DRAFT FOR PUBLIC REVIEW

Greenhouse gas emissions and fossil energy demand from poultry supply chains

Guidelines for quantification

LIVESTOCK ENVIRONMENTAL ASSESSMENT AND PERFORMANCE PARTNERSHIP

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FOREWORD

The methodology developed in these draft guidelines aims to introduce a harmonized international approach to the assessment of the environmental performance of poultry supply chains in a manner that takes account of the specificity of the various production systems involved. It aims to increase understanding of poultry supply chains and to help improve their environmental performance. The guidelines are a product of the Livestock Environmental Assessment and Performance (LEAP) Partnership, a multi-stakeholder initiative whose goal is to improve the environmental sustainability of the livestock sector through better metrics and data.

The livestock sector has expanded rapidly in recent decades and growth is projected to continue as a result of sustained demand, especially in developing countries. The Poultry[1] sector is dynamic and growing. In 2011, global poultry production of meat and eggs was estimated over 90 million tonnes of meat and 65 million tonnes of shelled eggs, growing at an annual rate of around 3.5 and 2 percent per year, respectively (FAOSTAT, 2012). Rising population, heightened purchasing power and increasing urbanization have been strong drivers of that growth. The poultry sector continues to be very diverse in structural terms. Along with large scale commercial operations, there continues to be traditional small-scale, rural, and family-based poultry systems which play a crucial role in sustaining livelihoods. Increasing demand for poultry products is also set to result in additional pressure on natural resources. This is of particular concern since the livestock sector already has a major impact on natural resources, using about 35 percent of total cropland and about 20 percent of green water for feed production (Opio et al., 2013). Globally, poultry-related emissions have been accounted for about 600 million tonnes of CO_2 equivalent per annum, with about half coming from feed production (Macleod et al., 2013). There is thus growing interest, including from the poultry sector itself, in measuring and improving the environmental performance of poultry supply chains.

In the development of these draft guidelines, the following objectives were regarded as key:

- To develop a harmonized, science-based approach resting on a consensus among the sector's stakeholders;
- To recommend a scientific but at the same time practical approach that builds on existing or developing methodologies;
- To promote an approach to assessment suitable for a wide range of poultry supply chains;
- To identify the principal areas where ambiguity or differing views exist as to the right approach.

[1] Poultry species includes: chicken, turkeys, guinea fowl, geese, quails, ducks, pigeons.

Over the coming months these guidelines will be submitted to public review.[2] The purpose will be to strengthen the advice provided and ensure it meets the needs of those seeking to improve performance through sound assessment practice. Nor is the present document intended to remain static. It will be updated and improved as the sector evolves and more stakeholders become involved in LEAP, and as new methodological frameworks and data become available. The development and inclusion of guidance on the evaluation of additional environmental impacts is also viewed as a critical next step.

The strength of the guidelines developed within the LEAP Partnership across the various livestock subsectors stems from the fact that they represent a coordinated cross-sectoral and international effort to harmonize measurement approaches. Ideally, harmonization will lead to greater understanding, transparent application and communication of metrics, and, importantly for the sector, real and measurable improvement in performance.

Lalji Desai

LEAP Chair

February 2014

[2] The public review period starts on 15 March 2014 and ends on 31 July 2014.

ACKNOWLEDGEMENTS

These guidelines are a product of the Livestock Environmental Assessment and Performance (LEAP) Partnership. Three groups contributed to their development:

The Technical Advisory Group (TAG) on poultry conducted the background research and developed the core technical content of the guidelines. The poultry TAG was composed of: Greg Thoma (Leader, University of Arkansas); Stephen Wiedemann (FSA Consulting, International Egg Commission, International Poultry Council, Australian Chicken Meat Federation, Australia); Julio Cesar Pascale Palhares (Embrapa Pecuária Sudeste, Brazil); Md Abu Saleque (International Network for Family Poultry Development, Bangladesh); Masayuki Kanzaki (Japan Environmental Management Association for Industry, Japan); Ayao Missohou (Ecole Inter-Etats des Sciences et Médecine Vétérinaires de Dakar, Senegal); Ilias Kyriazakis (University of Newcastle, International Poultry Council, International Egg Commission, British Poultry Association, United Kingdom); Jason Gittins (ADAS, United Kingdom), Jamie Burr (Tyson Foods Inc., United States).

The LEAP Secretariat coordinated and facilitated the work of the TAG, guided and contributed to the content development and ensured coherence between the various guidelines. The LEAP secretariat, hosted at FAO, was composed of: Pierre Gerber (Coordinator), Alison Watson (Manager), Carolyn Opio (Technical officer), Félix Teillard (Technical officer) and Aimable Uwizeye (Technical officer). Laura Drauker (World Resource Institute), John Kazer (Carbon Trust) and Christel Cederberg (SIK and Chalmers University of Technology, Gothenburg) assisted the Secretariat in reviewing the guidelines.

The LEAP Steering Committee provided overall guidance for the activities of the Partnership and helped review and cleared the guidelines for public release. During development of the guidelines the LEAP Steering Committee was composed of:

Steering committee members

- Douglas Brown (World Vision)
- Elsa Delcombel (Government of France)
- Lalji Desai (World Alliance of Mobile Indigenous People) – Chair 2013 to 2014
- Jan Grenz (Government of Switzerland)
- Vincent Guyonnet (International Egg Commission / International Poultry Council)
- Dave Harrison (International Meat Secretariat)
- Hsin Huang (International Meat Secretariat)
- Giuseppe Luca Capodieci (The European Livestock And Meat Trading Union)
- Delanie Kellon (International Dairy Federation)
- Lionel Launois (Government of France)
- Pablo Manzano (International Union for Conservation of Nature)

- Nicolas Martin (European Feed Manufacturers' Federation)
- Paul McKiernan (Governement of Ireland)
- Paul Melville (Government of New Zealand)
- Frank Mitloehner (University of California, Davis) – Chair 2012 to 2013
- Anne-Marie Neeteson-van Nieuwenhoven (International Poultry Council)
- Frank O'Mara (Irish Agriculture and Food Development Authority, Teagasc)
- Antonio Onorati (International Planning Committee for World Food Sovereignty)
- Lara Sanfrancesco (International Poultry Council)
- Fritz Schneider (Bern University)
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- Henning Steinfeld (Food and Agriculture Organization)
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Although not directly responsible for the preparation of these guidelines, the Technical Advisory Groups on feed and small ruminants indirectly contributed to their development through continuous exchanges during the preparation phase.

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1 GLOSSARY

Allocation	Partitioning the input or output flows of a process between the product system under study and one or more different product systems.
Attributional	Attributional Life cycle assessments focus on describing the environmentally relevant physical flows to and from a product or process.
Background process	Stages of the supply chain which provide goods and services to the foreground system; not under the control of the study commissioner. See also: **Foreground process.**
Biogenic	Derived from biomass, not from fossil sources.
Biomass	Material of biological origin, excluding fossilized material or material embedded in geological formations**.**
Boundary	Set of criteria specifying which unit processes are part of a product system (life cycle).
Breeding hen	Female parent bird producing fertile eggs for commercial poultry meat and egg production.
Breeding overhead	Animals dedicated to reproduction rather than to production; i.e. animals needed to maintain herd/flock size.
Broiler	Chicken reared for meat.
By-product	Material produced during the processing (including slaughtering) of a livestock or crop product that is not the primary objective of the production activity (e.g. oil cakes, brans, offal or skins).
Capital goods	Goods, such as machinery, equipment and buildings, used in the life cycle of products.
Carbon dioxide equivalent (CO_2eq)	Unit for comparing the radiative forcing (global warming potential) of a greenhouse gas expressed in terms of the amount of carbon dioxide that would have an equivalent impact.
Carbon footprint	The level of greenhouse gas emissions produced by a particular activity or entity or product.
Carbon storage	Retaining carbon of biogenic or atmospheric origin in a form other than atmospheric gas.
Chicken meat processing	A general term for further processing needed after dressing (e.g., cutting, selection, cooking, etc.)
Cold chain	Refers to a system for distributing products in which the goods are constantly maintained at low temperatures (e.g. cold or frozen storage and transport), as they move from producer to consumer.
Combined heat and power (CHP)	Simultaneous generation in one process of useable thermal energy together with electrical and/or mechanical energy.
Compound feed/concentrate	Mixtures of feed materials which may contain additives for use as animal feed in the form of complete or complementary feedstuffs.
Consequential LCA	Consequential LCA assessments describe how relevant environmental flows will change in response to different decisions.

Containers and packaging	Containers and packaging that reach consumers.
Conventional cage eggs	Eggs produced from hens living in communal cage systems. There are various cage systems, depending on the size of the birds and the facility. While providing hens with access to fresh food and water, cages also work as nesting spaces and help protect against predators. Cage-laid eggs are commonly collected automatically.
Co-production	A multifunctional process that produces various outputs such as meat and eggs in backyard systems. Production of the different goods cannot be varied, or only varied within a very narrow range.
Co-products	Output from a production activity that generates more than one product (e.g. meat, eggs, and, under some circumstances, litter are among the co-products of layer production). The term does not include any services that may also be provided.
Cull birds	Diseased or injured birds which are euthanized for animal welfare or health reasons before the end of the normal productive period. These animals are disposed of and do not enter the human food supply.
Data quality	Characteristics of data that relate to their ability to satisfy stated requirements.
Direct energy	Energy used on farms for livestock production activities (e.g. lighting, heating).
Dressed parts	Items divided or removed from carcasses or gutted chickens.
Dressing	Removal of parts not to be offered as edible products. Cutting up chickens into product parts.
Emission factor	Amount of greenhouse gases emitted, expressed as carbon dioxide equivalent and relative to a unit of activity (e.g. kg CO_2e per unit input). NOTE: Emission factor data is obtained from secondary data sources.
Emissions	Release to air or discharge to land and water that results in greenhouse gases entering the atmosphere. The main GHG emissions from agriculture are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4).
Eutrophication	Nutrients (mainly nitrogen and phosphorus) from sewage outfalls and fertilized farmland accelerate the growth of algae and other vegetation in water. The degradation of organic material consumes oxygen resulting in oxygen deficiency and, in some cases, fish death. Eutrophication translates the quantity of substances emitted into a common measure expressed as the oxygen required for the degradation of dead biomass.
Feed conversion ratio	Measure of the efficiency with which an animal converts feed into tissue, usually expressed in terms of kg of feed per kg of output (e.g. live weight, eggs or protein).
Feed digestibility	Determines the relative amount of ingested feed that is actually absorbed by an animal and therefore the availability of feed energy or nutrients for growth, reproduction, etc.
Free-range eggs	Are produced by hens raised outdoors or with outdoor access if weather permits. Shelter is provided during bad weather and as protection from predators. While having continuous access to fresh food and water, these hens may forage for wild plants and insects and are sometimes referred to as pasture-fed hens. They are also provided with outdoor floor space, nest space, and perches.

