Preface and Acknowledgements

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We would like to recognise Canada's Clean Development Mechanism/Joint Implementation Office, Department of Foreign Affairs and International Trade the Government of Canada for providing monetary support for the development of the baseline and the project design document for this project. Their financial assistance has helped reduce specific transaction costs incurred while preparing this project for the CDM registration process.

A. General Description of Project Activity

A.1. Title of the project activity:

"Methane capture and combustion from swine manure treatment for Peralillo."

A.2 Description of the project activity:

In December, 2000 Agricola Super Limitada (Agrosuper), the largest pork production company in Chile, initiated a voluntary process to implement advanced waste management systems (anaerobic and aerobic digestion of hog manure), in order to reduce greenhouse gas (GHG) emissions into the atmosphere. The anaerobic and aerobic digestion technology is being phased in gradually in some of Agrosuper facilities. The goal is to eventually implement this technology to capture GHG emissions from all of the company's swine barns. However, this will depend upon the generation of revenues from the sale of Certified Emission Reductions, (CERs) which will be used to partially finance the anaerobic digesters.

Agrosuper initiated the first phase of the project in 2000 with the construction and operation of the first unit at Peralillo, and subsequently implemented the second phase of the project, through the construction and implementation of additional digesters in 2002 and early 2003. All of them use the same technology and are based on the same concept. In addition, Agrosuper owns the technology and the facilities.

The decision to consider the implementation of more expensive technology was influenced by the adoption of the Kyoto Protocol and the Clean Development Mechanism. The investment decision to continue beyond the first phase of the project was further influenced by the confirmation as part of the Marrakech Accords "…. that a project activity starting as of the year 2000, and prior to the adoption of this decision, shall be eligible for validation and registration as a CDM project activity if submitted for registration before 31 December 2005. If registered, the crediting period for such project activities may start prior to the date of its registration but not earlier than 1 January 2000".

As a result of the strong statement made by at COP7, the company decided to move forward the implementation of more digesters and aerobic treatment systems during 2002 and 2003. The implementation of additional Digesters or other advanced technology is now on standby until the outcome of this CDM project activity.

The expected result from this project activity will be a significant reduction in the volume of methane (CH) and nitrous oxide (N2O) emissions compared to those emissions that would otherwise occur in a scenario with traditional swine manure treatment systems.

The manure treatment system considered as the baseline is the use of traditional (open) stabilisation lagoons as the treatment process of liquid waste from swine production. Open lagoons lead to the direct release of CH4, N2O and CO2 into the atmosphere as a result of the anaerobic digestion process that takes place inside the lagoons. Open lagoon treatment process should be considered as the current Chilean national baseline for the agricultural sector, as will be detailed later in this document.

- Agrosuper: The Company

The "**Methane capture and combustion from swine manure treatment"** " is a project developed by Agrosuper, a pork meat and poultry meat producer. It has more than 92,000 sows in production and is considered the 8th largest swine meat producer in the world.

Agrosuper is affiliated with the Association of Pork Meat Producers of Chile (ASPROCER) and with the private industry Association (SOFOFA).

Agrosuper's goal is to offer the best product to the market, and at the same time, maintain a good relationship with the community through initiatives such as good environmental performance.

Agrosuper complies with all Chilean environmental regulations. In addition, the majority of its facilities are either internationally certified, or are in the process of implementing ISO9000 and ISO 14000 standards.

A.2.1 Purpose of the project activity

The purpose of the project activity is to:

- Replace the traditional open lagoon swine manure treatment system with an advanced system based on the implementation of anaerobic digesters and aerobic treatment in a second stage of the project activity, in order to reduce GHG emissions.
- Effectively mitigates odour from treatment of the swine manure through the use of digesters as opposed to open lagoons.
- Start a forestation program by using water from the digesters for the irrigation of eucalyptus forests and crops.

Anaerobic swine manure treatment systems take into account biogas production due to degradation of organic matter by several acidogenic and methanogenic bacteria. Anaerobic digestion in closed and controlled environments such as in heated or ambient temperature digesters reduces the time required for treatment and allows capture of biogas that would otherwise be released to the atmosphere. As a result of this, GHG

emissions are significantly reduced and the waste treatment time is reduced from 5 plus (+) months to 24 days on average.

The improved management of the swine manure as a result of the implementation of anaerobic digesters does not require changes to the barns or their physical structure, i.e.; there will be no changes in the physical housing capacity or in the management of the barns. Therefore, the volume of effluents to be treated does not increase and only treatment parameters are improved.

The Peralillo digester is based in a technology where the biogas recovered is used as fuel for heating the digester boiler in order to optimise operation and to increase the speed of decomposition of the organic matter of effluents, thus replacing the use of fossil fuel that would otherwise contribute to emissions leakage. Biogas exceeding the operational needs of the digester is immediately flared or used to replace fuel used for process heating, preventing the emission of greenhouse gases since the origin of that CO2 is regenerative.

The project activity considers two stages of implementation. The first one (2001-2003), manure is treated only by the anaerobic digester, and the effluent is received by a storage lagoon.

For the second stage of the project (from 2003) the inclusion of an aerobic post-treatment is included. After manure is treated in the digester, it goes to an aerobic post-treatment by activated sludge. The activated-sludge process is an aerobic, continuous flow, secondary treatment system that uses sludge-containing, active, complex populations of aerobic micro-organisms to break down organic matter in wastewater. Activated sludge is a flocculated mass of microbes comprised mainly of bacteria and protozoa. The liquid effluent from the aerobic treatment goes to a storage lagoon, within the project boundaries.

The project activity has not envisaged selling electricity that could be generated by the use of the biogas. The main reason for this is the significant investment required to implement the technology required to generate electricity compared to the low prices of the electricity in Chile. As such is not at all financially viable. Another important reason is that the electricity market is highly specialised sector in which Agrosuper has no experience.

A.2.2. Contribution to the sustainable development of the host country

1) Host Country Approval by the Designated National Authority

Host country approval for the project activity was granted by the National Commission for the Environment (CONAMA), the Chilean Designated National Authority (DNA), on July 01, 2003 (letter and unofficial translation is attached).

According to the Chilean system, to receive Host Country Approval, the DNA will, as a priority, confirm whether the Project successfully meets all environmental assessment and other environmental regulations related to that project. If the project does not meet all of the regulations, Host Country Approval will not be granted. If it does meet all of the regulations related that project it will be granted Host Country Approval. In line with this procedure, Agrosuper submitted to the DNA, all environmental permits required for the implementation of Project of this kind and its corresponding approvals. This information will be made available to the Designated Operational Entity (DOE) for the validation process.

2) Example for other Pork producers in Chile and South America

Agrosuper is the leading pork meat producer in Chile and South America. The company has historically been considered as an example to follow by other pork producers throughout the region. If this digester system activity is approved as a Clean Development Mechanism (CDM) project, it is envisioned that other companies may follow Agrosuper's example in the future. However, this will be done only if the costs of implementing digester systems can be partially offset from sales of CERs. Otherwise, given that such technology is still too expensive to implement, others most probably would not undertake efforts to improve traditional swine manure treatment systems.

3) Global and local environmental benefits

It is well known that CH4 contributes to global warming. Its global warming potential (GWP) is 21 times that of CO2. This confirms the importance of biogas-related CDM projects (generally made up of a mixture of 60% CH4 and 40% CO2) as a method for contributing to the mitigation and/or reduction of GHG emissions. The implementation of anaerobic digesters and aerobic treatment for swine manure can lead to substantial reductions in GHG emissions. In addition, there are a number of other important benefits that are realised:

a) Odour is virtually eliminated because stabilisation of organic matter takes place inside an airtight reactor. There is no odour impact on any residential or agricultural operations surrounding the project facilities.

b) CH4 recovery systems use lined lagoons (most existing lagoons are unlined), thereby reducing leakage into water tables and nutrient run-off from surface spreading on fields, a major source of rural water pollution. Effluents of lower organic content results from the anaerobic digestion process thereby reducing the risk of contamination of surface and underground water resources as well as the amount of sludge from lagoons.

c) Controls pathogens.

d) Local employment benefits are also realised due to the need for trained personnel to operate the bio-digesters.

4) Technology Transfer, Innovation and Capacity Building

The implementation of this project activity facilitates improved knowledge of sustainable management practices in the treatment of swine manure in Chile and throughout the region. It also promotes technology innovation. The revenue streams from sales of CERs reduce the costs for new digesters, this in turn, which could promote improvements across the pork meat production sector.

The technology is considered leading edge. However some of the most relevant technical aspects are the development and implementation of operating and maintenance practices to ensure continuous performance, high quality output and environmental protection.

A.3. Project Participants

The following participants are involved in the project: "Methane capture for swine manure treatment for Peralillo":

CHILE

1. **Project developer:** Agricola Super Limitada, privately owned company engaged in the cattle and farming business.
2. **Agrosuper's advisors in Engineering, Environmental and Legal Affairs:**
   - POCH Ambiental Ltda -- Chilean Company engaged in integrated services.
   - URQUIDI, RIESCO & CIA, Attorneys at Law
3. **Designated National Authority -** CONAMA

Chile ratified the Kyoto Protocol on August 26, 2002

CANADA

1. **Potential purchaser:** Canadian Company
2. **Brokerage and consulting services**: CO2e.com (Canada) Company

Canada ratified the Kyoto Protocol on December 17, 2002

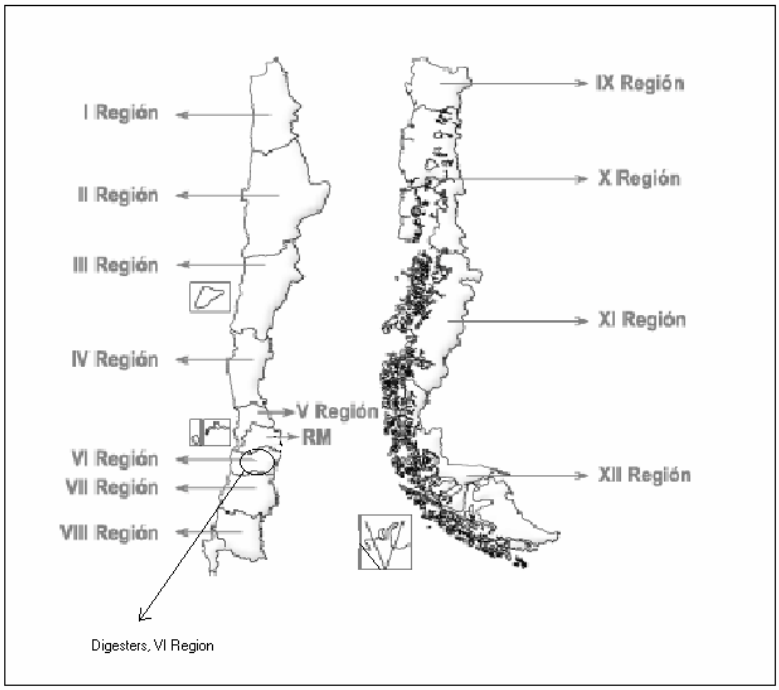
A.4. Technical description of the project activity

A.4.1. Location of the project activity

A.4.1.1. Host Country Party(ies):

The project is located in Chile, South America

Figure 1 Project Location



A.4.1.2. Region:

Region VI known as Libertador Bernardo O'Higgins Region

A.4.1.3. City/town/community, etc:

Province of Colchagua/ Community of Peralillo

A.4.1.4. Details on physical location, including information allowing the unique identification of this project activity

There are no protected resorts or national monuments located next to the project installations.

The next table presents the Universal Transversal Mercator (UTM) co-ordinates for the digester:

Table A.1

Name of the digester	**Farm name**	**Nearest location**	**North**	**East**
Peralillo	"Los Pequenes de Calleuques"	Marchihue	6,193,770	275,200

Figure 2: Project Activity, VI Region

The next table summarises the Project Activity characteristics:

Table A.2

Project	Digester type	Number of pigs supplying	Size of digester, volume (m^3)	Irrigation project	Aerobic Treatment (y/n)	Starting date of the anaerobic treatment	Starting date of aerobic treatment
Peralillo	Heated	118,800	37,000	Yes	Yes	01/12/2000	01/12/2003

A.4.2. Category of project activity

The project can be identified as *"Methane Recovery"* which falls into the category of manure management from farming production.

The GHG emissions relevant for this analysis include; the open release of CH4 from an anaerobic lagoon or a storage lagoon, losses of CH4 due to leakage in the digester, its burn by a flare, and the emissions of N2O for each scenario. The fugitive CO2 generated from anaerobic digestion does not represent any difference in emission volumes between each scenario, because there are no possible additional transformations by the burning of this component. Since the project also considers aerobic treatment component for the second stage of implementation, a default decay of nitrogen content via nitrification-denitrification, and an additional decay in the CH4 generation from treated manure will be assumed (this is explained in chapter B and Annex 3).

A.4.3. Technology to be employed in the project

Anaerobic Digesters

The project is based on the implementation and operation of a liquid waste treatment system for high organic content waste, using anaerobic digestion, with the recent addition of an aerobic treatment system.

Figure 3 Methane combustion at Flare in Peralillo

Figure 4 Digester equipment and installation

An anaerobic digester is a reactor that is sized both to receive a daily volume of organic waste and to grow and maintain a steady-state population of CH4 bacteria to degrade that waste. CH4 bacteria are slow growing, environmentally sensitive bacteria that grow without oxygen and require a pH greater than 6.9 to convert organic acids into biogas over time.

Anaerobic digestion can be simplified and grouped into two steps. The first step is easy to recognise because the decomposition products are volatile organic acids with disagreeable odours. During the second step, CH4 bacteria consume the products of the first step and produce biogas-a mixture of carbon dioxide and methane-a usable fuel by-product.

Part of the project technology includes a cover of high-density polyethylene HDPE 40-60 mils, (1 - 1.5 mm) which is floated over the primary lagoon of a two-cell lagoon system. The primary lagoon is maintained as a constant volume treatment lagoon and the second cell is used to provide storage of treated effluent until the effluent can be properly applied to land.

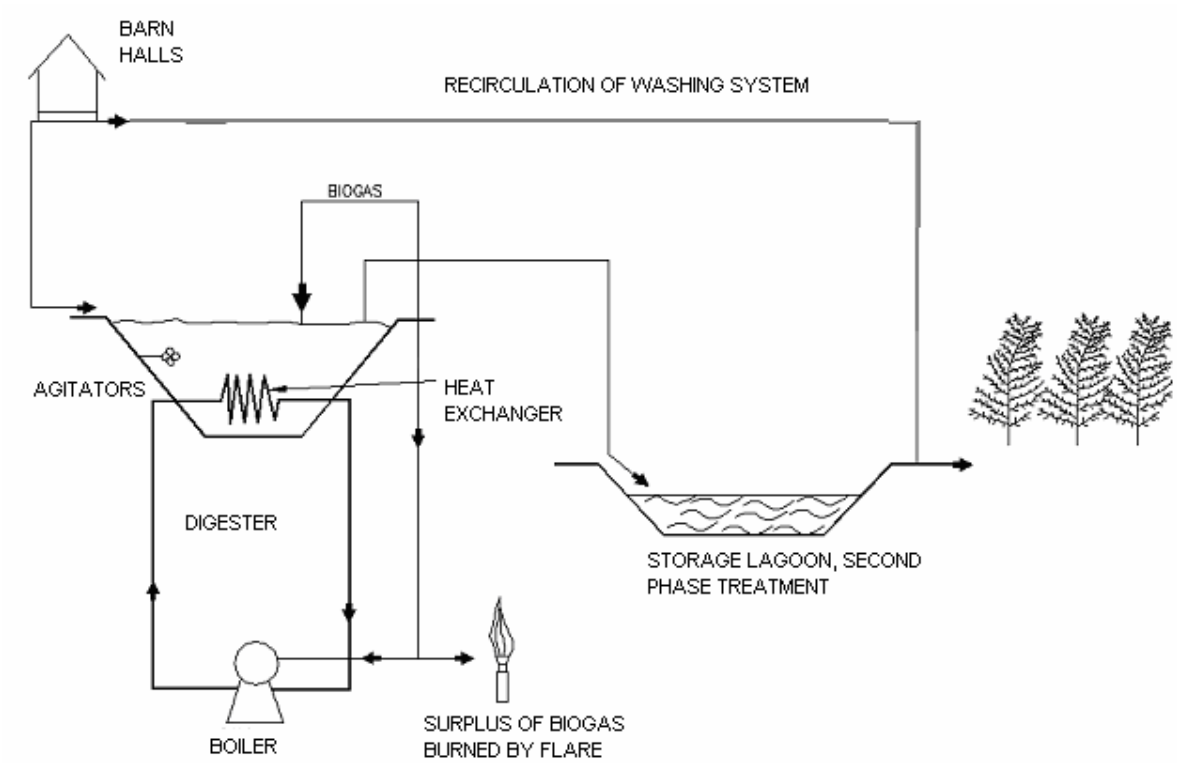
The project digester uses a complete-mix technology treatment unit that anaerobically decomposes animal manure using controlled temperature, constant volume, and mixing. Complete-mix design has been adapted to function in a heated or ambient temperature, mixed, covered earthen basin. Mixing can be accomplished with gas re-circulation and mechanical propellers. A complete-mix digester can be designed to maximise biogas production as an energy source or to optimise volatile solids (VS) reduction with less regard for surplus energy. Either process is part of a manure management system, and supplemental effluent storage is required.

Anaerobic digestion is one of the few manure treatment options that reduces the environmental impact of manure and generates energy. Digesters are used to stabilise manure to produce methane, while at the same time reducing odour.

Agrosuper's digesters are based on two processes: "with recovery and use of biogas" (with boiler - referred to as heated digesters) and "without use of biogas" (without boiler - referred to as ambient temperature digesters). Biogas extraction, reuse and burning from the digester are managed using an automatic control system in which, through parameters such as biogas flow and pressure differences, optimal treatment operation conditions are established. Therefore, it is possible to state that the external environment does not affect digester treatment, i.e., it operates independently from meteorological factors.

The following flowcharts explain the treatment system for a "heated" digester (not considering the aerobic treatment):

- **Figure 5: Flowchart of Treatment System (heated digester)**



The emission reduction achievement is based on the transformation of CHG to CO2 through combustion, thereby avoiding fugitive CH4 emissions.

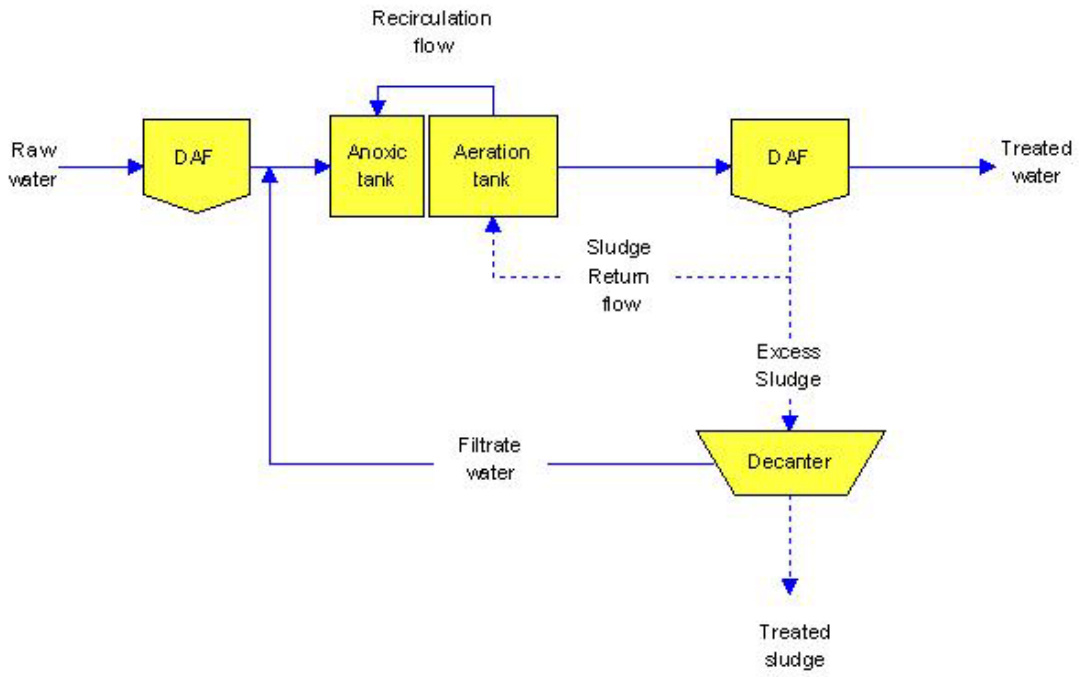
Treated water is used for the irrigation of eucalyptus forest plantations located on the site the company's property of its neighbouring areas. In the case of Peralillo, a total of 28 hectors of eucalyptus have been planted around the lagoon. During the winter season when no irrigation is required, effluents are accumulated in the lagoons.

