its application to the agricultural sector justifies particular attention and support (Pellini, Morris and Emmett, 1999). According to MAFF (1998a) 'the development of indicators [relating to sustainability] for agriculture is not as straightforward as for other sectors since its impacts tend to be complicated, diverse and liable to substantial local variation'.

The IPPC Directive implies important changes for the pig industry, especially in terms of imposing costs of compliance, and at a time when agriculture and the pig sector in particular has faced economic decline (MAFF, 2000a).

Compliance costs involve two distinct groups of costs, as follows. The first group refers to costs associated to the permitting process, which comprises direct charges and fees by the regulator, and time and resources necessary for obtaining and running the permit (therefore, they could be classified as transaction and administrative costs). It is assumed here that, under the polluter pays principle, that such fees and charges cover the administrative costs of the authority which monitors and enforces IPPC, otherwise these costs are also to be taken into account. The second group is associated with additional capital investment and operation costs (or savings, perhaps) in complying with regulation requirements. There are also opportunity costs associated to losses of income and value added. Again, it must be recognised that some opportunities for savings or improve competitiveness can possibly emerge.

Therefore, applying measures of integrated pollution prevention and control to intensive pig production requires re-allocation of resources within the enterprise, changing the material, human resource and financial flows

The performance standards or minimum requirements for pig rearing under IPPC regime are set up in England and Wales through Standard Farming Installation Rules and Guidance (SFIR). SFIR (Environment Agency, 2001a) provide guidance to operators and regulators during the period previous to the release of the Best Available Techniques Reference documents (BREF Notes) for intensive livestock farming (pig and poultry), which are being produced by the EIPPC Bureau.

The initial idea of the Agency to assess every individual installation for the purpose of issuing a PPC permit has been replaced by the proposal to apply, where appropriate, standard conditions through the SFIR. These are a set of conditions representing techniques or proceedings commonly applied for the industry (regarded as BAT) which the operator agrees to adopt (Pellini and Morris, 2000). The Directive authorises the use of General Binding Rules (GBR) for IPPC implementation. According to the Agency, the use of GBR seeks to reduce the complexity and effort for the regulatory body in delivering its duties of authorising permits and monitoring controlled installations, and the costs of the regulatory system borne by the industry (Environment Agency, 1999a). The SFIR were adopted by the Agency for practical and legal reasons[8], being actually an alternative to GBR.

The SFIR provide the *performance criteria* that should be addressed by the operator when applying for a permit and gives indication of their *applicability* to installations.

[8] GBR are exclusively issued or approved by the Secretary of State. Therefore the Agency gave preference to a flexible framework through SFIR in implementing the regulations into a sector previously not regulated.

The current SFIR for the pig sector (Environment Agency, 2001a) includes many items of general good practice and housekeeping, and covers all production processes and related activities such as: raw materials use and storage; management of animal manures; management practices and record keeping. It also covers energy and water consumption, and emissions to air, land and water (including noise and odours).

Regarding their applicability (Environment Agency, 1999a), the SFIR can be of three types, namely:
'A' - likely to apply to all installations, both a) prior to the whole sector being brought under IPPC, any new or substantially altered plant will be expected to employ these immediately, and b) once the whole sector being brought under IPPC, as in item 'a', plus that any existent plant will be expected to employ these across the installation within an agreed time scale;
'N' - generally only applicable for new plant or plant where there is a major modification in that particular area of the plant; and
'B' - for any new or existing plants which require site specific determination of BAT.

The IPPC permitting process involves the consideration by the regulator of existing environmental standards and obligations affecting the operation of the controlled installation. Therefore, environmental standards set up locally can go beyond BAT. Also, although both SFIR and BREFs are likely to describe assumed appropriate standards[9], operators are expected to make continuous improvement, as BAT is a dynamic concept, permanently subject to new developments and innovation (Environment Agency, 1999a).

IPPC in England and Wales appears to be adopting a similar approach to that in Ireland for IPC regulations to pig production, where standard conditions were used for an IPC licence (equivalent to a permit under IPPC) referenced in BATNEEC guidance note for pig production (EPA, 1998). The regulatory authority for IPC in Ireland, the Irish Environmental Protection Agency (EPA) discusses that "the employment of identified techniques does not, by itself, meet the requirements in relation to IPC", but that the

[9] As discussed previously, the technology-based approach of IPPC through BAT assumes that minimum environmental standards are implicitly meet.

licensee (operator) has also to demonstrate adoption of sustainable agricultural practices. This illustrates a core aspect of the environmental regulation also verified in IPPC, which is that compliance is dependent on both technological and managerial aspects. Moreover, operators are clearly required to commit to the principles of prevention and control of pollution rather than merely to minimum compliance with rules.

BAT and standard conditions approaches (through SFIR) are likely to favour greater homogenisation of techniques used in the sector, as under the IPPC permit operators have to demonstrate compliance. Also, innovation in the industry tends to be driven by the BAT-like options. Moreover, the 'dynamic' nature of the concept of BAT raises the degree of uncertainty in the medium or long term for operators, as mandatory requirements for the sector can be changed as BAT changes.

2.2.2 Regulations interacting with IPPC in the pig sector

There are a number of UK and EU standards and obligations that are likely to interact with IPPC for intensive animal rearing. IPPC needs to incorporate or build on these existing (and forthcoming) regulations where possible to ensure consistency, avoid duplication and where possible reduce the regulatory burden. It is important to identify the broader regulatory framework to better understand the incremental effect of IPPC.

Regulation on water resources in UK relevant to the pig sector comprise several pieces of legislation (Environment Agency, 1999a), such as: *Statutory Instrument* (1989) *No 2286* and (1998) *No 389*; *The Surface Waters Regulations*; *Surface Water Abstraction Directive* and *Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations*, which involves the design and maintenance of structures for storage of slurry. The new Water Framework Directive will require the management of water based on river basins. The proposed directive will possibly replace some of the above regulations and set up ELVs for point sources and EQSs (DETR, 2000a). The Groundwater Regulations enact in UK the *EC Directive 80/68/EEC*, on the Protection of Groundwater against Pollution Caused by Certain Dangerous Substances (DETR, 2000a).

The *Air Quality Directive* and the *Nitrates Directive* also have links with IPPC (Peters, 1999). The latter directive designates the Nitrate Vulnerable Zones (NVZs) which have specific limits for application of nitrogen per area and therefore for the maximum amount of manures spread to land. Within a NVZ the total N applied from manures must not exceed 210 kg per ha per year, limit that will be reduced to 170 kg N per ha per year by 2003.

The *EU Directive on Environmental Impact Assessment (EIA Directive, 85/337/EEC* and its amending *Directive 97/11/EC)* requires the assessment of the environmental effects of certain public and private projects. These requirements were incorporated into *the Town and Country Planning* systems in England and Wales (DTLR, 2002). When applying for planning permission, projects for pig rearing installations over the threshold of 400 sows or 5,000 fattening pigs have to undertake an assessment of their effects on the environment. Although the size thresholds for EIA Directive are not exactly those under IPPC, new large pig installations are likely to be subject to compliance by both statutory requirements.

The removal of trade barriers in the EU brought implicitly the need of harmonisation of the standards in health, hygiene and welfare in all member states (MLC, 1999a). Animal welfare regulation has been one of the foremost driving factors for change in the pig industry in recent years, affecting not only the on-farm structure of production through minimum standards for installations and ban of tethers for sows (*Council Directive 91/630*), but also transport of animals (*91/628* and amendments), slaughter (*91/629* and amendments) and other issues, such as prohibition of use of hormones as growth promoters in livestock production (*Council Directive 96/22*). However, MLC (1999a) pointed out that countries have been widely different "in terms of freedom for or occurrence of major animal diseases, in standards of practice in meat production and in various attitudes towards animal welfare".

Human health and safety regulations, such as Health and Safety at Work Act 1974, interact with IPPC. Regulators must ensure that the IPPC and health and safety regulation are harmonised (DETR, 2000a).

Also the legislation on conservation of wild life and natural habitats, *Conservation (Natural Habitats etc) Regulations 1994*, requires that an IPPC application must have 'appropriate assessment' by the regulator if there is risk of a significant effect of the proposed operation to a designated conservation site (DETR, 2000a). The permit may not be granted if significant adverse impacts are identified.

The *Directive 200/76/EC on Incineration of Waste* (WID) may also affect IPPC installations, as substantial part of pig units run small incinerators on site for disposal of carcasses. The majority of small incinerators (operating at less than 50kg per hour) are currently exempt of licensing and WID appears to allow such licensing exemptions to continue, as carcass incineration can be classified as disposal of non-hazardous waste at the place of its production. However, it is not clear whether incinerators under licensing exemption would nevertheless still need to comply with the onerous requirements of the WID (requiring a secondary combustion chamber, for example) (DEFRA, 2002a).

Relevant ELVs applied to certain other Directives are to be applied as minimum ELVs under IPPC, without prejudice of stricter requirements implicitly associated to BAT or EQSs (DETR, 2000a).

It is apparent from the aforementioned that there is a substantial and increasingly comprehensive framework that overlaps and integrates with IPPC. Therefore, it can be implied that: IPPC needs to join up to the broader regulatory framework; the incremental regulatory effect of IPPC is reduced; and, pig installations non captured by IPPC are regulated by a series of other mandatory instruments.

2.2.3 Voluntary control instruments in the pig sector

Non-statutory instruments have also been driving significant changes in the pig production in recent years. Voluntary schemes such as the *British Meat Quality*

Standard for Pigmeat (AB Pigs), the *Linking Environment and Farming* (LEAF) auditing process and the Codes of Good Agricultural Practices for Air, Soil and Water of the Ministry of Agriculture, Food and Fisheries (COGAPs)[10] have created greater awareness and motivated the voluntary adoption of environmentally beneficial practices in agriculture (LEAF, 1997; MAFF, 1998b, 1998c and 1998d; and ABM, 1999).

The Government argues (DETR, 1997a) that the COGAPs 'provide a benchmark of good practices which all farmers should be capable of meeting within the context of commercial farming'. Compliance with the COGAPs was incorporated, among other required standards for producers wishing to be accepted in the scheme, in the *Assured Combinable Crops* scheme of the National Farmer's Union (NFU).

Voluntary schemes indicate the growing importance of market driven approaches to help provide assured environmental quality standards of production (DETR, 1997a). Many retailers now require their suppliers to meet specific standards of production, including good environmental practice. The protocols between NFU and major retailers for a wide range of horticultural crops and the adoption of LEAF environmental audit by growers stimulated by retailers and processors are examples of these.

In discussions of the IPPC Pig and Poultry Steering Group meetings, pig production representatives argued that the compliance with other mandatory non-IPPC regulation and the adoption of voluntary schemes duplicates several requirements posed by IPPC regulation on the sector. Therefore, they argue the Agency should not include in the IPPC permit monitoring and control of components already tackled by recognised, independent auditing systems. However, the regulator does not agree that the framework in place previous to IPPC (both voluntary and mandatory) can guarantee acceptable environmental protection. This fits with the view that applying environmental management systems (such as the above voluntary schemes) does not necessarily assure achievement of environmental objectives (Smith, 1996a; ENDS, 2000a and 2001).

[10] Also referred as The Air Code, The Water Code and The Soil Code (MAFF, 1998b, 1998c and 1998d).

2.3 The UK Pig Industry: Economic and Environmental Aspects

This section presents the characteristics and performance of the pig industry in England and Wales. This also identifies the type and relevance of environmental issues associated to intensive livestock production, particularly on the rearing of pigs.

2.3.1 Characterisation of the commercial production systems for pigs

Traditionally, three main types[11] of commercial production units operate in the pig industry (Pellini *et al.*, 1999), namely breeding herds, feeding herds and breeding-and-feeding herds.

Breeding herds carry the adult breeding stock of sows and boars to produce piglets. On an efficiently run unit it is therefore possible to obtain 2.1-2.3 litters from each sow per year, producing around 21-25 piglets per sow per year. These piglets are removed from the mother after 3-4 weeks (6kg) and further reared to 10 weeks of age (25-30kg) before being sold to a feeding herd. Feeding herds buy-in the 30 kg weaner pig, and feed and house them until they reach marketable weights between 60-100 kg liveweight. They are usually indoor intensive units, justified in terms of efficient feed conversion and management systems. Breeding-and-feeding herds combine both stages of the system and finish all or part of the young piglets produced in the unit.

In the UK over recent years outdoor pig production has increased considerably, and for the year 2000 around 30% of breeding sows (c. 250,000 sows) were kept outside. This has arisen because of increased welfare requirements for breeding sows, which has banned stall and tethers[12], and increased unit cost per sow place given outdoor system cost advantage. There are, however, growing concerns about the impacts of intensive outdoor pig systems on the land and water environment. Light, free-draining soils are essential to avoid surface damage in wet seasons (FAWC, 1996). Current stocking rate recommendations are however being reviewed in the light of experimental

[11] The production system can be further divided according to whether it is carried out on an *indoor* or an *outdoor* basis. Outdoor systems are outside of the scope of the IPPC Directive.

[12] In the UK sow stalls are banned but across Europe for year 2000 approximately 60% of sows will be housed in individual stalls with slatted floors and no bedding, achieving a relatively higher stock density and reduced building costs (R. Emmett, pers.comm.).

measurements of nitrate loading on these soils. Climate and topography throughout Europe however do not allow the same scope for outdoor production, and the vast majority of pigmeat production in Europe will come from indoor units as described below for the UK. Outdoors units, even though some of them contain very large herds, have been omitted from IPPC regulation.

The characteristics of the production systems are dependent on the particular production phase. Each production phase requires specific conditions and management of the herd, which determines different feeding, housing and waste management systems, as follows.

a) Typical indoor production systems for breeding herds

Housing: most housing for adult pigs are of a simple type with no extra heating supplied above that produced by the animals themselves. Air temperature and quality are maintained by extractor fans, and roof, walls and floor may be insulated to restrict heat loss to the exterior. In the UK, stall and tether systems (slatted floor, individual pens) were replaced by bedded yards (solid floor, straw based pens) for group housing as predominant accommodation for dry sows. Young piglets (weaners), having left the protection of the sow, need more elaborate housing with heating. Many specialist building companies provide standard housing designs, incorporating feeding, watering and waste collection systems.

Feeding: feed is delivered to the animal mechanically via automated systems installed in the house.

Waste management: in stall systems excreta is collected as slurry and stored in tanks or lagoons. Bedded systems (or straw based) periodically collect solid manure from housing (excreta plus straw bedding) for storage in heaps.

Appendix 2.1 illustrates the main types of pig housing according to flooring, namely, fully slatted, partly slatted and solid floor (straw based).

b) Typical indoor production systems for feeding herds

Housing: here controlled environment is the norm either by fan extraction or natural ventilation systems, or a mixture of both (ACNV - Automatic Control of Natural Ventilation housing). Non-bedded pens (solid floor without straw) are common but in the UK there is a move back to straw bedding on welfare grounds. Stocking densities are strictly controlled by codes of practice and/or market contract terms.

Feeding: feed is automatically delivered with multiple drops each day or ad lib access are common.

Waste management: emphasis is on slurry because of large quantities of manure produced, as the handling of liquid material can be easily mechanised (scraped/pumped) and is economical on labour use. It is during the feeding period of the system (30-100kg.) that the vast majority of the faecal waste is produced by the pigs.

The main market outlets for finished pigs are as pork, cutter and bacon. Porkers designate animals in the range of 60-75 kg liveweight (lw), which go to the fresh meat trade. Baconers are those between 85-100 kg lw, destined for some form of preservation/curing and sale to the public as bacon and hams. Cutters are between 75-85 kg lw, intermediate between the two previous categories, and may be channelled to either fresh or cured outlets.

2.3.2 Structure of pig production

Table 2.1 shows the number of pig holdings, number of total pigs and sows, slaughtering and tonnes of pig meat produced for the UK. Pig holdings with more than 2,000 pigs accounted for just 7.4% of the total holdings but 54.1% of the total number of pigs. For sows, holdings with more than 500 sows were 3.2% of holdings, but contained 30% in the total sows. This indicates high concentration of the herd in the larger pig units. This concentration is more intense in the UK than in any other EU member state (Pellini, Morris and Emmott, 1999).

Table 2. 1 – Structure of UK pig holdings and annual production

Feature	Unit	Value ('000)
Number of pigs, total and per size of holding:		
Total pigs	Head	7,335
Number of pig holdings (total)	Holding	13,5
Number of holdings with more than 2,000 pigs in the herd	Holding	1.1
Total pigs in herds >2,000 pigs	Head	3,968
Total sows	Head	835
Number of holdings with more than 500 sows	Holding	0.3
Total sows in herds > 500 sows	Head	276
Annual production:		
Slaughtering	Head	15,496
Meat production	Tonnes	1,098

Source: Eurostat (1997) and SOEC (MLC, 1998a).

Pig installations are captured by IPPC based on thresholds for number of sows or finishing pigs over 30 kg. Therefore, the concentration of the pig herd in large units likely to surpass the threshold, suggests that IPPC may achieve a substantial level of environmental control of pig activity in England and Wales. It is estimated that between 400 (Bateman, 1998) and 500 (MAFF and Environment Agency, 1999) pig farms would come under IPPC control in the UK. Of course one holding may encompass more than one IPPC installation.

Figure 2.1 presents the participation of main type of unit by specialisation of the herd in terms of number of holdings, total sows and trading pigs based on the 1998 National Survey of Pig Production Systems for England and Wales (NSPPS) (Sheppard, 1998). The survey results are based on data obtained from 2,438 respondents of pig units with more than 20 sow and/or 200 trading pigs

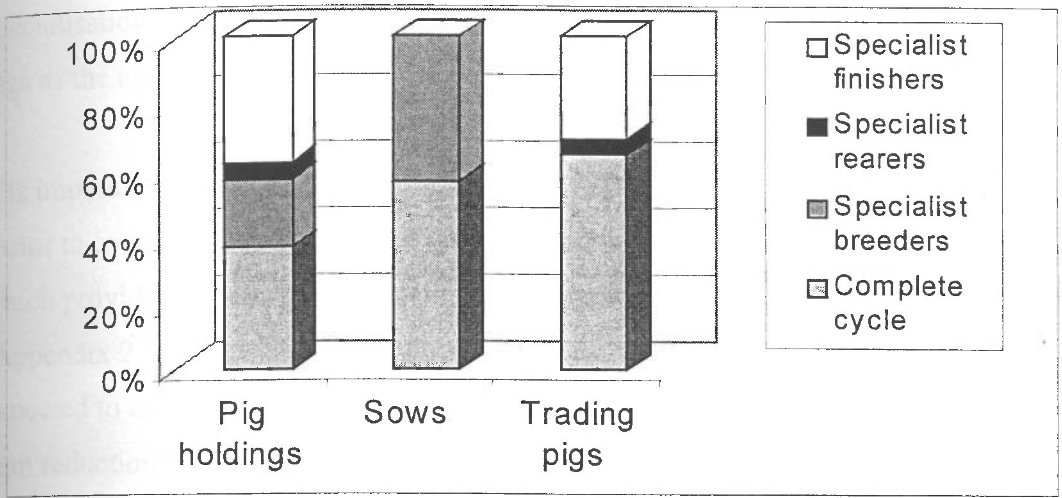

Figure 2. 2– Pig holdings, sows and trading pigs by type of herd in England and Wales
Source: adapted from Sheppard (1998) p.11.

Complete cycle[13] units contain the majority of sows and trading pigs, even though they are not the most common type of pig unit. According to Sheppard (1998) the great majority of these breeding-and-feeding are non-contract herds – that is, the pigs are owned by the operator. Contract operations, where the pigs are owned by a third party abattoir or processing company, are common for specialist rearers and finishers[14]. Contracts indicate the degree of vertical integration of the industry.

These data suggests that the pig industry is less integrated than the IPPC regulated poultry industry. Vertical integration implies that all stages of a supply chain are controlled by a single organisation. The greater the degree of vertical integration generally the greater is the scale of operations at each stage of the supply chain[15], the greater the interconnections among the various stages, the greater the market orientation, and the greater is the willingness and ability to promote technical progress.

However, a study of 351 pig herds, representing approximately 12 per cent of the British herd (MLC, 1997), showed that 55% of pig holdings had more than half of their

[13] Complete cycle is a synonymous definition of breeding-and-feeding herd.
[14] Specialist rearer refers to breeding-only herd and specialist finisher to feeding-only herds.
[15] Breeding, feeding and slaughtering pigs; processing, packing and distribution of pigmeat and products.

farm income from the pig activity. This implies, on the one hand a high level of specialisation of units, but on the other that a large number of this producers do not have pigs as the only activity.

It is important to identify type and frequency of different types of pig housing in the sector to compare with IPPC (BAT) requirements. The reference systems for housing, which provide a baseline for ammonia emissions, generally involve fully slatted floor (Appendix 2.1). Benchmarked against the reference systems, BAT for housing[16] are expected to deliver at least 20% reduction in the ammonia emissions. Other criteria than reduction in ammonia emission are also assessed in candidate techniques, such as cost-effectiveness of abatement, energy use and applicability to existing housing.

Table 2.2 presents predominant housing systems based on the same survey (Sheppard, 1998). The number of animals for rearing kept in fully slatted floor houses is significant accounting for 46% of total rearing pigs. If the implementation of IPPC requires the improvement or changes of such systems to meet BAT, there will be substantial impacts on the sector regarding investments in new or modified buildings.

At the time of the 1998 NSPPS some units still used stalls and tethers to keep dry sows. These were banned in January 1999 under welfare regulations, now mainly replaced by yards and kennels for group housing involving straw based solid floor system. Large units differentiated from medium and small ones by type of feeding systems for sows. That is, electronic sow feeders are mainly used in large sow herds whilst individual feeders and trough are predominant in small and medium units. Outdoor systems have increased in use in the period, being characteristically large size herds. (Sheppard, 1998).

[16] BAT for housing in draft BREF Note for intensive rearing of pigs (EIPPCB, 2001). This documents differentiate housing for the following phases: mating and pregnancy (dry sows), farrowing (lactating sows), weaning (rearing pigs) and finishing.

Table 2. 2 - Number of holdings and pigs according to housing and management of herd

Production Phase	Type of Housing	Holdings		Pigs	
		Number	%	Number*	%
Farrowing	Outdoor arks	271	15.9%	259,685	31.6%
	Farrowing crates	1,192	69.7%	533,162	64.8%
	Individual housing reduced confinement	116	6.8%	16,683	2.0%
	Group farrowing systems	13	0.8%	877	0.1%
	Traditional pens	110	6.4%	10,939	1.3%
	Unspecified and other	7	0.4%	956	0.1%
	Subtotal Farrowing	1,709	100%	822,302	100%
Breeding sow Accommodation	Indoor	1,382	83.1%	60,082	72.2%
	Outdoor	281	16.9%	23,087	27.8%
	Subtotal Breeding sows	1,663	100%	83,169	100%
Dry sows and Served gilts	Stall	188	8.4%	18,031	6.4%
	Tethers	88	4.0%	7,013	2.5%
	Cubicles and free access stalls	157	7.1%	13,442	4.8%
	Yards, electronic sow feeders	160	7.2%	27,909	9.9%
	Yards, individual sow feeders	406	18.2%	35,919	12.8%
	Yards or kennels, short stall feeders	104	4.7%	18,148	6.5%
	Yards or kennels, floor/trough feeders	805	36.2%	72,924	26.0%
	Outdoor accommodation	292	13.1%	83,937	29.9%
	Unspecified and other	26	1.2%	3,506	1.2%
	Subtotal Dry sows	2,226	100%	280,829	100%
Rearing Accommodation	Houses with fully slatted floors (flat decks)	411	17.3%	310,212	24.6%
	Houses with partly slatted floors	562	23.7%	266,679	21.1%
	Houses solid lying area & dung passage	764	32.2%	365,947	29.0%
	Deep straw yards	478	20.1%	205,625	16.3%
	Outdoors	134	5.6%	106,681	8.5%
	Other	24	1.0%	6,442	0.5%
	Subtotal rearing	2,373	100%	1,261,586	100%
Finishing Accommodation	Houses with fully slatted floors	310	11.3%	259,885	14.5%
	Houses with partly slatted floors	537	19.6%	350,354	19.5%
	Houses solid lying area & dung passage	1,143	41.7%	808,648	45.1%
	Deep straw yards	704	25.7%	349,639	19.5%
	Outdoors	26	0.9%	16,279	0.9%
	Other	20	0.7%	8,866	0.5%
	Subtotal Finishing	2,740	100%	1,793,671	100%

Note: *the value 'numbers of pigs' for farrowing refers to number of litters per year.
Source: *National Survey of Pig Production Systems 1998* (*NSPPS*) (Sheppard, 1998 p.9).

Rearing pigs or weaners (up to 35 kg) are predominantly accommodated in houses with fully slatted (flat decks) or partly slatted floors. The NSPPS survey identified that finishing herds reared in deep straw yards had increased in use while more traditional systems, such as solid lying areas with none or limited straw and with solid dunging areas, had declined. The latter type of housing was predominantly used for smaller and medium herds, whereas fully slatted accommodation was clearly more common in the largest finishing herds[17].

The above description of the structure of the pig industry indicates that larger size herd and breeding-and-feeding units contain the majority of the total pigs and sows. Also, the predominant housing system depends on the production phase and size of herd. For the purpose of this research, it is particularly important to identify the likely changes required under IPPC for fully slatted floor systems, as these are typically related to larger units (those being captured under IPPC), and on straw based systems. The latter, according to Sheppard (1998) has grown considerably in recent years amongst finishing herds, and now is the dominant form of accommodation for dry sows.

2.3.3 Performance of pig production systems

Technical efficiency in the UK pig industry improved considerably in the 1990s, as is shown in Table 2.3. In the period 1992 to 2000, the number of pigs reared per litter increased, feed conversion ratio from weaning to slaughter was reduced and average carcass weight rose. Furthermore, improvements in quality were achieved, with most carcasses classified as 'S' or 'E' in the EC grade (according to the lean meat content, as indicated in Table 2.3).

Table 2. 3 –Physical performance indicators for UK pig production, year 1992 and 2000

Indicator	Value 1992	Value 2000	Improvement (1992-2000)
Number of pigs reared per litter	9.50	9.89	+ 4.1%
Feed conversion ratio (FCR) - weaning to slaughter*	2.60	2.62	- 0.8%
Average carcass weight (kg)	62.9	70.5	+12.1%
Carcasses classified as top grade**	-	88%	-

Notes: *FCR was slightly reduced in the period, but it is needed to take into account that heavier pigs are being finished (see average carcass weight), which tends to reduce efficiency in use of feed by pigs; **classified in categories 'S' or 'E' according to the EC Classification System for carcasses, which means having more than 60% or between 55-59% of lean meat, respectively. Source: MLC, 1997 and MLC (2001a).

[17] As referred in section 2.2.1, finishing units involve production of large quantities of manure, being easier and more economical handled as liquid material (slurry), particularly in large units.

A summary of the composition of production costs per pig is shown in Table 2.4. Variable costs of production account for more than 70% of the total production cost. Feed is the major individual production cost, followed by labour.

The profitability of pig production is highly dependent on the ratio of pig price to feed cost. The break-even point for pig production occurs at a ratio of about 6.0-7.0:1 (Vaughan and Wright, 2000). The cost of feed is regarded as the most volatile of the input costs in pig production, whereas pig prices are subject to a cyclical but regular pattern, having generally a downturn at every 2 years, associated with an increase in the market supply of pigmeat. Thus, variations in gross margins, and consequently in the net margins of pig production, are mainly dependent on relative changes in these two variables.

Table 2. 4 – Financial results per pig sold for indoor, breeding-and-feeding herd (year ended September 2000)

Financial results	**£**	**%**
Variable costs:		
Feed*	31.19	57.0
Veterinary and medicines	1.95	3.6
Transport	1.50	2.7
Electricity and gas	1.89	3.5
Water	0.74	1.4
Straw and bedding	0.83	1.5
Miscellaneous costs	1.20	2.2
Total variable costs (V)	39.30	71.8
Fixed costs:		
Labour	8.76	16.0
Buildings**	2.96	5.4
Machinery and equipment**	2.08	3.8
Other fixed costs	1.63	3.0
Total fixed costs (F)	15.43	28.2
Total variable and fixed costs (V + F)	**54.73**	100.0
Revenue – av. pig sale value (R)	59.50	-
Gross margin (GM) = R – V	19.88	-
Net Margin (NM) = R – (V + F)	4.78	-

Notes: *feed costs refer to the average costs of home mix and purchase compound feed (£29.34 and £33.03, respectively); **costs include capital depreciation plus maintenance and repairs.
Source: based on *MLC Pig Yearbook 2001* (MLC, 2001a p.54-5).

2.3.4 An overview of the pig meat supply chain in Britain

The sectoral affordability of compliance costs of IPPC regulation depends on the capacity of the pig industry to accommodate this increase in costs by: increasing prices, reducing margins or achieving efficiency gains. The purpose of this subsection is to characterise the competitiveness of the UK pig meat supply chain, comparing the performance and structure of pigs production with major EU pig producer countries.

The competitiveness of the pigmeat supply chain is largely dependent on structural factors, such as scale of production, degree of integration between suppliers and processors, taxation and regulation, and market factors, such as prices, costs, and levels of protection and subsidies. Therefore, the profitability of pig units, and IPPC affordability, is to a great extent dependent on the overall performance of the supply chain.

Drawing on 1997 data, a MLC study compared the relative performance of UK pig units compared with other EU countries (Driver, 1999). According to the report, the physical performance across the countries studied has largely converged. For instance, the number of pigs sold per sow per year was very similar. The feed conversion ratio in the UK was the second best, only exceeded by Ireland (respectively, 2.57 and 2.39[18]). However, the daily liveweight gain per pig in Britain was substantially lower than the Danish, Dutch and French averages and Britain produced the lightest pigs and carcasses. Moreover, MLC considers the relatively high costs of production in Britain to be the most critical indicator of relative performance, positioning its pig industry behind the major European competitors in terms of cost competitiveness.

The reasons for higher production costs, according to the above MLC study, were mainly due to the relatively high feed cost. Labour costs were also significantly higher reflecting a lower use of family labour in the activity in the UK. The advanced implementation of regulations on welfare (prohibition of tether and stall in accommodation for sows, as previously pointed out in section 2.2.2) imposed an

[18] Feed conversion ratio (FRC) is calculated using the total kg feed given divided by the liveweight of pigs at slaughter.

estimated extra cost on British production of 8 p/kg relating to buildings, machinery and equipment costs. This cost is not present in any other EU country except Denmark. This indicates that IPPC is perceived as a threat by UK pig producers because it is likely to lead to further increases in total production cost in an industry which is already not cost competitive.

Competitiveness is also affected by macroeconomic factors, such as the exchange rate. For instance, the relative strength of Sterling against the Euro and the currency of EU members has brought disadvantages for British pig producers. Additionally, several types of economic incentives such as tax reductions, if given unilaterally by an individual member state, can affect competitiveness. Taxation arrangements for UK farmers are considered less favourable than for EU competitor states. The study refers for example to the longer write-off period for buildings for tax purposes, of 25 and 15 years in the UK and in other EU member states, respectively. Deductions from prices received by farmers (levies) for transport, offal disposal and promotion and research are significantly higher in the UK than other EU countries.

Despite the problems raised, the MLC report recognises that competitive costs in EU will tend to converge in the next few years due to the expected fall of Sterling against the Euro and indications that new welfare and environmental regulations will increase costs elsewhere, particularly in Holland and Denmark.

Also, MLC (1997) points out that pig meat industry is particularly dynamic due to strong cost-price pressures on margins over the long term, intensified since the establishment of the Single European Market in 1993 and respective increase in trade amongst national boundaries. This has "led to more marked rationalisation and greater economies of scale in the pig industry than for other species". This is evident in the 40% reduction in the number of pig producers and 57% drop in the number of abattoirs handling pigs in the UK during the ten years to 1995 (MLC, 1997).

Continued concentration has been a common trend for the slaughter/processing industry. In Great Britain there were 308 pig abattoirs in 1996/97 and the Top 10 industries (biggest slaughterers) had a market share of 52 per cent. From 1990 to 1997 the number of specialist pig abattoirs fell from 46 to 29. Their share of total British throughput, however, rose from 54 to 87 per cent (MLC, 1998b).

Despite this concentration, the British pig slaughter and processing industry has no major competitive advantage over the same industries in the main EU producer countries, namely, France, Denmark and the Netherlands (MLC, 1997). According to this MLC study, based on 1995 data, the British pig industry was comparatively much smaller than those in the other three countries and highly domestically orientated, reflecting Britain's relatively lower self-sufficiency in pig products. Relative disadvantages of the British pig industry have been attributed to the smaller size of the slaughtering and processing companies and to the lack of linkages within the pig procurement and marketing chain, partly reflecting the absence of fully integrated co-operatives found in the other countries. Other reasons pointed out related to the unfavourable exchange rate of sterling, the costs of traceability and assurance schemes and the ban of sow stall and tether systems in advance of other EU member-states.

According to MLC (1997), throughout Europe the pig supply chain has been affected by demands of the large retailers. For instance, in Britain the larger supermarkets controlled approximately 65 per cent of the pork and 75 per cent of the bacon retail trades in 1996.

MLC (1999b) asserts that because the ban of stalls and tethers for sows in the UK, many British retailers now require assurance that their bacon imports come from pigs raised in loose systems. One could suggest therefore that there is possibility of similar policy to be adopted with regard to IPPC, that is, environmental standards in pig production as outlined in the IPPC Directive may become a condition to export pig products to this country. However, the view of producers is that the domestic industry has not drawn benefit in market terms for pioneering the adoption welfare standards (NPA spokesperson, 2002). Similar worries are raised in respect to the implementation of IPPC.

Increasing environmental controls in northern EU countries resulted in migration of production to countries that do not have the same controls, as demonstrated by recent Dutch investments in Eastern Europe (MLC, 1998b). The EU long term trends for livestock production, also according to MLC (1998b), have been towards increased individual herd or flock size, decline in the number and contribution of small producers, and an increase in the proportion of total production coming from larger units. As discussed in earlier sections, IPPC could, on the one hand, reinforce the trend for concentration of production in large units, in order to obtain lower unit cost of compliance, and, on the other, induce reduction of scale of units marginally close to the IPPC thresholds, in order to avoid capture by regulation.

The aforementioned conditions suggest that, on the one side, that UK pig production has relatively limited scope to accommodate additional costs determined by IPPC regulation, because it already operates at comparatively high production cost. Notwithstanding, it is recognised that the pressures determined by requirements, either voluntary (market-based) or mandatory, such as by IPPC are likely to be balanced at EU level in the medium to long term.

2.3.5 Impacts of intensive livestock systems on the environment

The purpose of this subsection is to identify main types of pollutants generated by livestock activities to different environmental media. The intensification of systems for animal rearing is seen as a major cause of environmental problems associated with livestock production in developed economies. IPPC applied to pig production can be regarded as a policy response to the impacts from intensive livestock systems on the environment.

Pollution to environmental media from livestock production needs to be distinguished in two types: point source and diffuse (non-point source) pollution. Whereas the former refers to pollution from an identified building or field, the latter can originate from several emitting sources and is caused by a single event or action (MAFF, 1998b).

Point source pollution

Pollution incidents from livestock units in England and Wales are mainly, but not exclusively, associated with the generation of animal wastes. Also the use and storage of feed and veterinary medicinal products needs to be carefully managed because of their high potential of pollution to land or water (Environment Agency, 1999b).

According to Owen (1994), 20 per cent of the serious incidents of water pollution in the UK come from farms[19], being related mainly to slurry, silage liquor and dirty water.

The number of pig related incidents for the year 1998 is presented in Table 2.5, broken down by incident category and by region according to the Agency. Pollution incidents are classified by the Agency according to their total impact on the environment, that is, by considering the severity of their impact on all three media, in four categories, namely major, significant, minor and unsubstantiated incidents (as described in Appendix 2.2).

The majority of incidents (80%) were classified as minor incidents (Category 3). However, 19% were considered as significant incidents (Category 2) which have a considerably impact on the environment and one was a major incident (Category 1). Category 4 incidents, referring to unsubstantiated pollution events, are not counted.

Table 2. 5 - Number of pollution incidents that occurred as a result of pig farming,1998

Region Category	**Thames**	**Mid-lands**	**SW**	**Southern**	**Anglian**	**NW**	**Wales**	**NE**	**Total**
1 – major	0	0	0	0	0	0	0	1	1
2- significant	1	5	0	0	6	5	0	6	23
3 – minor	2	16	14	3	35	6	3	16	95
Total	**3**	**21**	**14**	**3**	**41**	**11**	**3**	**23**	**119**

Source: Environment Agency, personal communication (14/01/2000).

In broad terms, the distribution of number of pollution incidents follows the distribution of numbers of pigs, concentrated in the eastern and north-eastern counties (East Anglia

[19] Agriculture was identified as source of 26.5% of all Category 1 and 2 pollution incidents to water in 2001, being the biggest single polluter that year (Environment Agency, 2002a).

and Yorkshire/Humberside regions have the largest concentration of pigs according to 1998 MAFF Census).

There are particular human health risk associated with pollution by untreated slurry and manure which contain micro-organisms such as salmonellae, *E. coli* and campylobacters. Surface or groundwater polluted by manures can be contaminated by these pathogens (MAFF, 1998b).

Non-point source pollution

Major sources of environmental pollution from agriculture are non-point source: nitrate leaching, ammonia volatilisation and phosphorous flow (Kjaer & Madsen, 1998).

Ammonia losses from pig housing and from storage of pig manures are estimated to be about 15,000 tonnes annually (Webb, 2001), representing 7 per cent of those from agriculture[20]. Despite not being a major contributor to total ammonia emission, piggeries tend to concentrate great numbers of livestock units per area[21]. High deposition rates of N associated with ammonia have been verified in the vicinity of large pig units, with risks of damage to habitats as a result of acidification and eutrophication. (Environment Agency, 2000a).

Livestock production has a major impact on eutrophication[22] of waters. It is the main source of phosphorous input to surface waters in the UK, contributing with 29% of total for inland waters in England and Wales (Morse et al., 1993, in Environment Agency, 1998). The Agency estimates that 70% of the total input of nitrogen comes from diffuse sources, namely agriculture, precipitation and urban run-off. Fertilisers are the major source of N input in agriculture.

[20] Agriculture alone accounts for 80 per cent of the total emissions ammonia in the UK (Webb, 2001).
[21] There is an analytical difficulty here to classify type of pollution to air by source: air emissions from animal housing and storage facilities are relatively 'point source'. However, they are a continuous and not associated to an event. Many of these can be regarded as *fugitive* emissions because they represent ongoing leakages from a range of positions on the installation which often escape controls. Emissions from landspreading are comparatively more spatially dispersed but can be identified as an event where substantial ammonia emission is released.

Several sources (among them ECETOC, 1994; van der Peet-Schewering *et al.* 1999; Webb *et al.* 2000) refer that the releases of ammonia from animal processes and production into atmosphere contribute to the problems of environmental acidification. Additionally, methane (CH_4) releases from ruminants are a significant factor in global warming. Gaseous emissions and odour can cause harm or nuisance to both livestock and humans (Owen, 1994). However, the impact of agricultural processes on the above emissions is complicated because they both release and absorb greenhouse gases. But it is clear that on the release side, most of emissions come from digestive processes in animals, animal waste and fertiliser use. Thus, livestock systems are a major source of concern regarding emissions from agriculture, especially for methane and nitrous oxide (N_2O).

Kjaer and Madsen (1998), using data from Denmark, argue that nitrogen leaching is between 1.4 to 2.4 times higher on livestock farms than on cropping farms, reflecting the higher quantity of total N applied. However, nitrate leaching is a process related to soil characteristics, being more common in lighter soils. Also, the build-up of phosphorous (P) in soil is more likely to occur on livestock specialised or mixed farms than on cropping fields. In the latter, the total amount of P applied through inorganic fertiliser and manures is similar to the amount of P utilised by the crops and exported at harvest. However, livestock farms (the study involved cattle, pig and mixed farms) showed excess of application of P mainly from the considerable manure applied – leading to build-up of the nutrient in the soil and potential of run-off to surface waters.

Mixed crop and livestock systems are potentially more capable than livestock systems to absorb or mitigate environmental impacts. However, there are suggestions (Ho and Chan, 1998) that industrial, land-detached livestock units can be integrated with arable farms in a regional perspective (which they define as a giant 'regional mixed farm').

Intensive livestock systems

Intensive livestock systems are understood here as production systems highly dependent on outside inputs, especially feed and energy and, also, having technology, capital and

[22] 'Enrichment by inorganic plant nutrients, which results in disturbance on the balance of present

infrastructure based on large economies of scale (de Haan *et al.*, 2000)[23]. Also, these systems can be interpreted as those with high concentration of livestock units per area, where the mineral supply exceeds the requirements of the agricultural area with crops and grassland (EIPPC, 2001) or as those where the feed supply and waste absorption are unbalanced with the capacity of the available land (Delgado *et al.*, 1999). The IPPC Directive defines 'intensive livestock farms' based on capacity in terms of number of places for pigs (above the thresholds, previously referred, of 750 sows or 2,000 finishing pigs over 30 kg).

Intensive livestock rearing systems are particularly common for poultry and pigs. According to the Environment Agency (1999b), high livestock densities create large quantities of animal wastes which must require suitable methods for their recycling or be disposed of safely. It is estimated that approximately 80 million tonnes of animal slurry are spread on the land each year in England and Wales. Half of this quantity, some 40 million tonnes, is applied mechanically[24] (Environment Agency, 1999b). The spreading of livestock wastes to land is desirable as this recycles nutrients and organic matter to soil, benefiting cropping and grazing activities. However, intensive livestock rearing, particularly pig farming, raises risks associated with pollution as it stores and applies to land large quantities of animal wastes. Handling, treatment and disposal of such wastes requires careful management (Environment Agency, 1999b).

A list of impacts from intensive pig production was given by the Agency in an early draft for the SFIR (Environment Agency, 1999a), as compiled in Table 2.6. This list associates impacts with production phase or stage (*operation*) and also with the environmental issues according as defined by IPPC.

[23] The exact term used by de Haan *et al.* (2000) is industrial livestock systems, which is employed as a synonymous for intensive livestock systems by FAO and other authors such as Delgado et al. (1999).
[24] The remainder is directly deposited by animals to land.

Table 2. 6 - Impacts of pig rearing according to resources use and emissions to media

Issues	Operation/activity	Description of impact/effect
Raw materials	Farrowing & Weaning	animal feed and bedding (straw)
	Growing/Finishing	most of feed input is required in this phase
Air	Farrowing & Weaning	emissions of odour and ammonia
	Finishing	emissions of odour and ammonia can be significant, particularly from fully slatted floor
	Outdoors pigs*	direct deposition of faeces onto soil lead to emissions of ammonia and odour
	Collection and storage of slurries, FYM and dirty water	significant release of ammonia and odours, especially in warm weather
	Use and disposal of slurry, FYM and dirty water	significant release of ammonia and odours, particularly from slurry
	Disposal of carcasses	smoke and odour can be a problem if carcasses are burnt or stored on site before disposal of
Waste	Farrowing & Weaning	slurry or manure; also small number of carcasses
	Finishing	slurry or manure; occasional carcasses
	Outdoors pigs	animal wastes and straw bedding from arks
	Collection and storage of slurry, FYM and dirty water	minimal
	Use and disposal of slurry, FYM and dirty water	minimal if spread to benefit of agricultural land
	Disposal of carcasses	carcass production is kept to a minimum by good welfare practice
Water	Farrowing & Weaning	potential or releases of contaminated water from buildings
	Finishing	potential or releases of contaminated water from housing
	Outdoors pigs	risk of run-off to surface water and leaching to groundwater are significant
	Collection and storage of slurry, FYM and dirty water	risk of spillage and run-off
	Use and disposal of slurry, FYM and dirty water	risk of run-off and leaching
	Disposal of carcasses	minor risk of run-off as most carcasses are kept in sealed bags

(cont.)

(continued Table 2.6)

Issues	Operation/activity	Description of impact/effect
Energy	Farrowing & Weaning	heating and ventilation systems
	Finishing	forced ventilation systems if in place
	Outdoors pigs	Minimal
	Collection and storage of slurry, FYM and dirty water	Minimal
Noise	Farrowing & Weaning	animals, ventilation, feed delivery
	Finishing	animals, ventilation, feed delivery
	Outdoors pigs	Minimal
	Collection and storage of slurry, FYM and dirty water	may be significant if slurry and manure are transported in bulk
Land	Outdoors pigs	significant risk of soil erosion and build up of soil nutrients
	Use and disposal of slurry, FYM and dirty water	risk of build up of nutrients and metals (Cu, Zn)
	Disposal of carcasses	risk of build up of contamination associated with burial

Note: *outdoor production is not covered by IPPC, but its impacts are briefed in this table in order to describe a system in expansion, already with substantial % of total sows in the UK.
Source: compiled from Environment Agency (1999a). *Interim guidance for Integrated Pollution Prevention and Control for Intensive Livestock.* Guide V1 April 1999.

The UK Government (DETR, 1998) expects the implementation of IPPC for intensive pig and poultry rearing to deliver improvements in energy efficiency and reductions in diffuse nitrogen emissions. It recognises that the reduction of these N emissions initially focuses mainly on ammonia, which is not included in the Kyoto Protocol [25]. Nevertheless, it is argued that expected improvements in nutrients management and in adoption of ammonia abatement techniques are likely to reduce the nitrous oxide losses, as they should have a knock-down effect on the emission of this gas.

The IPPC definition of 'intensive pig rearing' is likely to deliver environmental control over a substantial share of the pig herd. According to the MLC, the application of IPPC thresholds to existing pig units would bring approximately 58% of the total pig herd in the UK under the IPPC regime (ENDS, 2000b).

[25] The targets of Kyoto Protocol are the following greenhouse gases: CO_2, methane , N_20, two fluorocarbons –HFC and CFC - and sulphur hexafluoride (DETR, 1998).

IPPC as a response to impacts of intensive livestock systems

The interaction between livestock and environment, and thereby the associated environmental impacts, are dependent on the degree of intensity of the enterprise.

De Haan *et al.*, 2000 used a Driving force-State-Response (DSR) framework to analyse intensive livestock and environment framework. Here, their initial insight is adapted to a DPSIR format[26], as follows. In the industrialised world economies external factors such as increasing population, growing incomes and market opportunities (*Driving forces)* had lead agricultural production systems, even the integrated ones, to intensification (*Pressures*). The great amount of input imports has as consequence a dis-equilibrium in the balance of nutrients (surpluses), with the overloading of water and soil causing pollution. So, the *State* of the environment suffers a deterioration of air, land and water quality, damaging the associated ecosystems (*Impacts*). *Response* to these problems comes through technology and policy options, including regulation. The response may influence the driving forces, changing pressures and impacts, which affect the state of the environment. IPPC is essentially a regulatory response, but it also, throughout BAT, involves economic and technological elements.

This subsection provided a discussion on environmental aspects of livestock production, concentrating particularly on impacts of intensive systems. Point source and diffuse pollution were differentiated. Livestock units are associated with a significant part of the total pollution incidents, especially those cause by accidental release and run-off of slurry or dirty water into surface waters. Diffuse pollution is associated mainly to nitrate leaching, ammonia release and phosphorous flow. It was identified that whereas the majority of studies of N emissions from livestock production focus on nitrates to water, in BAT for pig production (see section 2.2) the focus is clearly on control of ammonia to air. The environmental impacts of livestock activities depend on site specific conditions, particularly characteristics of soils and land availability for spreading of manures, which confirms these are a central aspects to be considered when determining BAT measures. In summary, considerable impacts on the environment arise from

[26] In the latter, Driving Forces and Pressures are differentiated, as well as Pressures and Impacts. The view, however, is the same originally used by the OECD.

intensive rearing of pigs and other livestock. In this respect, environmental regulation, such as IPPC, is essentially a policy response to the pressures and impacts imposed on the environment by intensive livestock production.

2.4 ECONOMIC AND ENVIRONMENTAL ASSESSMENT OF REGULATION

Regulation is an option among other policy instruments. Therefore, it is important to assess and monitor its efficiency in addressing policy targets. This is the remit of regulatory impact assessment, which comprises environmental and economic analysis tools.

2.4.1 Defining environmental regulation

Pollution control instruments can be classified (Perman *et al.*, 1999) in three groups: command and control instruments, economic incentive instruments and institutional approaches. Command and control (CAC) instruments involve quantitative and qualitative controls and regulations on output produced or input used, as well as to technology used in production processes, location and timing of pollution activities (Perman *et al.*, 1999). Economic incentive instruments (also known as quasi-market or market-based instruments) refer to application of taxes on emissions or on use of inputs, offers of subsidies on pollution abatement measures and use of transferable emissions or abstraction permits. Institutional approaches to facilitate the internalisation of externalities involve methods such as encouraging education and social awareness on environmental issues, and bargaining solutions for environmental problems.

By definition, regulation through a directive, such as IPPC, is a command and control (CAC) approach to environment protection. Baumol and Oates (1989), quoted by Clinch (2001), define CAC as "a directive to individual decision makers requiring them to set one or more output or input quantities at some specified levels or prohibiting them from exceeding (or falling short of) some specified levels".

In economic terms, the criticism of the application of CAC to environmental policymaking is that this approach is relatively inefficient if compared to flexible mechanisms, due to its higher costs of compliance[27]. Market-based approaches (such as emissions trading or charges on emissions) are generally preferred by economists. Underlying their superior cost effectiveness in relation to other instruments is the argument that market-based instruments benefit from the operator (or a firm) knowledge on how best to allocate resources.

Conversely, because of the considerable information required, the regulator is unlikely to achieve total costs of compliance and administration as low as those by the market itself (Tietenberg, 1990; Clinch, 2001). However least cost (cost effectiveness) is an important but not exclusive criterion for selection of one policy instrument. The government and regulatory authority take into account other criteria, such as considering to what extent they can rely on a given instrument (dependability) and how enforceable it is (enforceability). Also dynamic efficiency (which is concerned with the effects of chosen instrument on continuous incentives for improvement of the product or processes involved), administrative feasibility, flexibility and equity are important criteria (Perman et al., 1999).

Command and control instruments may assume distinct formats. That is, 'control' may apply to the quantity of output produced (usually the undesired output, emission of pollutant), to the quantity of input consumed, to the production technology used, or to spatial (location) or temporal (timing) distribution of an activity (Perman et al., 1999). In this classification, IPPC falls into the category of instruments that impose minimum technology requirements (technology-based or process-based regulation). Technology-based instruments have been those dominant for environmental protection in OECD countries according to the above authors.

Setting Environmental Limit Values (ELVs) and Environmental Quality Standards (EQSs) or Objectives (EQO, using the OECD denomination of environment-based

[27] Extensive evidence of comparative costs of CAC and market instruments can be found in Tietenberg (1990). In addition, cost for monitoring, administering and enforcing compliance can be substantial.

requirements) are examples of instruments regulating the permissible quantity of emission (DETR, 2000a). The IPPC regime is based on the use of BAT, therefore, it is typically an instrument imposing minimum technology requirements (Rajotte, 2000) or, as Sorrel (2001) defines, a *process-based* approach. Of course there are ELVs underpinning BAT and IPPC is subject to EQS posed by other mandatory instruments (OJ, 1996; DETR, 2000a).

2.4.2 The origins, definition and use of Regulatory Impact Assessment (RIA)

The economic analysis of regulations or Regulatory Impact Assessment (RIA), according to Morgenstern (1997), draws on the discipline of environmental economics, which particularly expanded in the 1980s and 1990s. It applies modern concepts of welfare economics to regulatory issues, including environmental regulation. Mainstream environmental economists, according to this author, identify three main functions for the economic analysis of regulation, namely: presenting information about benefits and costs associated to the regulation, determining cost-effectiveness and showing how costs and benefits are distributed.

Despite an extensive theoretical and practical literature on valuation of benefits, in essence the economic results from these methodologies reflect the value that individuals put on protection of a given environmental good. However, several difficulties underpin these tools, such as what discounting rate to use, how to define a baseline for comparison, and treatment of risk and uncertainty (Morgenstern, 1997).

Avoidance of the complexity of benefits estimation in such methodologies determines that most of the assessment of policy options has been confined to the comparison between the extra costs determined by compliance and the reduction of release of pollutants. Defined as Cost-Effectiveness (CE), it is usually presented in an annual basis (see more details in section 2.4.3).

Some economic models were developed for assessment of the application of the 'As Low As Reasonably Achievable' (ALARA) Principle[28], such as MIOW$^+$ model applied in the Netherlands (van der Woerd, 2001) and Belgium (Vercaemst, 2001). The ALARA principle was introduced in Dutch legislation and means that the environmental impacts of economic activities must be 'as low as reasonably possible'. The MIOW$^+$ model combines environmental costs (compliance costs, in this context) with business resilience and market indicators to determine sectoral or corporate feasibility of compliance.

The two most important aspects on economic analysis of regulation are: 1) cost effectiveness of measures which operators are required to comply, and 2) sectoral affordability of the policy being implemented (Sorrel, 2001). Determining impacts of measures based on a framework concept such as BAT and BATNEEC represents a challenge. The implementation of the IPC regime showed that even though guidance is provided through documents, the assessment of conditions for application and compliance with a permit involves a degree of subjectivity (Sorrel, 2001). There is a certain degree of discretion for the regulatory authority staff in determining whether or not conditions offered are sufficient to meet requirements for a permit to be granted. Factors such as specific conditions of the site and management of the unit are unlikely to be covered in standard rules and guidance.

A central theme in the literature on environmental regulation (Smith, 1996b; Gouldson and Murphy, 1998) is that compliance with regulation is better defined as a *process* than an *event*. This notion of compliance with regulation as a process defines implementation as that of continuous negotiation and as a product of the interaction of stakeholders involved.

The notion of regulatory compliance as negotiation process, for Bailey and Haq (2001), may determine that the implementation may turn out rather different than originally envisaged by regulators. According to the authors, it also partially explains the

[28] In the UK, the Health and Safety Executive (HSE) employs for similar purposes the concept of 'As Low As Reasonably Possible' (ALARP).

difference between estimated *ex ante* and *ex post* compliance costs. They suggest that anticipated compliance costs are usually higher than realised costs, reflecting the over-estimation of environmental measures by the industry during the negotiation of regulation.

Other factors besides the strategic behaviour of stakeholders may make the *ex ante* forecasting of compliance costs of regulation difficult, namely: unpredictability of technological innovations likely to emerge during, and in response to the process, and the ability of a business to reduce the compliance costs once legislation is introduced (Bailey and Haq, 2001).

These factors must be acknowledged as important sources of bias in the results when investigating impacts prior or at the very beginning of the policy implementation, such as in this research.

The work by Porter and van der Linde (1995), frequently referred to in the implementation literature on environmental regulation, put the regulatory process as a driver for innovations in the firm or sector regulated. These innovations would lead, argue the authors, to efficiency gains or increase in value of produce, which offset incremental cost of environmental protection. Therefore, environmental regulation is seen by Porter and van der Linde as a factor with potential to increase the competitiveness of regulated entities.

2.4.3 Environmental Impact Assessment (EIA) of intensive pig rearing

Environmental Impact Assessment (EIA) is defined as a technique or process involving gathering and analysing the effects of a project on the environment. Methods used for EIA include the use of checklists, matrices, flow charts, ecological modelling and risk analysis. It is argued that EIA is a suitable assessment approach to capture the integrated features of IPPC regulation.

One of the most widely used tools in environmental impact assessment (EIA) is the use of flow charts or process diagrams. A flow chart enables a systemic representation of *processes and activities* and their *effects* on relevant environmental issues. In showing links between processes and effects, the flow chart technique can portray the dynamics of the system and provide an overall view of the impact of a given activity.

In applying EIA, an important step is the identification of environmental effects and impacts of a project or activity being assessed. They include: emissions to receiving environmental media (air, land and water), generation of wastes, use of inputs and natural resources, generation of noise, odours and visual impact and effect on ecosystems.

EIA also attempts to where possible to measure the environmental effects or impacts by using objective indicators, as follows.

Use of environmental and economic indicators

Indicators have been used or proposed to design, monitor and evaluate policy associated to sustainable development in general and sustainable agriculture in particular. Several have links with issues addressed by IPPC.

Indicators provide a practical and reasonable way to deal with complex nature of the term 'sustainability' and have been increasingly used in agriculture (Pannell and Schilizzi, 1999). Pannell and Glenn (2000) suggest that two main groups of indicators can be differentiated for policy purposes: indicators recommended and promoted to farmers and indicators to assist policy making.

The usefulness of indicators in assessment of policy is pointed out by DoE (1996), which suggests that a framework of indicators enables an overview for considering environmental problems and the associated interconnection between them. That is, it offers a systematic way to approach issues (not only environmental ones), reducing the risk of overlooking relevant elements.

Determining environmental impacts in agriculture can be complicated, diverse and liable to substantial local variation (DETR, 1997a). Therefore, selecting and monitoring environmental indicators and targets need to take this into account. Moreover, DETR (1999) notes that working with indicators is not without its challenges. For instance, to be meaningful the assessment of performance using indicators has to consider four key aspects, namely: target, timescale, prioritisation, and measurement (Pretty, 1998). Measurability and comparability and are particularly disputable issues when someone is making use of such indicators. Notwithstanding these limitations, the Government (DETR, 1999) produced a revised[29] national set of sustainable development indicators, reinforcing that indicators provide a better understanding of the links between policies, enabling the application of integrated approaches rather than tackling issues individually.

Table 2.7 presents some sectoral indicators of sustainability from DETR (1999), some of which are relevant for assessing the impact of intensive pig systems and a potential framework related with IPPC for intensive livestock farming.

Table 2. 7 - Selected indicators of sustainability for the UK based on the DETR list

Sector/Domain	Indicators	IPPC relevant
General indicators (for all sectors)	Energy and water consumption	✓
	Waste and hazardous emissions	✓
	Adoption of environmental management systems	✓
	Environmental and sustainable development reporting	✓
Food and drink	Producing affordable and good quality food and drink in accordance with high environmental and welfare standards	✓
Farm and countryside	Pesticide residues in food	✓
	Area under agreement under the Environmentally Sensitive Areas and Countryside Stewardship agri-environmental schemes	✓
	Area converted to organic production	
Building sustainable communities	Access to rural services	

(cont.)

[29] The 1996's set was later revised (HMSO, 1996). In the new set of indicators, which are about 150, changes made are related particularly with the social issues.

(continued Table 2.7)

Sector/Domain	Indicators	IPPC relevant
Managing the Environment and resources	Concentration of persistent organic pollutants	✓
Air and atmosphere	Emissions of greenhouse gases; (In this research, acidificator – ammonia is relevant)	✓
Freshwater	Rivers of good or fair quality Water demand and availability Water affordability Water leakage Nutrients in water	✓ ✓ ✓ ✓
Contaminated land	Net loss of greenfield soils to development Concentrations of organic material in agricultural topsoils.	 ✓
International co-operation and development	UK public expenditure on global environmental agreements ((In this research could be company expenditure on pollution control techniques) Sustainable Development footprint (are the systems causing unsustainable production in other countries?)	✓ ✓

Source: compiled from *A better quality of life: a strategy for sustainable development for the United Kingdom.* DETR (1999).

Sectoral level indicators, such as those selected in Table 2.7, can provide some analytical insights into the environmental performance of livestock production. However, specifically indicators need to be developed for pig systems, in order to help design, implement and monitor environmental regulation such as IPPC.

Performance indicators at farm level

Webster (1999) reports that significant effort is being expended in the search of appropriate indicators of sustainability at the agricultural sector level. Illustrative of this effort is the series of 13 'priority issues' and suggested potential indicators identified by OECD (1997), using a 'Pressure – State – Response' (PSR) framework[30], focusing on assessment of agri-environmental schemes. Also the UK government proposed a series of 34 individual indicators based on 13 themes (MAFF, 1998a). Table 2.8 compares OECD's issues and MAFF's (now DEFRA) themes and notes the potential link to IPPC.

[30] As referred to previously, the PSR framework was more recently (EEA, 1999) redefined as DPSIR (Driving Force – Pressure - State - Impact – Response), but the principles behind it are basically the same of the original OECD version.

Table 2. 8 - OECD issues and MAFF themes and set of indicators for agriculture

OECD 'issues'	MAFF 'themes'		MAFF indicators	IPPC relevant
Nutrient use	1	Nutrient losses to freshwater	N losses in selected catchments	✓
Greenhouse gases	2	Soil P levels	P losses in selected catchments	✓
Pesticide use	3	Nutrient management practices	% land sampled for P	✓
			Slurry storage and timing of application	✓
			Nutrient application techniques	✓
Water use	4	Ammonia emissions	Quantity emitted	✓
Water quality	5	Greenhouse gas emissions	CH_4 emissions	✓
			NO emissions	✓
Soil quality	6	Pesticide use	Pesticide in rivers	✓
			Pesticides in groundwater	✓
			Quantity of active ingredient	✓
			'Spray area' treated	✓
			Number of wildlife 'incidents'	
			Residues in food	
Land use and conservation	7	Water use	Storage capacity as % of irrigated use	✓
			Economic value of irrigated crops	
Landscape	8	Soil protection	Topsoil organic matter content	✓
			Topsoil heavy metal content	✓
			Soil management practices	✓
Biodiversity	9	Agricultural land resource	Area lost to non-agricultural development	
			Area restored following mineral extraction or landfill	
Wildlife habitats	10	Conservation value of agricultural land	Area under environmental conservation	✓
			Area under organic production	
			Length of hedgerows and walls	
			Population of key farmland birds	
			Area of semi-natural grassland	
			Upland management	
Farm management	11	Environmental management systems	Adoption of EMS by farmers	✓
Socio-cultural issues	12	Rural economy	EU producer subsidy equivalent	
			Environmental payments as % of CAP expenditure	
			Agricultural productivity	✓
			Rural unemployment	✓
	13	Energy	Area planted with energy crops	✓

Source: Webster (1999) *The challenge of sustainability at farm level*. p.9 (OECD and MAFF themes and indicators).

Webster (1999) regards as there is broad agreement between many of OECD's 'issues' and MAFF's 'themes', and on the relevance on the use of indicators for policy purposes. However, it is noticeable the emphasis of the former document upon the adoption of farm management practices and financial viability.

A set of environmental indicators (mostly response indicators) for intensive livestock production systems are suggested by the de Haan *et al* (2000), as shown in Table 2.9.

Table 2. 9 – Set of indicators for industrial livestock production systems

Type/Indicator	IPPC relevant
Input-related	
- Land use changes and land requirements for food production	✓
- Percentage of grains in concentrates and diet	✓
- Rangeland requirements for young stock	
- Livestock breeds used	✓
- Inputs to feed production (fuel, fertiliser)	✓
Production-related	
- Conversion efficiencies for N and P by animal species	✓
- Farm gate N and P balance	✓
- Ammonia emissions	✓
- Methane emissions	✓
- Fossil energy consumption	✓
- Animal welfare index	
- Chemical use	✓
Output-related	
- Manure discharge	✓
- Nutrient balance	✓
- Fertilising value of manure	✓
- Methane emissions	✓
- Tonnes of liveweight slaughtered	✓
- Tonnes of raw meat	
- Manure storage	✓

Source: adapted (set of indicators) from de Haan *et al* (2000). *Livestock and the environment: finding a balance*.

There is considerable convergence between the issues addressed by IPPC and sets of indicators proposed for assessment of policy strategy[31] towards a sustainable agriculture for developed economies in general and at UK level. Therefore, it can be inferred that

[31] This involves agricultural, agri-environmental and environmental policies.

there is synergy between IPPC regulation and the emerging policies and initiatives with respect to sustainable agriculture.

That is, on the one hand IPPC implementation can potentially contribute to a more sustainable agriculture and livestock production. On the other hand, the overall policy framework and independent initiatives (such as voluntary schemes) are likely to reinforce IPPC and, therefore, reduce the burden associated with this regulation. In other words, to an extent, what is now being required as compliance with IPPC is likely to be brought about in the sector by other instruments in due course.

2.4.4 Approaches to benefits and costs of regulation

The regulatory authority has a duty to balance its role of protecting and enhancing the environment with the costs involved in doing so (Environment Agency, 1996). Therefore, it is recommended to the Agency to work collaboratively with the involved actors (including regulated parties) in order 'to develop approaches which deliver environmental requirements without imposing excessive costs (in relation to the benefits gained)'. That is the condition of proportionality[32] for the policy being implemented.

The Agency has a duty to account for the costs and benefits of its actions (as required by the Environment Act 1995). The Agency has issued guidance (Environment Agency, 1996) that suggest that in determining the means to achieve environmental objectives or targets, the Agency should use: *cost-effectiveness analysis* where those environmental objectives are non-discretionary (e.g. statutory); *cost-benefit analysis* where costs and benefits of action need to be decided and the monetary valuation of non-financial costs and benefits is achievable ('reasonably acceptable'), and *multi-attribute analysis* where costs and benefits of action need to be decided but the monetary valuation of non-financial costs and benefits is inappropriate.