Foreground process	The stages of the supply chain under the direct control of the commissioner of the LCA. For product developers and process operators, the foreground data is of special interest because direct changes in the system (changes in materials, designs, processes) have direct effects on the result, while the background system impacts can be influenced only indirectly (by the choices above). See also: **Background process.**
Functional unit	Quantified performance of a product for use as a reference unit. It is essential that the functional unit allows comparisons that are valid where the compared objects (or time series data on the same object, for benchmarking) are comparable.
Global Warming Potential (GWP)	The intensity of a GHG's warming potential, which is different for each gas. The factors used to convert GHGs into CO_2 equivalents are defined by IPCC guidelines and can be found in Section 4.6.
Greenhouse gases (GHGs)	Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluoro-carbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).
Gutted chicken	A bird whose viscera (excluding kidneys), cloaca, trachea, and oesophagus have been removed. Inclusion of caudal portion is arbitrary.
Infrastructure	Product not intended for consumption, with a lifetime exceeding one year. Synonym: **Capital goods.**
Input	Product, material or energy flow that enters a unit process.
Joint production	A multifunctional process in which production of the various outputs can be varied separately. For example in a backyard system the number of poultry and swine can be set independently.
Layer / Laying hen	Bird kept producing eggs for human consumption.
LCA	See **Life cycle assessment**
Life cycle assessment	Compilation and evaluation of inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.
Life cycle GHG emissions	Sum of GHG emissions resulting from all stages of the life cycle of a product and within the specified system boundaries of the product.
Life cycle	Consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to end of life, inclusive of any recycling or recovery activity.
LCI	See Life cycle inventory
Life cycle inventory	Compilation of the exchanges for a unit process. These include purchased input materials, materials extracted from nature (e.g., well water), emissions to the environment, and the output(s) produced.
Material contribution	Contribution of any one source of GHG emissions to a product amounting to more than one percent of its total anticipated life cycle GHG emissions. A materiality threshold of one percent has been established to ensure that minor sources of life cycle GHG emissions do not require the same treatment as more significant sources.

Natural or cross ventilation	Limited use of fans for cooling; frequently a building's sides can be opened to allow air circulation.
Offsetting	Mechanism for claiming a reduction in GHG emissions associated with a given process or product by removing or preventing the release of GHG emissions in an unrelated process or product.
Organic eggs	Eggs produced according to national/international organic standards covering various areas such as feeding practices, animal husbandry and housing system. Organic eggs are produced by hens fed on products grown without most conventional pesticides, fungicides, herbicides or commercial fertilizers. Antibiotics are prohibited. Hens must be free range.
Output	Product, material or energy that leaves a unit process.
Packing	Process of packing products in the production or distribution stages.
Primary data	Data directly measured or collected data representative of processes at a specific facility or for specific processes within the product supply chain.
Primary activity data	Quantitative measurement of activity from a product's life cycle which, when multiplied by an emission factor, determines the GHG emissions arising from a process. Examples include the amount of energy used, material produced, service provided or area of land affected.
Primary packaging materials	Items other than containers/packaging, which reach consumers (including additives for preservation).
Process centre	A facility where products are repackaged into smaller units without additional processing in preparation for retail sale.
Product parts	Cuts of meat for retail sale (e.g., breast/thigh meat, wings, livers).
Product(s)	Any good(s) or service(s). Services have tangible and intangible elements.
Proxy data	Secondary LCI data or unit process used to represent a similar unit process in the product system. For example, using a Chinese unit process for electricity production in an LCA for a product produced in Viet Nam.
Raw material	Primary or secondary material used to produce a product.
Removal	The sequestration or absorption of GHG emissions from the atmosphere, which most typically occurs when CO_2 is absorbed by biogenic materials during photosynthesis.
Rendering	A process that converts waste animal tissue into stable, value-added materials.
Residual	Material leaving the system in the condition as it created in the process, but which has a subsequent use. There may be value-added steps beyond the system boundary, but these activities do not impact the poultry system calculations. Materials with economic value are not considered residual.

Secondary data	Information obtained from sources other than direct measurement of the inputs/outputs (or purchases and emissions) from processes included in the life cycle of the product (PAS 2050:2011, 3.41). Secondary data are used when primary data are not available or it is impractical to obtain primary data. Some emissions, such as methane from litter management, are calculated from a model, and are therefore considered secondary data.
Secondary packaging materials	Containers/packaging and materials, which are used in raw materials acquisition, production and distribution but which do not reach consumers
Sink	A natural or artificial reservoir that accumulates and stores some carbon-containing chemical compound for an indefinite period.
Spent hen	Adult female poultry at the end of their productive life.
Stocking density	Spatial volume occupied by poultry.
System boundary	Set of criteria specifying which unit processes are part of a product system (life cycle).
System expansion	Expanding the product system to include additional functions related to co-products.
System, background	Stages of the supply chain which provide goods and services to the foreground system; not under the control of the study commissioner. See also: **System, foreground**.
System, backyard	Small-scale, free-range or caged productions where birds may be fed scraps or purchased rations. These may be found in urban areas or in rural subsistence areas (See **Village systems**).
System, caged	Birds are housed in indoor cages in groups of various sizes.
System, cage-free or barn	Birds are free to roam indoors, sometimes on multiple floor levels (aviary system). Flooring may consist of litter and/or other material such as slats or mesh.
System, foreground	The stages of the supply chain under the direct control of the commissioner of the LCA. For product developers and process operators, the foreground data is of special interest because direct changes in the system (involving other materials, designs, processes, etc.,) have direct effects on the result, while the background system impacts can be influenced only indirectly (by the choices above). See also: **System, background**.
System, free range	System where animals can range outdoors. The definition of “range” is variable depending on individual country requirements.
System, large-scale indoor	Birds are free to roam indoors over the floor, with litter, but cannot go outdoors. Birds may also be housed on tiered mesh structures with belts for manure removal.
System, organic	In addition to providing free-range conditions, these systems adhere to local country standards for organic production.
System, Village	Village systems allow free-range birds to scavenge for food; they may also be fed compound feed/concentrate rations.
Tunnel ventilation	Fans located at the building ends provide axial airflow.

Unit process	The smallest unit of analysis in a life cycle assessment. It is used to keep an account of the exchanges necessary to produce the reference flow of the product output from the operation being modeled. In preparing the LCI model of the system, many unit processes are linked, with the output from each one potentially used as an input exchange for another. Thus the LCI model is a representation of the supply chain necessary to produce the product from the top-most unit process in the model.
Volatile Solids (VS)	Volatile solids (VS) are the organic material in livestock manure and consist of both biodegradable and non-biodegradable fractions. The VS content of manure equals the fraction of the diet consumed that is not digested and thus excreted as faecal material which, when combined with urinary excretions, constitutes manure.
Waste	Materials for disposal that have no value, and may require further processing as part of the management of the materials. See also: **Residual**.

PART 1:

OVERVIEW AND GENERAL PRINCIPLES

1 INTENDED USERS AND OBJECTIVES

The methodology and guidance developed here can be used by stakeholders in all countries and across the entire range of poultry production systems. In developing the guidelines, it was assumed that the primary users will be individuals or organizations with a good working knowledge of life cycle assessment. The main purpose of the guidelines is to provide sufficient definition of calculation methods and data requirements to enable consistent application of LCA across differing poultry supply chains.

This guidance is relevant to a wide array of livestock stakeholders including:

- Livestock producers who wish to develop inventories of their on-farm resources and assess the performance of their production systems.
- Supply chain partners such as feed producers, farmers and processors seeking a better understanding of the environmental performance of products in their production processes.
- Policy makers interested in developing accounting and reporting specifications for livestock supply chains.

The benefits of this approach include:

- Use of recognized, robust and transparent methodology developed to take account of the nature of poultry supply chains;
- Identification of supply chain hotspots and opportunities to improve and reduce environmental impact;
- Identification of opportunities to increase efficiency and productivity;
- Ability to benchmark performance internally or against industry standards;
- Supporting reporting and communication requirements;
- Raising awareness and supporting action on environmental sustainability.

2 SCOPE

2.1 Environmental impact categories addressed in the guidelines

These guidelines cover only the following environmental impact categories: climate change, and fossil energy demand. This document does not provide support towards the assessment of comprehensive environmental performance, nor to the social or economic aspects or poultry supply chains.

The environmental impact categories were selected by the Technical Advisory Group (TAG) members, based on the following criteria:

- Relevance for the feed and livestock sectors as well as to the agendas of governments, intergovernmental organizations, non-government organizations, civil society and private sector;
- Agreement in the LCA community on the validity of the impact categorization model (scientific consensus);
- Quality and availability of characterization factors;
- Local versus global level of impact.

The LEAP Animal Feed Guidelines cover additional impact categories: acidification, eutrophication, and land use. These categories may be reported for the life cycle stages of poultry products. It is intended that in future these guidelines will be updated to include multiple categories.

Biodiversity loss, phosphorus depletion, water consumption, depletion of marine resources, soil degradation, and eco-toxicity are other environmental impacts that the TAG considered highly relevant but for which no consensual quantification techniques are available. For this reason, they could not be included in the guidelines. Human toxicity, ozone depletion, ionising radiation and photochemical ozone formation were estimated to be less important impact categories.

In the LEAP Animal Feed Guidelines, GHG emissions from direct land-use change is analysed and recorded separately from GHG emissions due to other sources. There are two reasons for doing this. The first is a question of time frame because emissions attributed to land-use change may have occurred in the past or may be set to occur in the future. Secondly, there is much uncertainty and debate about the best method for calculating direct land-use change.

Regarding land use, the LEAP Animal Feed Guidelines divided land areas into two categories: arable land and grassland. Appropriate indicators were included in the guidelines as they provide important information about the use of a finite resource (land) but also in view of the follow-on impacts on soil degradation, biodiversity, carbon sequestration or loss, water depletion, etc. Nevertheless, users wishing to specifically relate land use to follow-on impacts will need to collect and analyse additional information on production practices and local conditions.

2.2 Application

Some flexibility in methodology is desirable to accommodate the range of possible goals and special conditions arising in different sectors. This document strikes a pragmatic balance between flexibility and rigorous consistency across scale, geographic location, and project goals.

A more strict prescription on the methodology, including allocation and acceptable data sources, is required for product labelling or comparative performance claims. Users are referred to ISO 14025 for more information and guidance on comparative claims of environmental performance.