Aerobic Treatment (Activated Sludge): The activated-sludge process is an aerobic, continuous flow, secondary treatment system that uses sludge-containing, active, complex populations of aerobic micro organisms to break down organic matter in wastewater. Activated sludge is a flocculated mass of microbes comprised mainly of bacteria and protozoa.

Manure effluent from digesters is delivered into the dissolved air floatation (DAF) and then into the aeration basin where it is mixed with an active mass of micro-organisms (referred to as activated sludge) capable of aerobically degrading organic matter into water, new cells, marginal quantities of CO2 and other end-products. Mechanical aeration maintains the aerobic environment in the basin and keeps reactor contents (referred to as mixed liquor) completely mixed.

After a specific treatment time, the mixed liquor passes into the secondary DAF, where the sludge settles under quiescent conditions and a clarified effluent is produced for discharge. The process recycles a portion of settled sludge back to the aeration basin to maintain the required activated sludge concentration. The process also intentionally wastes a portion of the settled sludge to maintain the required solid retention time for effective organic (BOD) removal.

- ***Figure 6: Flowchart of the Aerobic Treatment***



A.4.4. Brief explanation of how the anthropogenic emissions of anthropogenic greenhouse gas (GHGs) by sources are to be reduced by the proposed CDM project activity, including why the emission reductions would not occur in the absence of the proposed project activity, taking into account national and/or sectoral policies and circumstances:

1) How the GHGs are reduced by the CDM project activity:

Agrosuper has improved its swine waste treatment process in order to reduce GHG emissions. This has been accomplished through the implementation of an advanced system that includes the implementation of anaerobic digesters and, in some cases, aerobic treatment systems. The first phase of the swine waste management program began in December 2000 with the implementation of the first digester and in 2003 with the addition of the aerobic treatment system at this facility.

CDM project activity (Advanced System implemented by Agrosuper):

Wet manure from several barns is pumped from a collection and mixing tank to the bio-digester. The digester consists of an earthen pit lined with an impervious membrane. The digester is covered with a floating membrane. All biogas generated is collected by perforated pipes surrounding the digester's edge, below the cover. The water from the digester is pumped into a boiler where it is heated and returned to the digester in order to maintain an independent environment for the bacteria. The boiler is powered with methane gas generated in the digester. Surplus methane is flared to form carbon dioxide. Effluent is removed from the digester and is pumped to a nearby lagoon via a retaining tank. This effluent still contains nutrients and can be used as irrigation water. GHG emissions are considerably reduced with this system.

Through this process, the anaerobic treatment is optimal and duly controlled, employing an efficient biogas collection system and a new aerobic post-treatment for the second stage of the project.

- **Baseline (Traditional System):**

Even though the project is assuming the traditional system (open lagoon) as the national baseline (stabilisation lagoon), unfortunately not all companies have implemented even this system. Only 50% of the companies in Chile (including Agrosuper) have introduced the open lagoon system, in response to the Clean Development Agreement signed in 1999 between the Government and the Pork Industry to enhance the level of swine

manure treatment in the country. Some companies are using other manure treatment systems that are less environmental friendly (for more details see Nº 2 below). Assuming a conservative approach, this project activity has considered the traditional system as the baseline.

In the traditional system the manure is washed or flushed from the barn and then collected in a lagoon or other earthen storage facility. Here the manure is partially digested by naturally occurring micro-organisms, and solids settle on the bottom of the storage facility. During irrigation period, water is collected from the surface of the lagoon to lower the water table and increase the storage capacity. The collected water is then utilised in a land application program, either for use as fertiliser and irrigation water, or for straight land disposal. Solids collected in the bottom of the lagoon are removed once every 10 to 20 years, and are used on land to enhance fertilisation. Low levels of management participation, low development costs, and minor environmental safeguards characterise this system. Additionally, these systems are a high source of GHG emissions, particularly, CH4.

2) Why the emission reductions would not occur in the absence of the proposed project activity:

If the CDM project activity was not undertaken, all greenhouse gases would have been emitted to the atmosphere. The net emissions from Agrosuper's facilities have been considerably reduced since the first phase of this project and the anticipated total in tonnes of CO2 equivalent as detailed in section E.

National and sectoral policies and circumstances: Apart from the existing legislation in Chile that establishes strict water quality parameters that do not allow manure to be discharged into watercourses, there is no legislation that requires a specific swine manure treatment. That is why the Chilean government and the industry have promoted a voluntary "Clean Production Agreement" aimed at improving the swine manure management in the country.

Apart from the advancements in manure management made by Agrosuper in this project activity, the remainder of the swine industry lags behind in the adoption and implementation of manure management technologies. In Chile, the basic methods of swine manure management do not provide for the reduction of GHG emissions.

As stated above, only 50% of the Chilean pork production industry use open lagoons for their swine manure treatment. The remaining ones are using less environmental friendly techniques. Agrosuper has implemented the open lagoon system for all of its facilities and then has gone even further by installing advanced anaerobic treatment systems since December 2000 in some facilities, adding in 2003 an aerobic treatment system for some of its Digesters, like Peralillo.

With the open lagoon system CH4, N2O and CO2 are produced and are freely released into the atmosphere. On the other hand, the CDM project activity (Digester) leads to the optimal and efficient anaerobic digestion of swine manure in an efficient and closed manner. Biogas collected in the project activity can be used as a fuel to heat the digesters' boilers with the remaining biogas being burned in a flare.

In considering the baseline of the project Agrosuper has chosen a conservative approach, by using the objectives of the Clean Production Agreement signed in 1999, which establishes the voluntary commitment of open lagoons system to be implemented in the industry.

Additionality of the project

The additionality of the project can be demonstrated as follows:

1) **Would it be cheaper for Agrosuper to maintain the Traditional (Open Lagoon) system?** Yes. The cost of implementing Digesters can be as high as 3 times the cost of an open lagoon system. Specifically regarding the Peralillo anaerobic and aerobic treatment system, the following economic analysis in each scenario demonstrates this conclusion:

Table A.3

	Baseline (US$)	Project (US$)
Digester Equipment Gas handling skid (GHS) consisting of blower system, PLC, heat exchange system, boiler and flare system.	-	450,000
Digester Installations	-	600,000
Digester Extra costs (operation, consultancy)	-	150,000
Aerobic treatment **(investment)**	-	1,711,620
Aerobic treatment **(operation)**	-	343,620
Anaerobic Lagoon	450,000	
Storage Lagoon		150,000
TOTAL without aerobic treatment	**450.000**	**1.350.000**
TOTAL with aerobic treatment	**450.000**	**3.405.240**

Reference: Agrosuper Ltda.

The advanced treatment equipment is based upon different components that guarantee its optimal functioning: Gas handling skid (GHS) consisting of blower system, Controlled

Logical Programmer (CLP), heat exchange system, boiler (for heated digesters) and flare system.

Considering that the manure management costs are representative for Peralillo (118,800 pigs), the costs per pig of manure management can be identified for each of the scenarios.

	Baseline (US$/head)	**Project (US$/head)**
Without aerobic treatment	**3.78**	**11.4**
With aerobic treatment	**3.78**	**28.6**

For competitiveness reasons, the cost information included above is approximate rather than precise. Detailed figures, and justification for such figures, are available for confidential review by the respective applicant DOE.

2) Does the project lead to technology advancement (innovation)? Yes. The technology employed is considered to be the most advanced treatment process for swine waste in Chile and one of the most advanced world-wide. The baseline for the Chilean pork industry and for Agrosuper is the so-called "Traditional System." The considerable reduction in GHG by the implementation of the "Advance System" compared to the "Traditional System" confirms that if this technology is not implemented, GHG emissions will continue.

3) Does the project activity exceed National legislation? Yes, the project completely and substantially exceeds all national regulatory requirements and more specifically the Clean Production Agreement that only establishes storage through the "Traditional System". Agrosuper is following all Chilean Regulations and all its manure management projects have been reviewed and approved by national relevant authorities. This has been confirmed by the Environmental Impact Declaration presented by Agrosuper for all of its facilities and by the Host Country Approval letter it received from CONAMA (for more details see Chapter A.2.2).

4) Technical Barriers: Digester technology is not widely used world-wide, and it is even less used locally because of high implementation costs compared to other swine manure treatment systems. Although this system will improve the environmental management of the company's swine manure, it is not expected to result in direct earnings other than those associated with sales of CERs.

A.4.5. Public funding of the Project Activity

Not applicable. There is no public funding involved in this Project.

B. Baseline methodology

B.1 Title and reference of the methodology applied to the project activity:

There is no methodology available on the UNFCCC website yet. So the present methodology is proposed:

Title: **METHODODOLOGY FOR ON-FARM ANAEROBIC and AEROBIC TREATMENT OF ANIMAL WASTE IN THE SWINE INDUSTRY**

Reference: This methodology is described in Annex 3 of this Project Design Document (to be approved by the CDM Executive Board).

B.2. Justification of the choice of the methodology and why it is applicable to the project activity:

According to the modalities and procedures of the CDM, project participants should select the baseline approach that is most relevant for the proposed project. The baseline approach adopted for this project activity is option 48 (b). Accordingly, the baseline scenario is determined as the scenario that represents "emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment". Given that approach 48 (b) assumes that economically rational behaviour determines the most likely future baseline scenario, it seems appropriate to operationalise this approach in the form of an investment or financial analysis.

In pursuing swine waste management in Chile, companies have the following alternatives:

a) Traditional Open Lagoon

Brief description of technology: In an anaerobic treatment lagoon, liquid animal waste is stored for at least 5 months and normally one year or more. Anaerobic bacteria "treat" the liquid waste and decrease the organic matter content. This results in the emission of CO2, CH4, hydrogen sulphide, and ammonia. In the anaerobic treatment lagoon, sludge settles on the bottom of the lagoon. Once a year the supernatant is removed (draw down) and discarded or beneficially reused in a land application program. Solids are removed once every 10 - 20 years when the lagoon is full. Solids are used as fertiliser.

The anaerobic stabilisation lagoon represents the voluntary compromise for Agrosuper, to improve their manure management treatment.

b) Advanced System (anaerobic use of digesters):

Brief description of technology: The advanced system, for which the GHG emission reductions are calculated by applying the Methodology, consists of a continuous gas flow from an anaerobic digester with a floating cover. The digester uses a technology of complete mix. The digester is comprised of a lined earthen lagoon and is completely sealed with an impervious liner cover that has a linear strength of 30 kg/cm. Four circulation jets agitate its content. Gas produced in the digester is captured by a suspended collection system, for reuse as fuel or flared.

Advanced plus secondary aerobic treatment: The CDM project activity scenario includes an additional component in the manure management process, represented by an active sludge plant implemented in the second phase of the project (from 2003). The activated-sludge process is an aerobic, continuous flow, secondary treatment system that uses sludge-containing, active, complex populations of aerobic micro-organism to break down organic matter in wastewater. Activated sludge is a flocculated mass of microbes comprised mainly of bacteria and protozoa. Mechanical aeration maintains the aerobic environment in the basin and keeps reactor contents (referred to as mixed liquor) completely mixed.

Storage Lagoon: The effluent from the advanced system is treated in a storage lagoon, where liquid waste is stored for one year or more. When the lagoon is full (usually in the spring) the contents are mechanically mixed and the mixed content is used in a land application program. The storage of effluent lasts for at least one winter season (five months), and not more than a year. The storage lagoon is emptied every year. Due to the semi-anaerobic conditions in the storage lagoon, GHGs and ammonia are emitted to the atmosphere. These emissions have been accounted for.

The detailed assessment of net costs for each of the scenarios involved in this analysis is referenced as a quantitative demonstration of additionality, in B.4.

All mentioned manure management treatment alternatives are legally accepted in the Chile. Differences relate to their environmental performance. However, the advanced system reduces odour, treats the water and reduces GHGs well beyond that of the most economically attractive option, namely the traditional open lagoon system (which is also much less expensive than the CDM project activity).

B.3. Description of how the methodology is applied in the context of the project activity:

The Methodology for estimating GHG emissions from manure management in an intensive swine production facility is established based on a baseline for GHG emissions using conventional manure management technologies (anaerobic lagoon system, no solid separation considered). The Methodology can also be used to calculate GHGs not emitted (as tCO2e) when advanced technologies (CH4 capture and aerobic treatment) are implemented for the treatment of swine manure from large-scale intensive swine production operations.

The methodology includes the calculation of emissions from the swine manure management facility before and after advanced CH4 capture technology has been installed. Calculations are based on the International Panel on Climate Change (IPCC) calculation method for agriculture detailed in **"IPCC Guidelines for National Greenhouse Gas Inventories, Revised 1996, Chapter 4 & Reference Manual"** and the **"IPCC Good Practice Guidance and Uncertainty management in National Greenhouse Gas Inventories, Chapter 4" (IPCC Guidelines and IPCC Good Practice).**

The GHG emissions relevant for this analysis include; the open release of CH4 from an anaerobic lagoon or a storage lagoon, losses of CH4 due to leakage in the digester, its burn by a flare, and the emissions of N2O for each scenario. The CO2 generated from anaerobic digestion does not represent any difference in emission volumes between each scenario, because there are no possible additional transformations by the burning of this component. The anaerobic lagoon in the baseline scenario, the storage lagoon in the project scenario and the land deposition of the treated effluent cause the N2O emissions.

The project also considers an aerobic treatment for the second stage of implementation, a 75% default decay of nitrogen content via nitrification-denitrification, and an additional decay in the methane generation from treated manure (This is explained in detail in Annex 3).

As mentioned above and for conservative purposes, the baseline scenario will be the Voluntary Clean Production Agreements, established between the national government and the swine industry, i.e., the open anaerobic lagoon scenario. This scenario is applicable to Agrosuper, since this system has been implemented at all of their facilities.

The emissions from the baseline scenario are quantified using the default parameters and equations from the **IPCC Guidelines for National Greenhouse Gas Inventories,**

Revised 1996, Chapter 4 & Reference Manual, adjusted to the special characteristics and conditions of Agrosuper facilities.

The emissions for the project scenario are represented by the following components:

Table B.1

Digester Including Aerobic Treatment (Peralillo)
Emissions from the burn of CH4 captured
Fugitive CH4 from the storage lagoon
Indirect emissions inside the project boundaries, related to digester losses
Indirect fugitive CH4 from the aerobic treatment

The parameters and equations used are default parameters and equations from the **IPCC Guidelines for National Greenhouse Gas Inventories, Revised 1996, Chapter 4 & Reference Manual** and the **IPCC Good Practice Guidance and Uncertainty management in National Greenhouse Gas Inventories, Chapter 4 adjusted to the special characteristics and conditions of Agrosuper facilities.**

The key parameters for this analysis are the **number pig heads**, the **average swine weight** and the **volatile solids generation** in raw and treated manure (for the baseline and project scenarios respectively). For the case of aerobic treatment, the **five-day biochemical oxygen demand (BOD5) and the effluent flow** from the manure management facility is also considered. Annex 5 details the baseline data and the parameters provided for the calculation of emissions in each scenario.

The baseline scenario takes into account the real capacity production of manure from each digester, developing a dynamic baseline, taking into account the number of pig heads and their average weight as key variables that change through time. For the purposes of this document, the potential emissions for each scenario have been quantified based on steady data corresponding to a "base" year. This "base year" represents the actual swine production capacity and its projection for the barns included in the project.

B.4. Description of how the anthropogenic emissions of GHG by sources are reduced below those that would have occurred in the absence of the registered CDM project activity *(i.e. explanation of how and why this project is additional and therefore not the baseline scenario)*

In Chile, and other parts of South and North America, the traditional system of manure management consists of the storage of swine manure in a large open storage facility and/or the partial treatment of the manure in an anaerobic lagoon followed by land application. Under the traditional system, all CH4 that is generated in an open lagoon or storage tank is emitted to the atmosphere.

Again, as mentioned above, approximately 50% of the Pork industry in Chile and all Agrosuper facilities use this conventional method of manure disposal, so this will represent the baseline scenario for Agrosuper's pork production. Swine manure is washed or flushed from the barn and then collected in a lagoon or other earthen storage facility. Then the manure is partially digested at ambient temperature by naturally occurring anaerobic micro-organisms, releasing carbon dioxide, methane, hydrogen sulphide, and ammonia in the process. Anaerobic bacteria "treat" the liquid manure and decrease the organic matter content. Solids are allowed to settle on the bottom of the storage facility. Solids collected in the bottom of the lagoon are removed once every 10 to 20 years, and are used on land to enhance fertility.

Once a year, water is collected from the surface of the lagoon to lower the water table and increase the storage capacity. The collected water is then utilised in a land application program, either as fertiliser and irrigation water, or simply land disposal.

Agrosuper has implemented an advanced treatment system. The anaerobic digester functions to capture a significant portion of the digested volatile solids (VS) in the form of CH4 and CO2 produced from the activity of the anaerobic bacteria present in the digester. The digester consists of an earthen pit-lined with an impervious membrane and is covered with a floating membrane. Any gas produced is collected in a grid of collection pipes suspended above the surface of the swine manure. This collected gas is used for heating purposes in the digester or is flared. Mixed effluent is removed from the digester and is pumped to a nearby storage lagoon. This effluent still contains nutrients and is used as irrigation water for non-edible crops. Additional solids will settle in the bottom of the lagoon and will be removed once every 20 years for use as fertiliser in land application programs.

Due to the capture of CH4 in the digester and its transformation into CO2, CH4 emissions to the atmosphere are avoided. Due to the inclusion of an aerobic treatment after the digester, for the second stage of the project, the volatile solids content in the storage lagoon will be significantly reduced, as will be CH4 and N2O fugitive emissions.

The decision to implement this more expensive technology was influenced by the adoption of the Kyoto Protocol and the Clean Development Mechanism (CDM) contained therein. The continued investment program has been strongly influenced by the decisions relating to CDM taken by the Conference of the Parties at COP7 in Marrakech.

As a direct result of the clear direction given at COP7 7th, Agrosuper took a decision to continue the implementation of more digesters and aerobic treatment systems during 2002 and 2003. The construction of additional digesters is on currently standby until the outcome of this CDM project activity.

The additionality of the project can be demonstrated by answering the following questions:

1) **Would it be cheaper for Agrosuper to maintain the Traditional (Open Lagoon) system?** Yes. As demonstrated in section A.4.4, the cost of implementing Digesters can be as high as 3 times the cost of an open lagoon system.

2) **Is Agrosuper receiving any economic benefit by introducing this new technology?** No. The Chilean energy market does not give any incentives to sell biogas from these kinds of facilities into the grid. The investment involved in the production of energy by the utilisation of biogas is still to high and is not profitable, compared to the electricity prices in Chile.

3) **Were the revenues from the potential sale of emission reductions considered in the investment decision?** Yes. The potential to sell CERs was the main factor that influenced the decision to implement the anaerobic digesters and aerobic treatment systems. It will also influence additional investment in the type of technology at other Agrosuper facilities.

4) **Is this technology (digester and aerobic manure treatment) world-wide and/or nationally used?** No. This anaerobic and aerobic manure treatment process is one of the most advanced technology systems in the world. Only a few developed countries have implemented this technology because of the high costs involved in the investment compared to other available systems.

5) **Are other systems available that are cheaper and reduce the same or more amount of GHG?** According to our information, there are not. It is possible to implement improvements such as the traditional system, but they do not reduce similar amounts of GHG, in fact they reduce much less than a digester-based system. Both manure management alternatives are described in B.2.

6) **Are there technology barriers to implement this system?** Yes. To implement a digester-based system, a significant level of waste and barns that are close to each other is required in order to have enough flow to justify the construction of a digester. Maintenance requirements involved in this technology, including a detailed monitoring program of its performance level, must also be considered.

7) **What is the baseline for the Chilean pork industry?** Using a conservative approach, the baseline for the Chilean pork industry is the so-called traditional open lagoon system. If Agrosuper had not implemented the digester systems, GHG emissions would continue.

8) **According to the Chilean legislation, this project activity exceeds what are the legal requirements for the swine treatment in Chile?** Yes. The implementation of the "Advanced System" by Agrosuper highly exceeds current Chilean regulations. Apart from existing legislation in Chile that establishes strict

water quality parameters that do not allow manure to be discharged into watercourses, there is no legislation in place that requires specific swine manure treatment. That is why the Chilean government and the industry have promoted a voluntary "Clean Production Agreement" aimed at improving swine manure management. Apart from the advancements in manure management made by Agrosuper in this project activity, the remainder of the swine industry lags behind in the adoption and implementation of manure management technologies. In Chile, the basic methods of swine manure management do not provide for the reduction of GHG emissions. There are no expectations that the Chilean legislation will require future implementation of digesters or aerobic treatment, due to the significant investments required, without economic compensation.