[32] Proportionality here refers to the condition where the cost determined by a policy in question are proportionate to the benefits delivered by this policy.

The IPPC Directive is empowered in England and Wales through a governmental act. This is a situation where the regulator should use cost-effectiveness analysis to assess the options in delivering the requirements. However, the challenge is that BAT involves assessment of economic viability of pollution prevention and control measures.

Another challenge is that IPPC involves an integrated approach. This is a BPEO-like selection process (HMSO, 1997), but the analysis tends to favour elements already defined by scientific evidence in terms of techniques, such as performance in terms of emissions of ammonia. Therefore, a risk assessment of trade-offs and inclusion of other factors to select techniques is important, giving regulators and operators necessary flexibility and, possibly, widening the scope of a single factor focused BAT.

O'Connor and Spash (1999) argue that Cost Efficiency Analysis (CEA), synonymous of cost-effectiveness in this context, can avoid some complex and disputable assumptions intrinsic to CBA when trying to establish monetary valuation of environmental benefits.

Cost effectiveness (CE) can be defined (de Jonge, 2000; InfoMil, 2002) as presented in Box 2.1. However, other costs such as permitting costs for operators and administrative costs of the regulator are not explicitly described.

Box 2. 1 - Calculation of Cost effectiveness of an environmental measure

$$CE = \frac{\textbf{Total extra annual costs}}{\textbf{Total annual reduction in emissions}}$$

where:

CE is cost effectiveness of the environmental measure;

Total extra annual costs is a sum of extra capital investment costs
disinvestments
extra operating costs
less extra revenues and savings; and

Total annual reduction in emission is the difference between
annual emission without measure and
annual emission with measure.

Source: InfoMil (2002).

A more detailed approach to calculate the annual costs of proposed BAT (investment analysis or cash flow of technological change) is suggested by Schultmann *et al.* (2000). This comprises determination of costs related to additional investments and operation costs (if required), determination of relevant material and energy flows related to BAT measures and their costs and, finally, determination of other decision relevant costs and revenues (e.g. personnel costs, follow up costs, overhead, revenues for products of recycling measures). From this, the cost concept for BAT can be expressed as in Box 2.2.

Box 2. 2 - Calculation of BAT annual cost

$$K^{BAT} = K^{BAT}{}_{I} + K^{BAT}{}_{ME} + K^{BAT}{}_{Process} + K^{BAT}{}_{Other}$$

where:

K^{BAT} = total cost for the evaluated BAT
$K^{BAT}{}_{I}$ = costs related to investments
$K^{BAT}{}_{ME}$ = costs for inputs and outputs induced by material and/or energy flows
$K^{BAT}{}_{Process}$ = process costs for relevant unit operation
$K^{BAT}{}_{Other}$ = other decision relevant costs

(All of them expressed in currency units/ annum).

Source: adapted from Schultmann et al. (2000).

The definition of *available* in BAT (see section 2.1.3) incorporates the consideration of economic criteria for the selection of environmental techniques. By implication, the standards determined for compliance with IPPC regulation are subject to sectoral affordability. The IPPC regulatory authority has a statutory duty to account for the proportionality of its actions. Thus, the estimation and evaluation of likely environmental and economic impacts of IPPC are elements necessary to support the implementation process of IPPC and policy review. This research is set in this context, aiming to contribute to the implementation of IPPC to the pig industry by developing and applying a framework for assessment of the its regulatory impact.

2.4.5 Stakeholders Analysis and Policy actors network for IPPC

IPPC implementation process necessarily involves a wide range of stakeholders. These include regulators, the regulated and many other agents who have interest or influence in the regulatory process applied to the particular sector of concern. The representation of power and interest of stakeholders on IPPC indicates some challenges and synergies associated with the IPPC implementation process.

The matrix of power/interest (Johnson and Scholes, 1997) is useful to indicate the type of relationship between each stakeholder group and the issue of concern, in this case IPPC implementation. Figure 2.3 places stakeholders according to the power they hold and the extent to which they are likely to show interest in the implementation of IPPC.

For example, British pig and farmers associations, on the one hand, are concerned about enforcement of IPPC Directive, because they believe that they will lose competitiveness with the new IPPC regulations. They claim that rules must be flexible and consider special cases. On the other hand, these associations acknowledge that this new legislation represents an opportunity to enhance and/or establish common standards of domestic production and meet market demands for produce quality and safety (Pellini *et al.*, 1999).

The key players in IPPC implementation are shown in segment D, and these include both industry participants and the regulators. Players in segment C are in general passive but have potential influence if they choose to use it, particularly through pressures placed on those organisations contained in segment D. Segment B players, namely producers and those consumers with focused environmental concerns, have high interest but exert their influence through lobbying other more powerful stakeholders. The players in segment A, containing perhaps the majority of consumers, are not likely to have substantial relevance to the development of the IPPC strategy. This segment also comprises producers not likely to be captured by the IPPC, who do not have, at least immediately, major interest in the new regime.

From Figure 2.3 it can be inferred that farm level producers, despite having high interest in the IPPC implementation, have relatively low influence in the definition of changes (especially technological ones) in the supply chain, although this fragmentation of power is partly addressed by trade associations. There is evidence that more recently they have mobilised their interest with a great degree of participation, particularly in the IPPC Pig Steering Group and supporting technical groups.

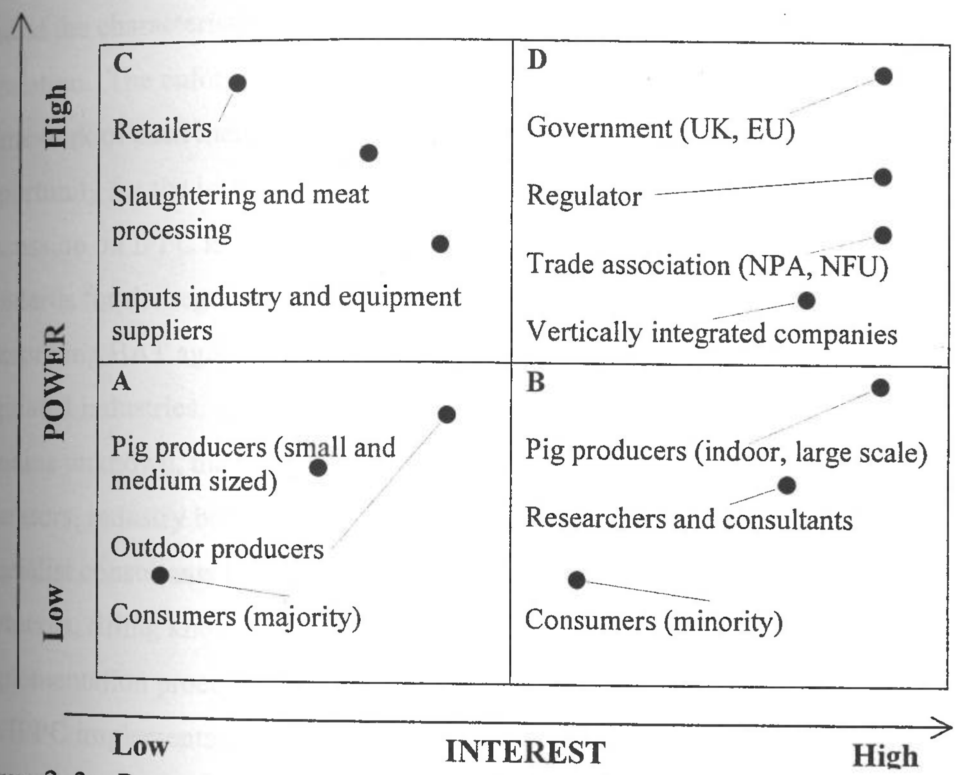

Figure 2. 3 – Power/interest matrix of stakeholders for IPPC implementation
Source: Pellini et al. (1999).

Retailers, despite having a high degree of power, are not likely to be involved in the implementation of IPPC due to relatively low degree of interest. Consumers can influence the policy through interest groups concerned with particular issues such organic farming, food safety and quality, and animal welfare. Clearly, the major role regarding changes in production systems associated with IPPC lies with the regulators[33] and the Government[34].

Stakeholders influencing the evolving process of IPPC implementation in the sector were presented. The interdependency among these stakeholders for policy implementation gives raise to policy actor network.

One of the characteristics of an EU directive is that it defines principles and scope of a regulation. The enforcement, though, requires its transposition into the national legal framework of each member state. In this process there is a degree of flexibility, and opportunity for the interested parties to exert political influence. In the core of the discussion on IPPC is the determination of a sectoral BAT, from which most of the standards for the regulated activity are derived. Defining BAT, and especially interpreting BAT against current systems, is a complex task, particularly for newly regulated industries. As much of the environmental performance of current systems remains unknown, the regulator has to rely on technical information provided by operators, industry bodies, and research organisations. The role of researchers and specialist consultants is also critical in terms of definition of regulatory standards and protocols, filling knowledge gaps, and providing particular competences to support the implementation process. This confirms that an overview of the political dimensions of the IPPC implementation process, as this describes the interaction of key actors, is important for the general understanding of the evolving process of IPPC regulation.

O'Connor and Spash (1999) argue that proper analysis of policy requires the understanding of the broader context of institutional change, conflict resolution and political negotiation. Martinez-Alier et al. (1999) pose that in general environmental targets (in this context, ELVs and EQSs) are set by practical judgements, a process which involves not only scientific expertise but also social evaluation (or, as referred to by the author, 'extended peer review'). Söderbaum (1999) suggests that economic actors engage in activities and are connected in relationships and networks. This non-

[33] The rules and guidance produced by the Agency define in practical terms what BAT is and set the basis to determine whether or not operators applying for an IPPC permit comply with them.
[34] Understood here as Government at national and European levels.

market interaction can be as important as market ones for social and economic change. Therefore, economic, institutional and social context can be interpreted in actor-network terms.

Smith (1996b), examining the case of IPC in the UK, suggests the use of policy networks to analyse the implementation of pollution regulation. This approach focuses upon the interactions between the actors interested in influencing policy decisions. Smith (1996b) argues that modern policy problems (including pollution control) are highly complex and, therefore, policy actors (see Figure 2.3) trying to address the issues are, most of time, interdependent on the resources of others. The basic premise underlying the policy networks concept is that such resource interdependency 'brings actors together into policy network arrangements and constrains and influences the policy process'. In other words, 'resource interdependency[35] means organisations have to bargain with one another if they are like to secure policy outcomes'. The lack of information held by from the regulator about the process being regulated relative to that held by the operator who is subject to regulation (sometimes known as *information asymmetry*), means that 'pollution standards will reflect, at least to some extent, political judgement and industrial lobbying pressures, as well as technical feasibility and costs' (Lyons, 1992 quoted by Smith, 1996b).

Therefore, technical proposals may affect interests of the parties involved with IPPC, causing reactions leading to influence the policies (lobbying) to reduce the pressure on private domain. It can be verified that, among other pressures on the sector, the introduction of IPPC has caused (or at least, reinforced) an important re-organisation of the UK pig operators into a new association. Particularly in previously unregulated sectors, the regulatory authority has to work in liaison with the industry, as the basic information on systems relies on operators. Financial and economic sound information is a powerful input in such a situation, which is more easily obtained from a well organised trade body where the sector contains relatively small businesses such as farmers. In the pig sector, the most important aspects involving negotiation during the

[35] The five resources (Rhodes, 1986 quoted by Smith, 1996) central to the interaction between network members are: authority; money; political legitimacy; information; and organisation.

implementation process have included definition of BAT, scope and format of SFIR, and mechanisms to support implementation. Therefore, it is important to identify the role of stakeholders in the process of IPPC implementation. This, as reported later, was achieved by participation in IPPC Pig Steering Group and by means of stakeholder analysis.

2.5 SUMMARY OF THE CHAPTER AND CONCLUSIONS

Implementation of the IPPC Directive to pig industry is seen as a step towards improving environmental performance of livestock production systems. However, along with the environmental benefits, IPPC is likely to have important implications in terms of costs for the industry. The effectiveness of IPPC regulation will be reduced if operators can avoid legislation, either by scaling down the units to below the thresholds or shifting to outdoor systems. There is a risk that significant aggregate emissions continue from livestock units not regulated by IPPC.

In section 2.3, it was confirmed that the application of IPPC to the pig sector is justified in terms of the pursuing the achievement of sustainable development by reducing the potential negative impacts on the environment (Environment Agency, 1998; DETR, 1998). However, it was verified in section 2.4 that the implementation of the IPPC regime is expected to have important cost and benefit implications for the industry, especially during the initial adoption period. It is also likely, through BAT and SFIR to encourage convergence of technology and practice, with possible implications for the structure and competitiveness of the industry. Under the 1995 Environment Act, the regulator has a duty to consider cost and benefit impacts of policy implementation, including those impacts borne by those whose processes are regulated, in order to comply with the proportionality principle (DETR, 1999). Thus, the relevance of the aim of this research is confirmed, namely to develop a framework for assessing the economic and environmental impacts of the implementation of the IPPC Directive in the pig sector, considering the integrated nature of this regulation.

Particularly for previously unregulated sectors, the regulatory authority has to establish liaison with the industry to obtain information on the environmental and economic performance of systems. In this respect, access to reliable data is a powerful input in determining the feasibility of BAT. There is an important role for research to provide analytical methods to assess BAT options and guide impact assessment of regulation.

IPPC implementation using a technology-based approach (BAT) and standard permit conditions (SFIR) is likely lead to a greater homogenisation of pig production systems. Also larger scale pig units are more likely to be able to afford the IPPC compliance costs. An even greater concentration of producers in large units can have negative social and economic consequences.

Environmental Impact Assessment (EIA) is appropriate for analysing IPPC as it involves an integrated approach to pollution regulation. A flow chart approach can describe the link between resource use, emissions and processes involved in a pig installation. The changes in the systems associated with IPPC can be captured with use of indicators. Also, IPPC Directive is predominantly a command-and-control instrument, delivered through the concept of BAT, which is predominantly based on the concept of promoting the most cost:effective measures for prevention and control. This justifies the use of CEA as an analytical tool.

Having defined the scope and boundary of the study in this chapter, the research questions posed in Chapter 1 can be revisited and their validity confirmed. This chapter has gone some way to addressing these questions, and in so doing prepares the way for primary research.

Research question (RQ) I (*What is the current financial and environmental performance of pig intensive livestock systems?*) is relevant to define the baseline for the study and for the comparative unregulated scenario. This question was partially answered in this chapter. It has been shown that there are substantial pollution problems associated to intensive livestock production, and that the UK pig industry has, in recent years, been under increasing competitive pressure from other competitor producer countries because of efficiency, structural and macroeconomic factors.

RQ II (*What are the relevant indicators for assessment of the impacts of IPPC to the pig industry?*) is relevant to verify the interrelation between the main financial and environmental issues for pig production and those addressed by IPPC. Also, the answer to this question help to scrutinise the regulation against its design criteria, that is as a cost effective mechanism for delivering 'integrated' pollution prevention and control.

Answering RQ *III (How does IPPC relate to other statutory and voluntary instruments?*) helps a broader understanding of the forces driving technical and structural change in the pig sector and how producers perceive and respond to them. This is needed to assess the relative importance of role of IPPC in promoting change, and how IPPC interacts with other legal and voluntary frameworks covering the activity. It is also important for determining the incremental effect of IPPC over and above existing or likely future environmental legislation. Partially, this question has already been addressed by the review of the literature.

The answer to RQ IV (*What are the impacts of IPPC on the financial and environmental performance of the UK pig industry?*) is the core element of this research. This will provide useful insights into the likely compliance costs of regulation, which will be compared to the baseline performance in order to assess affordability. This will require cost-effectiveness of alternative BAT options to be estimated, enabling different sets of environmental measures suited to site specific conditions to be explored. Even though it is recognised that there are inherent limitations in undertaking *ex ante* estimation of compliance costs associated with environmental regulation, it has been argued here that answering the proposed research question IV is valid. Firstly, this is because it appears that no other works have specifically analysed the likely IPPC impacts on the pig industry. Secondly because, despite the methodological and practical difficulties (lack of economic and technical data), the determination of magnitude and relative participation of costs of permitting and costs of compliance with BAT can help to identify necessary policy adjustments during the process of implementation. Also investigating the affordability of IPPC by pig producers can help to select suitable policy measures to support the pig industry as a whole during the transition period.

Finally, answering RQ V (*Is the current policy design of IPPC appropriate for its application to the pig sector?*) and its two sub-questions (*what are the likely responses of the pig industry to IPPC* and *what are the processes whereby stakeholders interact to influence the IPPC implementation in this newly regulated industry?*) will provide the reasoning for recommendations to the regulator based on the identified strengths, weaknesses and challenges of the IPPC regime as regards its implementation in the pig sector. The literature review partially answered the second sub-question, identifying and describing stakeholders.

The next chapter, identifies data needed to answer these confirmed research questions and describes the methods used to collect and analyse these data, including the development of an analytical framework to assess the likely impacts of IPPC on the level of individual pig installations and for the industry as a whole.

CHAPTER 3

METHODOLOGY

This chapter describes the selection and development of the methods used to address the research questions. Procedures and techniques used for gathering, checking and analysing data are reported. The chapter also points out the main limitations of this research posed by the inherent problems with methodologies, data availability and/or quality and also by time constraint. The selection and application of analytical tools for assessment for IPPC impacts on the case studies pig units in this research are described for didactical reasons in Chapter 3. However, the process of 'assembling and describing' the analytical framework for assessment is also, in its very own, an output of this research.

3.1 OVERVIEW OF RESEARCH APPROACH

Figure 3.1 summarises the main components of the research process and their chronology. The research comprised three main phases. *Phase 1* refers to the proposal and confirmation of the validity of the research questions (RQ) through the literature review (Chapter 2), expert opinion and exploratory surveys. Also, in this phase the analytical framework was drafted. Once data needs were defined, in *Phase 2* the following methods were applied to approach them: a set of case studies pig installations, to provide an in-depth analysis of production systems and techniques and also consideration of site specific conditions involved with IPPC (as presented in section 3.4), and a sectoral survey in the pig industry, to extrapolate the findings based in individual case studies and explore awareness of operators with IPPC and their readiness to comply with its requirements (section 3.5). The analytical framework was then further developed. *Phase 3* comprises the validation and review of the results; which comprised a workshop with main stakeholders involved in the implementation process and getting feedback from regulator and operators and a peer review through communication and engagement in academic and IPPC forums (section 3.6).

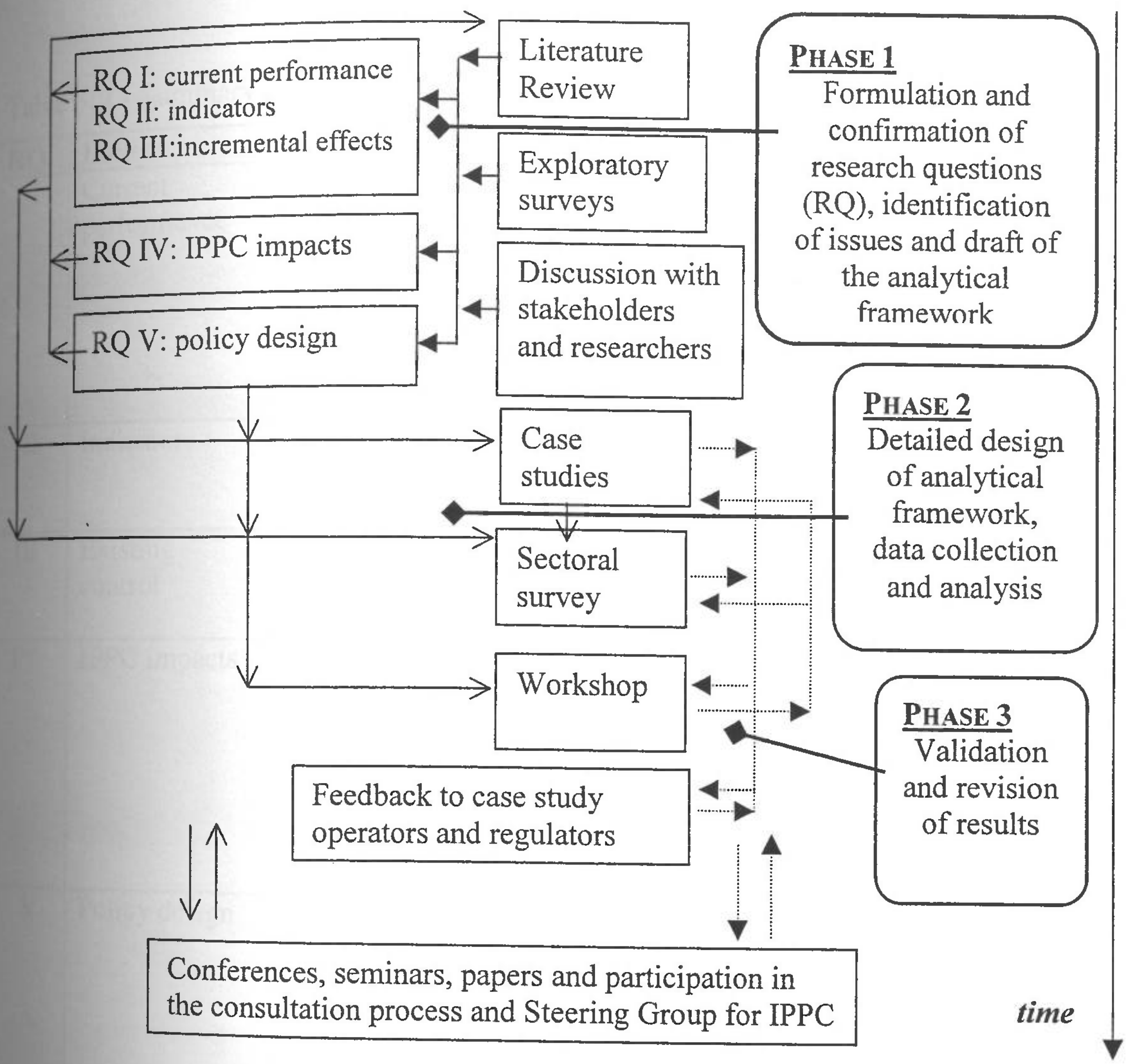

Figure 3. 1 - Representation of the research process: linkages and chronology

3.2 Data requirements

Table 3.1 summarises the data needs to answer the research questions and methods for their collection.

Research questions I and II required detailed technical and economic information on the pig installations. RQ I refers to the definition of a baseline for the impacts of regulation by IPPC in individual installations (current or 'without IPPC' situation). RQ II requires the identification and compilation of some performance indicators for the pig activity as regards IPPC.

Table 3. 1 - Summary of the data needs and methods used for their collection

RQ	Issue	Data needs	Sources and collection methods
I	Current performance	Production systems and waste management Inputs and outputs Financial results Emissions Site-specific features	Case studies, using checklists and records. Emissions using standard values based on secondary sources. Sectoral survey (questionnaire)
II	Indicators	Environmental and Financial parameters	Literature review (selection). Case studies, as above described.
III	Existing control	Mandatory instruments and voluntary schemes	Literature review Case studies
IV	IPPC impacts	Compliance costs Emission abatement Resources use Business affordability	Simulation of SFIR and BAT applied to the baseline (current situation) on case studies, using a spreadsheet model Sectoral survey
V	Policy design	Cost –effectiveness Power and interest of Stakeholders Performance indicators	Conclusion drawn from the analysis of results and their discussion with key stake-holders in workshop and feedback meetings Literature review

RQ III, related to the identification and role of other pieces of legislation influencing the legal framework and voluntary instruments of control was approached though the literature review and discussions in the IPPC Pig and Poultry Steering Group.

RQ IV required investigation of the impacts of IPPC on individual installations. The 'with-IPPC' scenario required a simulation of application for and compliance with an IPPC permit, based on the requirements determined in the SFIR (Environment Agency, 2001a) and complementary documents (application form and guidance; draft guidance on noise and odours; general guidance on IPPC). Economic and environmental data on performance of BAT and reference systems for pig housing and for storage and disposal of manures was gathered from the drafts of the BREF Note (EIPPCB, 2000 and 2001) and member states contributions to the documents (specially the Dutch and Italian ones). Other technical information such as applicability to existing installations was also based on BREF.

RQ V refers to the overall results of this research: evaluation of strengths, weaknesses and challenges of the IPPC regime as regards its implementation to the pig sector, based on the findings obtained from the case studies and confirmed through a structured questionnaire survey send to producers likely to be captured by IPPC regime within the NPA membership. The latter was focused on the identification of circumstances and practices on large pig installations as IPPC is regarded and also captured some perceptions of pig farmers on environmental issues and IPPC. Results of case studies and sectoral survey were discussed with stakeholders in a one-day workshop.

3.3 The Analytical Framework of Research

Having defined the overall steps and data needs for this research, it is necessary to report how data analysis was carried out. The flowchart shown in Figure 3.2 outlines the analytical framework of this research. The figure identifies applied methodologies and techniques during the course of the research project.

Three sets of techniques and procedures for data analysis are differentiated in the dashed line boxes in Figure 3.2. First, the top box describes the approach to case study pig units.

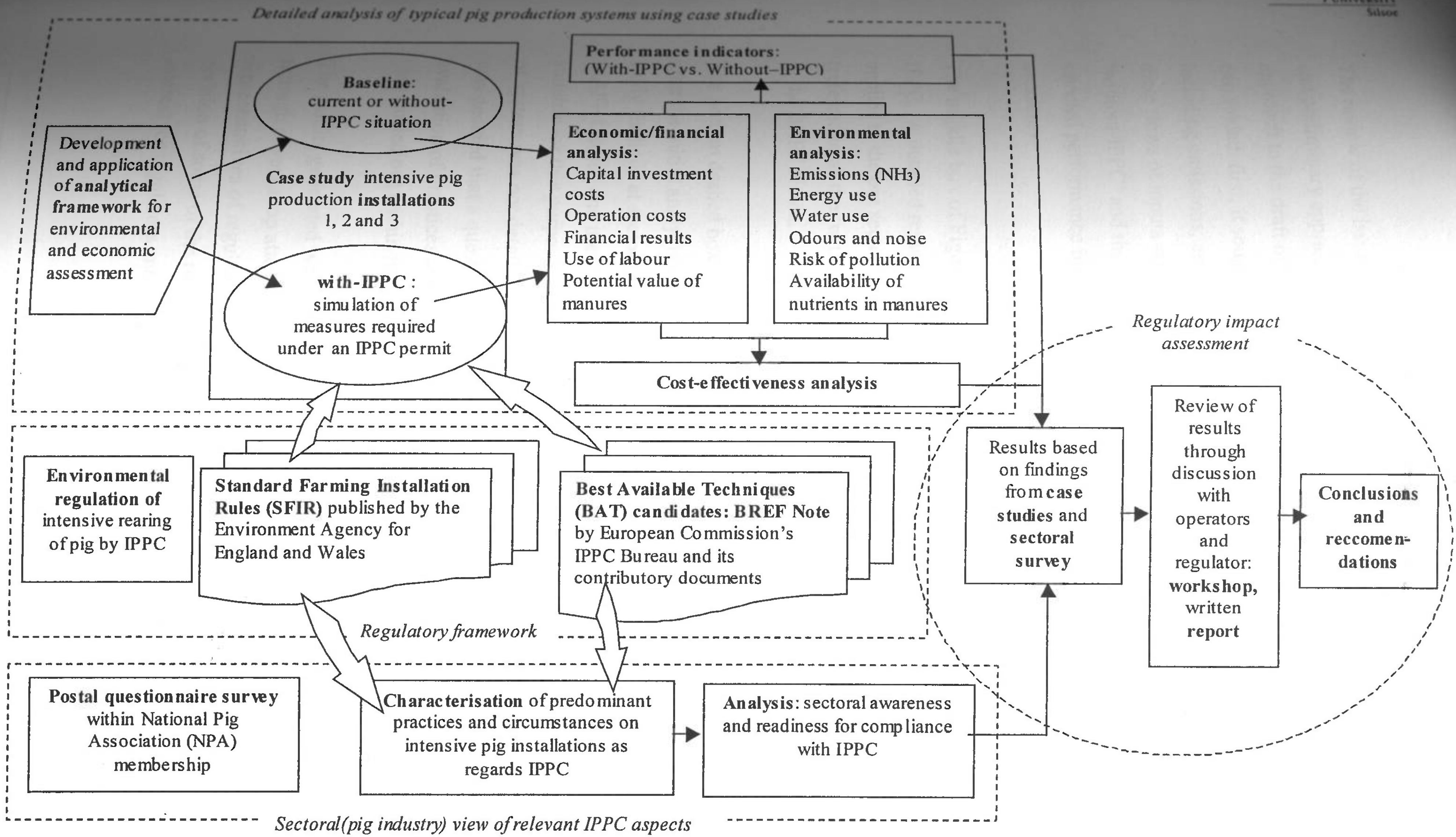

Figure 3. 2 - Analytical framework of research

The review of the issues, including exploratory visits and discussion with specialists, and preliminary appraisal of case study pig installations using an IPPC-focused EIA approach to the draft of an analytical framework for assessment. The framework was two folded: first, it sought to identify and quantify inputs and outputs of the systems, including emissions; and, second, it sought to determine financial values associated with these flows of inputs and outputs. The framework enables comparison between the 'without-IPPC' and the simulated 'with-IPPC' situations. This is indicated by use of selected performance indicators and cost-effectiveness analysis of proposed abatement measures.

The middle box of Figure 3.2 indicates the elements of the regulatory framework for IPPC. A detailed review of the European and national documentation on IPPC as it applies to the pig sector enabled setting up scenarios of compliance with IPPC regime (referred to as the 'with-IPPC' situation) defined in terms of SFIR and candidate BAT in the BREF Notes.

The bottom dashed box in Figure 3.2 shows the sectoral survey. This was undertaken after the initial analysis of the case studies in order to confirm the relevance of the case study findings at sectoral level. Available information on pig holdings, mostly from the MAFF Census and the National Survey on Pig Production Systems (NSPPS) were not suitable for this purpose, because categorisation of producers by size of herds and type of system was not detailed enough for the assessment of IPPC impacts. Therefore, it was decided that a questionnaire survey of large pig operators was necessary for the evaluation of practices and circumstances of pig installations relevant to IPPC. This was carried out within the NPA membership.

The results generated were scrutinised by the stakeholders. This was accomplished through a workshop attended by the case study operators, pig industry representatives, representatives of regulatory authority and researchers. This feed-back enabled the revision of some of the results and further analysis of some of the aspects of particular interest for regulators and operators.

Figure 3.2 shows the heuristics of the research process in separated, independent components. In practice, these elements were inherently linked and overlapping, and it is not easy to determine a precise chronological order among them. It is worthy to say that when the research started there was not a clear definition of how the IPPC regime would be implemented in the pig industry and, therefore, the analytical framework was also in continual development in order to capture the evolving process of regulation.

The approach to case studies and sectoral survey are presented in detail in the next two sections.

3.4 Assessment of IPPC impacts on intensive pig production installations using case studies

The two main aspects of the economic analysis of regulation, as referred to in Chapter 2, are the cost effectiveness of measures required to meet the objectives of the regulation, and the sectoral affordability of the regulatory policies being implemented.

As mentioned earlier (section 2.2.1 of Chapter 2), IPPC compliance costs can be differentiated in two groups, namely: a) costs associated to the permitting process (fees and charges, time and resources necessary for obtaining and running the permit), and b) extra capital investment and operation costs in complying with the regime (cost associated to changes in management and operation of the unit, including transaction and opportunity costs).

The use of case study approach was appropriate to investigate the compliance costs, change in environmental performance (effectiveness) and affordability, as it enabled an empirical, in-depth view of pig installations, allowing examination of particular aspects that affect the implementation of IPPC. Also, as the IPPC implementation process was at its beginning in England and Wales, and thus very much in the agenda (interest) of the industry, it offered favourable conditions for establishment of good rapport with operators, an essential aspect when using the case study approach (Green and Tull, 1988).

Of course the case study approach has its limitations especially linked with difficulty in making generalisations based on findings from cases. This research dealt with this problem by making careful selection of the case study pig installations, being cautious in interpretation of the results (including discussion with key stakeholders) and conducting a sectoral survey to validate the extrapolation of findings and messages drawn from these case studies.

At the time of these pilot or exploratory surveys, in the beginning of 1999, the IPPC Directive had already been approved by the European Commission. However, it was unclear how the implementation would be carried out. There was a need to define a sectoral BAT through the issuance of BREF Notes. This task was attributed to the Technical Working Group (TWG) headquartered in Seville. The transposition of the IPPC Directive to national level was enacted by the PPC Act 1999 and Regulations 2000, whereas specific rules and guidance for intensive rearing of pigs in England and Wales were set up through the SFIR. The opportunity to attend the Steering Group meetings, which started in 1999 and have been convened periodically, provided a privileged view of the evolving regulatory process and constant update of technical information being made available. Dates of meetings and main documentation discussed and produced are reported in section 3.6.

A noticeable aspect of the forum provided by the IPPC Pig Steering Group was how the perceptions of the industry representatives on the impacts of the regulations shifted as the implementation framework emerged. In the beginning, the reaction of industry representatives mostly focused on two identified threats: first, that regulation would be unfavourable for the national industry as stricter control would apply in UK compared to other member states or overseas competitors; and, second, that the direct costs associated with fees and charges by the regulators were an excessive burden to relatively small businesses. Subsequently, as familiarity with IPPC requirements grown, the concern has been with the incremental costs for the activity associated to compliance with BAT.

The fact that we (T. Pellini and J. Morris) have been involved in the consultation process, both for BREF and SFIR, on the one hand allowed access to relevant information for the research project and, on the other, was able to feed back to the participants and research collaborators some of the results emerging from the study.

3.4.1 Selection of pig installations and development of an assessment framework for case studies

IPPC requires a thorough, integrated appraisal of prescribed installations. The use of case studies involving pig installations over the thresholds determined by the IPPC Directive would provide detailed information on production systems and site specific conditions. This level of detail is required for a correct evaluation of IPPC impacts. That is, compliance with IPPC is evident through the adoption of BAT, and this requires technical considerations that can only be assessed at installation/site level.

The selection of case studies needs to ensure that they are representative of major typologies of installations from the viewpoint of IPPC. It also requires guaranteed collaboration from the respondents (operators). These conditions are described as follows.

The initial stage in conducting the case studies was to decide the criteria for selection of the pig installations. As reported in Chapter 2, a review of literature identified that pig production systems differ according to: specialisation of the herd, type of animal housing and waste management (Appendix 3.1). It was necessary to corroborate these assumptions with representatives of the industry. This was realised by a meeting with the chairman of the recently established National Pig Association (NPA). This was very helpful in confirming relevant production systems and identifying possible installations to be used as case studies.

Housing and waste management are closely related, given that building design determines how manure (animal waste) is collected, as slurry or FYM, and therefore how it is handled for storage and landspreading. Three main groups were identified for housing, distinguished by type of floor, namely: fully slatted floor, partly slatted floor and solid, and straw based floor. According to herd specialisation, there are also three main types of pig units, that is, breeding-only, feeding-only and breeding-and-feeding (see Chapter 2). These were the criteria used to guide the selection of case studies.

Three pig installations were selected for case study, as this number could represent main variants of systems according to the classificatory elements referred above and also given the limited resources of the research project. The pig installations which collaborated as case studies for this research are described as follows.

Case study installations 1 and 3 are complete cycle, that is, breeding-and-feeding, pig production units, whereas case study installation 2 is a feeding-only unit. From here they will be referred to as Case study 1, 2 and 3. Case study 1 was selected to represent a partly slatted system for finishing herd, but growers and dry sows are reared in straw based, solid floor pens. Case study 2, the feeding-only pig production unit, was selected to represent a straw-based system for finishing herd. Case study 3 was selected to represent a fully slatted system for pig rearing, as pigs are kept on fully slatted floors in all production phases with exception of mating and pregnancy (where sows are kept either on solid or partly slatted floor with limited straw). Appendix 2.1 illustrates these three types of flooring systems. These pig units are described in detail in Chapter 4.

All these pig production units belong to agricultural businesses that operate multiple pig farms across England. Case 1 and 2 are part of the same pig production company but are located in separate sites and are distinct installations, situated in Suffolk in East Anglia. Case 3 is situated in Oxfordshire, in the South Midlands. The case studies installations can be considered as independent, self-contained pig production units, for there is no operational links between the activities being carried out on these installation and the other pig farms owned by the group (except milling and mixing of feed compounds for case units 1 and 2, which is done in a common central facility). However, one can assume that some management and marketing aspects are common when a unit operates under the umbrella of a major business organisation.

3.4.2 Development of the analytical framework applied to case studies

An exploratory exercise was carried out with operators and managers of case studies 1 and 2, providing an overview, based on the scope of IPPC, of flows of use of resources, outputs and emissions. This participatory approach with researchers and operators also helped to determine which of these flows were quantifiable (or with readily available information) and non quantifiable. These flows can also be represented in monetary terms. Figure 3.3 presents the diagram drawn by one manager on a flip chart during the initial 'brainstorm' for IPPC applied to a pig unit.

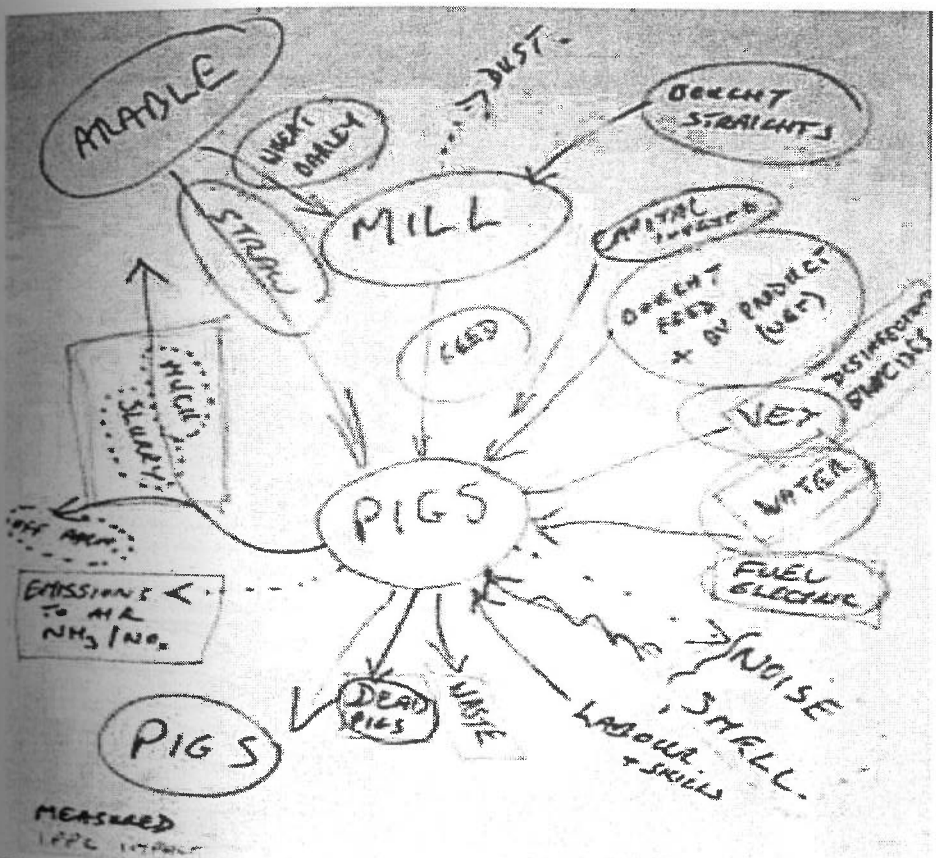

Figure 3.3 - Exploring IPPC issues in a pig unit using a participatory method

Figure 3.3 suggests a flow model of input and outputs in a pig installation. Associated with the characteristics of IPPC, which requires dealing with resource use and emissions to different environmental media, it suggests that an Input-Output (I/O) model would be appropriate to describe the overall performance of pig production units.

The rationale for using an I/O model to capture the IPPC impact to pig installations is represented by the flow chart in Figure 3.4. As referred previously in Chapter 2, an IPPC permit involves the majority of production processes and related activities in a controlled installation. Therefore, the following elements are required, linked with data needs previously summarised in Table 3.1: identification and consumption levels of foodstuffs and raw materials; use of energy and water; type of animal housing; type of stores and techniques used for landspreading of manures; quantity of manures produced, and emission levels for ammonia. All these elements require monitoring and evaluation under the IPPC permit, which involves manpower use.

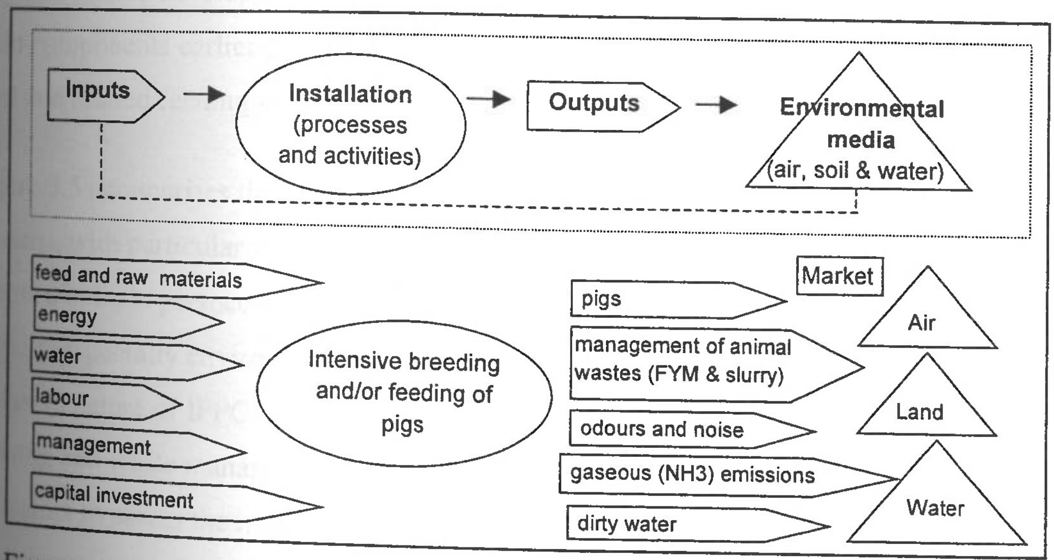

Figure 3. 4 - Representation of the input-output model for IPPC applied to a pig unit

Pig production and waste management activities impact on different environment media, namely air, water and land. The impacts of generation of outputs such as solid and liquid manures, emission of ammonia and odours are particularly important. Although it is understood that the production of inputs needed for pig production, such as feed compounds and machinery, have impact on these environmental media, the framework does not tackle this issue, as this aspect is not currently being considered by IPPC. Also, IPPC is not a cradle-to-grave[1] approach to pig production. Therefore, only those incoming flows directed associated with pig production within the boundaries of the installations are subject to analysis here. Analogously, outgoing flows are limited to the farm gate, with exception of the disposal of animal waste to the land of third parties.

The referred flows of materials and energy have equivalent financial flows, comprising the monetary values (costs and prices) associated with products and services provided to and generated by pig production. Given the current focus on the regulatory burden on pig producers, and related affordability issues, the analysis focuses on financial impacts on producer income rather than broader economic costs and benefits to the national economy.

Having further defined the focus and remit of the framework to assess IPPC implementation to case study pig installations, its initial representation (Figures 3.3 and 3.4) was further developed as shown in Figure 3.5. Emphasis was placed on the three main components earlier presented for classification of pig installations, namely type of herd and related feeding regimes, housing design, and management of organic waste.

Figure 3.5 summarises the main inputs, components and outputs of pig production systems, with particular reference to environmental performance and IPPC. IPPC adopts a holistic perspective, linking inputs, technology and management processes, and outputs, especially environmental ones. Figure 3.5 shows the comprehensive and inclusive nature of IPPC as it applies BAT and SFIR to herd and feeding regimes, housing and waste management. The figure provides a framework for developing indicators to assess the impact of IPPC regulations on pig installations, both in terms of environmental performance and related financial performance. This analytical framework is considered to be an important output of the research effort.

[1] Life Cycle Analysis of the pigmeat production would be more appropriate in the context of assessing the total footprint of supply chain for pork meat products as a whole.

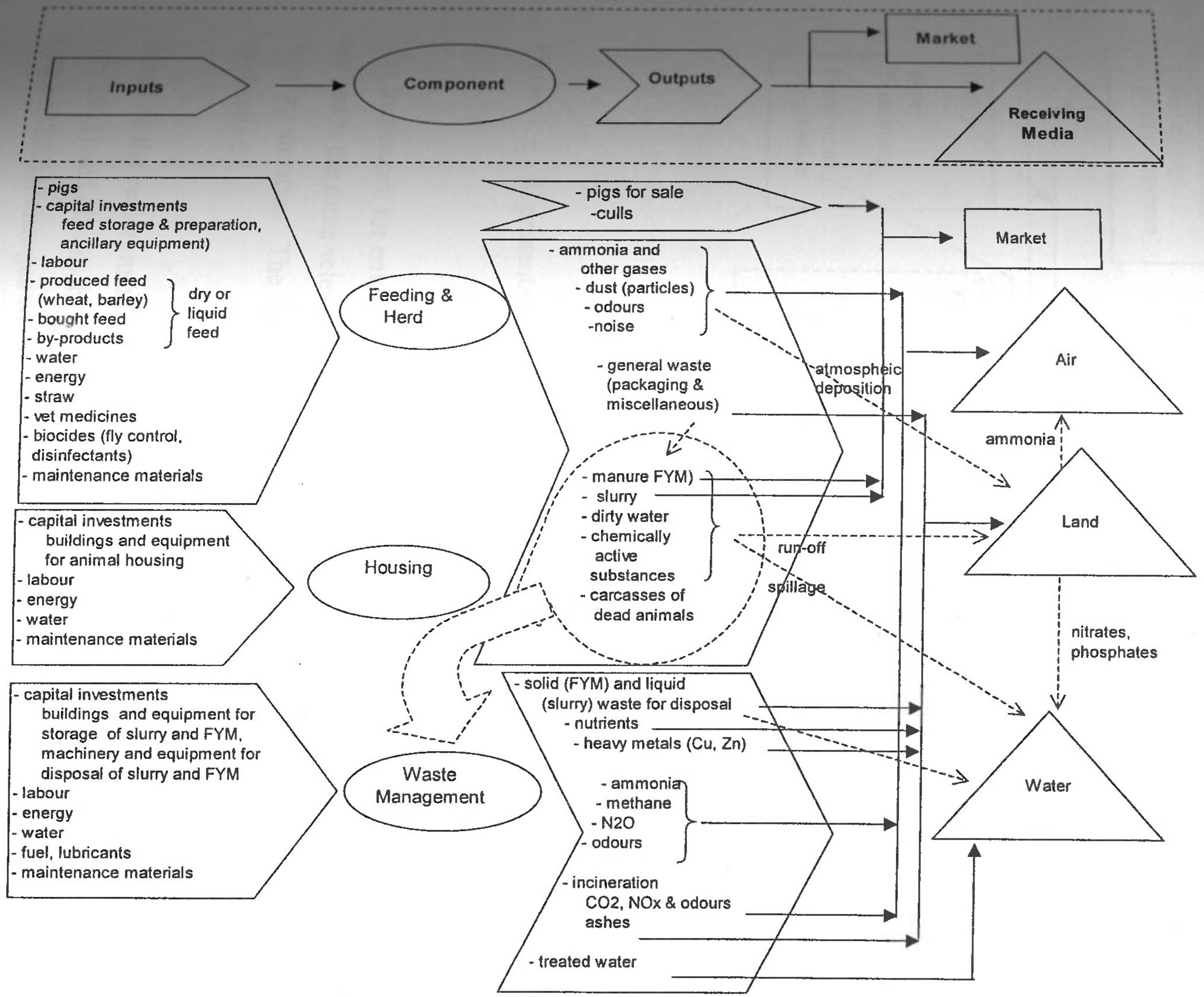

Figure 3. 5 - Analytical framework to assess the impact of IPPC on the case study installations

The framework was made operational via a series of spreadsheets, referred to here as the spreadsheet model, which uses a MS Excel 97 platform to enable handling and processing data collected from the case studies. This is shown in Figure 3.6.

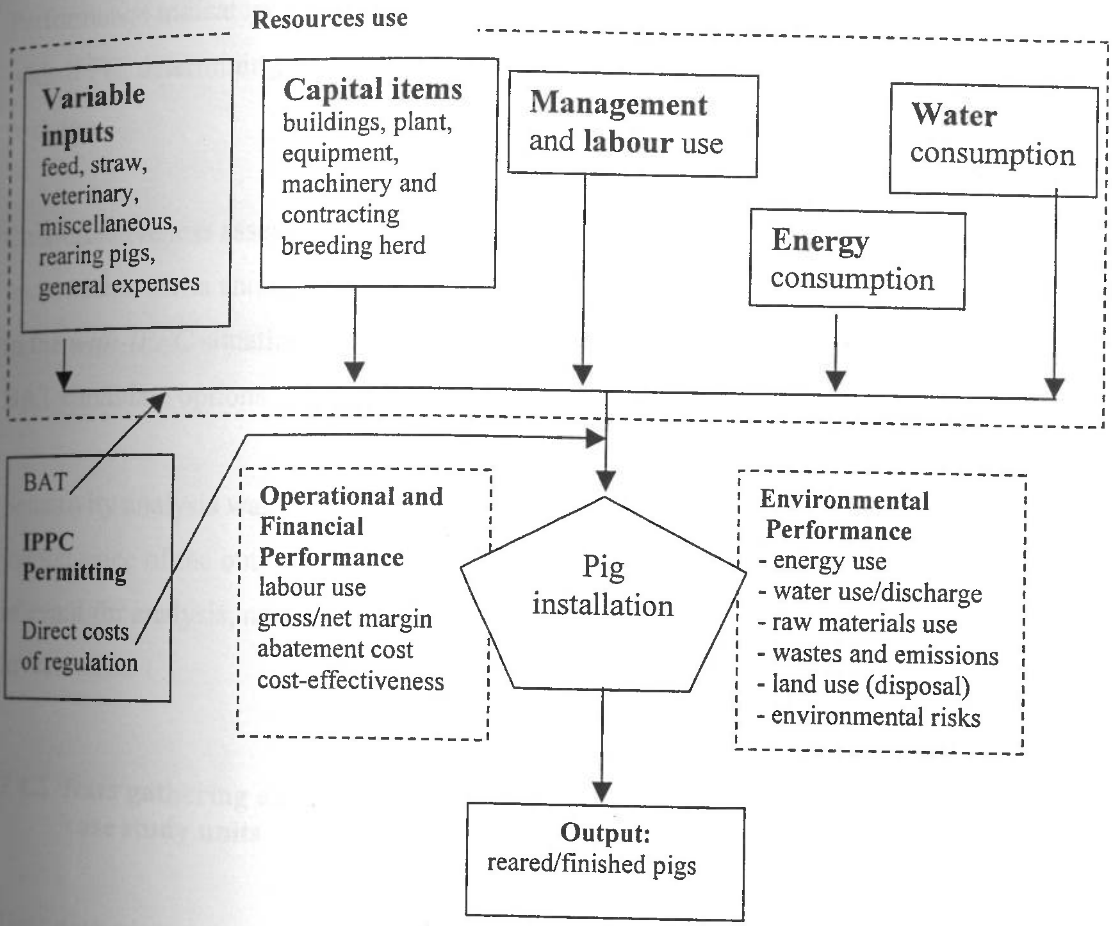

Figure 3. 6 - Representation of the spreadsheet model applied to case studies

The framework for environmental and economic assessment was first drafted and then applied to the three selected case study pig units. This enabled the generation of a *baseline* situation. The framework was subsequently modified and improved through its application.

Based on the requirements for an IPPC permit defined in the current SFIR (version 3 of July 2001) and also in the BAT candidates contained in the BREF Notes (2nd draft of October 2001), changes were simulated for the case studies, involving technical and managerial measures. The framework was then re-applied to capture the impact of compliance with IPPC.

Performance indicators were compared between both situations, that is, baseline and with-IPPC, determining the environmental and economic impact of the IPPC regulatory package.

Cost-effectiveness assessment (see Chapter 2) of different arrays of IPPC measures was undertaken. Extra annual costs were evaluated against abatement in ammonia emissions in the *with-IPPC* situation for the case study pig installations, considering different BAT candidate options.

Sensitivity analysis was carried out to assess the potential effects of variation in the market price of the output (pigmeat) and items of pig production cost particularly relevant for analysis, namely feed, interest rate and period of return of capital investments.

3.4.3 Data gathering and assumptions for calculation of costs and revenues in the case study units

Data gathering

Data used for evaluation are primarily based on records of the case study pig units. An initial visit to the site, taking about half a day for each selected installation, provided an overview of location of the installation, herd management, buildings and waste stores. A photographic file was produced for further reference. Available records or documents were obtained at the first visit but most of the data was collected through a series of enquiry checklists subsequently sent to the managers for completion. Table 3.2 summarises information requested and obtained.

Table 3. 2 - Information gathered from the case study installations

Information	Description
1 General characterisation of the site	Area Predominant soil (s) Other agricultural enterprises than pigs, land use in the farm Maps or sketches with location of unit and main landscape features – watercourses, access, dwellings.
2 Pig Enterprise	Organisational flowchart of management (pig business within the farm or company) Processes and operations in the installation: flowchart of main inputs, production phases, outputs and emissions to media. Identification of those measured or quantifiable elements. Inventory of input: feed, bedding, veterinary and disinfectant products. Characteristics of feed: protein and energy content by feed type Outputs: FYM and slurry production; mortalities; pigs finished per year, Number of pigs by category Type of housing accommodation and herd management by category Sketch of pig installation, including waste stores
3 Capital assets	Inventory of buildings: housing type, size and capacity; insulation, ventilation and heating systems; feeding and watering systems; and age and condition. Inventory of stores for FYM and slurry: type, capacity in volume, surface area, and waste conveying equipment. Inventory of machinery and equipment: specification, power (tractor), and age. Techniques used for landspreading of manures: timing, application rate, incorporation.
4 Physical parameters of the herd	Breeding herd: several, such as pigs sold per sow per year, mortality, % replacement and kg feed per sow per year. Feeding herd: several, such as feed conversion ratio, liveweight at slaughter and mortality.
5 Use of labour and management	Manpower for management of the herd Labour needs by pig production phase Supervision and business management activities Hours of work for spreading of manures Use of contractors and expenditure
6 Energy and water use	Electricity consumption by type of use, such as heating, fans and lightening. Clean water consumption: drinking and added to feed, cleaning of pens.
7 Financial	Accounts according to pig operator system Prices received per pig sold; water and electricity bills; labour rates; contractor charges; cost of feed; cost of vet products; trade of manure; period of amortisation of investments, average gross and net margins per pig sold
8 Other	Management systems in place: quality assurance schemes. Mandatory regulation: NVZs, Control of Storage of Fuel and Slurry. Impact of IPPC (given the knowledge of operators at the time of the survey) on: training, BAT, record keeping, direct costs and charges by regulator.

Source: checklist applied to case studies.

In addition to the checklist, other case specific data were used to describe the case study units, such as company profiles, Farm Waste Management Plans and previous surveys[2] on the installations. Aerial photographs of the site were acquired to help the assessment of site features and comparison with information provided by operator.

A follow-up data request form helped to reinforce some aspects not clear in the original information provided and to obtain data not provided in the first round or confirm its non-availability. Contact was maintained on an *ad hoc* basis with the operators during the period of analysis of the data to confirm and complement information (by e-mail, telephone and meetings). During the period of study pig farms had their direct access restricted for sanitary reasons twice: first, during the Classic Swine Fever (CSF) by end of 2000 and, second and more seriously, with the Foot-and-Mouth Disease (FMD) outbreak in 2001. Despite these problems, contact was kept with operators as reported above and their continued assistance under these very difficult circumstances was most appreciated.

Calculation of costs and revenues for baseline

Financial data was explicitly requested from units. However, in some cases operators were able to offer only partial information. This was because data was not available in the form required or data was regarded as commercially sensitive (and it was considered politic not to press unduly for such data). Thus, data was drawn from multiple sources. In the first place site specific data was used, as reported for the checklist data form. Where not available, secondary data is used, based on values published by, among other sources, Meat and Livestock Commission (MLC, 2001a), SAC (1999, 2000 and 2001), Nix (1999), MAFF (2000b) and DEFRA (2001a and 2002b). Data were also obtained from contact with suppliers of equipment and services.

The calculation of production costs for the three case studies follows conventional differentiation between variable and fixed costs, focusing on the key elements as

[2] That is the case of case units 1 and 2, which have been subject of an undergraduate dissertation at Cranfield University at Silsoe (Gibbs, 2000) on manure handling and also an ADAS energy audit (case 2 only).

regards IPPC. All costs are estimated in an annual basis, following guidance contained in the BREF Note (EIPPC, 2001). Where reported data was missing, estimations were made and put back to operators for scrutiny and approval. This method was also used to derive estimates of data which otherwise might be considered confidential.

Capital investment costs for buildings assume a life span of 20 years (unless otherwise stated) and an annual average interest rate of 6% (using a standard conversion factors[3], as presented in Appendix 2.1). Depreciation of machinery and equipment (except those in animal housing) is determined by the linear method based on standard tables for depreciation according to average use in hours per year.

The total annual pig production cost comprises the sum of variable and fixed costs per year plus, when breeding phase is involved, average annual replacement costs of breeding animals (sows and boars).

Revenues comprise the value obtained by the pigs sold annually plus, if appropriate, any value of the manure sold. Also, the potential value of the nutrient contents (N-P-K) of pig manures applied onto land was calculated. This was compared with the value attributed by operators to slurry and FYM applied to land.

Table 3.3 describes source of data used in the framework for assessment to determine the baseline for case study pig installations. As referred to above, priority was given to the use of data obtained directly from the case study units. Where not available, secondary data were applied and checked with operator for goodness of fit.

[3] Basically it applies a conventional amortisation formulae: $Ca = Ci \, . \, [r(1+r)^n]/[(1-r)^n - 1]$, where *Ca* is the annual cost of capital, *Ci* is the initial capital investment, *r* is the average interest rate and *n* is the expected life in years.

Table 3. 3 - Data sources used for determination of the *baseline* situation for the case study installations

Item	Source for information on:	
	Physical data (quantity used, size, characteristics)	**Financial data** (price or value)
Feed	case studies (installations)	case studies; SAC; MLC
Raw materials	case studies	case studies; SAC
Energy	case studies	Case studies; SAC
Water	case studies	SAC; Environment Agency (abstraction charges)
Services (contracting etc)	case studies	case studies; SAC; Nix
Buildings	case studies	SAC
Machinery	case studies	SAC, Nix (depreciation and repairs), suppliers
Labour and management	case studies	SAC II
Outputs	case studies	case studies

Sources: SAC refers to *The Farm Management Handbook* published by the Scottish Agricultural College (SAC), 19th to 22nd editions (SAC, 1999 and 2001); SAC II is the *Farm Building Guide Cost* (SAC, 2000). MLC refers to the *Pig Yearbook 2001* (MLC, 2001a) and Nix is based on the *Farm Management Pocketbook* (Nix, 1999). Environment Agency's water abstraction charges are available in DEFRA (2002c).

With-IPPC scenarios

The assumptions for simulation of the 'with-IPPC' situations on the case study installations were based on the adoption of candidate BAT and the compliance requirements specified in the documents SFIR and BREF Note (second draft version). Table 3.4 summarises assumptions for changes in input use, infrastructure and practices applied in the simulation, referring the respective sources of data.

Table 3. 4 - Assumptions and references sources for determination of 'with-IPPC' situation applied to the case study installations

Item	Degree of change in performance: Environmental	Degree of change in performance: financial	Reference
Feed	Up to 50% reduction in NH_3 emissions from housing	Increase of 20 to 30% in the feed cost	DEFRA (2001a) Environmental R&D Newsletter.
Raw materials: use of straw	Generous use of straw bedding lock up NH_3 from urine	Increase in use of labour hours to handle straw and FYM, straw cost	DEFRA (2001a); case studies
Energy	Potential reduction of 5 to 10% by improving efficiency	75-80% of reduction in energy cost as net saving	MAFF (2000b) Opportunities for saving money by reducing waste; Peirson (1999)
Water	Potential reduction of 5 to 10% by improving efficiency	Equivalent level of reduction in water cost; reduction of slurry	MAFF (2000b)
Services (contracting etc.)	Reduction of emissions from landspreading of manures by up to 70% of potential level	Increase in cost for contracting, either for incorporation or for use of other BAT. Scope for savings due to reduced ploughing	Chambers et al. (2001) Making better use of manures, booklets 1, 2 and 3. EIPPCB (2001): BREF Note for the intensive livestock production of pigs and poultry
Housing	Reduction of NH_3 emissions vary for each production phase and whether involves in-process or end-of-pipe measures. Reported reductions applying BAT candidates range between 25% and 90%	Costs involved with abatement techniques vary largely depending on abatement level, phase (animal category) and type of technique applied.	Mostly BREF Note; CRPA (1999): Italian contribution to BREF; Hendriks and van de Weerdhof (1999): Dutch Notes on BAT for Pigs; SFI Rules Peirson and Brade (1999)
Storage of manures	Reductions between 90 and 95% of NH_3 by use of flexible or rigid covers in slurry stores	Considerably higher costs involved (double the typical cost for storage)	SFIR SAC (2000): Farm Building Costs
Landspreading of manures	Potential reduction of up to 70% depending on timing and technique used	Extra costs for incorporation and applying BAT techniques (to replace traditional practices by farmers or contractors). Scope for savings by reducing soil movement for some of BAT.	Chambers et al. (2001) BREF Note Note: applicability is subject to technical restrictions of landscape and soil characteristics

(cont.)

(continued Table 3.4)

Item	Degree of change in performance		Reference
	Environmental	financial	
Housing & waste management	Higher concentration of nitrogen (TAN) in the manure applied into soil reduce use of bought fertiliser Higher risk of pollution in spreading /disposal of stage	Savings in bought fertilisers if allowance for nutrients in manure is considered Increase in landspreading costs as extra area is needed to comply with 250 kg/ha/year	MAFF, 2000b (value for NPK in manures) Webb (2001): TAN in manures
Labour and management	Non referred.	Extra costs	case studies; Housley (2001)
Odours	Reduced odours associated with reduction of gaseous emissions (NH_3). However, trade-offs may occurs with increased production of methane in storage due to cover.	Extra costs if further measures are required under the IPPC permit due to special conditions of the site.	Environment Agency (2000b): Draft Odour management at intensive livestock installations
Noise	Significance depends on site specific condition	Re-scheduling of some operations such as stock movements and truck traffic on site	Environment Agency (2000c): Draft Noise management at intensive livestock installations; Metcalfe (1999)
Permit	-	Direct costs: application and subsistence charges by regulatory authority Indirect: costs to prepare an application for a permit	Environment Agency (2001b and 2001c): IPPC Permit for pig and poultry installations and guidance for applicants; DETR (2000a): IPPC practical guide

Sensitivity analysis

Sensitivity analysis was carried out with respect to financial results of installations, aiming to determine the variation in the results if different assumptions were made in determining costs or valuing output, as shown in Table 3.5. The ranges for variation were obtained from the literature, as follows. Prices of pigmeat and feed refer to maximum and minimum values verified in the period 1992-2000. The applied interest rate (6%) was varied by +/-2% and the amortisation period for buildings by +/- 10 years.

Table 3. 5 - Variables and range of variation used for sensitivity analysis

Variable	Range of values	
	minimum	maximum
Price of pigmeat (includes reduction in price of piglets) - p/kg lw	75	125
Feed cost– variation in relation to 9-year average cost	-21%	+13%
Amortisation period of capital investment in building (years)	10	30
Interest rate of capital	4%	8%

Note: range of variation for feed costs: -21% to +13% and -15% to +11% respectively for home mix and purchase feed range of variation for a nine year period 1992-2000, based on MLC (2001a). Minimum cost of feed relates to year 2000; if costs were as average, that is +21%, they would be of £41.03 per pig.
Sources: case studies (current values); feed costs variation (MLC, 2001a); amortisation tables (Nix, 1996; SAC, 2001).

3.5 Questionnaire survey on large pig producers within NPA membership

A case study approach was adopted because it allows an empirical enquiry to investigate the phenomenon of the implementation of IPPC regulation within the real-life context of pig installations. Bearing in mind that the subject of this research project was not the impact of IPPC on particular installations but the impacts of such environmental regulation on the industry as a whole, a postal survey through a structured questionnaire was carried out involving a large number of indoor pig units. The evidence from the case studies and issues raised by the review of the IPPC implementation were checked against a circumstances and practices in the sector survey.

Therefore, a postal questionnaire survey of selected pig producers was carried out to capture the variations in current circumstances (systems, resources) and practices as they might affect the impacts of the IPPC implementation on pig installations in England and Wales. Perceptions of operators on the main issues addressed by IPPC and their awareness of IPPC regulations were explored. Relationships amongst the various elements likely to influence IPPC effects were explored based on the response from operators. The broader view of the pig sector offered by this survey enabled the extrapolation of findings of the case studies to industry level.