These guidelines are generally based on the attributional approach to life cycle accounting. The approach refers to process-based modelling, intended to provide a static representation of average conditions.

Due to the limited number of environmental impact categories covered here, results should be presented in conjunction with other environmental metrics to understand the wider environmental implications, either positive or negative. It should be noted that comparisons between final products should only be based on full life cycle assessment. Users of these guidelines shall not employ results to claim overall environmental superiority of some poultry production systems and products.

The methodology and guidance developed in the LEAP Partnership is not intended to create barriers to trade or contradict any WTO requirements.

3 STRUCTURE AND CONVENTIONS

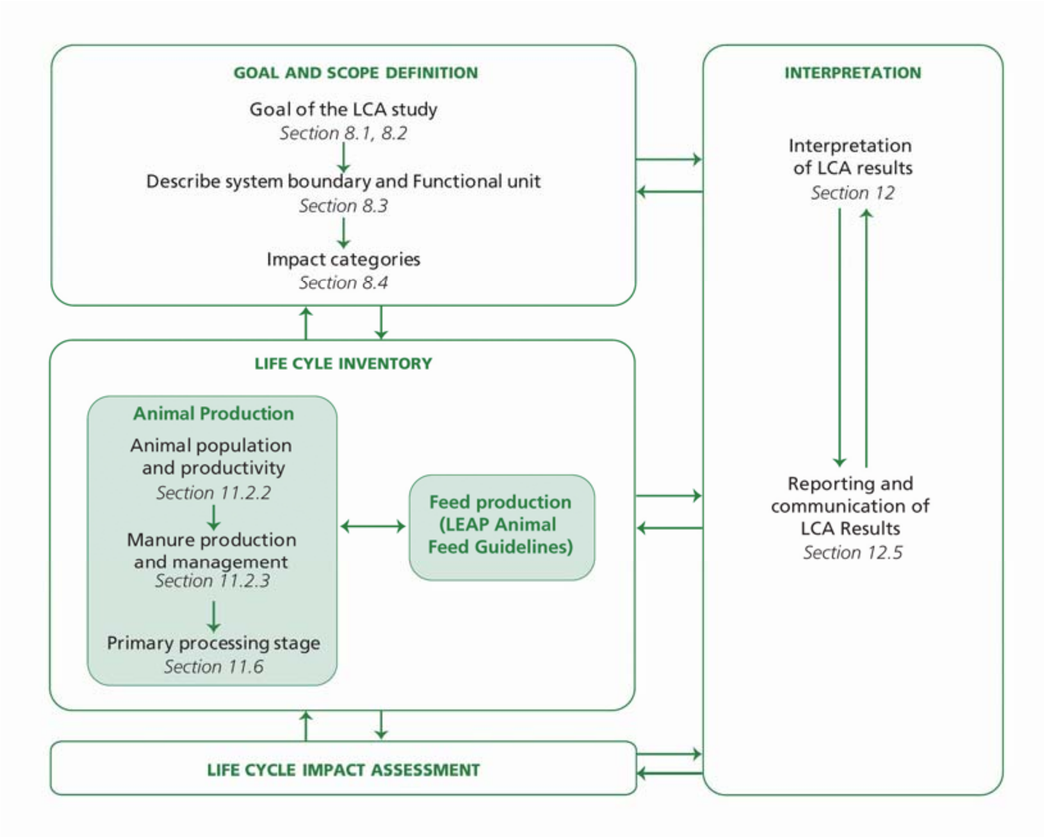
3.1 Structure

This document adopts the main structure of ISO 14040:2006 and the four main phases of Life Cycle Assessment – goal and scope definition, inventory analysis, impact assessment, and interpretation. Figure 1 presents the general relationship between the phases of an LCA study defined by ISO 14040:2006 and the steps needed to complete a GHG inventory in conformance with this guidance. Part 2 of this methodology sets out the following:

- Section 7 outlines the operational areas to which these guidelines apply.
- Section 8 includes requirements and guidance to help users define the goals and scope, and system boundary of an LCA.
- Section 9 presents the principles for handling multiple co-products and includes requirements and guidance to help users select the most appropriate allocation method to address common processes in their product inventory.
- Section 10 presents requirements and guidance on the collection and assessment of the quality of inventory data as well as on identification, assessment, and reporting on inventory uncertainty.
- Section 11 outlines key requirements, steps, and procedures involved in quantifying GHG emissions and other environmental impact inventory results in the studied supply chain.
- Section 12 provides guidance on interpretation and reporting of results and summarizes the various requirements and best practice in reporting.

A glossary intended to provide a common vocabulary for practitioners has been included. Additional information is presented in the appendices.

FIGURE 1: MAIN LIFE CYCLE STEPS IN THE POULTRY SUPPLY CHAIN



Users of this methodology should also refer to other relevant guidelines where necessary and indicated. The LEAP poultry guidelines are not intended to stand alone but are meant to be used in conjunction with the LEAP Animal Feed Guidelines. Relevant guidance developed under the LEAP Partnership but contained in other documents will be specifically cross-referenced to enable ease of use. For example, specific guidance for calculating associated emissions for feed is contained in the LEAP Animal Feed Guidelines.

3.2 Presentational conventions

These guidelines are explicit in indicating which requirements, recommendations, or permissible or allowable options that users may choose to follow.

The term “shall” is used to indicate what is required for an assessment to conform to these guidelines.

The term “should” is used to indicate a recommendation, but not a requirement.

The term “may” is used to indicate an option that is permissible or allowable.

Commentary, explanations and general informative material (e.g. notes) are presented in footnotes, and do not constitute a normative element.

Examples illustrating specific areas of the guidelines are presented in boxes.

4 ESSENTIAL BACKGROUND INFORMATION AND PRINCIPLES

4.1 A brief introduction to LCA

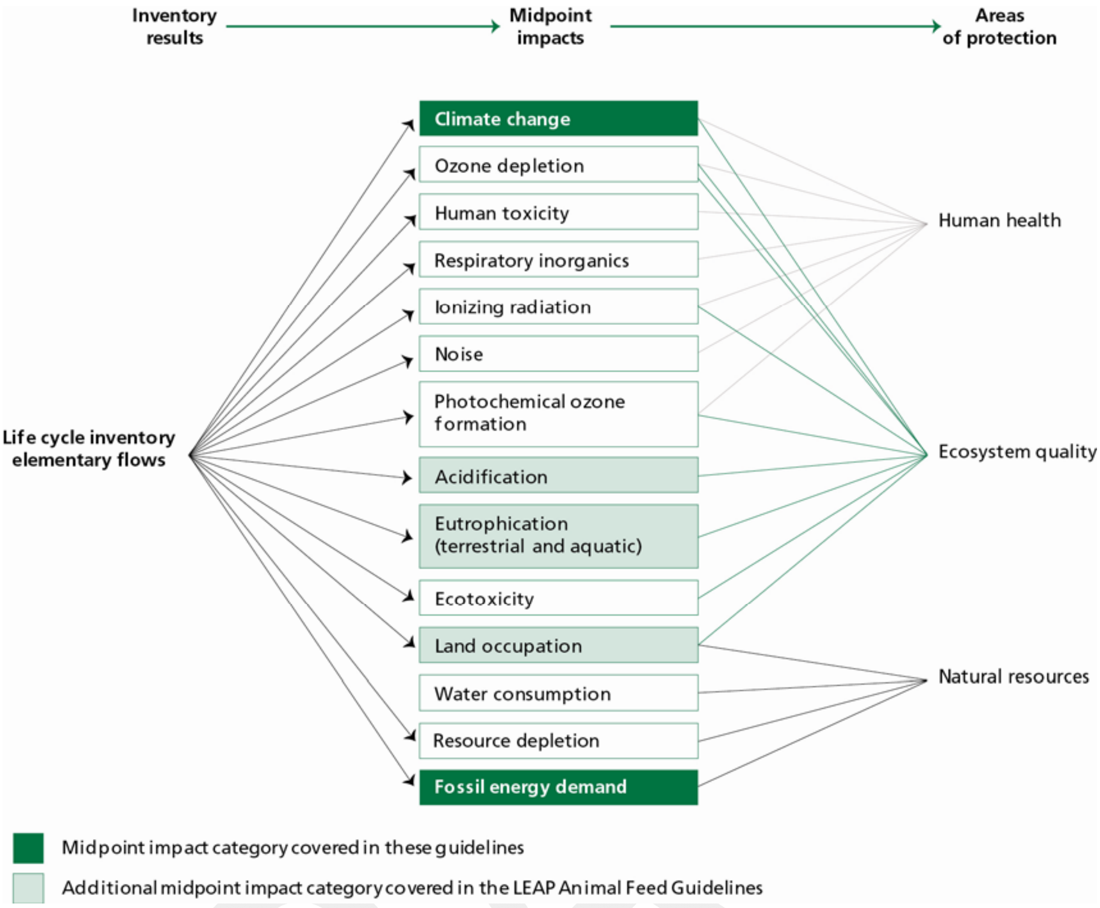
Life cycle assessment (LCA) is recognized as one of the most important methods developed to assess the environmental impact of products and processes. LCA can be used as a decision support tool within environmental management. ISO 14040:2006 defines LCA as a “compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle”. In other words, LCA provides quantitative, confirmable, and manageable process models to evaluate production processes, analyse options for innovation, and improve understanding of complex systems. LCA can identify processes and areas where process changes stemming from research and development can significantly contribute to reduce environmental impacts. According to ISO14040:2006, LCA consist of four phases (Figure 1):

- Goal and scope definition – including appropriate metrics (e.g. greenhouse gas emissions, water consumption, hazardous materials generated, and/or quantity of waste);
- Life cycle inventories (collection of data that identify the system inputs and outputs and discharges to the environment);
- Performance of impact assessment (application of characterization factors to the LCI emissions which normalizes groups of emissions to a common metric such as global warming potential reported in CO_2 equivalents);
- Analysis and interpretation of results.

4.2 Environmental impact categories

Life Cycle Impact Assessment (LCIA) aims at understanding and evaluating the magnitude and significance of potential environmental impacts for a product system throughout the life cycle of the product (ISO 14040:2006). The selection of environmental impacts is a mandatory step of LCIA and this selection shall be justified and consistent with the goal and scope of the study (ISO 14040:2006). Impacts can be modelled at different levels in the environmental cause-effect chain linking elementary flows of the life cycle inventory to midpoint and areas of protection (Figure 2).