B.5. Description of how the definition of the project boundary related to the baseline methodology is applied to the project activity:

Swine waste is primarily composed of organic material from which, when decomposed in an anaerobic environment, methanogenic bacteria produce methane. This is a common occurrence when large numbers of animals are managed intensively. In the baseline scenario, the swine manure is disposed of in large lagoons. The decomposition of manure in these lagoons produces CH4, which is released directly into the atmosphere. N2O is also produced during the storage and treatment of manure before, during and after land application. For the aerobic treatment (Peralillo) the **EPA - CAFO** (2001) document gives a reference of 75 percent decay of nitrogen content via nitrification-denitrification and an important level of volatile solids decay that can be related to the five-day biochemical oxygen demand, as explained Annex 3.

The project boundary for the baseline scenario is restricted to on-site emissions. The application of (treated) manure in the immediate surroundings of the animal production unit does not contribute to CH4 emissions in the project boundary. The project boundary includes only the emissions (and emission reductions) from manure management techniques dealing with swine manure from a cluster of production units discharging manure to handling systems.

The term "manure" includes both solids and liquids (dung and urine, respectively) produced by swine.

The next schematic diagrams present the project activity and baseline boundaries. The segmented line represents the project boundary.

Figure 1: Baseline Scenario Boundary

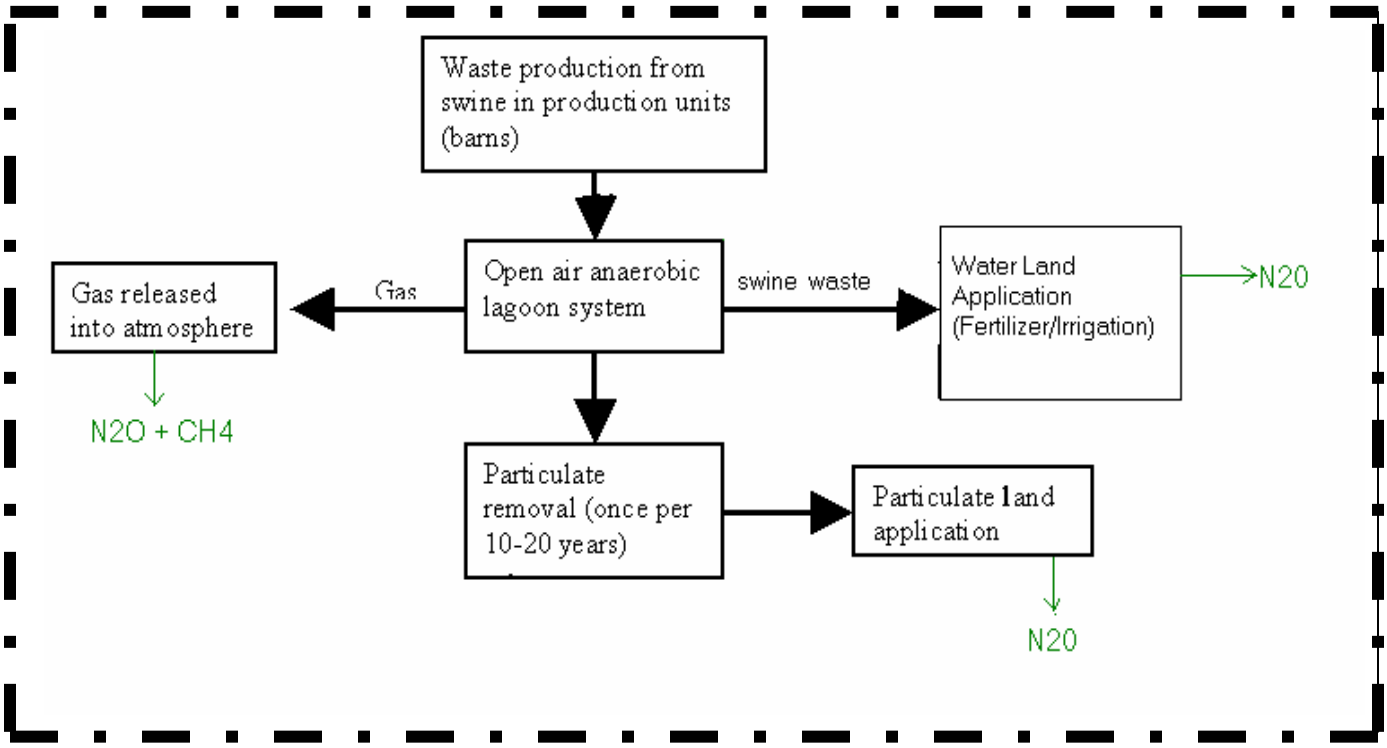


Figure 2: CDM Project Activity Boundary (no aerobic treatment-Stage I)

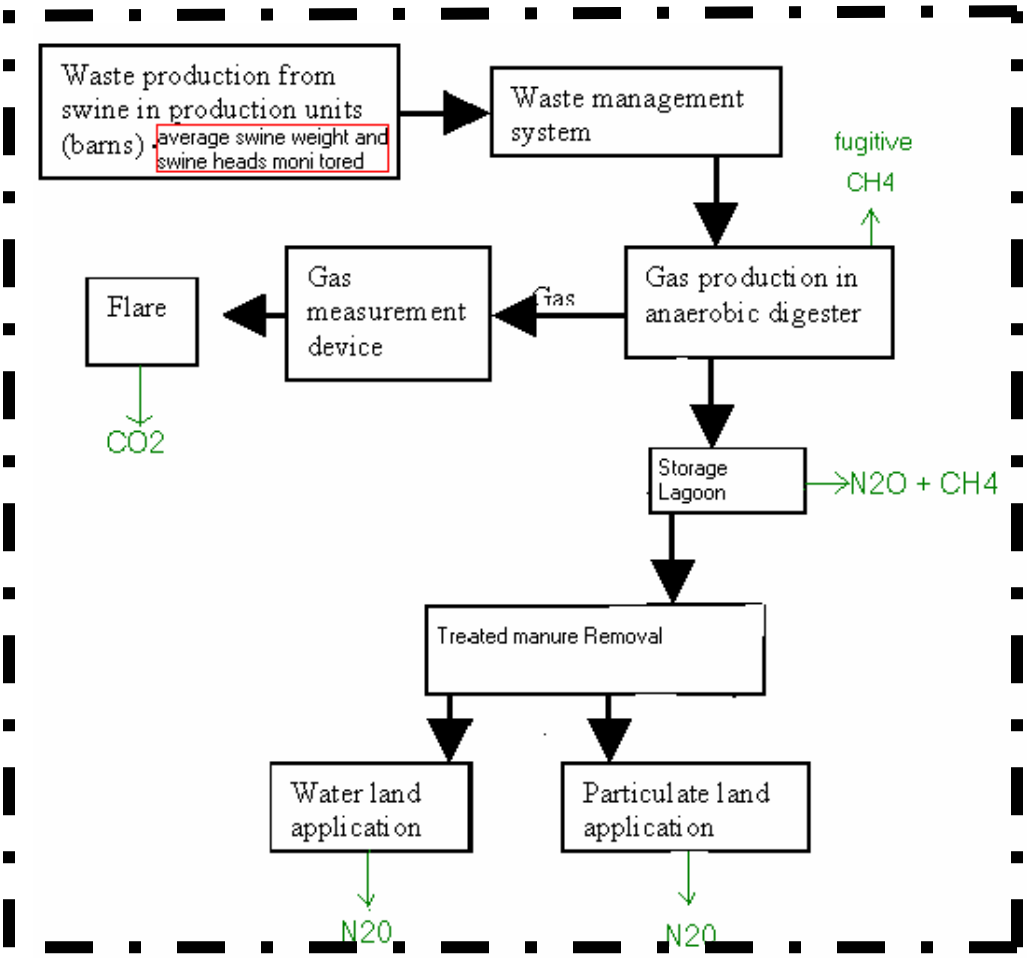
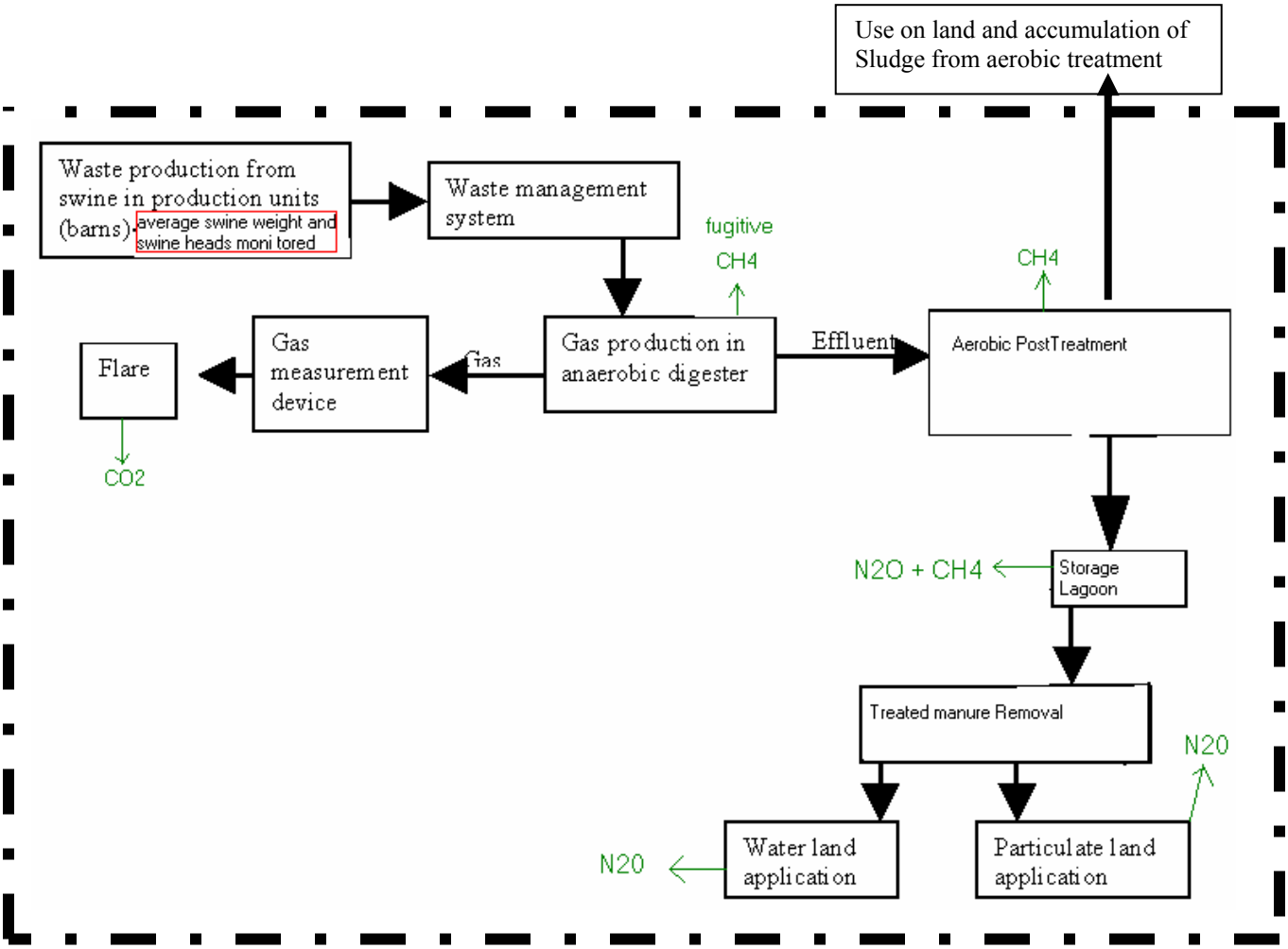


Figure 3: CDM Project Activity Boundary (including aerobic treatment – Stage II)



This advanced waste management system recognises leakage. The volume of sludge from the aerobic treatment will be used as fertiliser in land application programs and also disposed on a controlled landfill, outside the project boundaries. The potential CH4 emissions and the N2O generation from this source (leakage due to emissions outside the project boundaries) are marginal. This is because the nitrogen content in the sludge

effluent from the aerobic treatment (dry and moist), is in the shape of nitrate and nitrite, and has lost its volatile potential.

Since the volatile solids (VS) are consumed in the anaerobic digester in the CH4 capture process and in the storage lagoon, it cannot be applied to land as CH4 emissions.

B.6. Details of baseline development

B.6.1 Date of completing the final draft of this baseline section (DD/MM/YYYY):

22/08/2003

B.6.2 Name of person/entity determining the baseline:

Provide contact information and indicate if the person/entity is also a project participant listed in Annex 1.

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C. Duration of the project activity / Crediting period

C.1 Duration of the project activity:

We are applying for a crediting period of 7 years with the potential for subsequent renewal(s).

C.1.1. Starting date of the project activity:

The first Digester implemented under the swine management program was Peralillo, on December 1st, 2000. This will be considered the starting date of the project.

C.1.2. Expected operational lifetime of the project activity: *(in years and months, e.g. two years and four months would be shown as: 2y-4m)*

50 years (expected)

C.2 Choice of the crediting period and related information:

C.2.1. <u>Renewable crediting period *(at most seven (7) years per period)*</u>

C.2.1.1. Starting date of the first crediting period *(DD/MM/YYYY)*:

01/12/2000

C.2.1.2. Length of the first crediting period *(in years and months, e.g. two years and four months would be shown as: 2y-4m)*:

7 years

C.2.2. Fixed crediting period *(at most ten (10) years)*: Not applicable

C.2.2.1. Starting date *(DD/MM/YYYY)*: Not applicable

C.2.2.2. Length (max 10 years): *(in years and months, e.g. two years and four months would be shown as: 2y-4m):* **Not applicable**

D. Monitoring Plan and Methodology

In order to verify actual emission reduction of the project with regard to its baseline, it is essential to conduct an efficient monitoring plan.

As explained in section B.1, the baseline methodology follows the analysis presented in the "**Guidelines for National Greenhouse Gas Inventories, Revised 1996, Chapter 4**". The emissions for the project scenario can be verified using the current monitoring system of swine production parameters, explained in this chapter. This system helps backup and ensure consistency with theoretical calculations. This monitoring methodology also gives the baseline calculation continuity in time, projecting it through time, considering the changes in average swine weight and number of pigs.

D.1. Name and reference of approved methodology applied to the project activity

Currently there are no official references available in the UNFCCC's page for the implementation of a monitoring plan.

Detailed and background information on the methodology used for the monitoring plan is described in Annex 4.

The principal difference of project emissions compared to the baseline scenario is the result of replacing fugitive CH4 emissions with combustion of these emissions in a

digester. In "heated" digesters, part of the biogas extracted from the digester is reused as fuel for the boiler with the remaining biogas being burned in a flare. The project scenario also involves CH4 emissions and N2O emissions from the storage lagoon, and fugitive CH4 emissions from the aerobic treatment.

D.2. Justification of the choice of the methodology and why it is applicable to the project activity

Monitored parameters are used to calculate project emissions and the resulting reductions compared to the baseline. Chapter E describes each of the formulae that represent the emissions for every source in baseline and project scenario. Most of the parameters involved in these equations are default parameters provided by the IPCC Guidelines or the IPCC Good Practice and Uncertainty management, *adjusted to the special characteristics and conditions of Agrosuper facilities*. The VS percentage reduction from digester treatment does not have a default reference in the IPCC documents. As a result, the CAFO-EPA's "**Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations"** have been used.

D.3. Data to be collected in order to monitor emissions from the project activity, and how this data will be archived:

The current emission monitoring systems for digesters will be used, assigning a calibration frequency; the corresponding associated record and a preventive maintenance program.

ID number *(Please use numbers to ease cross-referencing to table D.6)*	Data type	Data variable	Data Unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will data be archived? (electronic/paper)	For how long is archived data to be kept?	Comments
D.3-1	number	Diary Swine stock	Heads	M, measured	Weekly	100%	Paper	At least two years from completion of authorisation period or last CERs issued	All of the pig barns have an exhaustive contabilisation of the stock of pigs.
D.3-2	mass	Average weight of pigs	Kg.	Measured	Monthly	100%	Paper	At least two years from completion of authorisation period or last CERs issued	
D.3-3	mass	5 days Biochemical Oxygen Demand after aerobic post-treatment	mg/L	Measured	Monthly	100%	Paper	At least two years from completion of authorisation period or last CERs issued	This is relevant just for the stage that include aerobic post-treatment
D.3-4	volume	Manure inflow to the aerobic post-treatment	m^3/day	Measured	Monthly	100%	Paper	At least two years from completion of authorisation period or last CERs issued	This is relevant just for the stage that include aerobic post-treatment

D.3-5	flux density	Biogas Flow extracted by digester	SCFM (standard cubic feet meter)	Measured	Daily	100%	Paper	At least two years from completion of authorisation period or last CERs issued	This parameter guarantees the correct performance of the digester. Measure of the biogas flow.
D.3-6	percentile	CO_2 concentration in gas flow	%	Measured	Daily	100%	Paper	At least two years from completion of authorisation period or last CERs issued	

CERs: Certified Emissions Reduction.

The only purpose for monitoring the biogas flow is to confirm the correct functioning of the digester. Biogas extraction rate and CO2 percentage concentration do not have any influence in the emission reduction calculation, they just guarantee the continuity in the digester's gas extraction capacity. For that reason, the registration of data is controlled periodically, jointly along with parameters like temperature and pH.

In the case of "heated" digesters, the internal automatic control program regulates and optimises the extraction, re-use and burn of the gas, based upon the pressure differential and the internal gas temperature. This internal automatic control program is known as controlled logical program (CLP), its purpose is to manage the digester operation as well as the distribution of gas to the boiler or to the flare. Flow sensors based on the pressure differentials and transmitted to the CLP as an electric signal measure the daily gas flow.

The monitoring of required parameters in the aerobic treatment is part of the normal quality control in an aerobic wastewater treatment facility.

D.4. Potential sources of emissions which are significant and reasonably attributable to the project activity, but which are not included in the project boundary, and identification if and how data will be collected and archived on these emission sources.

The project does not envisage emissions generated outside the project boundary which are significant and reasonably attributable to changes in liquid manure treatment. The project already includes the potential fugitive emissions related to the digester, as emissions in the project boundary.

Nevertheless, the project has an installed capacity to operate of 0.001 MW (100kWhs) that would not be consumed in the baseline scenario. The installed capacity of the central grid in Chile (SIC) is 6,682 MW (from that 58% is Hydro, 16.7% Natural Gas, 14.1% Coal, 8.8% Petroleum and 2.1% Biomass)[1]. Because this volume is so insignificant, is has not been included for the purposes of the main calculations.

The volume of sludge from the aerobic post-treatment will be used as fertiliser in land application programs and also disposed of in a controlled landfill, outside the project boundaries. The potential CH4 emissions and N2O generation from this source (leakage outside project boundaries) are marginal. This is because the nitrogen content in the sludge effluent from the aerobic treatment (dry and moist), is in the shape of nitrate and nitrite, and has lost its volatile potential,.

[1] National Energy Commission (CNE), www.cne.cl

The next table presents the emissions of GHGs involved with the project and the baseline scenarios, identifying which are inside or outside the project boundaries.

Table D.1

		In the boundary	Outside the boundary
Baseline scenario	Non-negligible	Methane emissions from stabilisation lagoon	-
	negligible small	-	Nitrous oxide emissions from anaerobic lagoon, treated manure land application and runoff
	Not counted	-	-
Project scenario	Non-negligible	Methane emissions from: storage lagoon, digester and aerobic treatment losses (if exists); Carbon dioxide emissions from methane combustion.	-
	negligible small	GHGs associated with the use of energy in the implementation	Nitrous oxide emissions from storage lagoon, treated manure land application and runoff
	Not counted	-	-

As part of an advanced manure treatment system it is important to control and monitor the effluent wastewater quality. The parameters involved are usually for this system: BOD5 (five days biochemical oxygen demand), ammonia, phosphorus, COD (chemical oxygen demand) and Kjeldahl nitrogen content.

D.5. Relevant data necessary for determining the baseline of anthropogenic emissions by sources of GHG within the project boundary and identification if and how such data will be collected and archived.

As explained in point B.1, this methodology follows the instructions of the "**IPCC Guidelines for National Greenhouse Gas Inventories, Revised 1996, Chapter 4**". These guidelines relate directly to emissions from swine manure treatment in anaerobic lagoons or digesters. A description of the calculations is given in Chapter E and annex 3. The relevant data for determining the baseline emissions within the project boundaries are already considered in the monitoring plan of the project activity emissions (D.3), and consider:

- Number of swine heads
- Average swine mass

D.6. Quality control (QC) and Quality Assurance (QA) Procedures are being undertaken for data monitored

These procedures can be adjusted to the current monitoring system for the generation and composition of biogas from digesters.