3.5.1 Topics (data need) and questionnaire design

The questionnaire design draws on the review of IPPC as it applies to the pig sector and on the preliminary findings from case studies. The topics covered by the questionnaire are presented in Table 3.6. The complete questionnaire form is provided in Annex 3.1.

The NPA membership is based on pig businesses or pig producers, and therefore a NPA member can be associated, by ownership or management, to one or more pig units. Thus, the questionnaire was designed to collect individual information in relation to production systems and site specific aspects from separate pig installations under a single membership.

Table 3. 6 - Topics covered in the questionnaire survey

Section	Topics
Description of the installation and site	Type of system(s) by specialisation of herd and the number of pigs typically kept in the installation. Type of housing system(s) for each pig production phase Original construction and refit of buildings Predominant soil in the adjacent area of the installation. Environmentally sensitive features in the vicinity of the installation.
Management and labour	Membership of pig assurance schemes Other voluntary and assurance schemes and environmental guidance Training activities for staff
Waste Management	Farm Waste Management Plan Type of storage system and capacity for slurry and manure Techniques of treatment for slurry and manure Spreading of manure and slurry – land availability Spreading of manure and slurry – techniques and practices
Use of raw materials, water and energy	Use of raw materials Clean water use Clean water source(s) Energy use
Awareness of the IPPC Directive	Current knowledge on IPPC as it applies to the pig sector Perceptions on the impacts of intensive pig farming Perceptions on the key environmental issues associated with indoor pig production IPPC likely impacts on the current management of the pig installation (changes)

Source: questionnaire form (Annex 3.1).

The questionnaire was pre-tested with two pig producers and two livestock consultants before it was sent to respondents. It was posted between April and May 2001 and replied to the NPA, to guarantee confidentiality.

3.5.2 Selection of respondents to the questionnaire and rate of response

The questionnaire survey was applied within the membership of the National Pig Association (NPA). The NPA represents commercial British pig producers. As the scope of SFIR refers to England and Wales, the 403 NPA members from these countries were included in the survey prior to selection based on the IPPC thresholds for herd size.

This NPA list of pig producers is organised according to size of the pig herd, in the following three categories: a) by number of sows where progeny is not finished; b) by number of sows where progeny is finished; and c) by number of pigs finished per year. For the purposes of the questionnaire survey it was necessary identify those producers likely to be captured by IPPC threshold, namely with more than 750 breeding sows or more than 2,000 fattening pigs.

Thus, all producers with 750 sows or more (for both above categories *a* and *b*) were selected. However, other considerations were made to capture breeding-and-feeding units where the number of sows was below 750 but which would potentially be regulated under IPPC according to the number of pigs finished per year. It was assumed, based on Peirson and Brade (1999), that breeding-and-feeding pig units with more than 450 sows could fall under IPPC because they are likely to operate above the threshold of 2,000 fattening pigs. Therefore, for units where progeny is finished (category *b* above referred), the questionnaire was to send to all producers declaring 450 sows or more.

It was necessary to do indirect estimates for category *c* too, where producers declare the total number of finished pigs annually. It was assumed that a breeding-and-feeding system has, on average, 2.3 complete production cycles per year (from mating to finishing phase). Thus, if a unit has in any period of the year 2,000 pigs in finishing stage (equals to the IPPC threshold for fatteners), and considering an average of 2.3 cycles per year, such unit is likely to finish at least 4,600 pigs per year (result of 2,000 times 2.3 cycles). Therefore, the questionnaire was sent to all producers declaring 4,600 or more pigs finished per year. Feeding-only units have more cycles per year than a breeding-and-feeding one, as they do not have production phase related to breeding of pigs. In that case, the minimum number of finished pigs per year would be higher than 4,600 to represent an average 2,000 fatteners in the herd. Here, it was considered better to include feeding-only units marginally below the threshold rather than risk omitting potentially eligible installations from the survey.

The total number of producers within NPA membership selected for the survey was 247. The questionnaire was sent out by post, with a covering letter from the NPA supporting the survey. The period of time for return of the questionnaire given to respondents was of between two and three weeks, considering two days for delivery by the post service. A free post, pre-addressed envelope accompanied the questionnaire form for its return by respondents. The completed questionnaires were returned from respondents directly to the NPA, and then from the NPA to researchers. This procedure was adopted to provide confidentiality to respondents and also because it was thought that members would be more likely to complete and return a questionnaire form to the NPA than to an external institution.

In total, 87 questionnaires were returned completed, a response of 35% which is considered an excellent response rate for a postal survey. However, some of the returned questionnaires were discarded and 75 questionnaires were used for analysis. As each pig unit, or in the case of this survey each NPA member, may comprise more than one pig installation, the information obtained referred to a total of 117 pig installations. The 12 returned forms not used for analysis were discarded for one of the following reasons: they involved breeding-only herds kept outdoors[4], had numbers of

[4] Although the guidance to respondents at the beginning of the questionnaire dismissed completion by outdoor units, still some of the respondents reported this system, which is not subject to IPPC regulation.

sows or pigs smaller than those determined for selection[5], they were insufficiently completed or omitted information on the size of pig herd. Incomplete or inadequate responses were not eligible to be checked or followed up as respondents remained anonymous.

Data from the questionnaires were coded and entered into the software Statistical Package for Social Sciences – SPSS for Windows - for analysis of the results. Data entries were double checked to reduce the possibility of errors.

For assessment of the data obtained from the questionnaires, the first step of the analysis of the responses was to explore the patterns of the data collected. This assessment showed that the most data obtained in this survey did not comply with parametric assumptions[6] and, therefore, their analysis required non-parametric tests.

The occurrence of a foot and mouth disease (FMD) outbreak early in 2001 threatened the realisation of the survey. Advice and support by NPA were crucial to successfully complete it, and the membership of the NPA is thanked for their kind responses.

3.6 Communication and Debate of Research Aim and Results

The preliminary results of the case studies and sectoral survey were presented to pig producers, industry and regulatory authority representatives in a workshop organised at Cranfield University at Silsoe in January 2002. The workshop consisted of two main sections, namely: the preliminary results of the case study analysis, and the findings of the sectoral survey. They were followed by discussion in small groups on issues arising followed by a session. Recommendations for action were drawn from the workshop. The discussion of results with people working within the industry and in IPPC regulation provided important inputs to this research, as it raised relevant issues from

[5] It is likely to be due to out of date information in the membership database. The information reported by operator did not classify the unit within the selected for the survey.
[6] Parametric data assume the following conditions: normal distribution, homogeneity of variance, interval scale and independence (Field, 2000).

the point of view of different stakeholders to the policy implementation and identified aspects for further enquiry and analysis.

These inputs contributed to the research by directing its focus on particularly relevant (and sometimes disputable) aspects of the application of regulation and, moreover, explored possible effects of the regulatory framework on the structure of the industry and strategy of businesses to deal with IPPC. The research results also raised awareness of operators and regulators on specific aspects of IPPC. Particularly relevant were the evidence that compliance costs associated with BAT were likely to be more significant than those associated with permitting; that straw based systems in finishing housing were common yet at the time excluded from candidate BAT, and that the scale of possible costs associated with IPPC was likely to exceed affordability criteria on many existing installations.

Other activities involving communication and contact for information related to this research are listed as follows.

a) IPPC related forums and activities

Written comments were submitted on the following IPPC consultation papers: 3rd and 4th Consultation paper on IPPC to DETR (via the Anglian Regional Environmental Protection Advisory Committee - REPAC); 1st and 2nd draft consultation of BREF Notes for intensive livestock rearing of pig and poultry by the EC IPPC Bureau (Seville, Spain).

Attendance at the IPPC Pig and Poultry Steering Group meetings, 1999 to 2002, on the following dates:

Pig Industry, at MLC, Milton Keynes, 22 November 1999.
Poultry Industry, at British Poultry Meat Federation (BPMF), London 2 December 1999 (Effectively after the two above meetings between the industry and regulator, they were named Steering Group meetings).
IPPC Pig Steering Group meeting 18 April 2000
IPPC Pig Steering Group meeting 28 June 2000

IPPC Pig Steering Group meeting 11 September 2000

IPPC Steering Group Meeting 6 November 2000

IPPC Steering Group Meeting 1 February 2001

IPPC Steering Group meeting 19 July 2001

IPPC Pig and Poultry Steering Group meeting 4 February 2002

IPPC BREF meeting 19 February 2002

IPPC BREF Meeting 22 July 2002

b) Externally to the IPPC related forums

Pellini, T.; Morris, J. and Emmett, B. (1999) *Review of the European Pig and Poultry Industries with particular reference to IPPC Implications*. Report for the Environment Agency of England and Wales. Silsoe: Cranfield University at Silsoe.

Presentation of research project in the *First Postgraduate Conference 2000 and Second Postgraduate Conference 2001*, Cranfield University at Silsoe, respectively in 28-29 June 2000 and 21-22 June 2001.

The assessment framework of this research was presented in the following conference: Pellini, T. and Morris, J. Assessing the Impact of IPPC Directive on the Performance of the Pig Industry. In: *Proceedings of the 2000 Business Strategy and the Environment Conference*, Leeds UK, 18th-19th September 2000. Shipley: ERP Environment, 311-318.

Seminar *Impacts of the EU Directive on Integrated Pollution Prevention and Control to the pig industry in England and Wales* presented in the Agronomic Institute of Parana State (Londrina, Brazil) and National Research Centre for Pig and Poultry, from the Brazilian Enterprise for Agricultural Research – EMBRAPA (Corcordia, Brazil) in December 2000. A paper originated from the seminar was submitted as a contribution for a book to be published by the National Research Centre for Pig and Poultry/EMBRAPA).

Preliminary results from case studies were presented at:

Pellini, T. and Morris, J *The compliance costs of the IPPC Directive on an intensive pig production unit: an UK case study. Environmental Policy and Costs of Compliance Workshop*. London: *London School of Economics*, 17-19 September 2001.

The research also generated one paper submitted and published by:

Pellini, T and Morris, J. A framework for assessing the impact of the IPPC directive on the performance of the pig industry. *Journal of Environmental Management,* 63 (3) 325-333 (November 2001, doi:10.1006/jema.2001.0501).

c) Contacts

The contacts below mainly refer to discussion of the scope and objectives in initial phase of the research project and, more recently, to obtain information on the specific issues noted. Their assistance is gratefully acknowledged.

Alan Barnden (IPPC Pig and Poultry Project manager, Environment Agency) – 1999

Alan Brewer (FRCA) –1999

Helen Richardson (Environment Agency) - 1999

Pig producers (exploratory survey): Bedfordia Group, Milton Ernest, Beds and David Black and son Ltd, Stowmarket, Suffolk - 1999

Colin Baldwin (Pig Strategist, Meat and Livestock Commission – MLC) – 1999

James Black (predominant pig production systems, chairman of National Pig Association) - 1999

Dr Oleh Pahl (low emission landspreading techniques, Cranfield University/MLC) - 1999

Dr. V. Roger Phillips (control of aerial emissions from livestock buildings, Silsoe Research Institute -SRI) - 1999

Michel Lunther (co-ordinator of the BREF Note for intensive rearing of pig and poultry, European IPPC Bureau) – 2000

Ian Scotford (control of emissions from animal housing and waste stores, SRI) - 2001

Dr. Brian Chambers (author of series of booklets on Management of Livestock Manures, ADAS) – 2001

Theo Demmers (application of low cost ammonia reduction measures for pig housing, , Silsoe Research Institute -SRI) – 2002.

d) Participant as a consultee in the following research projects:

Identification of indicators of sustainability and evaluation of externalities (environmental costs) of pig and poultry production in Santa Catarina State, Brazil, part of a PhD project by Airton Spies, EPAGRI / CNPq and School of Natural and Rural Systems Management, University of Queensland, Australia.

Use of the Delphi Technique in the context of a poultry unit where the concern is to reduce nitrogen pollution to meet the requirements of the IPPC Directive, MPhil project by Andrew Angus, Department of Land Economy, University of Cambridge. Research project is part of the Natural Environmental Research Council' s (NERC) Global Nitrogen Enrichment Programme.

3.7 Critique

The major limitations of this research approach are related to isolation of IPPC effects, data availability, definition of sectoral BAT, and use of case study analysis.

The first limitation refers to the practical difficulties to define the process of compliance with IPPC. The requirements of IPPC may also be subject of other legislation and therefore it is difficult to see it in isolation of the broad regulatory framework or predict the incremental cost associated directly with IPPC regulation.

Determining the impacts of measures based on a framework concept such as BAT presents a particular challenge. Even though guidance is provided through documents such as the SFIR and BREF Notes, the determination of compliance or not with BAT is likely to involve a degree of subjectivity (which for permitting purposes will depend on the discretion of the regulatory authority).

Data used to estimate additional costs were based on secondary data. The applicability of some of the candidate BAT in UK conditions was not confirmed yet. Determining the applicability of abatement measures is particularly complex for existing installations.

The peer review, participation in the IPPC Steering Group and in the consultation process, particularly on BREF Notes, were factors that helped to elaborate the 'with-IPPC' scenario in practical terms, enabling its application to the case studies.

As discussed in Chapter 2, *ex ante* costs associated with regulation are likely to be overestimated in comparison to observed costs (*ex post*), because it is difficult to anticipate the effect of efficiency gains likely to be generated by the widespread use of cleaner techniques and constant innovation.

The use of case study approach has inherent methodological problems. The main important ones are that, first, it is difficult to make generalisations from results from a few cases and, second, there is need to rely on different sources of data, sometimes collected for different purposes. In this research the case study pig installations were carefully selected to partially overcome the 'specificity' problem. Also the sectoral survey was planned to support the generalisation of the evidence generated from case studies. Different data sources, if available, were compared to the data gathered or estimated from the case studies to check their consistency. A good rapport with the managers of the case study installations was established, which was an important factor to obtain good quality data.

Sectoral surveys have an associated risk of obtaining a biased response. In this research, this risk was reduced by careful questionnaire design and trial and by comparison of the survey results with other similar surveys or data available for the sector.

The exploratory nature of some of the issues addressed by this research suggests that interpretation of results must be treated cautiously. However, bearing in mind the limitations referred, its outcomes are still valid and justifiable.

3.8 Summary of Chapter

Data requirements to answer the research questions comprise major inputs and outputs flows of pig installations and associated financial flows. An analytical framework to assess the IPPC impacts on the pig industry was developed and applied. A case study approach was adopted to capture the environmental and financial performance of main types of pig systems likely to determine the effects of IPPC. A sectoral survey was carried out to confirm the validity of results from the case study installations to the industry as a whole. Other elements supporting the analysis comprise a workshop, research communication in conferences and involvement in the discussion forum with key stakeholders. Limitations of the research approach are recognised but the outcomes of this study are thought to contribute towards a formal, objective assessment tools for policy implementation of IPPC to the pig sector.

CHAPTER 4

ANALYSIS OF THE IMPACTS OF IPPC ON CASE STUDY PIG INSTALLATIONS

This chapter assesses the impacts of IPPC Directive on intensive pig rearing installations by applying the analytical framework described in Chapter 3 to three case study pig installations. Indicators to enable the assessment of environmental and economic performance of pig units are suggested. A baseline situation is determined for each case, focusing on resource consumption, emissions levels and financial performance associated with current production systems and techniques. A simulated 'with-IPPC' situation applied to each case study installation is then compared with the baseline 'without-IPPC' situation to determine the degree of impact.

4.1 CHARACTERISATION OF THE CASE STUDY PIG INSTALLATIONS

As previously referred to in Chapter 3, herd type, housing and waste management were identified to be the key elements for classification of pig installations as regards IPPC. The two latter elements are closely related, given that building design determines how manures are collected, as slurry or FYM, and therefore how it is handled for storage and landspreading. On this basis, and in collaboration with representatives of the National Pig Association (NPA), three case studies were selected for detailed study, as described in Table 4.1. They represent the predominant types of pig units according to the classification variables referred to above, being consistent with the relevant commercial pig production systems described in Chapter 2.

Case study installations 1 and 3 are complete cycle, that is, breeding-and-feeding, pig production units, whereas case study installation 2 is a feeding-only unit. From here they will be referred to as Case study 1, 2 and 3. Case study 1 has been selected to represent a partly slatted system for finishing herd, but growers and dry sows are reared in straw based, solid floor pens. Case study 2, the feeding-only pig production unit, has been selected to represent a straw based system for finishing herd. This unit is also distinct because of its relatively low availability of land for disposal of manures, relying heavily on the land of third parties for this purpose. Case study 3 has been selected to represent a fully slatted system for pig rearing, as pigs are kept on fully slatted floors in all production phases with exception of mating and pregnancy (where sows are kept either on solid or partly slatted floor with limited straw).

Table 4. 1 – Case studies pig installations according to size and type of system

Installation and size of herd		Classification of system		
		by herd specialisation	by housing / waste management	
			Production phase	*System*
Case 1		Breeding & Feeding	Mating & Pregnancy	Solid floor, straw based
No. sows*:	886		Farrowing	Fully slatted floor, slurry based
No. finishers:	2,420		Weaning	Fully slatted floor, slurry based
Total pigs**:	10,041		Growing	Solid floor, straw based
			Finishing	Partly slatted floor, slurry based
Case 2		Feeding only	Finishing	Solid floor, straw based
No. finishers***:	4,075			
Case 3		Breeding & Feeding	Mating & Pregnancy	Solid floor, straw based (70%)
No. sows*:	688			Partly slatted floor, slurry based (30%)
No. finishers:	2,257		Farrowing	Fully slatted floor, slurry based
Total pigs**:	9,023		Weaning	Fully slatted floor, slurry based (85%)
				Partly slatted floor, slurry based (15%)
			Growing	Fully slatted floor, slurry based
			Finishing	Fully slatted floor, slurry based

Notes: *number of sows = total sows (breeding and farrowing sows plus served gilts); ** total pigs at the time of the survey, comprising, in addition to sows and finishers, boars, suckling piglets, weaners and growers; *** number of finishers is equal to total pigs in this installation.

All these pig production units belong to agricultural businesses that operate multiple pig farms across England. In spite of this, the case studies installations have been considered as independent, self-contained pig production units, for there are no operational links between the activities carried out on these installation and the other pig units operated by the group (except for the milling and mixing of feed compounds for case units 1 and 2, which is done in a common central facility). However, one can assume that management and marketing aspects of units are associated when these operate under the umbrella of a major business organisation.

The three case study installations are located within farms with arable crops and, therefore, land is available for the disposal of animal manures by spreading. The cropping area is, however, substantially more restricted for case study 2. Table 4.2 summarises land use on the farms on which pig units are sited.

Cropping and set aside areas are used for the disposal of manures in the case study units. These areas represented a significant part of total farm area for all units (respectively, 91%, 87% and 92%, for case studies 1, 2 and 3). However, the area effectively available for spreading is smaller than the sum of these areas. For instance, according to the Farm Waste Management Plan (FWMP) of case study 3 unit, the total available area for spreading is 176 ha, or 75% of total farm area, having considered buffer areas close to watercourses and streams, neighbouring dwellings, steep slopes and subject to flooding.

Table 4.2 - Land use in the farm area belonging to the case study installation

Type of use	**Area (hectares)**		
	Case1	Case 2	Case 3
Crops*			
Wheat	67.1	19.1	77.4
Winter barley	10.7	-	42.3
Leeks	-	-	11.8
Sugar beet	36.0	-	-
Oil-seed rape	8.5	-	-
a) Subtotal area with crops	122.3	19.1	131.5
Non-cropping area			
Set-aside or rotation	-	-	64.6
Buildings, roads and other	11.7	2.9	9.4
Woodland	-	-	9.0
Permanent grass	-	-	21.0
b) Subtotal other areas	11.7	2.9	104.0
Total area (a + b)	134.0	22.0	235.5
Area available for spreading	**122.3**	**19.1**	**217.1**
Predominant soil type	Clay grade 2/3	Boulder clay	Boulder clay

Note: *data refer to cropping for harvest year 1999/2000.

Even though a major proportion of the total farm land is suitable and used for disposal of animal manures, the operators of the case study installations have agreements with other parties to match the land requirement for appropriate disposal of animal wastes. Thus the disposal of manures involves costs in order to guarantee enough land for landspreading. Moreover, all potential benefits from use of manures, such as nutrient value as fertiliser, are not be attained by the pig operator. Therefore, there is a relative advantage for the pig operator to have a pig production unit integrated with other agricultural enterprises, such as cropping and grazing, which can benefit from the disposal of manures onto land, compared to a pig unit without or with very restricted area available for landspreading. In practice, however, even where there is farm land available for spreading, the arable farm manager may prefer to avoid the necessity to deal with animal waste, particularly slurry.

On the study sites, most farmyard manure (FYM) is spread using a broadcast spreader using hired equipment (loaders and muck spreader). Part of the solid manure is sold to nearby farmers, being collected on site by the third parties. Slurry, however, is spread by broadcasting tanker or irrigation (rain gun) systems, which are mainly undertaken by contractors. The expenses for the landspreading of slurries, even where done on third party land, are paid by the pig operator. Even though manures have potential monetary value as a substitute for purchased inorganic fertilisers, the market in organic fertiliser is not well developed, and pig operators generally regard manures as a waste to be got rid of. For their part, arable farmers are often reluctant to take pig waste because of practical difficulties of achieving beneficial use. This issue is further explored in the sectoral survey, as presented in Chapter 5.

The sites where the pig units are located were examined in respect to presence of potential environmentally sensitive receptors. Ordinarily, the identified environmentally sensitive receptors consist of neighbouring dwellings and watercourses. The sensitivity of dwellings is associated with the potential nuisance caused by odours arising from housing and storage facilities on the pig installation and also from the landspreading of manures. If a given IPPC controlled installation is particularly a focus of complaints related to nuisance by odours (and noise), it may be required to adopt specific measures for monitoring, avoidance or abatement of these events.

Case studies 1 and 2 reported that occasionally there are complaints about odours from neighbours. Surprisingly complaints have not been reported from case study 3, which is, of the three pig installations, the closest one to a major residential area (see sketches of the case study areas in Appendix 4.1). Natural features, such as the landscape of the site, interfere in the transport of odours. Therefore, a hilly area between the case study 3 and the built area works as a natural barrier to dispersion of air emissions and may explain the absence of problems with odours in its neighbourhood. This illustrates how complex is the issue on nuisance, which depends on local site characteristics, is generally subjective, depending on individual perceptions and sensitivity, and therefore varies a great deal from place to place.

Another identified aspect was the occurrence of watercourses close to the pig housing, waste storage facilities and areas used for landspreading of manures, which increases the risk of pollution incidents to water by direct discharge of dirty water. Indirect pollution can occur through the percolation of water carrying nutrients in the water basin or groundwater. However, as clay soils are predominant in the pig units studied, and assuming that clays are not excessively drained soils, one can infer that the farm areas used for landspreading are not particularly at risk to pollution caused by nitrate and phosphate leaching (although surface run-off can be significant in these soils). Moreover, none of the pig units are within a Nitrate Vulnerable Zone (NVZ).

4.2 Description of pig production systems in the case study units

The relative efficiency of a pig production system can be described through physical and financial parameters. The physical parameters obtained from the case studies are presented in this section. This section also describes the use of manpower (labour and management) and provides an inventory of capital assets existing in the case study pig units. As referred to in Chapter 2, these are important elements to assess the performance of systems and determine the baseline for effects of IPPC.

4.2.1 Physical results

This section discusses the most commonly used physical parameters for assessment of performance of pig systems, presenting the results for case study units.

Table 4.3 presents the duration of each phase and the transfer out weights in the case study pig installations. They represent typical production systems. Diagrams illustrating pig production cycle in each of the pig units are given in Appendix 4.2.

Table 4. 3 - The pig production cycle in the case study units – duration and liveweight

Herd	Phase	Case 1		Case 2		Case 3	
		Stay (days)	Departure Weight (kg)	Stay (days)	Departure weight (kg)	Stay (days)	Departure weight (kg)
Breeding		147				154	
	Service	12	-		-	12	-
	Pregnancy	114	-		-	114	-
	Farrowing	21	6.2		-	28	6
Feeding		153				140	
	Weaning	50	25		-	28	12
	Growing	57	55		-	35	35
	Finishing I	-	-		-	21	50
	Finishing II	46	98	120	95	56	97

Note: on case study 2 unit, pigs enter at 40 kg liveweight from an outdoor herd.

The main production efficiency parameters for the pig herds in the case study units are presented Table 4.4. Other production performance indicators, such as the use of feed, water and energy by the pig herd are presented and discussed later in section 4.3, on the use of resources.

Comparison of performance indicators requires cautious interpretation because case specific production techniques may differ substantially. For example, case studies 1 and 3 are completely cycle indoor pig production units, while case 2 receives pigs at about 40 kg liveweight (lw) from an outdoor rearing unit to be finished. Therefore, average figures are provided for breeding-and-feeding and feeding-only herds, based on MLC's Signet Pigplan Recording and Costing Service, which is regarded as a sectoral reference for pig production indicators. These averages can be compared, respectively, with the values reported for case 1 and 3 and for case 2.

The comparison of physical parameters reported for the case studies and average industry figures, indicates that the physical performance of unit 1 and 2 is about or slightly below average, whereas case study 3 shows a better performance than the average for commercial pig units. Also, Table 4.4 shows the size of case units is well above sector average.

Table 4. 4 - Physical parameters of the case studies herds and average figures of commercial breeding-and-feeding and feeding-only herds

Parameter	Breeding & feeding			Feeding-only	
	Case 1	Case 3	MLC[a] average	Case 2	MLC[b] average
Breeding herd					
Litters/sow/year	2.26	2.46	2.26	-	-
Live pigs born/litter	9.8	12.2	11.1	-	-
Mortality before weaning (%)	12.3	10.4	12.3	-	-
Pigs weaned/sow/year	19.4	26.2	21.4	-	-
Age at weaning (days)	21	28	26	-	-
Live weight at weaning (kg)	6.2	6.5	7.1	-	-
Pigs sold/sow/year	18.2	25.1	19.8	-	-
% of sows replaced annually	41	50	35.4	-	-
Sow feed/sow/year (kg)	1,120	1,251	1,299	-	-
Feeding herd					
Feed conversion ratio (FCR)	2.59	2.49	2.48	2.88	2.85
Daily gain (g)	602	626	603	-	702
Liveweight at sale (kg)	97.0	97.6	85.7	94.0	95.8
Deadweigth at slaughter (kg)	72.2	71.0	71.5	70.0	71.7
Pigs as Grade 1 (%)	95	95	-	82	-
Mortality growing/finishing (%)	7.3	6.1	5.0	7.3	3.1
Total pigs sold per year (head)	19,360	18,306	5,564	11,857	6,965

Note: a) average figures refer to breeding-and-feeding herds using all feed sources. b) average for feeding herd, home mixers.
Source: case studies data reported by operators; MLC Pig Yearbook 2001 (MLC, 2001a), annual average for year ended Sept.2000.

According to MLC, the more financially successful herds are those with: more litters per sow per year; more piglets born alive per litter; lower mortality; better feed conversion (which means lower FCR); more pigs sold per sow per year and heavier pigs at slaughter.

The environmental performance of the pig unit is often directly associated with the physical efficiency of its herd (EIPPC, 2001). If better performance can be obtained in terms of parameters such as feed conversion ratio, number of pigs sold per sow and period to complete a pig cycle (age in days), lower level of emissions per pig produced would be expected (as they are directly correlated with feed intake, number of animals and duration of the cycle). Even though the intensification of livestock systems is generally associated with an increased potential of pollution to the environment, some aspects of large scale, intensive animal production units could lead to a better environmental performance.

4.2.2 Labour and management

Table 4.5 shows the distribution of the labour force and management according to the pig production phases or activities carried out in the case study pig units. Relatively, the breeding herd (comprising the Mating and Pregnancy and also Farrowing phases) requires more labour per number of animals being reared. It demonstrates how crucial the first stages are for a successful accomplishment of a pig production cycle, and the need for careful husbandry at these phases. After weaning, the mortality of pigs usually decreases substantially and there is no longer need of strictly controlled environment conditions inside animal housing for growers and finishers. It is possible to rely on automated systems for feeding which require very low use of labour.

For the breeding herd, the use of labour was similar for case study units 1 and 3, given similarity of systems for service and pregnancy (solid floor, straw based housing) and farrowing (fully slatted, slurry based farrowing crates). However, the farrowing period is longer for case study unit 3 than for unit 1 (28 and 21 days before weaning, respectively, as shown in Table 4.3).

It is more difficult to compare labour use between the different production phases of a feeding herd, because of differences in ages and liveweight for weaners and finishing pigs. However, broad conclusions can be drawn from the data collected. The intensity in labour use by the production systems appears to decrease in the following order: solid floor, straw based system (case study 2 unit); partly slatted floor, slurry based (case 1); and fully slatted, slurry based floor (case 3). More labour is needed to clean pig pens when there are solid floors and to manage bedding materials when straw based systems are used. Some specific activities are carried out using general farm labour, such as landspreading of manures. Also contractors are often used for spreading of slurry.

Table 4. 5 - Distribution of total labour force and management by phase/operation

Resource	Description	Phase or activity	Case 1	Case 2	Case 3
Labour	Number of FT stockman per phase	Service&Pregnancy	1.5	-	1.75
		Farrowing	1.5	-	1.75
		Weaning	2.5	-	1.75
		Finishing	2.5	2	1.75
		Complete cycle	8	2	7
	Sows/FT*	Service&Pregnancy	585	-	368
	Sows/FT	Farrowing	101	-	59
	Weaners/FT	Weaning	729	-	1,787
	Fatteners/FT	Finishing	2,306	2,038	2,256
	Pigs sold/FT	Complete cycle	2,420	5,929	2,471
	General staff	Agricultural, mill and office staff, drivers	0.13	0.05	
Management	Manager	pig unit			1
		general or farm	0.16	0.03	0.25

Note: *FT (full-time equivalent) = 1 permanent worker (stockman) working 47 hr/week (Nix, 1996).
Source: case studies

All three case study pig units operate under the rules of the Assured British Pigs – Certification Scheme (AB Pigs) whereby required practices for pig production are externally verified, especially those related with the welfare of pigs and quality of meat being produced. Compliance with this voluntary scheme involves routine monitoring and control on aspects related with animal husbandry and use of materials such as vet medicines and disinfectants. It can be assumed that such practices have a positive effect on the general management of the unit and the ability to accommodate some of the requirements now being brought about under environmental regulation, such as by the IPPC regime.

4.2.3 Animal housing and general buildings

Table 4.6 describes the existing animal housing buildings in terms of their technical specification and also presents estimated total and annual capital investment costs. Unless otherwise indicated, capital costs are estimated over a 20 years investment life at an interest rate of 6% per annum. It is noted that costs per animal place are substantially higher for the breeding herd compared to the feeding herd. This evidence confirms that, to offer the strict environmental conditions required, relatively greater capital investment is necessary in the breeding phase than in the feeding phase (as well as more labour). However, as a greater number of pigs are concentrated in the feeding herd, the majority of total capital cost in buildings is associated with the feeding phase, which accounts for 56% to 60% of the total housing cost (case study 3 and 1, respectively).

As the type of animal housing varies between the case studies for the same production phase, so does the estimated building cost. Stocking densities also affect the unit cost for housing per pig place. Notwithstanding these variations, it is possible to identify a reasonable degree of agreement among estimated building costs for each production phase (Table 4.6).

The highest unitary building costs are for farrowing sows, with an investment of around £2,400 per sow place (prices for year 2000). This reflects the relatively tighter environmental control systems in place to guarantee ideal conditions for sow and litter during the farrowing phase. Control systems involve substantial capital investment in equipment for heating and ventilation, as well as pen design and materials.

There were considerable differences in terms of space allowance among the case study units. This complicates the comparative analysis of costs per pig place. For instance, the capital cost for housing in the growing phase (pigs from 25 to 55 kg lw) in case study 1 unit is estimated as being £138 per pig place, assuming a stocking density of 1.08 m^2 per grower in deep straw yards. For the equivalent growing phase in case study 3 unit (named Finishing I, which comprises pigs from 35 to 50 kg lw) the estimated cost is of £121 per pig place, but for a space allowance of only 0.34 m^2 per grower in a fully slatted pens.

Cranfield

Table 4. 6 – Description of current housing facilities in the case study pig units and their estimated capital costs

Unit	Description of building	Capacity (heads)	Building Size (m^2)	Stock density (m^2 per pig)	Building total cost (£)	capital costs £/year	(£/place)	(£/year /place)
Case 1	Sow yards, straw based solid floor, drop feed	450	1,763	3.92	274,096	23,846	609	53
	Service house, straw based solid floor	382	1,322	3.46	205,572	17,885	538	47
	Gilt pens, straw based solid floor	161	789	4.89	117,534	10,225	728	63
	Subtotal dry sows and gilts				597,202	51,957		
	Farrowing crate, fully slated floor	168	1,239	7.38	401,820	34,958	2,392	208
	Subtotal Breeding				999,022	86,915		
	Flat decks, fully slatted floor (Weaning)	2,496	858	0.34	196,924	17,132	79	7
	Grower pens, straw based solid floor (deep straw yards)	3,350	3,623	1.08	460,802	40,090	138	12
	Finishing pens, partly slatted floor, concrete slats	3,264	3,457	1.06	845,613	73,568	258	22
	Subtotal Feeding				1,503,339	130,791		
	Total **Breeding and Feeding** housing				**2,502,361**	217,705		
Case 2	House with solid floor, straw based pens	5,000	2,688	0.54	546,928	55,180	109	11
	Subtotal Finishing = **Total** herd	5,000	2,688		**586,928**	55,179		
Case 3	Service house, hand fed, solid floor +shavings	120	275	1.98	49,477	4,304	412	36
	Trobridges, hand fed, shavings, part slatted floor	80	137	1.70	22,640	1,970	283	25
	Sow yards, dump fed, straw solid floor	380	1,011	2.31	183,422	15,958	483	42
	Outside pens, hand fed, straw solid floor	75	185	2.40	30,550	2,658	407	35
	Holding pens, dump fed, shavings, part slatted floor	200	461	2.05	116,290	10,117	581	51
	Subtotal dry sows and gilts	855			402,379	35,007	471	41
	Farrowing crates	160		7.50	376,498	32,755	2,353	205
	Subtotal Breeding				778,877	67,762		
	Houses with fully slatted floors / flat-decks	1,272	365	0.17	97,015	8,440	76	7
	Hospital pens, part slatted, shavings	192	45	0.20	12,830	1,116	67	6
	Subtotal Weaning	1,464			109,845	9,556	75	-
	Grower pens, fully slatted	1,450	562	0.34	175,173	13,076	121	9
	Trobridge's, part slatted, shavings	280	99	0.35	16,361	1,423	58	5
	Subtotal Growing	1,730			191,534	14,499	111	-
	Finishing shed 1, fully slatted	1,344	604	0.40	173,944	15,133	129	11
	Finishing sheds 2,3 & 4, fully slatted	2,688	1,863	0.62	535,131	46,556	199	17
	Subtotal Finishing	4,032			709,075	61,689		
	Subtotal Feeding				1,010,454	85,744		
	Total **Breeding and Feeding** housing				**1,789,331**	153,506		

Note: standard unit costs based on *Farm Building Cost Guide* (SAC, 2000). Amortisation assumes a period of return of investment 20 years and interest rate of 6% a.a.

Comparing housing costs in the finishing phase presents similar difficulty. Case study 1 unit estimated capital costs for housing in the finishing phase (pigs from 55 kg lw to slaughter weight) are £258 per pig place, referring to partly slatted finishing pens with an allowance of 1.06 m^2 per finisher. These costs are £109 in case study 2 unit, relating to solid floor, straw based finishing pens and allowance of 0.54 m^2 per finisher (pigs from 40 kg lw to slaughter weight). Case study 3 unit has estimated capital costs of £199 for fully slatted finishing pens with an allowance of 0.62 m^2 per finisher (pigs from 50 kg lw to slaughter weight).

Overall, space allowances are determined on welfare grounds, and must assure pigs are thermally comfortable (ABM, 1999). Therefore, space allowance has to deliver an animal density inside the pen that does not have an excess of pigs per unit area, and does not cause temperature stress. Factors such as the use of bedding and environmental controls may affect the stocking density capacity per pen, but there are minimum requirements under the MAFF Code of Recommendations for the Welfare of Livestock: Pigs (MAFF, 1996). Also, as environmental control systems (heating and ventilation) have been identified as major uses of energy in the case study units. One can infer that pig farmers prefer to operate at a high density of animal per pen. That is, as high as is economically sustainable, within the law or agreed under assurance scheme.

Solid floor, straw based systems are relatively more expensive than slatted floor systems because they require more space allowance per animal, which partially offset the initial advantage in terms of lower unit construction costs. Slatted floor housing systems require extra equipment and infrastructure work (manure pit underneath slats and slurry drainage system), but proved to be cheaper per pig place.

The identified variations in the baseline situations have repercussions for additional costs associated with IPPC measures (section 4.5). However, as cost data for BAT relies upon 'standard' or 'pilot-scale' systems, it is difficult to capture the variations that may arise once they are applied to specific site conditions. However, applying technical measures to existing installations is to a great extent 'tied' to current space and design of buildings, and standard figures may not be robust enough to represent the actual impact of these changes in every pig unit.

In addition to the specialised buildings for animal housing (presented in Table 4.6), other existing facilities are of general or common use. These are referred to here as miscellaneous buildings, as shown in Table 4.7. Costs are derived from standard cost per m^2 multiplied by reported or estimated building size from the case studies. The most relevant aspect of these other building is the sizeable capital costs represented by facilities for storage of straw used as bedding material.

Table 4. 7 - Miscellaneous buildings in the case study installations and their capital costs

Building	Case 1			Case 2			Case 3		
	Size (m^2)	Capital cost total (£)	Capital cost annual (£/year)	Size (m^2)	Capital cost Total (£)	Capital cost Annual (£/year)	Size (m^2)	Capital cost total (£)	Capital cost annual (£/year)
Office	-	-	-	20	2,820	245	14	2,042	178
Store shed (feed, inputs)	440	20,615	1,794	48.4	6,824	594	106	14,946	1,300
Straw storage shed	2,628	59,394	5,168	844	18,556	1,614	-	-	-
Workshop	450	20,980	1,825	-	-	-	64	9,073	789
Total		100,989	8,787		28,201	2,453		26,061	2,267

Note: unit cost of buildings based on *Farm Building Cost Guide* (SAC, 2000). Annual amortisation of capital estimated assuming a 20 year payback period and 6% a.a. interest rate. Dimensions (area of buildings, m^2) are from the case studies.

4.2.4 Storage of animal wastes

After collection from animal housing, manures need storage before they are spread to land. Generally, liquid manure is pumped from the slurry pit underneath pig housing into a lagoon through a mechanic separator to reduce its solid content. Solid manure (FYM) is scraped from solid floor house and pilled up in a stack outside the buildings. Seepage from the manure heap is drained into the slurry lagoons by gravity.

Table 4.8 describes the size and annual capital costs for slurry lagoons and manure heap in the case study units. The storage facilities for case study 1 and 3 units are typical of pig installations, namely earth-banked lagoon for slurry and muck slab for FYM. Case study 2 unit also stores slurry in a lagoon but has a covered, walled building for the storage of FYM.

The unitary capital costs (£ per cubic metre or, roughly, £ per tonne) needed for storage of FYM using muck slabs, which consist of open yards with a concrete base, are relatively much lower than lagoons. Based on SAC (2000) data applied to the case study units, the estimated capital cost for storage of FYM in a muck slab is of about £3.30 per m^3 capacity, whereas the respective value for storage of slurry in earth-banked lagoons is of £19.80 per m^3 capacity. However, FYM storage using an purpose made building such as in case study 2 is estimated to have capital costs of £36.00 per m^3 capacity.

Table 4. 8 - Storage facilities for slurries and manure in the case study units and their associated capital costs

Type of Manure	Unit	Type of Storage facility	Size surface (m^2)	Size volume (m^3)	Storage capacity (months)	Capital cost Total (£)	Capital cost Annual (£/year)
Slurry	Case1	Lagoons	5,640	18,269	16	364,910	31,746
	Case 2	Lagoon	600	1,200	3	23,760	2,067
	Case 3	Lagoons	7,000	10,000	9	198,000	17,226
FYM	Case1	heap slabs	3,250	6,500	16	21,613	1,880
	Case 2	Covered building	1,400	3,500	8	126,067	10,968
	Case 3	heap slab	180	360	12	2,394	175
Total (£) (slurry + FYM)	Case1					386,523	33,626
	Case 2					149,827	13,035
	Case 3					200,394	17,401

Note: costs based on SAC (2000) p.14 and 21; includes slurry reception pit in case study 1. Annual costs assume a 20 years period for return of investment and 6%a.a interest rate.

The current costs for storage of manures are dependent on the existing waste storage capacity, which, as shown in Table 4.8, varies a great deal among the units. Also, because of the relative simplicity of storing FYM in open yard heaps, there is no limitation in terms of capacity unless the area is not suitable for storage of animal waste. The IPPC rules do not define a minimum period to be matched by the storage capacity, but according to *The Water Code* (*Code of Good Agricultural Practice for Protection of Water*, MAFF, 1998c) the capacity of storage facilities must comply with *The Control of Pollution (Slurry, Silage and Fuel Oil) Regulations 1991 (as amended)*, which determine that they must hold at least 4 months of slurry production, unless the management of the system allows intervening disposal of manures. If this is required, case study 2 unit would need to expand its current capacity. Case study 1 and 3 units have enough capacity to match the rule, but have disposal of slurry by landspreading concentrated in post-harvest period (Autumn). This means that the storage capacity has to be at least 9 months. The existing storage capacity for case study 1 unit is well above the present requirement of the pig installation and results in relatively high estimated capital costs for manure storage for this pig unit.

Machinery and equipment for the case study pig units are presented in Table 4.9. Additionally, as referred before, tractor plus driver from general farm resources are used

Table 4. 9 - Annual depreciation and maintenance costs for machinery and equipment in the case study pig units

Description	Case 1			Case 2			Case 3		
	New price (£)	Depre-ciation (£/year)	Repairs & spares (£/year)	New price (£)	Depre-ciation (£/year)	Repairs & spares (£/year)	New price (£)	Depre-ciation (£/year)	Repairs & spares (£/year)
Tractor	15,600	1,170	1,014	15,600	1,170	1,014	33,400	2,505	2,171
Tractor	15,600	1,170	1,014	-	-	-	15,600	1,170	1,014
Fork-lift (JCB)	27,000	2,025	1,755	27,000	2,025	1,755	27,000	2,025	1,755
Dung spreader	3,200	360	08	-	-	-	-	-	-
Front end loaders	9,100	1,024	592	-	-	-	-	-	-
Plough, mounted	4,500	356	293	-	-	-	4,500	356	293
Hydraulic scraper	2,481	-	-	-	-	-	2,481	295	-
Pump	4,500	-	-	1,800	143	-	1,800	368	-
Trailer	5,600	665	-	-	-	-	2,800	222	-
Yard scraper	450	113	-	450	56	-	450	56	-
Total	88,031	**7,533**	4,875	44,850	3,394	2,769	88,031	**6,996**	5,233
Total Mach&Equip (£/year)			**12,408**			**6,163**			**12,229**

Source: prices of new equipment based in SAC (1999); linear depreciation based on estimated annual hours of use (Nix, 1995). Fuel costs are presented separately further in this chapter.

to undertake the incorporation of manures by ploughing. Most of the capital cost of machinery involves depreciation of tractors, which are used mainly for transport of inputs within the unit, handling of straw, removal of FYM from housing and its management during storage and disposal.

All case study units make use of contractors to, completely or partially, undertake the disposal of slurry (Table 4.10). Also, two of them (units 2 and 3) hire equipment for landspreading of FYM. This widespread use of contracting and hiring means, in practical terms, that individual pig units avoid capital investment costs related machinery and equipment for spreading of slurry and FYM by paying third parties to do such operations. This also suggests that contractors are likely to offer landspreading services at a lower total cost than those achievable by the pig operator because of advantages of scale of their businesses. Therefore, contractors, having relatively superior capacity to make investments, may be able to offer low emission landspreading techniques as required under IPPC rules (and adopt such practices more rapidly than pig producers themselves).

Table 4. 10 - Expenditures with contracting and equipment hiring for disposal of manures in the case studies

Description of service	unit	Case 1	Case 2	Case 3
Contacting landspreading of slurry				
slurry volume	m^3	13,600	4,546	9,821
contracting cost total	£/year	8,228	2,750	10,057
Hiring muckspreader for FYM				
total hours	hr	-	25	15
equipment hiring cost	£/year	-	418	160
Total contracting and hiring	£/year	8,228	3,168	10,217

Source: quantities and rates paid reported by case studies' operators.

4.3 Resource consumption and pollution emissions levels

Pollution emissions levels of a given production system are often directly associated with its consumption of materials and energy. On the consumption side, the IPPC permit focuses on use of feed, water and energy. IPPC requires a minimum of two different diets for sows and finishers according to their production phases[1]. Energy and water must be audited and a plan to achieve efficient use drawn up. Inventories of veterinary medicines and biocides are required but no rules on use are set under IPPC (except for disposal of packaging and residues). Emission levels focused on ammonia (NH_3) and odours arising from animal housing, and the storage and landspreading of manures.

4.3.1 Feed consumption

Each pig production phase requires specific characteristics of feed defined in terms of energy and protein content, as shown in Table 4.11 for the case study units.

Table 4. 11 - Feed characteristics and usage by production phase in the case studies pig units

Unit	Type of feed/production phase	Characteristics			Usage	
		Crude Protein (%)	DE (MJ/kg)	Lysine (g/kg)	tonnes per year	% of total
Case 1	*Breeding herd*					
	Sow meal (dry sows, farrowing sows)	16	13.5	0.86	1,028	21%
	Weaning (purchased, up to 12 kg lw)	22	16.0	1.59	130	3%
	Feeding herd					
	Weaning (home mix)	22	14.7	1.45	325	6%
	Growing (grower pens)	18	14.1	1.20	1,572	31%
	Finishing	18	13.7	1.10	1,945	39%
	Total feed (*Breeding & Feeding*)				**5,000**	100%
Case 2	Finishing 1 (40 to 70 kg)	18	14.3	1.23	785	40%
	Finishing 2 (70 to 95 kg)	18	13.9	1.24	1,178	60%
	Total feed (*Feeding-only*)				**1,963**	100%
Case 3	*Breeding herd*					
	Dry Sow meal	13	13		541	12%
	Lactating sow meal	17	13.5		353	8%
	Creep feed (1st stage weaners)	22	15.6		230	5%
	Feeding herd					
	Weaners diet 12 up to 35	20	15		563	12%
	Growers diet 35 up to 55 kg	19	14.5		514	11%
	Finishing diet	19	13.3		2,403	52%
	Total feed (*Breeding & Feeding*)				**4,603**	100%

Note: DE = digestible energy.
Source: case studies.

[1] Feeding measures such as manipulation of diets to reduce N emission techniques are likely to be incorporated in BAT further, as they become available.

The finishing phase (for pigs above 12kg) accounts for the 75% of the feed consumption of the total production cycle (Table 4.11). Even though production of excreta varies among production phases, as younger animals have higher conversion of energy and protein into meat than older, heavier pigs, these feed consumption figures also imply that most of excreta production and, therefore, most of the emissions from the pig production, are associated with the feeding herd. The production of excreta is discussed below (section 4.3.6).

4.3.2 Water consumption

Table 4.12 presents the water consumption in the case study pig units based on standard values for water intake by pigs (referred as theoretical consumption), and total actual volume of water consumed reported by operators. Detailed water use by activity or animal category was not available from available data, but standard estimates show that more than 80% of water use can be ascribed to the feeding phase in complete cycle units.

Table 4. 12 - Water use in the case study units

Consumption		Case 1		Case 2		Case 3	
a) Estimated use*	(m^3/year)	25,550	100%	8,286	100%	11,753	100%
b) by production phase /category	Theoretical Consumption (litres/pig/day)	Estimated use water (m^3/year)	%	Estimated use water (m^3/year)	%	Estimated use water (m^3/year)	%
Breeding herd				-	-		
Dry sows & gilts	5-9	2,629	13%			1,177	12%
Boars	9	95	0.5%			36	0.4%
Lactating sows	18-23	1,137	6%			679	7%
Feeding herd							
Weaning	2-9	1,330	7%	-	-	1,240	12%
Growers	2-9	6,717	34%	-	-	2,278	23%
Finishers	2-9	7,950	40%	8,181	100%	4,530	46%
Total	(m^3/year)	19,859	100%	8,181	100%	9,940	100%
c) by type of use							
Drinking water for the herd		n.r.		n.r.		4,701	40%
Water added to feed (wet feed)						2,351	20%
Water for cleaning pens area						4,701	40%

Source: *actual clean water consumption reported by case studies' managers; theoretical consumption, EIPPC (2001) and MAFF (2000b). n.r. = no reference available.

According to the type of water use, based on case study 3 unit data, drinking and cleaning are equally important uses of water. However, if water added to feed is considered as drinking water, drinking would account for 60% of total water consumption.

It is important to determine the contribution of processes and operation in the total consumption of water in the pig unit. Under IPPC, the operator is expected to review the use of water and identify potential opportunities to reduce consumption or avoid wastage.

The reported total water consumed in the case study units is substantially higher than that based on estimated unit values , except for case study 2 unit. For the complete cycle units, 1 and 3, actual consumption exceeded, respectively, 28% and 18% the estimated consumption. However, the use of typical values as a benchmark for actual water consumption in case study units needs caution because of the large variation within the range of standard values per pig.

4.3.3 Non-food energy consumption

Table 4.13 presents non-food energy consumption in the case study pig units by source. Electricity is the major source of energy input to the case study 2 and 3 pig units, accounting for, respectively, 53 and 78% of total energy used. Conversely, case study 1 unit relies mainly (77%) on fuels - heating oil and diesel - for its energy input.

Although it has not been possible to quantify the use of energy against each individual process, the unit managers consider the heating system for farrowing houses and flat decks for the weaning phase as the major user of energy in complete cycle pig unit (case studies 1 and 3). Lighting and ventilation systems using fan motors consume the most energy in the feeding-only unit (case study 2). The latter unit does not require heating in the animal housing.

Table 4. 13 – Energy use in the case study pig units

Source	Use by type*	Unit	Case 1	Case 2	Case 3
Electricity*	Buildings (lightning)			✓	
	air control systems			✓	
	feeding equipment:				
	milling, mixing and conveyors				
	cold/frozen storage				
	heating system (electrical)				✓
	slurry conveyors (pumps)				
	Total electricity	kWh	300,945	158,430	668,767
Fuel	Transport of materials on-farm	Litres			2,000
	Spreading of manure/slurry				4,000
	Incinerator		✓	✓	12,000
	heating system (oil fuelled)		✓		-
	Total fuel	Litres	95,416	13,333	18,000
	(fuel converted into kWh)	kWh	982,021	139,623	190,440
Total energy (kWh)			1,282,966	298,053	859,207

Notes: *operators could not determine use against individual production processes. However, the tick symbol ✓ indicates identified major energy consumers.

Source: case studies (annual consumption); conversion factors for fuel based on Peirson (1999), respectively 10.22 kWh per litre for heating oil and 10.58 kWh per litre for diesel and gas oil.

Pig units which use home-mix feed usually require more non-food energy input in comparison to those using purchased feed, because of operations of milling and mixing of feed compounds. However, as feeding preparation is undertaken in a central milling-mixing plant for case study units 1 and 2, this has not been accounted for here. Peirson (1999) refers to an energy use of 15 to 22 kWh per tonne of meal produced[2] in pig units. Thus, based on feed tonnage in Table 4.11, a minimum of 75,000 and 29,295 kWh should be added to the total energy consumption of case studies 1 and 2, respectively, due to on-farm milling and mixing of feed. If included they would increase the current total energy use by 5.9% and 9.8%.

All units have small incinerators for disposal of carcasses, which, based on case 3 data, accounts for a sizeable share (about 14%) of the total energy consumption of a pig unit.

[2] Based on hammer mill and pneumatic transfer from mill to mixing or meal storage. If feed is pelleted or cubed, the energy input needs further 20 kWh.

An ADAS survey[3] on energy use in 60 pig farms (Peirson, 1999) determined that a figure for energy consumption in large breeding-and-feeding units (referring to those selling more than 2,100 pigs per year) is between 41 and 147 kWh per pig produced. This variation among pig units is possibly associated with considerable variation on energy used according to the production systems. These estimates do not consider, however, energy use in the carcass incinerator. Comparing them with the estimate 66 and 47 kWh per pig produced for, case studies 1 and 3 respectively (also complete cycle pig installations), suggest these units have good energy use performance, as they are closer to the minimum value in the benchmark range (i.e. 41 kWh per pig), even though they include energy consumption of the incinerator. Case 2 has an estimated average unit consumption of 25 kWh per pig produced, but no benchmark for feeding-only unit is available for comparison.

4.3.4 Veterinary and cleaning products

The use of veterinary products in the pig units mainly refers to worm control and antibiotics. Disinfectants are mainly used for cleaning of pens between production batches. Under IPPC, it is required the inventory of stock and the keeping of records on the use of these products. Some of the most commonly used commercial products are listed in Appendix 4.3. The case study pig installations are part of the AB Pigs quality assurance scheme. The use of veterinary products and disinfectants, as well as growth promoters, are closely monitored and recorded within a *Veterinary Health Plan and Cleansing Plan* for the pig unit (ABM, 1999). COSHH data must be available on-farm for all chemicals used with pig husbandry and disinfectants, and these must be MAFF approved[4]. Samples of pig carcasses are taken periodically from the slaughterhouse for residue testing, and these must comply with limits for antimicrobials under the *EEC Residue Directive 86/469 EEC.*

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[3] *Guidance on the Control of Energy in Pig Units*, August 1999.
[4] MAFF, Scottish Office Agriculture, Environment and Fisheries Department and Welsh Office Agriculture Department. *List of Disinfectants Approved for the purpose of the Diseases of Animals (Approved Disinfectants) Order 1978* (as amended) April 1999.

As medication is added to feed and therefore present in animal excreta, and disinfectants are diluted in cleansing water and collected as dirty water, in practice the disposal of veterinary products is simultaneous with the disposal of manures. Excessive discharges of such chemical active and derivatives can affect the biological processes occurring during storage of manures and also after their spreading onto land. Also, they can cause water and groundwater contamination through run-off and leaching processes.

The use of veterinary and sanitary products is mostly related with the breeding phase and first stage of feeding, as it is shown by comparison of the costs per pig sold for the case study pig units (Table 4.14).

Table 4. 14 – Overall cost of veterinary medicines in the case study pig units

	Pig unit		
Total cost of vet products	Case 1	Case 2	Case 3
£/pig sold	3.32	0.73	3.56
pence/kg meat	4.60	1.09	5.01

Source: case studies.

Comparing the complete cycle units (1 and 3), the cost of veterinary products is approximately 9% higher for Case 3. This is likely to be associated with a better physical performance and health status in the latter, as previously discussed in section 4.2. However, it could also be needed to support a more intensive system involving higher stocking rates in the fully slatted floors.

IPPC permit requires that an inventory detailing quantities and relevant environmental characteristics of raw material used. Disinfectants, pesticides and veterinary medicines listed in the MAFF's approved list, MAFF/HSE Book Reference 500 or National Office for Animal Health (NOAH) compendium do not need to be individually listed. However, products not listed in the above documents require specific information. In practice, IPPC will promote the use of 'listed' products only.

4.3.5 Bedding materials

The use of bedding material is dependent on the housing system and production phase. There is considerable variation in the amount of straw used among the case study pig units (Table 4.15), even within a same pig category and similar system, as for the *dry sows and service* phase for case study 1 and 3 units.

Table 4. 15 - Bedding material use in the case study units

Pig unit	Use of bedding by category or phase					
	type of bedding	unit	dry sows and service	growers	finishers	**Total herd**
Case 1	straw	tonnes/year	350	900		**1,250**
		kg/pig/year	386	52		**-**
Case 2	straw	tonnes/year	-	-	350	**350**
		kg/pig/year	-	-	30	**-**
Case 3	straw + wood shavings	tonnes/year	94	-	-	**94**
		kg/pig/year	-	-	134	**-**

Note: new straw is put into the pens three times per week after scraping the FYM.
Source: case studies.

4.3.6 Emissions from housing, storage and landspreading

As referred in Chapter 2, ammonia (NH_3) emission factors have been used as the key indicator of environmental performance of BAT for IPPC application to intensive livestock. Three main reasons underpin this IPPC focus on ammonia emissions to air. First, the fact that there is control of pollution to other media, such as by legislation on nitrate and water quality. Second, the substantial amount of scientific results recently generated, which have been able to attribute ammonia emissions to livestock production techniques, including storage and processing or disposal of animal manures. And, third, the need to implement policy instruments to achieve the national target for reduction of ammonia under the Gothenburg Protocol[5] (UN/ECE, 1999).

[5] UN/ECE Convention on Long-range Transboundary Air Pollution, *The 1999 Protocol to Abate Acidification, Eutrophication and Ground-level Ozone.* Gothenburg (Sweden).

techniques and measures selected as BAT mainly on their potential ammonia abatement rates may result in increased emissions of other pollutants or increased resource consumption. Covering slurry stores, which is regarded as BAT for storage of liquid manure, is an illustrative example of the trade-off between different environmental performance criteria. On the one hand, this substantially reduces ammonia emissions but, on the other, it favours anaerobic conditions in storage, which increases the production and release of methane, a greenhouse gas.

Conversely, this NH_3-based approach offers a quite straightforward tool for assessment of the environmental performance of techniques and systems, as ammonia emissions are present at all the individual pig production and waste management phases. . Therefore, for the purpose of this study such a NH_3-based approach has also been adopted to describe current systems and compare proposed BAT options.

The emissions factors used to estimate NH_3 emissions for the case study units are based on those compiled in other studies, mainly in the first and second drafts of the BREF Notes for intensive animal rearing (EIPPCB, 2000 and 2001) and in the new *Inventory for Ammonia Emission from UK Agriculture* (Pain et al., 1998; Misselbrook et al, 2000). Ammonia emissions throughout the production cycle up to the disposal of animal wastes are based on the Total Ammoniacal Nitrogen (TAN). TAN is made up of labile N compounds in animal excreta, mainly urea and acid uric, which readily hydrolyse to ammonium (NH_4) form. These labile N are the source of almost all NH_3 emissions (Webb, 2001). Such an approach was used in the MARACCAS[6] (Cowell and ApSimon, 1998) and SALAAM[7] models (Cowell et al. 1999), and by Misselbrook et al. (2000) and Webb (2001). The following figure illustrates how the TAN is calculated in each stage of production and waste management.

As it is shown in Figure 4.1, from the total nitrogen given to pigs in feed (*N total* or *ingested-N*) around 33% is converted into animal protein (pigmeat) and other 67% is

[6] MARACCAS is the acronym for Model for the Assessment of Regional Ammonia Cost Curves for Abatement Strategies.
[7] Sectoral Analysis of Livestock Ammonia Abatement Model.

As it is shown in Figure 4.1, from the total nitrogen given to pigs in feed (*N total* or *ingested-N*) around 33% is converted into animal protein (pigmeat) and other 67% is excreted. Losses of feed by spillage or during transportation are considered insignificant.

Deducting N exported as pigmeat from N-total results in *excreta-N*. This contains organic and inorganic forms of N. The organic N does not cause direct emission, but is slowly transformed into inorganic N, which can potentially be released in the form of NH_3 or N_20. Therefore, the total available or ammoniacal nitrogen (TAN) is the relevant form of N as far as emissions are concerned. TAN is estimated as being approximately 70% of the excreta-N.

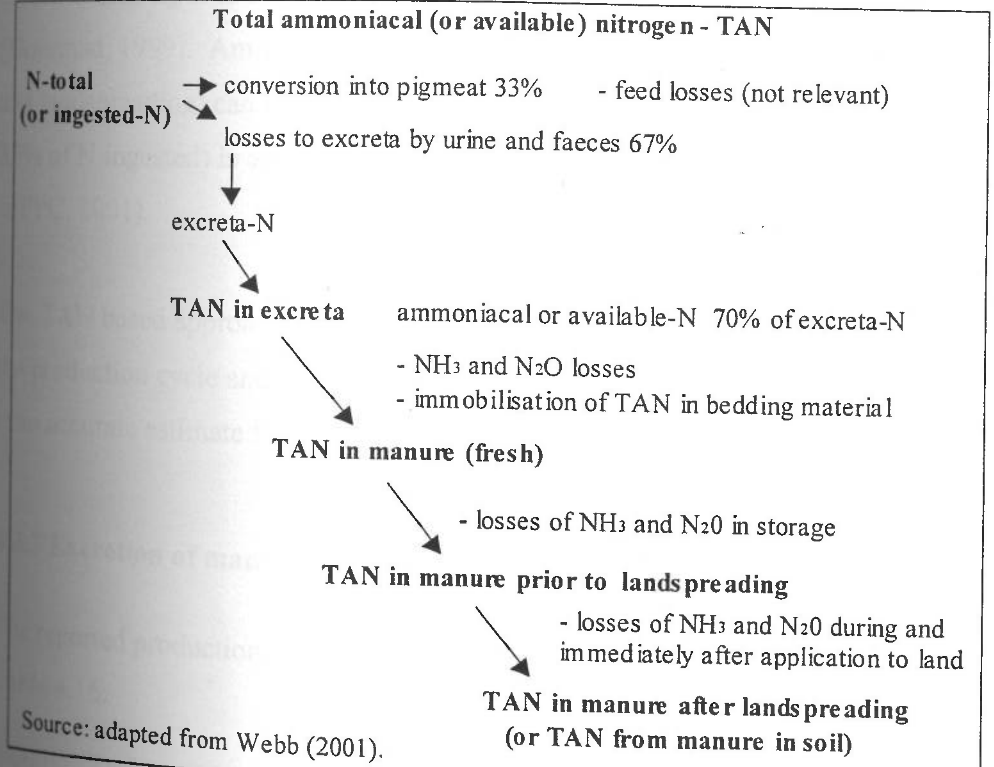


Figure 4. 1 – TAN in different stages of pig production and waste management

However, *TAN in excreta* is the value given for this ammoniacal fraction of excreta-N at the time when excreta is released from the animal's digestive system. Thus it is necessary to discount losses of N during the housing period to determine the *TAN in manure*. These losses are dependent on the housing system. In turn, the *TAN in manures prior to spreading* to land requires reduction for losses of N during the storage period.

Finally, there are N losses in manures associated with the landspreading operation, depending on, for example, weather conditions, dry matter content of manure, techniques used for distribution of manures onto land and the length of time prior to incorporation of the material into the soil. Discounting these losses from TAN prior to spreading gives *TAN in manures after landspreading*.

As an example, for a pig fattened to 100 kg liveweight, the total N-ingested is 8.03 kg, of which 2.81 kg N is retained (converted into meat) and 5.22 kg N is lost to excreta (Dourmad, 1999). Ammonia emissions to air (from housing and during waste storage and landspreading) can be as much as 2.74 kg. Only 2.57 kg N (respectively, 34% and 32% of N ingested) is available in soil after spreading (Relandeau, 2000 quoted in EIPPC, 2001).

The TAN based approach offers a useful representation of the N pathways throughout the production cycle and waste handling stage. The first step for the calculation of TAN is an accurate estimate for excretion of manures, which is described as follows.

4.3.7 Excretion of manures and estimated Total Ammoniacal Nitrogen (TAN)

The reported production of slurry and FYM for the case study pig units is presented in Table 4.16.

The total quantities of nutrients in excreta estimated for the case study pig installations, including N, are shown in Table 4.17. These calculations are based on manure production reported by the operators of the case study units (Table 4.16) and average nutrient content in manures as presented in Appendix 4.4.

Table 4. 16 – Slurry and FYM production in the case study units

Category or production Phase	Quantity of pig manure produced annually					
	Case 1		Case 2		Case 3	
	slurry (m^3)	FYM (tonnes)	Slurry (m^3)	FYM (tonnes)	slurry (m^3)	FYM (tonnes)
Dry sows and gilts	-	2,000			421	312
Service	-				-	52
Farrowing	1,360	-			1,398	-
Weaning	1,360	-			687	-
Growers*	-	3,000			2,232	-
Finishing*	10,880	-	4,546	5,000	9,291	-
Total	13,600	5,000	4,546	5,000	14,029	364

Source: case studies.

These estimates of total excreta production were checked against estimated values derived from feed inputs (Table 4.18) assuming standard N consumption and losses by pigs shown in Appendices 4.5 and 4.6.