FIGURE 2: ENVIRONMENTAL CAUSE-EFFECT CHAIN AND CATEGORIES OF IMPACT



Source: adapted from (ILCD, 2010)

A distinction must be made between midpoint impacts (which characterize impacts somewhere in the middle of the environmental cause-effect chain), and endpoint impacts (which characterize impacts at the end of the environmental cause-effect chain). Endpoint methods provide indicators at, or close to, an area of protection. Usually three areas of protection are recognized: human health, ecosystems, and natural resources. The aggregation at endpoint level and at the areas of protection level is an optional phase of the assessment according to ISO 14044:2006.

Climate change is an example of a midpoint impact category. The results of the Life Cycle Inventory are the amounts of greenhouse gas emissions per functional unit. Using a characterization model and a characterization factor such as the global warming potential for each gas these results can be expressed under the same midpoint impact category indicator, i.e. kilograms of CO_2 equivalents per functional unit.

These guidelines provide guidance on a selection of midpoint impact categories and indicators (Figure 2). They do not, however, provide guidance or recommendations regarding endpoint methods.

4.3 Normative references

The following referenced documents are indispensable in the application of this methodology and guidance.

- ISO 14040:2006 *Environmental management – Life cycle assessment – Principles and framework*
  These standards give guidelines on the principles and conduct of LCA studies providing organizations with information on how to reduce the overall environmental impact of their products and services. ISO 14040:2006 define the generic steps which are usually taken when conducting an LCA and this document follows the first three of the four main phases in developing an LCA: Goal and scope, Inventory analysis, Impact assessment and Interpretation (ISO 14040:2006).
- ISO14044:2006 *Environmental management – Life cycle assessment – Requirements and guidelines*
  ISO 14044:2006 specifies requirements and provides guidelines for life cycle assessment including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, relationship between the LCA phases, and conditions for use of value choices and optional elements (ISO 14044:2006).
- ISO 14025:2006 *Environmental labels and declarations – Type III environmental declarations – Principles and procedures*
  ISO 14025:2006 establishes the principles and specifies the procedures for developing Type III environmental declaration programmes and Type III environmental declarations. It specifically establishes the use of the ISO 14040:2006 in the development of Type III environmental declaration programmes and Type III environmental declarations.
  Type III environmental declarations are primarily intended for use in business-to-business communication, but their use in business-to-consumer communication is not precluded under certain conditions (ISO 14025:2006).
- ISO/TS 14067:2013 *Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification and communication*
  It specifies principles, requirements and guidelines for the quantification and communication of the carbon footprint of a product (CFP), based on ISO 14040 and ISO 14044 for quantification and on environmental labels and declarations (ISO 14020, ISO 14024 and ISO 14025) for communication (ISO/TS 14067:2013).
- WRI/WBCSD (2011) *Product Life Cycle Accounting and Reporting Standard*
  The GHG Protocol from the World Resources Institute & World Business Council for Sustainable Development (WRI/WBCSD, 2011) provides a framework to assist users in

estimating the total GHG emissions associated with the life cycle of a product. It is broadly similar in its approach to the ISO standards, although it lays more emphasis on analysis, tracking changes over time, reduction options and reporting. Like PAS2050, this standard excludes impacts from production of infrastructure, but whereas PAS2050 includes 'operation of premises' such as retail lighting or office heating, the GHG Protocol does not.

- British Standards Institution PAS 2050:2011 *Specification for the assessment of life cycle greenhouse gas emissions of goods and services* (PAS 2050, 2011).

  It is a Publicly Available (i.e. not standard) Specification. A UK initiative sponsored by the Carbon Trust and Defra, PAS 2050 was published through the British Standards Institution (BSI) and uses BSI methods for agreeing a Publicly Available Specification. It is targeted at applying LCA over a wide range of products in a consistent manner for industry users, focusing solely on the carbon footprint indicator. PAS 2050, 2011 has many elements in common with the ISO 14000 series methods but also a number of differences, some of which limit choices for analysts (e.g. exclusion of capital goods and setting materiality thresholds).

4.4 Guiding principles

Five guiding principles support users in their application of this sector-specific methodology. These principles are consistent across the methodologies developed within the LEAP Partnership. They apply to all the steps, from goal and scope definition, data collection and LCI modelling through to reporting. Adhering to these principles ensures that any assessment made in accordance with the methodology prescribed is carried out in a robust and transparent manner. The principles can also guide users when making choices not specified by the guidelines.

The principles are adapted from the WBCSD-WRI's Greenhouse Gas Protocol Product Life Cycle Accounting and Reporting Standard, the BSI PAS 2050:2011, the ILCD Handbook and ISO/TS 14067:2013 and are intended to guide the accounting and reporting environment impacts categories.

Accounting and reporting of GHG emissions and other environmental impacts from poultry supply chains shall accordingly be based on the following principles:

Relevance

Data, accounting methodologies and reporting shall be appropriate to the decision-making needs of the intended users. Information should be reported in a way that is easily understandable to the intended users.

Completeness

All product life cycle GHG emissions, removals and sinks, and other environmental criteria within the specified system and temporal boundaries under study, shall be reported. Any specific exclusion shall be disclosed and justified.

Consistency

Consistent methodologies, data and assumptions shall be used throughout the assessment to allow for meaningful comparisons and reproducibility of the outcomes over time. Any changes to the data, boundaries, assumptions, methods, or any other relevant factors shall be reported and documented.

Accuracy

Bias and uncertainties shall be reduced as far as practicable. Sufficient accuracy shall be achieved to enable intended users to make decisions with reasonable confidence as to the reliability and integrity of the reported information.

Transparency

In external communications, sufficient information shall be disclosed and appropriate references made to allow third parties to verify all data, calculations and assumptions, and intended users to make associated decisions with confidence. A clear audit trail shall address all the relevant issues in a factual and coherent manner.

5 LEAP AND THE PREPARATION PROCESS

LEAP is a multi-stakeholder initiative launched in July 2012 with the goal of improving the environmental performance of livestock supply chains. Hosted by the Food and Agriculture Organization of the United Nations, LEAP brings together the private sector, governments, civil society representatives and leading experts who have a direct interest in the development of science-based, transparent and pragmatic guidance to measure and improve the environmental performance of livestock products.

Demand for livestock products is projected to grow 1.3 percent per annum until 2050, driven by global population growth and increasing wealth and urbanization (Alexandratos and Bruinsma, 2012). Against the background of climate change and increasing competition for natural resources, this projected growth places significant pressure on the livestock sector to perform in a more sustainable way. The identification and promotion of the contributions that the sector can make towards more efficient use of resource and better environmental outcomes is also important.

Currently, many different methods are used to assess the environmental impacts and performance of livestock products. This causes confusion and makes it difficult to compare results and set priorities for continuing improvement. With increasing demands in the marketplace for more sustainable products there is also the risk that debates about how sustainability is measured will distract people from the task of driving real improvement in environmental performance. And there is the danger that labelling or private standards based on poorly developed metrics could lead to erroneous claims and comparisons.

The LEAP Partnership addresses the urgent need for a coordinated approach to developing clear guidelines for environmental performance assessment based on international best practices. The scope of LEAP is not to propose new standards but to produce detailed guidelines that are specifically relevant to the livestock sector, and refine guidance as to existing standards. LEAP is a multi-stakeholder partnership bringing together the private sector, governments and civil society. These three groups have an equal say in deciding work plans and approving outputs from LEAP, thus ensuring that the guidelines produced are relevant to all stakeholders, widely accepted and supported by scientific evidence.

With this in mind, the first three technical advisory groups (TAGs) of LEAP were formed in early 2013 to develop guidelines for assessing the environmental performance of small ruminants (goats and sheep), animal feeds and poultry supply chains.

The work of LEAP is challenging but vitally important to the livestock sector. The diversity and complexity of livestock farming systems, products, stakeholders and environmental impacts can only be matched by the willingness of the sector's practitioners to work together to improve performance. LEAP provides the essential backbone of robust measurement methods to enable assessment, understanding and improvement in practice. More background information on the LEAP Partnership can be found at www.fao.org/partnerships/leap/en/.

5.1 Development of sector-specific guidelines

Sector-specific guidelines to assessing the environmental performance of the livestock sector are a key aspect of the LEAP Partnership work programme. Such guidelines take into account the nature of the livestock supply chain under investigation and are developed by a team of experts with extensive experience in life-cycle assessment and livestock supply chains.

The benefit of a sector-specific approach is that it gives guidance on the application of life-cycle assessment to users and provides a common basis from which to evaluate resource use and environmental impacts.

Sector-specific guidelines may also be referred to as supplementary requirements, product rules, sector guidance, product category rules or product environmental footprint category rules – although each programme will prescribe specific rules to ensure conformity and avoid conflict with any existing parent standard.

The first set of sector-specific guidelines addresses animal feeds, poultry and small ruminants. The former two place emphasis on climate-related impacts, while the LEAP Animal Feed Guidelines address a broader range of environmental categories. LEAP is also considering developing guidance for the assessment of other animal commodities and wider environmental impacts such as biodiversity, water and nutrients.

5.2 The Poultry TAG and the preparation process

The Poultry TAG of the LEAP Partnership was formed at the start of 2013. The team included selected nine experts in poultry supply chains as well as leading LCA researchers and experienced industry practitioners. Their backgrounds, complementary between products, systems and regions, allowed them to understand and address different interest groups and so ensure credible representation. The TAG was led by Dr Greg Thoma of the University of Arkansas, USA.

The role of the TAG was to:

- Review existing methodologies and guidelines for assessment of GHG emissions from livestock supply chains and identify gaps and priorities for further work;
- Develop methodologies and sector specific guidelines for the life cycle assessment of GHG emissions from poultry supply chains; and
- Provide guidance on future work needed to improve the guidelines and encourage greater uptake of life-cycle assessment of GHG emissions from poultry supply chains.

The TAG met for its first workshop from 12-14 February 2013. The TAG continued to work via email and teleconferences before holding a second workshop from 5-7 September 2013 in Rome. The nine experts in the TAG were drawn from seven countries: Australia, Bangladesh, Brazil, Japan, Senegal, United Kingdom and the United States.

As a first step, existing studies and associated methods were reviewed by the TAG to assess whether they offered a suitable framework and orientation for a sector-specific approach. This avoids confusion and unnecessary duplication of work through the development of potentially competing standards or approaches. The review also followed established procedures set by the overarching international guidance sources listed in section 4.3.