Data	Uncertainty level of data (High/Medium/Low)	Are QA/QC procedures planned for these data?	Outline explanation why QA/QC procedures are or are not being planned.
D.3-1	Low	Yes	QA/QC procedures are established; this data will be used as basis for calculating emission reductions
D.3-2	Low	Yes	QA/QC procedures are established; this data will be used as basis for calculating emission reductions
D.3-3	Low	Yes	QA/QC procedures are established; this data will be used as basis for calculating emission reductions
D.3-4	Low	Yes	QA/QC procedures are established; this data will be used as basis for calculating emission reductions
D.3-5	Low	Yes	QA/QC procedures are established; this data will be used as basis for calculating emission reductions
D.3-6	Low	Yes	QA/QC procedures are established; this data will be used as basis for calculating emission reductions

The number of living pigs and the average pig weight for each barn involved in the project are parameters relevant for Agrosuper's permanent monitoring production plan. The accuracy of this existing monitoring plan can be assured on the actual quality certification process being implemented in Agrosuper.

The gas flow from the digester is a consistent guide to guarantee the performance of the digester, and is also part of an existing monitoring plan. The quality control of this parameter monitoring depends in its continuity and in other parameters monitored as temperature and pH.

D.7. Name of person/entity determining the monitoring methodology

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E. Calculation of GHG emissions by sources

E.1 Description of formulae used to estimate anthropogenic emissions by sources of GHGs of the project activity within the project boundary:

The following analysis shows the representative formulae used for the emissions of the project. Emissions related to the baseline (stabilisation lagoons) and to the project (digester, activated sludge for stage II and storage lagoon) were quantified based on the methodology presented in the **"IPCC Guidelines for National Greenhouse Gas Inventories, Revised 1996, Chapter 4"**. These guidelines relate directly to emissions from swine manure treatment in lagoons and anaerobic digesters.

E.1.1. CH4 EMISSIONS FROM MANURE MANAGEMENT SYSTEMS

EQ. 1: Methane emissions related to manure management

$$CH_4 \text{ emissions (tonnesCO2eq/year)} = EF \cdot GWP_{CH4} \cdot \text{stock of pigs} / 1000$$

Where:

CH_4 emissions (tonnes/year) = CH4 emissions related to manure management, for a defined stock of pigs per year.

Stock of pigs = number of living pigs for a certain barn.

GWP_{CH4} = Methane Global Warming Potential of 21.

EF = Emission Factor for swine manure management. [kg/per pig/year]. This emission factor can be represented by the next equation:

EQ. 2: Emission Factor for manure management

$$EF\ (kg/year) = VS \cdot 365\ days/year \cdot Bo \cdot D_{CH4} \cdot MCF$$

Where:

EF = Emission Factor for a livestock of swine [kg/year]

Bo = Maximum CH_4 production capacity from manure, per head for a given stock of pigs m^3/kg of volatile solids.

D_{CH4} = Methane Density, 0.67 kg/m^3

MCF = Conversion factor of CH4, for an anaerobic lagoon (90 %), activated sludge after digester (0.1%), or storage lagoon (45 %). Detailed in Annex 5.

VS = volatile solids rate in kg/day/head for a given stock of pigs. Volatile solids before the digester for baseline emissions and volatile solids after the digester in the aerobic treatment and the storage lagoon (for project emissions) are detailed in Annex 5. For the volatile solids decay after the activated sludge aerobic process, equation 3 that relates methane produced to long term BOD, was considered. It must be highlighted that the aerobic treatment process, and all its effect on the volatile solids content in the storage lagoon, is only relevant for stage II.

EQ. 3: Relation of long term BOD and methane gas

$$CH4\ generation\ (kg/year) = 0.25 \cdot BOD_{lt}\ (mg/lt) \cdot F\ (m^3/day) \cdot 365 / 1000$$

Where:

CH4 generation (kg/year) = Methane generation potential in storage lagoon after the aerobic treatment of activated sludge.

BOD_{lt} = Long term Biochemical Oxygen Demand in aerobic treatment = 1.42 x BOD5 (Five-day Biochemical Oxygen Demand)

F (m3/day) = Average inflow waste of treated manure after digester, into activated sludge process.

The theoretical argument of this relation is documented in Annex 5.

E.1.2. CO2 EMISSIONS FROM DIGESTER CH4 BURNED IN FLARE

Although the Methodologies Panel of the CDM Executive Board has not decided yet whether the CO2 emissions from methane combustion, must be included or not, it was considered and quantified as part of the project emissions scenario for conservative purposes. This was done even thought not considering this (because of its biogenic origins) would represent a bigger amount of emission reductions. **A clarifying recommendation from the Methodologies Panel is requested.**

The next equation quantifies the emissions from Digester CH4 (converted to CO2 in flare).

EQ. 4: Digester methane converted to CO2 in flare

$$CO_2\,(\text{tonnes}) = \text{Stock of Pigs} \cdot \text{VS (kg/hd/day)} \cdot 365\,(\text{days}) \cdot Bo \cdot D_{CH4} \cdot MCF_d \cdot M_{CH4/CO2} / 1000$$

Where:

CO2 = Carbon dioxide emissions from methane burn up in flare (tonnes)**.**

Stock of pigs = number of living pigs for a certain barn.

VS = volatile solids rate in kg/day/head for a given stock of pigs.

Bo = Maximum CH_4 production capacity from manure, per head for a given stock of pigs m^3/kg of volatile solids.

$\mathbf{D_{CH4}}$ = Methane Density, 0.67 kg/m^3

$\mathbf{MCF_d}$ = Conversion factor of CH4, 90 % for methane potential generation in digester.

$\mathbf{M_{CH4/CO2}}$ **=** Molar mass quotient CO_2/CH_4 = 2.75

E.1.3 CH4 FUGITIVE EMISSIONS FROM DIGESTER

The losses due to indirect emissions from the digester, **inside** the project boundaries are considered as minimal. For a conservative approach, the MCF default IPCC value of 5% was considered as representative.

EQ. 5: CH4 emissions related to losses from the digester

$$CH_{4\_L} \text{ emissions (tonnesCO2eq/year)} = EF2 \cdot GWP_{CH4} \cdot \text{stock of pigs} / 1000$$

Where:

CH_{4_L} emissions (tonnes/year) = Methane emissions related to losses from digester, for a defined stock of pigs per year.

Stock of pigs = number of living pigs for a certain barn.

GWP_{CH4} = Methane Global Warming Potential of 21.

EF2 = Emission Factor related to losses from the digester [kg/head/year]. This emission factor can be represented by the next equation:

EQ. 6 Emission Factor for indirect emissions from the digester

$$EF2 = VS \cdot 365 \text{ days/year} \cdot Bo \cdot D_{CH4} \cdot MCF_{DL}$$

Where:

EF2 = Emission Factor related to indirect emissions from the digester for a livestock of swine [kg/year]

VS = volatile solids rate in kg/day/head for a given stock of pigs. This parameter must substituted by the volatile solids content for the respective manure management stage.

Bo = Maximum CH_4 production capacity from manure, per head for a given stock of pigs m^3/kg of volatile solids].

D_{CH4} = Methane Density, 0.67 kg/m^3

MCF_{DL} = Conversion factor of CH4, for an anaerobic digester. Emissions are from fugitive indirect emissions (5 %). Detailed in Annex 5.

E.1.4 ESTIMATING N2O EMISSIONS FROM MANURE MANAGEMENT SYSTEMS

Because only the insertion of aerobic treatment consider a reduction in the nitrogen content of manure, this analysis of N20 emissions is relevant only for stage II of the project.

E.1.4.1 ANAEROBIC LAGOON & STORAGE LOSSES:

a. Non volatile emission component

EQ. 7 Non volatile emission component

N2O = NEX • stock of pigs • (1 – **FracGASM**) • EF3 • CF /1000

Where:

N2O = N2O direct emissions from swine manure Management Systems (tonnes N2O/year);

NEX = Corrected Default Nitrogen excretion rate (kg/hd/year). This is explained for each scenario in Annex 5.

Stock of pigs = number of living pigs for a certain barn.

FracGASM = fraction of livestock nitrogen excretion that volatilises as NH3 and NOx (kg NH3-N and NOx-N/kg of N excreted)

EF3 = N2O emission factor for manure management System (kg N2O-N/kg of Nitrogen excreted);

CF = CONVERSION FACTOR N2O-N TO N (1.57 = 44/28)

b. Volatile emission component (indirect emissions)

EQ. 8 volatile emission component

$N2O_{indirect}$ =NEX • stock of pigs • **FracGASM** • EF4 • **CF** /1000

Where:

$N20_{indirect}$ = N2O volatilised indirect emissions from swine manure management Systems (tonnes N2O/year)

Stock of pigs = number of living pigs for a certain barn.

EF4 = N2O emission factor for atmospheric deposition (kg N2O-N/kg of NH3-N and NOx-N emitted);

NEX = Corrected Default nitrogen excretion rate (kg/hd/year). This is explained for each scenario in Annex 5.

FracGASM = fraction of livestock nitrogen excretion that volatilises as NH3 and NOx (kg NH3-N and NOx-N/kg of N excreted)

CF = CONVERSION FACTOR N2O-N TO N (1.57 = 44/28)

E.1.4.2. N2O LAND APPLICATION AND RUNOFF LOSSES:

a. Emissions from non-volatilised nitrogen.

EQ. 9 land emissions from non-volatilised nitrogen.

$$N2O_{(LAND)} = NEX \cdot \text{stock of pigs} \cdot CF \cdot (1 - FracGASM) \cdot EF1$$

Where:

$N2O_{(LAND)}$ = emissions from non-volatilised nitrogen (tonnes N2O/year).

Stock of pigs = number of living pigs for a certain barn.

EF1 = emission factor for direct soil emissions (kg N2O-N/kg N input)

NEX = Corrected Default nitrogen excretion rate (kg/hd/year).

FracGASM = fraction of livestock nitrogen excretion that volatilises as NH3 and NOx (kg NH3-N and NOx-N/kg of N excreted)

CF = CONVERSION FACTOR N2O-N TO N (1.57 = 44/28)

b. Emissions from runoff.

EQ. 10 Emissions from runoff.

$$N2O_{(RUNOFF)} = EF_5 \cdot R \cdot (NEX \cdot \text{stock of pigs} \cdot (1 - FracGASM)) \cdot CF / 1000$$

Where:

$N2O_{(RUNOFF)}$ = emissions from non-volatilised nitrogen (tonnes N2O/year).

Stock of pigs = number of living pigs for a certain barn.

NEX = Corrected Default nitrogen excretion rate (kg/hd/year).

FracGASM = fraction of livestock nitrogen excretion that volatilises as NH3 and NOx (kg NH3-N and NOx-N/kg of N excreted)

R = Non-volatilised Runoff, (Reference from IPCC Leaching & runoff table 4-24 = 0.3 kg N/ kg of manure non-volatilised nitrogen).

EF_5 = Emission factor for indirect emissions from runoff (kg N2O-N/kg N runoff)

CF = CONVERSION FACTOR N2O-N TO N (1.57 = 44/28)

EQ. 11: Total emissions of N20 (tonnes/year)

$$N20_{TOTAL\_EMISSIONS} = N2O_{(RUNOFF)} + N2O_{(LAND)} + N2O_{(AWMS)\ indirect} + N2O_{(AWMS)}$$

EQ. 12: Total emissions of N20 expressed in tonnes CO2eq/year

$$CO2_{eq}(N2O) = GWP_{N2O} \cdot N20_{TOTAL\_EMISSIONS}$$

GWP_{N2O} = Nitrous Oxide Global Warming Potential of 310

E.2 Description of formulae used to estimate leakage, defined as: the net change of: anthropogenic emissions by sources of greenhouse gases that occurs outside the project boundary, and that is measurable and attributable to the project activity:

The project does not envisage emissions generated outside the project boundary which are significant and reasonably attributable to changes in liquid manure treatment. The project already includes the potential fugitive emissions related to the digester, as emissions in the project boundary.

Nevertheless, the project has an installed capacity to operate of 0.001 MW (100kWhs) that would not be consumed in the baseline scenario. This refers to power consumption by the digesters. The installed capacity of the central grid in Chile (SIC) is 6,682 MW (from that 58% is Hydro, 16.7% Natural Gas, 14.1% Coal, 8.8% Petroleum and 2.1% Biomass)[2]. Because this volume is so insignificant, we have chosen to disregard it for the purposes of our main calculations.

The volume of sludge from the aerobic post-treatment will be used as fertiliser in land application programs and also disposed on a controlled landfill, outside the project boundaries. The potential CH4 emissions and the N20 generation from this source (leakage outside project boundaries) are marginal. This is because the nitrogen content in the sludge effluent from the aerobic post-treatment (dry and moist), is in the shape of nitrate and nitrite, and has lost its volatile potential, so its ammonia and N20 generation capacity as leakage.

E.3 The sum of E.1 and E.2 representing the project activity emissions:

The sum of emissions in the project scenario is synthesised by the formulae presented in E.1. and E.2.

Table E.1 Project Emissions.

	Emissions	**type of digester**	**average weight**	**stock of pigs**	**Aerobic Post-treatment**
Peralillo	**TONNES CO2EQ/year**		**kg**		
Stage I: 2001-2003	20,248	heated	72.24	118,800	No
Stage II: 2004-2008	22,692	heated	72.24	118,800	Yes

[2] National Energy Commission (CNE), www.cne.cl

E.4 Description of formulae used to estimate the anthropogenic emissions by sources of GHGs of the baseline: *(for each gas, source, formulae/algorithm, and emissions in units of CO_2 equivalent)*

The representative formulae used for the emissions of the project baseline (anaerobic lagoon) are detailed in E.1.

Table E.2 Baseline Emissions

	Emissions	**Type of digester**	**Average weight**	**Stock of pigs**	**Aerobic Post-treatment**
Peralillo	**TONNES CO2EQ/year**		**kg**		
Stage I: 2001-2003	108,841	heated	72.24	118,800	No
Stage II: 2004-2008	117,966	heated	72.24	118,800	Yes

E.5 Difference between E.4 and E.3 representing the emission reductions of the project activity:

EQ. 11

$$E_{reductions} = E_{baseline} - E_{project}$$

$\mathbf{E_{reductions}}$**=** Emission reductions (tonnesCO_2e/year)

$\mathbf{E_{baseline}}$ **=** Baseline emissions (tonnesCO_2e/year)

$\mathbf{E_{project}}$ **=** Project emissions (tonnesCO_2e/year)

E.6 Table providing values obtained when applying formulae above:

BASELINE: Barn → anaerobic lagoon → field application

PROJECT: Barn → anaerobic digester → aerobic post-treatment (for stage II) → storage lagoon → field application

In the digester – flare and boiler combination, CH4 is transformed into CO2.

Table E.3 Overall Results - Carbon emissions and emission reductions per annum for the Peralillo digester

Peralillo	Reductions	Type of digester	Average weight	Stock of pigs	Aerobic Post-treatment
	TONNES CO2EQ/year		kg		
Stage I: 2001-2003	88,593	heated	72.24	118,800	No
Stage II: 2004-2008	95,274	heated	72.24	118,800	Yes

F. Environmental impacts

F.1. Documentation on the analysis of the environmental impacts, including transboundary impacts

According to the Chilean legislation, the implementation of a digester in existing facilities does not require a specific Environmental Impact Study. However, the construction of barns and the respective waste treatment does require this specific authorisation and study. The National Commission for the Environment (CONAMA) approved and authorised the construction of the barns with a traditional waste treatment system. Nevertheless, Agrosuper improved the system to digesters and aerobic treatment systems reducing considerably all potential impacts to the environment. Those changes do not require an additional Environmental Impact Evaluation, apart from gathering the respective sectoral permits. Those permits were processed and obtained in due time by the company.

All these affirmations are confirmed by the endorsement of the project given by the Designated National Authority (CONAMA), in its Host country approval process (Letter of Host Country Approval is attached). In that instance the DNA reviewed all the different environmental permits related to the project and found them to be in accordance with all national environmental regulations.

The fact that CH4 has a global warming potential (21) that exceeds greatly the global warming potential of CO2 (1), determines the relevance of the CDM projects related to biogas capture. The project activity can be stated as a relevant improvement for sustainable development, reducing local (odour) and environmental pressures. This advanced system (anaerobic digester and aerobic treatment) minimises the odour related to swine manure management, because organic matter is stabilised inside a hermetically closed reactor.

The substitution of traditional manure waste treatment (stabilisation lagoon) by this advanced treatment also creates environmental benefits related to effluent quality. In the

advanced treatment, this effluent has a low organic matter content that does not imply a potential risk of groundwater or river contamination. This digester also leads to a lower volume of mud from effluent. In addition, the advanced system doesn't require the transport or management of solid manure, because this is part of the substrate for the anaerobic fermentation in the digester.

In the traditional system, average temperature is a key parameter. In contrast, the digester uses the re-circulation of heated water to raise the internal operation temperature up to an optimal level for bacterial life, where there is no external environment dependency.

Both systems can work without additional requirements to be applied for the water treatment.

The environmental impacts due to the development of this project can be summarised as ancillary benefits:

a) Odour is greatly reduced by CH_4 recovery systems,

b) CH_4 recovery systems use lined lagoons (most existing lagoons are unlined), reducing leakage into water tables and nutrient run off from surface spreading on fields, a major source of rural water pollution, and

c) Controls pathogens.

F.2. If impacts are considered significant by the project participants or the Host Party: please provide conclusions and all references to support documentation of an environmental impact assessment that has been undertaken in accordance with the procedures as required by the host Party.

The impacts are very low or not existent. That is why the Chilean environmental regulations do not require specific environmental impact evaluation for digesters, according to the explanation given above. However, the construction of barns and their waste treatment system, does require an environmental impact evaluation, according to article 10 of the Law 19.300[3] and Supreme Decree Nº 30 of 1997 .[4]

The project participants don't recognise any relevant impact on local or global environment due to the project. It has been stated that this project contributes to sustainable development in the region.

[3] Law 19,300 "General Environmental Framework" Official Gazette 04.09.94.
[4] Supreme Decree Nº 30 of 1997 of the General Secretariat of the Presidency, Regulation of the Environmental Impact Assessment System. Official Gazette 04.03.97

Host country approval for the project activity was granted by the National Commission for the Environment (CONAMA), the Chilean Designated Authority (DNA), on July 01, 2003 (letter and unofficial translation is attached).

G. Stakeholders comments

G.1. Brief description of the process on how comments by local stakeholders have been invited and compiled:

The Project has been available for public comment on Agrosuper's web page of Agrosuper (www.agrosuper.com) since February 2003. To date, no comments have been received with respect to the project.

The first stage of the project (Peralillo Digester) was launched in December 2000 with the presence of the Minster Secretary General of the Presidency, the Executive Director of CONAMA and other regional authorities. Comments about the project at the launch referenced the major environmental improvement that would be achieved by implementing this type of project.

G.2. Summary of the comments received:

Not available.

G.3. Report on how due account was taken of any comments received:

Not applicable.

Annex 1

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Annex 2

INFORMATION REGARDING PUBLIC FUNDING

Not applicable. There is no public funding for the Project.

Annex 3

1. Title of the proposed methodology:

METHODODOLOGY FOR ON-FARM ANAEROBIC and AEROBIC TREATMENT OF ANIMAL WASTE IN THE SWINE INDUSTRY

2. Description of the methodology:

2.1. General approach

The methodology is for greenhouse gas (GHG) emission reduction projects, mainly methane (CH4), by implementing the advanced swine waste management technology with anaerobic treatment and, an optional of aerobic post-treatment.

The baseline technology is selected as the anaerobic lagoons as shown below.

According to the modalities and procedures of the CDM, project participants should select the baseline approach most relevant to the project from these three choices:

(a) Existing actual or historical emissions, as applicable; or

(b) Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment*; or*

(c) The average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 per cent of their category."

The baseline approach adopted for this methodology is option (b) above. The approach 48 (b) in the CDM M&P by assuming that economically rational behaviour determines the most likely future baseline "scenario" is used by demonstrating an investment or financial analysis.

2.2. Overall description (other characteristics of the approach):

The baseline scenario is the traditional open lagoon system where swine manure is washed or flushed from the barn and then collected in a lagoon or other earthen storage facility. Here the manure is partially digested at ambient temperature by naturally occurring anaerobic micro-organisms, releasing carbon dioxide (CO2), CH4, hydrogen sulphide, and ammonia in the process. Anaerobic bacteria "treat" the liquid manure and

decrease the organic matter content. Solids are allowed to settle on the bottom of the storage facility. Solids collected in the bottom of the lagoon are removed once every 10 to 20 years, and are used on land to enhance fertility. Once a year, water is collected from the surface of the lagoon to lower the water table and increase the storage capacity. The collected water is then utilised in a land application program, either as fertiliser and irrigation water, or simply land disposal.