Comparing Tables 4.17 and 4.18, there is a good agreement between the two methods to estimate the nutrient content in manures for case study installations1 and 3, as figures calculated differed by less than 1% and 5%, respectively. This suggests that data supplied by operators appears reliable. However, case study 2 installation showed a substantial difference between TAN based on manure production and TAN based on standard pig N consumption and losses (the former one c.70% higher). Such difference possibly reflects a likely overestimation of manure and slurry production for this unit. Therefore, for case study unit 2 the N content in manures based on average standard N losses per pig has been adopted.

Table 4. 17 - TAN in excreta based on reported annual slurry and FYM production

Type	Case Study	Category	Tonnes (annually)	Content (kg) Dm dry matter	Organic Matter	N total	Nm metabolic N	Norg organic N	P_2O_5	K_20	TAN in excreta
Slurry	Case 1	Sows	1,360	122,400	81,600	9,792	5,712	4,080	5,712	9,792	
		Other pigs	12,240	673,200	428,400	51,408	30,600	20,808	36,720	52,632	
		Total herd	13,600	795,600	510,000	61,200	36,312	24,888	42,432	62,424	42,840
	Case 2	Other pigs	4,546	136,380	22,730	20,457	27,731	1,818	6,592	15,911	
		Total	4,546	136,380	22,730	20,457	27,731	1,818	6,592	15,911	14,320
	Case 3	Other pigs	12,210	1,098,873	732,582	87,910	51,281	36,629	51,281	87,910	
		Sows	1,820	100,084	63,690	7,643	4,549	3,093	5,459	7,825	
		Total herd	14,029	1,198,957	796,272	95,553	55,830	39,723	56,740	95,735	66,887
FYM	Case 1	Total herd	5,000	1,150,000	800,000	37,500	7,500	30,000	45,000	17,500	26,250
	Case 2	Total herd	5,000	1,150,000	800,000	35,000	7,500	30,000	45,000	17,500	24,500
	Case 3	Total herd	364	83,720	58,240	2,548	546	2,184	3,276	1,274	1,784
Total	Case 1	Total herd		1,945,600	1,310,000	98,700	43,812	54,888	87,432	79,924	**69,090**
(Slurry	Case 2	Total herd		1,286,380	822,730	55,457	35,231	31,818	51,592	33,411	**38,820**
+ FYM)	Case 3	Total herd		1,282,677	854,512	98,101	56,376	41,907	60,016	97,009	**68,670**

Note: slurry and FYM production reported by operators of case units, average nutrient content in manures based on LNV and Chambers *et al*. (2001) (see Appendix 4.4).

Table 4. 18 - TAN in excreta based on pig consumption

Case Study	Av. pig (kg lw)	lw correction Factor *	kg N . pig^{-1} (adjusted) consumption	Retention	Losses	Pigs sold per year	Total N (kg N . $year^{-1}$) ** consumption	retention	losses	TAN in excreta
Case 1	97	1.03	7.79	2.72	5.06	19,360	150,735	52,748	97,987	**68,591**
Case 2	39-94	1.27	4.20	1.55	2.66	12,307	51,731	19,049	32,683	**22,878**
Case 3	98	1.02	7.87	2.75	5.12	18,306	144,057	50,411	93,646	**65,552**

Sources: nitrogen (N) excreted per pig based on Dourmad et al., 1999 (Appendix 4.6); pigs sold per year reported from case studies.
Notes: *the standard pig quoted by the authors is finished to 100 kg liveweight (lw), therefore a correction factor (lw ratio) was applied to compensate the lower lw of pigs produced in the case study units. Case 2 rears only finishing pigs (which enter at 39 kg lw).
** total N per year for consumption, retention and losses is the produce of adjusted N per pig and number of pigs sold per year.
It is assumed that N losses per pig are equal to N in excreta; the figures comprise N feed to sows.

Having estimated TAN in excreta, the next step is to estimate NH_3 losses from the current housing systems in the case studies(Table 4.19).

Table 4. 19 - Current NH_3 emissions from housing systems in the case study pig units

Unit	Phase	Current housing system	Category	No. Heads	NH_3 Emissions (kg NH_3 /year)* /pig place	Total
Case 1	Service and Pregnancy	CSF full litter	Dry sows and gilts	734	3.70	2,717
			Boars	29	3.70	107
			Maiden gilts	143	1.85	265
		subtotal				3,089
	Farrowing	Farrowing sows in crates with storage pit underneath	Lactating sows	152	8.30	1,259
	Weaning	Flat deck (FSF pens with slurry pit underneath)	Weaners	1,822	0.60	1,093
	Growing	CSF full litter (straw)	Growers	3,346	1.80	6,023
	Finishing	PSFpit	Finishers	2,420	2.40	5,808
	Total					**17,272**
Case 2	Finishing	CSF full litter (straw)	Finishers	4,075	3.00	12,225
	Total					**12,225**
Case 3	Mating and Pregnancy	CSF full litter	Dry sows and gilts	434	3.7	1,605
		PSFpit (Ita)	Maiden gilts	211	2.95	623
		subtotal Mating&Pregnancy				2,228
	Farrowing	FSF farrowing crates with storage pit underneath	Lactating sows	103	8.3	857
	Weaning	Flat decks	Weaners	2,656	0.6	1,593
		PSF pens		472	0.4	184
		subtotal				1,777
	Growing	FSF pens	Growers	1,316	1.80	2,369
	Finishing	FSF pens with storage pit underneath	Finishers	2,632	3.0	7,897
	Total					**15,129**

Notes: * based on EIPPCB (2001). It was considered here that gilts intended for breeding would have an emission factor of 50% of those for dry sows. Emission for farrowing sows includes suckling piglets. A correction factor for emission 0.60 was used to convert emission from finishers to growers (based on lw ratio, 30-55 kg growers and 55-95 kg for finishers).
FSF = fully slatted floor, PSF = partially slatted floor and CSF = concrete solid floor.

Table 4.20 shows the emissions estimated from the current storage of slurry and manure.

Table 4. 20 – Current NH_3 emissions from storage facilities for slurry and FYM

Unit	System	Facility	Surface area (m^2)	Emission factor[a] g NH_3-N/m^2/day	Emission per year ($kg\ NH_3$-N) per m^2	total
Case 1	Slurry	lagoon 1	1,640	2.4* - 3.0**	0.88 - 1.1	
		lagoon 2	1,200			
		lagoon 3	2,800			
		subtotal	5,640			6,176
	FYM	heap slab	1,500	4.8***	1.75	2,847
	Total					**9,023**
Case 2	Slurry	lagoon	600	2.4 - 3.0	0.88 - 1.1	657
	FYM	building	1,400	4.8	1.75	1,226
	Total					**1,883**
Case 3	Slurry	lagoon 1	3,000	2.4 - 3.0	0.88 - 1.1	
		lagoon 2	4,000			
		subtotal	7,000			7,665
	FYM	slab 1[b]	1,500	4.8	1.75	
		slab 2	180			
		subtotal	180			158
	Total					**7,823**

Sources: * Phillips *et al.* (1997); ** Pain *et al.* (1998) quoted by Scotford and Williams (2001) and ***Williams (unpublished) quoted in Misselbrook et al. (2000);
Note: a) 2.4 to 3.0 g NH_3-N per m^2 is the range of emissions for slurry lagoons surface, of which 3.0 (equivalent to 1.1 kg NH_3-N per m2 per year) was used to calculate annual ammonia emission (factor used in the *UK Inventory of Emissions from Agriculture*).
b) muck slab 1 is not in use currently, therefore no emissions are accounted for it.

Estimated TAN values throughout the pig production cycle and waste management are presented in Table 4.21. Emissions from landspreading of manures are also presented in Table 4.21 because they are based on TAN in manures after losses of N from housing and storage.

It is important to note that other N losses can occur besides those already mentioned, such as in the form of nitrogen peroxide (N_2O). However, these losses have not been estimated as detailed information is not available for emissions according to different housing systems and waste management. These losses occur mainly during storage and after landspreading of manures and are regarded as much lower than N emissions as ammonia. Such losses are considered negligible. Calculating TAN throughout the pig production and manure handling phases is considered to be a robust account of N content in manures (B.J. Chambers, personal communication).

Table 4. 21– Current TAN and ammonia emissions estimated for the case study units

Total Ammoniacal Nitrogen (TAN) and NH_3 emission	Case 1	Case 2	Case 3
TAN in excreta	Kg N/year	Kg N/year	Kg N/year
TAN in excreta based on pig consumption (a)	68,591	**22,878** (1)	65,552
TAN in excreta based on manure production (b)	**69,090** (1)	38,820	**68,670** (1)
ratio between methods (a/b)	99%	59%	95%
of which, based in (1):			
TAN excreta from slurry	42,840	8,439	66,887
TAN excreta from FYM	26,250	14,439	1,784
NH_3 losses from housing	Kg NH_3/year	Kg NH_3/year	Kg NH_3/year
Mating & pregnancy	3,089		2,228
Farrowing	1,259		857
Weaning	1,093		1,777
Growing	6,023		2 ,369
Finishing	5,808	12,225	7,897
Total NH_3 losses in housing (2)	17,272	12,225	15,129
TAN in manures (3) = (1 - 2) - Kg N/year	**51,818**	**10,653**	**53,542**
NH_3 losses from storage			
Slurry lagoons	6,176	657	7,665
FYM heaps	2,847	1,226	158
Total losses of NH_3 from FYM and slurry storage (4)	9,023	1,883	7,823
TAN in manures before spreading (5) = (3 - 4) - kg N/year	**42,785**	**8,769**	**45,719**
NH_3 losses after spreading	Kg NH_3/year	Kg NH_3/year	Kg NH_3/year
TAN in manures before spreading from slurry	26,556	3,273	44,486
TAN in manures before spreading from FYM	16,260	5,497	1,233
Current NH_3 landspreading losses*			
- from slurry (6)	3,893	491	3,203
- from FYM (7)	5,632	4,178	412
Total losses of NH_3 on landspreading (8) = (6 + 7)**	9,525	4,668	3,615
TAN in soil after spreading (9) = (5 - 8) *kg N/year*	**33,271**	**4,101**	**42,104**
Total losses NH_3 during production and disposal (2 – 9)	**35,819**	**18,797**	**26,567**

Notes: *Landspreading emission factors based on Misselbrook et al. (2000):15% of TAN applied in slurry (less than 4% dry matter); 76% of TAN applied in FYM. Abatement factors based on Hendriks and Weerdhof, 1999 and MAFF (1999) in BREF (2001):80% reduction with incorporation <4 hrs slurry/FYM; 40% reduction with incorporation <24 hrs for slurry and 70% (range 50 to 90%) reduction with incorporation <24 hrs for FYM.

**Considers that, where undertaken, FYM incorporation is effective for 80% of total FYM landspread, as factors such as weather and soil conditions affect operational performance. For slurry, there is the same 80% rate effectiveness. However, the timing is even tighter to achieve a good abatement with incorporation and also slurry can be applied to growing crops and in areas not suitable for incorporation. Therefore, an effective rate of 70% of the total volume of slurry spread is assumed to be subject to ammonia emission abatement.

Source: tables 4.17 and 4.18 (TAN) and 4.19 and 4.20 (emissions of ammonia).

Estimated losses of ammonia from housing range for the case study units between 22% and 53% of TAN in excreta. Another 8% to 14% of TAN in excreta is estimated to be released from storage of manures, and 5% to 13% from landspreading. Therefore, the for current systems in place, the case units are estimated to be losing a minimum of 38% and a maximum of 81% of the TAN as ammonia emission during the production cycle and waste management stage.

4.4 Current Financial Performance

This section analyses the financial performance associated with the current systems and techniques in place on the case study pig units. Production costs and returns are estimated on an annual basis, according to the output and use of inputs and resources presented in the previous section. The potential value of nutrients in manures applied to land is also estimated. However, it is recognised that valuing the nutrients content in manures based on equivalent value of bought fertiliser is a disputable issue, because of the inherent physical properties of organic manures.

4.4.1 Production costs and Returns

The estimated costs and revenues for the case studies presented in this section provide the baseline on which IPPC compliance costs are to be added.

Table 4.22 presents a summary of the costs and returns of the case study installations on an annual basis. The overall results are compatible with the MLC data for year ended September 2000 (MLC, 2001a), which estimated a gross margin per pig sold of between £19.67 and 25.96 for breeding-and-feeding units (top third producers), similar to case units 1 and 3. For feeding-only herds, MLC's sale value less feed and weaner purchase gives £12.66 per pig, against £10.10 for case study 2.

The figures indicate that variable costs are the major component of production cost, accounting for at least two-thirds (67%) of total annual production costs. Feed is, by far, the greatest individual cost item, representing around 60% total pig production cost and more than 85% of the variable costs

Water and energy costs are a relatively modest part of the total production cost, having a maximum of 0.6% and 2.8%, respectively, less than expenditure on either veterinary products or bedding materials (except for case 3, which used limited straw).

For the three case studies, most of the fixed costs relate to capital costs in animal housing and labour and management costs. Capital costs in housing ranged between 13.5% and 17.9% of the total production cost in the case units. Labour and management count for about 10% of the total production costs in the complete cycle units and for 5% in the feeding-only unit.

The estimated average unit costs of production for the case study installations vary between 93 and 97 pence per kg of pigmeat (carcass deadweight), against a reported sale price at the time of 96 pence per kg. This price covers the total production costs for the breeding-and-feeding units (case studies 1 and 3). However, it is not able to recoup the totality of the production costs for the feeding-only unit (case study 2).

For comparison purposes, the total animal throughput of each case study has been converted into a standard 95 kg liveweight pigs in order to determine a reference production cost per pig produced. These costs have been calculated as £66.32, £68.78 and £64.80 per pig sold, respectively for case study units 1, 2 and 3, for an average price received of £67.53 per pig.

Therefore, at prices prevailing at the time of the survey, breeding-and-feeding pig units appear to recover the totality of their production costs and obtain net margins in a range of 2% to 3%. The feeding-only case study unit 2 has been operating with losses around 1% of its total production cost. An increase from 1.2 pence per kg to the current pig price would allow case study unit 2 to breakeven.

Table 4. 22 - Current annual financial results of the case study pig units

Item	Description	Case 1 (£/year)	%*	Case 2 (£/year)	%*	Case 3 (£/year)	%*
Variable costs	Feed (total herd)	735,439	58.1%	289,052	69.1%	742,999	63.2%
	electricity	13,729	1.1%	7,227	1.7%	30,509	2.6%
	fuel (diesel and heating oil)	11,259	0.9%	1,573	0.4%	2,124	0.2%
	subtotal Energy	24,988	2.0%	8,801	2.1%	32,633	2.8%
	veterinary medicines	64,275	5.1%	8,656	2.1%	65,169	5.5%
	straw and wood shavings (bedding)	31,250	2.5%	8,750	2.1%	2,340	0.2%
	water	450	0.04%	146	0.03%	8,345	0.7%
	subtotal Other Variable costs	95,975	7.6%	17,552	4.2%	75,854	6.5%
	subtotal **Variable Costs** (V)	**856,402**	**67.6%**	**315,404**	**75.4%**	**851,485**	**72.5%**
Fixed costs	a) Buildings (animal housing and other)	226,492	17.9%	57,632	13.8%	157,939	13.4%
	b) Machinery and equipment	12,908	1.0%	6,663	1.6%	12,729	1.1%
	b1) contracting and hiring spreading***	8,228	0.6%	3,168	0.8%	6,949	0.6%
	c) Slurry and FYM stores	33,627	2.7%	13,035	3.1%	17,313	1.5%
	subtotal Capital costs	281,255	22.2%	80,498	19.2%	194,931	16.6%
	Labour	108,955	8.6%	21,891	5.2%	106,960	9.1%
	Management	19,843	1.6%	498	0.1%	21,475	1.8%
	subtotal Labour & management	128,798	10.2%	22,389	5.4%	128,435	10.9%
	subtotal **Fixed Costs** (F)	**410,054**	**32.4%**	**102,887**	**24.6%**	**323,366**	**27.5%**
Total Cost	**Variable and Fixed** costs (V + F)	**1,266,456**	100.0%	**418,291**	100.0%	**1,174,851**	100.0%
Results	Gross Revenue with pig sales (R)	1,341,319		796,489		1,243,663	
	other revenue – FYM sold (R')	1,500		4,250		0	
	Growers – trade-in reared pigs (T)	-	-	388,650	-	-	-
	Gross Margin [(R + R') - V] - T = (G)	473,314		90,747		379,995	
	Gross margin per pig sold	24.45		7.65		20.76	
	Replacement of breeding herd (B)	43,974		-	-	39,498	
	Net margin [G - (F + B)]	32,389		**-6,203**		29,313	

Note: * percent of total cost; ** includes depreciation, spares and repairs.
*** contracting services for spreading of slurry and/or hiring equipment for FYM (muckspreader).
Do not include costs for: office/telephone etc. (overhead); insurance; professional fees; rent; Council Tax and maintenance of buildings.

The purpose of the estimation of the production costs in this research is to provide a baseline for comparison of the incremental costs associated with the IPPC regime. It is important that these estimated costs appear consistent with sectoral cost estimates, such as those periodically published by MLC, and that the methods used to estimate them follow accepted conventions. However, production costs figures may vary substantially depending on the purpose and use of data (Warren, 1992). The main uses of production costs are for: accountability and management of pig unit, calculation of insurance or financial viability (loan) by bank, political pressure by trade representatives to buyers (and vice-and-versa), and the design of government policies.

Depending on the purpose and underlying purpose for cost estimation, different assumptions are taken to account for cost items. An illustrative example is the period assumed for amortisation of capital investment. Farm management reference books generally suggest the use of 15 years for agricultural buildings, after that period the premises would achieve technical obsolescence. The MLC uses a 10 year payback period for piggeries, whereas operators said they think in terms of a 25 year period, that assumed for depreciation against tax liability. In this study building are amortised within a 20 year period has been adopted. Of course many agribusiness may apply much shorter pay back periods when they appraise possible capital investment projects. The effect of a bigger or smaller time allowance for recovery of capital investment is evaluated in the next section, which also verifies the sensitivity of production costs to variations in other important elements used to estimated costs, namely, feed cost, interest rate and pig prices.

4.4.2 Sensitivity of production costs to variations in capital investment and feed costs

This section aims to assess to what degree different assumptions on payback period and interest rate on capital costs would affect the total production cost estimated. Also, it assesses the change in the production costs if feed costs vary and the change in financial results if prices of pigmeat vary, based on level of prices and costs of a 9 year period (1992 to 2000). These evaluations enable a better understanding of and expand the scope of analysis of the results from the case studies.

Table 4.23 presents the results for changes in the cost components in the total production cost. Feed costs variation, as referred before, refers to the variation observed in average feed cost per pig in the period 1992-2000 (MLC, 2001a), from a minimum of 21% below to a maximum of 13% above the average feed cost for the referred period (£41.08 per pig produced). Changes in feed costs significantly affect total production cost: for the case studies, a 5% change in feed cost has an estimated increase or decrease of 2% to 3% in total production cost, equivalent to 2 to 3 pence per kg (p/kg). At the time of the survey (year 2000) feed costs were at the lowest point in the 9 year historical series, reflecting downward trends in CAP support prices for cereals. Assuming feed costs were equivalent to the 9 year mean (+21%) would mean an increase in the production costs between 7 and 11 p/kg of pig produced. If costs rose to the maximum for the same period, the increase in production cost would be between 12 and 17 p/kg.

Lowering the average annual interest rate from 6% to 4% would decrease the production cost between 1.5 and 3 p/kg, whereas increasing the interest rate to 8% would increase costs by 1 to 3 p/kg.

The production cost is more sensitive to reduction in the payback or amortisation period than for and increase on it. That is, when the referred period is reduced in 5 years to 15 years, the effect is an increase between 1.2 and 3 p/kg in the production costs, whilst an increase in 5 years to 25 years reflects in a decrease between 0.6 and 1.5 p/kg in costs.

These calculated figures confirm sensitivity of units to relatively small changes in costs. Especially if considered that such cost movements can be multiple. Therefore, it shows considerable vulnerability of units and indicating that IPPC compliance cost could, even if of small magnitude, substantially affect the financial viability of units, especially if revenues and cost items change unfavourably.

Changes in the pigmeat price result in directly proportional changes in the results for margins in the complete cycle units (1 and 3). However, for a feeding-only unit, it is

Table 4. 23 - Results of sensitivity analysis: variation in production cost due to variation in the variable item, new total production cost and net margin (p/kg)

Variable	Range of variation	Variation in production cost (p/kg dw)			Total production cost (p/kg dw)			Net margin (p/kg dw)		
		Case 1	Case 2	Case 3	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Current situation	-	-	-	-	93.7	97.2	93.3	2.3	(0.7)	2.4
FEED	-21%*	11.0	7	8.6	104.8	104.5	101.9	(8.7)	(8.1)	(6.2)
	+13%	6.8	5	6.3	111.6	109.0	108.2	(15.6)	(12.6)	(12.5)
INTEREST RATE**	4%	(2.8)	(1.4)	(2.0)	90.9	95.7	91.3	5.1	0.7	4.4
	8%	3.2	1.0	2.3	96.9	98.2	95.7	(0.9)	(1.7)	0.0
AMORTI-SATION PERIOD (years)	10	10.5	3.9	7.6	104.2	101.0	100.9	(8.2)	(4.6)	(5.2)
	15	3.2	1.2	2.3	96.9	98.4	95.7	(0.9)	(1.9)	0.0
	20	current			Current			current		
	25	(1.5)	(0.6)	(1.1)	92.2	96.6	92.2	3.8	(0.2)	3.5
	30	(3.0)	(1.1)	(2.2)	90.7	96.1	91.2	5.3	0.4	4.5

Note: range of variation for feed cost: -21% to +13% and -15% to +11% respectively for home mix and purchase feed range of variation for a nine year period 1992-2000, based on MLC (2001a);
*As minimum cost of feed relates to year 2000, values represent: if costs were as average, that is +21% (to £41.03 per pig).
Revenues (pigs + FYM) = 96.0, 96.4 and 95.7 respectively for case 1, 2 and 3.
**interest rate on capital investment, decrease from 6% (current) to 4% or increase from 6% to 8% average rate per annum.
Values that are between brackets ( ) are negative.
Sources: case studies (current values); feed costs variation (MLC, 2001a); amortisation tables (Nix, 1996; SAC, 2001).

less than proportional as the increase in price also increases the costs to buy reared pigs (trade-in animals). For the period 1992-2000 pigmeat peaked in 1996 at 136.5 p/kg and a fell in 1999 to 78.7 p/kg deadweight (based on AAPP UK adjusted, in MLC, 2001b and DEFRA, 2002b).

4.4.3 Valuing manures

The landspreading of pig manures can provide organic matter and nutrients to the soil, which otherwise would be made available by means of bought fertilisers. Estimated values of the potential benefits from the use of manures generated in the case study units are presented in Table 4.24.

According to the figures in Table 4.24, there is considerable potential financial benefit derives from the nutrients content in the manures spread onto land. The estimated financial value of nutrients in manures is well above the costs paid to contracting services and hiring equipment for their disposal.

However, as there is no evidence to date (the sectoral survey corroborates this point) of a well developed market for pig manures, the availability of land in the pig holding is a necessary condition to draw benefit from this resource. That is, pig operators only are able to benefit from the nutrient value of slurry and FYM produced if either they can spread it onto their own crop land or they can sell it. Thus, only pig units integrated with a farm holding with activities such as cropping and grazing can benefit from use of animal wastes through savings in bought fertiliser. Otherwise, disposal of manures is an additional item of the pig production cost.

Table 4. 24 – Potential benefit of application of manures to land (nutrient value as fertiliser to crops)

Type	Pig Unit	Production* tonnes or m^3	Total nutrient in manures (kg)			Nutrient supply/ha***			Fertiliser replacement (potential) considering next crop							
									For winter wheat (kg)			value(£)	for sugar beet (kg)			value (£)
			N	P_2O_5	K_2O	N available**	P_2O_5	K_2O	N	P_2O_5 (M)	K_2O(M)	total NPK	N	P_2O_5 (M)	K_2O (M)	total NPK
slurry	Case 1	13,600	54,400	27,200	34,000	138	125	156	29,920	6,528	8,813	13,142	29,920	7,507	27,026	16,886
	Case 2	4,546	18,184	9,092	11,365	138	125	156	10,001	2,182	2,946	4,393	10,001	2,509	9,034	5,645
	Case 3	14,029	56,118	28,059	35,074	138	125	156	30,865	6,734	9,091	13,557	30,865	7,744	27,879	17,420
FYM	Case 1	5,000	35,000	35,000	25,000	38	250	179	5,250	10,080	6,480	5,834	5,250	11,592	19,872	8,817
	Case 2	5,000	35,000	35,000	25,000	38	250	179	5,250	10,080	6,480	5,834	5,250	11,592	19,872	8,817
	Case 3	364	2,548	2,548	1,820	38	250	179	382	734	472	425	382	844	1,447	642
Total	Case 1		89,400	62,200	59,000	98	174	165	35,170	16,608	15,293	18,976	35,170	19,099	46,898	25,704
	Case 2		53,184	44,092	36,365	72	207	171	15,251	12,262	9,426	10,227	15,251	14,101	28,906	14,462
	Case 3		58,666	30,607	36,894	133	130	157	31,247	7,468	9,563	13,982	31,247	8,588	29,326	18,061

Notes: * total production per year

Nutrient content kg per tonne (N, P_2O_5, K_2O, respectively) - slurry: 4.0, 2.0 and 2.5; FYM: 7.0, 7.0 and 5.0.

** N availability in Autumn and Spring, respectively, for application with incorporation, 20 and 55% for slurry and 10 and 15% for FYM for medium/heavy soil (dry matter 4% for slurry and 25% for old FYM). Availability of P_2O_5 50 and 60% (slurry and FYM respectively) and K_2O 90%

***application rate of 250 kg N per ha (63 m^3 slurry or 36 tonnes FYM)

Recommended fertiliser use (kg/ha, N, P_2O_5, K_2O): winter wheat--220-60(M)-45(M); sugar beet -100-50(M)-100(M) for P and K indices of 2 and 2- .

Does not account for P and K surplus (allowance over crop rotation).

Value for nutrient content, 32 pence per kg N, 29 p/kg P_2O_5 and 19 p/kg K_2O (MAFF, 2000b).

Source: case studies (manure production); Chambers et al. (2001) - N-P-K contents, availability to next crop, MAFF recommended fertiliser dose.

However, allowance for nutrients in manures is generally underestimated by farmers. This is because the availability of nutrients in organic manures, especially N, is subject to a great number of factors, such as meteorological conditions, season of application and lapse of time between application and incorporation into soil. Comparatively, bought fertilisers are much more predictable, easy to apply and manage.

The managers of case study units 1 and 2 attribute some value for FYM, which is generally exchanged for straw with other farmers. However, they do not regard any financial benefit for slurry. They argue that manure is not a reliable source of N and that deviation in the target N application can be as big as 20 per cent. This may decrease crop yields when using manures instead of bought fertiliser. For these reasons, management perceives pig manures as wastes to be got rid of rather than as a potentially valuable organic resource.

Conversely, the manager of case unit 3 was more enthusiastic about the benefits derived from the spreading of animal manures onto land. He mentioned that continuous work with manures and soil provided better experience, helping to overcome the difficulties of calibrating application of manures and total N need by crops. He considered that slurry applied to land on his unit had a value of about £50 per ha. Case unit 3 spreads slurry on 176 ha of its own land, a benefit of £8,800 per year, sufficient to more than recover the costs of landspreading on this unit.

Some characteristics of pig manures, particularly slurry, render them difficult or simply undesirable to handle and apply, including the release of obnoxious smells.

4.5 – Impacts of IPPC on case study units

This section examines the incremental costs and affordability of IPPC measures applied to the case study units. Associated emission levels for ammonia and change in resource consumption are also estimated. Performance indicators are compared between 'without-IPPC' and 'with-IPPC' situations.

The performance standards or minimum requirements for a pig installation under the IPPC regime in England and Wales, as referred to in Chapter 2, are delimited by the Standard Farming Installation Rules and Guidance (SFIR). The changes simulating the adoption of IPPC applied to the case study pig units are based on the SFIR (Environment Agency, 2001a), draft versions of the BREF Note for intensive rearing of [poultry and] pigs (EIPPCB, 2000 and 2001) and their contribution documents (such as CRPA, 1999).

As this study applied BAT 'candidate' options based on information available in the draft versions of BREF Note, the scope of this impact assessment of IPPC is beyond that measures required under SFIR. For this reason, the simulated changes are likely surpass the requirements which operators have in practice to comply with IPPC at present. Notwithstanding this, SFIR have an intrinsic link with BAT, being therefore subject to revision over time. Therefore, the adopted approach is justified as the BAT concept in BREF anticipates that technological change in the pig sector is likely to be driven by the Directive.

The results drawn from the application of IPPC to the case studies units are reported in this section, which covers: a) compliance costs, reduction of ammonia emissions, energy and water use of applied measures; b) assessment of economic and environmental impacts based on indicators; c) risk assessment; and d) financial affordability.

4.5.1 Costs and ammonia abatement with IPPC compliance

This section identifies the additional costs associated with IPPC and the likely impacts of IPPC on the financial performance of the selected case study units. These costs were differentiated into costs of permit application and costs of compliance with the permit, namely those relating to adopting BAT measures, and to monitoring, control and record keeping of the conditions of the permit.

Costs associated with the application for a permit

Operators of prescribed activities must apply for a permit under IPPC. The application fee and subsistence charges applied to the case study installations are those for a standard conditions permit (i.e., using the SFIR). An installation qualifies for a standard IPPC permit if it is able to meet the requirements in the SFIR or to do so within a timescale agreed with the regulator (Environment Agency, 2001b). As described in Chapter 2, charges are reduced for a standard conditions permit, based on the fact that the regulatory duty is simplified. Moreover, the time required by the operator to complete the application (and comply with the permit conditions) is also expected to be less compared to a non-standard conditions permit.

Table 4.25 summarises the required information, statements and other documentation to be submitted by the operator when applying for an IPPC permit for a pig installation based on the current regulatory scheme (Environment Agency, 2001b and 2001c). Detailed information on the installation processes is required, including on topics not typically addressed by traditional agricultural management, such as emissions of pollutants and relevant environmental characteristics of raw materials used. Moreover, the application involves considerable activity planning, some far into the future, such as decommissioning of the installation. It is argued here that these factors render the application for an IPPC permit in this newly regulated sector a relatively complex task for the operator. These requirements for applying for a permit reflect the integrated nature of the IPPC regulation, and considerable effort is doubtless needed to complete the application form. Therefore, it is assumed that the services of a consultant will be necessary to complete the application process for the case study installations. At the time of writing, no IPPC applications have yet been made to the Environment Agency for pig installations.

The operators of the case study units were asked to identify those aspects of the IPPC requirements (based on the list in Table 4.25) which were already in place under current management. Their response confirmed the novelty of several issues and, consequently, it can be inferred that additional human resources will be needed for the adequate fulfilment of the conditions determined by the IPPC permit.

Table 4. 25 - Summary of the requirements in an IPPC permit application for a pig installation

Requirement in the application form	Description of requirement
1 Description of installation and site	Comprises a report on the site condition, maps and plans indicating the location and nature of activities related to the installation
2 Proposed techniques by the operator to run the permit	Comprises plans (and schedules) for: inspection and maintenance of structures and plant; training of staff in relation to IPPC; selection and use of raw materials and foodstuffs; water, energy and waste minimisation audits; manure management (including storage and spreading measures); accident prevention and management (emergency plan); monitoring of emissions; and decommissioning. Plans for control of odour and noise may be also required depending on site-specific conditions.
3 Environmental assessment	Impacts of the emissions from the installation including whether they are likely to affect sensitive sites (SSSIs, European sites etc.)

Source: Environment Agency (2001b and 2001c).
Note: copies of all applications shall be provided in order to be distributed to the statutory consultees, including Environment Agency, Health Authority, Food Standards Agency and Local Authority.

For feeding-and-breeding units (cases 1 and 3) the estimated time to complete relevant parts of the application form (see Appendix 4.7) is assumed to be 12 ½ days or 100 hours. In addition to the time by consultant, it is assumed that at least an equal time of the manager or relevant staff must be allocated. A reduced time, that is, 80 hours, is assumed for feeding-only unit, where description of processes (involving finishing herd only) and site conditions (limited land) are relatively straightforward.

One could argue that these time requirements are underestimated and that in practice it probably would require more manpower resources. However, DEFRA is commissioning ADAS to support applicants in the initial period of implementation of IPPC. Also, the regulatory authority (the Agency) is willing to be consulted by operators on the status of specific matters before they formally apply for an IPPC permit. A 15-hour allowance is given by the Agency for pre-application consultation on a prospective IPPC permit. A 1995 study on IPC applications by the then DETR (now DEFRA) reported that a complex industrial installation on average spend 22 person-weeks to put together an application for a permit (DETR, 2000b). This order of input was also suggested as the manpower needed from start to submission of an application under IPPC (Housley, 2001). However, the latter report, based on a review of IPPC permits in the public registry and postal questionnaire to operators, suggests that manpower needs may be greater for applications not previously regulated under IPC. For new applicants it says a 26 person-week period is more appropriate. Notwithstanding that IPPC regulation is wider than IPC, the level of complexity of a pig installation is, of course, substantially lower than that of other manufacturing industries (as those regulated by IPC). Moreover, there is scope for use of standard permit conditions as SFIR are applied. The minimum time reported for an IPPC application in the review of permits in the public registry was 6 person-weeks (Housley, 2001) but there is no reference to any permit for pig or poultry installation. Therefore, the total of 4 person-weeks (2 weeks for consultant plus 2 weeks for staff) appears to be a reasonable estimate[8].

It is important to bear in mind that the manpower requirements for an application for a permit for an existing installation do not end with the award of permit. Several plans and schedules for improvement or replacement of measures and practices not regarded as BAT may need to be produced within the following 12 to 24 months, in accordance with a transitional timetable (for instance, for covering external slurry stores).

Besides fees and charges by the regulator and for preparation of the application, the permitting process also involves costs related to the mandatory public advertisement of the planned application for an IPPC permit in a local newspaper and the London Gazette.

Costs for complying with BAT

Proposed BAT for pig rearing relate to the main phases or stages of pig production (Table 4.26), namely: mating and pregnancy, farrowing, weaning, and growing/finishing, generally referred to as BAT for animal housing. There are BAT for

[8] It is recognised here that consultancy input tends to fall once expertise is developed on the application process.

storage and BAT for disposal of manures. There are also BAT proposals for good housekeeping practices, which can be defined as 'stewardship BAT'. For the case study units some end-of-pipe pollution abatement measures are assessed, which *in themselves* are not sufficient to comply with use of BAT by the operator, but may be acceptable if combined with other in-system changes. BAT are, by definition, in-process rather than end-of-pipe measures. However, the evolving process of definition of BAT in the BREF Notes already concedes that measures such as use of additives in the manures to reduce emissions are acceptable as BAT. The above aspects are revisited later in the discussion of the chapter.

Table 4. 26 – Summary of requirement for compliance with BAT

Stage	What BAT means
Housing	There are specific techniques for housing referring to different pig production phase (see Annex 4.1 for detailed description). In general terms, in-process BAT involve: reduction of slatted area in the pen floor and/or reduction of open surface area of slurry pit (underneath the pen), frequent removal of slurry from buildings, and cooling slurry systems. End-of-pipe techniques refer to the application of bio and chemical scrubbers.
Storage of manures - slurry storage	External slurry stores must be impermeable and covered
Landspreading of manures - general rules	Application rate must not exceed 250 kg of N per hectare per year Disposal to land must follow a FWMP
- slurry	Use of low emission spreading techniques such as bandspreading or soil injection Broadcasting can be use if followed by incorporation into soil by ploughing within 6 hr
- FYM	Incorporation is required within 24 hr

Source: SFIR and BREF Notes.

It is reasonable to assume as suggested by FRCA (1997), that good practices are already in widespread use in the sector amongst the larger scale operators captured by IPPC.

For this reason it is assumed that existing management regimes on the case study installations already conform to 'stewardship BAT'. Indeed, under existing legislation, and under IPPC, operators have a 'duty of care' to properly manage identifiable risks associated with their undertaking. In the event of a pollution incident, an operator is less likely to be prosecuted if evidence is given of the use of good practices. Treating 'stewardship BAT' in this way avoids the complexity of describing and valuing many management activities. The sectoral survey (Chapter 5) explores the subject of adoption or awareness on good practices by pig operators likely to be captured under IPPC regime.

The IPPC regulator for England and Wales (Environment Agency) plans to incorporate a risk based approach to IPPC. This involves an assessment of operator management systems and environmental risk associated to the activity together, referred to as Environmental Protection Operator Performance and Risk Appraisal System (EP OPRA) (Environment Agency, 2002b). The principle underpinning the EP OPRA approach is that well managed installations require less resources and costs for monitoring and control by regulator, which may benefit operators with reduced fees and subsistence charges.

The selection and assessment of proposed BAT and emission abatement techniques applied to the case studies are discussed below.

BAT for animal housing

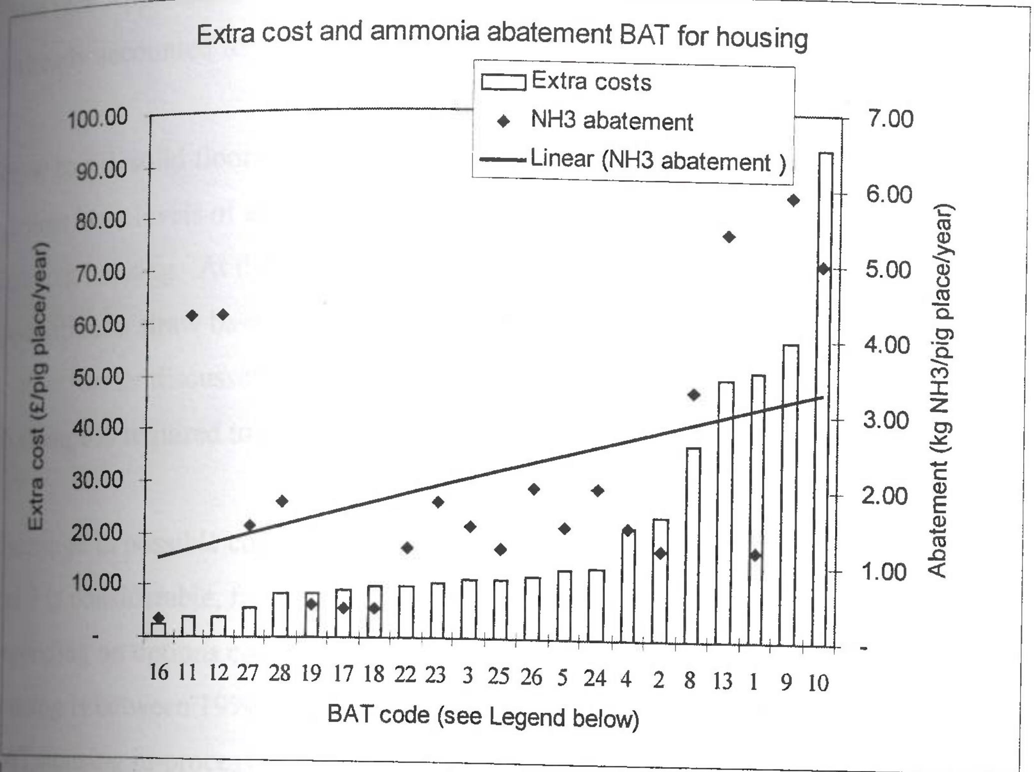
Most of the reference costs and technical information on BAT candidates for housing in the BREF Notes, including their applicability to existing buildings, comes from the Netherlands, Belgium, Italy and Denmark. Some 30 BAT candidates for housing were selected and applied to the case studies, including some end-of-pipe measures, as listed in Appendix 4.8. The latter shows the emission rates of ammonia associated with each BAT option and the total cost per pig place (converted to £ sterling at prevailing exchange rates) necessary to implement them.

As the pig production phases are distinct and have specific building design, they can be seen as modules of a production line. Therefore, BAT techniques for a particular phase may be applied independently of the option chosen for another phase. This is an important assumption, because it means that several 'baskets' of techniques can be possible options for the installation as a whole. However, this means that some techniques within the same production phase are mutually exclusive.

Different production phases as a rule share facilities for storage of manures and transport and distribution systems for disposal of slurry and FYM onto land. Therefore, they are technically connected as manure removed from housing is sent to a common store before spreading. Usually, pig installations deal with both liquid and solid manure.

Figure 4.2 shows extra average annual costs (capital and operating) and abatement levels per pig place per year for the selected in-process BAT techniques applied to the case study units (Annex 4.1 and Appendix 4.8). Each bar in this chart represents the cost of applying BAT measures for housing, whereas the abatement level is described by the plotted mark. It can be said, broadly, that more expensive techniques are those which offer higher reduction in ammonia emissions (as shown by the trendline in Figure 4.2).

It is necessary to bear in mind that Figure 4.2 gathers together BAT referring to all production phases (and herd categories), and costs and abatement vary substantially amongst techniques at different stages. Additional unit costs and unit NH_3 abatement are relatively higher for farrowing (phase which technique codes 8, 9, 10 and 13 refer to). However, when these additional unit costs are multiplied by the number of pigs in the respective production phase, BAT measures for growing and finishing account for a major proportion of total annual costs for housing.



Legend

Code	Phase	Description of BAT for housing and code in the BREF (in brackets)
1	Mating and Pregnancy	PSF with flush gutters or tubes (4618)
2		PSF with flush gutters or tubes (4618_belgi)
3		Refurbish PSFpit to PSF flush tubes [CRPA]
4		Manure surface cooling channel (4619)
5		Refurbish CSF alley pit to CSF alley flush tubes [CRPA]
8	Farrowing	Board under slats (4621)
9		Manure cooling (4625)
10		Flushing + manure gutters (4623)
11		FSF w&manu channel (4622)
12		FSF w&manu channel iron slats (4622b)
13		FSF manure pan (4624)
16	Weaning	Refurbish FSFpit to FSF pens with flush gutters or tubes (4633)
17		Manure channel with gutters PSF triangular iron slats (4637)
18		Manure channel with gutters PSF triang. Iron slats (4637_belg)
19		Manure surface cooling channel (46310)
22	Growing/ Finishing	Refurbish from FSFpit to FSF flush tubes [CRPA]
23		PSF with flush gutters or flush tubes (4641) concrete slats
24		PSF with flush gutters or flush tubes (4641b) iron slats
25		Refurbish from PSFpit to PSF flush tubes [CRPA]
26		PSF-ssw/iron (4642b)
27		Manure surface cooling channel PSF (4615 concrete slats
28		Manure surface cooling channel PSF (4615b) iron slats

Figure 4. 2 - Ammonia abatement and extra costs of BAT measures for housing applied to the case study pig units (values per pig place per year)

Table 4.27 summarises the extra costs, ammonia abatement and extra use of energy of in-process BAT measures for housing applied to the case studies 1 and 3, presenting the results for least cost, maximum abatement and most cost BAT for each production phase (see Appendices 4.9 and 4.10 for detailed results). The cost of additional energy is already accounted for in the annual extra cost.

Straw based, solid floor accommodations for finishers are not regarded as BAT, as these systems have levels of ammonia emission similar to those of the reference system for finishing housing. At the time of this study no in-process measures were available for application to straw based finishing systems, such as that used in case study 2 unit. This point is further discussed in Chapter 5. In the context of case study units, it implies that no change is required to case study 2 for compliance with BAT for housing.

The range in possible compliance costs for BAT for housing estimated for case studies 1 and 3 is considerable, from about £19,000 to over £94,000 per year per installation depending on options considered. The estimated reduction of ammonia emissions from housing is between 19% and 58% of the current levels. Average abatement costs for BAT housing in-process options vary between £4.64 and £10.36 per kg ammonia per year respectively for the minimum cost and maximum abatement technique.

Although by their very definition end-of-pipe options are not BAT, bio- or chemical scrubbers are included in the BREF Note draft as candidate techniques as they are very effective in reducing ammonia emissions from housing (70% and 90% abatement, respectively). However, as they require buildings with controlled air systems, they are not applicable to natural ventilated buildings, including automatically controlled natural ventilation (ACNV). For the case studies, these techniques achieved an estimated reduction between 53%and 67% of the current levels of ammonia emissions from animal housing. Abatement costs varied between £6.32 and 8.30 per kg ammonia per year for chemical wet scrubber and between £9.08 and 12.24 per kg ammonia per year for bioscrubber (Table 4.28).

Table 4. 27 - Summary of extra annual costs, ammonia abatement, energy and water use of BAT measures to animal housing in the case studies

Phase	code*	BAT technique	Annual extra cost (£)			Reduction (kg NH_3/year)			Extra energy (kWh)		
			case 1	case 2	case 3	case 1	case 2	case 3	case 1	case 2	Case 3
In-Process housing measures				none			none				
Mating & Pregnancy											
least cost	3	Refurbish from PSFpit to PSF flush	-	-	2,377	-	-	106	-	-	106
maximum abatement	4	Manure surface cooling channel (4619)	-	-	4,494	-	-	158	-	-	1,795
or	2	PSF with flush gutters or tubes (4618_belgi)	-	-	4,953	-	-	95	-	-	106
most cost	1	PSF with flush gutters or tubes (4618)	-	-	10,725			95			106
Farrowing											
least cost	11	FSF crates and water and manure channel (4622)	585	-	399	652	-	444	-	-	-
maximum abatement	9	Manure surface cooling channel (4623)	8,616	-	5,868	895	-	609	2,730	-	1,859
or	13	FSF and manure pan (new BREF 2001) 4624	7,512	-	5,117	819	-	558	-	-	-
most cost	10	Flushing system with manure gutters (4623)	14,182	-	9,659	758		517	1,289		878
Weaning											
least cost	16	Refurbish FSF pit to FSF pens flush gutters or tubes (4637)	4,486	-	6,538	437	-	637	3,462	-	5,046
maximum abatement	19	Manure surface cooling channel (46310)	15,216	-	22,178	820	-	1,195	11,843	-	17,262
or	17	Manure channel with gutters, PSF triang iron slats (4637)	16,484	-	24,027	711	-	1,036	1,367	-	1,992
most cost	18	Manure channel with gutters, PSF triang iron slats (4637_belg)	17,898	-	26,088	711	-	1,036	1,367	-	1,992
Growing											
least cost	27	Manure surface cooling channel PSF concrete slats (4615)	N/A	-	4,879	N/A	-	1,184	N/A	-	11,055
or	23	PSF with flush gutters or flush tubes, concrete slats (4641)	-	-	8,735	-	-	1,421	-	-	1,184
maximum abatement	26	PSF-ssw/iron (4642b)	N/A	-	10,184	N/A	-	1,579	N/A	-	-
max abate&most cost	24	PSF with flush gutters or flush tubes iron slats (4641b)	-	-	11,604	-	-	1,579	-	-	1,184
Finishing											
least cost	27	Manure surface cooling channel PSF concrete slats (4615)	13,905	N/A	15,124	2,178	N/A	3,948	33,880	N/A	36,851
or	23	PSF with flush gutters or flush tubes, concrete slats (4641)	24,896		27,079	2,904		4,738	3,630		3,948
maximum abatement	26	PSF-ssw/iron (4642b)	29,024	N/A	31,569	3,388	N/A	5,264	-	N/A	-
max abate&most cost	24	PSF flush gutters or flush tubes iron slats (4641b)	33,074	-	35,974	3,388	-	5,264	3,630	-	3,948
Subtotal In-process measures in all phases (Mating to Finishing)											
least cost BAT for housing		extra cost of least cost techniques	18,976	-	29,317						
		ammonia reduction with least cost techniques				3,267	-	6,320			
		cost efficiency of abatement (£/kg ammonia reduced/year)	5.81	-	4.64		-				
		extra energy (kWh/year)							37,342		53,058
maximum abatement for housing		extra cost of *maximum abatement* techniques (sum)	52,856	-	74,293						
		ammonia reduction with *maximum abatement* techniques				5,103	-	8,807			
		cost efficiency of abatement (£/kg ammonia reduced/year)**	10.36	-	8.44		-				
		extra energy (kWh/year)							14,573	-	20,917
most cost		extra cost of *most cost* techniques (sum)	65,154	-	94,051	4,857	-	8,491	6,286	-	8,108

Notes:*codes refer to Appendix 4.8, N/A - not applicable, as there are not in-process housing measures referred in BREF and contributing documents for straw based systems. Case 2 unit, which comprises only finishing phase and straw based system, does not applies any proposed BAT in-process for housing.**BAT housing measures for dry sows only applied to system other than straw based ones (also assumed as BAT). They refer here to 1/3 of total sow places in case 3. Where two option give same level of abatement here, it was considered that of lower cost. FSF - fully slatted floor; PSF -partially slatted floor and SCF - solid concrete floor.

Air scrubbers require substantial energy input. For breeding-and-feeding units (1 and 3) the increase in energy use was between 5% and 16%. Much greater impact in energy use was predicted for the feeding only unit, where use of such techniques would increase energy consumption by between 48% and 75% respectively compared to the baseline situation[9].

Bioscrubbers would also require an increase the total consumption of water by 9%, 49% and 22% respectively for case studies 1, 2 and 3. This relative increase is much higher than the estimated 5% or so saving in water use associated with good practices or 'optimising' use (MAFF, 2000b).

Therefore, a broad assessment of end-of-pipe measures suggests they are not a suitable option as the benefit offered in terms of abatement of ammonia emissions is offset by poor environmental performance against use of energy and water resources, and by high costs. High energy consumption, and very high incremental costs have reportedly ruled out scrubbers as BAT (TWG for intensive livestock farming meeting, February 2002).

[9] The estimated annual costs presented already account for additional use of energy and water.

Table 4. 28 - Extra annual costs, ammonia abatement, energy and water use of end-of-pipe measures applied to housing in the case studies

Phase	code ***End-of-pipe housing Techniques***	Annual extra cost (£)			Reduction (kg NH_3/year)			Extra energy (kWh/year)			Extra water (m^3/year)		
		case 1	Case 2	Case 3	Case 1	case 2	case 3	case 1	case 2	case 3	case 1	case 2	case 3
Mating & pregnancy	7 Chemical wetscrubber	25,525	-	N/A	2,780	-	N/A	47,582	-	N/A	-	-	N/A
	6 Bioscrubber	27,550	-	N/A	2,162	-	N/A	31,721	-	N/A	906	-	N/A
Farrowing	15 Chemical wetscrubber	N/A	-	3,485	N/A	-	775	N/A	-	10,330	N/A	-	-
	14 Bioscrubber	N/A	-	4,310	N/A	-	599	N/A	-	3,616	N/A	-	103
Weaning	21 Chemical wet scrubber	6,598	-	9,617	984	-	1,434	18,220	-	26,557	-	-	-
	20 Bioscrubber	7,352	-	10,716	765	-	1,115	14,576	-	21,246	1,822	-	2,656
Growing	21 Chemical wetscrubber	N/A	-	14,490	N/A	-	2,132	N/A	-	43,431	N/A	-	-
	20 Bioscrubber	N/A	-	16,959	N/A	-	1,737	N/A	-	27,638	N/A	-	1,316
Finishing	29 Chemical wet scrubber	41,299	69,543	44,920	5,082	11,003	7,107	133,100	224,125	144,771	-	-	-
	30 Bioscrubber	48,336	81,392	52,574	3,872	8,965	5,791	84,700	142,625	92,127	2,420	4,075	2,632
Subtotal end-of-pipe all phases (sum)													
Chemical Wetscrubber	Extra annual cost (£/year)	73,421	69,543	72,513									
	Ammonia reduction (kg NH_3/year)				8,846	11,003	11,448						
	Cost efficiency of abatement (£/kg ammonia reduced/year)	8.30	6.32	6.33									
	Extra energy (kWh/year)							198,902	224,125	225,090			
	Extra water use (m^3/year)										-	-	-
Bioscrubber	Extra annual cost (£/year)	83,239	81,392	84,560									
	Ammonia reduction (kg NH_3/year)				6,799	8,965	9,243						
	Cost efficiency of abatement (£/kg ammonia reduced/year)	12.24	9.08	9.15									
	Extra energy (kWh/year)							130,997	142,625	144,626			
	Extra water use (m^3/year)										5,148	4,075	6,707

N/A – not applicable, as the unit does not operate the referred phase or, in the case of scrubbers, natural ventilation system does not allow required control of air flows.
*end-of-pipe measures alone are not sufficient for BAT, they must be in addition to process integrated measures.
*Abatement levels and extra costs of BAT are compared to the emissions and costs of the reference system for respective production phase.
Growing phase applied BAT for finishers using conversion factor for emission and cost by liveweight and space allowance.
Source: compiled from the BREF Notes (EIPPCB, 2001) and CRPA (1999). Codes refer to Appendix 4.8.

BAT for storage and landspreading of slurry and farmyard manure

BAT measures for storage of manures mainly relate to the siting of the stores and cover of slurry lagoons. The feasibility of some proposed measures in BAT to be applied to cover large lagoons for storage of slurry remains unclear. Therefore, the costs of replacement by a new tank-type store are presented along with the costs for covering the existing lagoons. It is assumed here that additional costs of maintenance of such covers are negligible.

Table 4.29 shows extra costs and ammonia abatement for BAT storage measures applied to the case studies

There is a substantial potential reduction of ammonia emissions from slurry stores. Floating covers provide an average abatement of 80% (70 to 90%) of ammonia emissions from slurry stores, whereas rigid covers can abate about 95%. The abatement costs are estimated to be of £1.84 per kg of ammonia abated per year using rigid covers and between £2.45 and £3.53 using floating covers.

BAT for spreading of slurry and farmyard manure to land refer mainly to the application of low emission techniques compared to the conventional broadcasting method, such as slurry injection into soil or deposition close to surface using a bandspreader or trailing shoe. Alternatively, rapid incorporation of manures after conventional broadcasting is accepted as BAT.

Contractors undertake the landspreading of slurry on the case study units. Therefore the use of low emission methods (BAT) such as soil injection has implication for operating costs paid by the operator for disposal but not for capital investment costs. The same is assumed if incorporation is required, that is, contractors will charge for this extra service.

Table 4. 29 - Extra annual costs and ammonia abatement of BAT measures for storage of slurry applied to the case studies

Storage of slurry	BAT technique	Annual extra cost (£)			Reduction (kg NH_3/year)		
		case 1	Case 2	case 3	case 1	case 2	case 3
	1 Covering slurry stores with rigid covers	10,795	1,148	13,398	5,867	624	7,282
	2 Covering slurry stores with floating covers:			-			-
	2.a a) rapeseed oil	14,100	1,500	17,500	4,941	526	6,132
	2.b b) floating plastic sheet	11,393	1,212	14,140	4,941	526	6,132
	3 New store: glass-lined steel slurry tower + cover	18,394	2,203	17,835	5,867	624	7,282
Minimum cost (rigid cover)	Extra cost of *minimum cost* storage technique	10,795	1,148	13,398			
	Ammonia reduction with *minimum cost* techniques				5,867	624	7,282
	Cost efficiency of abatement (£/kg ammonia reduced/year)	1.84	1.84	1.84			
Maximum abatement 1) Covering slurry stores with rigid covers	This is both *max abatement & min cost* technique	(as above)					
3) glass-lined steel slurry Tower + cover	Extra cost of *maximum abatement* storage technique	18,394	2,203	17,835			
	Ammonia reduction with *maximum abatement* techniques				5,867	624	7,282
	Cost efficiency of abatement (£/kg ammonia reduced/year)	3.14	3.53	2.45			

Note: assumes no change in energy input; water balance is zero, as reduction in rainfall entry is compensated by reduction of evaporation.

Although applying BAT for landspreading of manures by contractors does not have a direct impact on farm labour resources in the case studies, the work rate of low emissions spreading techniques (hectares spread/hour) is lower than that of the current method of broadcasting using a splash plate and without immediate incorporation into soil. Therefore, additional hours of work are necessary to apply manures according to the rules, which will increase the overall cost for landspreading.

Table 4.30 shows extra costs and ammonia emission reduction estimated for the use of BAT for landspreading of manures in the case study units.

Rapid incorporation and soil injection reduce up to 80% of the potential emission of ammonia emitted with broadcasting and without incorporation. Not all the areas are suitable for BAT for landspreading and there are operational restrictions related to weather and soil conditions. For this reason, it was assumed that a 70% ammonia abatement rate can be achieved. Odour emissions are reported to be substantially reduced by use of low emission landspreading techniques, especially with the soil injection.

Slurry disposal abatement costs vary between £2.10 and £2.68 per kg of ammonia reduced per year for cases 1 and 3. Case 2 does not offer a reliable estimate of abatement cost as the amount of slurry produced reported by the operator is probably overestimated (as it is mentioned in the TAN calculation).

Regarding FYM, it is considered that the case study units 1 and 3 have enough machinery and labour to satisfactorily comply with the SFIR for incorporation within 24 hours after spreading. Case 2 does not.

It is suggested that, based on the estimated figures in Tables 4.27 to 4.30, BAT measures for storage and landspreading of manures are more cost effective in terms of ammonia abatement than in-process and end-of-pipe measures for animal housing. However, these measures can not be seen in isolation, as operators must comply with BAT in all stages.

Table 4. 30 - Extra annual costs and ammonia abatement of BAT measures for landspreading applied to the case studies

BAT techniques for ***landspreading of manure and slurry***		Annual extra cost (£)			Reduction (kg NH_3/year)		
		Case 1	case 2	case 3	case 1	case 2	case 3
1 rapid incorporation of slurry after landspreading (70% of total area)		4,844	1,821	1,464			
2 use of slurry soil injection (70%)		5,172	2,086	954			
3 increase in area required by extra N in manure with BAT:							
3.1 conventional spreading by broadcasting (30% of extra area)							
min cost BAT housing & storage		414	21	708			
max abatement BAT housing & storage		498	25	834			
3.2 using broadcast spreader + rapid incorporation by ploughing (70% extra area) *min cost*		1,780	96	2,867			
max abatement BAT housing & storage		2,138	114	3,379			
3.3 using soil injection (70% extra area) *min cost* BAT housing & storage		1,835	106	2,743			
max abatement BAT housing & storage		2,204	125	3,233			
Combined NH_3 reduction of BAT slurry landspreading techniques - *min extra area*					2,843	319	2,095
Combined NH_3 reduction of BAT slurry landspreading techniques - *max extra area*					2,939	327	2,323
4 rapid incorporation of FYM on-farm			467			307	
off-farm (85%)			2,649				
Minimum cost	Extra cost of *minimum cost* landspreading technique - *min area*	7,039	1,939				
Broadcasting + rapid	" (*max extra area*)	7,480	1,961				
Incorporation	Extra cost of *minimum cost* landspreading technique			4,405			
Slurry soil injection	" (*max extra area*)			5,021			
	Ammonia reduction with minimum cost techniques				2,843	319	2,095
(*max extra area*)	(*max extra area*)				2,939	327	2,323
	Cost efficiency of abatement (£/kg ammonia reduced/year)	2.48	6.08	2.10			
		2.55	5.99	2.16			
Rapid incorporation of	Extra cost of landspreading technique		467				
FYM on-farm	Ammonia reduction with techniques					307	
	Cost efficiency of abatement (£/kg ammonia reduced/year)		1.52				
Maximum abatement	It is both max abatement & min cost technique for case 1	as above		5,677			
1 broadcasting + rapid	(*max extra area*)			5,039			
Incorporation	Extra cost of maximum abatement landspreading technique	7,422	2,213				
2 use of slurry soil	(*max extra area*)	7,874	2,237				
Injection (70%)	Ammonia reduction with maximum abatement techniques				2,843	319	2,095
	(*max extra area*)				2,939	327	2,323
	Cost efficiency of abatement (£/kg ammonia reduced/year)	2.61	6.94	2.40			
	(*max extra area*)	2.68	6.83	2.44			

Notes: energy use changes were not estimated (hour/tractor) in this table;
do not consider off-farm costs of incorporation of FYM as it is sold to third parties (case 2).

Personnel costs

Implementation of IPPC may result in changes in the use of manpower in pig installations, based on the results from the case study installations. For analytical purposes, three IPPC-related groups of activities requiring manpower may be differentiated, namely: a) applying for an IPPC permit; b) monitoring, evaluating and keeping records of the compliance conditions of the IPPC permit; and, c) applying BAT (which, in turn, may be separated into techniques - animal housing, storage and spreading of manures – and stewardship measures).

Table 4.31 presents the estimated additional time required to comply with IPPC in the case study installations. The rates presented in Table 4.31 were checked by operators and adjusted where appropriate.

The time commitments for application are considerable. Experience to date suggests a tendency to underestimate these (Environment Agency, 2000d). The additional work required to comply with IPPC in the case study installations was estimated at around 700 hours per year (approaching half a full time worker equivalent) for the complete-cycle units and 200 hours per year for the feeding-only unit, mostly concerned with waste management and record keeping. It is recognised that economies of experience are likely to be achieve over time, reducing manpower requirements.

It was observed that the case study units already conformed to good practice and for this reason no additional costs were assumed for 'stewardship BAT'. This is likely to be the case for most large scale operators regulated by IPPC (FRCA, 1997).

Table 4. 31 - Estimated additional manpower for compliance with IPPC in pig units

Measure or operation related to IPPC	Manpower needed (hours/year)		
	Case 1	Case 2	Case 3
a) Application for the permit: time from managerial staff	100	80[a]	100
b) Monitoring, collection and record keeping; reviews of plans; training	148	89[a]	148
c) Compliance wit BAT:			
c.1) Good practices	nil	nil	nil
c.2) techniques for animal housing			
All phases, excluding Mating & Pregnancy[b]	374	0	467
c.3) techniques for storage of manures	nil	nil	nil
c.4) techniques for landspreading of manures[c]			
1) immediate incorporation of slurry	118	64	0
2) soil injection	42	27	-79
3) additional area (broadcast + rapid incorporation)	57-69	3-4	71-101
4) additional area using soil injection - minimum	39-46	2-3	48-68
5) rapid incorporation FYM (within 24 hours)	-	16	-
Subtotal Landspreading (broad+rapid incorp.), min. area	176	83	71
Subtotal Landspreading (soil injection), min. area	80	46	- 31
Total (hours)[d]	**798**	**254**	**786**
or using injection, min. area	703	215	684
of which (how above hours are distributed):			
Managerial personnel (1st year)[e]	228	161	228
" " (2nd year onwards)	128	81	128
Stockman	394	8	487
Contractor (broadcast + rapid incorporation, min. area)	176	83	71
or Contractor (using injection, min. area)	80	46	- 31
Total (hours)[d], 2nd year onwards	**698**	**172**	**686**
Or using injection, min. area	603	135	584
(value, £)* 1st year[e]	£4,599	£1,336	£5,252
2nd year onwards	£3,805	£700	£4,458

Notes: a) 20% reduction for permit application and 40% monitoring for case study 2; b) assumes straw based systems are acceptable as BAT for dry sows; techniques for animal housing do not account for Growing phase in case study1; c) excludes hours of work and costs of contracting; d) assumes immediate incorporation as BAT measure for landspreading; and e) first year involves application process (hours exclude services of consultant).

Total compliance costs

The total compliance costs comprise the estimated costs presented in previous subsections, namely costs associated to BAT and additional manpower plus direct costs through fees and charges by regulator related to the permit. End-of-pipe measures are not considered. These costs are compiled in Table 4.32, which presents the overall incremental cost of applying IPPC to the three case study pig installations.

For the complete-cycle installations the estimated extra costs of IPPC are between £43,000 and £54,000 per year for cases 1 and 3 respectively, with an overall average abatement cost of £4 per kg NH_3. The extra cost of maximum abatement options ranges between £77,000 and £99,000 per year for these cases, with overall average abatement costs of £6 per kg NH_3. The feeding-only installation (Case 2) shows a compliance cost of about £10,000/year and an overall average abatement cost of £3 per kg NH_3. These costs do not include those associated with any possible modifications to the existing straw based finishing system, due to the reasons that, as previously discussed, at the time of writing it is not clear whether this system will conform to BAT. If it does not, there will be significant additional costs for case 2.