Eighteen studies addressing aspects of the poultry meat or egg supply chains were identified by the TAG. The selection of these studies for background review in support of the development of these guidelines was driven by the availability of full LCA studies in the poultry sector. The interest was in determining the range of methodological choices that have been used. The intention was to evaluate as broadly as possible and therefore included peer-reviewed articles, theses and dissertations, and conference proceedings. These sources allowed an evaluation of the methodological consistencies and differences for global systems. A review of these studies can be found in Appendix 0. As a result, it was found that no existing approach or study set out comprehensive guidance for quantifying GHG emissions and fossil energy demand across the supply chain and that further work was needed by the TAG to reach consensus on more detailed guidance. The Japanese Carbon Footprint Product Category Rules, or CFP-PCRs,[3] including PA-CN-01 for eggs and PA-CP-01 for chicken meat, have however acted as an important guiding instrument in the development of the methodology and guidance offered here (JEMAI, 2011a, 2011b).

5.3 Period of validity

It is intended that these guidelines will be periodically reviewed to ensure the validity of information and methodologies on which it relies Because there is not currently a mechanism in place to ensure such review in the future, users are invited to visit the LEAP website (www.fao.org/partnerships/leap) for the latest version.

6 BACKGROUND INFORMATION ON POULTRY SUPPLY CHAINS

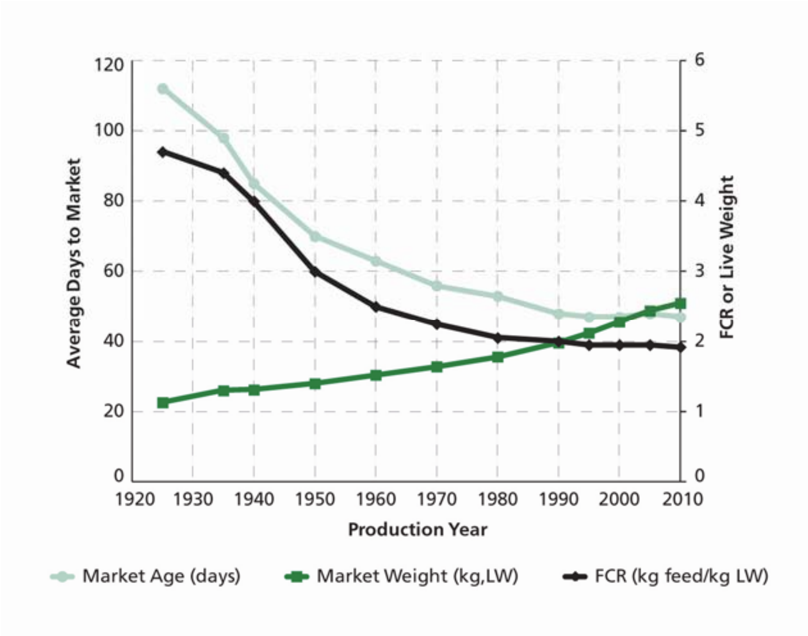
6.1 Background and context

Poultry is the most diffused domestic animal species in the world. The global poultry population in 2010 was estimated at almost 22 billion birds, nearly three times as many as in 1980, with chickens (including nearly 6 billion laying hens) making up 90 percent of the total. Other poultry including ducks, geese, and turkeys make up 6 percent, 2 percent and 2 percent, respectively (Macleod et al., 2013). In addition, quail eggs are also mainly produced in Latin America, Asia and Europe. Hatching poultry has been used on a commercial scale since the 1870s and today poultry is a rapidly expanding livestock sector. Modern poultry production systems emerged in the late nineteenth century in Europe and America as breeders focused on improving meat and egg production, and it has subsequently spread across the globe. Continued research and innovation in breeding, feeding, disease controls, housing, and processing have resulted in continual improvement of the sector. Specialization in raising broilers and layers has been important in the sector's expansion.

Chickens raised for eggs are usually called layers while chickens raised for meat are often called broilers. Second to fish, chickens are the most efficient converters of grain to food. The poultry sector has made huge strides in feed conversion in the past 75-100 years as shown by Figure 3, which tracks efficiency improvements in market age, weight, and feed-to-meat gain in the United States since 1925.

[3] Japanese CFP-PCRs are available online: http://www.cms-cfp-japan.jp/english/pcr/pcrs.html

FIGURE 3: HISTORICAL PERFORMANCE IMPROVEMENT IN US BROILER PRODUCTION EFFICIENCY

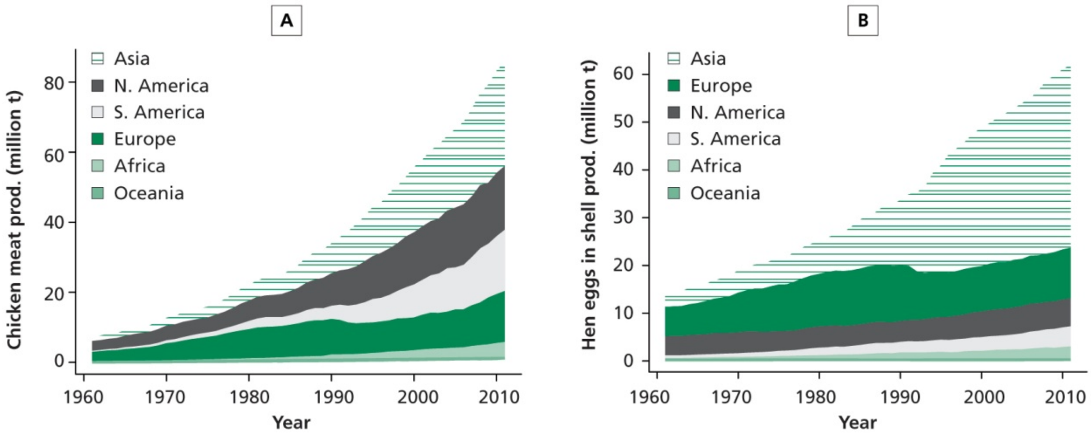


Source: National Chicken Council: Us broiler performance[4], 2010

Nevertheless, there are wide differences in the scale, goals and types of system that produce meat and eggs from poultry. These may range from smallholder backyard subsistence systems (in developing economies) to backyard systems that are small-scale but not subsistence-oriented (in developed countries, often operated by non-agriculturalists). There are also various types of indoor systems including some that allow outdoor access with or without safeguards against infectious diseases and/or protection against predators. Some systems offer detailed management and housing prescriptions (for example on the use of organic feed).

[4] http://www.nationalchickencouncil.org/

FIGURE 4: TRENDS IN GLOBAL PRODUCTION FROM THE POULTRY SECTOR: (A) CHICKEN MEAT AND (B) HEN EGGS



Source: (FAOSTAT, 2011)

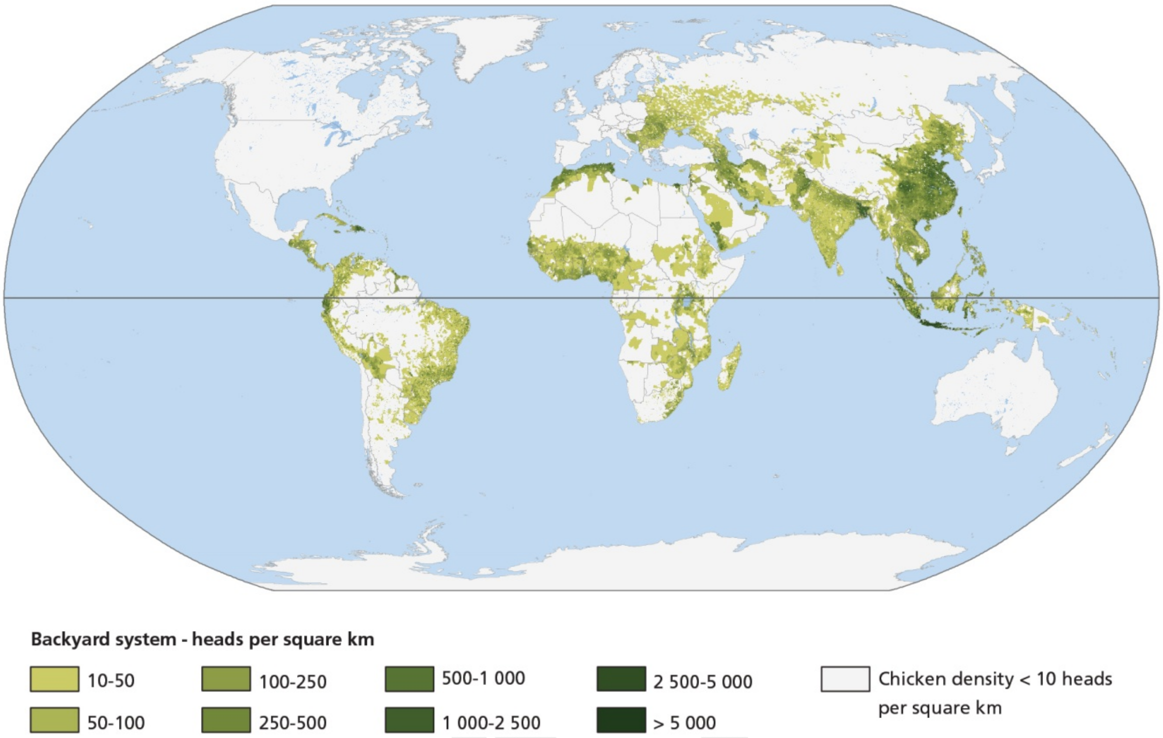
6.2 Diversity of poultry production systems

Poultry production systems can be classified on the basis of scale, feed sources and animal genetics. Feed represents a major component of poultry supply chains. The possibility of producing feed far from poultry production sites and of shipping it by energy-efficient sea transport has enabled many poor agricultural regions to develop poultry sector. These first arose in Europe (Germany, Netherlands, and France), and the United States and they are now making headway in the developing economies.

6.2.1 BACKYARD PRODUCTION

Backyard production systems can be divided into subsistence-driven (in developing and developed economies), "specialty production" – where small-scale farms produce for private consumption, local markets or specialty restaurants or food chains – and "hobby". In developing countries, production is aimed not only at local markets but also at specific high-priced outlets (up to 5 percent of the market for backyard and intermediate systems). Backyard animal performance is mostly lower than in intermediate and high- level production systems. In "specialty" or "hobby" production in developing economies, poultry are often fed swill and locally-sourced materials. The use of purchased feed varies widely and such systems tend to raise local or specialty breeds. Figure 5 shows the global distribution of poultry in backyard systems.