Anaerobic digesters function to capture a significant portion of the digested volatile solids (VS) in the form of CH4 and CO2 produced from the activity of the anaerobic bacteria present in the digester. The digester consists of an earthen pit lined with an impervious membrane, and is covered with a floating membrane. Any gas produced is collected in a grid of collection pipes suspended above the surface of the swine manure. This collected gas is used for heating purposes in the digester or is flared. Mixed effluent is removed from the digester and is pumped to a nearby storage lagoon. This effluent still contains nutrients and is used as irrigation water for non-edible crops. Additional solids will settle in the bottom of the lagoon and will be removed once every 20 years for use as fertiliser in land application programs.

Due to the capture of CH4 in the digester and its transformation into CO2, this CH4 is prevented from being emitted to the atmosphere. Under the Traditional conditions, all CH4 that is generated in an open lagoon or storage tank is emitted to the atmosphere. For those digesters with an additional aerobic treatment, the volatile solids content from manure will be significantly reduced, minimising the fugitive CH4 emissions from the storage lagoon. Also, as discussed above, the nitrogen content in manure is also reduced by use of the digester.

As for the projects for which this methodology is applicable, the scenarios can be synthesised as:

- **Baseline Scenario: Traditional Open Lagoon**: Barns → Anaerobic Lagoon → Use of effluents on site
- **Project Scenario:** Barns → Anaerobic digester → Aerobic Treatment (activated sludge if present) → Storage lagoon → Use of effluents on site.

This Methodology is applied to the waste treatment and waste handling system only. Barn systems and barn flushing systems are not part of the technology for which the described Methodology calculates emission reductions, because they are not influenced by the project implementation.

The baseline emissions (*BE*) and the project emissions (*PE*) are expressed as follows:

***BE* = CH4 from anaerobic lagoon**

+ N2O emissions from land application

+ N2O from volatilised and non-volatilised NH3 (see figure 1 that represents this scenario)

***PE* = CO2 from burned CH4 from anaerobic digester**

+ Fugitive CH4 from the storage lagoon

+ Indirect emissions inside the project boundaries (digester losses)

+ Fugitive CH4 from the aerobic treatment (if present)

+ N2O emissions from land application

+ N2Ofrom volatilised and non-volatilised NH3 (see figure 2 & 3 that represent this scenario)

A description of these GHG emissions for each scenario is also detailed in Table 4.

Although the Methodologies Panel of the CDM Executive Board has not decided yet whether the CO2 emissions from CH4 combustion must be included or not, it was considered and quantified as part of the project emissions scenario for conservative purposes. If these emissions were not considered (because of its biogenic origins) a larger amount of emission reductions could be achieved from this methodology **A clarifying recommendation from the Methodology Panel is requested.**

The GHG emissions relevant for this analysis (for baseline and project scenarios) are the open release of CH4 from an anaerobic lagoon or a storage lagoon, losses of CH4 in the digester and its burn by a flare. In addition, for those digesters that consider an aerobic post treatment, there is a relevant emission reductions of N2O and also the project scenario must be include indirect emissions from losses of the aerobic treatment.

The fugitive CO2 emissions from anaerobic digestion (storage and stabilisation lagoon) do not represent any difference in emission volumes between each scenario, because there are no possible additional transformations by the burning of this component.

For those digesters that do not include an aerobic treatment, N2O production would not be quantified, because there are no relevant emissions reductions of this GHG due to the digester system. This conclusion is based on a complete-mix digester scenario, in the document "**Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations**" (EPA, 2001).

The anaerobic lagoon in the baseline scenario, the storage lagoon in the project scenario and the land deposition of the treated effluent cause the N2O emissions. For the group of digesters with no aerobic treatment, both scenarios have equal volumes of N2O emissions because there is no nitrogen reduction due to the digester. For those digesters that include aerobic treatment, the EPA document gives a reference of 75 % decay of nitrogen content due to the aerobic treatment, via nitrification-denitrification.

3. Key parameters/assumptions (including emission factors and activity levels), and data sources considered and used:

3.1 Key parameters and assumptions

The parameters and equations used are default parameters and equations from the **IPCC Guidelines for National GHG Inventories, Revised 1996, Chapter 4 & Reference Manual** and the **IPCC Good Practice Guidance and Uncertainty management in National GHG Inventories, Chapter 4.**

The key parameters for this analysis are:

- the number of pigs,
- the average pig weight
- volatile solids (VS) generation in raw and treated manure (for the baseline and project scenarios respectively).
- Wastewater flow from the aerobic post-treatment (if considered)
- Five Day Biochemical Oxygen Demand (BOD) in the aerobic post-treatment (if considered)

For the case of post-aerobic treatment, the long-term biochemical oxygen demand (BOD_{lt}) and the effluent flow from this manure management facility is also considered.

Operation Size: This Methodology uses the IPCC model which is based on number of pigs and volatile solids, to provide an accurate description of the emissions on a regional or national basis. The size of the operations for which this Methodology is developed includes multiple farm sites discharging liquid hog waste to one treatment facility. The Methodology can be applied for any hog production facility for which accurate and current local parameter data is available.

Volatile Solids (VS): Calculations in the Methodology are driven by the VS content of treated waste. Typically, the amount of VS in raw waste is either measured or calculated.

This methodology uses the IPCC default of 0.5 kg/head/day, which is then to be corrected for the average swine weight representative of the barns served in each digester. The correction is linear, so it is a function of the weight quotient, with the purpose of making this parameter representative to the volatile solids content in raw manure.

In order to quantify emission reductions, the default values are corrected as follows:

$$VS_{rm} = (W_{ss} / W_{df}) \times VS_{df}$$

Where:

VS_{rm} = Volatile solids content in site specific raw manure (kg/head/day)

W_{ss} = Site Specific average swine weight (kg)

W_{df} = Default value average swine weight (kg)

VS_{df} = Default value of Volatile solids content in raw manure (kg/head/day)

The emission calculation is restricted to the use of default values for volatile solids content in raw manure. Though these values are corrected by the site-specific average swine weight, still uncertainties exist regarding these assumptions. This is the only way to identify the emission calculation for each scenario, if volatile solids content are not possible to be monitored.

There are no site-specific raw VS measurements available, so the default reference (IPCC) is considered representative. The percentage decay of this parameter (VS) after the digester, is referenced in the "**Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations**" (EPA, 2001). This document assures a **60 percent** reduction of volatile solids due to the digester.

The following analysis explains the CH4 emissions (in the storage lagoon) and the VS decay when included an aerobic treatment, after the digester:

- Initially, the outflow from the aerobic treatment process is organic matter in the form of glucose. In anaerobic conditions, this is transformed to CH4 and CO2.

$C_6H_{12}O_6$	$\longrightarrow$	$3CO_2 + 3CH_4$
180		132 48

- Even though glucose has transformed itself already, CH4 has an intrinsic biochemical oxygen demand (BOD) for its final conversion into CO2 and steam.

$3CH_4 + 6O_2$	$\longrightarrow$	$3CO_2 + 6H_2O$
48		192

As demonstrated by these two stoichiometric relations, long-term BOD per kilogram of glucose is (192/180) kg, and 1 kilogram of glucose produces (48/180) kilograms of CH4. So, we can state that the **CH4 production (kg) for each kilogram of stabilised long term BOD** is 48/192 = **0.25**. This is the CH4 potential generation in the storage lagoon, due to the residual VS content in the effluent of the aerobic treatment.

The aerobic process considers an important consumption of organic matter from manure. This will be represented by an important decay in the VS content. Considering a maximum concentration of 35 mg/lt of total BOD5, we can calculate VS after the aerobic process (for estimating emissions from the storage lagoon) as follows:

BOD lt(mg/lt)= 1.42 • BOD5 (mg/lt)

VS (kg/head/day) = BOD long term • 0.25 • Q (waste flow m^3/day) • 1000 • 0.25/ (10^6 • Stock of pigs • Bo • D_{CH4} • $MCF_{aerobic\ treatment}$)

Where:

Bo = Maximum CH_4 production capacity from manure, per head for a given stock of pigs m^3/kg of VS.

BODlt = Long Term biochemical oxygen demand (mg/lt)

BOD5 = five-day biochemical oxygen demand (mg/lt)

Q = waste flow (m^3/day)

D_{CH4} = CH4 Density, 0.67 kg/Nm^3

MCF = Conversion factor of CH4 for aerobic post-treatment (45%)

BOD5 in the aerobic treatment, and the average inflow of treated manure after digester are monitored parameters.

The following table represents the VS decay for different steps involved in the manure treatment :

Table 1

kg/head/day		
VS raw manure	**VS digested manure**	**VS post-activated sludge (for stage II)**
VS_{rm} = Default IPCC Volatile solids value , corrected by mass quotient .	VS_{dm} = 60% of VS	VS_{pas} = approx. 0.5% of VS_{dm}

Bo = Maximum CH4 production capacity from manure, per head for a given stock of pigs [m3/kg of VS]. Where it is not possible to monitor this parameter, default values can be obtained in the Table B-2 of the "IPCC Guidelines for National Greenhouse Gas Inventories, Revised 1996, Reference Manual". This parameter varies by species and diet, identifying different values for developing and developed countries. There are no measurements available for this parameter, so this reference is considered representative.

CH4 Conversion Factor (MCF): This parameter is referenced in two IPCC reports. Emissions calculated from storage lagoons include the release of 45 percent of the VS under lagoon conditions (MCF = 45 percent for template climates, as stated in the **IPCC Good Practice Guidance and Uncertainty management**). For the rest of the GHG emission sources, the Guidelines default value will be used (MCF = 90 percent digester and anaerobic lagoon, MCF = 5 percent losses due to leakage, template climates, MCF = 0.1 percent for the aerobic treatment). The following table summarises the different types of manure management systems involved in the project and baseline scenario, and their CH4 conversion factors (MCFs).

Table 2 CH4 Conversion Factor in different emission sources

	MCF %	
Baseline	Anaerobic Lagoon*	90%
Project	CH4 Combustion*	90%
	Indirect Fugitive Emissions from Digester*	5%
	Storage Lagoon**	45%
	Aerobic Treatment (activated sludge)***	0.10%

Source : * IPCC Guidelines (Reference Manual table 4-8 and table B-6) and ** IPCC Good Practice and uncertainty management (Table 4.10) and *** IPCC Good Practice and uncertainty management (Table 4.11), temperate climate.

There are no measurements available for this parameter, so this reference is considered representative.

Nitrogen excretion rate (NEX): NEX = 20 kg/head/day for developed countries, as stated in Table 4-20 of the 1996, IPCC Guidelines. This data (NEX) is then corrected to the mean swine weight for each barn.

The digester anaerobic process (complete mix) does not have an effect on the nitrogen content of manure, as stated in the "**Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for CAFO**" (EPA, 2001). This document also gives a reference of **75 percent decay of** nitrogen content due to the aerobic treatment, via nitrification-denitrification. This analysis of N20 emissions is relevant only for those project scenarios that consider aerobic treatment after the digester.

In order to quantify emission reductions, the default values are corrected as follows:

$$NEX_{rm} = (W_{ss} / W_{df}) \times NEX_{df}$$

Where:

NEX_{rm} = Nitrogen excretion rate for site specific raw manure (kg/head/day)

W_{ss} = Site Specific average swine weight (kg)

W_{df} = Default value average swine weight (kg)

NEX_{df} = Corrected Default value of Nitrogen excretion rate in raw manure (kg/head/day)

There are no site-specific measurements available for NEX_{rm}, so the default reference is considered representative but it should be corrected for the average weight of pigs in the barns.

The nitrogen content in raw and treated manure, implies the emission of N2O from non-volatilised storage losses, volatilised ammonia losses, land application and runoff, for the baseline and project scenario.

Conversion Factor N2O-N TO N: For reporting purposes the conversion is performed using the following equation

$$N_2O_{(mm)} = (N_2O - N)_{(mm)} \cdot 44/28$$

44/28 =1.57

The following table presents the relevant emission factors and parameters involved in the calculation of emission reduction of N20, for each scenario.

Table 3: Key Parameters and Emission Factors involved in the nitrous oxide emission calculations for each scenario.

Parameter		Units	Description	Reference
FracGASM	**20**	**%**	fraction of livestock nitrogen excretion that volatilises as NH3 and NOx	Table 4-19 IPCC Guidelines
EF1	**0.0125**	kg N2O-N/kg N input	Emission factor for direct soil emissions	Table 4-17 IPCC Good Practice Guidance Document
EF3	**0.001**	kg N2O-N/kg of Nitrogen excreted	N2O emission factor for Swine Manure Management System	Table 4-22 IPCC Guidelines
EF4	**0.01**	kg N2O-N/kg of NH3-N and NOx-N emitted	N2O emission factor for atmospheric deposition	Table 4-23 IPCC Guidelines
R	**0.3**	kg N/ kg of manure Non-volatilised nitrogen	Non-volatilised leaching & Runoff	Table 4-24 IPCC Guidelines

3.2 Data and Calculation Methods

Data

GHG emissions in tCO_2e (tonne CO_2 equivalents) will be calculated using the following references:

- **IPCC Guidelines for National GHG Inventories, Revised 1996, Chapter 4 & Reference Manual:** Equations and default parameters of volatile solids in raw manure, CH4 conversion factor for anaerobic lagoon and leakage.

- **IPCC Good Practice Guidance and Uncertainty management in National GHG Inventories, Chapter 4:** Default value of MCF (CH4 conversion factor) for a storage lagoon after a digester

- **Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations (EPA : CAFO 2001):** volatile solids percentage reduction by complete-mix digester, and nitrogen percentage reduction by aerobic treatment.

- **Site-Specific hog operations data:** Average swine weight and number of pigs. Data will be made available from monitoring activities to occur on either a weekly or monthly basis.

The baseline scenario takes into account the real capacity production of manure from each digester, developing a dynamic baseline with the number of pig heads and their average weight as key variables that change over time. For the purposes of this document, the potential emissions for each scenario were quantified based on steady data corresponding to a "base" year.

Calculation Methods

I.1. CH4 EMISSION EQUATIONS FOR MANURE MANAGEMENT SYSTEMS

EQ. 1: CH4 Emissions related to manure management

$$CH_4 \text{ emissions (tonnesCO2eq/year)} = EF \cdot GWP_{CH4} \cdot \text{stock of pigs} / 1000$$

Where:

CH_4 emissions (tonnes/year) = CH4 emissions related to manure management, for a defined stock of pigs per year.

Stock of pigs = number of living pigs for a certain barn.

GWP_{CH4} = CH4 Global Warming Potential of 21.

EF = Emission Factor for swine manure management. [kg/per pig/year]. This emission factor can be represented by the following equation:

EQ. 2: Emission Factor for manure management

$$EF \text{ (kg/year)} = VS \cdot 365 \text{ days/year} \cdot Bo \cdot D_{CH4} \cdot MCF$$

Where:

EF = Emission Factor for a livestock of swine [kg/year]

Bo = Maximum CH_4 production capacity from manure, per head for a given stock of pigs m^3/kg of volatile solids.

$\mathbf{D_{CH4}}$ = CH4 Density, 0.67 kg/m^3

MCF = Conversion factor of CH4, for an anaerobic lagoon (90 %), activated sludge after digester if applies (0.1%), or storage lagoon (45 %).

VS = volatile solids rate in kg/day/head for a given stock of pigs, in the respective manure treatment stage. This parameter must substituted by the volatile solids content for the respective manure management stage.

For the VS decay after the activated sludge aerobic process, equation 3 that relates CH4 produced to long term BOD, was considered.

EQ. 3: Relation of long term BOD and CH4 gas

$$\text{CH4 generation (kg/year)} = 0.25 \cdot BOD_{lt}\ (\text{mg/L}) \cdot F\ (m^3/\text{day}) \cdot 365 / 1000$$

Where:

CH4 generation (kg/year) = CH4 generation potential in storage lagoon after the aerobic treatment of activated sludge.

$\mathbf{BOD_{lt}}$ = Long term Biochemical Oxygen Demand in aerobic treatment (mg/L)

F (m3/day) = Average inflow waste of treated manure after digester, into activated sludge process.

Both the long-term BOD in the aerobic treatment and the average inflow of treated manure after digester, are monitored parameters.

I.2. CO2 EMISSIONS FROM DIGESTER CH4 BURNED IN FLARE

Emissions from CH4 combustion:

Although the Methodologies Panel of the CDM Executive Board has not decided yet whether the CO2 emissions from CH4 combustion must be included or not, it was considered and quantified as part of the project emissions scenario for conservative purposes. If these emissions were not considered (because of its biogenic origins) a larger amount of emission reductions could be achieved from this methodology. **A clarifying recommendation from the Methodology Panel is requested.**

Because these emissions are from CH4 capture and combustion, the GWP of 21 (for the anaerobic baseline scenario) is replaced by the molar mass quotient between CO2 and CH4, as explained in the next stoichiometric equation:

$$CH4 + 2O_2 \longrightarrow CO2 + 2H_2O$$

16 44

The next equation quantifies the emissions from Digester CH4 (converted to CO2 in flare).

EQ. 4: Digester CH4 converted to carbon dioxide in flare

$$CO_2\,(\text{tonnes}) = \text{Stock of Pigs} \cdot VS\,(\text{kg/head/day}) \cdot 365\,(\text{days}) \cdot Bo \cdot D_{CH4} \cdot MCF_d \cdot M_{CH4/CO2} / 1000$$

Where:

CO2 = Carbon dioxide emissions from CH4 burn up in flare (tonnes)**.**

Stock of pigs = number of living pigs for a certain barn.

VS = volatile solids rate in kg/day/head for a given stock of pigs.

Bo = Maximum CH_4 production capacity from manure, per head for a given stock of pigs m^3/kg of volatile solids.

$\mathbf{D_{CH4}}$ = CH4 Density, 0.67 kg/Nm^3

$\mathbf{MCF_d}$ = Conversion factor of CH4, 90 % for CH4 potential generation in digester.

$\mathbf{M_{CH4/CO2}}$ **=** Molar mass quotient CO_2/CH_4 = 2.75

I.3 CH4 FUGITIVE EMISSIONS FROM DIGESTER

The losses due to indirect emissions from the digester, **inside** the project boundaries are considered as minimal. For a conservative approach, the MCF default IPCC value of 5% was considered as representative.

EQ. 5: CH4 emissions related to losses from the digester

$$CH_{4\ L}\ \text{emissions (tonnesCO2eq/year)} = EF2 \cdot GWP_{CH4} \cdot \text{stock of pigs} / 1000$$

Where:

CH_{4_L} emissions (tonnes/year) = CH4 emissions related to losses from digester, for a defined stock of pigs per year.

Stock of pigs = number of living pigs in a certain barn.

GWP_{CH4} = CH4 Global Warming Potential of 21.

EF2 = Emission Factor related to losses from the digester [kg/head/year]. This emission factor can be represented by the next equation:

EQ. 6 Emission Factor for indirect emissions from the digester

$$EF2 = VS \cdot 365\ days/year \cdot Bo \cdot D_{CH4} \cdot MCF_{DL}$$

Where:

EF2 = Emission Factor related to indirect emissions from the digester for a livestock of swine [kg/year]

VS = volatile solids rate in kg/day/head for a given stock of pigs.

Bo = Maximum CH_4 production capacity from manure, per head for a given stock of pigs m^3/kg of volatile solids].

D_{CH4} = CH4 Density, 0.67 kg/m^3

MCF_{DL} = Conversion factor of CH4, for an anaerobic digester. Emissions are from fugitive indirect emissions (5 %).

II ESTIMATING N2O EMISSIONS FROM MANURE MANAGEMENT SYSTEMS

Because only the insertion of aerobic treatment consider a reduction in the nitrogen content of manure, this analysis of nitrous oxide emissions is relevant just for stage II of the project.

II.1.1 ANAEROBIC LAGOON & STORAGE LOSSES:

a. Non-volatile emission component

EQ. 7 Non-volatile emission component

$$N2O = NEX \cdot \text{stock of pigs} \cdot (1 - \textbf{FracGASM}) \cdot EF3 \cdot CF / 1000$$

Where:

N2O = N2O direct emissions from swine manure Management Systems (tonnes N2O/year);

NEX = Corrected Default Nitrogen excretion rate (kg/hd/year).

Stock of pigs = number of living pigs for a certain barn.