Table 4.32 - Summary of incremental annual costs with IPPC on the case study units

Unit	Description		Extra cost (£/year)	Reduction Emission (kg NH_3 per year)	Cost effectiveness (£/kg NH_3 abated)
Case 1	Permit		2,594		
	Labour and Managerial		3,805		
	Changes for Animal housing	*Least cost BAT 'basket'*	18,976	3,267	5.81
		Maximum abatement 'basket'	52,856	5,103	10.36
		Most expensive 'basket'	65,154	4,857	13.41
	Storage of manure And slurry	*Least cost &max abatement*	10,795	5,867	1.84
		Most expensive & max abatement	18,394	5,867	3.14
	Landspreading	*Least cost & max abatement*	7,039	1,244	2.48*
		Most expensive &max abatement	7,422	1,244	2.61*
	Total case 1	Least cost	**43,208**	**10,379**	4.16
		Max abatement	**77,089**	**12,214**	6.31
		Most expensive	**97,370**	**11,968**	8.14
Case 2	Permit		2,526		
	Labour and Managerial		700		
	Changes for animal housing		N/A		
	Storage of manure And slurry	*Least cost &max abatement*	1,148	624	1.84
		Most expensive & max abatement	2,203	624	3.53
	Landspreading	*Least cost & max abatement*	1,939	319	6.08
		Most expensive &max abatement	2,213	319	6.94
		FYM on-farm	467	307	1.52
	Total case 2	Least cost & max abatement	**9,430**	**2,905**	3.25
		Most expensive	**10,759**	**2,813**	3.82
Case 3	Permit		2,594		
	Labour and Managerial		4,458		
	Subtotal		7,052		
	Changes for Animal housing	*Least cost BAT 'basket'*	29,317	6,371	4.60
		Maximum abatement 'basket'	74,293	8,807	8.44
		Most expensive 'basket'	94,051	8,491	10.68
	Storage of manure And slurry	*Least cost & max abatement*	13,398	7,282	1.84
		Most expensive &max abatement	17,835	7,282	2.45
	Landspreading	*Least cost & max abatement*	4,405	17	2.10*
		Most expensive &max abatement	5,039	17	2.17*
	Total case 3	Least cost	**54,172**	**13,670**	3.96
		Max abatement	**99,148**	**16,106**	6.16
		Most expensive	**123,977**	**15,790**	7.85

Notes: a) Annual capital costs refer to a 20 years payback period and 6%a.a. interest rate. b) Application fee of £2,950 plus £1,975 annual subsistence charge by the Agency (also consultant and manager time). c) BAT options assumed as not mutually exclusive (i.e. not incompatible between phases and stages of production). d) End-of-pipe measures for housing (air scrubbers) were not included. e) None BAT in-process for housing were applied to case 2 (straw base, feeding-only pig unit). * Cost efficiency here was calculated based on NH_3 reduction against the potential emission (not against the baseline).
Source: Tables 4.27 to 4.31.

4.5.2 TAN applying BAT

It was mentioned earlier that the determination of TAN enables an overall view of the N-balances throughout the pig production phases and waste management. The TAN calculated for the current ('without IPPC') situation was presented in Table 4.21. After applying BAT to the case study units, TAN was estimated again, as presented in Table 4.33.

The range of TAN values showed in Table 4.33 for cases 1 and 3 reflect the fact that more than one BAT option could be applied to a given phase of pig production or during storage and landspreading of manures. However, this condition was not verified for case 2, where BAT measures for the straw based system of housing were not prescribed and, therefore, no ranges for alternative BAT options, produced.

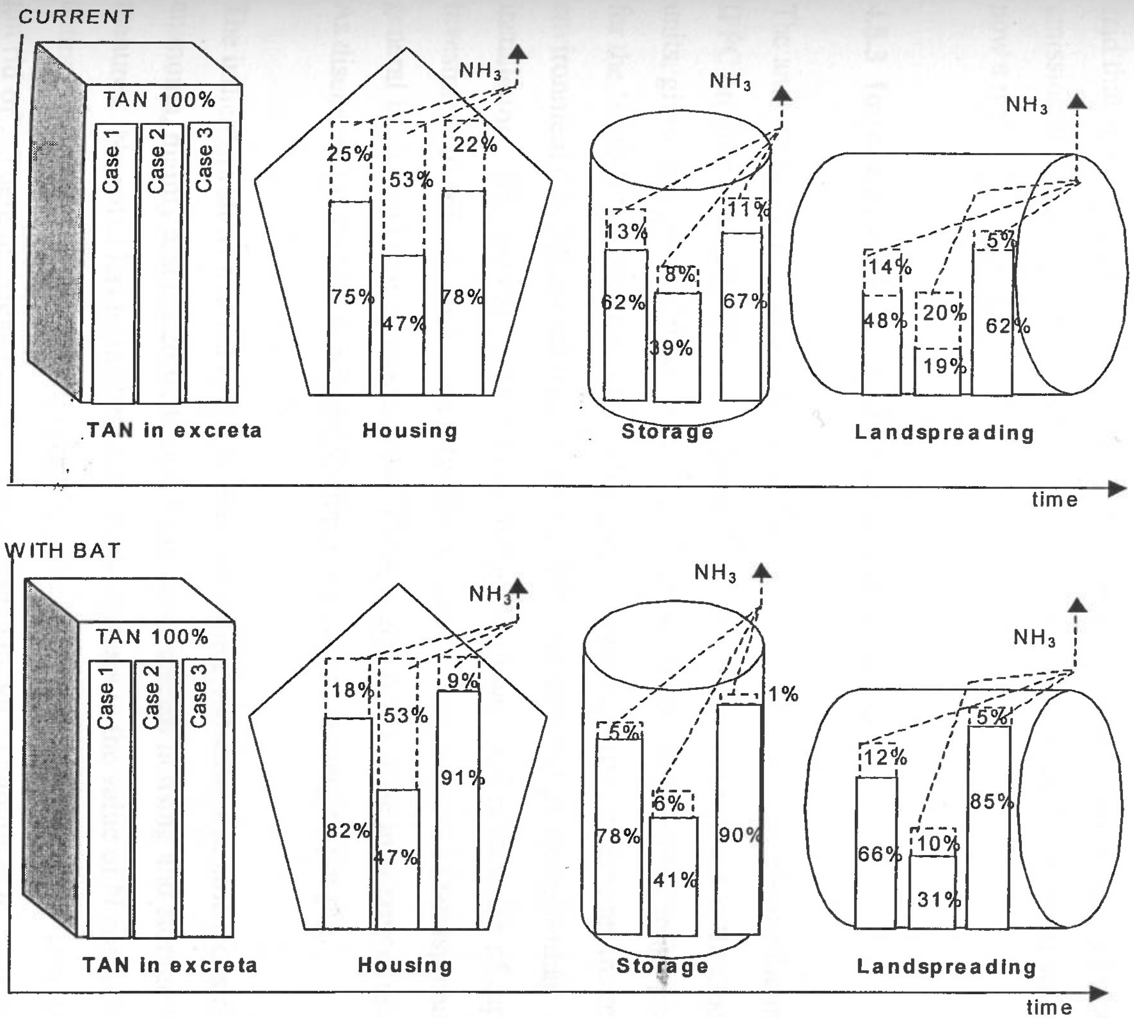
Where BAT were applied, the reduction in ammonia emissions resulted in significant increase in TAN. Figure 4.3 compares the TAN estimated for the baseline (current) situation (Table 4.21) and the 'with BAT' estimated TAN in Table 4.33 for the three case studies. It is important to note that TAN in excreta is equal for both situations and the numbers in Figure 4.3 are percentages of TAN in excreta.

Figure 4.3 illustrates N losses through release of ammonia at each stage of pig production (housing) and waste management (storage and landspreading of manures) and shows how TAN varies among these different stages. It also shows that the reduction in ammonia emissions by applying BAT for housing and BAT for storage serve to increase TAN before spreading (as shown by the difference in TAN values in storage).

Table 4.33 - TAN and ammonia emissions 'with BAT' applied to case studies

Total Ammoniacal Nitrogen (TAN)	**Case 1 Kg N year^{-1}**		**Case 2 Kg N year^{-1}**	**Case 3 Kg N year^{-1}**	
TAN in excreta based on pig consumption (1)	**69,090**		**22,878**	**68,670**	
TAN excreta from slurry	42,840		8,439	66,887	
TAN excreta from FYM	26,250		14,439	1,784	
NH_3 losses from housing (BAT)	least cost	max abatement	least cost	least cost	max abatement
Mating & pregnancy	3,089	3,089		2,072	2,070
Farrowing	607	364		413	248
Weaning	656	273		1,140	398
Growing	6,023	6,023		1,184	974
Finishing	3,630	2,420	12,225	3,948	2,632
Total	14,004	12,169	12,225	8,758	6,322
TAN in manures (4) = (2) - (3)	**55,086**	**56,921**	**10,653**	**59,912**	**62,348**
NH_3 losses from storage (BAT)					
Slurry lagoons	309		32.85	383	
FYM heaps	2,847		1,226	158	
Total FYM and slurry storage (5)	3,156		1,259	541	
TAN in manures before spreading (6) = (4) - (5)	**51,930**	**53,765**	**9,394**	**59,372**	**61,808**
Losses of NH_3 after spreading					
TAN in manures before spreading from slurry	33,848	34,986	3,897	57,973	60,346
TAN in manures before spreading from FYM	18,082	18,780	5,497	1,398	1,462
Losses with incorporation into land (abatement)**					
Slurry spreading	2,234	2,309	257	3,131	3,259
FYM spreading	6,047	6,280	2,131	468	333
Total losses NH_3 in spreading (7)	8,281	8,589	2,388	3,598	3,592
TAN in soil after spreading (8) = (6)-(7)	**43,649**	**45,176**	**7,006**	**55,773**	**58,216**
Total losses NH_3 during production and disposal (2) - (8)	25,441	23,914	15,872	12,897	10,455

Source: Table 4.21(current TAN and NH_3 emissions); Tables 4.27 to 4.30 for emission reduction 'with BAT'.



<u>Case 1 as example</u>:
In the current situation, 25% of total TAN is estimated to be emmited from housing, 13% from storage and 14% from landspreading, which results in that in 48% of TAN in soil after disposal. 'With-IPPC', that is applying BAT, would change the above situation as follows: losses from housing are estimated as 18%, 5% from storage and 12% from landspreading, which results in an overall increase of TAN in soil to 66%.

Figure 4. 3 Current and 'with BAT' TAN and ammonia emissions in the case study pig units

There are two immediate consequences for this increase in N-content (TAN) in manures prior to spreading. First, this requires an increase in the area of land available for spreading, as the application of N must not exceed 250 kg per ha per year. This is particularly relevant because the operators would need to find the extra land area off their farms, which already is producing surpluses of manures. Second, the transfer of the N load which was previously released in the form of ammonia in housing and storage to the landspreading stage results in a reliance of the overall efficiency of the abatement measures on the last stage of waste management. The performance of techniques for the spreading of manures is particularly sensitive to atmospheric conditions and to variations in the quality of the material being disposed of. It can be said that special attention is required at this stage to actually guarantee abatement of emission from the system as a whole, and to reduce risks of pollution from what is now a nutrient rich product for land disposal.

4.5.3 Impact assessment based on the selected indicators

The analytical framework helped to derive a set of indicators to determine the impact of IPPC on the pig production units. Table 4.34 applies these indicators to the case study units, giving existing 'without-IPPC' baseline values and the relative change predicted for the 'with-IPPC' regime. Although the set is not exhaustive, it captures the main environmental and financial implications of IPPC at the level of the individual installation. The indicators show that the biggest impact will be in terms of capital investment in animal housing and the storage of manures, the cost of landspreading, and general labour and management costs. There is also an increase in energy consumption. As discussed later, there is a negative impact on financial margins per pig.

The indicators show that IPPC can deliver substantial reductions in emissions of ammonia, mainly associated with modifications to animal housing and storage of manures. No value has been attributed in the analysis to the value of N contained within animal manures because, for the most part, they are commonly regarded as 'wastes to be got rid of'. There are signs that new waste management technologies may encourage manures to be considered as a 'resource'.

Table 4. 34 - Performance indicators for the case study installations and relative change for 'with-IPPC' situation

Indicator*	Current (without-IPPC) value			With-IPPC change, percentage or value (range***)					
	Case 1	Case 2	Case 3	Case 1		Case 2		Case 3	
Production and financial indicators									
pigs produced 95 kg liveweight per year**	19,759	11,732	18,740	=		=		=	
kg feed per pig produced	253	167	246	=		=		=	
kg N in feed per pig produced	7.63	4.41	7.69	-	-	-		-	
kWh per pig produced	66	25	47	1.1%	2.9%	-	-	2.9%	6.2%
litres water per pig produced	1.3	0.7	0.6	=		=		+	
cost of disposal of slurry (£/pig produced)	0.42	0.27	0.55	86%	95%	63%	70%	44%	49%
kg straw per sow per year	395	n/a	136	+		n/a		+	
kg straw per pig produced	63	30	5	+		+		+	
capital investment in housing (£/pig produced/year)	11.02	4.70	8.31	9%	24%	-	-	19%	48%
capital in machinery and equipment (£/pig produced/year)	0.38	0.29	0.37	+		+		+	
capital investment in manures stores (£/pig produced/year)	1.70	1.11	0.92	32%	54%	9%	17%	77%	103%
pigs produced per FT equivalent (stockman)	2,823	5,729	2,677	-2.8%		-		-3.4%	
labour & management cost (£/pig produced)	6.52	2.71	6.85	4.5%		4.4%		4.4%	
kg FYM per pig produced	152	426	19	+		+		+	
litres slurry per pig produced	619	387	652	-		-		-	
slurry storage capacity (months)	16	3	9	=		25%		=	
Gross Margin per pig produced (£)	23.21	7.35	20.15						
Net Margin per pig produced (£)	0.92	-1.67	1.75	-0.79	-2.51	-1.33	-1.45	-0.99	-3.63
Environmental indicators									
ammonia emissions from housing (kg NH_3/year)	17,272	12,225	15,129	-14%	-30%	=		-34%	-58%
ammonia emissions from storage of manures (kg NH_3/year)	9,023	1,883	7,823	-55%	-65%	-28%	-33%	-78%	-93%
ammonia emissions from landspreading (kg NH_3/year)	9,525	4,668	3,615	-16%	-17%	-1.7%	-2.0%	-7%	-13%
total ammonia emission (kg NH_3/year)	35,819	18,777	26,567	-29%	-33%	-15%	-16%	-43%	-61%
total ammonia emission per pig produced ((kg NH_3)	1.81	1.60	1.42	1.21	1.29	1.36	1.36	0.81	0.56
Total Available Nitrogen (TAN) applied to land (kg N/year)	33,271	4,101	42,104	31%	36%	69%	71%	27%	38%
P available applied to land (kg P_2O_5/ha/year)	138	85	128	121	127	83	84	101	108
ratio on-farm/off-farm area used for landspreading (%)	39:61	12:88	75:25	34:66	35:65	11:89	12:88	59:41	63:37

Notes: *comparison of indicators among the three units requires to consider that case 2 undertakes only part of the production cycle (rearing pigs from 39 kg); **as pigs are sold at different slaughter liveweight, total production was converted to 'standard' 95 kg pigs to calculate indicators per pig produced; ***the range of change is related to different performance depending on the BAT options simulated.
The '=' sign means no chance. When the indicator has not been quantified, '+' or '–' indicates the direction of change (+ is increase and – is reduction)

4.5.5 Financial Impacts

In the UK, the regulator has a duty to determine the cost:benefit impacts of its regulatory actions on third parties and to demonstrate that the regulatory burden is minimised and proportionate to the alleviation of environmental risks (Environment Agency, 1996).

The costs of compliance for the case study installations were equivalent to between 1% and 10% of the value of output depending on the BAT options adopted and the degree of environmental improvement achieved. Comparing additional cost and current farm net margins, it appears that, at the pigmeat prices for the year 2000, compliance with IPPC regulations would render the installations unprofitable. Even the least cost proposed BAT measures would not be covered by the estimated net margin currently obtained by pig unit. The breakeven 'without IPPC' pigmeat price was calculated to be between 93 and 97 p/kg for these case study units, for an average price of 96p/kg at the time of the study. Implementing IPPC measures would require extra returns of between 3p/kg and 10p/kg of pigmeat (between £0.81 and £6.77 per pig sold), depending on the type of BAT selected.

Minimum prices would need to be between at least £0.97 and £1.06 per kg approximately to guarantee profitability under IPPC regime. This would require a return to the pigmeat prices of the mid 1990s to allow the pig units to cover the estimated IPPC compliance costs. This may not happen in the short term given the context of the pig market as described by MAFF (2000a).

There is, however, some scope for gains which will partially offset compliance costs, such as rebates of 80% of Climate Change levy in energy use for IPPC controlled installations. However, potential synergy for environmental and commercial gain appears to be very limited for existing installations. There would appear to be scope for efficiency gains in feeding regimes which remains, in the context of the UK sector a relatively underdeveloped topic.

IPPC and BAT, together with ongoing structural changes in the pig industry, are likely to encourage larger scale, specialist production units, and convergence of production and management systems.

4.6 Discussion

The implementation of IPPC is required to deliver the objectives of the Directive efficiently, that is, guarantee proportionality of policy measures when providing necessary environmental protection. Based on the results of the case studies, it is possible to draw some conclusions on the major issues, impacts, risks and uncertainties associated with the implementation of IPPC regulation. A summary is shown in Table 4.35.

Table 4. 35 - Summary of key factors associated with IPPC compliance emerging from the analysis of case studies

Issues	Case 1	Case 2	Case 3
Feeding	Need to move from one to two diets for sows	Already comply with BAT	Already comply with BAT
Water and energy	Increase in the use of energy applying BAT measures by 1% to 3%. However, it is recognised that there is scope for savings.	Increase in the use of energy applying BAT measures to spreading of manures. More limited scope for savings if compared to the other two installations.	Increase in the use of energy applying BAT measures by 3% to 6%. However, it is recognised that there is scope for savings.
Housing	BAT measures associated with weaning and finishing phases account for the majority of extra housing costs. Uncertainty to have current straw base housing for growing pigs accepted as BAT in the future	Uncertainty to have current straw base housing for finishing pigs accepted as BAT in the future	BAT measures associated with growing/finishing phases account for the majority of extra housing costs

(cont.)

(continued Table 4.35)

Issues	Case 1	Case 2	Case 3
Waste storage	Covering the existing slurry lagoon is costly and difficult	Covering the existing slurry lagoon is costly and difficult Likely to require expansion of capacity of slurry storage	Covering the existing slurry lagoon is costly and difficult
Disposal of waste to land	Incorporation after spreading is needed or replacement of current practice by a lower emission technique	Incorporation after spreading is needed or replacement of current practice by a lower emission technique	Already incorporates manures into land but requires extra service/power to comply with rapid incorporation (<6hr)
Labour and management	Increase in control and monitoring activities, possibly accommodated within current work force and some extra contracting	Increase in control and monitoring activities, possibly accommodated within current work force and some extra contracting	Increase in control and monitoring activities, possibly accommodated within current work force and some extra contracting
Emissions	Reduction of 25% to 33% of NH_3 emission	Reduction of 15% to 16% of NH_3 emission	Reduction of 41% to 61% of NH_3 emission
TAN	Increased in TAN in soil after spreading between 31% and 36%	Increased in TAN in soil after spreading between 69% and 71%	Increased in TAN in soil after spreading between 27% and 38%
Compliance costs	Extra annual cost estimated as from £43,000 to £87,000	Extra annual cost estimated as from £9,000 to £11,000	Extra annual cost estimated as from £54,000 to £99,000
Cost-effectiveness	Abatement cost in a range between £4 and £6 per kg NH_3 abated	Abatement cost in a range between £3 and £4 per kg NH_3 abated	Abatement cost in a range between £4 and £6 per kg NH_3 abated
Affordability (for least cost and maximum abatement BAT)	Extra cost recoup would require increase in price or reduction of other costs between 2p and 4p per kg of pigmeat	Extra cost recoup would require increase in price or reduction of other costs by 1p per kg of pigmeat	Extra cost recoup would require increase in price or reduction of other costs between 3p and 6p per kg pigmeat

It is important that IPPC, and its constituent BAT, provides robust and reliable solutions for environmental protection which are compatible with other standards, such as those relating to health and safety, and in the case of farming, animal welfare. For example, if not well managed, partly slatted floor housing systems might produce dirtier pens than fully slatted ones, increased emissions of gases and odours, and lower standards of animal health, wellbeing and ultimately performance.

The majority of the proposed BAT for housing require an increase in the use of energy in comparison with existing systems associated with flushing and other transport systems for slurries and with more frequent mechanical removal of solid manure. This is also the case for BAT for landspreading, where BAT measures generally require more power than conventional techniques. So, an increase in the total energy consumption can be expected with IPPC requirements on existing installations. In this respect, there appears to be a trade-off between reducing emissions levels and energy intensity. There is, however, scope to reduce energy input by optimising its use in other processes and activities associated with pig production, such as heating, ventilation and lighting.

Reducing emissions throughout the pig production phases, especially by in-process BAT housing, results in N-enriched manures going to storage. The same principle applies to the landspreading phase: if measures are taken to reduce releases during housing and storage, N- richer manures are available for spreading onto land. This fact has two immediate implications: greater risk of pollution by these nutrient-enriched manures; and, higher N-content manures require more land suited for spreading.

The previous point is core to the assessment of BAT. That is, the approach to BAT focuses on solutions for each identifiable process or phase within the system. However, at present, the approach to BAT does not offer an integrated assessment of options applied to an installation as a whole, which is, after all, the very purpose of the IPPC Directive.

By focusing on the reduction of ammonia emissions, some proposed BAT may actually promote the release of other pollutants. For example covering slurry stores can substantially reduce the release of ammonia. But this favours anaerobic processes in the liquid material which contribute to formation of methane, a greenhouse gas. Odours are also likely to increase under anaerobic conditions (Williams and Nigro, 2000).

Conversely, the proposed low emission landspreading techniques offer a more precise distribution of slurry, which contributes to a more reliable use of manures as fertiliser. The drawback here is that these techniques are less flexible than conventional spreading methods, requiring chopping/separation of dry matter from slurry, do not operate on slopes over 6% and operations cause more damage to standing crops (Chambers et al., 2001).

Methods to abate ammonia emissions at the point of disposal of animal manures generally offer relatively high cost-efficiency, compared to storage and housing measures. For this reason, they have been a favoured instrument of environmental policy in countries with particularly serious problems of pollution from intensive livestock production, such as in the Netherlands (LNV, 1999). However, this is not the approach adopted for IPPC implementation where measures relating to the production phase *per se* and measures for associated activities such as storage and disposal of animal manures are being assessed independently. Rather, they should be regarded as a whole. This criticism challenges the very nature of the 'integrated' concept of the IPPC Directive.

The current approach to BAT may not deliver the principle of 'integrated' pollution control on a number of counts. First, it focuses on one major pollutant: ammonia/N to the possible exclusion of others. Second, it tends to focus on discrete phases of the production cycle, rather than considering the whole cycle abatement. Third, most of the N-related candidate BAT for pig sector could be regarded as 'end-of-pipe' rather than 'in-process' unless the amount of excreta TAN value produced per pig is reduced. Current BAT are predominantly trying to better manage emissions from fundamentally the same production process.

One further point is worthy of comment. The case study evidence, consistent with general experience of environmental abatement strategies, suggests that achieving reduction of direct emissions to air from relatively diffuse (non-stack) sources is one of the most expensive, and in this respect potentially less efficient, pollution control methods. BAT for the pig sector has placed particular emphasis on the reduction of ammonia emissions, which suggests that the IPPC regime is likely to involve relatively costly measures for regulated installations. Although pig installations are (relatively) point sources of potential pollution and therefore potentially easier more easy to control at the housing stage, field disposal of N-enriched animal waste switch to a diffuse source of potential pollution which is more difficult to control. This portrays an interesting case of switching from a point source to a diffuse one. The BAT abatement in IPPC housing does not really abate: it stores up pollutants for diffuse disposal, which unless carried out properly, exacerbates the potential risk of diffuse pollution.

The cost effectiveness analysis of IPPC showed that the ammonia abatement costs estimated for the case study units were in a range between £3 and £6 per kg of NH_3 abated (this range refers to the least cost and maximum abatement 'baskets' of BAT). There are few references to assess whether these abatement costs are reasonable, that is, if IPPC is efficient in controlling emissions from pig installations. One reference was found in the results of application of the MARACCAS model in a European wide survey (Cowell and ApSimon, 1998) involving different measures to control ammonia emissions from livestock (including pigs). The marginal costs of abatement of potential control measures were calculated, which can be regarded in this case as analogous to cost efficiency. The 'knuckle-point' to select potential options was establish as being ECU 10, which is approximately to the £6 value obtained in the case studies. Therefore, the overall IPPC ammonia abatement cost seems to be efficient as it appears not to determine excessive costs. However, more evidence is necessary to a correct evaluation of efficiency of regime as it applies to pigs.

Effectiveness is another criterion for assessment of policy performance. As IPPC assumes use of BAT and candidate BAT were selected if they could deliver at least 20% abatement of ammonia emissions compared to the reference systems, it could be assumed that it is effective. Therefore, BAT is inherently effective. However, the case studies analysis showed that the overall effectiveness of abatement depends on the measures carried out in each stage of production and waste management. Using the same criterion of 20% abatement to be considered BAT, for the 'with-IPPC' simulation the overall abatement achieved in the case studies 1 and 3 would comply with BAT; however, case study 2 had an estimated abatement of 15% of the baseline emissions and would require additional abatement measures to those applied be considered BAT compliant.

On *applicability*, it is recognised that the standard conditions approach through the SFIR was adopted seeking to simplify the application for a permit and also the monitoring and evaluation of granted permits. However, the case studies suggest that this 'standard' approach still requires a considerable effort for completion by the operator, being, it could be inferred, equally challenging for the regulator. A learning process is involved here, and the process is likely to become more cost and time efficient as experience is obtained by all parties. It can also suggest that newcomers (initial IPPC applicants) are likely to confront more difficulties and have a more costly permitting process. These transaction costs are likely to decrease with experience gain and with improvements to the permitting process itself.

On *proportionality*, it can be said that the abatement levels estimated in the case studies are compatible with those required by the UK strategic target for ammonia abatement under the UN/ECE protocol. However, the compliance costs of IPPC estimated for the case studies were significantly high and unlikely to be absorbed by the current financial margins.

As IPPC capture captures large pig units, which contribute with the majority of the ammonia emissions from the sector, it is expected to meet *equity* criterion. However, as the remit of the IPPC Directive is only the pig and poultry sectors, it leaves out of the pollution control regime the major individual contributors to ammonia and methane emissions in the livestock sector, namely dairy and cattle activities. It also does not cover outdoor pigs, which are often considerable large units.

Overall, the case study evidence suggests that BAT can deliver significant reductions in total ammonia emissions, thereby meeting the principle of prevention contained in IPPC. Emphasis is placed on containing emissions during the housing and waste storage stages, the benefits of which are realised by subsequently adopting low emission disposal methods to land. The overall effectiveness and efficiency of the IPPC regulation, therefore, rest heavily on the efficacy of land spreading, which is of course an integral part of the total process. Compared to earlier stages in the process, however, the disposal stage is subject to considerable risk given its dependency on climatic and field conditions. Furthermore, where land spreading is carried out by a third party, which is the case for some non-farm pig installations, the IPPC regulation does not apply to the disposal process. The point at issue here is that disposal of animal waste to land is potentially the weakest link in the ability of IPPC to deliver its key environmental objectives. It is a critical topic for BAT, SFIR and subsequent monitoring.

4.7 Summary and Conclusions of Chapter

A framework for assessment of IPPC impact on pig units was developed and applied to three case studies. The framework and its constituent set of indicators can help to provide a robust and integrated assessment of environmental and financial performance of pig installations. That is particularly important when the applicability and appropriateness of some of the emerging BAT are not yet confirmed.

The case study evidence suggests that the IPPC regime involve relatively costly measures for regulated installations. Compliance costs associated with BAT measures, particularly for animal housing, account for the majority of the additional cost associated with by IPPC. BAT for storage and BAT for landspreading of manures appear to be relatively more cost-effective in reducing ammonia emissions than BAT for housing, but of course they cannot be seen in isolation.

Reduced ammonia emissions from animal housing and storage of manures increases the nitrogen content of manures to be applied to land. Therefore, the overall effectiveness of measures for the reduction of ammonia in BAT rests on that of disposal techniques. These are strongly affected by weather and field conditions, thus increasing the risk factor.

Case study analysis shows that IPPC is likely to impose a significant regulatory burden on existing installations which, given current conditions in the UK pig industry, could prejudice the financial viability of some businesses. Caution at this early stage of the IPPC implementation process is required in order to avoid promoting techniques which may prove financially expensive and of limited environmental benefit.

The analysis reported here adopts an *ex ante* perspective and in this respect many underestimate the potentially more flexible, less costly responses to IPPC in practice once the industry faces up to the reality of the new regulation. This new regulation is likely to encourage innovation in pursuit of compliance and efficiency gains, such that the magnitude of the regulatory burden may be actually less than predicted here.

The analytical framework developed here and the results of the case study analysis provide a basis for assessing the likely extent of IPPC induced change at sectoral level. This is assessed in the next chapter.

CHAPTER 5

ANALYSIS OF THE IMPACTS OF IPPC DIRECTIVE IN THE PIG SECTOR

This chapter presents the results from the survey to pig producers in England and Wales. The specific objectives of the survey were to: 1) characterise systems, resources and techniques in place on pig installations captured by IPPC; 2) identify awareness and perceptions of pig operators of IPPC regulations; and, 3) extrapolate findings of the case studies to the industry level. The chapter reports on each of these aspects in turn. The chapter also reports the outcomes of a workshop which engaged stakeholders in a preliminary review of the results of the case study analysis and the sectoral survey.

5.1 IMPACTS OF IPPC AT SECTORAL LEVEL

With the assistance of the National Pig Association (NPA), a survey of pig producers likely to be captured by IPPC was carried out as described in section 3.5 above. 75 responses were obtained and used for analysis, covering 117 pig installations. The following sections discuss the findings of the survey and the implications for the likely impact of IPPC at sectoral level.

5.1.1 Characterisation of respondents by type of system

Systems by specialisation of the herd

The analysis of the case studies confirmed that the impacts of IPPC on pig installations may vary considerably depending on systems by specialisation of herd, showing that units managing breeding herds have more intensive use of capital and labour resources than feeding-only units.

The questionnaire response according to system by specialisation of the herd is presented in Table 5.1. Breeding-only pig units accounted for 6% of total responses. This was considered low as they represented 18% of the NPA membership. However, it is important to bear in mind that a substantial proportion of sows is kept outdoors and, as referred previously, was beyond the remit of the survey. Such a low number of cases (7 in total) raise problems of validity of data for this system, as well as limiting the degrees of freedom for the statistical analysis.

Breeding-and-feeding systems accounted for the major share of fattening pigs (54%) even though they represented only 39% of the units. It suggests that these complete cycle breeding-and-feeding units have a larger scale of production than specialised feeding-only ones

Table 5. 1 - Number of responses and total pigs according to specialisation of the herd

System by Specialisation of herd	Response		No. of pigs	
	Frequency	% of total	Total sows	Total fatteners (pigs over 30 kg)
Breeding only	7	6.0	5,055	-
Feeding only	65	55.5	-	118,127
Breeding & Feeding	45	38.5	31,252	140,256
Total	117	100.0	36,307	258,383

Source: questionnaire survey.

This relative larger scale in terms of number of pigs being finished for breeding-and-feeding units is confirmed by the calculated mean values presented in Table 5.2. However, the same was not verified in terms of number of sows: breeding-and-feeding units had similar average number of sows if compared to breeding-only units.

Table 5. 2 - Number of sows and finishing pigs by type of herd

Herd System	Category	Number of heads		
		Mean	Minimum	Maximum
Breeding only	total sows	722	300	1,200
Breeding &Feeding	"	709[a]	175	6,000
Feeding only	Fatteners over 30 kg	1,962	280	6,400
Breeding & Feeding	"	3,184[b]	180	7,500

Notes: a) there is no statistical difference between mean values for sows, based on the Mann-Whitney test; b) mean values different at significance value < 0.001.
Source: questionnaire survey.

It is worthy to note that the maximum reported values for number of fatteners represents between 3 and 4 times the IPPC threshold (respectively 6,400 and 7,500 fatteners in a single unit), whereas the maximum number of sows was 8 times the threshold (6,000 sows). Appendices 5.1 and 5.2 show the distribution of pig units by number of sows and number of finishing pigs.

The results in Table 5.2 show that although the average number of sows in breeding-and-feeding units were below the threshold for this category (i.e. 708 against a threshold of 750 sows), these units would fall under IPPC regulations. This is because the number of finishing pigs is well above the 2,000 fatteners determined in the Directive. Therefore, breeding-and-feeding units are more likely to be affected by IPPC than specialised units (breeding-only and feeding-only). Although they may have an average number of sows lower than the IPPC threshold for sows, in practical terms breeding-and-feeding units with more than 400 sows are likely to be captured for having more than the threshold number for finishing pigs (over 30 kg).

The strategic responses to regulation by IPPC, as discussed with pig operators and representatives of the pig industry in the workshop organised in Silsoe (section 5.2), include the options of scaling down the size of pig herd (number of sows and finishers) in order to avoid being captured by the threshold. Alternatively, breeding-and-feeding units might split their feeding phase in a number of smaller units to avoid the threshold, without changing the breeding herd status, or yet become specialised breeders, keeping sows and selling piglets to be finished in another unit. However, such conversions would be limited on grounds of bio-security: a complete system is relatively closed, which is a beneficial factor for herd health and control of disease outbreaks. A conversion of great number of complete units to specialised breeders would require the feeding-only units to increase their capacity, leading to further concentration of fatteners in very large units.

Systems by type of animal housing

Table 5.3 shows the frequencies of housing systems in each pig production phase. This shows a very high incidence of straw based housing systems in the *service* (mating) phase, with 81% of total responses. Straw based systems comprised around 85% to 91% of total sows in the survey[1]. This confirms the widespread use of such systems, especially following the ban of stall and tethers in the beginning of 1999. The effects of welfare regulations on animal housing are further discussed in section 5.2 on construction and refurbishment of premises.

Table 5. 3 - Housing systems according to the pig production phase

Production phase	Housing system	Frequency	Percent*
Service	straw based	42	81%
	solid floor	7	13%
	straw based + solid floor	3	6%
Farrowing	partly slatted floor	21	46%
	straw based	10	22%
	fully slatted floor	7	15%
	fully + partly slatted floor	3	7%
	mixed (straw based + fully or partly slatted)	5	11%
Weaning	fully slatted floor	21	35%
	partly slatted floor	16	27%
	straw based	16	27%
	fully + partly slatted floor	3	5%
	mixed (straw based + fully or partly slatted)	4	7%
Finishing	straw based	60	53%
	fully slatted floor	23	20%
	partly slatted floor	17	15%
	solid floor (no or limited straw)	4	4%
	mixed (straw based + fully or partly slatted)	10	10%

Note: *percent of the total installations reporting type of housing for the phase.
Source: questionnaire survey.

Slatted floor systems (either partially or fully slatted) are predominant in the *farrowing* and *weaning* phases. They were present in about 67% of the pig installations involved in this survey, excluding mixed slatted and straw based housing.

Straw based systems showed quite a high incidence (of 53%) in the *finishing* phase according to the responses obtained in the survey. Other sources of data, such as the

[1] The range refers to the fact that some installations reported a combination of straw based and non-straw systems.

National Survey on Pig Production Systems (NSPPS) 1998, suggested that the predominant housing system for finishing phase is the solid floor (with solid dung passage). Straw based systems, defined in the NSPPS 98 as deep straw yards, were present in 26% of pig holdings for finishing phase. The slatted floor systems were expected to have a higher presence in this production phase, because they are large installations (see section on *structure of pig production*, Chapter 2). However, partly or fully slatted were reported to be the dominant housing system for finishers in only 35% of the units in our survey, similar to 30% published in the NSPPS 98, which involves all pig farms declaring 20 or more breeding sows or 200 or more pigs.

Figure 5.1 shows the distribution of finishing pigs (over 30 kg) according to type of housing based on the information by respondents to the questionnaire survey. The figure confirms the importance of straw and fully slatted systems.

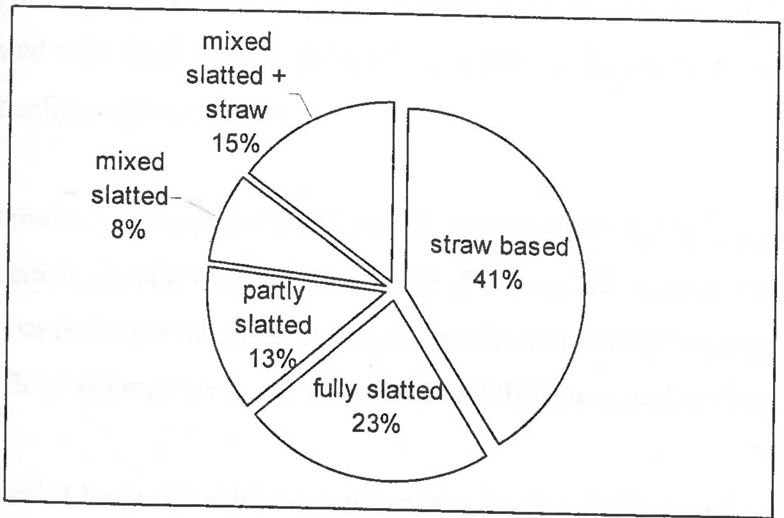


Figure 5. 1 - Number of finishing pigs by housing type, % of total installations
Source: Table 5.3.

It is still unclear what BAT measures are required for some housing systems for compliance with IPPC. Great uncertainty remains on the definitive acceptance or not of straw based systems as BAT at European Union level. The results from the case studies pig installations suggest that compliance with BAT for housing may be the most costly individual item of the IPPC compliance costs. The characterisation of predominant production systems for housing by the sectoral survey indicated that particularly for the finishing phase, the sector is far from compliant with BAT. There is the risk that imposing replacement of predominant housing systems will force a substantial proportion of pig producers out of business because they are not prepared to make or capable of making the necessary capital investments.

Solid floor, straw based systems are accepted under BREF Note as BAT for dry sows. However, the negotiation for inclusion in BAT of the straw based housing for finisher pigs, which is particularly widespread in the UK, was a more contentious issue within the Technical Working Group (TWG) for IPPC. The outcome was a moratorium on the use of straw based systems until more scientific evidence is generated on their performance in terms of ammonia emission. Therefore, there is a risk that in the medium to long term (the BREF is due for revision every 4 years) straw based will no longer be accepted as BAT for housing for finishers pigs. In that case IPPC would have a great impact of IPPC on the pig industry as a whole. Straw based systems are associated with feeding-only units, whereas slatted floor systems seems to be associated with breeding-and-feeding units.

Cross tabulation of types of unit by herd specialisation and by types of housing showed significant association for *finishing* phase (Pearson Chi-squared test, Appendix 5.3). That is, straw based finishing houses are associated with feeding-only herds whereas slatted floor systems are more associated with breeding-and-feeding herds.

In fact, solid floor and solid dung passage systems (which do not use, or have very limited use of, straw) seem to have been recently converted into straw based pens or yards. This conversion needs little change in animal buildings, other than the introduction of bedding material, usually straw, and its management (replacement of new bedding three times a week, mucking out the old plus excreta). This profile of low investment by the pig industry in recent period was confirmed in the workshop organised at Cranfield University at Silsoe to discuss the preliminary results of this research (section 5.2). One of the consequences of this phenomenon is that there is divergence between direction of pig systems in the UK and that of systems currently being accepted as BAT. In spite of their common incidence, straw based did not feature in BAT in January 2002. For this reason there is the risk that a large part of the UK sector would be rendered potentially non-compliant with BAT, with major implications for additional costs to switch to slurry based systems if required by IPPC[2].

5.1.2 Current profile of pig installations: age and refurbishment

The case study analysis confirmed that IPPC compliance costs are likely to be relatively high for existing installations rather than for new ones, and that the need for extra capital investment was a major element of compliance costs.

The sectoral survey identified that two main structural change have recently took place in the pig industry, namely: the conversion of sow accommodation to group housing, straw based systems, and, the conversion of solid floor (no straw) and solid dung passage housing for finishers towards straw based systems. The former one was driven by welfare regulation, which banned stall and tethers for sows. However, the latter one reflects a more complex set of reasons. Among them, and possibly the most important reason, is the strategic view of operators of the pig market. Competition by other pig production countries, relatively higher costs of production and a long term low price for pigmeat[3] have discouraged major investments in housing. As a result, the stock of housing and related facilities have in many respects been run down, and operators have adopted short term measures to accommodate change.

The argument that the low investment in buildings is a reflection of the low expectations in the pig market by operators, who therefore prefer to avoid the risk of making substantial capital investments in their activity, appears to be confirmed by the fact that the running costs of straw based systems are higher than those for slatted systems. According to a major UK supplier of pig housing and equipment (Pyramid Ltd., pers. comm.) the total production cost is comparatively lower for fully slatted floor systems than straw base ones (approximately 7p per kg pigmeat produced). The difference is

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[2] Straw based systems were given a provisional BAT status in the forthcoming BREF Notes, after the 2nd public consultation. However, BAT predominantly is associated with partly slatted, slurry based systems.
[3] These are arguments continuously raised by sector representatives and other industry forums. They do not are necessarily reflect the opinion of the author here.

mainly due to more intensity in labour use required by straw based systems. Thus, if in the long term straw based systems are more costly, the immediate preference for them by operators reflect a short term response to uncertainty about future industry prospects.

Suffice it to say that a fully slatted floor with a full width manure pit is not BAT. However, the secondary information in the BREF drafts suggest that for new installations the additional costs of abatement measures to this system, or of alternative BAT for housing, are negligible. That is, compliance with BAT does not imply substantial change in the overall cost of new housing. Adapting existing installations to BAT, however, is more of a challenge.

Figure 5.2 presents the distribution of buildings by year of construction in the pig installations surveyed. Around 75% of the buildings for animal housing were built after the year 1970. Assuming a 30-year period as life span for such constructions, this means that 25% of the current (year 2001) installations are now completely depreciated. It also shows that more than 60% of the total buildings were already built by 1980, suggesting that a major part of animal housing is at the end of its operational life. Around 25% of these buildings are reported less than 10 years old.

Continuous improvement and refurbishment of buildings for animal housing are common practice in the sector, as reported by 56% of pig units. It was reported that in some cases pig production had been carried out on the same site for more than 140 years. Information on refit and refurbishment was gathered in order to help to better qualify the current condition of the buildings, as presented in Figure 5.3.

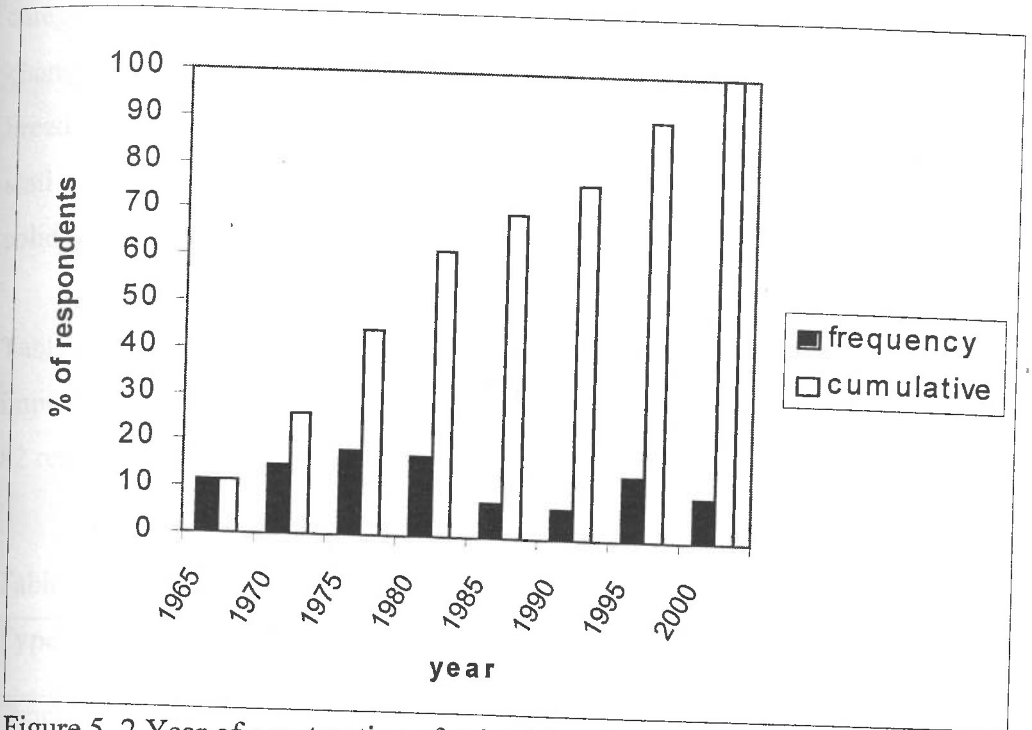

Figure 5. 2 Year of construction of animal housing

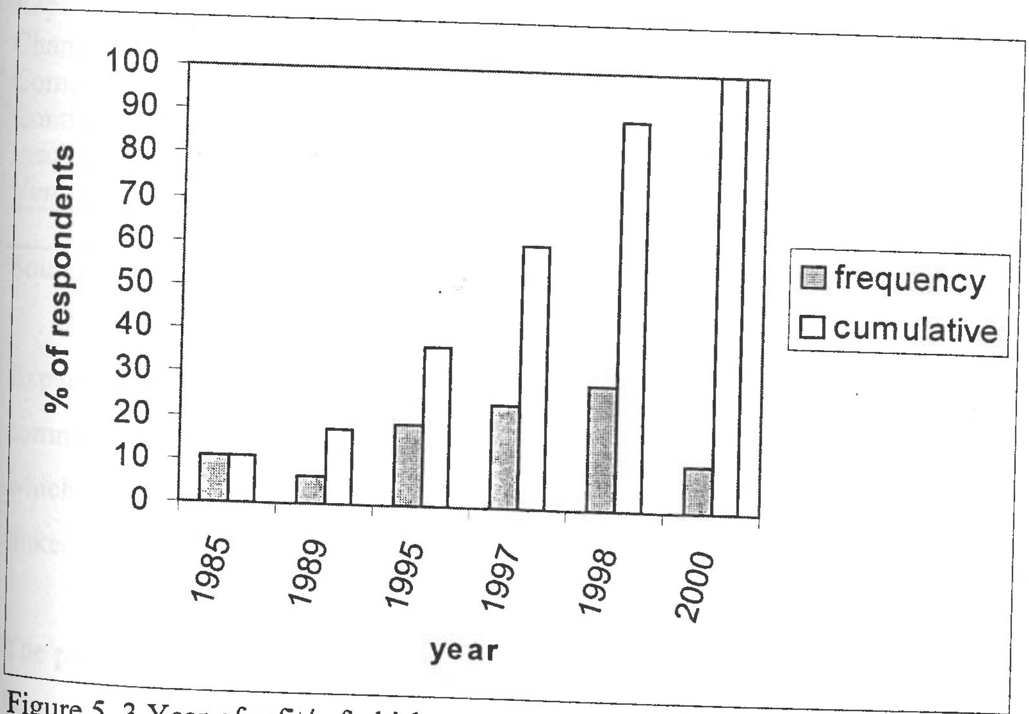

Figure 5. 3 Year of refit/refurbishment of pig buildings

Figure 5.3 shows that more than half of reported refit or refurbishment of animal housing was carried out between 1996 and 1998. Table 5.4 summarises type or category of refit in buildings reported in the questionnaire survey. These mainly refer to changes in the housing system to comply with welfare regulation which banned keeping breeding sows in stalls or tethers from 1999. Pig producers switched from individual stall or tethers systems for sows, usually on slatted floor, to group housing for sows on solid floors with straw.

Table 5.4 confirms that many refits involved incremental modifications and improvements rather than complete or extensive works in the pig units. Only 7 out of 82 responses, or 9%, reported a complete refurbishment of the unit at once.

Table 5. 4 – Type of refit in pig installations

Type or category name for refit	**Frequency**	
	Absolute	%
Change from individual to group housing for sows	23	28%
New building or expansion of animal housing	20	24%
Conversion of existing house to new use or system	10	12%
Replacement or improvement of the feeding system	9	11%
Changes in housing for finishers	7	9%
Complete or extensive refurbishment	7	9%
Continuous improvement of buildings	4	5%
Insulation	1	1%
Ventilation	1	1%
Total	82	100%

Source: questionnaire survey.

Expansions of facilities were mostly associated with the finishing phase. The most common new feeding technique was the installation of electronic sow feeders (ESF), which enables each sow to be individually fed in group housing by use of a transponder linked to an automated computer controlled system.

The profile of refit in pig buildings as above mentioned confirms the trend for the breeding herd (sows) to move towards straw based, group housing. However, this was not evident for other production phases. Three units reported refit related to the conversion from finishing pens to straw yards, an equal number of units reported they had converted their finishing systems for slurry based ones.

These results show that pig installations involve relatively old buildings and much refurbishment is needed and, therefore, considerable capital expense is required. However, much of the stock is already depreciated or approaching the replacement investment period.

5.1.3 Characteristics of the sites where the pig units are located

Site specific features of the installation, especially possible impacts on local sensitive receptors, are an important aspect of IPPC. These include soil type, proximity to water courses, conservation sites, and local settlements.

The characteristics of the soil relate with the aptitude of area for landspreading of manures and with the intensity of processes associated to this practice such as nitrate leaching and surface run off. The predominant soil reported for the pig units and adjacent areas is presented in Figure 5.4. This figure shows that clays and loams are the most common types of soils. Light, well-drained soils such as sands were predominant in only 16% of the cases. This suggests most of areas surrounding the pig units and, therefore land likely to be used for disposal of manures, are not particularly risky for the leaching of nitrates. However, surface run-off can be a problem in heavier soils, especially when dealing with disposal of liquid manure (slurry).

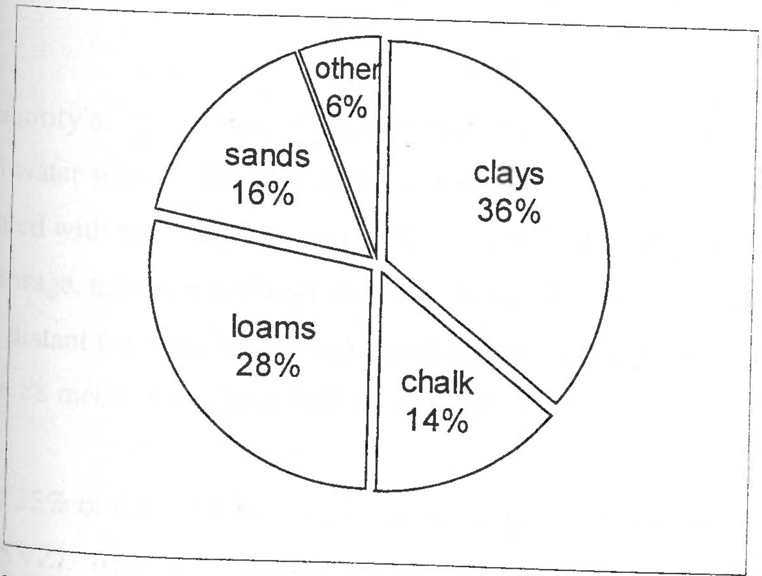

Figure 5. 4 - Predominant soils in pig units and adjacent areas
Source: questionnaire survey.

Table 5.5 presents the reported information by respondents on the occurrence of environmental features potentially sensitive to the pig production activity and associated processes. The most common potentially sensitive receptors verified (71% of responses) were residential areas near to the pig unit (within a three-kilometre radius, following criteria used by the Agency). The closest neighbouring house to the pig unit, not including farm dwellings, was on average 568 metres away (mode value 500 m), whereas a major residential area, such as village or town was on average at 1,237 m (mode 2,000 m) far from the unit. The sensitivity of receptors here is related mainly with the potential nuisance cause by emission of odours to dwellings from the pig buildings, storage and landspreading of manures.

Table 5. 5 - Occurrence of potentially sensitive environmental features in the vicinity of the pig unit

Sensitive receptor	No	Yes	Don't know
residential area in the vicinity*	34	83	-
watercourses, spring or borehole	44	73	-
areas within a NVZ	86	27	4
nature conservation or protected areas**	98	14	5
other environmentally sensitive features	114	3	-

Notes: *within a 3 km radius; **such as SSSI and woodland, in a 2 km radius
Source: questionnaire survey.

The majority of the pig units (62%) reported proximity to watercourses or some other natural water source. This highlights that special measures are need to reduce the risks associated with run-off of dirty water from yards and by spillage of dirty water or slurry from storage, transport and distribution systems. Watercourses were on average 168 metres distant from the installation (mode = 100 m). Springs or boreholes were on average 88 metres from the installation (mode of 10 – 100 m).

Around 23% of the pig farms were reported to have areas within a Nitrate Vulnerable Zone (NVZ). Also, 12% reported the existence of a nature conservation or protected area within a two kilometres (km) radius. Only 3 out of 117 installations reported other sensitive features in the vicinity of the pig installation, referring to non-agricultural businesses and historic site with tourist interest.

Having areas within a NVZ implies a reduction of the allowance of nitrogen application from organic manure on arable land, that is, limiting N loading to a maximum of 210 kg per ha per year. This current threshold will be further reduced to 170 kg per ha per year by December 2002 (EC Nitrate Directive 91/676). A considerable expansion of NVZs is expected in England (DEFRA, 2001b), which in practice will require an increase in the total area for spreading of manures. The Government announced that NVZs will cover 55% of the total agricultural area (DEFRA, 2002d), being concentrated in the Midlands and eastern counties (therefore, coinciding with major pig production areas). Drawing on the case studies results, a maximum of 63 cubic metres of slurry per hectare (slurry with 4% N in content) can be spread if the limit of 250 kg N per ha per year is not to be exceeded. If this limit is reduced to 170 kg N per ha per year (according to Nitrate Directive, from 2003) the maximum slurry to be spread is 43 cubic metres per ha per year. The average areas for spreading varied between 211 and 330 ha, and the increment to the average spreading area required under NVZs would be, respectively, of 100 ha and 155 ha (i.e. 47%).

Furthermore, the existence of nature conservation or protected areas close to a pig unit may determine the demand of additional measures in the installation under the IPPC permit to reduce the risk of damage to these special sites. Ammonia emissions are particularly associated with negative effects to these ecosystems, although it is difficult to determine with certainty the local effects[4].

5.1.4 Waste management

The case studies analysis showed that waste management stage, involving the storage and disposal of manures to land, is very important for the achievement of the overall efficiency of BAT. As TAN in manures increases during animal housing, especial

[4] Results from Ammonia Distribution and Effects Project (ADEPT) showed that local redeposition of ammonia onto farmland can be as high as 30% (DEFRA, 2001b).

attention is necessary in the waste management stages (storage and disposal of manures) to guarantee reduction of emissions of ammonia.

Around 67% of the installations reported a Farm Waste Management Plan (FWMP), which indicates that there is already a degree of planning and monitoring for use of manures in pig farms. Although the sectoral survey did not assess the degree of compliance, the fact that a majority of pig operators holds a FWMP at least suggests that there is awareness of good practices for handling farm wastes. Drawing on the case studies, the operators have the FWMP as guidance but they are not necessarily following them in the way required under IPPC.

Storage of slurry and FYM

The type and capacity of manure and slurry stores are important features of waste management both because they are associated with the gaseous emissions during storage and for they determine the flexibility that the pig operator has for the timing of the landspreading operation. The case studies suggest that compliance with BAT for storage of slurry, which requires covering of surface areas of slurry stores, involve considerable costs.

The incidence of types of storage facilities for slurry and solid manure is shown in Figure 5.5. Slurry is predominantly stored in earth banked lagoons and below ground tanks or structures (with, respectively, 38% and 31% of the total installations reporting slurry storage). Also above ground circular tanks are commonly used for slurry storage (21% of responses). It was also reported that 8% of installations managing slurry do not have an external facility for storage, which means the slurry stays in the pit underneath pens and then is directly transported from there to be disposed of. This long term storage is not recommended as gaseous emissions are likely to increase inside the pig housing.

Broadly, these responses agreed with the characterisation of slurry stores by Smith *et al.* (2000), which refers to a 1996 survey on pig units with more than 100 pigs in England and Wales. However, our sectoral survey identified higher participation of earth banked lagoons and circular tanks and, conversely, lower use of below ground type structures. This possibly reflects the fact that lagoons are more frequently used in the relatively large scale pig units involved in our survey, whereas below ground tanks are possibly best suited for units not handling great volumes of slurry.

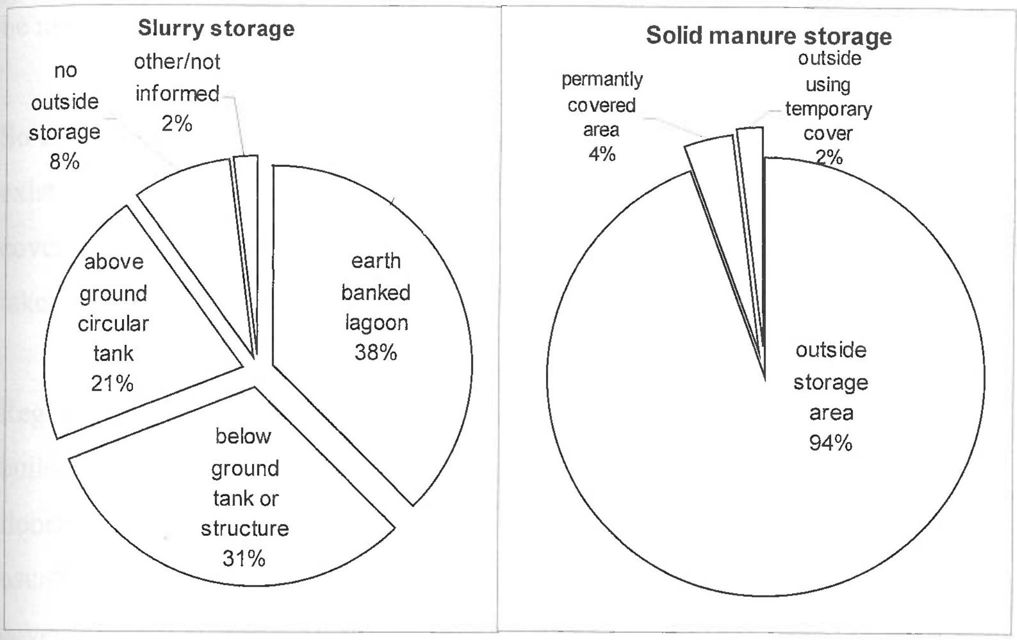

Figure 5. 5 - Storage facilities for slurry and farmyard manure, % of total
Source: questionnaire survey

There was association between type of specialisation of herd and type of slurry storage. Earth-banked lagoon seem to be linked to breeding-and-feeding units whereas below ground tanks or structures are associated with breeding-only herds. Appendices 5.4 and 5.5 contain cross tabs and statistical tests supporting these assertions.

Discussion with specialists and farmers suggested that slurry stores are as a rule uncovered structures, independently of their type. Therefore, the sectoral survey did not asked whether or not slurry stores were covered. One of the respondents (out of 109 installations reporting slurry stores) did report slurry storage under a covered area.

Lagoons are difficult to cover as they have a relatively large surface area compared to tanks (generally deeper, thus having more volume capacity per surface area) and no rigid structure to fix cover materials (Williams and Negri, 2000; Scotford and Williams, 2001). Floating covers are possible alternatives but more sound evidence is required of their applicability at a commercial level (I. Scotford, pers. comm.). Notwithstanding, more than half (52%) of the respondents reportedly use tanks, either above or below ground, which means the implementation of mandatory coverage of slurry stores could be more practicable for them than for those having lagoons.

So far, the case studies evidence suggests that is more feasible the replacement of existing large surface lagoons by other new structures with reduced open area than covering them. Substantial compliance costs are involved whichever the option is taken, based on the estimated costs for the case study units.

Regarding solid manure, storage is mostly outside. External areas close to the pig buildings, uncovered and without any or very little structural work such as concrete flooring, are commonly used to store manure removed from the animal housings, usually piled up to form heaps or stacks. Only 4% reported roofed (permanently covered) areas for storage and as little as 2% had temporary covering for storage of solid manure.

Often a pig unit will have both types of organic waste, slurry and manure, as different production phases may comprise different housing and waste handling systems. Also the way by which waste is handled produces more than one type of manure. For instance, solid manure usually produces effluent, especially if it is exposed to rainfall as occurs in outside storage, which need to be stored (adding to dirty water from yards) as slurry. Conversely, slurry pumped from the reception pit underneath animal housing often requires partial removal of solid content before entering the lagoon or tank. This mechanically separated fraction of the slurry is handled as solid manure.

Most of respondents (75) reported existing capacity for storage of slurry in terms of a period of time to full capacity, which was on average five months (mode two months). As shown in Figure 5.6, the majority of pig producers have storage capacity between 2 and 6 months. 15 informants provided volume of stores, with average capacity of about 6,500 cubic metres (m^3) for slurry storage.

Solid manure is considered to have unlimited storage capacity in an outside storage (basically it only needs a fraction of land). So it does not make sense to refer to this capacity in terms of volumes of solid manure stored, being more appropriate to determine length of time (months here) required to full the storage yard. A substantial part of the units have storage capacity for solid manure equal to or greater than 12 months (Figure 5.6).

Treatment of manures is not common practice in the pig installations surveyed. Only 18 units (15% of respondents) reported treatment for slurry or solid manure. Mostly, treatment was mechanical separation of solids of slurry (14 of the respondents), which involves reduction of solid content by separation using sieves of major granules, mainly to avoid blockage of pipes used for transport and distribution systems for liquid manure. Only 4 units informed composting and 1 reported doing some aerobic treatment of manure.

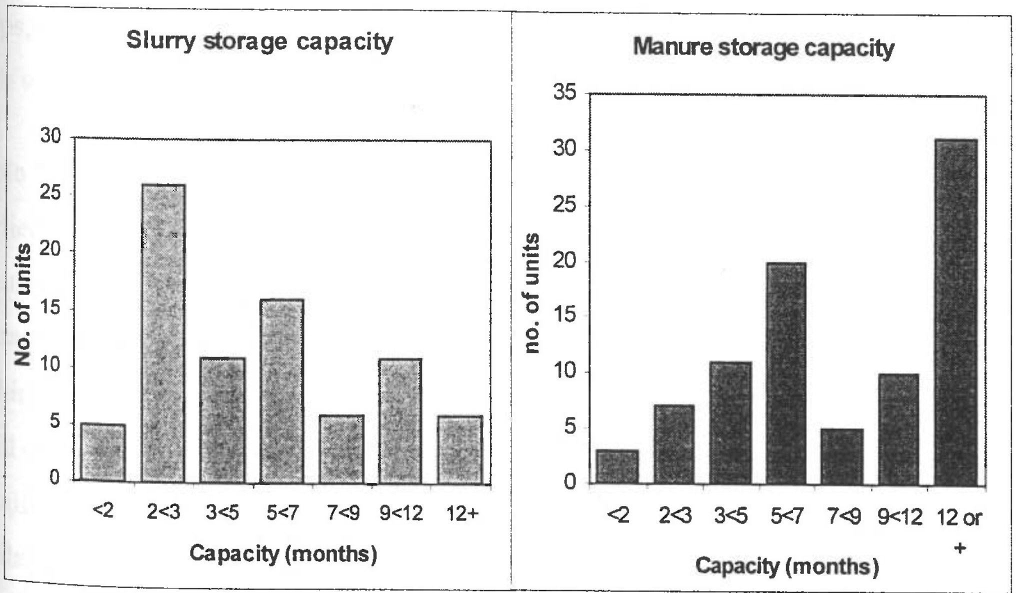

Figure 5. 6 - Storage capacity of slurry and FYM in months

Disposal of manures through landspreading

The results from the case studies suggest that the costs of compliance associated with incorporation of manures into soil can be substantial, especially because incorporation has to be done as quickly as possible to reduce emissions (within 6 hr for slurry and 24 hr for FYM).

The great majority of the units (86%) declared disposal of manures by spreading them onto their own land (owned or managed by the pig operator). Also, 37% make use of third party land for disposal of animal waste. These results suggest that, first, in general, pig units are integrated with other on farm enterprises as far as waste management is concerned and, second, the management of animal wastes (disposal of manures) is a shared operation between the pig enterprise and other enterprises such as arable crops. It can be inferred from the latter that the pig unit may obtain advantages of scale on the use of machinery and equipment such as tractor and cultivation equipment. Integration of enterprises or agricultural systems is one crucial aspect to realise the potential benefits of using by-products from one system (animal waste from livestock) as an input to another system (fertiliser for crops and pastures). Based on the results of the case studies there are potential financial benefits of use of manures in crops, which could to some extent reduce or even cover completely the costs associated with waste management in the pig units.

Table 5.6 presents the average area available for landspreading of animal manures in the studied pig installations. Not all installations reported estimations of area and, in addition, some data have been discarded for calculation purposes as they were likely to contain errors (often by double counting of available spreading area for installations within the same farm holding or managed by the same operator). Thus, based on the valid data, the average area available for disposal of manures was of 211 hectares on installations declaring disposal of manures exclusively on own-farm land. The land available for spreading for installations declaring to spread manures exclusively onto third party land was of 240 ha on average. Finally, the average landspreading area for those installations declaring to use both on-farm and third party land was 330 ha. Interesting to note that for the latter group, the third party area was greater than the on-farm only area for spreading of manures.

Table 5. 6 - Average available area of land for spreading of manures

Type of spreading	No. of units	Available area in hectares(ha)		
		on-farm	third party	total
Only on-farm	60	211	-	211
Only on third party area	18	-	240	240
On-farm and third party	16	119	211	330

Source: questionnaire survey.