FIGURE 5: GLOBAL DISTRIBUTION OF BACKYARD CHICKEN PRODUCTION



Source: (Macleod et al., 2013)

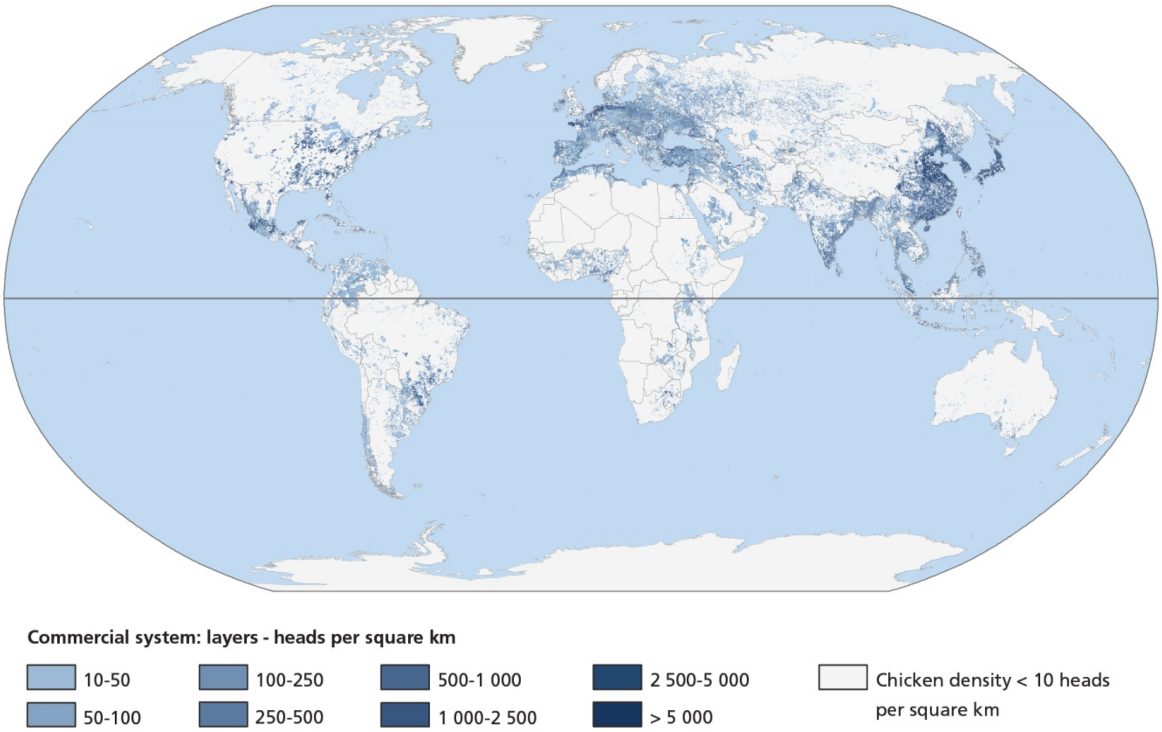
6.2.2 INTERMEDIATE PRODUCTION

These are market-oriented production systems that often rely on partially enclosed housing and a medium level of capital input. Feed materials may be locally sourced for 30 to 50 percent of the ration. Birds are generally provided with regular access to water, improved shelter and care of chicks at an early age, vaccination against prevalent diseases and deworming. Interestingly, in upcoming economies farmers often move from private subsistence to somewhat larger systems using modern breeds, selling their products either on the local markets or via (sometimes jointly organized) distribution/processing channels. In developed economies, a range of medium-scale specialty production systems are also intermediate, often with closed housing and outside runs (with or without cover for appropriate disease protection). They may be set among bushes or trees and accredited for organic labelling (requiring that they use organic feed and meet a number of specific conditions). Intermediate systems frequently have a reduced level of performance compared with high-level intensive systems.

6.2.3 COMMERCIAL/LARGE SCALE PRODUCTION

These are large-scale market-oriented poultry production systems, usually with fully enclosed housing, high capital input requirements (including infrastructure, buildings and equipment) and non-local purchased feed, or feed produced on-farm with a high level of inputs. Large-scale systems have high overall herd performance. Intensive systems may involve contract farming, with the integrators usually supplying chicks, feed, technical and animal health services, and purchasing the meat or eggs at the end of the production cycle. Figure 6 shows the global distribution of layers, and Figure 7 shows global distribution of broilers.

FIGURE 6: GLOBAL DISTRIBUTION OF CHICKEN – LAYERS

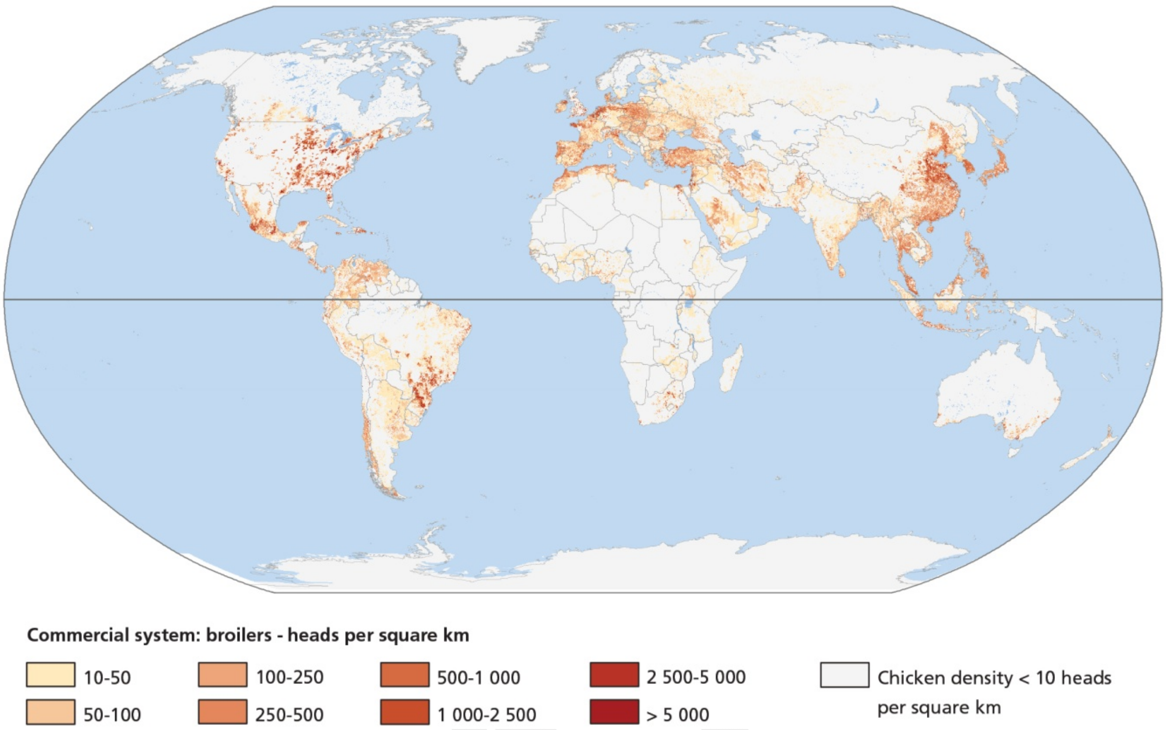


Source: (Macleod et al., 2013)

Poultry supply chains are complex. They involve natural processes that are difficult to control and measure, and are characterized by many different farming systems that may vary significantly in: number of actors, supply chain lengths and number of products and co-products, and levels of integration.

Feed represents a major component of poultry supply chains. Feed production often takes place a considerable distance away from the animal rearing site, and at times in different regions. Examples of the diversity of poultry primary processing systems and products are given below.

FIGURE 7: CHICKEN POPULATION DENSITY – BROILERS



Source: (Macleod et al., 2013)

6.2.4 EGG-LAYING CHICKENS

Egg-laying hens usually begin laying at 16–20 weeks of age, with egg production remaining constant over long periods and reaching over 300 eggs per annum in some cases. Dual-purpose chickens lay fewer eggs. In backyard or diversified systems, hens surviving the high day-old-chick mortality rates – due to disease or predators – may live for five or more years.

Environmental controls such as air flow and lighting are often used to mimic natural conditions in egg-laying systems. For example, the duration of the light phase is initially increased to prompt the beginning of egg-laying at 16–20 weeks of age and then mimics summer day length, which stimulates the hens to continue laying all year round (under natural conditions, egg production usually decreases and stops with decreasing length of daylight). In those breeds which produce only in the warmer months, life cycle impact assessment shall account for the non-productive months too.

Examples of laying systems include:

- **Backyard systems:** Backyard systems can best be described as a small farming system in which a sufficient number of hens are raised to provide eggs for a single family or to sell at local farmers' markets. The system is typically similar to the free-range laying hen system below, but on a smaller scale.

- **Free-range laying hens:** Free-range poultry farming allows chickens to roam freely for a part of the day, although they are usually confined in sheds to protect them from predators at night or when necessary due to bad weather. Excessive heat, cold or damp can have harmful effects on free-range poultry and their productivity. Free-range farmers also have less control than farmers using cages over what food their chickens eat. This can lead to lower productivity.
- **Organic laying hens:** In organic egg-laying systems, chickens are also free range. All organic production systems require that rations are organically produced according to regional or national standards and regulations. Organic systems also restrict or ban the routine use of yolk colorants, medications (including antibiotics), and synthetic amino acids.
- **Conventional cages:** Most hens in many countries are reared in cages which house from three to eight hens. Cages are usually constructed of solid metal or mesh, and floors are meshed to allow the faeces to drop through and eggs to roll onto an egg-collecting conveyor belt. The cages are arranged in long rows and multiple tiers, often with cages back-to-back. In farms using cages for egg production, there are more birds per unit area, allowing for greater productivity and lower feed costs. Feed and water are often provided by automatic feeding and watering systems. In many modern systems, the birds' environment is closely controlled through computerized systems.
- **Enriched cages for laying hens:** Enriched cages for egg-laying hens are designed to meet animal welfare concerns over conventional cages while maintaining part of their economic benefit. Enriched cages provide some facilities such as scratch areas and separate nesting areas or perches in an effort to provide conditions similar to free-range systems.
- **Egg products systems:** Birds in these operations are typically housed in conventional cages, some maybe in the new enriched cage system. The only difference is the close proximity to the site where these eggs are either packed (shell eggs) or broken (processing for liquid or dry powders). These systems are common in the United States, but less so elsewhere.

6.2.5 MEAT-PRODUCING CHICKENS

Chickens raised for meat, commonly called broilers, are normally raised indoors in climate-controlled housing with floors covered in litter such as wood shavings or rice hulks. Under modern farming methods, such chickens reach slaughter weight at 5-7 weeks of age.

- **Backyard Systems:** Backyard broiler systems are similar to the free-range broiler system described below, but are typically smaller. In some countries these systems mostly produce meat for the family farm but in others, birds may be sold to the live bird market. Eggs may also be produced in backyard broiler systems.