FracGASM = fraction of livestock nitrogen excretion that volatilises as NH3 and NOx (kg NH3-N and NOx-N/kg of N excreted)

EF3 = N2O emission factor for manure management System (kg N2O-N/kg of Nitrogen excreted);

CF = CONVERSION FACTOR N2O-N TO N (1.57 = 44/28)

b. Volatile emission component (indirect emissions)

EQ. 8 Volatile emission component

$$N2O_{indirect} = NEX \cdot \text{stock of pigs} \cdot \textbf{FracGASM} \cdot EF4 \cdot \textbf{CF} / 1000$$

Where :

$N2O_{indirect}$ = N2O volatilised indirect emissions from swine manure management Systems (tonnes N2O/year)

Stock of pigs = number of living pigs for a certain barn.

EF4 = N2O emission factor for atmospheric deposition (kg N2O-N/kg of NH3-N and NOx-N emitted);

NEX = Corrected Default nitrogen excretion rate (kg/hd/year).

FracGASM = fraction of livestock nitrogen excretion that volatilises as NH3 and NOx (kg NH3-N and NOx-N/kg of N excreted)

CF = CONVERSION FACTOR N2O-N TO N (1.57 = 44/28)

II.1.2. N2O LAND APPLICATION AND RUNOFF LOSSES:

a. Emissions from Non-volatilised nitrogen.

EQ. 9 land emissions from Non-volatilised nitrogen.

$$N2O_{(LAND)} = NEX \cdot \text{stock of pigs} \cdot CF \cdot (1 - FracGASM) \cdot EF1$$

Where:

$N2O_{(LAND)}$ = emissions from non-volatilised nitrogen (tonnes N2O/year).

Stock of pigs = number of living pigs for a certain barn.

EF1 = emission factor for direct soil emissions (kg N2O-N/kg N input)

NEX = Corrected default nitrogen excretion rate (kg/hd/year).

FracGASM = fraction of livestock nitrogen excretion that volatilises as NH3 and NOx (kg NH3-N and NOx-N/kg of N excreted)

CF = CONVERSION FACTOR N2O-N TO N (1.57 = 44/28)

b. Emissions from runoff.

EQ. 10 Emissions from runoff.

$$N2O_{(RUNOFF)} = EF_5 \cdot R \cdot (NEX \cdot \text{stock of pigs} \cdot (1 - FracGASM)) \cdot CF / 1000$$

Where:

$N2O_{(RUNOFF)}$ = emissions from non-volatilised nitrogen (tonnes N2O/year).

Stock of pigs = number of living pigs for a certain barn.

NEX = Corrected default nitrogen excretion rate (kg/hd/year).

FracGASM = fraction of livestock nitrogen excretion that volatilises as NH3 and NOx (kg NH3-N and NOx-N/kg of N excreted)

R = Non-volatilised Runoff, (Reference from IPCC Leaching & runoff table 4-24 = 0.3 kg N/ kg of manure non-volatilised nitrogen).

EF_5 = Emission factor for indirect emissions from runoff (kg N2O-N/kg N runoff)

CF = CONVERSION FACTOR N2O-N TO N (1.57 = 44/28)

EQ. 11: Total emissions of N2O (tonnes/year)

$$N2O_{TOTAL\ EMISSIONS} = N2O_{(RUNOFF)} + N2O_{(LAND)} + N2O_{(AWMS)\ indirect} + N2O_{(AWMS)}$$

EQ. 12: Total emissions of nitrous oxide expressed in tonnes CO2eq/year

$$CO2_{eq}(N2O) = GWP_{N2O} \cdot N20_{TOTAL\ EMISSIONS}$$

GWP_{N2O} = Nitrous Oxide Global Warming Potential of 310

4. Definition of the project boundary related to the baseline methodology:

Swine waste is primarily composed of organic material from which, when decomposed in an anaerobic environment, methanogenic bacteria produce CH4. This is a common occurrence when large numbers of animals are managed intensively. In the baseline scenario, the swine manure is disposed of in large lagoons. The decomposition of manure in these lagoons produces CH4, which is released directly into the atmosphere. N2O is also produced during the storage and treatment of manure before, during and after land application, but the analysis emission of this gas is only relevant when considering aerobic treatment, as stated before.

The project boundary for the baseline scenario is restricted to on-site emissions. The application of (treated) manure in the immediate surroundings of the animal production unit is not a cause for any CH4 emissions in the project boundary. The project boundary includes only the emissions (and emission reductions) from manure management techniques dealing with swine manure from a cluster of production units discharging manure to one handling system.

The term "manure" includes both solids and liquids (dung and urine, respectively) produced by swine. The next schematic diagrams present the project activity and baseline boundaries. The segmented line represents the project boundary.

Figure 1: Baseline Scenario Boundary

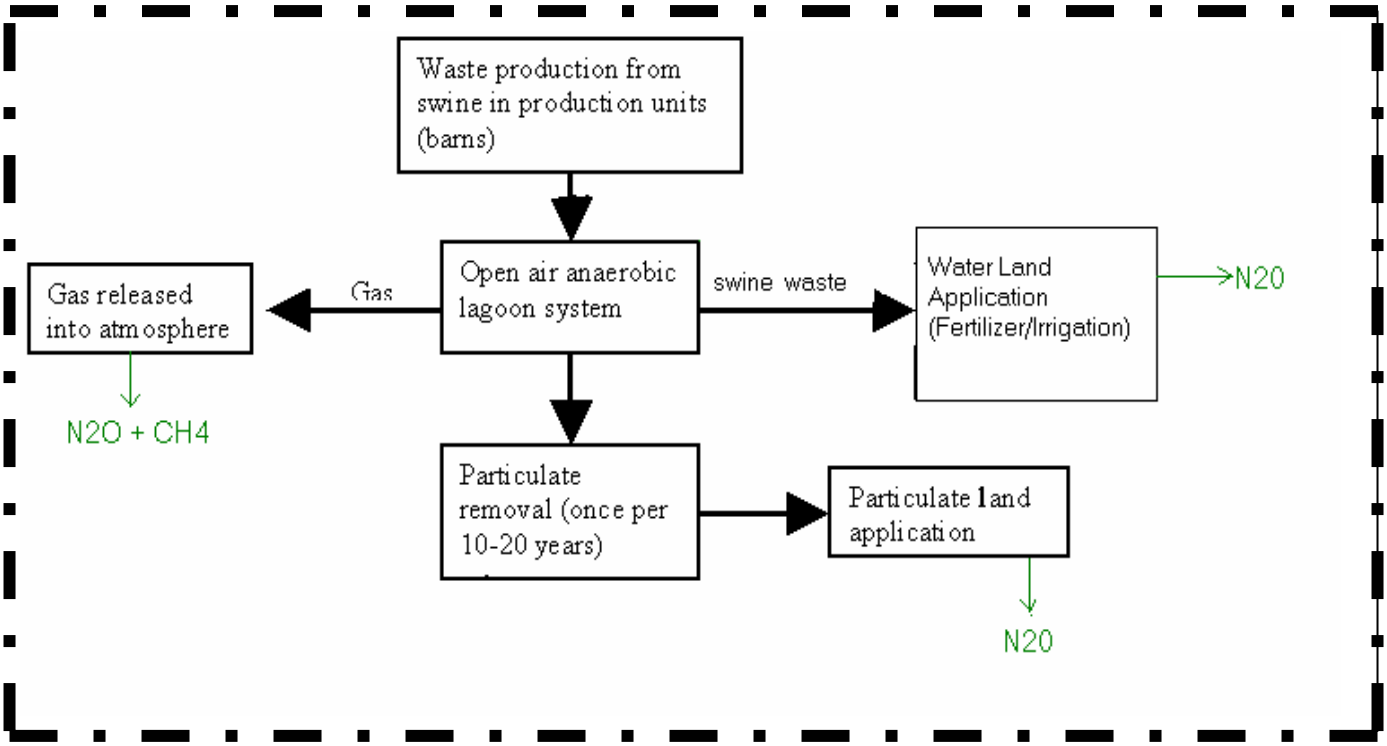


Figure 2: CDM Project Activity Boundary (no aerobic treatment)

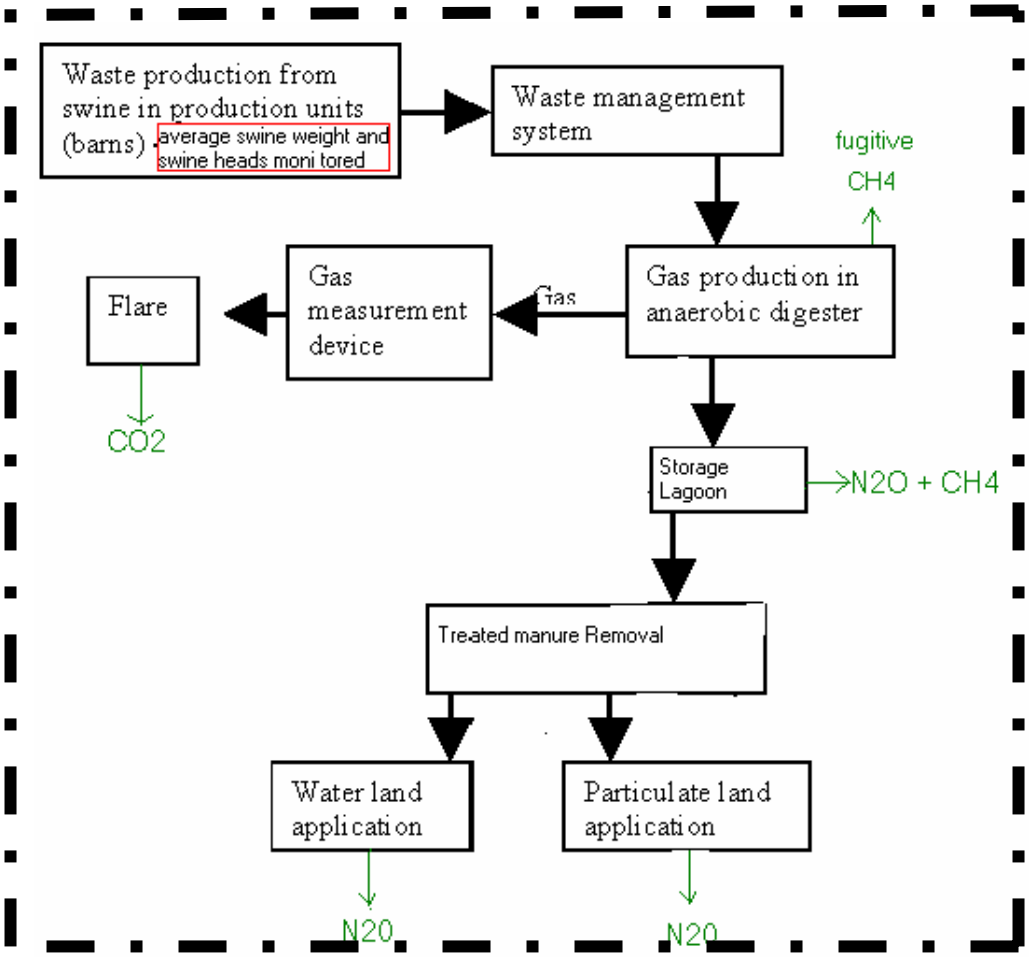
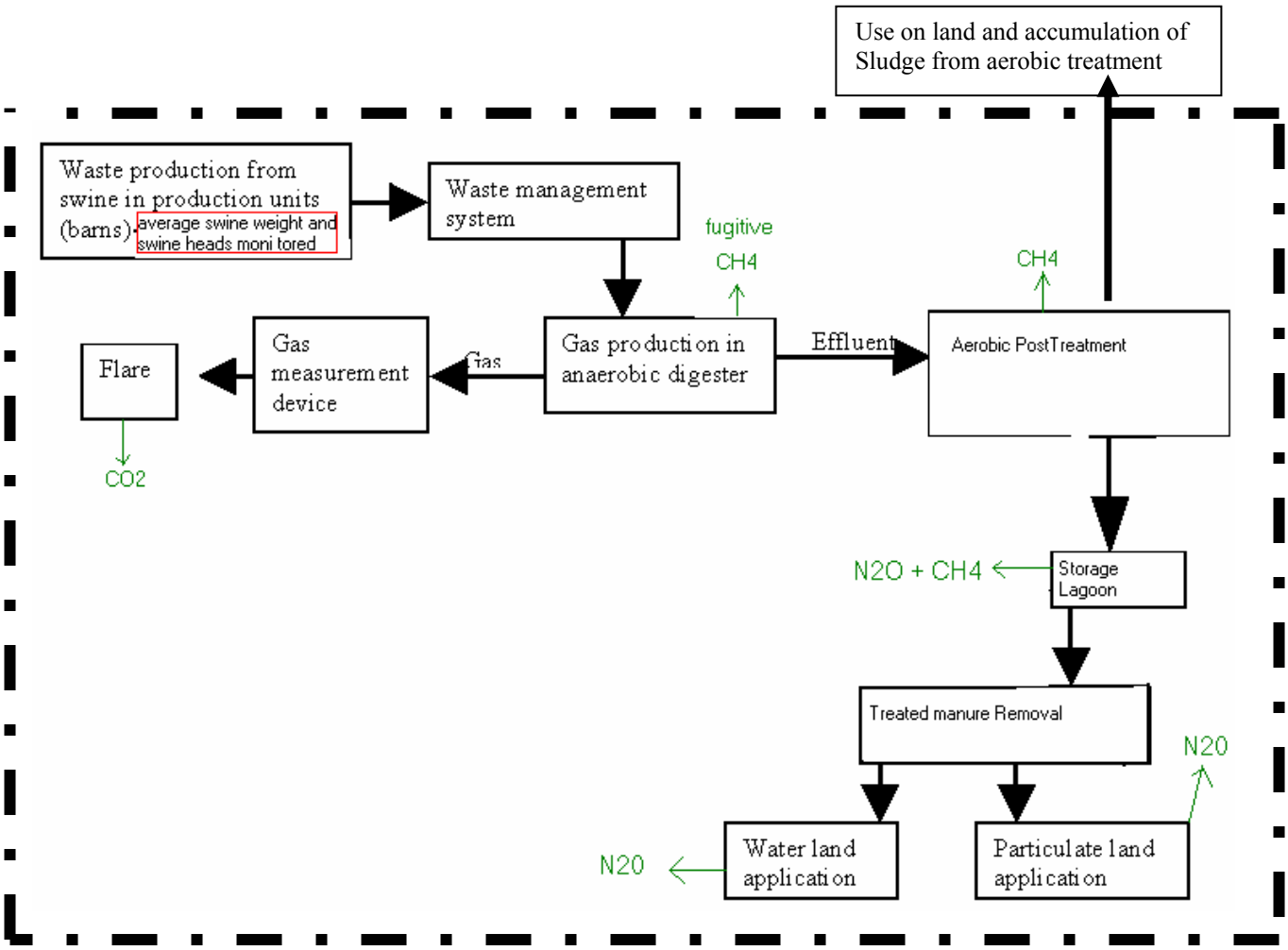


Figure 3: CDM Project Activity Boundary (including aerobic treatment)



This advanced waste management system recognises leakage. The volume of sludge from the aerobic treatment will be used as fertiliser in land application programs and also disposed on a controlled landfill, outside the project boundaries. The potential CH4 emissions and the N2O generation from this source (leakage due to emissions outside the project boundaries) are marginal. This is because the nitrogen content in the sludge effluent from the aerobic treatment (dry and moist), is in the shape of nitrate and nitrite, and has lost its volatile potential.

Since the VS are consumed in the anaerobic digester in the CH4 capture process and in the storage lagoon, it cannot be applied to land as CH4 emissions.

The following table recognises every GHG involved in the project and baseline scenario, inside and outside the project boundary:

Table 4

		In the boundary	Outside the boundary
Baseline scenario	Non-negligible	Methane emissions from stabilisation lagoon	-
	negligible small	-	Nitrous oxide emissions from anaerobic lagoon, treated manure land application and runoff
	Not counted	-	-
Project scenario	Non-negligible	Methane emissions from: storage lagoon, digester and aerobic treatment losses (if exists); Carbon dioxide emissions from methane combustion.	-
	negligible small	GHGs associated with the use of energy in the implementation	Nitrous oxide emissions from storage lagoon, treated manure land application and runoff
	Not counted	-	-

5. Assessment of uncertainties:

The key parameters involved in the emission reduction calculations include the number of swine heads in the barn, the average weight and the volatile solids content in on-site raw manure. This last one considers an uncertainty level in the default IPCC values.

The associated uncertainty for each parameter in the baseline and monitoring methodology can be reduced by its identification. This uncertainty can be based on a monitoring error, or an error in the default parameter.

The uncertainty level associated with the use of the default volatile solids content in raw manure can be guaranteed using the next calculation presented in Table B-2 of the IPCC Guidelines Reference Manual:

Equation 15 of the IPCC Guidelines Reference Manual

VS (kg dm/day) = Intake (MJ/day) • (1 kg/ 18.45 MJ) • (1 - DE%/100) • (1 - ASH%/100)

Where:

VS = VS excretion per day on a dry weight basis;

dm = dry matter;

Intake = the estimated daily average feed intake in MJ/day;

DE% = the digestibility of the feed in per cent;

ASH% = the ash content of the manure in per cent.

The energy density of feed is about 18.45 MJ per kg of dry matter. The next table presents the parameters that determine the volatile solids content in raw manure.

Table 5

	Feed Digestibility	Energy intake	Feed intake	ASH content	VS
	%	MJ/hd/day	kg/hd/day	%	(kg/hd/day)
Developed Countries IPCC default value	75	38	2.1	2	0.50

The default VS content in raw manure is to be corrected for the representative swine weight of each group of barns in digester, as explained above.

There are no additional emissions to be defined as leakage. All of these potential sources of leakage have been identified as negligible, in contrast with the margins of baseline emissions.

Uncertainties exist regarding the emissions from the storage lagoon, when limited empirical data exists as regional aspects of microclimate and other environmentally related factors affect emissions. The advanced technology will affect the concentration of certain parameters in the stored wastewater (such as VS), but the intrinsic mechanisms of emissions generation from lagoons will not change. This uncertainty will therefore minimally affect a calculation of GHG emission reductions.

6. Description of how the baseline methodology addresses the calculation of baseline emissions and the determination of project additionality:

The anaerobic digester technology implemented in the project scenario represents an additional activity that is well beyond that of the baseline scenario. The heated anaerobic digester works to capture a significant portion of the digested VS in the form of CH4 and CO2. The CH4 is then transformed into CO2 though a combustion process including the use as boiler feed and in a flare. This reduces the GHG impact of the facility as the transformation reduces the potency of the GHG. In addition, changes in the VS content of the digester effluent will affect the emissions of the storage lagoon and the land application. The implementation of the digester technology enhances CH4 production in the digester thereby increasing the amount of CH4 that can be captured during the residence time in the digester, and as such limiting the amount of GHGs released from the lagoon. The installation of anaerobic digester technology and the aerobic post-treatment result in significant reductions of anthropogenic GHG emissions.

In the project proponent's host country, (and possibly the broader region), the traditional systems of manure management typically consists of the storage of swine manure in a large open storage facility and/or the partial treatment of the manure in an anaerobic lagoon followed by land application.

The baseline for the project proponent is the Traditional open lagoon system since the country's swine sector, and the project proponent, have generally practised and prefer to implement this conventional method of manure disposal. In the Traditional system swine manure is washed or flushed from the barn and then collected in a lagoon or other earthen storage facility. Here the manure is partially digested at ambient temperature by naturally occurring anaerobic micro-organisms, releasing CO2, CH4, hydrogen sulphide, and ammonia in the process. Anaerobic bacteria "treat" the liquid manure and decrease the organic matter content. Solids are allowed to settle on the bottom of the storage facility. Solids collected in the bottom of the lagoon are removed once every 10 to 20 years, and are used on land to enhance fertility. Once a year, water is collected from the

surface of the lagoon to lower the water table and increase the storage capacity. The collected water is then utilised in a land application program, either as fertiliser and irrigation water, or simply land disposal.

The project proponent has implemented and/or intends to implement an advanced treatment system. The anaerobic digester functions to capture a significant portion of the digested volatile solids (VS) in the form of CH4 and CO2 produced from the activity of the anaerobic bacteria present in the digester. The digester consists of an earthen pit lined with an impervious membrane, and is covered with a floating membrane. Any gas produced is collected in a grid of collection pipes suspended above the surface of the swine manure. This collected gas is used for heating purposes in the digester or is flared. Mixed effluent is removed from the digester and is pumped to a nearby storage lagoon. This effluent still contains nutrients and is used as irrigation water for non-edible crops. Additional solids will settle in the bottom of the lagoon and will be removed once every 20 years for use as fertiliser in land application programs.