These data reveal that although most pig units rely on their own land for the disposal of animal manures, a considerable number of pig units make use of areas on other agricultural holdings to meet their land requirements for this operation. Also, they show that a considerable number of pig units depend exclusively of the land of third parties. This means these units would not benefit from the use of manures as fertiliser and, also important, they have to bear transaction costs related to the establishment and maintenance of agreements between pig operators and third parties for the use of land for spreading of manures.

There is association between type of system by specialisation of herd and use of third party land for disposal of manures, that is, breeding-and-feeding units tend to be associated with landspreading on third parties land (see cross tabs and Chi-square results in Appendix 5.6).

The average distance from the pig unit to the on-farm spreading area was 824 metres and 4.7 km for the third party land. These data suggest that cost of transport may be significantly higher for the disposal of manures undertaken off-farm.

Figure 5.7 shows that main systems used for transport and distribution of slurry involve tankers (55% of responses), with considerable use of umbilical hose and irrigation equipment. The distribution of slurry is mainly undertaken using broadcast spreaders (68% of responses) followed by band spreaders (16%). Slurry soil injectors, trailing shoe spreaders and irrigation systems presented similar frequency of use, that is, were reported for around 5% of respondents.

Rear discharge spreaders are dominant technique for disposal of FYM to land, being used by 88% of respondents, with the balance using a rotor- or side discharge spreader.

There appears to be an association between transport and distribution of slurry and FYM, type of herd and housing. That is, as shown in Appendix 5.7, transport of slurry using umbilical hose tends to be linked with breeding-and-feeding herds, which are relatively bigger and, therefore, manage considerable volume of animal waste. Significant association was also determined between the use of slurry tankers and broadcast spreaders (transport and distribution methods) and straw based housing systems for finishers (Appendices 5.8 and 5.9).

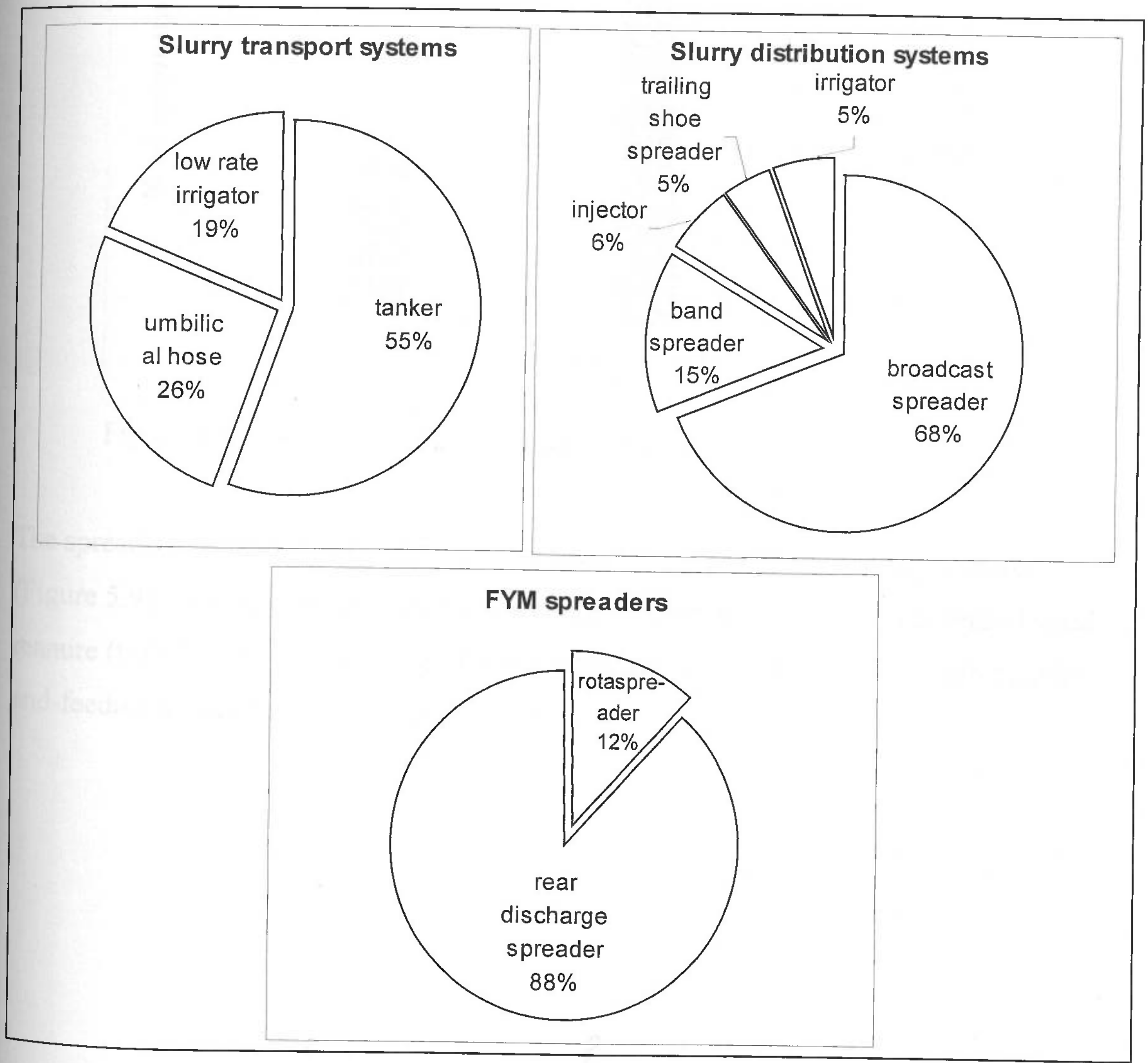

Figure 5. 7 - Slurry and FYM transport and distribution systems, % of respondents
Source: questionnaire survey.

After spreading, as shown in Figure 5.8, slurry and FYM involve very different management practices. Whereas 75% of respondents said FYM is incorporated, only 36% incorporated slurry after application. With respect to guidance on good practice, only 12% of respondents informed that slurry was incorporated within 6 hours from spreading, and 26% for FYM within 24 hours next to landspreading operation.

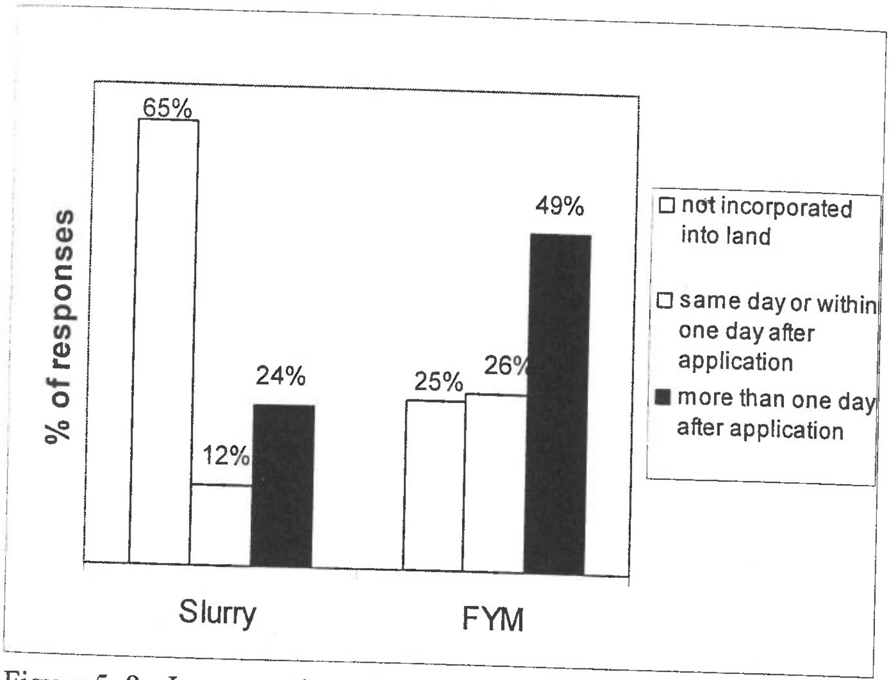

Figure 5. 8 - Incorporation of manures onto land

The spreading of manures to land is predominantly undertaken by the pig operator (Figure 5.9). It is also common to use contractors, especially for the spreading of solid manure (FYM). Use of contractors for spreading of slurries is associated with breeding-and-feeding units (Appendix 5.10).

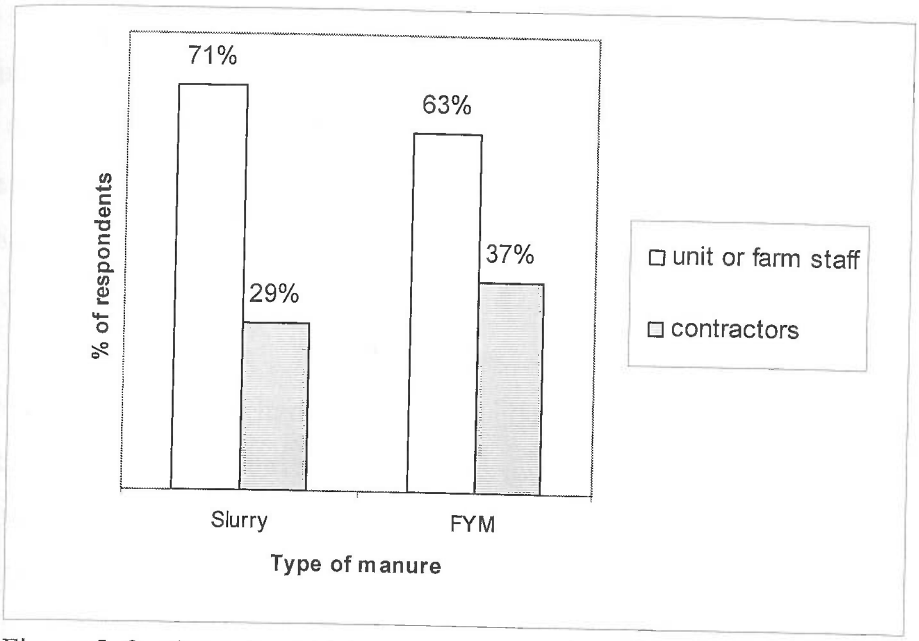

Figure 5. 9 - Operator and contractor spreading of slurry and FYM onto land

Respondents were asked to indicate the use of methods to calculate the quantity of slurry and FYM which is spread per area of land. This is important because the volume or tonnage of manures determines the total N applied per area of land (subject to a maximum of 250 kg N per ha per year). Around 50% of respondents said they use one or more techniques to calculate N in manures, as follows.

The slurry application rate is mainly based on the volume of slurry pumped by time (pump capacity, with 15% of responses) or control of volume of slurry inside the lagoon (14%). This means standard values (standard estimates of N per volume of slurry based on average nutrient content tables) are used to estimate N applied per area. Only 9% of respondents reported use of a slurry rapid N tester on farm. Also only two respondents reported use of a rainfall measurement and laboratory analysis to calibrate N application and consultation with a farm advisor.

Application rates of FYM are also almost exclusively based on estimates of tonnage (26%) by weighing loads of vehicles or volume of FYM heap (16%) and use of standard nutrient content tables.

There is little evidence that robust methods are used to assess the nutrient value, particularly of nitrogen, of manures applied to land. A waste approach to manures, rather than a resource-based one, is still dominant. However, exploring this issue with the managers of the case studies units suggest that there is increasing awareness of the potential value of manures as a source of nutrients for crops, and greater integration to the farm practices as a whole.

The predominance of rough methods for calculation of application rates of manures indicates that pig farmers have limited means to measure the contribution of manures as soil nutrients. In fact, there is indication that in the UK there is little difference in (bought) fertiliser input between fields where manures are applied and those not receiving manures (Smith and Chamber, 1995 quoted in Smith et al. 2000). Smith et al. (2000) suggest that a lack of confidence by farmers to rely on nutrients applied in manures, especially for N, is the main factor why they often do not significantly reduce the use of bought fertiliser following application of manures. There is a need for guidance on improving the assessment of the potential contribution of manures in supplying nutrients for plants, such as that contained in the advisory software MANNER[5] by ADAS (MAFF, 2000c).

According to the secondary information used to estimate costs for the case studies, low emission landspreading techniques such as slurry soil injection cost more per hectare and are operationally less flexible than broadcasting. However, a manager of one of the case study units referred that they moved from broadcasting plus incorporation to soil injection technique (done by contractors) and that no limitations were verified in terms of operating the technique for the whole area. Rather, the new technique enabled difficulties related to material handling to be overcome, for it does not need reduction of solids by a dry matter separator.

The above point illustrates well the difficulty of determining *ex ante* costs based on several assumptions and data sources. The agents tend to innovate and advantages not

[5] Manure Nitrogen Evaluation Routine (MANNER).

perceived before are generated. However, they are only perceived when the new technique is actually in place.

Disposal of carcasses

Figure 5.10 shows the methods used for disposal of carcasses in the pig units surveyed, as reported by the respondents.

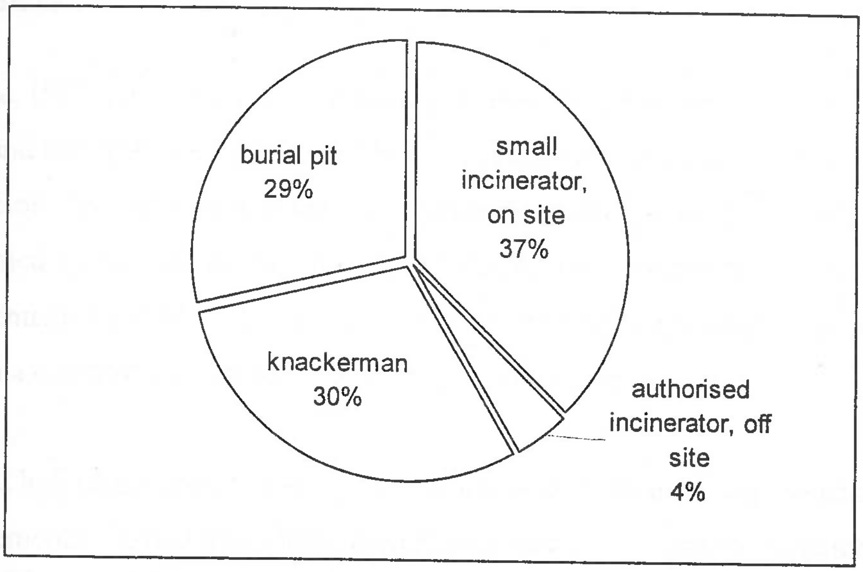

Figure 5. 10 - Disposal of pig carcasses (mortalities) in the pig units
% of responses
Source: questionnaire survey

The disposal of carcasses is predominantly carried out on-site, most commonly (37%) using a small incinerator (up to 50 kg per hour capacity). The other option for on site disposal of mortalities is the burial in a proper pit, reported by 29% of respondents.

Off site disposal of carcasses is mainly undertaken by knackermen (30%). Only a small percentage of respondents (4%) informed to contract an authorised incinerator.

5.1.5 Use of raw materials, water and energy

This section describes the use of feed, use and management of clean water and of energy in the pig units based on the questionnaire responses. Therefore, the characterisation of practices is focused on IPPC requirements, which intends to assess the readiness of pig units for the regulation.

Feed preparation and management

To date, IPPC requirements for feed refer to use of a minimum of two different diets for sows and two or three diets for finishers, which is already predominant practice in the pig sector. As feed cost accounts for a major proportion of the total production cost, as confirmed by the case studies, there is little scope for very prescriptive feed requirements by IPPC to be applied to the current feeding regimes. Feeding tend to remain a commercially driven feature of pig production.

Around half of the units (51%) use home-mix feed. Home mixing foodstuffs involves two elements relevant to an IPPC permit, as follows. First, on the resource consumption side, it involves a relatively higher energy input (on farm) associated to milling, mixing and conveyance equipment (see case studies). Second, on the emissions side, home mixer units are more likely to generate nuisance by noise with operation of the above described equipment, and to produce dust.

Preparation of swill within the premises was only reported by one respondent. The preparation of swills can be source of odours and cause nuisance problems. Following the foot-and-mouth disease outbreak in 2001, the government imposed tighter regulations on use of swills as feed for livestock.

The great majority of respondents (75%) reported the use of multiple diets for pigs. This confirms that the use of different diets, which vary in content, especially for protein, according to the production phase where pigs are in, is a commercially driven phenomenon. It is important to bear in mind that it is not the same as having multiple phase feeding regimes, which is still a novel feeding management technique.

Water use and management

About 58% of respondents reported water supply by mains (an additional 9% reported mixed mains plus abstraction), which suggest that permitting tariffs apply to the use of this resource. Therefore, no misuse is rationally expected as water is a priced resource. The common practice of several measures identified in the sectoral survey confirm the results from the case study analysis suggesting that there is limited scope for improvement in the use of clean water. Therefore, IPPC is unlikely to determine a major change in the use of this resource.

Figure 5.11 shows the participation of different sources of supply of clean water according to the respondents of the sectoral survey. Predominantly clean water is supplied from mains (58%), or by a combination of mains and groundwater abstraction (9%). However, a substantial part of the respondents (32%) informed to rely on the abstraction of groundwater for water supply of their pig units.

Usually there is no measurement of water use against individual operations in the pig units surveyed. Only 14% of respondents indicated to have in place water meters for monitoring of consumption of activities such as cleaning and washing pens or drinking water for livestock.

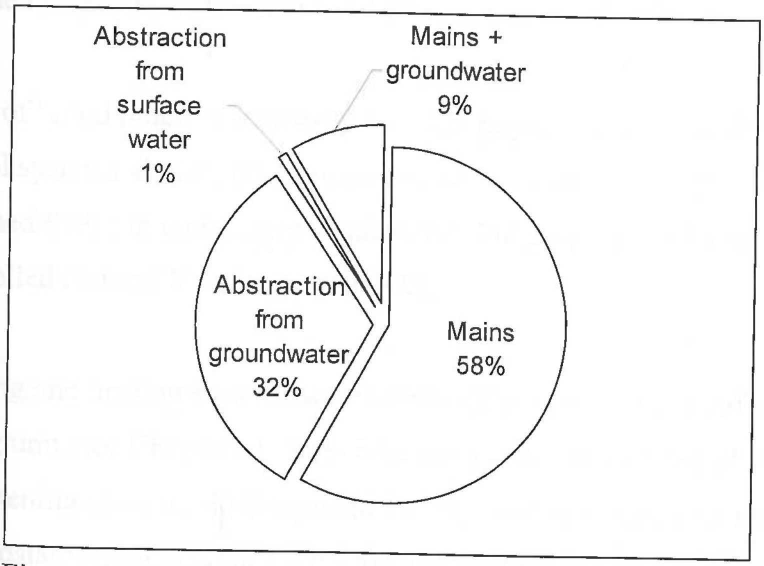

Figure 5. 11 - Clean water supply by source, % of responses
Source: questionnaire survey.

Respondents were also asked to report on equipment and practices which are regarded as good practice in the use of water. Some of them are already predominant practices, such as use of high pressure washers (for cleaning of pens) and byte type drinkers, which were reported by respectively 93% and 92% of respondents. Also practices such as scraping or scrubbing floor and walls before the washing down of pens and yards, and covering tanks and reservoirs of clean water (to avoid evaporation) are significantly disseminated in the sector (both were verified in 44% of the responses). However there is scope for diffusion of other simple measures such as fitting hose use trigger nozzles, which were reported by only 24% of respondents. Additionally, 8% of respondents informed collection and storage of rainwater for washing and 3% reported re-use of dirty water in flushing systems of slurry pit.

Clean rainwater from roofs is separated from the dirty water systems and run-off from yards in the pig units according to 76% of respondents.

Use and management of energy

Most of the respondents (84%) reported not having separate metering for electricity in the pig unit, which suggests a poor level of monitoring of the energy consumption. However, the sectoral survey identified the use of measures and equipment which are regarded as good practice on use of energy, presented as follows.

Some of 'good practice on energy use' techniques are associated to environmental control systems already predominant in the pig units. Thus, 77% of respondents informed their pig units apply insulation of buildings and 57% use Automatically Controlled Natural Ventilation (ACNV).

Lighting and heating systems were identified as major sources of energy consumption in the pig unit (see Chapter 4). 64% of respondents reported use of independent switching of lightening systems, 46% reported having heating systems controlled automatically (thermostats and timers) and 37% the use of piglets creep lamps fitted with dimmers. In addition, 36% of respondents reported use of low energy consumption lamps and 16% energy efficient motors and equipment.

The majority of respondents reported regular checking and servicing of machinery and equipment (74%). Also, 12% reported training for drivers and equipment operators on how to economise fuel. Buying premixed feed was reported by 37% of respondents as an energy saving measure. Only 2% of respondents did not identify any energy saving techniques in their units.

The cost of energy and water, based on estimated values from case study units, did not have a substantial impact on total pig production cost. Therefore, comprehensive review of use of these resources in the pig unit has a limited scope in terms of substantially change the way they are being used. However, energy and water costs tend to increase and it could promote the use of measures to reduce the use of these resources. Also, an IPPC permitted installation may benefit from reduced costs of other compliance requirements, such as the relief of 80% of charges for energy use under the Climate Change Levy Agreement (CCLA).

5.1 6 Management and Training in pig units

Evidence of the case studies suggests that management systems in place in the pig units can be used to help compliance with IPPC. The sectoral survey assessed the existence of management systems and training as indicators of the level of readiness to adopt the monitoring and control measures required under the IPPC regime.

Membership to assurance schemes

Virtually all respondents (95%) reported membership of a pig production assurance scheme[6], predominantly Assured British Pigs (AB Pigs), comprising 90% of pig units. 11% of units also reported (including some of members of AB Pigs) auditing by the Royal Society for Protection of Cruelty to Animals (RSPCA). One of the respondents

[6] The term 'pig production' was used because assurance schemes for pigs can involve 'quality assurance' (focus on pig meat), 'pig farming assurance' (how pigs are reared) or, more comprehensively, both of them (FAWC, 2001).

declared to be an organic producer for the Soil Association (possibly part of the installation only, as organic pig production applies to outdoor systems).

In addition, 59% of respondents reported that the farm where the pig installations is located also follows other farm assurance schemes. The most frequent responses identified the Assured Combinable Crop Scheme (ACCS) and Linking Environment and Farming (LEAF) Audit, with respectively 17% and 11% of total responses. Two respondents informed organic production (not specified for which product).

It appears that the majority of pig installations and associated farms follow quality and farming assurance schemes. It can be inferred that there are associated management systems in place to guarantee 'certification' and therefore a substantial part of the requirements of monitoring and control of operations by IPPC are likely to be in place.

Training

Respondents were asked to report about involvement of staff (managers and stockman) in training activities in the previous two years (Table 5.7).

Table 5. 7 – Issues and type of training activities in the pig holdings according to respondents

Training issue	Number of responses*				hours	Certification
	In service	Outside	Total**	% of total	**	given
General farm management	6	6	18	24%	15	5
Emergency plan and risk management	7	5	20	27%	3	2
Health and safety	6	12	28	37%	8	7
Pig husbandry	7	12	27	36%	7	9
Animal welfare	13	10	34	45%	2	11
Good agricultural practices	7	3	18	24%	3	5

Notes: * here responses refer to holding level (75) and not for each installation; **includes responses non specifying venue of training; and, *** hours refer to average duration informed by respondents.
Source: questionnaire survey.

Table 5.7 shows that the training issues reported by respondents predominantly focus on pig production (animal welfare and pig husbandry). However, training on subjects linked to safety of staff and how to act in emergency situations were reported by a substantial part of the respondents. Also about 24% of respondents informed training related to general management of farm and on good agricultural practices.

There is an association between training issues and type of systems by herd specialisation. Pig units involving breeding phase, namely breeding-and-feeding and breeding-only units are, are associated with greater participation in training in general farm management, risk management and health and safety (Appendices 5.11 to 5.13)

The training activities were carried out similarly in service and outside the units, according to the respondents. Only a minor part of the training awarded a certificate.

5.1.7 Awareness and perceptions of operators on environmental issues and IPPC

Respondents were asked about the perceived relevance they attribute to a series of environmental issues associated to indoor pig production, in a scale from zero (not relevant at all) to great (very relevant).

Table 5.8 presents the mean ranks obtained from statistical analysis of the responses using the Friedman test. This shows that in the opinion of the pig operators, emission of pollutants to water is the most relevant environmental issue associated with indoor pig production, followed by emission of pollution to land and nuisance by odours.

There is no statistical difference in the ranks for the next four issues, which suggest a similar relevance is attributed by respondents to the use of energy and clean water, emission of ammonia and use of raw materials. Nuisance caused by noise was ranked as the least relevant issue.

Although other pieces of legislation are addressing control of pollution from agriculture, it is interesting to point out that the IPPC focus on ammonia is somehow disconnected from the main issues from the point of view of pig operators. This can be partially attributed to the relatively low level of knowledge of operators about IPPC (in their own view). This is reinforced by the fact that the issues and impacts foreseen by respondents are divergent of the evidence given by case studies. That is, whereas the monitoring and record keeping activities were identified by respondents as those with the greatest perceived impact for their units, the results from the case studies suggest that compliance with BAT for housing and waste management is the element of major impact.

Table 5. 8 - Key environmental issues of indoor pig production according to operators

Environmental issue	**Mean Rank**[a]	Relative position
Emission of pollutants to water	6.15	1
Emissions of pollutants to land	5.24	2
Nuisance by odours	4.89	3
Use of energy	4.44	4
Use of clean water	4.44	4
Emission of ammonia	4.27	4
Use of raw materials	4.25	4
Nuisance by noise	2.32	8

Note: a) Friedman Test (Test Statistics:N = 65, Chi-Square = 113.601, df = 7 and Asymp. Sig = 0.000).

Figure 5.12 presents the frequency of responses for the current level of knowledge on IPPC. This shows that the majority of respondents at the time of the survey felt

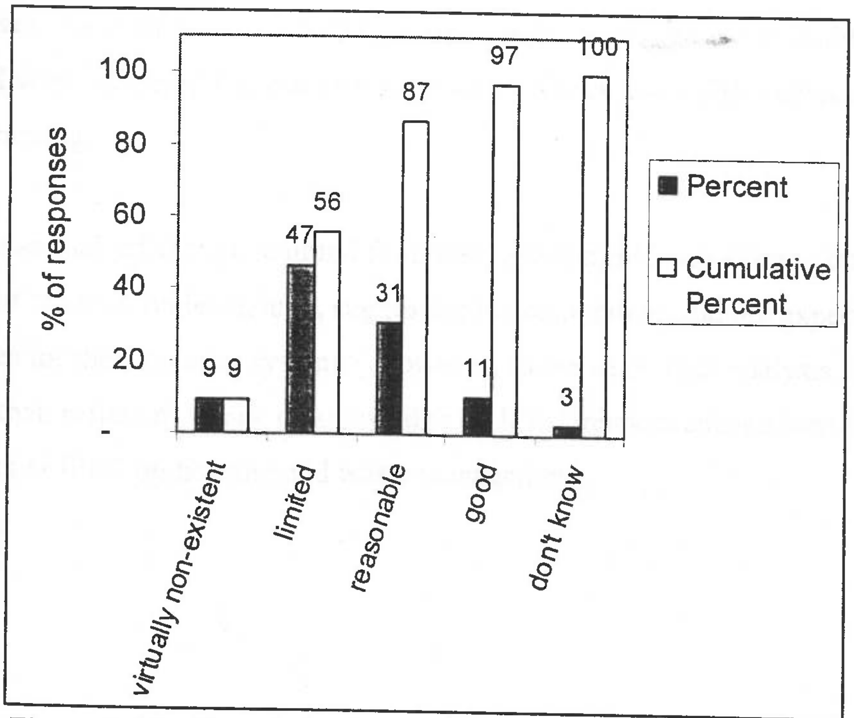

Figure 5. 12 - Knowledge level of respondents on IPPC

uninformed about IPPC; 56% said their level of knowledge was virtually non-existent or limited. Only 11% felt they were well informed on IPPC.

Table 5.9 presents the mean ranks obtained from statistical analysis (Friedman test) for the responses related to the expected level of change associated to the current to operation and management of the pig unit with the IPPC regime.

Table 5. 9 - Degree of change required for specific activities with IPPC

Activity	Mean score[a]	Relative position
Planning, Control and record keeping	3.30	1
Animal waste storage	3.21	1
Disposal of animal wastes	3.17	1
Staff training	3.05	1
Housing	2.27	5

Note: a) Friedman Test (Test Statistics: N = 75, Chi-Square =35.052, df = 4, Asymp. Sig.= 0.000)

Table 5.9 shows that pig operators identified activities of planning, control and record keeping as those were major change would be required for compliance with IPPC. However, the mean rank estimated for this variable is similar to those obtained for animal waste storage, disposal of animal waste (slurry and FYM landspreading) and for staff training.

The mean rank of change required for housing was significantly lower than the mean ranks of other activities though, suggesting the respondents did not expect major changes for their housing systems. However, as the case study analysis shows, it is likely that, reflecting a lack of knowledge on IPPC, respondents underestimate the impacts of IPPC on housing and waste management.

5.1.8 Summary of main issues analysed in the sectoral survey

The main results based on the responses to the sectoral survey and their interpretation are presented as follows.

Breeding-and-feeding units are more likely to be affected by IPPC than specialised units (breeding-only and feeding-only).

Some 60% of building were already built by 1980 and only 25% were less than ten years old, being completely or to a great extent, written-off.

The characterisation of predominant housing systems indicated that particularly for the finishing phase, the sector is far from complying with BAT.

Great uncertainty remains on the definitive acceptance or not of straw based systems as BAT at European Union level.

There is the risk that imposing replacement of predominant housing systems will force a substantial proportion of pig producers out of business because they are not prepared or capable of making the necessary capital investments. In that case IPPC would have a great impact of IPPC on the pig industry as a whole. Straw based systems are associated with feeding-only units, whereas slatted floor systems seems to be associated with breeding-and-feeding units.

Recent structural change in the pig industry is associated with: the conversion of sow accommodation to group housing, straw based systems, and, the conversion of solid floor (no straw) and solid dung passage housing for finishers towards straw based systems. Secondary data suggest that for new installations, the additional costs of abatement measures for this system, or of alternative BAT for housing, are negligible. Adapting existing installations to BAT, however, is more of a challenge.

As for housing, the predominant practices for storage and landspreading of manures reported by respondents to the sectoral survey are not BAT.

The slurries are mainly stored in earth-banked lagoons and below ground tanks. It is technically difficult and expensive, as required by IPPC, to cover slurry stores, especially lagoons.

A substantial proportion of operators used land of third parties for the spreading of manures.

There is little evidence that robust methods are used to assess nutrients, particularly nitrogen, in manures applied to land. A waste approach to manures, rather than a resource-based one, is still dominant.

Use of multiple diets for pigs is common practice in the sector. There is little scope for very prescriptive feed requirements by IPPC to be applied to the current feeding regimes, as feeding tend to remain a commercially driven feature of pig production.

Although the review of use of clean water and energy in the pig units indicated that there is limited scope for change in their use, the fact that their costs tend to increase can promote the use of measures to reduce the use of these resources.

The expansion of current NVZs in England could affect considerably the costs of disposal of manures.

The great majority of pig units, according to the respondents of the sectoral survey, were operating under a quality assurance scheme for pigs.

The most relevant environmental issues related to indoor pig production appear to be, in order of importance, emissions of pollutants to water, emissions of pollutants to land and nuisance cause by odours.

Operators perceive a relatively low level of knowledge about IPPC. The issues and impacts foreseen by respondents are divergent of the evidence given by case studies.

5.2 WORKSHOP ON PRELIMINARY RESULTS OF THIS RESEARCH

A workshop was held at Cranfield University at Silsoe on *IPPC Directive and the Pig Industry in England and Wales*, to discuss the preliminary findings of the case studies and sectoral survey with key stakeholders, namely producers, trade associations, regulators and researchers. The workshop objectives and schedule are described in section 3.6. The report of the workshop circulated among the participants after the event, including the list of participants, is provided in Annex 5.1.

Drawing on the outputs of the research reported above, the workshop identified major areas of concern and uncertainty, implications for business operations and strategy and possible actions to be taken by stakeholders. These are discussed in turn.

Stakeholder perceptions of key issues and uncertainties

On the issues and uncertainties associated with IPPC identified by stakeholders in the workshop (Table 5.10) the main points are as follows.

Producers found the comprehensiveness and detail of the IPPC regime 'frightening' in terms of the cost of compliance and the management burden, and that pig units already operate under a regulatory framework relating to health and safety, environment and animal welfare which have implications for costs and management practices.

Producers said that there are too many unknowns at this stage with respect to the IPPC requirements and therefore it was difficult to make informed judgements. They also questioned the benefit:cost aspect of IPPC applied to the pig sector, and questioned whether the application of IPPC would meet the principle of proportionality. Moreover, IPPC is likely to render pig units financially non-viable.

Table 5. 10 - Summary of the discussion of IPPC impact in the pig industry with key stakeholders

Stakeholders perceptions of key IPPC issues and uncertainties	**Implications of IPPC for Operations and Business Strategy**	**Action Points for IPPC and pigs**
• Significant *compliance costs* and management burden are likely to arise with the IPPC regime • Several *unknowns* remain in respect to environmental and financial performance of BAT • There are *uncertainties* on whether IPPC will deliver environmental benefits at a reasonable cost (proportionality) • *Definition of BAT*: not clear yet (see above 'unknowns') and dynamic nature of concept • *Financial viability*: difficulty to absorb financial impacts in a sector on the borderline of profitability • Performance criteria of measures are almost exclusively dependent on *ammonia* emissions • *Straw based systems* are dominant and non-BAT • *UK representation*: needed to balance the BAT 'bias' towards EU continental pig systems • *Structures and attitudes*: fragmentation of interests in the industry and a in general negative reaction towards IPPC • *Learning process* for all relevant stakeholders is expected for a newly regulated sector • *Environmental assessments* for other purposes such as planning are not appropriate for IPPC • Developing an approach towards *value of manures* is dependent on local circumstances; producers said it tends to remain a *waste* approach instead of *resource* one • *Environmental Standard*: there is no environmental auditing system at present for pig production	• *Increased costs:* producers predicted that production costs will increase due to compliance with IPPC, affecting their competitiveness, • *Affordability* is questioned • Difficulty to make informed judgements and *decisions* • *Structural adjustment* scaling down of existing pig installations Restructuring existing installations into smaller ones could result in efficiency losses and offset expected benefits of avoiding compliance costs • *Convergence and common practices:* stakeholders confirmed that for systems above the IPPC thresholds, it is likely that IPPC will force convergence in production and management systems as defined by BAT and SFIR • *Alternative systems:* IPPC could encourage a more strategic approach to pig production, which might include significant changes not only in production systems, but also perceptions about what is feasible or desirable	• *Engaging:* pig sector representatives must continue to engage in the process by which IPPC is implementation, particularly in definition of BAT and SFIR • *Reviewing needs:* producer organisations should undertake a review of producer needs with respect to IPPC adoption • *Creating awareness:* producer awareness and understanding must be enhanced to help the industry prepare itself for IPPC adoption • *Communications:* a communication and promotion strategy will be needed to support the IPPC process • *Extension:* advice and practical demonstration of BAT/SFIR will be needed to support producers. • *Research and Development:* targeted research and development is needed to support the UK IPPC process for the pig sector, especially: the environmental (and related business) performance of existing systems; the identification and comparative analysis of UK relevant candidate BAT and SFIR, especially regarding housing and waste management (such as straw based systems and lagoon covers); and, alternative production systems for indoor pigs. • *Environmental Management Systems:* the feasibility and acceptability of an accredited environmental management system for pig producers should be explored.

Source: report on the workshop *IPPC and pig industry in England and Wales*, Cranfield University at Silsoe, 17th January 2002.

Pig producers perceive that BAT is being biased towards continental pig rearing systems, reflecting a relatively well organised lobby by interests in EU member states, leaving UK systems under-represented. Partially this situation is caused by the fragmentation of interests in the UK pig industry, and a reactive attitude towards environmental regulation perhaps reflects a broader pessimism in the sector as a whole. Straw based systems, which are predominant in UK, were not regarded as BAT, which could represent a major impact on the industry.

It was strongly felt that so far, candidate BAT appear to almost exclusively focused on ammonia emissions, and questions were raised on whether IPPC is effectively delivering an integrated approach to environmental protection.

It was pointed out that the initial phase of IPPC implementation clearly involves a learning process for all relevant stakeholders, requiring a degree of flexibility on the part of regulator and the regulated for the newly regulated industries such as the pig industry.

Regulators argued that pig manures should be regarded as a potential resource with a value as an agricultural nutrient rather than a waste product with no value to be disposed of, however the view that pig manure is a by-product to be got rid of at least cost is still dominant.

Stakeholders remarked that the pig sector did not have, or had not adopted, the equivalent of a LEAF type externally accredited environmental auditing scheme, which could be an efficient, industry regulated means of demonstrating a high standard of environmental management and a commitment to improvement.

Implications for Operations and Business Strategy

The main points expressed by stakeholders on operations and business strategy as IPPC is concerned (Table 5.10) are as follows.

Producers predicted that production costs will increase due to compliance with IPPC, but that they would not be able to recoup these through any increase in the producer pigmeat price. It was appreciated that IPPC has major relevance to business strategy as it affects operating costs, determines investment in housing and waste management, and defines the competitiveness of the business.

Producers thought that industry representative organisations should assess the value of advising pig producers to try to avoid IPPC regulation by adjusting the size of their units to below the IPPC thresholds, through the scaling down of existing pig installations. However, it was discussed that if this was a common practice, the regulator might respond with modifications to the threshold limits. The point was raised that restructuring existing installations into smaller ones could result in efficiency losses and offset expected benefits of avoiding compliance costs.

Stakeholders confirmed that for systems above the IPPC thresholds, it is likely that IPPC will force convergence in production and management systems as defined by BAT and SFIR, so that there is likely to be less variation in large scale units than at present. Below threshold installations will continue to demonstrate greater variety in practices.

IPPC could encourage a more strategic approach to pig production, which might include significant changes not only in production systems, but also perceptions about what is feasible or desirable. A re-examination of pig production processes, including dietary systems, under UK conditions could identify alternative strategies for pig producers. These changes might be encouraged by other legislative and market drivers.

Action Points

The action points on IPPC identified by participants of workshop (Table 5.10) are discussed as follows.

Pig sector representatives must continue to engage in the process by which BAT and SFIR are defined. Also, producer organisations should undertake a review of producer needs with respect to IPPC adoption, informing the need for research, development, demonstration and advice.

Producer awareness and understanding must be enhanced to help the industry prepare itself for IPPC adoption, especially as the regulation will have critical implications for business management and strategy. Communication and promotion strategy will be needed to support the IPPC process, working through producer organisations. Appropriate messages and communication channels need to be identified to meet producer needs. The need for workshops, conferences and training courses requires to be assessed. A targeted IPPC support service, web based answering frequently asked questions, and listing sources of information and help, including advisors and consultants. Advice and practical demonstration of BAT/SFIR will be needed to support producers.

Research and Development: targeted research and development is needed to support the UK IPPC process for the pig sector. Main themes are referred to in Table 5.10.

The feasibility and acceptability of an accredited environmental management system for pig producers should be explored. This could support the IPPC permitting process as well as quality assurance for the product and its supply chain. Such a scheme would constitute a significant strategic response by the industry. Experience in other small/medium business sectors with respect to business response to environmental regulation should be drawn on. This has included business networks and clubs to help the adoption of cleaner technology and share good practice which can exploit potential business advantage.

Outcomes of the workshop

The results of research confirmed that straw based systems for finishing housing are widespread, but were not regarded as BAT at the time. The workshop drew the attention of stakeholders to the issue and action was taken in form of political pressure by the UK representatives on the Technical Working Group (TWG) responsible for the elaboration of the BREF Note for intensive rearing of pigs to accommodate straw based systems for finishers in the forthcoming BREF. DEFRA has ongoing projects for BAT solutions in existing housing and specifically on the performance of straw based systems.

5.3 Summary and conclusion of the chapter

This chapter has reported on the sectoral survey on large pig producers and a workshop with key stakeholders, with a view to verifying and extrapolating the findings of the case studies to industry level.

IPPC impacts are likely to have relatively greater effect on breeding-and-feeding pig units than specialised (breeding-only or feeding-only) either because their relatively larger scale or by being captured by IPPC thresholds for finishing pigs even though keeping 400 sows or less. Straw based systems account for a substantial share of finishing pigs, but there is still uncertainty on whether or not they are accepted as BAT. Broadly, large pig units in England and Wales are far from compliant with requirements for BAT. This is particularly concerning as most of the respondents reported low degree of awareness on IPPC and associated issues. This also explains the negative reaction of the regulated parties to IPPC, as explored in the workshop. In a sector on the borderline of profitability, timing is not favourable for negotiation of compliance, as the requirements are mainly perceived in terms of their cost implications.

The next chapter presents a summary of the research survey and the conclusions and recommendations that can be drawn from it.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

Following a summary of the whole research process, this chapter presents the conclusions set against the research questions of the study. In addition, drawing on the conclusions and research outputs, recommendations on future work and prospects for IPPC and the pig sector are discussed.

6.1 SUMMARY

The IPPC Directive regulates economic activities which use or impact on natural resources and the environment, and is an important element of the EU strategy of sustainable development. IPPC extends integrated environmental regulation to a range of activities not previously regulated, including the intensive rearing of pigs, where it applies to installations with more than 2,000 fattening pigs or 750 places for breeding sows. The Directive is in force in England and Wales from August 2000 and the whole pig industry will be phased in by 2007. The principles of the IPPC Directive have their origins in the environmental regulation of the manufacturing and processing industries and its application to the agricultural sector justifies particular attention and support. Although the application of the IPPC Directive to the pig sector is justified in terms of reducing environmental risks, it is likely to have important economic implications in terms of costs for the industry. However, to meet the required proportionality criteria, the regulatory burden imposed on industry should be in proportion with the environmental risks to be controlled. It is difficult to determine the 'correct' degree of regulation for the newly regulated sectors until the environmental risks and the costs and benefits of regulation have been ascertained.

In this context, the broad aim of this research was to develop an analytical framework for assessing the economic and environmental impacts of the implementation of the IPPC Directive in the pig sector in England and Wales to inform policy management.

This research was driven by a number of research questions (RQ), posed in Chapter 1. In order to address the research questions, a framework for the assessment of IPPC was developed and applied to selected case study pig installations. The analysis used regulatory impact assessment as a theoretical background, incorporating environmental impact assessment, cost effectiveness analysis and the use of performance indicators. Also, stakeholder analysis was employed to provide an overview of actors and interests involved with policy implementation. Thus, the process of the implementation of IPPC to the pig industry was analysed focusing on its potential environmental and financial impacts, based on the use of emerging Best Available Techniques (BAT) and the requirements of the standard permit conditions applying to England and Wales. In essence, the research involved an exploratory appraisal of sectoral impacts of the IPPC environmental regulation, using the pig sector as it focus. The research outcomes reflect the *ex ante* nature of the analysis.

An assessment framework was simultaneously developed and applied to three case study pig installations (Chapters 3 and 4). These case studies were selected to represent predominant pig production systems in England and Wales, based on the key factors which differentiate performance of pig installations as far IPPC is concerned, namely: specialisation of the pig herd, type of animal housing, and waste management. A detailed flow of inputs and outputs was obtained for every case study unit. This physical flow comprised data on: use of materials, water and energy, animal stock and movements, production of wastes, labour and management requirements, type, capacity and condition of pig housing and other buildings, waste storage facilities and related machinery and equipment. Also ammonia emissions were estimated based on standard emissions for housing and waste management systems present in the case units. The representation of physical flows in the framework enabled an overview of the main links between input, components (processes) and outputs of pig installations. A corresponding financial flow was generated, identifying, on an annual basis, costs and revenues associated with pig production in the case study units. In addition, the condition of the sites where the pig installations were located was assessed with particular reference to the existence and proximity of environmentally sensitive receptors, predominant soil type, land use, and on-farm and off-farm availability of land areas for animal waste spreading. These two elements, physical and financial description of the actual pig production system and the characteristics of the site where the pig installation is located, provided the empirical evidence for interpretation of current environmental and financial performance of the case study pig units and a realistic basis for simulating the likely impacts of IPPC compliance at the level of typical production units.

Once the baseline situation was constituted, IPPC requirements were simulated for each of the case study units. These requirements were defined according to the Environment Agency's Standard Farming Installation Rules and Guidance (SFIR), which defines the standard conditions for an IPPC permit in England and Wales, and on the draft technical guidance on the Best Available Techniques (BREF Note) for intensive rearing of pigs by the European Commission's IPPC Bureau. In addition to general rules, if appropriate, BAT options (which were candidate BAT at the time of the study) were selected for application to the case study units, involving measures for housing and waste storage and disposal. These candidate BAT focused on abatement of ammonia emission. Simulating BAT consisted of assessing the impact of candidate BAT on the financial and environmental performance of the units compared to that obtained under the baseline situation. Information on candidate BAT was drawn from secondary data sources, mainly collated in the draft BREF Note. The framework of assessment was re-applied and comparison between the baseline and 'with-IPPC' situation, for various BAT options, was supported by a series of financial and environmental performance indicators.

Estimated compliance costs and abatement levels enabled the cost effectiveness of BAT options to be obtained for the case study units. The impact of BAT adoption and IPPC compliance on annual income and expenditure was determined, and a measure of affordability obtained. The latter was defined in terms of the ability of the case study units to absorb the additional financial burden of IPPC compliance and still retain a satisfactory return to management and investment. Additionally, sensitivity analysis was carried out for factors likely to determine substantial change in results. The potential financial benefits of the use of manures as fertiliser were also estimated.

The validity of the predictions of IPPC impacts based on case study units for the pig industry as a whole was assessed by means of a sectoral survey of pig producers and a workshop with key stakeholders (chapter 5).

The questionnaire design reflected the contents of the application for an IPPC permit and the emerging issues and results from the case studies at the time. This questionnaire was sent by post to large, indoor pig production units likely to be captured by IPPC within the National Pig Association (NPA) membership in England and Wales. The sectoral survey sought information on circumstances and practices in the sector, covering site specific conditions (installation and surroundings), management of energy, water and waste, readiness of units for IPPC in terms of good practices, training and management. Perceptions of operators on IPPC regulation and environmental issues involved with intensive pig production were also explored. The response covered a total of 117 pig installations.

A workshop was organised to present and discuss the preliminary results of case studies and sectoral survey with key stakeholders. The researchers, regulators and operators and their representatives attending the workshop contributed qualitatively to this research by identifying relevant IPPC issues according to their different perspectives and interests. Moreover, the workshop provided an opportunity for the scrutiny of the preliminary findings of research. Corroborating or challenging the results, the comments from this workshop helped to identify issues and factors requiring further attention.

Throughout the research programme, the researcher participated in the industry Steering Group on IPPC for the pig sector, and actively contributed to the consultation process for IPPC regulation and supporting BREF with respect to pigs.

The research coincided with a difficult period for the pig sector, not only regarding a deteriorating business environment, but also one containing the most severe epidemic of Foot and Mouth Disease ever experience in Britain. The research gratefully acknowledges the support of the research collaborators during this difficult period.

6.2 Conclusions

The objectives of this research were pursued by seeking answers to a number of research questions. The conclusions of the research can be based on the analysis of these research questions and on the review of associated issues, as follows.

Answering RQ I *'What is the current financial and environmental performance of intensive pig production systems?'*, the literature review confirmed that intensive pig production systems are linked to significant environmental and pollution risks. It also indicated that the UK pig industry is less cost competitive than major players in the pigmeat market and that pig producers have been facing financial problems in recent years.

The detailed assessment of the case studies provided the baseline for the application and comparison of the simulated with-IPPC situation. BAT for pigs particularly seeks to reduce ammonia emissions. Most emissions of ammonia occur from housing for all types of systems. The estimated losses of ammonia during storage and landspreading were found to be relatively higher for animal waste managed as FYM than for slurry. The financial results from the case studies and secondary sources suggested that pig producers are operating at very low or negative margins. Under present conditions, there is very limited scope to absorb any additional financial burden that may be imposed as a consequence of IPPC.

Answering RQ II '*What are the relevant indicators for assessment of the impacts of IPPC on the pig industry?*' the following conclusions can be drawn.

A list of performance indicators was generated for comparison of the baseline and the with-IPPC situations. Performance indicators were relatively easy to define and are commonly used by operators in the in current management and by those reporting on the physical and financial performance of the industry. Most of the environmental indicators, however, were not immediately available and they needed definition and estimation, with estimation often being based on standard values using secondary sources of data. By requiring the description and monitoring of environmental performance in controlled pig units, IPPC favours the development and use of farm level indicators within the sector. Compliance with the IPPC permit, starting from the application, is likely to promote the increased awareness and use of environmental indicators within the management systems of the pig units. This is a step towards a better understanding of and a commitment to manage the effects of pig production on the environment.

The use of indicators can help to provide a robust and integrated assessment of environmental and financial performance of pig installations. This is particularly important when the applicability and appropriateness of some of the emerging BAT are to be confirmed.

Environmental regulation through the IPPC Directive affects different dimensions of sustainability of intensive pig rearing. European Community or national indicators level of environmental performance are more likely to come under the scrutiny of regulators, while operators are mainly concerned with on-farm indicators. Financial performance is emphasised by the latter group whilst environmental performance is the focus of the former. Benefits to the environment can be offset by losses in the financial performance of the production unit. Sustainable businesses involve reduced environmental costs, and in the short term this may mean they carry a higher financial burden as these environmental costs are internalised. In the medium to long term, providing all businesses are treated equally, competitive advantage will not be compromised. But the adjustment period may be challenging.

The research question III '*How does IPPC relate to other statutory instruments and to voluntary agreements that apply to the pig production and associated activities?*' was partially answered by the literature review, which indicated the main voluntary and statutory instruments interacting with IPPC in England and Wales. Farm assurance schemes, such as AB Pigs, introduced several control and monitoring practices in the pig units which are now being required under the IPPC permit. Important interactions were identified between IPPC and NVZs (Nitrate Directive), water and groundwater mandatory instruments and planning permitting system (including EIA Directive) in England and Wales. In general, the IPPC is reinforced through the conditions set by these other instruments. However, some conflicts were identified in relation to animal welfare regulations, such as the promotion of straw based systems by the latter. RQ III has, in many aspects, common characteristics with RQ V below.

The great majority of pig producers, according to the respondents of the sectoral survey, were operating under a quality assurance scheme for pig production. Other assurance schemes, for different agricultural enterprises on the pig holdings, were often identified. Also, most units were reported to already have a Farm Waste Management Plan. These elements suggest that there is existing experience of monitoring and control systems on many installations.

Pig units below the thresholds escape IPPC regulation, but they are subject to other non-IPPC environment constraints which are in place and are likely to increase in their comprehensiveness. Guidance on good practice and quality assurance schemes have an important role to play in improving environmental performance of the pig production.

Answering RQ IV *'What are the impacts of IPPC on the financial and environmental performance of the UK pig industry, including impacts on business viability and affordability?'*, the following conclusions are drawn.

The results from the case studies suggest that BAT can deliver significant reductions in the total ammonia emitted from pig installations (housing and waste management stages). Generally, measures aimed at reducing ammonia emissions also promote reduction of emissions of nitrous oxide (N_2O) and odours. However, by focusing almost exclusively on the reduction of ammonia emissions, some proposed BAT may actually provoke an increase in the release of other gaseous pollutants, such as methane by covering slurry stores, or nitrates leaching by incorporation of slurry in some soil conditions.

Case study analysis also suggested that IPPC is likely to impose a significant regulatory burden on existing installations which, given current conditions in the UK pig industry, could prejudice the financial viability of some businesses. Comparing additional cost and current farm net margins, at the pigmeat prices at the time of the study (2000), compliance with IPPC regulations would render the case study installations unprofitable. Even the least cost proposed BAT measures would not be covered by the estimated net margin currently obtained by pig unit. Implementing IPPC measures would require extra returns of between 3p/kg and 10p/kg of pigmeat, depending on the type of BAT selected. Minimum prices would need to be between at least £0.97 and £1.06 per kg approximately to guarantee profitability under the simulated scenario of compliance with IPPC.

Compliance costs associated with BAT measures, particularly for animal housing, account for the majority of the additional cost associated with IPPC. BAT for storage and BAT for landspreading of manures appear to be relatively more cost-effective in reducing ammonia emissions than BAT for housing, but of course they cannot be seen in isolation. The costs of permitting, which were initially perceived by operators and industry representatives as a major additional cost associated with IPPC, account for a relatively small proportion of the total compliance cost on the study unit.

Potential synergy between environmental benefit and commercial gain appears to be very limited for existing installations. There is, however, some scope for gains which will partially offset compliance costs, such as rebates of Climate Change Levy in energy use for IPPC controlled installations. Also, IPPC may induce adoption of techniques in anticipation of their mandatory enactment by other policy instruments, such as the design requirements for waste stores under the Nitrate Directive. These conditions may lessen the regulatory burden exclusively associated with IPPC.

As feed cost account for a major proportion of the total production cost, as confirmed by the case studies, there is little scope for very prescriptive feed requirements by IPPC to be applied to the current feeding regimes. However, it was identified that there is great potential for reduction of emissions from pig production through modifications to feeding regimes, such as use of low nitrogen (protein) and low phosphorous diets and multiphase feeding, which have had their adoption prevented to date by perceived excessive costs. Therefore, they do not comply with the '*available*' definition implicit in BAT, that is, they are not presently 'developed at a scale which allows the implementation in the relevant industrial sector, under economically and technically viable conditions'. The analysis suggests, however, an important role for 'clean technologies' which, through modified feed intake, reduce waste and potential pollutant at source.

The approach to N flows in the case studies using Total Available Nitrogen (TAN) showed that reducing ammonia emissions throughout the pig production phases, especially by in-process BAT for housing, results in N-enriched manures going to storage. The same applies to waste management: if measures are taken to reduce releases during storage, N- richer manures are available for spreading onto land. This fact has two immediate implications: greater risk of pollution by these nutrient-enriched manures, and increased requirement of land for spreading. This approach to BAT, which focuses on solutions for each identifiable process or phase within the housing and waste management, appears not to offer an integrated assessment of abatement options applied to an installation as a whole. This is, after all, the very purpose of the IPPC Directive. Therefore, sectoral BAT does not appear yet to reflect the necessary integrated approach required by IPPC.

The overall efficiency of BAT as currently identified rests heavily on the efficacy of slurry and FYM landspreading. Compared to earlier stages, disposal of manures is subject to considerable risk given its dependency on climatic and field conditions and the common practice of disposing to third party land, the latter often without direct control by the pig operator. Housing and waste storage are (relatively) point sources of potential pollution from a pig installation, but field disposal switches to a diffuse source which is much more difficult to control. The BAT abatement measures for housing and waste storage do not really abate ammonia: they store up pollutants for diffuse disposal.

Besides the risks above referred, IPPC may support the use of slurry and FYM as fertilisers by requiring more control on waste management. This is reinforced by requirements of periodic soil analysis. More N is available in manures as a consequence of reduction of ammonia emissions with BAT prior to disposal. The proposed low emission landspreading techniques offer a more precise distribution of slurry to land, which contributes to a more reliable use of manures as fertiliser. The drawback here is that low emission landspreading techniques are generally more complex, less flexible, more costly and more difficult to manage than conventional spreading methods.

As pig installations often do not rely exclusively on their own land for disposal of animal wastes, more dependency on third parties' land may reduce the control of disposal by the pig operator. There is usually no or only very low payment for the organic waste by third parties, generally attributed for purposes of exchange between FYM and straw. The case studies indicated that the disposal of manures remains almost entirely a cost burden cost for the operator, with no evidence of development of a market for these nutrients rich, organic materials. However, exploring this issue with the managers of the case studies units suggest that there is increasing awareness of the potential value of manures as a source of nutrients for crops, and greater integration with the farm practices as a whole. The potential economic benefits of application of manures as a fertiliser is generally not realised if the pig operator applies these to the land of third parties (especially where no sale value is attributed to manure). However, the value attributed by farm managers to manures is only a fraction of the theoretical value of nutrients in terms of equivalent bought fertiliser. This is because farm managers feel they can not rely on manures the same degree that they can on inorganic fertiliser to provide nutrients to crops when needed. Furthermore, handling these large quantities and volumes of manures is operationally challenging. Organic wastes can be particularly offensive in terms of odours for operators and neighbours.

It is still unclear exactly what BAT measures are required for some housing systems for compliance with IPPC. Great uncertainty remains on the definitive acceptance or otherwise of straw based systems as BAT at European Union level. The results from the case studies pig installations suggest that compliance with BAT for housing may be the most costly individual item of the IPPC compliance costs. The characterisation of predominant production systems for housing by the sectoral survey indicated that, particularly for the finishing phase, the sector is far from compliant with BAT.

Competition by other pig production countries, relatively higher costs of production and a long term low price for pigmeat have discouraged major investments in pig housing in the UK in recent years. Most of the change in housing has been driven by welfare regulations. The sectoral survey indicated that most of buildings were, from a technological or accounting point of view, completely, or to a great extent, written-off. This could imply that shutting down existing buildings by 2007 (sectoral deadline for phasing in of existing installations to IPPC) would have a relatively low impact in terms of dis-investments for the industry as a whole. In this respect, however, IPPC will remove the sector's common coping strategy of temporary extending building life by minor refurbishment or other similar measures.

Information in the BREF Notes drafts suggest that for new installations the additional costs of BAT for housing are negligible or even negative (having lower cost than current systems). That is, compliance with BAT does not imply substantial change in the overall cost of new housing. Adapting existing installations to BAT, however, is much more of a challenge.

As for housing, the predominant practices for storage and landspreading of manures reported by respondents to the sectoral survey do not conform to BAT. For example, it was reported that slurries are mainly stored in earth-banked lagoons and below ground tanks. Slurry lagoons are associated with breeding-and-feeding systems, which, because they are relatively large scale, generate large volumes of manures which require sizeable storage facilities. It is technically difficult and expensive, as required by IPPC, to cover slurry stores, especially lagoons. So far, it seems more feasible to replace existing large surface stores by other new structures with reduced open areas. Substantial compliance costs are involved whichever the option is taken, based on the estimated costs for the case study units. Storage of farmyard manure (FYM) requires more straightforward measures of which most are already common practice.

The results from the case studies suggest that the costs of compliance associated with incorporation of manures into soil can be substantial, especially because incorporation has to be done within 6 hours for slurry and 24 hours for FYM in order to reduce ammonia. According to secondary information, low emission landspreading techniques such as slurry soil injection cost more per hectare and are operationally less flexible than broadcasting. However, evidence from one case study showed that it was possible to move from broadcasting plus incorporation to slurry soil injection with operational advantages.

The above point illustrates well the difficulty of determining *ex ante* costs based on assumptions and data sources which reflect existing practice and knowledge. In reality, new conditions encourage agents to innovate and relative advantages can be obtained which were not previously perceived. Necessity, or in this case IPPC, can be the mother of beneficial invention and innovation.

Based on the responses to the sectoral survey and results from the case studies, it appears to be that there is some, albeit limited scope for further improvements in the use of water. Also several good practices for energy use are already adopted in the sector as a whole. The cost of energy and water, based on estimated values from case study units, did not have a substantial impact on total pig production cost. Therefore, comprehensive review of use of these resources in the pig unit has a limited scope in terms of substantial changes of use. However, energy and water costs are expected to increase and this could promote the use of measures to reduce the use of these resources over time.

The expansion of current NVZs in England could affect considerably the costs of disposal of manures and reinforce the IPPC pressure on obtaining extra land for disposal of animal manures. This could restrict location of pig farming in areas where availability of land for landspreading is scarce. NVZ is an example of where non-IPPC regulatory measures will in fact reduce the incremental burden on IPPC regulated installations, but also require non-IPPC regulated installations to adopt similar environmental practices to those required on IPPC units.

Answering RQ V '*Is the current policy design of IPPC appropriate for its application to the pig sector?*' and sub-questions '*What are the likely responses of the pig industry to IPPC?*' and '*What are the processes whereby stakeholders interact to influence the IPPC implementation in this newly regulated industry?*', the following conclusions can be drawn.

The UK environmental regulatory tradition is that of site specific approach (Skea and Smith, 1996; Smith, 1996b). Although *standard conditions* limit the range of techniques regarded as acceptable as BAT within a permit, there is scope for interpretation of particular conditions of the unit based on the expert judgement of the regulator. The intention to extend the same approach taken by IPC's OPRA to IPPC is a sign of the regulator's understanding of the important role of site specific conditions, and a recognition that environmental risk is dependent on the combination of the environmental risks inherent to a process, the sensitivity of local receptors and the environmental management systems in place.

The strategic responses to regulation by IPPC, particularly for pig breeding-and-feeding units, as discussed with operators and representatives of the pig industry in the workshop included scaling down the size of pig herd (number of sows and finishers) in order to avoid being captured by the threshold, and splitting the finishing herd into a greater number of finishing units below the threshold (modulation). The NFU response to the Agency consultation of the IPPC charging scheme (NFU, 1999) argues that additional cost would become 'a major driver in determining the structure of the intensive livestock sector, polarising it into units below the threshold for regulation and very large units which might be able to sustain the cost of regulation by spreading it over many [...] pig places'.

The above points imply that IPPC and BAT, together with ongoing structural changes in the pig industry, are likely to encourage larger scale, specialist production units, and convergence of production and management systems.

The most relevant environmental issues related to indoor pig production according to operators were, in order of importance, emissions of pollutants to water, emissions of pollutants to land and nuisance cause by odours. Although other pieces of legislation are addressing control of pollution from agriculture, it is interesting to point out that the IPPC focus on ammonia is somehow disconnected from the main issues seen from the point of view of pig operators, namely emissions of pollutants to water and land. This can be partially attributed to the low level of knowledge of operators about IPPC, which is reinforced by the fact that the issues and impacts foreseen by respondents to the sectoral survey diverged from the evidence given by case studies. This suggests that operators were not well prepared for IPPC implementation, although existing installations have until 2007 to be phased into the regime.

Major stakeholders involved in the IPPC implementation were identified and classified in the literature review, which also indicates that their mutual dependency and information asymmetry determines the establishment of a network of policy actors. These aspects were confirmed through the participation of the researcher in the IPPC Pig Steering Group, in the consultation for IPPC implementation in England and Wales, and consultation on the sectoral BREF Notes.

The analytical framework of assessment of IPPC for pigs can also be reported as an output of this research. The development and application of this framework provided a methodological contribution, enabling the assessment of the effects of IPPC implementation process on the newly regulated pig sector.

6.3 Recommendations

On the basis of the conclusions drawn from this research, it is possible to make a number of recommendations. These recommendations indicate actions which can contribute to more informed policy management, and target the regulator and policy makers, pig operators and researchers. The recommendations refer to research topics and methods, definition of BAT and related BREF Notes, industry awareness and the regulator's approach to implementation.

It is still unclear what BAT measures are required for some housing systems for compliance with IPPC. Great uncertainty remains on the definitive acceptance or not of straw based systems as BAT at European Union level, which accounts for the majority of dry sows and finishing pigs in England and Wales according to this research's sectoral survey. Therefore, it is recommended that research effort targets such pig housing systems, in terms of determining their environmental performance and also identification of appropriate, low cost techniques for their improvement regarding IPPC criteria. Assessment of the applicability of BAT techniques to UK conditions is an important element at this initial stage of policy implementation, enabling reassurance to operators and regulators on the efficacy and viability of the proposed measures. This does already seem to be under way according to information given by researchers and regulators (T. Demmers, M. Brade and J. James, pers. comm.), especially under projects funded by DEFRA (A. Brewer, report to the IPPC Steering Group), involving institutions such as Silsoe Research Institute (SRI) and Agricultural Development and Advisory Service (ADAS). The review of literature suggested that applying BAT for housing to new pig installations may not involve additional housing costs. Indeed there may be potential savings compared to existing systems, based on gains of efficiency in capital allocation or reduced operation costs. However, this should be confirmed for UK conditions. Therefore, it is recommended that these R&D responses are strengthened to support policy implementation and decision making.

Sectoral BAT mainly consist of containing ammonia emissions from pig housing and waste management stages (EIPPCB, 2001). The emphasis is therefore essentially on nutrient output-BAT, as it attempts to contain the release of ammonia from manures.

By comparison, nutrient input-BAT which reduces N in diets fed to pigs and could reduce the level of nutrients in excreta, have received little attention to date. Rather, one perhaps radical interpretation is that N (ammonia)-related BAT for pig sector are predominantly end of pipe techniques unless they result in a reduction in the amount of excreta produced per pig, or its TAN content. Current BAT candidates for the most part attempt to improve the management of emissions from fundamentally the same production process. The recommendation from this research is two fold here. First, there is need to consistently pursue nutrient input-BAT options, which reduce the production of nutrient rich wastes in the first place rather than focusing on their containment. These involve for example feeding strategies such as multiphase feeding, lower protein content diets and other modified diets. Possibly it also involves reconsidering the 'design' of pig production itself, looking at aspects such as finishing weights and breeds. Second, assessment of 'baskets' of BAT, involving housing and waste management together, could provide a better integrated view of abatement measures, in accordance with the underlying philosophy of IPPC.