- **Free-range broilers:** Free-range broilers are reared under conditions similar to those of free-range, laying hens. While the birds raised in free-range systems may be allowed outdoors, many stay inside the barn for comfort and security from weather and predators. In some countries free range systems use specific breeds which grow more slowly than those in intensive production and which reach slaughter weight no sooner than at eight weeks of age.
- **Organic broiler chickens:** Organic broilers can be raised either in the backyard or free-range systems described above. Regulations are region-specific but all require that feed is produced according to relevant organic standards[5], which generally also include restrictions on the routine use of certain additives and medications Chickens raised in organic systems generally have more room and reach slaughter age later. Specific regulations and labelling requirements for organic chickens usually preclude their being fed or treated with antibiotics.
- **Modern broiler production:** Broilers are normally raised in large, open barns, some of them up to 182 meters long and 20 meters wide; but some premium-label broilers are kept in cages during the final growth phase. The floors of the houses are covered with litter consisting of wood chips, rice hulks, or peanut shells. Barns are frequently equipped with automatic systems to deliver feed and water. They have ventilation and heaters which may be computer-operated in order to closely control the environment inside the barn. Older barn houses are equipped with curtain walls which can be rolled up in good weather to admit natural light and fresh air. Modern barns are completely enclosed and use tunnel ventilation in which several fans are used to pull air through the ban to maintain fresh air and to control temperature. A wide variety of management systems are used, with low to high-level optimization of living conditions.

Examples of post-farm processes include:

- Integrated abattoirs where poultry are slaughtered and processed into a very wide range of meat products and co-products. The latter include feathers and blood (for meal and pharmaceutical products), tallow (for soap or biofuel), internal organs and meat waste (for pet food), material for rendering (e.g. for fertilizer).
- Specialist egg processing plants that produce a wide range of basic products including liquid or dry eggs or yolks.

A large number of secondary processing systems also exist and no attempt is made to describe them here. Examples include transforming meat into specialist cuts or into final processed products such as cooked meals pre-packed for retailers.

[5] Codex Alimentarius - Organically Produced Foods: http://www.fao.org/docrep/005/y2772e/y2772e0b.htm#bm11.2.1

6.3 Multi-functionality of poultry supply chains

Farmers deciding to keep poultry may do so with many objectives in mind. Poultry plays an important role in the food security and livelihoods of farmers by providing meat and eggs for their consumption as well as income from the sale of poultry products. At global level, poultry production often takes place in less favoured regions and in poor, remote areas where alternative sources of income may be difficult to find. This means that in many cases the future of rural areas is closely dependent on the viability of the local poultry sector.

Poultry production in Europe and the United States developed from such humble origins and by following similar poor-to-rich trajectory, the sector is expected to make a significant contribution to economic growth in the Southern Hemisphere over the next 10 to 20 years.

Smallholder poultry production systems are multi-functional. While the first objective of the poultry sector is to produce meat and eggs, it also delivers a number of other valuable commodities such as chicken manure, or litter, which is sought-after as a natural fertilizer. In most Asian countries, for example, the price of chicken manure varies from US$5 to US$10 per tonne (IAEA, 2008) and it reaches almost US$30 per tonne in the United States. In some countries, chicken manure is also sold pelletized and burned as renewable fuel for electricity generation either on- or off-farm.

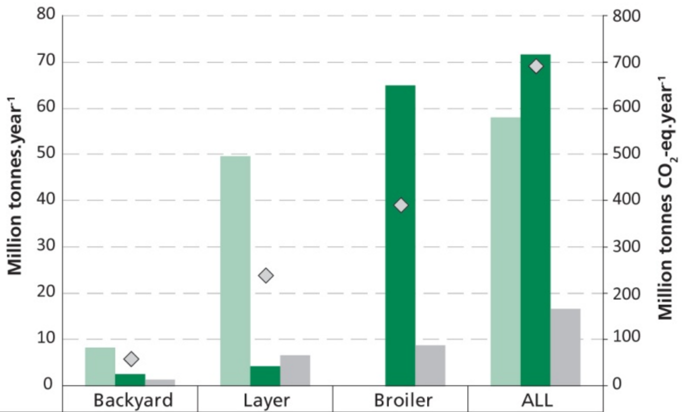
Poultry serves important social functions in different regions of the world. Chickens represent a valuable source of income for women in rural areas and they are often used as dowry and as religious offerings.

6.4 Overview of global emission from poultry supply chains

According to one global-scale analysis (Macleod et al., 2013), production of poultry meat and eggs is estimated to account for 8 percent of the global annual emissions of greenhouses gases from the livestock sector, or 606 million tonnes of CO_2 equivalent. The average emission intensity of broilers is estimated at 5.4 kg of CO_2 equivalent per kg of carcass weight, and for layers at 3.5 kg of CO_2 equivalent per kg of eggs. Poultry production is highly dependent on imported feed in large-scale operations. Such production is responsible for 57 percent of the sector's emissions, including 18 percent from land-use change to accommodate more feed crops. Emissions associated with manure storage, removal and processing are also significant at 11 percent. Overall emissions increase from backyard, to layer, to broiler systems. This is explained by the fact that the latter rear several generations of chickens in a year and use feed rations with high protein content. Total annual production and estimated emissions from all poultry systems are shown in Figure 8.

Gerber et al. (2013) estimate the mitigation potential for reducing GHG emission in poultry supply chains at 14 percent. This estimate is based on several assumptions including constant output, no farming system change, and adoption of the most efficient production practices. Such practices include improvement of feed conversion, best manure management, reduction of animal mortality in backyard systems, and animal health. However, as the poultry sector is expected to grow in coming years, mitigation options will need to address the reduction of emission intensity, but also emissions raised by increased demand.

FIGURE 8: GLOBAL CHICKEN PRODUCTION AND ESTIMATED EMISSIONS BY SYSTEM



	Backyard	Layer	Broiler	ALL
Million tonnes EGG.year^{-1}	8.3	49.7	-	58.0
Million tonnes CW.year^{-1}	2.7	4.1	64.8	71.6
Million tonnes protein.year^{-1}	1.4	6.7	8.8	16.8
◇ Million tonnes CO_2-eq.year^{-1}	52.4	210.3	343.3	606.1

Source: GLEAM, (Macleod et al., 2013)

PART 2:

METHODOLOGY FOR QUANTIFICATION OF GREENHOUSE GAS EMISSIONS AND FOSSIL ENERGY DEMAND OF POULTRY PRODUCTS

7 DEFINITION OF PRODUCTS AND PRODUCTION SYSTEMS

7.1 Products description

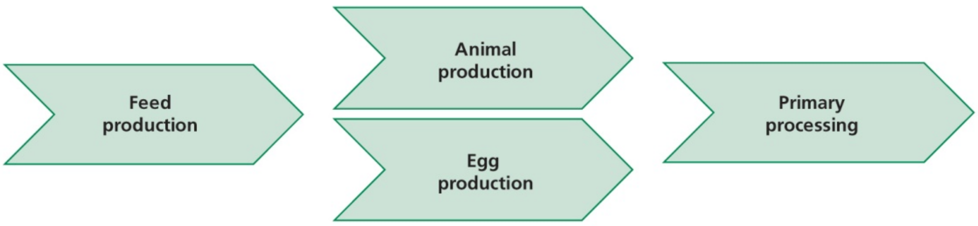
These guidelines cover the supply chain from cradle-to-primary-processing-gate and the main products are one or more of:

- Meat products, with possible co-products of skin, feathers, blood, bone and inedible offal;
- Eggs or egg products, which include shelled eggs and processed egg products such as dried whole eggs, egg whites, egg yolks and liquid egg products.

7.2 Life cycle stages: modularity

LCA-based data for materials and goods, including energy carriers and other inputs that are used in manufacture or production, may be used to calculate the footprint for those products. In this situation, these inputs can be considered as modules (or background data sets –Figure 9), which may be incorporated as representations of the entire or partial life cycles of those inputs. These modules may have been developed for other life cycle assessment studies, not specific to the poultry sector. See ISO 14025 for more detail regarding modularity.

FIGURE 9: MODULAR SCHEME OF THE POULTRY PRODUCTION CHAINS



8 GOAL AND SCOPE DEFINITION

8.1 Goal of the LCA study

The first step required when initiating an LCA is to clearly set the goal or statement of purpose. This statement describes the goal pursued and the intended use of results. Numerous reasons for performing an LCA exist. LCAs can be used to serve the goal of GHG emission management by determining the carbon footprint of products, understanding the GHG emission hotspots and prioritizing emissions-reduction opportunities along supply chains. LCAs provide detailed information on a product's environmental performance and can serve performance tracking goals as well as setting progress and improvement targets. They could also be used to support reporting on the environmental impacts of products, although these guidelines are not intended for comparison of products or labelling of environmental performance.

It is therefore of paramount importance that the goal and scope be given careful consideration because these decisions define the overall context of the study. A clearly articulated goal helps ensure that aims, methods and results are aligned. For example, fully quantitative studies will be required for benchmarking or reporting, but somewhat less rigour may be required for hotspot analysis.

Interpretation is an iterative process occurring at all steps of the LCA and ensuring that calculation approaches and data match the goal of the study (Figure 1 and Section 12). Interpretation includes completeness checks, sensitivity checks, consistency checks and uncertainty analyses. The conclusions (reported or not) drawn from the results and their interpretation shall be strictly consistent with the goal and scope of the study. Seven aspects shall be addressed and documented during the goal definition (European Commission, 2010):

- Subject of the analysis;
- Key properties of the assessed system: organization, location(s), dimensions, products, sector, and position in the value chain;
- Purpose of performing the study and decision-context;
- Intended use of the results: will they be used internally for decision-making or shared externally with third parties?
- Limitations due to the method, assumptions, and choice of impact categories: in particular, limitations to broad study conclusions associated with exclusion of impact categories shall be addressed;
- Target audience of the results;
- Comparative studies to be disclosed to the public and need for critical review;
- Commissioner of the study and other relevant stakeholders.

8.2 Scope of the LCA study

The scope is defined in the first phase of an LCA, as an iterative process with the goal definition. It states the depth and breadth of the study. The scope shall identify the product system or process to be studied, the functions of the system, the functional unit, the system boundaries, the allocation principles, and the impact categories. The scope should be defined so that the breadth, depth and detail of the study are compatible and sufficient to achieve the stated goal. While conducting an LCA of livestock products, the scope of the study may need to be modified as information is collected to reflect data availability and techniques or tools for filling data gaps. Specific guidance is provided in the subsequent sections. It is also recognized that the scope definition will affect the data collection for the life cycle inventory, as described in more detail in Section 10.1.