Due to the capture of CH4 in the digester and its transformation into CO2, this CH4 is prevented from being emitted to the atmosphere. Under the traditional conditions, all CH4 that is generated in an open lagoon or storage tank is emitted to the atmosphere. For those digesters with an additional aerobic treatment, the volatile solids content from manure will be significantly reduced, minimising the fugitive CH4 emissions from the storage lagoon. Also, as discussed above, the nitrogen content in manure is also reduced by use of the digester to the digester.

Finally, the decision to implement an activity other than the baseline, such as this advanced system of waste management, has or will reduce the GHG emissions that would have occurred, if those improvements have not been made. Therefore, the project is assured to result in significantly lower emissions than that which would have occurred in the baseline scenario.

The additionality of the project should be demonstrated by answering the following questions as specified below:

1) **Would it be cheaper for the project proponent to maintain the Traditional (Open Lagoon) system?** Yes, if the project proponent can demonstrate that the cost of implementing the advanced treatment system can be as high as [2 or 3] times the cost of an open lagoon system. For the case of a typical advanced treatment system, the following cost comparison should be undertaken for the baseline and the project scenarios:

	Baseline (US$)	Project (US$)
Digester Equipment (Blower, CLP, flare and boiler)		
Digester Installations		
Digester Extra costs (Operation, consultancy)		
Aerobic treatment (Investment)		
Aerobic treatment (Operation)		
Anaerobic Lagoon		
Storage Lagoon		
TOTAL without aerobic treatment		
TOTAL with aerobic treatment		

Reference:[provide reference for data contained in table]

The advanced treatment equipment is based in different components that guarantee its optimal functioning: Blower, Controlled Logical Program (CLP), flare and boiler (for heated digesters).

Considering that the manure management costs are representative for the digester noted, [(#) swine head], the costs per swine head of manure management for each of the scenarios is to be calculated by using the following guidance:

	Baseline (US$/head)	Project (US$/head)
Without aerobic treatment		
With aerobic treatment		

2) **Is the project proponent receiving economic benefits by introducing this new technology?** No. The proponent should identify that for these kinds of projects the only potential benefit could come from selling the potential generation of electricity to the local grid with the biogas generated. Usually, the investment involved in the production of electricity by the utilisation of biogas is still too high and is not profitable, compared to the electricity prices in the local grid.

3) **Were the revenues and/or other tangible benefits from the potential sale of emission reductions considered in the investment decision?** The proponent should be able to demonstrate that the answer to this question is yes. The potential to sell CERs should be one of the main factors that influence the decision to implement this advanced treatment system given that there are typically no other direct revenues associated with the implementation of the project scenario outlined in this Methodology (as outlined in number 2 directly above).

4) **Is this technology (digester and aerobic manure treatment) world-wide and/or nationally used?** The proponent should typically be able to demonstrate that the answer to this question is no. This anaerobic and aerobic treatment process is one of the most advanced technology systems for manure treatment. Only a few developed countries have implemented this technology because of the high costs involved in the investment compared to other available systems.

5) **Are other systems available that are cheaper and reduce the same or more amount of GHG?** The proponent should demonstrate that the answer to this question is no. Although it is possible to implement improvements such as the traditional system, they do not reduce similar amounts of GHG, in fact they reduce much less than a digester-based system.

6) **Are there technology barriers to implement this system?** The proponent should demonstrate that the answer to this question is yes. To implement a digester-based system, a significant level of waste and barns that are close in proximity to one another is required in order to have enough flow to justify the construction of a digester. Capacity building and maintenance requirements involved in this technology, including a detailed monitoring program of its performance level must also be considered.

7) **Is the baseline scenario of the project and the common practices in the host country's pork industry similar to project activity?** The project activity has to demonstrate that the baseline of the project is different from the project activity, and that with the project activity GHG will be reduced. If the project proponent had not implemented (or decided to implement) the digester system(s), and instead implemented or planned to implement the more generally preferred activity, GHG emissions would continue. Add host-country related explanations.

8) **Does the local legislation for swine waste treatment require the technology proposed by the project proponent?** The implementation of the "Advanced System" by the project proponent must exceed current national regulations (which must be described to support this claim).

6.1 Calculation Methods for Baseline Emissions (*BE*)

***BE* = CH_4 from anaerobic lagoon** (specified in I.1)
+ N_2O emissions from land application (specified in II.1.2)
+ N_2O from volatilised and non-volatilised NH_3 (specified in II.1.1)

[Details to be transferred to Annex 4 and specify the results only.]

I.1. CH4 EMISSION EQUATIONS FOR MANURE MANAGEMENT SYSTEMS

CH4 emissions related to manure management

$$CH_4 \text{ emissions (tonnesCO2eq/year)} = EF \cdot GWP_{CH4} \cdot \text{stock of pigs} / 1000$$

Where:

CH_4 emissions (tonnes/year) = CH4 emissions related to manure management, for a defined stock of pigs per year.

Stock of pigs = number of living pigs for a certain barn.

GWP_{CH4} = CH4 Global Warming Potential of 21.

EF = Emission Factor for swine manure management. [kg/per pig/year]. This emission factor can be represented by the next equation:

Emission Factor for manure management

$$EF \text{ (kg/year)} = VS \cdot 365 \text{ days/year} \cdot Bo \cdot D_{CH4} \cdot MCF$$

Where:

EF = Emission Factor for a livestock of swine [kg/year]

Bo = Maximum CH_4 production capacity from manure, per head for a given stock of pigs m^3/kg of volatile solids.

D_{CH4} = CH4 Density, 0.67 kg/m^3

MCF = Conversion factor of CH4, for an anaerobic lagoon (90 %), activated sludge after digester if applies (0.1%), or storage lagoon (45 %).

VS = volatile solids rate in kg/day/head for a given stock of pigs, in the respective manure treatment stage.

II -ESTIMATING N2O EMISSIONS FROM MANURE MANAGEMENT SYSTEMS

Because only the insertion of aerobic treatment consider a reduction in the nitrogen content of manure, this analysis of nitrous oxide emissions is relevant just for stage II of the project.

II.1.1 ANAEROBIC LAGOON & STORAGE LOSSES:

a. Non-volatile emission component

Non-volatile emission component

N2O = NEX • stock of pigs • (1 – **FracGASM**) • EF3 • CF /1000

Where:

N2O = N2O direct emissions from swine manure Management Systems (tonnes N2O/year);

NEX = Corrected default nitrogen excretion rate (kg/hd/year).

Stock of pigs = number of living pigs for a certain barn.

FracGASM = fraction of livestock nitrogen excretion that volatilises as NH3 and NOx (kg NH3-N and NOx-N/kg of N excreted)

EF3 = N2O emission factor for manure management System (kg N2O-N/kg of Nitrogen excreted);

CF = CONVERSION FACTOR N2O-N TO N (1.57 = 44/28)

b. Volatile emission component (indirect emissions)

Volatile emission component

$N2O_{indirect}$ = NEX • stock of pigs • **FracGASM** • EF4 • **CF** /1000

Where :

$N2O_{indirect}$ = N2O volatilised indirect emissions from swine manure management Systems (tonnes N2O/year)

Stock of pigs = number of living pigs for a certain barn.

EF4 = N2O emission factor for atmospheric deposition (kg N2O-N/kg of NH3-N and NOx-N emitted);

NEX = Corrected default nitrogen excretion rate (kg/hd/year).

FracGASM = fraction of livestock nitrogen excretion that volatilises as NH3 and NOx (kg NH3-N and NOx-N/kg of N excreted)

CF = CONVERSION FACTOR N2O-N TO N (1.57 = 44/28)

II.1.2. N2O LAND APPLICATION AND RUNOFF LOSSES:

a. Emissions from Non-volatilised nitrogen.

Land emissions from Non-volatilised nitrogen.

$N2O_{(LAND)}$ = NEX • stock of pigs • **CF** • (1 – FracGASM) • EF1

Where:

$N2O_{(LAND)}$ = emissions from non-volatilised nitrogen (tonnes N2O/year).

Stock of pigs = number of living pigs for a certain barn.

EF1 = emission factor for direct soil emissions (kg N2O-N/kg N input)

NEX = Corrected default nitrogen excretion rate (kg/hd/year).

FracGASM = fraction of livestock nitrogen excretion that volatilises as NH3 and NOx (kg NH3-N and NOx-N/kg of N excreted)

CF = CONVERSION FACTOR N2O-N TO N (1.57 = 44/28)

b. Emissions from runoff.

Emissions from runoff.

$$N2O_{(RUNOFF)} = EF_5 \cdot R \cdot (NEX \cdot \text{stock of pigs} \cdot (1- \textbf{FracGASM})) \cdot CF / 1000$$

Where:

$N2O_{(RUNOFF)}$ = emissions from non-volatilised nitrogen (tonnes N2O/year).

Stock of pigs = number of living pigs for a certain barn.

NEX = Corrected default nitrogen excretion rate (kg/hd/year).

FracGASM = fraction of livestock nitrogen excretion that volatilises as NH3 and NOx (kg NH3-N and NOx-N/kg of N excreted)

R = Non-volatilised Runoff, (Reference from IPCC Leaching & runoff table 4-24 = 0.3 kg N/ kg of manure non-volatilised nitrogen).

EF_5 = Emission factor for indirect emissions from runoff (kg N2O-N/kg N runoff)

CF = CONVERSION FACTOR N2O-N TO N (1.57 = 44/28)

Total emissions of N2O (tonnes/year)

$$N2O_{TOTAL\ EMISSIONS} = N2O_{(RUNOFF)} + N2O_{(LAND)} + N2O_{(AWMS)\ indirect} + N2O_{(AWMS)}$$

Total emissions of N20 expressed in tonnes CO2eq/year

$$CO2_{eq}(N2O) = GWP_{N2O} \cdot N20_{TOTAL\ EMISSIONS}$$

GWP_{N2O} = Nitrous Oxide Global Warming Potential of 310

7. Description of how the baseline methodology addresses any potential leakage of the project activity:

All the potential emissions in the baseline scenario due to leakage are considered in the methodology presented and judged to be negligible small (see Table 4).

The project scenario recognise should recognise leakage. The volume of sludge from the aerobic treatment can be used as fertiliser in land application programs and also disposed on a controlled landfill, outside the project boundaries. Thus, the potential CH4 emissions and the N2O generation from this source (leakage due to emissions outside the project boundaries) can be demonstrated to be marginal. This is because the nitrogen content in the sludge effluent from the aerobic treatment (dry and moist), is in the shape of nitrate and nitrite, and has lost its volatile potential.

8. Criteria used in developing the proposed baseline methodology, including an explanation of how the baseline methodology was developed in a transparent and conservative manner:

The Methodology is entirely based on the model described in the IPCC documentation. The IPCC model is widely accepted. The Methodology is therefore developed in a transparent manner and also uses input data collected on-site to correct the default values in a timely and accurate fashion.

9. Assessment of strengths and weaknesses of the baseline methodology:

The strength of the Methodology is based on

- The clarity and simplicity of the IPCC calculation model.
- The accuracy and precision of data specifically collected on-site (average swine weight, number of pig heads) to correct the IPCC default values.
- The conservative assumption of CH4 losses from the digester.
- The conservative approach in the determination of the project baseline
- The series of questions that can check with assurance the additionality conditions.
- No non-specific data is required and the vagaries of interpretation of outside or statistical data are avoided.

Weaknesses of the Methodology include:

- Accuracy reduced when moving from project specific and measured values to regional default values.
- Accuracy of N2O percentage reduction due to advanced treatment in project scenario.

10. Other considerations, such as a description of how national and/or sectoral policies and circumstances have been taken into account:

National or sectoral policies are not involved in the construction of the baseline and project scenario, and also not involved in the quantification of emissions.

Annex 4

NEW MONITORING METHODOLOGY

Proposed New Monitoring Methodology

In order to verify actual emission reduction of the project with regard to its baseline, it is essential to implement an efficient monitoring plan.

This methodology follows the analysis presented in the "**Guidelines for National Greenhouse Gas Inventories, Revised 1996, Chapter 4**". The emissions for the project scenario can be verified using the current monitoring system of swine production parameters outlined in this Annex. This system helps backup and ensure consistency with theoretical calculations. This monitoring methodology also gives the baseline calculation continuity, projecting it through time, considering the changes in average swine weight and number of pigs.

Brief Description of New Methodology

The monitoring plan describes the procedures for data collection, and auditing required for the project in order to determine and verify emissions reductions achieved by the project compared to the baseline scenario. This project will require very straightforward collection of data, which is already collected routinely by the local staff of digesters.

This monitoring methodology is highly compatible with the baseline methodology named "**METHODODOLOGY FOR ON-FARM ANAEROBIC and AEROBIC TREATMENT OF ANIMAL WASTE IN THE SWINE INDUSTRY**".

Monitored parameters are used to calculate project emissions and the resulting reductions compared to the baseline. Most of the parameters involved in the equations are default parameters provided by the IPCC Guidelines or the IPCC Good Practice and Uncertainty management. The rest of these parameters are the volatile solids percentage reduction (documented in EPA's "**Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations**"), corrected for the average swine weight and the number of pigs.

In order to quantify emission reductions, these monitored parameters are related with default values:

$$VS_{rm} = (W_{ss} / W_{df}) \times VS_{df}$$

Where:

VS_{rm} = Volatile solids content in site specific raw manure (kg/head/day)

W_{ss} = Site Specific average swine weight (kg)

W_{df} = Default value average swine weight (kg)

VS_{df} = Default value of Volatile solids content in raw manure (kg/head/day)

The same approach is given for correcting the nitrogen excretion rate:

$$NEX_{rm} = (W_{ss} / W_{df}) \times NEX_{df}$$

Where:

NEX_{rm} = Nitrogen excretion rate for site specific raw manure (kg/head/day)

W_{ss} = Site Specific average swine weight (kg)

W_{df} = Default value average swine weight (kg)

NEX_{df} = Corrected Default value of Nitrogen excretion rate in raw manure (kg/head/day)

The changes through time in the parameters monitored will determine the time-dependence of the emissions calculation for each scenario.

The importance of monitoring the number of swine heads lies in the calculation of volatile solids content and nitrogen excretion in total manure.

Data to be collected or used in order monitor emissions from the project activity, and how this data will be archived.

The current emission monitoring systems for digesters will be used, assigning a calibration frequency, the corresponding associated record and a preventive maintenance program.

ID number *(Please use numbers to ease cross-referencing to table D.6)*	Data type	Data variable	Data Unit	Measured (m), calculated (c) or estimated (e)	Recording frequency	Proportion of data to be monitored	How will data be archived? (electronic/paper)	For how long is archived data to be kept?	Comments
D.3-1	number	Diary Swine stock	Heads	M, measured	Weekly	100%	Paper	At least two years from completion of authorisation period or last CERs issued	All of the pig barns have an exhaustive contabilisation of the stock of pigs.
D.3-2	mass	Average weight of pigs	Kg.	Measured	Monthly	100%	Paper	At least two years from completion of authorisation period or last CERs issued	
D.3-3	mass	5 days Biochemical Oxygen Demand after aerobic post-	mg/L	Measured	Monthly	100%	Paper	At least two years from completion of authorisation period or last CERs issued	This is relevant just for digesters that include aerobic post-treatment

		treatment							
D.3-4	volume	Manure inflow to the aerobic post-treatment	m^3/day	Measured	Monthly	100%	Paper	At least two years from completion of authorisation period or last CERs issued	This is relevant just for digesters that include aerobic post-treatment
D.3-5	flux density	Biogas Flow extracted by digester	SCFM (standard cubic feet meter)	Measured	Daily	100%	Paper	At least two years from completion of authorisation period or last CERs issued	This parameter guarantees the correct performance of the digester. Measure of the biogas flow.
D.3-6	percentile	CO_2 concentration in gas flow	%	Measured	Daily	100%	Paper	At least two years from completion of authorisation period or last CERs issued	

CERs: Certified Emissions Reduction.

The only purpose for monitoring the biogas flow is to confirm the correct functioning of the digester. Biogas extraction rate and CO2 percentage concentration do not have any influence in the emission reduction calculation, however they guarantee the continuity in the digester's gas extraction capacity. For that reason, the registration of data is controlled periodically, jointly along with parameters like temperature and pH.

In the case of "heated" digesters, the internal automatic control program regulates and optimises the extraction, re-use and burn of the gas, based upon the pressure differential and the internal gas temperature. This internal automatic control program is known as controlled logical program (CLP). Its purpose is to manage the digester operation as well as the distribution of gas to the boiler or to the flare. The daily gas flow is measured by flow sensors based on the pressure differentials and transmitted to the CLP in the form of an electric signal.

In the case of "ambient temperature" digesters, the gas flow monitoring is not part of the controlled blower system (CLP), although there is no internal automatic control program. For "heated" and for "ambient temperature" digesters, the monitoring of carbon dioxide (CO2) percentage in the gas flow, uses potassium hydroxide as a contrast media.

The monitoring of five days BOD and the waste flow that goes into the aerobic treatment gives a reference of the volatile solids decay due to the activated sludge treatment, using the following relationships:

- **CH4 production (kg) for each kilogram of stabilised long term BOD** is 48/192 = **0.25**. This is the CH4 potential generation in the storage lagoon, due to the residual volatile solids content in the effluent of the aerobic treatment.

- The aerobic process considers significant consumption of organic matter from manure. This will be represented by a significant decay in the volatile solids content. Considering a maximum concentration of 35 mg/lt of total BOD5, we can calculate volatile solids after the aerobic process (for estimating emissions from the storage lagoon) as follows:

- BOD lt (mg/L)= 1.42 • BOD5 (mg/L)

- BODlt = Long term biochemical oxygen demand

- (mg/L)BOD5 = five-day biochemical oxygen demand (mg/L)

Potential sources of emissions which are significant and reasonably attributable to the project activity, but which are not included in the project boundary, and identification if and how data will be collected and archived on these emission sources.

The project does not envisage meaningful emissions generated outside the project boundary that is significant and reasonably attributable to changes in liquid manure treatment. The project already includes the potential fugitive emissions related to the digester, as emissions in the project boundary.

The potential leakage emissions of CH4 and N2O come from the volume of sludge from the aerobic post-treatment. These are marginal because the nitrogen content in the sludge effluent from the aerobic treatment (dry and moist), is in the shape of nitrate and nitrite, and has lost its volatile potential.

There are also leakage emissions considered for the consumption of energy in the project boundaries, for the implementation of the new technology.

The next table presents the emissions of GHGs involved with the project and the baseline scenarios, identifying which are in or outside the project boundaries.

		In the boundary	Outside the boundary
Baseline scenario	Non-negligible	Methane and Nitrous Oxide emissions from stabilisation lagoon	-
	negligible small	-	Nitrous oxide emissions from treated manure land application and runoff
	Not counted	-	-
Project scenario	Non-negligible	Methane and Nitrous Oxide emissions from: storage lagoon, digester and aerobic treatment losses; Carbon dioxide emissions from methane combustion.	-
	negligible small	GHGs associated with the consumption of energy in the implementation	Nitrous oxide emissions from treated manure land application and runoff
	Not counted	-	-

As part of an advanced manure treatment system it is important to control and monitor the effluent wastewater quality. The parameters for this type of system include: BOD5 (five days biochemical oxygen demand), ammonia, phosphorus, COD (chemical oxygen demand) and Kjeldahl nitrogen content.

Assumptions used in elaborating the new methodology:

In order to relate CH4 combusted to a corresponding amount of $CO_{2\ equiv.}$, emissions, the following factors are considered:

- There are 22.4 litres per CH4 mole and each CH4 mole has 16 grams.

- **Emissions from CH4 combustion:** Because these emissions are from CH4 capture and combustion, the GWP of 21 (for the anaerobic baseline scenario) is replaced by the molar mass quotient between CO2 and CH4, as explained in the next stoichiometric equation:

$$CH4 + 2O_2 \longrightarrow CO2 + 2H_2O$$

16 + 2 x 32 gr. 44 + 2 x 18 gr.

80 80

- For each CH4 mole burned, one CO_2eq mole is released into the atmosphere, whereas for each ton of free CH4 released in to the atmosphere, 21 tons of CO_2eq are released into the atmosphere.

It is also assumed that the default IPCC VS content are proportional to the average swine weight monitored in every digester's group of barns.

The key parameters for this analysis are the number of pigs, the average pig weight and the VS generation in raw and treated manure (for the baseline and project scenarios respectively). For the case of aerobic treatment, the 5 days biochemical oxygen demand ($BOD5_{lt}$) and the effluent flow from this manure management facility is also considered.