Pig housing techniques, involving building design and management of herd, have been driven in the last decade by welfare regulations. Some conflicts were identified between welfare and environmental objectives, with straw based systems being an illustrative example. Although environmental protection objectives are discretionary according to the Agency, IPPC implementation has to consider limits imposed by other pieces of legislation in the broad regulatory framework covering the sector. Therefore it is important that IPPC, and its constituent BAT, provide robust and reliable solutions for environmental protection which are compatible with other standards, such as those relating to health and safety, and in the case of farming, animal welfare. The recommendation here is that the regulator must permanently keep an open forum with other stakeholders, such as the current IPPC Pig Steering Group, for discussion and advice on policy issues,

The research showed that the overall efficiency of BAT in terms of reducing ammonia emissions depends on the extent to which emissions are controlled at the final stage of spreading wastes to land. However, where manures are disposed onto land of third parties and not controlled by the pig installation operator, there is no obligation to comply with BAT for landspreading. The recommendation of this research is that more explicit arrangements on the measures to apply manures on land of third parties should be part of the IPPC permit. This could reduce the possibility of disposal practices which fail to meet the required controls.

BAT measures refer mainly to management of manures as slurry. As straw based systems are widespread in UK, a significant proportion of animal wastes manure is handled as FYM. Therefore, it is recommended that researchers, equipment suppliers and contractors should explore the development of improved systems for storage and landspreading of FYM. It is important to note that solid manure is a material more suitable for long distance transport than slurry, which means there is more opportunity for trading this waste with other farms or businesses.

The critique of research methods presented in chapter 3 pointed out the difficulty of determining *ex ante* performance and costs based on several assumptions and data sources. Moreover, the context of the pig industry suggested a picture of businesses struggling to overcome 'pressures' associated with competition from other EU member-states, the relative strength of UK currency, tighter requirements related to food safety (post-BSE) and welfare of animals. Some of these challenges are particular to the pig industry but broadly they reflect the recent fortunes of the agricultural sector at a time of considerable structural change. Therefore, determining the viability of the pig units under the new emerging policy framework is a difficult task. It is necessary to consider prices of inputs and outputs over a period long enough to avoid the biases related to short term market cycles or crisis. It is recommended that pig units continuous monitoring to provide reliable data on costs of compliance.

The power of the regulatory authority is limited in terms of resources and lack of knowledge and experience in monitoring a new sector. This provides a need and an opportunity for operators to play a major role in the implementation process of bringing about IPPC without compromising the overall purposes. In view of these two elements, and variable market conditions accompanied by a longer term trend of structural adjustment in the industry, it is recommended that the regulator undertakes continuous monitoring of the compliance costs in pig units, particularly the costs associated to BAT. This could be through pilot units or, as used in this research, selected commercial pig units agreeing to participate in intensive monitoring programme. This also reinforces the above recommendation of maintaining a pig industry 'IPPC forum'.

This research did not investigate whether IPPC impacts, and therefore, viability of pig units, vary within the industry according to the size of the units. Although the IPPC thresholds assume the capture of large units, possibly there is scope for identification of different categories of pig holdings by size, described by number of pigs. This is recommended as a possible research topic as it would enable identify different degrees of impact and, possibly, helping to guide policies. Also, research on sensitivity analysis of key factors of production systems, circumstances and management systems can help to design of the sectoral EP OPRA.

This research used a cost-effectiveness analysis of IPPC, as justified in chapters 2 and 3, limiting itself to the comparison between compliance costs of regulation and emission abatement. However, at a different analytical level, that of cost:benefit, abatements can be valued in monetary terms. In doing so, monetary units expended in environmental control (IPPC compliance cost) could be assessed against the attributed value of the benefits delivered. However, the methodological (if not philosophical) assumptions necessary to carry out valuation of benefits of environmental goods are rather complex and, moreover, often highly disputable. Despite these limitations, policy makers and regulatory authorities increasingly seek cost:benefit ratios for the policy instruments they impose on economic activities. It is recommended to support future research addressing the cost:benefit analysis of IPPC implementation to the pig sector.

It is expected that principles similar to those being applied by IPPC to pig and poultry sectors will also cover other intensive livestock activities, especially dairy and cattle feed lot systems, as a basis for voluntary codes or move towards compliance requirements generally for agriculture. Therefore, the assessment framework developed and applied by this research could be adapted to estimate effects of regulation in other sector. Comparative cost-effectiveness of IPPC across different sectors is also recommended so that environmental enhancement measures adopted in the pig sector can be benchmarked against indicators in other sectors.

The standard conditions for IPPC under the SFIR offer an opportunity of a reduced permitting cost for pig installations and a relatively simpler application process. However, SFIR tend to generalise some important aspects of the performance of pig systems. For instance, estimation of emissions from housing are based solely in two types of flooring systems; landspreading techniques focus only on type of equipment, with little consideration given to timing aspects; and management systems are not objectively assessed. This does not allow the complete 'capture' of the site specific conditions and could lead to misinterpretation of the real performance of the installation. Therefore, it is recommended that an approach is developed to facilitate performance assessment and benchmarking robust enough to accommodate both physical conditions ('the installation', as a hardware element) and management capacity (as a software element). There is evidence that initiatives in this direction are being proposed (EP OPRA consultation, Environment Agency, 2002b) but more work is needed to make them appropriate for intensive farming installations.

It is recommended that the Government, the Agency and pig industry representatives join efforts to inform pig producers on the implementation of IPPC to the sector, particularly on minimum requirements and emerging BAT for pig installations. Actions could involve: promoting campaigns of awareness on IPPC, set pilot farms and demonstration units, and monitoring and supporting of the application process.

6.4 Closing Statement

The integrated approach which underpins the IPPC regime represents a significant step towards the internalisation of externalities caused by economic activities such as intensive pig production. It also can reinforce and guide the structural change and technological innovation in this sector to more efficient and environmentally responsible production systems. However, this research has identified the considerable challenge to 'operationalise' the integrated principle, as confirmed by the process of definition of sectoral BAT. This showed that BAT requires a multidisciplinary approach and can be biased towards specific aspects of environmental performance, while at the same time financial data and applicability are uncertain. Sectoral BAT for pigs should offer an integrated 'best option' for production and waste management but, rather, there is a risk that they may apply separate, uncoordinated measures for each different stages, namely housing, storage and landspreading. BAT accounted for the biggest apportion of the compliance cost estimated for implementation of IPPC to case study pig units.

It is crucial, therefore, that, especially in the initial period of IPPC implementation for existing installations, a careful assessment is made by the regulator when determining compliance requirements for operators under the permit. Excessive compliance costs can harm the ability of the pig units accommodate the measures, which in the extreme may persuade them to leave the business. This research developed and applied an analytical framework from which outputs and lessons can be drawn to support the IPPC implementation process for the pig industry and, potentially, for other sectors.

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Appendix 2. 1 - Main types of pig housing according to the flooring system

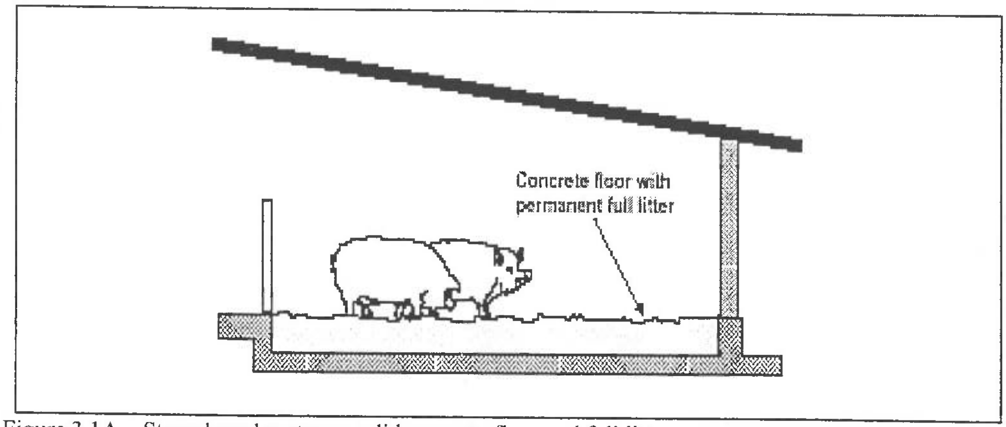


Figure 3.1A – Straw based systems: solid concrete floor and full litter

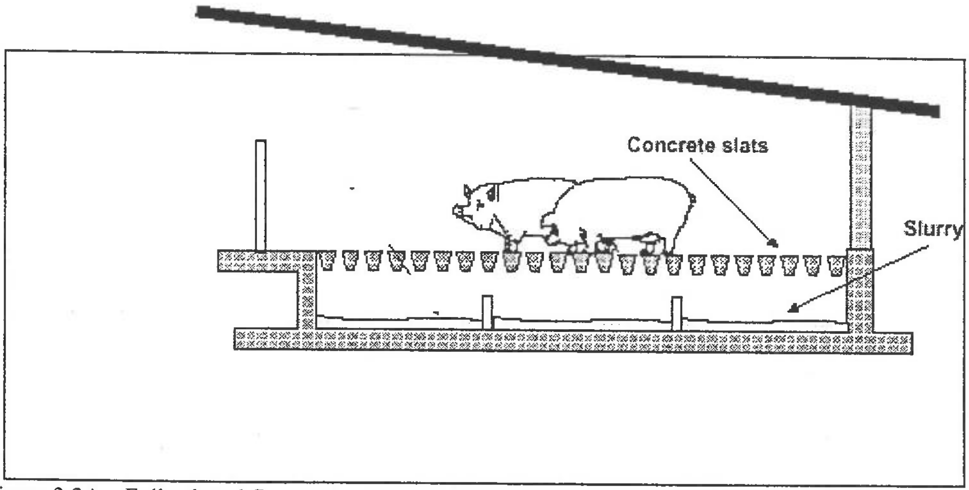


Figure 3.2A – Fully slatted floor system

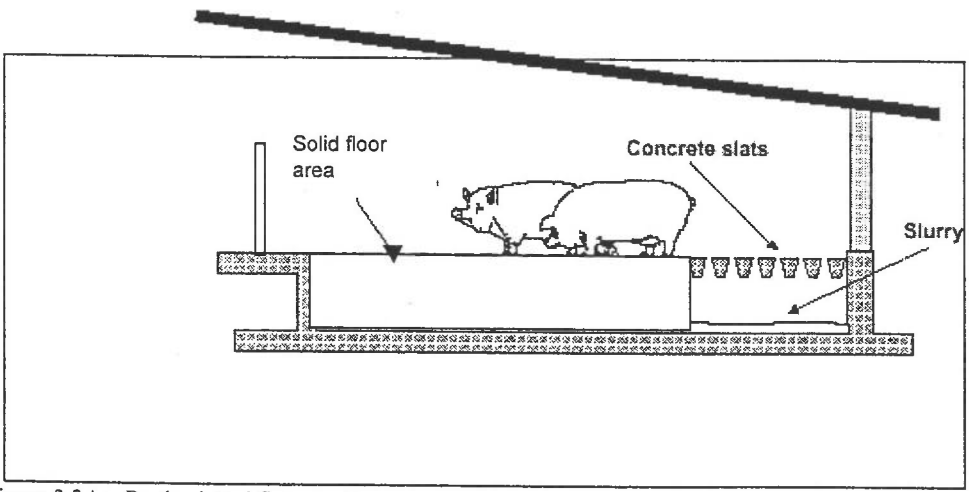


Figure 3.3A – Partly slatted floor system

Source: adapted from CRPA, 1999 quoted in 1st draft of BREF (EIPPC, 2000).

Appendix 2. 2 - Description of categories of pollution incidents by the Environment Agency

Category 1 is a major incident involving one or more of the following:
(a) potential or actual persistent effect on water quality or aquatic life.
(b) closure of potable water, industrial or agricultural abstraction necessary.
(c) extensive fish kill;
(d) excessive breaches of consent, conditions;
(e) investigation of extensive remedial measures;
(f) significant adverse effect on amenity value;
(g) significant adverse effect on site of conservation

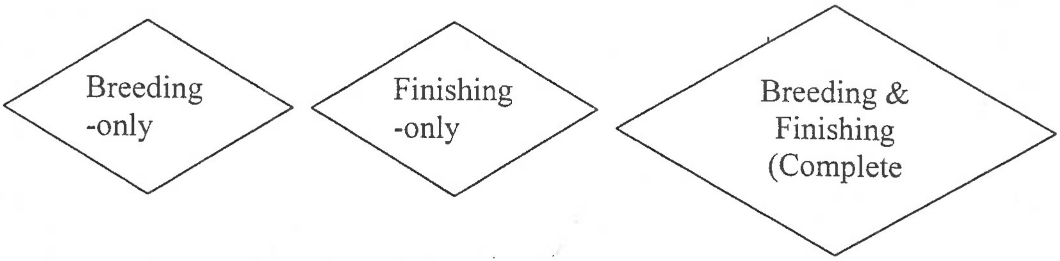
Category 2 is a significant incident involving one or more of the following:
(a) notification of abstractors necessary;
(b) significant fish kill;
(c) readily observable effect on invertebrate life
(d) water unfit for stock watering
(e) bed of watercourse contaminated;
(f) amenity value to downstream users reduced by odour or appearance.

Category 3 is a minor incident resulting in localised environmental impact only. Some of the following may apply:
(a) notification of abstractors not necessary;
(b) fish kill of less than 10 fish (species of no particular importance to the effected water);
(c) no readily observable effect on invertebrate life;
(d) water not fit for stock watering
(e) bed of watercourse only locally contaminated;
(f) minimal environmental impact and amenity value only marginally affected.

Category 4 is defined as a reported pollution incident that upon investigation proves to be unsubstantiated, that is, no evidence can be found of a pollution incident having occurred. Since these incidents are by definition not found, they are omitted from the breakdown of incidents by category.

Appendix 3. 1 - Key factors used to differentiate environmental and economic performance of indoor pig production systems

Key 1
Specialisation of herd



Importance:
There are different quantitative and qualitative feed requirements by animal category.
There are different housing design, consumption of energy and water use for each stage of production

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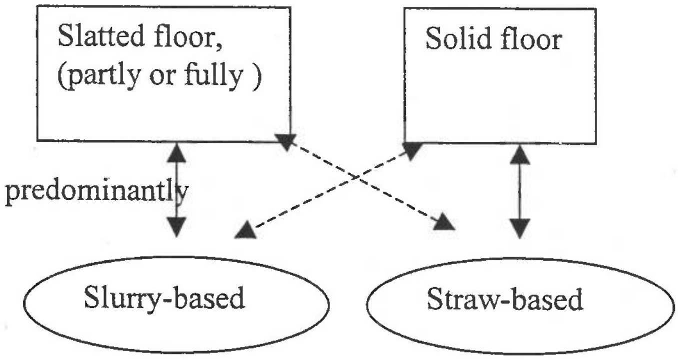
Key factor 2
Type of housing

and



Key factor 3
Waste Management (manures)

Importance:
Determine the level of emissions from housing
Determine practices and emissions from storage
Define the practices and emissions from spreading

Appendix 3. 2 - Factors used for conversion of capital to annual cost

Life (years)	Annual cost (£/£1,000 initial expenditure)				
	Real interest rate	4%	6%	8%	10%
5		225	237	250	264
10		123	136	147	163
15		90	102	117	131
20		74	**87**	102	117
30		58	73	89	106

Source: Farm Building Cost Guide 2000 (SAC, 2000 p. 9).

Note: marginal tax rate of 0%. Most of buildings considered 20 years life span.

Annex 3. 1 - Sample of the questionnaire form used for the postal sectoral survey

SURVEY ON THE IMPLEMENTATION OF IPPC DIRECTIVE TO THE PIG INDUSTRY IN ENGLAND AND WALES

This questionnaire is designed to obtain information from producers running either a single pig production unit or more than one pig unit. **If you have a single pig unit, please answer in the Unit 1 column throughout the questionnaire.**

Please exclude outdoor pig units, as they are not covered by IPPC.

A Description of the pig unit and site

A.1 For each of your pig units, please indicate the type of system (tick ✓ as appropriate) and complete with the number of pigs typically kept (sows and finishers only).

Features	Pig Unit[1]			
	Unit 1 Name[2]:	Unit 2 Name:	Unit 3 Name:	Unit 4 Name:
a) System by specialisation of herd				
Breeding-only	☐	☐	☐	☐
Feeding-only	☐	☐	☐	☐
Breeding & Feeding (complete cycle)	☐	☐	☐	☐
b) No. of pigs by category (*please complete no. animals for each unit*)				
Total sows	☐	☐	☐	☐
Fattening pigs over 30 kg	☐	☐	☐	☐

Notes: [1] If you have more than four units, please answer the questions for the largest four units here in Table A.1. Also please complete Table A.1.1.
[2] Completion with the name of unit is suggested for your own reference purpose only.

Table A.1.1 is to be completed if you have more than four pig units. **If not, please go to question A.2 in the next page.**

A.1.1 What is the total number and type of units? Please complete below.

System by specialisation of herd (*tick ✓ as appropriate*)	**Number of pig units** (*please complete with no. of units for each system*)	**No. of pigs by category** (*please complete total no. animals for each system*)	
		Total sows	Fattening pigs over 30 kg
Breeding only	☐	☐	
Feeding only	☐		☐
Breeding & feeding (complete cycle)	☐	☐	☐

A.2 Housing systems - Where relevant, for each unit please indicate with a tick ✓ the type of housing system(s) according to pig production phase. If more than one system is used, please indicate an approximate % for each.

Phase	**Housing system**	**Pig unit** 1	2	3	4
Service (Mating and Pregnancy)	Straw based, solid floor	☐	☐	☐	☐
	Solid floor (none or limited straw)	☐	☐	☐	☐
	(please specify if other)				
	Other ☐	☐	☐	☐	☐
	Other ☐	☐	☐	☐	☐
Farrowing	Straw based, solid floor	☐	☐	☐	☐
	Slurry based, fully-slatted floor	☐	☐	☐	☐
	Slurry based, part-slatted floor	☐	☐	☐	☐
	(please specify if other)				
	Other ☐	☐	☐	☐	☐
	Other ☐	☐	☐	☐	☐
Weaning	Straw based, solid floor	☐	☐	☐	☐
	Solid floor (none or limited straw)	☐	☐	☐	☐
	Slurry based, part-slatted floor	☐	☐	☐	☐
	Slurry based, fully-slatted floor	☐	☐	☐	☐
	(please specify if other)				
	Other ☐	☐	☐	☐	☐
	Other ☐	☐	☐	☐	☐
Finishing	Straw based, solid floor	☐	☐	☐	☐
	Solid floor (none or limited straw)	☐	☐	☐	☐
	Slurry based, part-slatted floor	☐	☐	☐	☐
	Slurry based, fully-slatted floor	☐	☐	☐	☐
	(please specify if other)				
	Other ☐	☐	☐	☐	☐
	Other ☐	☐	☐	☐	☐

A.3 Original construction and refit of buildings

Construction and refit	**Pig Unit**			
	1	2	3	4
a) When was most of the unit (i.e. buildings) originally constructed? *Please, complete with year (e.g.1978)*				
b) Since then, has major refurbishment or expansion been undertaken?				
No	☐	☐	☐	☐
Yes	☐	☐	☐	☐
If yes, please complete with year of refit				
If yes, please give details of refit (e.g. from individual to group pens for sows):				

A.4 Please indicate the predominant type(s) of soil in the adjacent area of the unit.

Predominant soil	**Pig Unit**			
	1	2	3	4
Sands	☐	☐	☐	☐
Loams	☐	☐	☐	☐
Silts	☐	☐	☐	☐
Clays	☐	☐	☐	☐
Peat soil	☐	☐	☐	☐
Other *please specify*	☐	☐	☐	☐

A.5. Please mark with a ✓ if there are potentially sensitive environmental features in the vicinity of the unit.

Relevant environmental features and Sensitive areas	**Pig Unit**			
	1	2	3	4
a) Are there any watercourses, spring or borehole nearby the unit?				
No	☐	☐	☐	☐
Yes	☐	☐	☐	☐
If yes, please give approximate distance of:				
- watercourse from unit (metres)	☐	☐	☐	☐
- spring or borehole from unit (metres)	☐	☐	☐	☐
b) What is the distance to the closest neighbouring house from unit (do not include farm dwellings)? *Distance from unit (in metres)*	☐	☐	☐	☐
c) Is there a residential area in the vicinity of the unit (village, town etc. within 3 kilometres from the unit)?				
No	☐	☐	☐	☐
Yes	☐	☐	☐	☐
If yes, please inform approximate distance from unit (metres)	☐	☐	☐	☐
d) Are there any nature conservation or protected areas (e.g. site of special scientific interest –SSSI, woodland etc.) which are within 2 kilometres from the unit?				
No	☐	☐	☐	☐
Yes	☐	☐	☐	☐
Don't know	☐	☐	☐	☐
e) Is the unit and adjacent area partly or completely within a Nitrogen Vulnerable Zone (NVZ)?				
No	☐	☐	☐	☐
Yes	☐	☐	☐	☐
Don't know	☐	☐	☐	☐
f) Are there any other particularly sensitive features in the vicinity of the unit?				
No	☐	☐	☐	☐
Yes	☐	☐	☐	☐
If yes, please name them and mark ✓ for unit:				
☐	☐	☐	☐	☐
☐	☐	☐	☐	☐
☐	☐	☐	☐	☐

B Waste Management

B.1 Does the unit have or is covered by a Farm Waste (Manure) Management Plan?

Farm Waste Management Plan	**Pig unit**			
	1	2	3	4
No	☐	☐	☐	☐
Yes	☐	☐	☐	☐
Not applicable	☐	☐	☐	☐

B.2 Please indicate the type of storage system and capacity for slurry and manure.

Type of waste	**Storage system**	**Pig unit**			
		1	2	3	4
a) Slurry *If **slurry** based, where slurry is stored after removal from animal house?*	earth banked lagoon	☐	☐	☐	☐
	below-ground tank or structure	☐	☐	☐	☐
	above-ground circular tank	☐	☐	☐	☐
	no storage	☐	☐	☐	☐
	(please specify if other) other ____	☐	☐	☐	☐
*What is the **slurry** Storage capacity?*	in cubic metres (m^3) or				
	in months				
b) Manure (FYM) *If **manure** based, where FYM is stored after removal from animal house?*	outside storage area	☐	☐	☐	☐
	outside using temporary cover or measures to reduce rainfall entry	☐	☐	☐	☐
	permanently covered area (roof over)	☐	☐	☐	☐
	(please specify if other) other ____	☐	☐	☐	☐
*What is the **FYM** storage capacity?*	in cubic metres (m^3) or				
	in months				

B.3 Do you carry out any treatment for slurry and manure?

Treatment of slurry and manure	**Pig Unit**			
	1	2	3	4
No	☐	☐	☐	☐
Yes - *please complete below*	☐	☐	☐	☐
If yes, please indicate treatment(s) with ✓:				
mechanical slurry separation	☐	☐	☐	☐
Anaerobic digestion	☐	☐	☐	☐
Aerobic digestion	☐	☐	☐	☐
Fermentation (production of biogas)	☐	☐	☐	☐
Composting	☐	☐	☐	☐
Other *please specify* ☐	☐	☐	☐	☐

B.4 Spreading of manure and slurry – land availability

Spreading – land availability	**Pig Unit**			
	1	2	3	4
a) Is manure or slurry spread on-site (i.e. fields adjacent to the unit which are owned or managed by the pig operator)?				
No	☐	☐	☐	☐
Yes	☐	☐	☐	☐
If yes, please indicate area of land available for spreading of slurry and manure in:				
hectares or	☐	☐	☐	☐
Acres	☐	☐	☐	☐
If yes, what is the average distance from storage to on-site spreading area? in metres	☐	☐	☐	☐
b) Is slurry or manure spread onto a third party's land?				
No	☐	☐	☐	☐
Yes	☐	☐	☐	☐
If yes, please indicate area of land available For spreading of slurry and manure in hectares	☐	☐	☐	☐
or acres	☐	☐	☐	☐
If yes, what is the average distance from storage to off-site spreading area? in metres	☐	☐	☐	☐

B.5 Spreading of slurry and manure – techniques and practices specific to the unit(s)

Type of waste	**Technique or resource used**	**Pig unit**			
		1	2	3	4
Slurry					
a) If slurry is spread onto land, what ***transport*** *system is used?*	slurry tanker	☐	☐	☐	☐
	umbilical hose	☐	☐	☐	☐
	low rate irrigator	☐	☐	☐	☐
	(please specify if other)				
	other ____	☐	☐	☐	☐
	other ____	☐	☐	☐	☐
b) If slurry is spread onto land, what ***distribution*** *system is used?*	broadcast spreader (splash plate or nozzle)	☐	☐	☐	☐
	band spreader	☐	☐	☐	☐
	trailing shoe spreader	☐	☐	☐	☐
	injector	☐	☐	☐	☐
	(please specify if other)				
	other ____	☐	☐	☐	☐
	other ____	☐	☐	☐	☐
c)If slurry is spread onto land, ***who undertakes*** *the slurry spreading?*	unit or farm staff	☐	☐	☐	☐
	contractors	☐	☐	☐	☐
	(please specify if other)				
	other ____	☐	☐	☐	☐
Manure (FYM)					
d) If FYM is spread onto land, what ***distribution*** *system is used?*	rotaspreader	☐	☐	☐	☐
	rear discharge spreader	☐	☐	☐	☐
	dual purpose spreader	☐	☐	☐	☐
	(please specify if other)				
	other ____	☐	☐	☐	☐
	other ____	☐	☐	☐	☐
e)If FYM is spread onto land, ***who undertakes*** *the spreading?*	unit or farm staff	☐	☐	☐	☐
	contractors	☐	☐	☐	☐
	(please specify if other)				
	other ____	☐	☐	☐	☐

B.6 Spreading of slurry and manure – general techniques and practices. Please note that information asked here do not refer to each unit but to the practices in broader terms.

a) If **slurry** is applied using a broadcast spreader (such as splash plate or nozzle) for distribution, is it incorporated into land after spreading?

- No ☐
- Yes, with slurry incorporated into land in the same day of application ☐
- Yes, with slurry incorporated in more than one day after application ☐
- Not applicable ☐

b) If **manure** is applied to uncropped land or bare soil, is it incorporated into land after spreading?

- No ☐
- Yes, being incorporated within one day after application ☐
- Yes, incorporated in more than one day after application ☐
- Not applicable ☐

c) Do you calculate the amount of slurry and manure that is applied to a given area of land?

No ☐

Yes ☐ *If yes please complete below*

How do you calculate this amount? It is based on:

- volume of slurry in the lagoon or tank ☐
- volume slurry pumped by period of time ☐
- weight loads of transporting vehicles ☐
- volume of manure in a heap or storage facility ☐
- rapid on-farm slurry N tester ☐
- other ☐ *please specify* ____________

C Use of raw materials, water and energy

Please indicate with ✓ the appropriate answer for the following questions.

C.1 Use of raw materials

Feed *please indicate with ✓ the practices in your unit(s)*	Pig unit 1	Pig unit 2	Pig unit 3	Pig unit 4
use multiple diets for pigs	☐	☐	☐	☐
preparation of swill within the premises	☐	☐	☐	☐
milling and preparation of feed (home-mix)	☐	☐	☐	☐

C.2 Clean water use

Water aspects	**Pig Unit**			
	1	2	3	4
a) What are the sources of water for the unit? Indicate ✓ if relevant.				
mains	☐	☐	☐	☐
abstraction from surface waters	☐	☐	☐	☐
abstraction from groundwater (borehole)	☐	☐	☐	☐
other *please specify* ______	☐	☐	☐	☐
b) Do you have water meters which measure water consumption for different uses within the unit (e.g. livestock drinking, cleaning and washing, domestic)?				
No	☐	☐	☐	☐
Yes	☐	☐	☐	☐
Don't know	☐	☐	☐	☐
c) Please indicated whether the following water use equipment or practices are adopted in the unit:				
trigger nozzles for hoses	☐	☐	☐	☐
high-pressure washers	☐	☐	☐	☐
scraping or scrubbing before washing down pens and yards	☐	☐	☐	☐
bite-type drinkers	☐	☐	☐	☐
tank or reservoir cover	☐	☐	☐	☐
using rainwater for washing	☐	☐	☐	☐
re-using dirty water in flushing systems for slurry pit	☐	☐	☐	☐
other *please specify* ______	☐	☐	☐	☐
other *please specify* ______	☐	☐	☐	☐
none	☐	☐	☐	☐
d) Is clean rainwater from roofs separated from dirty water systems and run-off from clean yards?				
No	☐	☐	☐	☐
Yes	☐	☐	☐	☐
Don't know	☐	☐	☐	☐

C.3 Energy use

Energy use aspects	**Pig Unit**			
	1	2	3	4
a) Are buildings metered separately for electricity?				
No	☐	☐	☐	☐
Yes	☐	☐	☐	☐
Don't know	☐	☐	☐	☐
b) Please indicated whether the following energy use equipment or practices for are adopted in the unit:				
low-energy lamps for lighting	☐	☐	☐	☐
independent switching of lighting systems	☐	☐	☐	☐
automatically controlled heating system (by thermostats or timers)	☐	☐	☐	☐
building insulation	☐	☐	☐	☐
piglet creep lamps with dimmers	☐	☐	☐	☐
natural ventilation system (ACNV)	☐	☐	☐	☐
buying premixed feed	☐	☐	☐	☐
energy efficient motors and equipment	☐	☐	☐	☐
training for drivers and equipment operators to economise fuel	☐	☐	☐	☐
regular checking and servicing of machinery and equipment	☐	☐	☐	☐
other *please specify* [ ]	☐	☐	☐	☐
other *please specify* [ ]	☐	☐	☐	☐
None	☐	☐	☐	☐

C.4 Disposal of pig carcasses

Disposal of carcasses	**Pig Unit**			
	1	2	3	4
*How is the disposal of pig carcasses carried out?**				
on site, using incinerator with capacity up to 50 kg/hour	☐	☐	☐	☐
off site, by authorised incinerator	☐	☐	☐	☐
off site, by knackerman, rendering plant or hunt kennel	☐	☐	☐	☐
other *please specify* [ ]	☐	☐	☐	☐

Note: *Considering ordinary procedure, not in an emergency or abnormal situation.

D Management and labour

D.1 Does the pig production in your unit(s) follow a farm assurance scheme?

Assurance schemes for pigs	**Pig Unit** 1	2	3	4
No	☐	☐	☐	☐
Yes *(If yes, please indicate below)*	☐	☐	☐	☐
Assured British Pigs – ABM	☐	☐	☐	☐
retailer scheme (e.g. Tesco, ASDA etc.)	☐	☐	☐	☐
Freedom Foods – RSPCA	☐	☐	☐	☐
Soil Association (Organic Pig Production)	☐	☐	☐	☐
other *please specify* ______	☐	☐	☐	☐
other *please specify* ______	☐	☐	☐	☐

D.2 Do you follow an assurance or voluntary scheme for other livestock than pigs or crop enterprises on your farm (where the pig unit is comprised)?

Other farm assurance schemes	**Pig Unit** 1	2	3	4
None	☐	☐	☐	☐
Linking Environment and Farming – LEAF Audit	☐	☐	☐	☐
Organic production	☐	☐	☐	☐
other *please specify* ______	☐	☐	☐	☐

D.3 Please indicate training activities in the last 2 years which have involved the staff in charge (farmer/manager and stockman) of your pig unit(s). Please note that here is being asked general information only, regardless each individual unit (if it is the case).

Training issue	✓ if yes	Venue ✓ In service	Outside Install.	Dura-tion (hours)	Certification given, if any ✓=yes
general farm management	☐	☐	☐	______	☐
emergency plan and risk management	☐	☐	☐	______	☐
health and safety	☐	☐	☐	______	☐
pig husbandry (production)	☐	☐	☐	______	☐
animal welfare	☐	☐	☐	______	☐
good agricultural practices	☐	☐	☐	______	☐
other *please specify* ______	☐	☐	☐	______	☐
______	☐	☐	☐	______	☐

E Awareness on the IPPC Directive

E.1 As a pig producer, which do you think are the key environmental issues associated with indoor pig production?

Environmental Issues	- ⟵ *degree of relevance*			⟶ +		
Emissions of ammonia and gases to air	None ( )	Small ( )	Moderate ( )	Substantial ( )	Great ( )	Don't know O
Emissions of pollutants to land	None ( )	Small ( )	Moderate ( )	Substantial ( )	Great ( )	Don't know O
Emissions of pollutants to surface waters and groundwater	None ( )	Small ( )	Moderate ( )	Substantial ( )	Great ( )	Don't know O
Nuisance by odours	None ( )	Small ( )	Moderate ( )	Substantial ( )	Great ( )	Don't know O
Nuisance by noise	None ( )	Small ( )	Moderate ( )	Substantial ( )	Great ( )	Don't know O
Use of energy	None ( )	Small ( )	Moderate ( )	Substantial ( )	Great ( )	Don't know O
Use of clean water	None ( )	Small ( )	Moderate ( )	Substantial ( )	Great ( )	Don't know O
Use of raw materials (feed)	None ( )	Small ( )	Moderate ( )	Substantial ( )	Great ( )	Don't know O

E.2 Would you describe your current knowledge of the Integrated Pollution Prevention and Control (IPPC) Directive as it applies to the pig sector to be:

- ⟵		*knowledge*		⟶ +	
Virtually non-existent ( )	Limited ( )	Reasonable ( )	Good ( )	Complete ( )	Don't know O

E.3 The Integrated Pollution Prevention and Control (IPPC) sets guidance on particular <u>aspects of managing the pig unit</u>. Given your understanding of IPPC, to what extent do you think IPPC will require you to make <u>changes</u> regarding:

Aspect of unit	- ⟵ *degree of change required*			⟶ +		
Housing	None ( )	Small ( )	Moderate ( )	Substantial ( )	Great ( )	Don't know O
Animal waste storage	None ( )	Small ( )	Moderate ( )	Substantial ( )	Great ( )	Don't know O
Disposal of animal wastes (slurry and manure spreading)	None ( )	Small ( )	Moderate ( )	Substantial ( )	Great ( )	Don't know O
Planning, control and record keeping	None ( )	Small ( )	Moderate ( )	Substantial ( )	Great ( )	Don't know O
Staff training	None ( )	Small ( )	Moderate ( )	Substantial ( )	Great ( )	Don't know O

Appendix 4. 1 - Sketches of pig units and sites

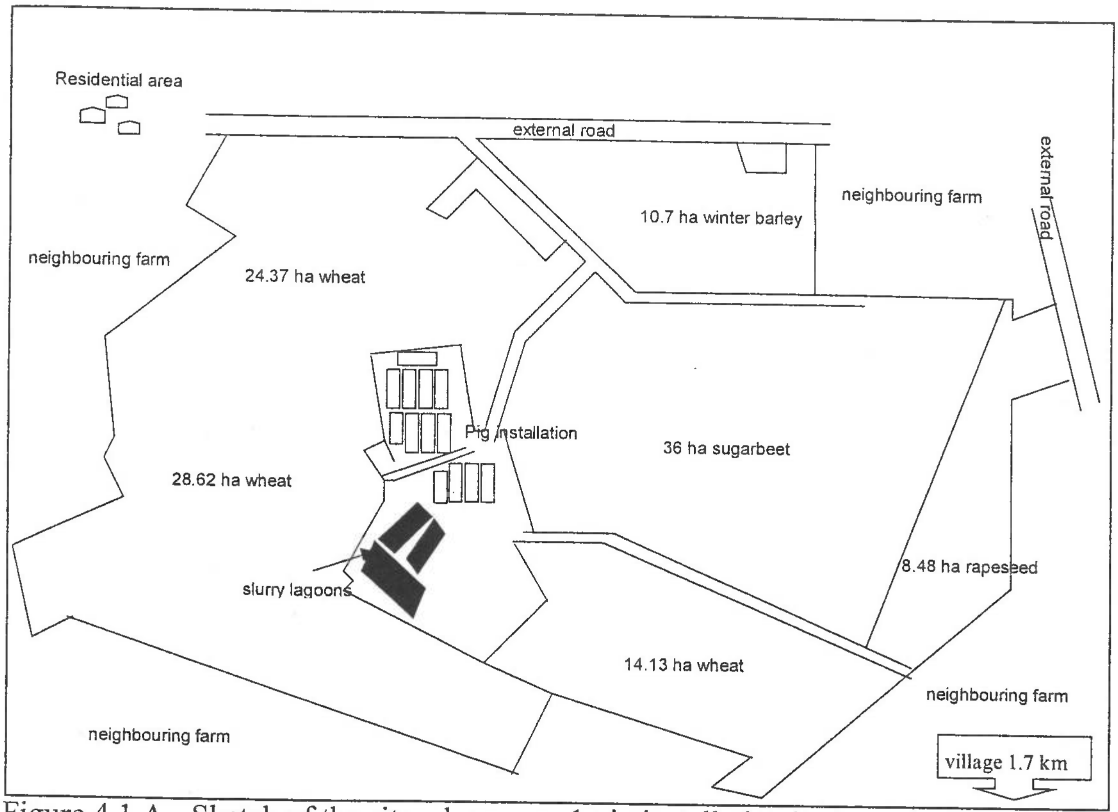


Figure 4.1.A - Sketch of the site where case 1 pig installation is situated

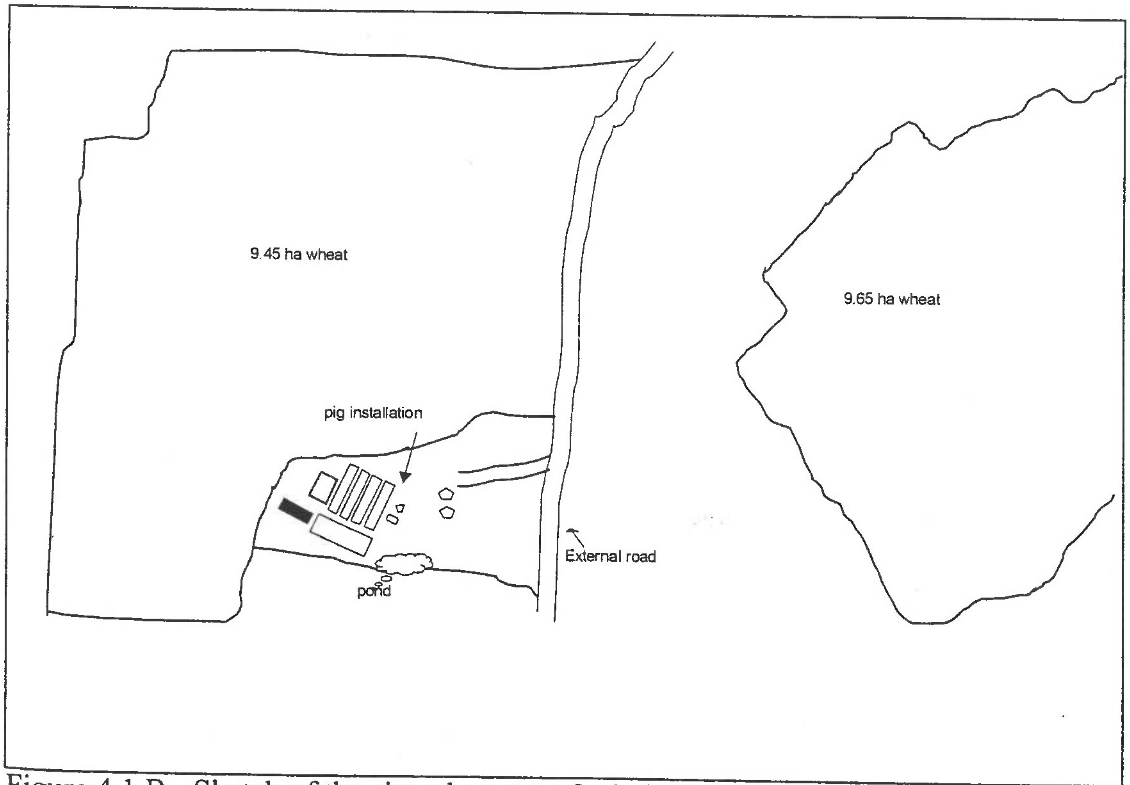


Figure 4.1.B - Sketch of the site where case 2 pig installation is situated

(continued Appendix 4.1)

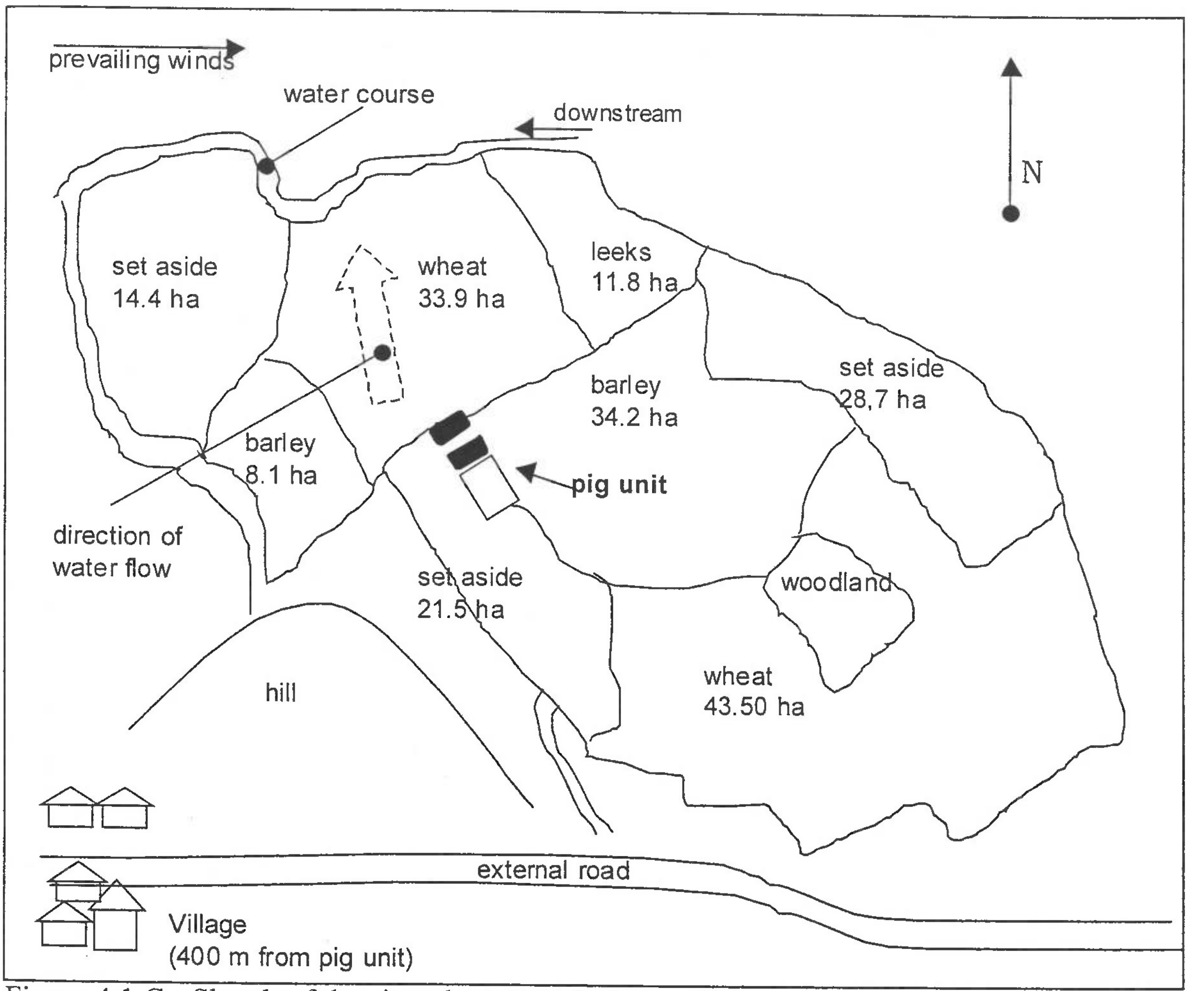


Figure 4.1.C - Sketch of the site where case 3 pig installation is situated

Appendix 4. 2- Flowchart of pig production in the case units

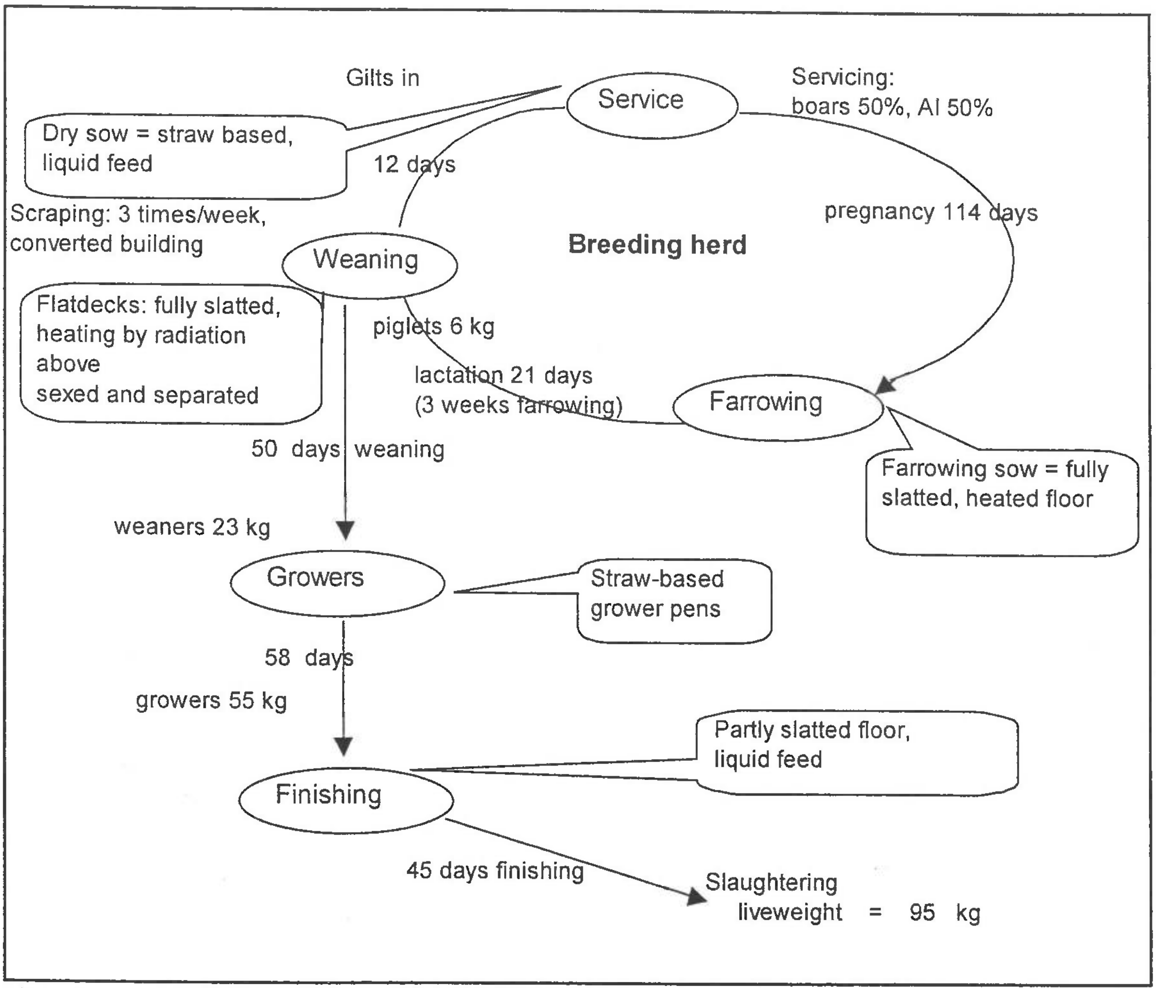


Figure 4.2.A - Representation of the production cycle at pig installation case study 1

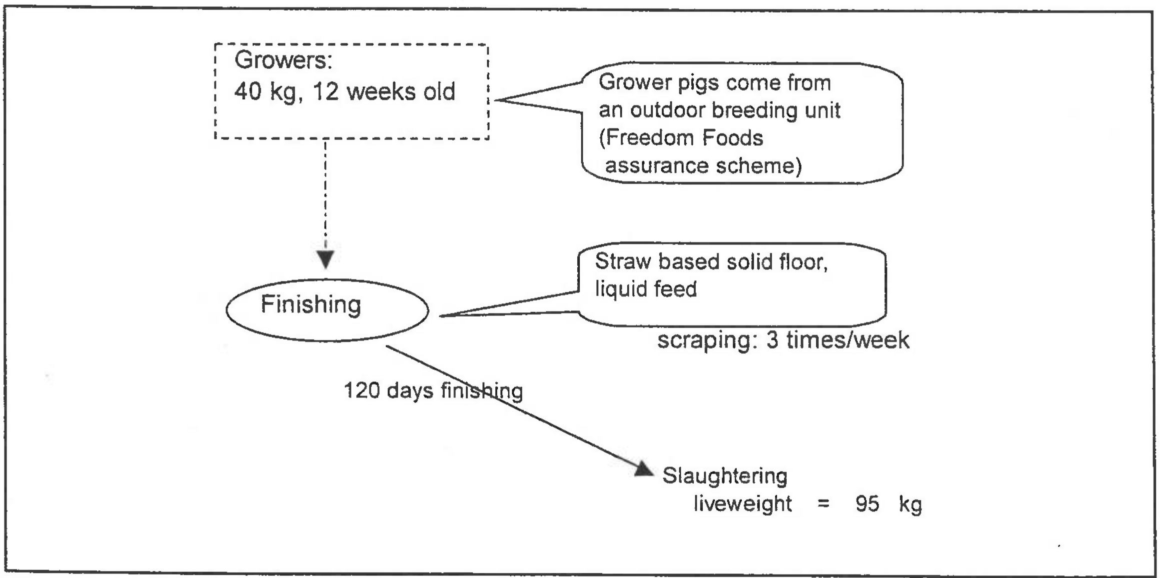


Figure 4.2.B - Representation of the production cycle at pig installation case study 2

(continued Appendix 4.2)

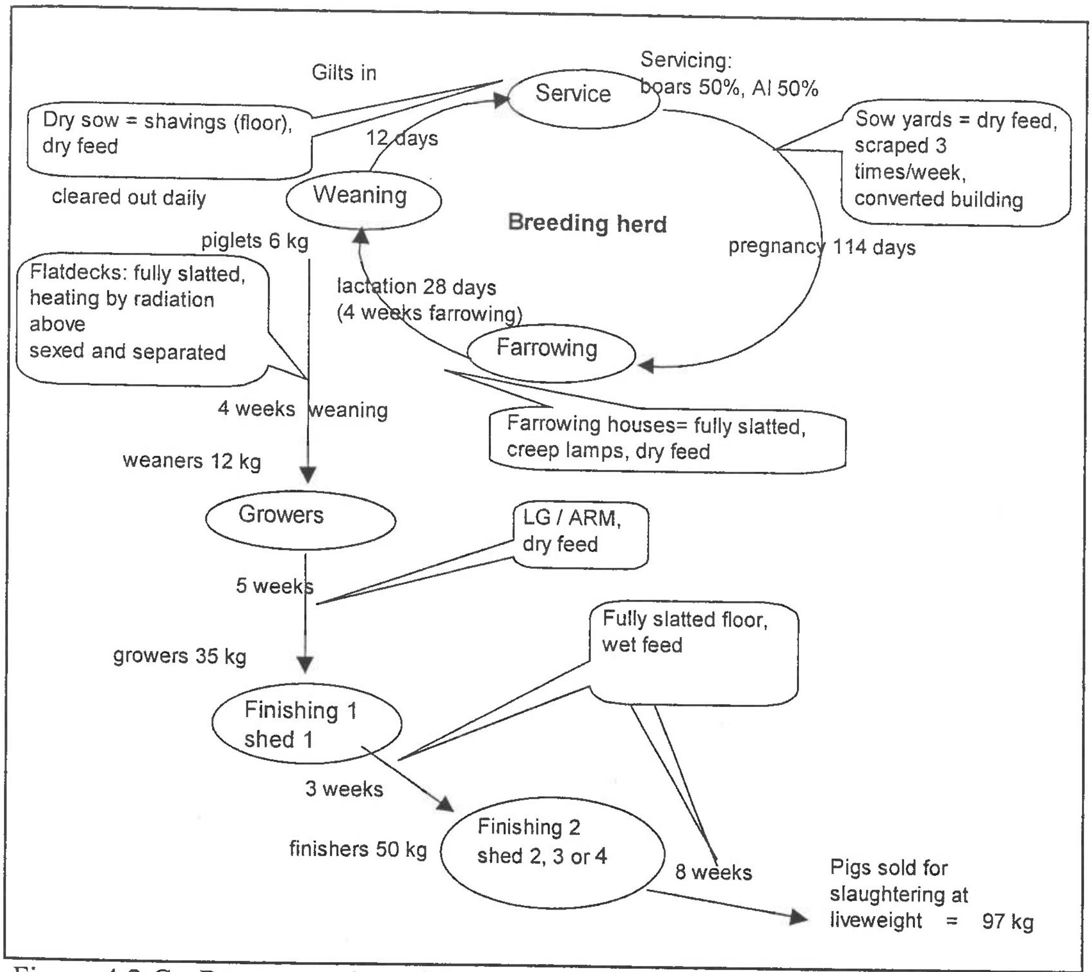


Figure 4.2.C - Representation of the production cycle at pig installation case study 3

Appendix 4. 3- List of the most used veterinary medicines and disinfectants

Pig Unit	Vet medicines	Disinfectants	Cost (total)	
			£/pig sold	(p/kg meat)
Case 1	Excenel Pen/Strep Engemycin Leddex Colisorb.	Farm Fluid S VirKon S	3.32	4.06
Case 2	Excenel Alamycin Symitrim Fortesol	Stulosan F	0.73	1.09
Case 3	Suyvaum M Myd Panacure (worm pellets) Gutval Planate Luytalyse	Antec VirKon S OO-cide Zac Drysan Antec Farm Fluid S	3.56	5.01

Source: case studies.

Appendix 4. 4 - Composition of pig manures
Composition by type of manure, in kg per 1000 kg of manure

Manure Type	Dm Dry matter	Om organic matter	Ntotal	Nm (metabolic N)	Norg (organic N)	P_2O_5	K_20	Density (kg/m^3)
Slurry								
Finishers	90	60	7.2	4.2	3.0	4.2	7.2	1040
(standard deviation)	(32)		(1.8)	(1.1)	(1.3)	(1.5)	(1.9)	
Sows	55	35	4.2	2.5	1.7	3.0	4.3	
(standard deviation)	(28)		(1.4)	(0.8)	(1.0)	(1.7)	(1.4)	
Solid manure								
Pigs (straw)	230	160	7.0-7.5	1.5	6.0	9.0	3.5	
Liquid fraction of solid manure								
Finishers	20-40	5	4-6.5	6.1	0.4	0.9-2.0	2.5-4.5	1010
Liquid fed (@ 4:1)*	60		4.5					
Sows	10	10	2.0	1.9	0.1	0.9	2.5	

Source: LNV (1993 and 1994) *quoted in* EIPPCB (2000) p. 79; updated EIPPCB, 2001 p.106.
*Chambers et al (2001) p.22, finishers (bacon type pig)11-23 week

Appendix 4. 5 - Standard excreta values for pigs

Values for excreta production by pig category

Animal category	**Excreta production, m^3/year/place**		
	FRCA (1997)[1]	MAFF (2000b)	LNV (1993-4)[2]
Sows and gilts			
Gestating sow	2.59	1.97	1.9-3.3
Farrowing sow			5.1
Gilts		1.46	1.3
Boars for service		1.46	
Pigs <20 kg; weaner	0.73	0.55	0.5-0.6
Finishing pigs >20 kg	2.04	1.46	1.1-1.5
Finishing pigs > 110 kg		1.97	

Notes: feeding and drinking systems account for variation in feed intake and slurry production;

1) including clean down water produced;

2) range refers to minimum and maximum values.

Appendix 4. 6 - Average N consumption and losses per pig produced

Nitrogen consumption, retention and losses in the production of a standard pig

Country	kg N per pig			av. Pig weight at
	Consumption	Retention	Losses	Slaughter (kg lw)
Denmark	8.03	2.81	5.22	100
France	8.64	2.87	5.76	108
Netherlands	8.39	2.86	5.53	113

Source: Dourmad et al. 1999 p.263.

Notes: it is assumed that N losses per pig are equal to N in excreta; the figures comprise N feed to sows.

Denmark has similar production indicators to the UK and was used as reference for losses per pig for the case studies.

Appendix 4. 7 - Estimated time for completion of an application form for IPPC permit

Application form requirement	*Manpower needed for completion (days)*
Description of activities and processes in place	2
Water audit	½
Energy audit	½ (nil if already under Climate Change Levy Agreement)
Manure Management Plan	2
Proposed measures for slurry storage	½
Accident prevention and management plan	1
Site report and decommissioning plan	3
Subtotal	9 ½
Overhead time (20%) – edit, formatting, filing etc.	2
Total	12 ½ (or c. 2 weeks)

Notes: 1) time shown refers to requirements in days for the consultant contracted; in addition, an equivalent time is assumed for manager/operator.
2) if odour or noise management are required, this would increase this time.

Annex 4. 1 – Selection of candidate BAT (for existing pig installations on the BREF Notes) to apply to case studies

4.1.1 - Housing for mating and gestating sows

The solid concrete floor with full litter (CSF full litter) can be applied as a reference housing system mating and gestating sows (Figure 4.1.1).

Description: The solid concrete floor is almost completely bedded by a layer of straw or other lignocellulosic materials to absorb urine and incorporate faeces. Solid manure is obtained, the removal of which has to be frequent in order to avoid the litter to becoming too moist. Frequency of removal of 1-4 times a year has been reported depending on litter type, depth of bedded area and general farm management. In case of one cleaning per year it is directly spread onto the field. With more cleanings the litter is generally stored, such as in a field clamp.

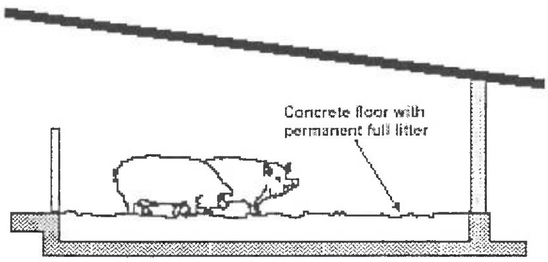


Figure 4.1.1 - Solid concrete floor and full litter (CSF full litter) [59, CRPA, 1999] BREF, 2000 p.51

Table 4.1.1 - Performance of housing techniques for new installations for mating and gestating sows.

Housing system	% NH_3-reduction	NH_3 (kg/sow place/year)[2]	Extra cost EUR/kg NH_3
Reference system for loose housing		3.69 (I) 3.12 (DK)	
Process integrated measures			
1. Reduce surface			
Small manure pit	33 42 20	1.04 (DK) 2.40 (NL,B) 2.95 (I)	n.r. [3] 3.25 (NL, 1998)[2] 3.82 (B, 1998)
Solid concrete floor and fully slatted external alley	20	2.95 (I)	
2. Fully slatted floors (FSF)with frequent and fast slurry removal			
FSF with vacuum system	25	2.77 (I)	
FSF with flush canals	30	2.58 (I)	
FSF with flush gutters or flush tubes	40	2.21 (I)	
3. Partly slatted floor (PSF) with frequent and fast slurry removal			
PSF with vacuum system)	30	2.58 (I)	
PSF with flush canals	40	2.21 (I)	
PSF with flush gutters or flush tubes	40 40	2.50 (NL,B) 2.21 (I)	34.05 (NL, 1998) 19.16 (B, 1998)
PSF with scraper	40)	2.21 (I	

(cont.)

(continued Table 4.1.1)

4. Manure cooling			
Manure surface cooling channel	n.r.	2.20 (NL,B)	10.20 (NL, 1998) 12.15 (B, 1998)
5. Solid concrete floor (CSF)+ external alley (EA) with frequent and fast slurry removal systems:			
CSF + EA flush canals	40	2.21 (I)	
CSF + EA scraper	40	2.21 (I)	
6. Straw systems:			
CSF full litter (reference)		3.70 (I) 5.20 (DK)	
CSF + EA litter	20	2.96 (I)	
CslatF bedding	20	4.15 (DK)	
PSF fast removal + EA litter	30	2.59 (I)	n.r.
End-of-pipe			
Bioscrubber	70	1.30 (NL)	5.75 (NL)
Chemical wetscrubber	90	0.40 (NL)	6.65 (NL)

() Member State from which the data originate
1 reference year of ecu exchange rate
2 sources NL [10, Hendriks and Weerdhof, 1999], B [37, Berckmans, 1999], I [59, CRPA, 1999]
3 n.r. not reported
BREF, 2000 p.124

Table 4.1.2 – Selection of BAT for housing for mating and pregnancy

Housing system	**% NH_3-reduction**	**NH_3 (kg/sow place/year)[2]**	**Criteria for selection or rejection**
Reference system for loose housing		3.69 (I) 3.12 (DK)	
Process integrated measures			
1. Reduce surface			
Small manure pit	33 42	1.04 (DK) 2.40 (NL,B)	Individual housing; applicability
CSF + fully slatted external alley	20	2.95 (I)	Use refurbish.
2. Fully slatted floors (FSF)with frequent and fast slurry removal			
FSF with vacuum system	25	2.77 (I)	Fully slatted system
FSF with flush canals	30	2.58 (I)	(not commonly used)
FSF with flush gutters or flush tubes	40	2.21 (I)	
3. Partly slatted floor (PSF) with frequent and fast slurry removal			
PSF with vacuum system	30	2.58 (I)	For new installations
PSF with flush canals	40	2.21 (I)	Use refurbish.
PSF with flush gutters or flush tubes	40 40	2.50 (NL,B) 2.21 (I)	34.05 (NL, 1998) 19.16 (B, 1998)
PSF with scraper	40	2.21 (I)	
Refurbish from PSFpit to PSF flush tubes [CRPA, 1999 table 4.9]	40	2.21	13.29
4. Manure cooling			
Manure surface cooling channel	n.r.	2.20 (NL,B)	10.20 (NL, 1998) 12.15 (B, 1998)

(cont.)

(continued Table 4.1.2)

5. Solid concrete floor (CSF)+ external alley (EA) with frequent and fast slurry removal systems:			
CSF + EA flush canals	40	2.21 (I)	
CSF + EA scraper	40	2.21 (I)	
Refurbish from CSF alley pit to CSF alley flush tubes [CRPA, 1999 table 4.9]	40	2.21	15.51
6. Straw systems:			
CSF full litter (reference)		3.70 (I) 5.20 (DK)	
CSF + EA litter	20	2.96 (I)	
CslatF bedding	20	4.15 (DK)	
PSF fast removal + EA litter	30	2.59 (I)	n.r.
End-of-pipe			
Bioscrubber	70	1.30 (NL)	5.75 (NL)
Chemical wetscrubber	90	0.40 (NL)	6.65 (NL)

() Member State from which the data originate
1 reference year of ecu exchange rate
2 sources NL [10, Hendriks and Weerdhof, 1999], B [37, Berckmans, 1999], I [59, CRPA, 1999]
3 n.r. not reported
BREF, 2000 p.124

4.1.3 - Selected techniques for mating and pregnancy

Housing system	% NH_3-reduction	NH_3 (kg/sow place/year)	Extra costs /pig place	(Euro)	Energy use (+)
			investment	operation	kWh
Reference system for loose housing		3.69 (I) 3.12 (DK)			
Process integrated measures					
3. Partly slatted floor (PSF) with frequent and fast slurry removal					
PSF with flush gutters or tubes (4617)	40	2.50 (NL,B)	161.80	57.90 19.16 (B)	0.5
Refurbish from PSFpit to PSF flush tubes [CRPA, 1999 table 4.9]	40	2.21		15.95	+
4. Manure cooling					
Manure surface cooling channel (4619)	n.r.	2.20 (NL,B)	112.75	20.35	8.5
5. Solid concrete floor (CSF)+ external alley (EA) with frequent and fast slurry removal systems:					
Refurbish from CSF alley pit to CSF alley flush tubes [CRPA, 1999 t. 4.9]	40	2.21		18.62	+
CSF full litter (reference)		3.70 (I) 5.20 (DK)			
End-of-pipe					
Bioscrubber	70	1.30 (NL)	111.35	16.7	35
Chemical wetscrubber	90	0.40 (NL)	62.75	25.05	52.5

4.1.2 - Housing systems for farrowing sows

A typical housing system is shown in Figure 4.1.2. The slurry manure is stored under the slatted floor of the crates in a deep pit from which the manure is removed only at the end of the lactating period or less frequently. The emissions of these houses vary and have been measured or derived:

8.30 kg NH_3/ sow place/ year (NL, B)
8.73 kg NH_3/ sow place/ year (I)

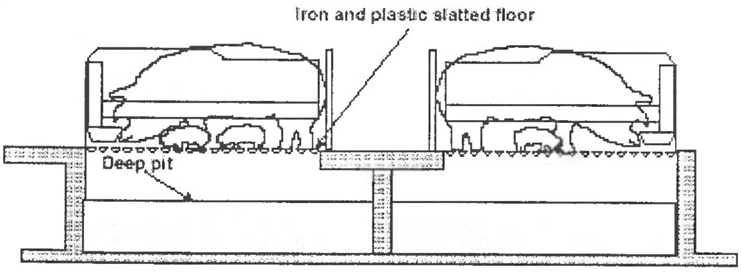


Figure 4.1.2 - Housing of farrowing sows in crates with storage pit underneath [59, CRPA, 1999] BREF, 2000 p.53

Table 4.2.1 - Housing techniques for new installations for farrowing sows.