The next analysis explains the methane emissions and VS decay when included an aerobic treatment. Both are a function of the long-term biochemical oxygen demand for the manure flow in the aerobic treatment:

- Initially, the outflow from the aerobic treatment process is organic matter in the form of glucose. In anaerobic conditions, this is transformed to CH4 and CO2.

$$C_6H_{12}O_6 \longrightarrow 3CO_2 + 3CH_4$$

180 132 48

- **Even though glucose has transformed itself already, CH4 has an intrinsic biochemical oxygen demand (BOD) for its final conversion into CO2 and steam.**

$$3CH_4 + 6O_2 \longrightarrow 3CO_2 + 6H_2O$$

48 192

As demonstrated by these two stoichiometric relations, long- term BOD per kilogram of glucose is (192/180) kg, and 1 kilogram of glucose produces (48/180) kilograms of CH4. So, we can state that the **CH4 production (kg) for each kilogram of stabilised long term BOD** is 48/192 = **0.25**. This is the CH4 potential generation in the storage lagoon, due to the residual volatile solids content in the effluent of the aerobic treatment.

The aerobic process considers an important consumption of organic matter from manure. This will be represented by an important decay in the volatile solids content. Considering a maximum concentration of 35 mg/lt of total BOD5, we can calculate volatile solids after the aerobic process (for estimating emissions from the storage lagoon) as follows:

BOD long term (mg/lt)= 1.42 • BOD5 (mg/lt)

BODlt = Long term biochemical oxygen demand (mg/lt)

BOD5 = five-day biochemical oxygen demand (mg/lt)

Please indicate whether quality control (QC) and quality assurance (QA) procedures are being undertaken for the items monitored?

These procedures are similar to the current monitoring system for biogas generation and composition from digesters.

Data	Uncertainty level of data (High/Medium/Low)	Are QA/QC procedures planned for these data?	Outline explanation why QA/QC procedures are or are not being planned.
D.3-1	Low	Yes	QA/QC procedures are established; this data will be used as basis for calculating emission reductions
D.3-2	Low	Yes	QA/QC procedures are established; this data will be used as basis for calculating emission reductions
D.3-3	Low	Yes	QA/QC procedures are established; this data will be used as basis for calculating emission reductions
D.3-4	Low	Yes	QA/QC procedures are established; this data will be used as basis for calculating emission reductions
D.3-5	Low	Yes	QA/QC procedures are established; This is supported by the control of temperature, pH and the variability of the gas flow rate
D.3-6	Low	Yes	QA/QC procedures are established;

The number of living pigs and the average pig weight for each barn involved in the project, are parameters relevant for permanent monitoring production plan. The accuracy of this existing monitoring plan can be assured on the actual quality certification process being implemented on-site.

The gas flow from the digester is a consistent guide to guarantee the performance of the digester, and is also part of an existing monitoring plan. The quality control of this parameter monitoring depends in its continuity and in other parameters monitored as temperature and pH.

What are the potential strengths and weaknesses of this methodology?

There are no references regarding official methodologies for monitoring emissions with which to compare the effectiveness of the proposed system, however, due to the simple calculations and low dependence on non-controllable variables, it is possible to ensure the effectiveness and accuracy of the monitoring system.

While there are no specific measurements of volatile solids content in raw manure (other than the IPCC default values), accuracy will be managed by monitoring the average swine weight in order to use this key parameter for the correction of IPCC default values.

The quality control and quality assurance programs are of great relevance ensure correct measurement of the variables involved in the monitoring program.

Has the methodology been applied successfully elsewhere and, if so, in which circumstances?

There are no other known cases (officially approved by the CDM EB), regarding the implementation of the described methodology.

Annex 5

BASELINE DATA

(Please provides a table containing the key elements used to determine the baseline (variables, parameters, data sources etc.). For approved methodologies you may find a draft table on the UNFCCC CDM web site. For new methodologies, no predefined table structure is provided.)

The following section includes the references used for calculating emissions in the base line scenario. Calculations were made based on information obtained by Agrosuper, default values of the model and additional base information. The following scenarios were used:

- **Baseline Scenario**: Barns → Anaerobic Lagoon → Use of effluents on site
- **Project Scenario:** Barns → Anaerobic digester → Aerobic Treatment (just for the Stage II) → Storage lagoon→ Use of effluents on site

BASELINE: Conventional System of Lagoons (without separation of solids): The lagoon system is a typical waste management system utilised in Chile, Latin America and in North America. Two types of systems are often classified as lagoon systems: the anaerobic treatment lagoon and the storage lagoon. In an anaerobic treatment lagoon, liquid animal waste is stored for one year or more. Anaerobic bacteria "treat" the liquid manure and decrease the organic matter content. This results in the emission of CO2, CH4, hydrogen sulphide, and ammonia. In the anaerobic treatment lagoon, sludge settles on the bottom of the lagoon. In a storage lagoon, liquid manure is stored for one year or more. Due to semi-anaerobic conditions in the storage lagoon, GHGs and ammonia are emitted to the atmosphere.

Table 1: General Characteristics of Peralillo

Name of the digester	Digester conditions	Region	average weight (kg)	stock of pigs
Peralillo	Warm	VI	72.24	118,800

Source : Specific hog operations data from Agrosuper.

GWP = Global Warming Potential. The next table presents the GWP values for each GHG under consideration:

Table 2

	Global Warming Potential (GWP)
Carbon Dioxide	1
CH4	21
Nitrous Oxide	310

<u>CH4 Emissions from Manure Management Systems</u>

VS = Volatile Solids rate in kg/day/head for a given stock of pigs. The IPCC provides a volatile solids rate in raw manure of 0.5 kg/day/head for developed countries (Table B-2 of IPCC Guideline, Reference Manual). We can trust that the IPCC default value (for developed country) represents the volatile solids content in raw manure for Agrosuper because every parameter involved in the next calculation, is consistent and similar to those presented in Table B-2 of the IPCC Guidelines Reference Manual:

Equation 15 of the IPCC Guidelines Reference Manual

$$VS\ (kg\ dm/day) = Intake\ (MJ/day) \cdot (1\ kg/\ 18.45\ MJ) \cdot (1 - DE\%/100) \cdot (1 - ASH\%/100)$$

Where:

VS = VS excretion per day on a dry weight basis;

dm = dry matter;

Intake = the estimated daily average feed intake in MJ/day;

DE% = the digestibility of the feed in per cent;

ASH% = the ash content of the manure in per cent.

The energy density of feed is about 18.45 MJ per kg of dry matter. The next table presents the results given for the parameters that determine the volatile solids content in raw manure.

Table 3

	Feed Digestibility	Energy intake	Feed intake	ASH content	VS
	%	MJ/hd/day	kg/hd/day	%	(kg/hd/day)
Developed Countries IPCC default value	75	38	2.1	2	0.50
Agrosuper monitoring data	78	44*	2.38*	2	0.514

* Average feed and energy intake in Agrosuper's barns. This is to be corrected for the representative swine weight of each digester, as explained below.

This data (VS) is corrected by the mean swine weight from Agrosuper's data (for each barn), in contrast with a representative weight of 82 kg/head (IPCC), resulting in 0.44 kg/day/head, for the case of Peralillo.

The next equation explains how the default volatile solids content in raw manure is corrected:

$$VS_{rm} = (W_{ss} / W_{df}) \times VS_{df}$$

Where:

VS_{rm} = Volatile solids content in site specific raw manure (kg/head/day)

W_{ss} = Site Specific average swine weight (kg)

W_{df} = Default value average swine weight (kg)

VS_{df} = Default value of Volatile solids content in raw manure (kg/head/day)

The percentage decay of this parameter after the digester, is referenced in the "**Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for**

Concentrated Animal Feeding Operations" (EPA, 2001). This document assumes a **60 percent** reduction of VS due to the digester.

The next analysis explains the CH4 emissions (in the storage lagoon) and the VS decay for the second stage of the project (2004-2008), when included an aerobic treatment:

- Initially, the outflow from the aerobic treatment process is organic matter in the form of glucose. In anaerobic conditions, this is transformed to CH4 and CO2.

$$C_6H_{12}O_6 \longrightarrow 3CO_2 + 3CH_4$$

180 132 48

- Even though glucose has transformed itself already, CH4 has an intrinsic biochemical oxygen demand (BOD) for its final conversion into CO2 and steam.

$$3CH_4 + 6O_2 \longrightarrow 3CO_2 + 6H_2O$$

48 192

As demonstrated by these two stoichiometric relations, long- term BOD per kilogram of glucose is (192/180) kg, and 1 kilogram of glucose produces (48/180) kilograms of CH4. So, we can state that the **CH4 production (kg) for each kilogram of stabilised long term BOD** is 48/192 = **0.25**. This is the CH4 potential generation in the storage lagoon, due to the residual volatile solids content in the effluent of the aerobic treatment.

The aerobic process considers an important consumption of organic matter from manure. This will be represented by an important decay in the volatile solids content. Considering a maximum concentration of 35 mg/lt of total BOD5, we can calculate volatile solids after the aerobic process (for estimating emissions from the storage lagoon) as follows:

$$BOD\ lt(mg/lt) = 1.42 \cdot BOD5\ (mg/lt)$$

Where:

BODlt = Long term biochemical oxygen demand (mg/lt)

BOD5 = five-day biochemical oxygen demand (mg/lt)

$$VS\ (kg/head/day) = BODlt \cdot 0.25 \cdot Q\ (waste\ flow\ m^3/day) \cdot 1000 \cdot 0.25/\ (10^6 \cdot Stock\ of\ pigs \cdot Bo \cdot D_{CH4} \cdot MCF_{aerobic\ treatment})$$

Where:

Bo = Maximum CH_4 production capacity from manure, per head for a given stock of pigs m^3/kg of volatile solids.

Q = waste flow (m3/day)

D_{CH4} = CH4 Density, 0.67 kg/m^3

MCF = Conversion factor of CH4 for aerobic post-treatment (45%)

Both, BOD5 in the aerobic treatment and the average inflow of treated manure after digester are monitored parameters.

Actually the Peralillo digester presents the following parameters for the projected aerobic post-treatment:

Q = 1200 m^3/day

BOD5 = Maximum content of Five-day Biochemical oxygen demand = 0.35 mg/lt

The next table presents the VS content, in each step of the manure management process, for the project scenario.

Table 4: VS content for different steps in manure treatment

	kg/head/day		
Digester	**VS raw manure**	**VS digested manure**	**VS post-activated sludge (for stage II)**
Peralillo	0.44	0.18	0.0009

Source: Developed based in IPCC guidelines, Agrosuper average swine weight data and EPA, 2001.

Bo = Maximum CH4 production capacity from manure, per head for a given stock of pigs [m3/kg of volatile solids]. Default values can be obtained in the Table B-2 of the "IPCC Guidelines for National Greenhouse Gas Inventories, Revised 1996, Reference Manual". This parameter varies by species and diet, and for Agrosuper barns it should be used the representative data for developed countries (0.45 m3/kg).

MCF = Conversion factors of CH4, for each manure management system and every regional weather. For the anaerobic lagoon (baseline) and the storage lagoon after the digester (project), we consider MCF to be 90 %, as a default reference from the IPCC. For the purposes of quantifying indirect fugitive emissions in the digester, we consider a 5 % as a default reference from the IPCC. The next table summarises the different types of manure management systems involved in the project and baseline scenario, and their CH4 conversion factors (MCFs).

Table 5: CH4 Conversion Factor in different emission sources

	MCF %	
Baseline	Anaerobic Lagoon*	90%
Project	CH4 Combustion*	90%
	Indirect fugitive emissions from digester*	5%
	Storage Lagoon**	45%
	Aerobic Treatment (activated sludge for stage II)***	0.10%

Source : * IPCC Guidelines (Reference Manual table 4-8 and table B-6) and ** IPCC Good Practice and uncertainty management (Table 4.10) and *** IPCC Good Practice and uncertainty management (Table 4.11), temperate climate.

Nitrogen excretion rate : NEX = 20 kg/head/day for developed countries, as stated in Table 4-20 of the 1996, IPCC Guidelines. This data (NEX) is adapted to the mean swine weight from Agrosuper's data (for each barn), in contrast with a representative weight of 82 kg/head (IPCC), resulting in 17.62 kg/day/head for the case of Peralillo.

Given that only the insertion of aerobic treatment contributes to a reduction in the nitrogen content of manure, this analysis of N20 emissions is relevant only for stage II of the project.

The next equation explains how the default nitrogen excretion rate in raw manure is corrected:

$$NEX_{rm} = (W_{ss} / W_{df}) \times NEX_{df}$$

Where:

NEX_{rm} = Nitrogen excretion rate for site specific raw manure (kg/head/day)

W_{ss} = Site Specific average swine weight (kg)

W_{df} = Default value average swine weight (kg)

NEX_{df} = Corrected default value of Nitrogen excretion rate in raw manure (kg/head/day)

The changes through time in the parameters monitored will determine the time-dependence of the emissions calculation for each scenario.

The importance of monitoring the number of swine heads lies in the calculation VS content and nitrogen excretion in total manure.

The digester anaerobic process (complete mix) does not have an effect on the nitrogen content of manure, as stated in the "**Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for CAFO**" (EPA, 2001). This document also gives a reference of 75 % decay of nitrogen content due to the aerobic treatment, via nitrification-denitrification.

Conversion Factor – N20 N TO N: For reporting purposes the conversion is performed using the following equation

$$N_2O_{(mm)} = (N_2O - N)_{(mm)} \cdot 44/28$$

44/28 =1.57

The next table presents the relevant emission factors and parameters involved in the emission reduction of nitrous oxide, for each scenario.

Table 6: Key Parameters and Emission Factors involved in the N20 emission calculations for each scenario.

Parameter		Units	Description	Reference
FracGASM	**20**	**%**	fraction of livestock nitrogen excretion that volatilises as NH3 and NOx	Table 4-19 IPCC Guidelines
EF1	**0.0125**	kg N2O-N/kg N input	Emission factor for direct soil emissions	Table 4-17 IPCC Good Practice Guidance Document
EF3	**0.001**	kg N2O-N/kg of Nitrogen excreted	N2O emission factor for Swine Manure Management System	Table 4-22 IPCC Guidelines
EF4	**0.01**	kg N2O-N/kg of NH3-N and NOx-N emitted	N2O emission factor for atmospheric deposition	Table 4-23 IPCC Guidelines
R	**0.3**	kg N/ kg of manure non-volatilised nitrogen	Non-volatilised leaching & Runoff	Table 4-24 IPCC Guidelines

Annex 6: References

- **IPCC Guidelines for National Greenhouse Gas Inventories, Revised 1996, Chapter 4 & Reference Manual**
- **IPCC Good Practice Guidance and Uncertainty management in National Greenhouse Gas Inventories, Chapter 4**
- **Development Document for the Proposed Revisions to the National Pollutant Discharge Elimination System Regulation and the Effluent Guidelines for Concentrated Animal Feeding Operations (EPA 2001)**
- **Specific hog operations data from Agrosuper**
- **Voluntary Clean Production Agreement signed between the Chilean Government and Pork Producers Association of Chile (ASPROCER A.G.), December 1999**
- **Law 19,300 "General Environmental Framework" Official Gazette 04.09.94**
- **Supreme Decree Nº 30 of 1997 of the General Secretariat of the Presidency, Regulation of the Environmental Impact Assessment System. Official Gazette 04.03.97**

Annex 7: Glossary of Terms

Bo = Maximum CH4 production capacity from manure

BODlt = Long Term biochemical oxygen demand

BOD5 = five-day biochemical oxygen demand

CO2 = Carbon Dioxide

CH4 = Methane

CLP = Controlled Logical Program

CO2eq = Carbon Dioxide Equivalent

DCH4 = CH4 Density, 0.67 kg/Nm3

GHG(s) = Greenhouse Gas(es)

GWP_{CH4} = Methane Global Warming Potential = 21

GWP_{N2O} = Nitrous Oxide Global Warming Potential = 310

IPCC = International Panel on Climate Change

MCF = Methane Conversion Factor

N2O = Nitrous Oxides

NEXdf = Default value of Nitrogen excretion rate in raw manure

NEXrm = Nitrogen excretion rate for site specific raw manure

Q = waste flow

UTM = Universal Transversal Mercator

VSdf = Default value of Volatile Solids content in raw manure

VS_{rm} = Volatile solids content in site specific raw manure

W_{ss} = Site Specific average swine weight

W_{df} = Default value average swine weight

Annex 8: Host Country Approval

Included as an attachment.

032102

GOBIERNO DE CHILE
COMISION NACIONAL
DEL MEDIO AMBIENTE

Santiago, 1 de julio de 2003

Ref.: Proyecto Reducción de Emisiones Gases Efecto Invernadero de Agrícola Super Ltda.

Sr.:
José Guzmán Vial
Gerente General
Agrícola Super Ltda.

Estimado Sr. Guzmán:

1. Considerando que Chile es Parte de la Convención Marco de las Naciones Unidas sobre Cambio Climático y ha ratificado y es Parte del Protocolo de Kioto.

2. Dado el artículo 12 de dicho Protocolo, que crea el Mecanismo de Desarrollo Limpio (MDL).

3. Atendido lo señalado en el Acuerdo N° 216/2003, de la Comisión Nacional del Medio Ambiente, que constituye la Autoridad Nacional Designada para efectos del MDL y faculta al Director Ejecutivo de la Comisión Nacional del Medio Ambiente para emitir y firmar los documentos que requiere el MDL.

4. Considerando los antecedentes por Ud. expuesto en su carta de fecha 15 de mayo de 2003, en la que postula el Proyecto "Proyecto Reducción de Emisiones Gases Efecto Invernadero de Agrícola Super Ltda." al MDL.

5. Considerando lo acordado por el Comité Ejecutivo que representa a la Autoridad Nacional Designada, en su sesión de 1 de julio de 2003.

6. En el marco de las atribuciones que la legislación chilena me concede, señalo que:

   a) Se aprueba la presentación del proyecto "Proyecto Reducción de Emisiones Gases Efecto Invernadero de Agrícola Super Ltda." para ser postulado al Mecanismo de Desarrollo Limpio, en el marco del artículo 12 del Protocolo de Kioto.

b) Confirmo que el proyecto "Proyecto Reducción de Emisiones Gases Efecto Invernadero de Agrícola Super Ltda." contribuye al desarrollo sustentable de Chile; y

c) Confirmo que el proyecto "Proyecto Reducción de Emisiones Gases Efecto Invernadero de Agrícola Super Ltda." ha sido presentado en forma voluntaria ante la Autoridad Nacional Designada.

A través de la presente, esta Parte manifiesta que, en su momento y según corresponda, prestará la debida colaboración para que el procedimiento establecido en el artículo 12 del Protocolo de Kioto se lleve a cabo, con el objeto de lograr la generación y transferencia de los Certificados de Reducción de Emisiones provenientes del proyecto "Proyecto Reducción de Emisiones Gases Efecto Invernadero de Agrícola Super Ltda."

Gianni López R.
Presidente
Comité Ejecutivo
Autoridad Nacional Designada

COMISION NACIONAL DEL MEDIO AMBIENTE
DIRECTOR EJECUTIVO

Santiago, Chile, July 1st, 2003.

Ref.:"Agrícola Super Ltda's Greenhouse Gas Emission Reduction" Project

Mr.
JOSE GUZMAN VIAL
General Manager
AGRICOLA SUPER LTDA.

Dear Mr. Guzmán :

1.- Considering that Chile is part of the United Nations Climate Change Framework Convention and that it has ratified and it is part of the Kyoto Protocol.

2.- Taking into account Article 12 of the mentioned Protocol, that creates the Clean Development Mechanism (CDM).

3.- Taking into the Agreement N°216/2003 of the Environmental National Commission, that constitutes for the purpose of the CDM the Designated National Authority and that empowers the Environmental National Commission Executive Director to issue and sign the documents required by the CDM.

4.- In consideration of the information given by you in your letter dated May 15th, 2003, in which you apply the "Agrícola Super Ltda's Greenhouse Gas Emission Reduction" Project to the CDM.

5.- Considering the agreed by the Executive Committee that represents the Designated National Authority, at its meeting of July 1st, 2003.

6.- Because of the authority the Chilean law has given to me, I declare as follows :

a) The "Agrícola Super Ltda's Greenhouse Gas Emission Reduction" Project to be applied to the Clean Development Mechanism is **approved** by this act, according to Article 12 of the Kyoto Protocol.

b) I confirm that the "Agrícola Super Ltda's Greenhouse Gas Emission Reduction" Project contributes to the sustainable development of Chile; and

c) I confirm that the "Agrícola Super Ltda's Greenhouse Gas Emission Reduction" Project has been voluntary presented before the Designated National Authority.

By means of this letter, we declare that, opportunely and whenever corresponds, we will help that the procedure established on Article 12 of the Kyoto Protocol will be carried out in order to issue and transfer the Certificates of Emission Reduction corresponding to the "Agrícola Super Ltda's Greenhouse Gas Emission Reduction" Project.

Gianni López R.
President
Executive Committee
Designated National Authority