Housing system	% NH_3-reduction	NH_3 (kg/sow place/year)[2]	Extra cost EUR/kg NH_3
Reference system		8.73 (I) 8.30 (NL, B) 1.57 (DK)	
Process integrated measures			
Crates with fully slatted floor and reduced manure surface	33	1.04 (DK)	n.r.
Board on a slope under the slatted floor	30 40	6.11 (I) 5.0 (NL, B)	n.r.[3], but =ref. 8.95 (NL, 1998)[1] 10.56 (B, 1998)
Manure surface cooling channel	70	2.4 (NL, B)	9.20 (NL, 1998) 10.88 (NL, 1998)
Combination of a water and manure channel	50	4.0 (NL, B)	0.25 (NL, 1998) 0.32 (B, 1998)
Manure pan	65	2.9 (NL,B)	8.80 (NL, 1998)
Manure scraper	35	5.67 (I) 4.0 (NL, B)	n.r., but =ref. 34.20 (NL, 1998) 40.53 (B, 1998)
Flushing system with manure gutters	60	3.3 (NL, B)	17.20 (NL, 1998) 20.35 (B, 1998)
End-of-pipe			
Bioscrubber	70	2.5 (NL)	5.65 (NL, 1998)
Chemical wetscrubber	90	0.8 (NL)	10.40 (NL, 1998)

() Member State from which the data originate
1 reference year of ecu exchange rate
2 sources NL [10, Hendriks and Weerdhof, 1999], B [37, Berckmans, 1999], I [59, CRPA, 1999]
3 n.r. not reported BREF, 2000 p.140

Table 4.2.2 – Selection of housing BAT for farrowing sows for case studies

Housing system	**% NH_3-reduction**	**NH_3 (kg/sow place/year)[2]**	**Criteria for selection or rejection of BAT**
Reference system		8.73 (I) 8.30 (NL, B) 1.57 (DK)	 Relatively too low!
Process integrated measures			
Crates with fully slatted floor and reduced manure surface	33	1.04 (DK)	Too low to compare; no reference to costs
Board on a slope under the slatted floor	30 40	6.11 (I) 5.0 (NL, B)	n.r.[3], but =ref. 8.95 (NL, 1998)[1] 10.56 (B, 1998)
Manure surface cooling channel	70	2.4 (NL, B)	9.20 (NL, 1998) 10.88 (NL, 1998)
Combination of a water and manure channel	50	4.0 (NL, B)	Adopted, despite not being in latest selected 60 , 0.25-0.32
Manure pan	65	2.9 (NL,B)	Technically similar to 'Board…' (despite best reduction performance)
Manure scraper	35	5.67 (I) 4.0 (NL, B)	For partly-slatted floor systems
Flushing system with manure gutters	60	3.3 (NL, B)	17.20 (NL, 1998) 20.35 (B, 1998)
End-of-pipe			
Bioscrubber	70	2.5 (NL)	5.65 (NL, 1998)
Chemical wetscrubber	90	0.8 (NL)	10.40 (NL, 1998)

4.2.3 - Selected techniques for farrowing sows

Housing system	% NH_3-reduction	NH_3 (kg/sow place/year)	Extra costs /pig place	(Euro)	Energy use (+)
			investment	operation	kWh
Reference system		8.30 (NL, B)			
Process integrated measures					
Board on a slope under the slatted floor (4621)	40	5.0 (NL, B)	260	29.5	Not relevant
FSF crates and combination of water and manure channel (4.6.2.2) conc/iron	50	4.0 (NL,B)	60	0.25 032	
Manure surface cooling channel (4625)	70	2.4 (NL, B)	302	54.25	18
Flushing system with manure gutters 4623	60	3.3 (NL, B)	535	86	8.5
FSF and manure pan (4624)	65	2.9	280	45.85	
End-of-pipe					
Bioscrubber	70	2.5 (NL)	111.35	32.75	35
Chemical wetscrubber	90	0.8 (NL)	83.65	28	100

Additionally, bioscrubber require an extra 1 m^3 of water per pig place.

4.1.3 - Housing for weaners

In Figure 4.1.3 an example of a commonly applied rearing unit for weaners is shown, where the manure is handled in the form of slurry. It is drained mainly through a pipe discharge plant where the individual sections of the manure channels are emptied via plugs in the pipes. The channels can also be drained via gates. The channels are cleaned after the removal of each group of pigs, often in connection with the cleaning of the pens, i.e. at intervals of 6-8 weeks.

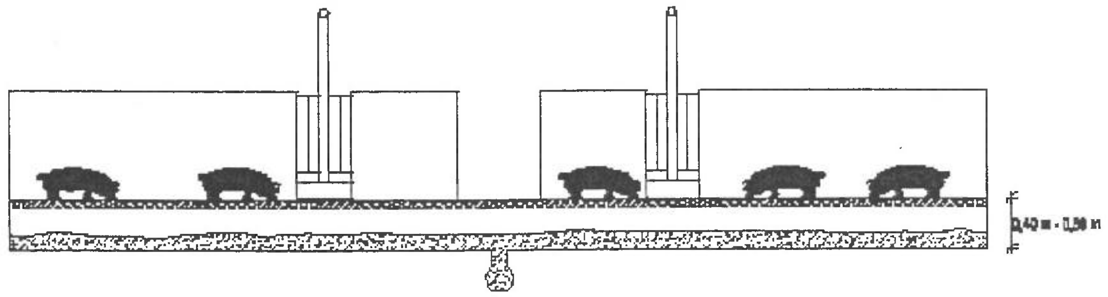


Figure 4.1.3 - Cross-section of rearing unit with fully slatted floor and plastic or metal slats [DAAC, 2000 #87] quoted in BREF, 2000.

Table 4.3.1 - Housing techniques for new installations for weaners

Housing system	% NH_3-reduction	NH_3 (kg/pig place/year)[2]	Extra cost EUR/kg NH_3
Reference system		0.80 (DK) 0.60 (I) 0.60 (NL)	
Process integrated measures			
Rearing units, Partly slatted floor, two-climate	34	0.53 (DK)	n.r.
Flat decks or pens with concrete sloped floor underneath to separate faeces and urine	30	0.43 (I)	n.r., but =ref.
Flat deck with a scraper underneath	35	0.39 (I)	n.r., but =ref.
Pens with fully slatted floor with flush gutters or flush tubes	40	0.36 (I)	5.30 (I, 1998)
Partly slatted or convex floor with iron or plastic slats	43	0.34 (NL)	~0
Shallow manure pit with a channel for spoiled drinking water	57	0.26 (NL, B)	1.35 (NL, B, 1998) 1
Manure channel with gutters, partly slatted floor with triangular iron slats	65	0.21 (NL, B)	10.65 (NL, 1998) 11.75 (B, 1998)
Manure scraper under partly slatted floor	70 40	0.18 (NL, B) 0.39 (I)	19.84 (NL, 1998) 89.54 (B, 1998)
Pen manure channel with side wall(s) on a slope, partly triangular iron bar slatted floor	72	0.17 (NL)	1.70 (NL, 1998)
Manure surface cooling channel	75	0.15 (NL, B)	9.75 (NL, 1998) 11.20 (B, 1998)
End-of-pipe			
Bioscrubber	70	0.18 (NL)	7.95 (NL, 1998)
Chemical wetscrubber	90	0.06 (NL)	5.55 (NL, 1998)

() Member State from which the data originate
1 reference year of ecu exchange rate
2 sources NL [10, Hendriks and Weerdhof, 1999], B [37, Berckmans, 1999], I [59, CRPA, 1999]
3 n.r. not reported
BREF, 2000 p.148

Table 4.3.2 – Selection of BAT for weaned piglets for case studies

Housing system	**% NH_3-reduction**	**NH_3 (kg/pig place/year)²**	**Criteria for selection or rejection**
Reference system		0.80 (DK) 0.60 (I) 0.60 (NL)	
Process integrated measures			
Rearing units, Partly slatted floor, two-climate	34	0.53 (DK)	Part slatted floor; no data available
Flat decks or pens with concrete sloped floor underneath to separate faeces and urine	30	0.43 (I)	No data on cost
Flat deck with a scraper underneath	35	0.39 (I)	Not applicable to existing installations
Refurbishing FSF pit to Pens with fully slatted floor with flush gutters or flush tubes	40	0.36 (I)	5.30 (I, 1998) Lit 28150 (CRPA, 1999)
Partly slatted or convex floor with iron or plastic slats	43	0.34 (NL)	Applicability to existing depending on design; Partly slatted. No data.
Shallow manure pit with a channel for spoiled drinking water	57	0.26 (NL, B)	Part slatted
Manure channel with gutters, partly slatted floor with triangular iron slats	65	0.21 (NL, B)	10.65 (NL, 1998) 11.75 (B, 1998)
Manure scraper under partly slatted floor	70 40	0.18 (NL, B) 0.39 (I)	Difficult to apply to existing installations
Pen manure channel with side wall(s) on a slope, partly triangular iron bar slatted floor	72	0.17 (NL)	Partly slatted, despite being applicable to existing installations
Manure surface cooling channel	75	0.15 (NL, B)	9.75 (NL, 1998) 11.20 (B, 1998)
End-of-pipe			
Bioscrubber	70	0.18 (NL)	7.95 (NL, 1998)
Chemical wetscrubber	90	0.06 (NL)	5.55 (NL, 1998)

() Member State from which the data originate
1 reference year of ecu exchange rate
2 sources NL [10, Hendriks and Weerdhof, 1999], B [37, Berckmans, 1999], I [59, CRPA, 1999]
3 n.r. not reported BREF, 2000 p.148

Table 4.3.3 - Selected techniques for weaned pigs

Housing system	% NH_3-reduction	NH_3 (kg/pig place/year)	Extra costs /pig place	(Euro)	Energy use (+)
			investment	operation	kWh
Reference system		0.60 (I, NL)			
Process integrated measures					
Refurbish FSF pit to Pens with fully slatted floor with flush gutters or flush tubes (4633)	40	0.36 (I)	2.22	1.27	+ Not reported
Manure channel with gutters, partly slatted floor, triangular iron slats (4637)	65	0.21 (NL, B)	25	10.65 11.75	0.75
Manure surface cooling channel (46310) (note: partly slatted; high energy)	75	0.15 (NL, B)	24	9.75 11.20	6.5
End-of-pipe					
Bioscrubber	70	0.18 (NL)	10	3.35	8
Chemical wetscrubber	90	0.06 (NL)	9	3	10

Additionally, bioscrubber require an extra 1 m^3 of water per pig place (possibly lower for weaners).

4.1.4 – BAT for housing of finishers

As a reference technique, a type of housing system is used that has been widely applied throughout the EU-15. It is comprised of a fully slatted floor and a deep underlying pit (Figure 4.1.4) from which the slurry is removed at the end of a finishing cycle or once a year (or less). The performance level is set at about 3.0 kg NH_3/pig place/year.

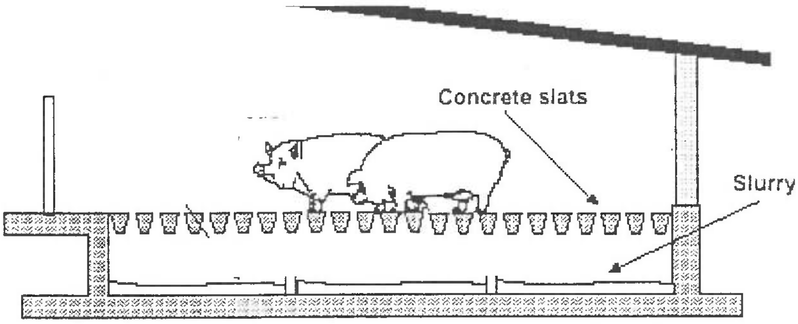


Figure 4.1.4 - Fully slatted floor with flushing of a permanent slurry layer in canals underneath [CRPA, 1999] quoted in BREF, 2000 p.128 (note it is originally representation of service house)

Table 4.4.1- BAT for new installations for finishers.

Housing system	**% NH_3-reduction**	**NH_3 (kg/pig place/year)[2]**	**Extra cost EUR/kg meat[1]**	**Extra cost EUR/kg NH_3**
Reference system		3.0 (I, NL, B) 2.39 (DK)		
Process integrated measures				
1. Reduce manure surface				
PSF pit	20 33	2.40 (I) 1.59 (DK)	0.0005 (I) n.r.	0.09 (I) n.r.[4]
Solid concrete floor and fully slatted external alley	20	2.4 (I)	0.017 (I, 1998)	6.05 (I, 1998)
2. Fully slatted floors (FSF) with frequent and fast slurry removal				
FSF with vacuum system	25	2.25 (I)	-0.026	-7.42 (I, 1998)
FSF with flush canals	30	2.10 (I)	-0.023	-5.47 (I, 1998)
FSF with flush gutters or flush tubes	40	1.80 (I)	-0.020	-3.59 (I, 1998)
3. Partly slatted floor (PSF) with frequent and fast slurry removal				
PSF with vacuum system	30	2.10 (I)	-0.024	-5.86 (I, 1998)
PSF with flush canals	40	1.80 (I)	-0.023	-4.10 (I, 1998)
PSF with flush gutters or flush tubes concrete slats iron slats	40 60 65	1.80 (I) 1.2 (NL, B) 1.0 (NL, B)	-0.012 n.r. n.r	-2.19 (I, 1998) 5.25 (NL, 98) 6.25 (NL, 98)
PSF-ssw/concrete PSF-ssw/iron	60 65	1.2 (NL, B) 1.0 (NL, B)	n.r.	0.28 (NL,98) 2.70 (NL,98)
PSF with scraper	40	1.80 (I)	-0.023	-4.07 (I, 1998)

(cont.)

(continue Table 4.4.1)

4. Manure cooling				
Manure surface cooling channel Iron slats	n.r.	2.20 (NL,B)	n.r.	10.20 (NL, 98) 12.15 (B, 98)
5. Solid concrete floor (CSF) + external alley (EA) with frequent and fast slurry removal systems:				
CSF + EA flush canals	40	1.80(I)	-0.0021	-0.38 (I, 1998)
CSF + EA scraper	40	1.80 (I)	-0.0015	-0.25 (I, 1998)
6. Straw systems:				
CSF full litter (reference)		3.0 (I)		
CSF + EA litter	20	2.4 (I)	0.0005	0.10 (I, 1998)
PSF fast removal + EA litter	30	2.1 (I)	n.r.	n.r.
End-of-pipe				
Bioscrubber	70-90	0.80 (NL)	n.r	7.60 (NL) 19.4 - 29.75 (B)
Chemical wetscrubber	90	0.30(NL)	n.r	5.20 (NL)

() Member State from which the data originate
1 reference year of ecu exchange rate
2 negative amount means technique cheaper than reference
3 sources NL [10, Hendriks and Weerdhof, 1999], B [37, Berckmans, 1999], I [59, CRPA, 1999]
4 n.r. not reported
BREF, 2000 p.160

Table 4.4.2 – Selection of BAT housing for fattening pigs for case studies

Housing system	**% NH_3-reduction**	**NH_3 (kg/pig place/year)[2]**	**Extra cost EUR/kg meat[1]**	**Criteria for selection or rejection**
Reference system		3.0 (I, NL, B) 2.39 (DK)		No data.
Process integrated measures				
1. Reduce manure surface				
PSFpit	20 33	2.40 (I) 1.59 (DK)	0.0005 (I) n.r.	Applic.to exist n.r.[4]
Solid concrete floor and fully slatted external alley	20	2.4 (I)	0.017 (I, 1998)	6.05 (I, 1998)
Refurbish from CSF alley pit to CSF alley flush tubes [CRPA, 1999 table 4.9]	40	1.80 (I)	0.09	15.51
2. Fully slatted floors (FSF) with frequent and fast slurry removal				
FSF with vacuum system	25	2.25 (I)	-0.026	-7.42 (I, 1998)
FSF with flush canals	30	2.10 (I)	-0.023	-5.47 (I, 1998)
FSF with flush gutters or flush tubes	40	1.80 (I)	-0.020	-3.59 (I, 1998)
Refurbish from FSFpit to FSF flush tubes [CRPA, 1999 table 4.9]	40	1.80 (I)	0.06	11.63
3. Partly slatted floor (PSF) with frequent and fast slurry removal				
PSF with vacuum system	30	2.10 (I)	-0.024	-5.86 (I, 1998)
PSF with flush canals	40	1.80 (I)	-0.023	-4.10 (I, 1998)
PSF with flush gutters or flush tubes concrete slats iron slats	40 60 65	1.80 (I) 1.2 (NL, B) 1.0 (NL, B)	-0.012 n.r. n.r	Use refurbish. 5.25 (NL, 98) 6.25 (NL, 98)

(cont.)

(continued Table 4.4.1)

Refurbish from PSFpit to PSF flush tubes [CRPA, 1999 table 4.9]	40	1.80 (I)	0.07	13.29
PSF-ssw/concrete PSF-ssw/iron	60 65	1.2 (NL, B) 1.0 (NL, B)	n.r.	0.28 (NL,98) 2.70 (NL,98)
PSF with scraper	40	1.80 (I)	-0.023	Not potential
4. Manure cooling				
Manure surface cooling channel iron slats	50 60	1.5 (NL,B) 1.2 (NL,B)	n.r. n.r.	3.65 (NL, 98) 4.50 (B, 98)
5. Solid concrete floor (CSF) + external alley (EA) with frequent and fast slurry removal systems:				
CSF + EA flush canals	40	1.80(I)	-0.0021	Use Refurbish.
CSF + EA scraper	40	1.80 (I)	-0.0015	-0.25 (I, 1998)
6. Straw systems:				
CSF full litter (reference)		3.0 (I)		
CSF + EA litter	20	2.4 (I)	0.0005	0.10 (I, 1998)
PSF fast removal + EA litter	30	2.1 (I)	n.r.	n.r.
End-of-pipe				
Bioscrubber	70-90	0.80 (NL)	n.r	7.60 (NL) 19.4 - 29.75 (B)
Chemical wetscrubber	90	0.30(NL)	n.r	5.20 (NL)

() Member State from which the data originate
1 reference year of ecu exchange rate
2 negative amount means technique cheaper than reference
3 sources NL [10, Hendriks and Weerdhof, 1999], B [37, Berckmans, 1999], I [59, CRPA, 1999]
4 n.r. not reported BREF, 2000 p.160

Table 4.4.3 - Selected techniques for case studies

Housing system	% NH_3-reduction	NH_3 (kg/pig place/year)	Extra costs /pig place	(Euro)	Energy use (+)
			Investment	operation	kWh
Reference system FSFpit (slurry) CSF full litter (straw)		3.0 (I,NL,B) 3.0 (I)			
Process integrated measures					
1. Reduce manure surface Refurbish from CSF alley pit to CSF alley flush tubes [CRPA, 1999 t.4.9]	40	1.80 (I)		18.62	+
**Not applicable, difficult to compare to current systems in the cases.*					
2. Fully slatted floors (FSF) with frequent and fast slurry removal					
Refurbish from FSFpit to FSF flush tubes [CRPA, 1999 table 4.9]	40	1.80 (I)		13.96	+
3. Partly slatted floor (PSF) with frequent and fast slurry removal					
PSF with flush gutters or flush tubes (4618/4641) concrete slats (4618/4641b) iron slats	 60 65	 1.2 (NL, B) 1.0 (NL, B)	 59 79	 9.45 12.50	 1.5 1.5
Refurbish from PSFpit to PSF flush tubes [CRPA, 1999 table 4.9]	40	1.80 (I)		15.95	+
PSF-ssw/concrete (4642) PSF-ssw/iron (4642b)	60 65	1.2 (NL, B) 1.0 (NL, B)	3 23	0.50 15	No No
4. Manure cooling					
Manure surface cooling channel Concrete slats (4615) Iron slats (4615b)	 50 60	 1.5 (NL,B) 1.2 (NL,B)	 30.40 43	 5.50 8	 14 14
End-of-pipe					
Bioscrubber	70-90	0.80 (NL)	49	16.7	35
Chemical wetscrubber	90	0.30(NL)	43	14	55

Additionally, bioscrubber require an extra 1 m^3 of water per pig place.

Regarding BAT for finisher the codes were revised according to BREF 2001 only in this table.

Appendix 4. 8 - BAT techniques for pig housing applied to the case study installations

Phase		Housing system*	Case study 1	Case study 2	Case study 3	NH_3 emission (kg NH_3 / pig place/ year)**	Extra costs (£ /pig place/ year)**	Cost efficiency £/kg NH_3 abated/ year
Mating& Pregnancy	*Current*	CSF full litter	✓		✓	3.70	-	-
		PSF pit (Ita)			✓	2.95	-	-
	Selected BAT candidates	None	✓	N/A			-	
		1 PSF with flush gutters or tubes (4618)			✓	2.50	50.78	42.31
		2 PSF with flush gutters or tubes (4618_belgi)			✓	2.50	23.45	19.54
		3 Refurbish PSFpit to PSF flush tubes			✓	2.21	11.25	7.55
		4 Manure surface cooling channel (4619)			✓	2.20	21.28	14.18
		5 Refurbish CSF alley pit to CSF alley flush			✓	2.21	13.14	8.82
	End-of-pipe	6 Bioscrubber	✓		N/A	1.30	22.46	9.36
		7 Chemical wetscrubber	✓		N/A	0.40	23.69	7.18
Farrowing	*Current*	Crates with storage pit underneath	✓		✓	8.30	-	-
	Selected BAT candidates	8 Board under slats (4621)	✓	N/A	✓	5.00	36.77	11.14
		9 Manure cooling (4625)	✓		✓	2.40	56.81	9.63
		10 Flushing + manure gutters (4623)	✓		✓	3.30	93.50	18.70
		11 FSF water & manure channels (4622)	✓		✓	4.00	3.86	0.90
		12 FSF w&m channel iron slats (4622b)				4.00	3.91	0.91
		13 FSF manure pan (4624)	✓		✓	2.90	49.53	9.17
	End-of-pipe	14 Bioscrubber	N/A		✓	2.50	33.79	5.83
		15 Chemical wetscrubber	N/A		✓	0.80	27.78	3.70
Weaning	*Current*	Flat deck FSF	✓		✓	0.60	-	-
	Selected BAT candidates	16 Refurbish FSF pit to FSF flush (4633)	✓	N/A	✓	0.36	2.46	10.26
		17 Manure channel gutters PSF iron slats (4637)	✓		✓	0.21	9.05	23.20
		18 Manure channel gutters PSF (4637_belg)	✓		✓	0.21	9.82	25.19
		19 Manure surface cooling channel (46310)	✓		✓	0.15	8.35	18.56
	End-of-pipe	20 Bioscrubber	✓		✓	0.18	3.32	7.91
		21 Chemical wetscrubber	✓		✓	0.06	2.98	5.52
Growing	*Current*	CSF full litter (straw)	✓	✓		1.80	-	-
		FSF pens			✓	1.80	-	-
	Selected BAT	None	✓	✓		-	-	-
		BAT candidates for finishers number 22 to 28			✓	(see note below)		
	End-of-pipe	Bioscrubber (29)	N/A	✓	✓			
		Chemical wetscrubber (30)	N/A	✓	✓			
Finishing	*Current*	PSFpit	✓			2.40	-	-
		FSFpit (slurry)			✓	3.00	-	-
		CSF full litter (straw)		✓		3.00	-	-
	Selected BAT candidates	None		✓		-	-	-
		22 Refurbish from FSFpit to FSF flush tubes			✓	1.80	9.85	8.21
		23 PSF flush gutters/ tubes (4641) concrete slats			✓	1.20	10.29	5.72
		24 PSF flush gutters/tubes (4641b) iron slats			✓	1.00	13.67	6.83
		25 Refurbish PSF pit to PSF flush tubes	✓		✓	1.80	11.25	9.38
		26 PSF-ssw/iron (4642b)	✓		✓	1.00	11.99	6.00
		27 Manure cooling PSF (4615) concrete slats	✓		✓	1.50	5.75	3.83
		28 Manure cooling PSF (4615b) iron slats	✓		✓	1.20	8.28	4.60
	End-of-pipe	29 Bioscrubber	✓	✓	✓	0.80	16.48	7.49
		30 Chemical wetscrubber	✓	✓	✓	0.30	14.00	5.19

Notes: ✓ - if housing technique applies to the case study; N/A - not applicable, as the installation does not operate the referred phase or, in the case of scrubbers, natural ventilation system does not allow required control of air flows.

* Number in brackets as technique is referred in the BREF Note.

**Abatement levels and extra costs of BAT are compared to the emission and cost of the reference system for the phase. Growing phase applied BAT for finishers using conversion factor for emission and cost by weight and space allowance. Source: compiled from the BREF Notes (EIPPCB, 2001) and CRPA (1999).

Appendix 4. 9 - BAT options for housing applied to case study 1

Description Phase/ BAT option	Capital investment required (£)	Annual cost (£/year) investment (A)	operation (B)	(6%a.a) total (A+B)	Emission emission kg/year	NH$_3$ reduction kg/year	Extra use of energy (kWh)
Mating & pregnancy							
reference					**3,089**		
Process integrated: none							
Farrowing							
reference					**1,259**		
Board on a slope under the slatted floor (4621)	27,820	2,420	3,156	5,577	758	501	-
Manure surface cooling channel (4625)	32,314	2,811	5,805	8,616	364	895	2,730
Flushing system with manure gutters (4623)	57,245	4,980	9,202	14,182	501	758	1,289
FSF crates and combination of water & manure channel (4.6.2.3)	6,420	559	27	585	607	652	-
" " " (iron slats) 4622b	6,420	559	34	593	607	652	-
FSF and manure pan (4624)	29,960	2,607	4,906	7,512	440	819	-
Weaning							
reference					**1,093**		
Refurbish FSF pit to pens FSF flush gutters or tubes (4633)	-	-	-	4,486	656	437	3,462
Manure channel with gutters, PSF triang iron slats (4637)	32,133	2,796	13,689	16,484	383	711	1,367
Manure channel with gutters, PSF triang iron slats (4637_belg)	or	-	15,103	17,898	383	711	-
Manure surface cooling channel (46310)	30,848	2,684	12,532	15,216	273	820	11,843
Growing							
Reference					**6,023**		
Process integrated measures: none							
Finishing							
Reference					**5,808**		
PSF with flush gutters or flush tubes concrete slats (4641)	100,725	8,763	16,133	24,896	2,904	2,904	3,630
iron slats (4641b)	134,869	11,734	21,340	33,074	2,420	3,388	3,630
Refurbish from PSFpit to PSF flush tubes [CRPA]	-	-	-	27,230	4,356	1,452	-
PSF-ssw/iron (4642b)	39,266	3,416	25,608	29,024	2,420	3,388	-
Manure surface cooling channel PSF concrete slats (4615)	51,899	4,515	9,390	13,905	3,630	2,178	33,880
iron slats (4615b)	73,410	6,387	13,658	20,044	2,904	2,904	33,880

Appendix 4. 10 - BAT options for housing applied to case study 3

Description Phase/ BAT option	**Capital Investment Required (£)**	**Annual cost** investment (A)	**(£/year)** operation (B)	**(6%a.a)** total (A+B)	**Emission** emission kg/year	**NH_3** reduction kg/year	Extra use of energy (kWh)
Mating & pregnancy					**2,228**		
Reference					623		
PSF with flush gutters or tubes (4618)	24,110	2,098	8,628	10,725	528	95	106
PSF with flush gutters or tubes (4618_belgi)	24,110	2,098	2,855	4,953	528	95	106
Refurbish from PSFpit to PSF flush	n.r.	n.r.	n.r.	2,377	467	156	106
Manure surface cooling channel (4619)	16,801	1,462	3,032	4,494	465	158	1,795
Refurbish from CSF alley pit to CSF flush	n.r.	n.r.	n.r.	2,775	467	156	n.r.
Farrowing					**857**		
Board on a slope under the slatted floor (4621)	18,948	1,648	2,150	3,798	517	341	-
Manure surface cooling channel (4625)	22,009	1,915	3,954	5,868	248	609	1,859
Flushing system with manure gutters (4623)	38,989	3,392	6,267	9,659	341	517	878
FSF combination of water&manure channel (4622)	4,373	380	18	399	413	444	-
" " " (iron slats) 4622b	4,373	380	23	404	413	444	-
FSF and manure pan (new BREF 2001) 4624	20,405	1,775	3,341	5,117	300	558	-
Weaning					**1,777**		
Reference					1,593		
Refurbish FSF pit to FSF pens flush gutters or tubes (4633)	-	-	6,538	6,538	956	637	5,046
Manure channel with gutters, PSF triang iron slats (4637)	46,837	4,075	19,953	24,027	558	1,036	1,992
Manure channel with gutters, PSF triang iron slats (4637_belg) or		-	22,013	26,088	558	1,036	1,992
Manure surface cooling channel (46310)	44,963	3,912	18,266	22,178	398	1,195	17,262

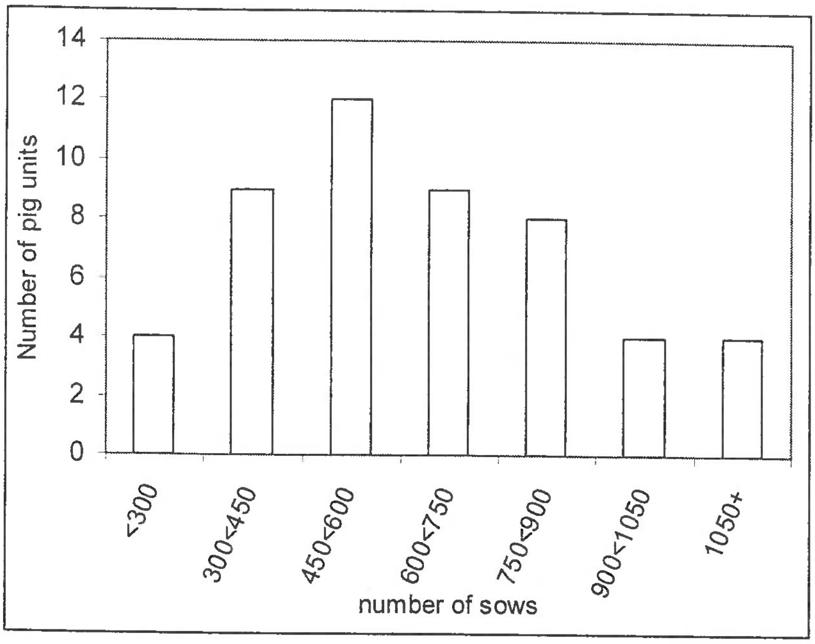
Note: BAT applied to 25% of dry sow places kept in partly slatted floor. Therefore reference emission is 623 kg NH_3, for a total emission of 2288 kg of NH_3 per year.

BAT to weaning involves 184 kg of ammonia not subject to reduction (15% places).

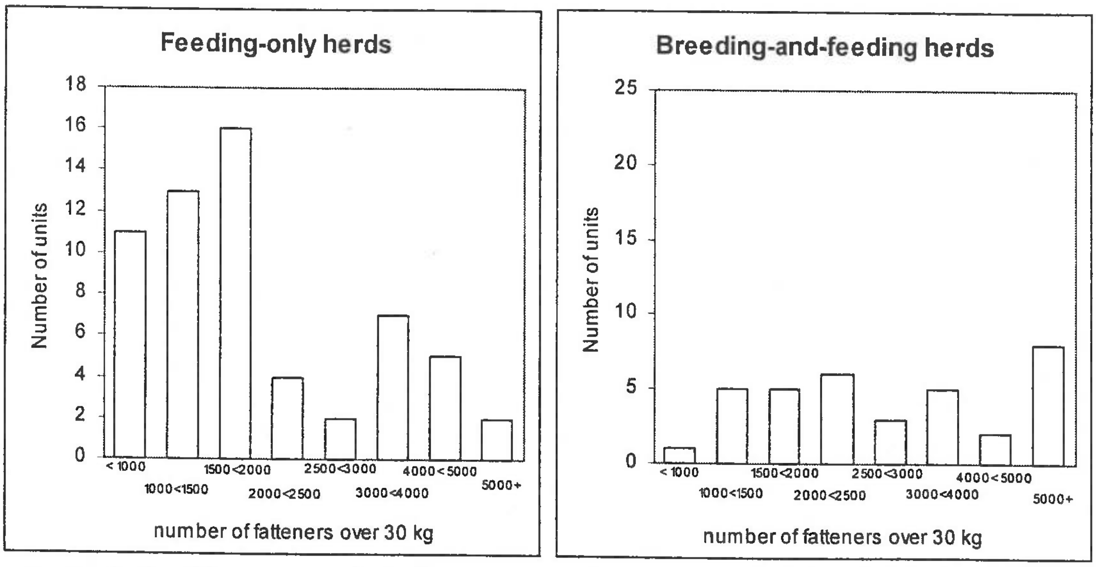
(cont.)

(continued Appendix 4.10)

Description Phase/ BAT option	Capital Investment Required (£)	Annual cost investment (A)	(£/year) operation (B)	(6%a.a) total (A+B)	Emission emission kg/year	NH_3 reduction kg/year	Extra use of energy (kWh)
Growing							
Reference					**2,369**		
Refurbish from FSFpit to FSF flush tubes [CRPA]	-	-	11,153	11,153	1,421	948	7,265
PSF with flush gutters or flush tubes concrete slats (4641)	35,341	3,075	5,661	8,735	948	1,421	1,184
iron slats (4641b)	47,321	4,117	7,487	11,604	790	1,579	1,184
Refurbish from PSFpit to PSF flush tubes [CRPA]	-	-	9,554	9,554	1,421	948	+
PSF-ssw/iron (4642b)	13,777	1,199	8,985	10,184	790	1,579	No
Manure surface cooling channel PSF concrete slats (4615)	18,210	1,584	3,294	4,879	1,184	1,184	11,055
iron slats (4615b)	25,757	2,241	4,792	7,033	948	1,421	11,055
Finishing							
Reference					**7,897**		
Refurbish from FSFpit to FSF flush tubes [CRPA]	-	-	34,575	34,575	4,738	3,159	24,216
PSF with flush gutters or flush tubes concrete slats (4641)	109,557	9,531	17,548	27,079	3,159	4,738	3,948
iron slats (4641b)	146,695	12,762	23,211	35,974	2,632	5,264	3,948
Refurbish from PSFpit to PSF flush tubes [CRPA]	-	-	29,618	29,618	4,738	3,159	+
PSF-ssw/iron (4642b)	42,709	3,716	27,853	31,569	2,632	5,264	No
Manure surface cooling channel PSF concrete slats (4615)	56,450	4,911	10,213	15,124	3,948	3,948	36,851
iron slats (4615b)	79,847	6,947	14,855	21,802	3,159	4,738	36,851



Appendix 5. 1 - Histogram: pig units according to the number of sows (breeding-only and breeding-and-feeding herds)



Appendix 5. 2 - Histogram: pig units according to the number of finishing pigs

Appendix 5. 3 - Cross tabulation: type of system by finishers housing and type by specialisation of herd (SPSS output)

			Type by specialisation of herd		Total
			Feed	Breed&Feed	
Type of system by finishers housing	Straw based and / or Solid floor	Count	45	13	58
		% of Total	43.30%	12.50%	55.80%
	partly slatted floor	Count	5	8	13
		% of Total	4.80%	7.70%	12.50%
	fully slatted floor	Count	4	15	19
		% of Total	3.80%	14.40%	18.30%
	mixed (straw and slurry based)	Count	5	9	14
		% of Total	4.80%	8.70%	13.50%
Total		Count	59	45	104
		% of Total	56.70%	43.30%	100.00%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	24.417(a)	3	0.000
Likelihood Ratio	25.432	3	0.000
Linear-by-Linear Association	18.761	1	0.000
N of Valid Cases	104		

a 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.63.

Appendix 5. 4 - Crosstab: type by specialisation of herd and slurry earth banked lagoon

			Slurry - earth banked lagoon		Total
			no	yes	
Type by specialisation of herd	Breed	Count	7		7
		% of Total	6.00%		6.00%
	Feed	Count	47	18	65
		% of Total	40.20%	15.40%	55.60%
	Breed&Feed	Count	22	23	45
		% of Total	18.80%	19.70%	38.50%
Total		Count	76	41	117
		% of Total	65.00%	35.00%	100.00%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	10.423(a)	2	0.005
Likelihood Ratio	12.5	2	0.002
Linear-by-Linear Association	10.299	1	0.001
N of Valid Cases	117		

a 2 cells (33.3%) have expected count less than 5. The minimum expected count is 2.45.

Appendix 5. 5 - Crosstab: type by specialisation of herd and slurry below ground tank

			Slurry - below ground tank or structure		Total
			no	Yes	
Type by specialisation of herd	Breed	Count	2	5	7
		% of Total	1.70%	4.30%	6.00%
	Feed	Count	49	16	65
		% of Total	41.90%	13.70%	55.60%
	Breed&Feed	Count	32	13	45
		% of Total	27.40%	11.10%	38.50%
Total		Count	83	34	117
		% of Total	70.90%	29.10%	100.00%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.719(a)	2	0.035
Likelihood Ratio	6	2	0.05
Linear-by-Linear Association	1.123	1	0.289
N of Valid Cases	117		

a 2 cells (33.3%) have expected count less than 5. The minimum expected count is 2.03.

Appendix 5. 6 - Crosstab: type by specialisation of herd and spreading of manures onto third parties' land

			Manure spread onto third party's land		**Total**
			no	yes	
Type by specialisation of herd	Breed	Count	4	3	7
		% of Total	3.40%	2.60%	6.00%
	Feed	Count	49	16	65
		% of Total	41.90%	13.70%	55.60%
	Breed&Feed	Count	21	24	45
		% of Total	17.90%	20.50%	38.50%
Total		Count	74	43	117
		% of Total	63.20%	36.80%	100.00%

Chi-Square Tests

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	9.554(a)	2	0.008
Likelihood Ratio	9.591	2	0.008
Linear-by-Linear Association	5.322	1	0.021
N of Valid Cases	117		

a 2 cells (33.3%) have expected count less than 5. The minimum expected count is 2.57.

Appendix 5. 7 - Crosstab: type of system by finishers housing and slurry transport with umbilical hose

			Slurry transport - umbilical hose		Total
			no	yes	
Type by specialisation of herd	**Breed**	*Count*	6	1	7
		% of Total	5.10%	0.90%	6.00%
	Feed	Count	56	9	65
		% of Total	47.90%	7.70%	55.60%
	Breed&Feed	Count	24	21	45
		% of Total	20.50%	17.90%	38.50%
Total		Count	86	31	117
		% of Total	73.50%	26.50%	100.00%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	
Pearson Chi-Square	15.277(a)	2	0	
Likelihood Ratio	15.088	2	0.001	
Linear-by-Linear Association	12.662	1	0	
N of Valid Cases	117			

a 1 cells (16.7%) have expected count less than 5. The minimum expected count is 1.85.

Appendix 5. 8 - Crosstab: type of system by finishers housing and transport with tanker

			Slurry transport - tanker		Total
			no	yes	
Type of system by finishers housing	straw based and / or solid floor	Count	33	25	58
		% of Total	31.70%	24.00%	55.80%
	partly slatted floor	Count	4	9	13
		% of Total	3.80%	8.70%	12.50%
	fully slatted floor	Count	6	13	19
		% of Total	5.80%	12.50%	18.30%
	mixed (straw and slurry based)	Count	1	13	14
		% of Total	1.00%	12.50%	13.50%
Total		Count	44	60	104
		% of Total	42.30%	57.70%	100.00%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	13.755(a)	3	0.003
Likelihood Ratio	15.453	3	0.001
Linear-by-Linear Association	12.741	1	0
N of Valid Cases	104		

a 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.50.

Appendix 5. 9 - Crosstab: type of system by finishers housing and manure distribution with broadcast spreader

			Spread distribution - broadcast spreader		Total
			no	yes	
Type of system by finishers housing	straw based and / or solid floor	Count	32	26	58
		% of Total	30.80%	25.00%	55.80%
	partly slatted floor	Count	5	8	13
		% of Total	4.80%	7.70%	12.50%
	fully slatted floor	Count	2	17	19
		% of Total	1.90%	16.30%	18.30%
	mixed (straw and slurry based)	Count	2	12	14
		% of Total	1.90%	11.50%	13.50%
Total		Count	41	63	104
		% of Total	39.40%	60.60%	100.00%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	16.377(a)	3	0.001
Likelihood Ratio	18.109	3	0
Linear-by-Linear Association	14.763	1	0
N of Valid Cases	104		

a 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.13.

Appendix 5. 10 - Crosstab: type of system by specialisation of herd and use of contractors for slurry spreading

			Slurry spread - contractors		Total
			no	yes	
Type by specialisation of herd	Breed	Count	6	1	7
		% of Total	5.10%	0.90%	6.00%
	Feed	Count	53	12	65
		% of Total	45.30%	10.30%	55.60%
	Breed&Feed	Count	27	18	45
		% of Total	23.10%	15.40%	38.50%
Total		Count	86	31	117
		% of Total	73.50%	26.50%	100.00%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	6.904(a)	2	0.032
Likelihood Ratio	6.799	2	0.033
Linear-by-Linear Association	6.168	1	0.013
N of Valid Cases	117		

a 1 cells (16.7%) have expected count less than 5. The minimum expected count is 1.85.

Appendix 5. 11 - Crosstab: type of system by specialisation of herd and training – farm management

			Training- General farm management		Total
			no	yes	
Type by specialisation of herd	Breed	Count	3	4	7
		% of Total	3%	3%	6%
	Feed	Count	59	6	65
		% of Total	50%	5%	56%
	Breed&Feed	Count	37	8	45
		% of Total	32%	7%	39%
Total		Count	99	18	117
		% of Total	85%	15%	100%

Chi-Square Tests

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	11.466(a)	2	0.003
Likelihood Ratio	8.76	2	0.013
Linear-by-Linear Association	0.655	1	0.418
N of Valid Cases	117		

a 1 cells (16.7%) have expected count less than 5. The minimum expected count is 1.08

Appendix 5. 12 - Crosstab: type of system by specialisation of herd and training – risk management

			Training -Risk management		Total
			no	yes	
Type by specialisation of herd	Breed	Count	4	3	7
		% of Total	3%	3%	6%
	Feed	Count	59	6	65
		% of Total	50%	5%	56%
	Breed&Feed	Count	34	11	45
		% of Total	0.291	0.094	0.385
Total		Count	97	20	117
		% of Total	83%	17%	100%

Chi-Square Tests

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	7.830(a)	2	0.02
Likelihood Ratio	7.392	2	0.025
Linear-by-Linear Association	0.399	1	0.528
N of Valid Cases	117		

a 1 cells (16.7%) have expected count less than 5. The minimum expected count is 1.20

Appendix 5. 13 - Crosstab: type of system by specialisation of herd and training – health and safety

			Training - Health and safety		Total
			no	yes	
Type by specialisation of herd	Breed	Count	4	3	7
		% of Total	3%	3%	6%
	Feed	Count	55	10	65
		% of Total	47%	9%	56%
	Breed&Feed	Count	30	15	45
		% of Total	0.256	0.128	0.385
Total		Count	89	28	117
		% of Total	76%	24%	100%

Chi-Square Tests

	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	6.171(a)	2	0.046
Likelihood Ratio	6.109	2	0.047
Linear-by-Linear Association	1.16	1	0.282
N of Valid Cases	117		

a 1 cells (16.7%) have expected count less than 5. The minimum expected count is 1.68

Appendix 5. 14 - Frequency of responses for relevance of environmental issues – percent (%) of total

Environmental issue	Degree of relevance						Total
	none	small	moderate	substantial	great	don't know	
emission of ammonia	4	29	43	9	7	8	100
emissions of pollutants to land	4	20	37	24	9	5	100
emission of pollutants to water	3	13	27	35	20	3	100
nuisance by odours	4	23	41	21	7	4	100
nuisance by noise	23	48	21	4	0	4	100
use of energy	5	27	37	25	0	5	100
use of clean water	9	31	32	17	7	4	100
use of raw material	16	25	29	17	7	5	100

Note: total of 75 respondents.

Annex 5. 1 - Report of the workshop IPPC and Pigs

REPORT OF THE WORKSHOP ON INTEGRATED POLLUTION PREVENTION AND CONTROL (IPPC) DIRECTIVE AND THE PIG INDUSTRY IN ENGLAND AND WALES
University of Cranfield, Silsoe Campus, Bedfordshire, 10.30 am to 4pm, 17th January 2002.

This document provides a summary of the proceedings and outcomes of discussion during the above workshop. The workshop was supported by the National Pig Association and the Environment Agency. A list of participants is appended.

BACKGROUND

Aim
The broad aim of the workshop was to share an understanding of the main features and likely impacts of IPPC with a view to assisting the pig industry to adapt to the new regulation.

The workshop posed and sought answers to the following questions:

What is IPPC? That is to refine the understanding of IPPC concepts and instruments as it applies to the pig industry in England and Wales.

What does IPPC mean for pig producers? That is to identify and discuss the key issues associated with the implementation of the IPPC regulation, focusing on the likely impacts on the industry.

What do producers do about it? That is to identify and discuss the ways in which the industry and its constituent producers can prepare themselves for the implementation of the IPPC regulation.

REPORT ON WORKSHOP PROCEEDINGS

Overview of IPPC

1 The introductory part of the workshop comprised a general presentation of the IPPC principles in the context of the policy commitment to sustainable development and how IPPC is being implemented in the pig sector in England and Wales. The workshop was briefed that 'candidate' Best Available Techniques (BAT) are being defined for the pig industry (currently in the form of the BREF Notes) and Standard Farm Installation Rules and Guidance (SFIRG) have been provisionally defined as a basis for formulating General Binding Rules (GBR). The latter are intended to simplify the process of application for and ward of an IPPC permit,

2 Participants drew attention to the fact that the IPPC regulation has to deliver environmental protection subject to the economic criteria implicit in BAT. Concern was expressed that some versions of BAT, given the current economic condition of the pig sector, may render many businesses non-viable. It was also pointed out that IPPC is part of, and needs to integrate with, a broader regulatory framework which covers things like surface and ground water quality, health and safety, and animal welfare. The latter, for example has been a major driver for modifications to buildings for breeding herds.

3 The workshop was briefed about the regulator's approach to IPPC implementation and the issues arising. There have to date been no IPPC applications by pig producers. It is understood that 2 applications for poultry units have been made and one application for a variation on a unit. Comment was made that applications did not meet the regulator's requirements regarding assessment of environmental effects. It seemed that applicants drew on assessments used to gain planning consent and these were inadequate for the purpose of IPPC. A point was raised about the competency on the part of applicants and their advisors to provide satisfactory environmental statements to support the IPPC application.

Impact Assessment: Case Studies

4 The findings were presented of research carried out by Cranfield University at Silsoe involving three case studies of pig installations qualifying for IPPC regulation. These case study units, selected to

represent dominant UK pig production systems for housing and management of manures, were assessed using an analytical framework developed to examine the environmental and financial impact of IPPC. Compliance requirements applied to the case studies were based on the Environment Agency's SFIRG and the European Commission IPPC Bureau's draft version of the BAT Reference Document (BREF Note) for intensive livestock farming.

5 In accordance with the regulation, the assessment of environmental performance focused on ammonia emissions throughout the production cycle, including the disposal of manures. The financial performance of the baseline situation (without-IPPC) was compared to the with-IPPC situation by using a set of environmental and financial indicators. The results estimated that applying IPPC can deliver substantial reductions in ammonia emissions from housing, storage and landspreading phases on the case study units. These reductions ranged from 9% to 70% depending on the candidate BAT and related practices involved.

6 The cost of compliance and achievement of ammonia emissions varied according to the combination of BAT options (in-process and end-of-pipe measures) tested. Average abatement costs were between £1.30 and £9.10 per kg of ammonia abated per year. The latter costs are associated with high performance but very expensive bio-filter systems, (which due to their excessive costs are unlikely to qualify as BAT).

7 The analysis shows that the major compliance costs relate to measures for the reduction of ammonia emissions from housing, the need for extra labour and management inputs, and actions to reduce emissions from storage and disposal of manures.

8 Financial assessment suggests that existing financial margins (revenues less costs) at the time of the survey would not be sufficient to cover the incremental costs of compliance with IPPC, even at the most modest application of BAT/SFIRG. This reflects the low margins currently obtained in the sector, and the changes that would be needed in housing, waste management, and management systems to meet IPPC requirements.

9 Market prices for pigmeat would need to increase between 1 and 15 pence per kg to recoup incremental costs associated with IPPC, in other words, minimum prices of £0.97 to £1.11 would be needed to guarantee coverage of total production costs under an IPPC permit regime.

10 It was emphasised that these results are based on an appraisal of 'candidate' BAT options which are not necessarily those that will be adopted as BAT under the IPPC permitting regime. Also the analysis considered a range of technically applicable solutions which themselves constitute 'baskets' of techniques. It is likely that other types and combinations of BAT will emerge in due course (especially when producers and regulators review the performance and impact of candidate BAT).

11 It was also emphasised that the estimated costs on the case study units refer to the implementation of IPPC to existing installations. It is likely that new build installations would be able to achieve lower compliance costs per unit of saleable output or emission because IPPC requirements would be built into initial design and subsequent operation.

Results of a Survey of IPPC Target Pig Producers

12 Results were presented from a questionnaire survey amongst members of the National Pig Association (NPA) deemed at or above the IPPC qualifying thresholds. This aimed to capture the current circumstances and practices on IPPC target installations. Following a 37% response rate, the survey drew on eligible 75 questionnaires, comprising a total of 117 pig installations, completed in the period between April and June 2001.

13 The results suggest that although average number of sows on Breeding-and-Feeding units is in some cases below the threshold of 750 places, these units would fall under IPPC regulations because they are linked to fattening units which are often well above 2,000 places. Breeding-and-feeding units account for 54% of total fattening pigs by number although they count for only 38% of total installations.

14 The survey revealed that existing waste management systems are predominantly straw-based. Eighty-one percent sow units use mainly straw. Over half (53%) of finishing-only installations are predominantly straw based. More than 60% of installations were built before 1980 and 25% of installations were less than 10 years old. With a depreciation life of say 25 years, clearly much of the housing stock is beyond its economic life.

15 It was reported, however, that there has been significant refurbishment or refit on 56% of the installations, mainly associated with the group housing of sows between 1996 and 1998 in response to welfare requirements.

16 IPPC requires that due regard is given to local site conditions as these define the likely environmental effects of installations. It was reported that the predominant soils in the vicinity of the units are clays and loams (63% of installations). These soils are less prone to the leaching of nutrients from manures than lighter, sandy soils. Respondents perceived that the main environmentally sensitive feature was that of a neighbouring residential area (71% of installations). Around 23% of the installations had areas at least partially on a Nitrogen Vulnerable Zone (NVZ) where the allowable application rates of N to land are lower than on areas outside these protected areas.

17 In terms of management of manures, the survey showed that slurry is mainly stored in earth banked lagoons (38% of slurry installations) or in underground tanks or structures (31% of slurry installations). The landspreading of slurry is predominantly by broadcast spreader and tanker. Solid, straw-based manures are predominantly (91% of solid systems) stored in outside, non-covered areas, and disposed to land using a rear discharge spreader. Although the great majority (86%) of all installations spread manures onto their own land, a significant proportion (37% of all installations) rely partially or totally on third party land for landspreading.

18 In the context of producers' understanding of IPPC, the survey identified perceptions of key environmental issues associated with indoor pig production. For the sample as a whole, emission of pollutants to water and emission to land were ranked first and second respectively, followed by nuisance by odours. Emission of ammonia, which is the focus of much of the IPPC regulation, was ranked only sixth in terms of perceived importance, preceding only the use of raw material and nuisance by noise.

19 Regarding awareness and understanding of IPPC, 56% of pig producers reported that their current knowledge of the regulation was limited or virtually non-existent. In terms of perceptions of the change that might be required by producers for them to conform with IPPC, producers ranked the following in order of perceived degree of change required: management systems (planning, control and record keeping), storage of animal waste, disposal of animal waste, staff training, and, with the lowest rank, animal housing.

20 The results of the survey are revealing with respect to circumstances and practices of the group of producers who are likely to be captured by the regulation. Straw based manure systems are common and yet at the present moment these do not appear to comply with the emerging definition of BAT, and would therefore be rendered infeasible. Many installations are old and have reached the end of their design life. The widespread use of straw reflects continued use of housing stock which, under more favourable economic conditions, would probably have been replaced by now. The emerging BAT favours partly slatted floors which are not common place.

21 Slurry lagoons are for the most part uncovered. Covering them is likely to prove expensive, if indeed it is feasible on existing designs. Disposal of waste to land mainly uses broadcasting methods which also may not conform to IPPC regulations.

22 Regarding perceptions, the survey showed a limited understanding of IPPC amongst the target group. Furthermore, and consistent with this, the perception of what is likely to be of most concern under IPPC (perceived to be water impacts and management systems) does not fit with the major issues that producers are likely to face in practice under IPPC, namely controlling ammonia emissions and housing improvement.

Discussion Groups and Outcomes

The workshop participants formed two discussion groups which subsequently reported the following points.

Key issues and uncertainties

Compliance Costs

23 Producers find the comprehensiveness and detail of the IPPC regime 'frightening' in terms of the cost of compliance and the management burden. It was argued that pig units already operate under a regulatory framework relating to health and safety, environment and animal welfare which have implications for costs and management practices.

Unknowns

24 It was felt by pig producers that there are too many unknowns at this stage with respect to the requirements of BAT and GBR to determine the likely impacts and the best way to respond to the regulation. It was difficult to make informed judgements. Reference was made to lack of definition of BAT/GBR, to lack of information on emissions from current or proposed pig units and management practices, and to lack of information about the improvements that might be achieved by changes in practices in specific circumstances.

And Uncertainties

25 The point was made that unless there is clear information on existing types and levels of pollution, and the reductions that can be achieved by changes in practices, it is difficult to argue that IPPC will (a) deliver environmental benefits and (b) do this at reasonable cost. Producers questioned the benefit:cost aspect of IPPC applied to the pig sector, and questioned whether the application of IPPC would meet the principle of proportionality raised earlier in the workshop.

Impact on Financial Viability

26 Producers expressed concern that any increase in the costs of pig production is likely to render pig units financially non-viable, as they have been operating at or below the margin of profitability for a number of years. It was felt that there was a risk that principle of economic viability included in the definition of BAT is not being applied. (It was pointed out that the analysis presented earlier referred to a range of 'candidate' BAT and that BAT 'for real' had not yet been defined). But it was argued that the industry could not carry additional cost given prevailing market conditions.

Defining BAT

27 This latter point was further elaborated. BAT in the pig sector is in the process of definition, and what will be decided is not clear. It is difficult to give or receive advice on how to accommodate IPPC while this remains the case. However, it was discussed that BAT is, by definition, a dynamic process and is likely to change over time. But at least, it was argued, point of entry BAT should not damage a fragile industry.

UK Representation

28 Pig producers perceive that BAT is being biased towards continental pig rearing systems, reflecting a relatively well organised lobby by interests in EU member states (including supplier companies), leaving UK systems under-represented. One of the reasons for this, it was suggested, could be the lack of technical information about the type and environmental performance of common UK installations , especially housing systems. However, it was pointed out that the references for manure landspreading techniques in the BREF draft mostly draw on data generated in the UK. (This perhaps confirms that BREF notes tend to reflect the information which is provided to, or most easily accessible to, the BREF writers at a given point in time).

Structures and Attitudes

29 It was suggested that the fragmentation of the UK pig industry and possibly linked to this the limited engagement by the UK pig sector in the processes by which BREF are defined, may be acting against this representation. It was also argued that, compared to EU member states with large pig sector interests (such as Netherlands, Denmark and Germany), the UK pig industry has demonstrated a more negative attitude towards environmental regulation, perhaps reflecting a broader pessimistic

attitude in the sector as a whole. Partly, it was felt, this reflected frustration that expectations of benefits to UK producers of previous attempts to achieve market advantage through quality differentiation and early adoption of welfare standards had not been realised.

Ammonia Focus

30 It was strongly felt that so far, candidate BAT appear to almost exclusively focused on ammonia emissions. This selected emphasis on the emission of one pollutant (NH_3) to one media (air) questioned whether IPPC is effectively delivering an integrated approach to environmental protection. However, the workshop was informed that the Technical Working Group for sectoral BREF is considering other criteria for selection of BAT, such as local relevance of techniques, emissions of pollutants other than ammonia, and cross media issues such as use of energy and water. The point was made that an excessively NH_3 driven approach to IPPC BAT may conflict with other statutory obligations by farmers such as N disposal to land and animal welfare. (The point was made earlier in the day about the need to ensure BAT and GBR adopt a broad definition of environmental performance consistent with the principle of Best Practical Environment Option).

Straw

31 Questions were raised about relevance of BAT in that they currently exclude straw based systems which are predominant in UK. These systems have witnessed considerable expansion due to animal welfare regulations (banning tethers and stalls for sows) and, given the economic fortune of the sector, a preference to extend the use of the existing housing stock rather than make new investment.

Learning Process

32 It was pointed out that the initial phase of IPPC implementation clearly involves a learning process for all relevant stakeholders, requiring a degree of flexibility on the part of regulator and the regulated for the newly regulated industries such as the pig industry. There was a clear need for a much better understanding of the IPPC regulation, its requirements, and its likely impact. This was needed, it was suggested, to encourage the industry to participate in the process of defining BAT, ensuring that what emerges in BAT and GBR is relevant and will not impose costs which clearly exceed the benefits to be gained.

Environmental Assessments

33 Although there had not been IPPC applications from pig producers to date, experience from the poultry sector suggested that environmental assessment submitted for planning permission to Local Authorities have not proved inadequate in scope and level of detail to satisfy the requirements of IPPC. It would appear that further guidance is needed on this.

Waste Values

34 It was argued that pig manure should be regarded as a potential resource with a value as an agricultural nutrient rather than a waste product with no value to be disposed of. It was argued that local site circumstances determine whether or not this is the case. Restrictions on application rates (associated with NVZs), tighter controls on application methods, lack of accessible land to receive manure, and the particular attributes of pig waste often encourage the view that pig manure is a by-product to be got rid of at least cost.

An Environmental Standard

35 It was remarked that the pig sector did not have, or had not adopted, the equivalent of a LEAF type externally accredited environmental auditing scheme. Such a scheme could be an efficient, industry regulated means of demonstrating a high standard of environmental management and a commitment to improvement. It could be linked to the adoption of IPPC type practices. It is not clear whether such a voluntary approach would be recognised by the regulator in the IPPC permitting process.

Implications for Operations and Business Strategy

Increased Costs

36 Producers predicted that production costs will increase due to compliance with IPPC, but that they would not be able to recoup these through any increase in the producer pig meat price. They saw that IPPC will affect not only operating costs but also capital investment costs. It was identified that

the industry has run down its investment stock, and there was little incentive at present to make new investment. It was appreciated that IPPC has major relevance to business strategy as it affects operating costs, determines investment in housing and waste management, and defines the competitiveness of the business. It was apparent, however, that these medium to long term issues were not being addressed at present (partly because there remain too many unknowns, and partly because the industry is in a relatively depressed condition with a focus on survival).

Structural Adjustment

37 Producers thought that industry representative organisations should assess the value of advising pig producers to try to avoid IPPC regulation by adjusting the size of their units to below the thresholds of 750 sows and 2,000 fatteners. This could be achieved, it was thought, through the scaling down or 'modulation' of existing pig installations. However, it was discussed that if this was a common practice, the regulator might respond with modifications to the threshold limits. The point was raised that restructuring existing installations into smaller ones could result in efficiency losses and off-set expected benefits of avoiding compliance costs. From an environmental perspective it was pointed out that a greater number of smaller pig units may reduce emission at any one point source, and possibly spread emissions such as those from waste over a larger area, but this would not reduce the overall burden on the environment.

Convergence and Common Practices

38 For systems above the IPPC thresholds, it is likely that IPPC will force convergence in production and management systems as defined by BAT and GBR, so that there is likely to be less variation in large scale units than at present. Below threshold installations will continue to demonstrate greater variety in practices. However, over time, it is likely that tightening non-IPPC environmental regulation on intensive livestock production generally will increasingly require below threshold installations to use techniques similar to, and benchmarked by, IPPC BAT.

Alternative Systems

39 The point was made that IPPC could encourage a more strategic approach to pig production, which might include significant changes not only in production systems, but also perceptions about what is feasible or desirable. (This point refers back to the idea of BAT as a dynamic which, as intended, promotes further beneficial change.) The view was expressed that producers may question the business sustainability of intensive pig systems under IPPC, and, as evident in the Dutch case, develop alternative lower-input : lower-output systems which are just as , if not more, commercially viable, as well as environmentally benign. A re-examination of pig production processes, including dietary systems, under UK conditions could identify alternative strategies for pig producers. These changes might be encouraged by other legislative and market drivers.

Action Points

Engaging

40 Pig sector representatives must continue to engage in the process by which BAT and GBR are defined. This was essential. At present, UK housing systems are under represented in BREF documentation.

Reviewing Needs

41 Producer organisations should undertake a review of producer needs with respect to IPPC adoption. This will inform the need for research, development, demonstration and advice.

Creating Awareness

42 Producer awareness and understanding must be enhanced to help the industry prepare itself for IPPC adoption, especially as the regulation will have critical implications for business management and strategy..

Communications

43 A communication and promotion strategy will be needed to support the IPPC process, working through producer organisations. Appropriate messages and communication channels need to be identified to meet producer needs. The need for workshops, conferences and training courses requires to be assessed

44 A targeted IPPC support service, web based answering frequently asked questions, and listing sources of information and help, including advisors and consultants

Extension

45 Advice and practical demonstration of BAT/GBR will be needed to support producers Consideration should be given to inclusion of an IPPC demonstration unit at the MLC's pig unit at Stotfold.

Research and Development

46 Targeted research and development is needed to support the UK IPPC process for the pig sector, especially:

- the environmental (and related business) performance of existing systems. There is an urgent need for data on UK pig buildings, especially for straw based systems to support the drafting of BREF Notes;
- the identification and comparative analysis of UK relevant candidate BAT and GBR, especially regarding housing and waste management;
- BAT development to address key UK issues, such as straw based systems, slurry management, lagoon covers, alternative treatments and uses of manures; and address the 'integrated' element of the IPPC regulation;
- the link between BAT, GBR and business performance;
- alternative production systems for indoor pigs, including dietary regimes and alternative input : output systems;
- environmental management systems for pig producers;
- attitudes towards and adoption of environmental management practices amongst pig producers in support of IPPC.

Environmental Management Systems

47 The feasibility and acceptability of an accredited environmental management system for pig producers should be explored. This could support the IPPC permitting process as well as quality assurance for the product and its supply chain. Such a scheme would constitute a significant strategic response by the industry. Experience in other small/medium business sectors with respect to business response to environmental regulation should be drawn on. This has included business networks and clubs to help the adoption of cleaner technology and share good practice which can exploit potential business advantage.

ACKNOWLEDGEMENT

We believe the workshop achieved the aim of sharing an understanding of the main features and likely impacts of IPPC with a view to assisting the pig industry to adapt to the new regulation. It did, of course, raise many questions that remain without answers. We thank participants for their valuable contributions to the workshop and the support provided by the National Pig Association and the Environment Agency.

LIST OF PARTICIPANTS

Producers

James Black of David Black and Sons Ltd
John Evans and Joe Blackstone of Midland Pig Producers Ltd
Sara Brown and Natalie (to confirm) of JSR Healthbred
Mike Sheldon of Greenway Farms Ltd
Hugh Crabtree of Farmex Ltd
George Gittus of G E Gittus & Sons Ltd

Environment Agency

Selena Randall and Jane James

National Farmers Union

Diane Mitchell

Researchers

Roger Phillips and Theo Demmers of Silsoe Research Institute, BBSRC
Joe Morris and Tiago Pellini of Cranfield University at Silsoe