These guidelines refer only to two environmental impact categories (climate change characterized through GHG emissions, and reported as CO_2 equivalent and fossil energy demand, reported as MJ of energy consumed) and therefore should not be used to provide an indicator of overall environmental effects of the production systems and products. Care is therefore needed in the reporting and communication of the results of assessments based on these guidelines to avoid misinterpretation of the scope and application of the results.

The recommended scope for studies following these guidelines encompasses, for meat products: cradle to dressed carcass, and for egg products: cradle to packaged product, whether the product is shelled eggs or any other egg product (liquid eggs, or dry egg powders).

8.3 Functional unit

The functional unit defines the form and units used to specify a product and different functional units are appropriate when different downstream system boundaries are specified (e.g., farmgate, processing plant, retail, post-consumption to grave). Recommended functional units for different main product types are given in Table 1. Where meat is the product type, the functional unit when the bird leaves the farm is live-weight and at the stage of leaving the meat processing plant is the weight of product (meat-product-weight) destined for human consumption. In many western countries with commercial processing plants, the product weight has traditionally been identified as carcass-weight at the stage of leaving the meat processing plant. Carcass-weight is generally measured after removal of the feathers, head, feet and internal organs including the digestive tract (and sometimes some surplus fat). However there are other edible parts (e.g. edible offal and meat from other organs and feet in some Asian countries) that are increasingly being captured and should be included. In developing countries, the meat processing site may vary from ‘backyard’ to processing plants or cottage industry processing (sometimes termed ‘wet market’) and a higher proportion of the bird should be extracted for human consumption. Note that the “product-weight” includes bone retained within the animal parts for human consumption. Where primary data for “product-weight” is not available, the cold carcass-weight may be used and can be estimated from the live-weight using default values, based on a summary of international data (Appendix A). No distinction is made between different cuts of meat, meat products, and other edible parts and it is recommended that they are treated as equivalent (with no specific allocation method used for different cuts). This recommendation holds for other parts considered edible in some cultures such as chicken feet in Asia, as mentioned above. An example of the relative content by weight of different meat cuts and co-products is given in Appendix A.

For purposes of this guidance document, the preferred functional unit is a specified quantity of the product ready for shipping (or sale) at the processing facility dock (or farmgate for backyard systems).

An example of a functional unit for meat products would be 1000 kg of meat – with specified edible yield, moisture, fat and protein packaged for delivery to retail or food services. For small-scale production where the farmer may sell live birds or eviscerated carcasses directly to consumers, an appropriate functional unit would be 1 kg live or carcass weight with a specified edible yield. Sometimes, specific poultry parts (bone, feet or skin) are also consumed and sold in local market, e.g. in part of Africa, South America or Asia. In this circumstance, the functional unit should also include the bone or skin (to the extent it is consumed). Because the fundamental purpose of this guide is to support benchmarking and system improvement, if different analysts choose different, but locally relevant, functional units, their ability to benchmark the progress of the system of interest will not be compromised.

An appropriate functional unit for eggs would be 1000 kg eggs, or another common quantity for the market of interest, including packaging, with a specified shell percentage. For egg products, additional characteristics of the functional unit (see Table 1) shall be specified.

TABLE 1: RECOMMENDATIONS FOR CHOICE OF FUNCTIONAL UNIT

	Functional Unit (weight of product)	System Boundary	Qualifying characteristics
Meat	Live weight	Farmgate	Specified carcass yield
	Carcass weight	Processor loading dock, or equivalent	Specified edible yield
Egg	Fresh, shelled weight	Farmgate or processor loading dock	Specify shell mass
	Liquid weight	Processor loading dock	Yolk, whole, white
	Dry (powder) weight	Processor loading dock	Yolk, whole, white

One important point to bear in mind is that there should be an agreement between the functional unit and the system boundary. Some literature, for example, applies a functional unit of dressed carcass at the farmgate (Boggia et al., 2010a; Leinonen et al., 2012a). However the appropriate functional unit at the farmgate is animal live weight because use of carcass yield at the farmgate is doubly mistaken: first none of the burdens of the post-farmgate processing are included in the analysis, and second no allocation of farm and pre-farm burdens are attributed to the co-products of the processing.

8.4 System boundary

The system boundary shall be defined following general supply chain logic including all phases from raw material extraction to the point at which the functional unit is produced. A full LCA would include processing, distribution, consumption and final disposal; however, this guide does not cover, post-processing stages in the supply chain. This guidance is targeted on the poultry sector, and is specifically inclusive of broiler and turkey meat and layer hen egg production. Some modifications may be necessary to include other types of poultry, ducks for example, which may be raised together with tilapia, thereby introducing additional allocation considerations. The following sections provide guidance regarding the specific steps of a life cycle assessment which are outlined in Section 4. It should be emphasized that due to the diversity of systems, the descriptions provided in Section 6 should be used as a guide rather than a definitive system description. Therefore the practitioner shall accurately and fully describe the system under study in defining the system boundary.

8.4.1 GENERAL / SCOPING ANALYSIS

The recommended system boundaries (Figure 10 and Figure 11) encompass and start with the great grandparent generation, and end with dressed carcass or eggs ready for transport to customers or storage. The choice of dressed carcass as a typical sector output is intended to provide a point in the supply chain that has an analogue across the range of possible systems, geographies, and goals that may be encountered in practice. For the dressed carcass is a necessary stage in both consumption and post-farm processing and practitioners whose system boundary extends further can use this guide to the point of dressed carcass and supplement the further stages based on the references in Section 6. In addition there is guidance provided for the post-processing supply chain in the Japanese Product Category Rule for Chicken (JEMAI, 2011a).

a) Scoping analysis

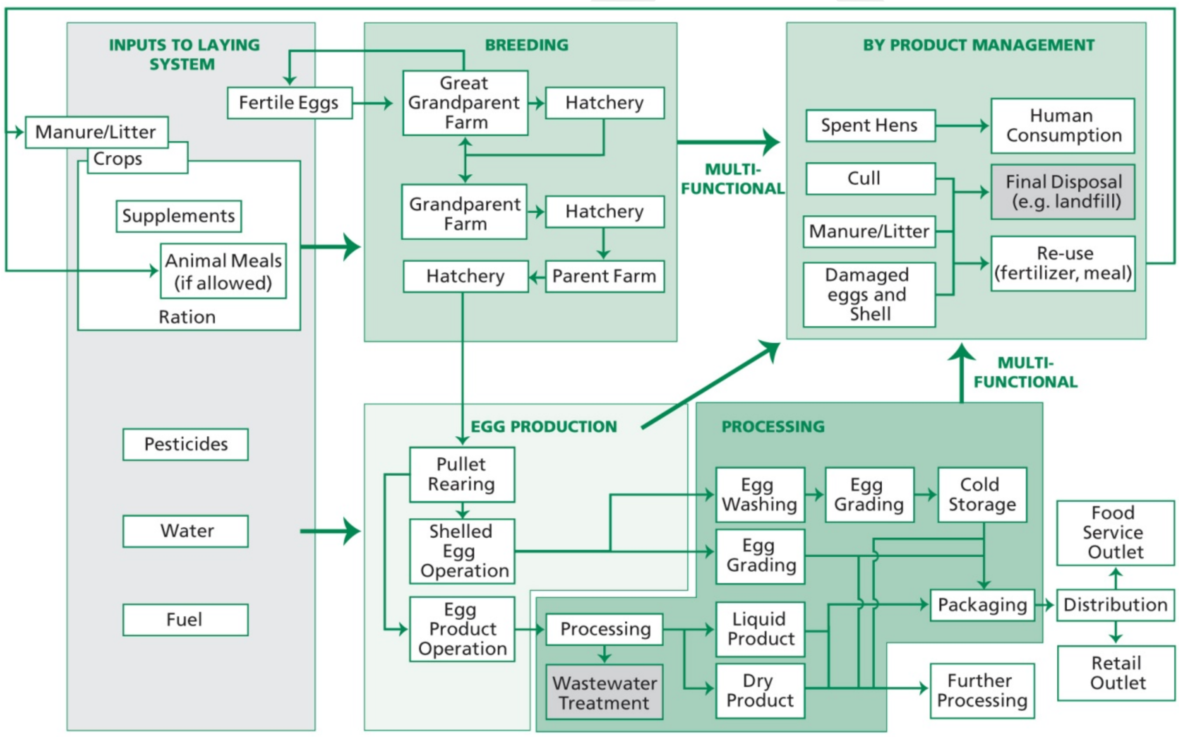
Frequently a scoping analysis based on a relatively rapid assessment of the system can provide valuable insight into areas which may require additional resources to establish accurate information for the assessment. Scoping analysis can be conducted using secondary data to provide an overall estimate of the system impact. Furthermore, based on existing literature reviews in the poultry sector (Appendix B), it is relatively clear that for production systems it is extremely important that the following factors are assessed with high accuracy: the ration, the feed conversion efficiency, manure production and management. Depending upon the particular operation under study, additional effects may be observed. In the post-farm supply chain, energy efficiency at the processing and manufacturing stages as well as an accurate assessment of transportation modes and distances is important.

8.4.2 CRITERIA FOR SYSTEM BOUNDARY

Material system boundary: Which entities and processes are included in the assessment? What is the analysed company's sphere of influence? Which entities and processes are excluded from the assessment, and for what reasons? A flow diagram of all assessed processes should be drawn indicating where processes were cut off. For the main transformation steps within the system boundary, it is recommended that a material flow diagram is produced and used to account for all of the material flows, e.g. within the processing stage the live weight is defined and shall equate the sum of the mass of the products produced.

Spatial system boundary and stages: The cradle-to-farmgate stage includes feed and animal components. The LCA of feeds is covered in detail in an associated document (LEAP Animal Feed Guidelines) and covers the cradle-to-animal-mouth (beak) stage for all feed sources (including raw materials, inputs, production, harvesting, storage, loss and feeding).

FIGURE 10: SCHEMATIC OF EGG AND EGG PRODUCTS PRODUCTION SYSTEM



Note: processes outside of the dashed line are excluded from the recommended system. Grey shading indicates waste treatment for which emissions shall be included in the system calculations. When manure has significant economic value for the farmer, it is considered a co-product. See Section 9.3.3 for detailed explanation.

The LEAP Animal Feed Guidelines covers all emissions associated with land use and land-use change. The poultry-related components cover all inputs and emissions in the poultry supply chain not covered by the LEAP Animal Feed Guidelines. This includes emissions associated with poultry production and management. The latter includes accounting for the utilization of excreta, where it is important to avoid double counting if excreta represents a direct input for feed production and is included in the LEAP Animal Feed Guidelines. The animal component includes accounting for breeding stock as well as those animals used directly for meat and egg production. This may involve more than one farm if animals are traded between farms prior to going to processing.

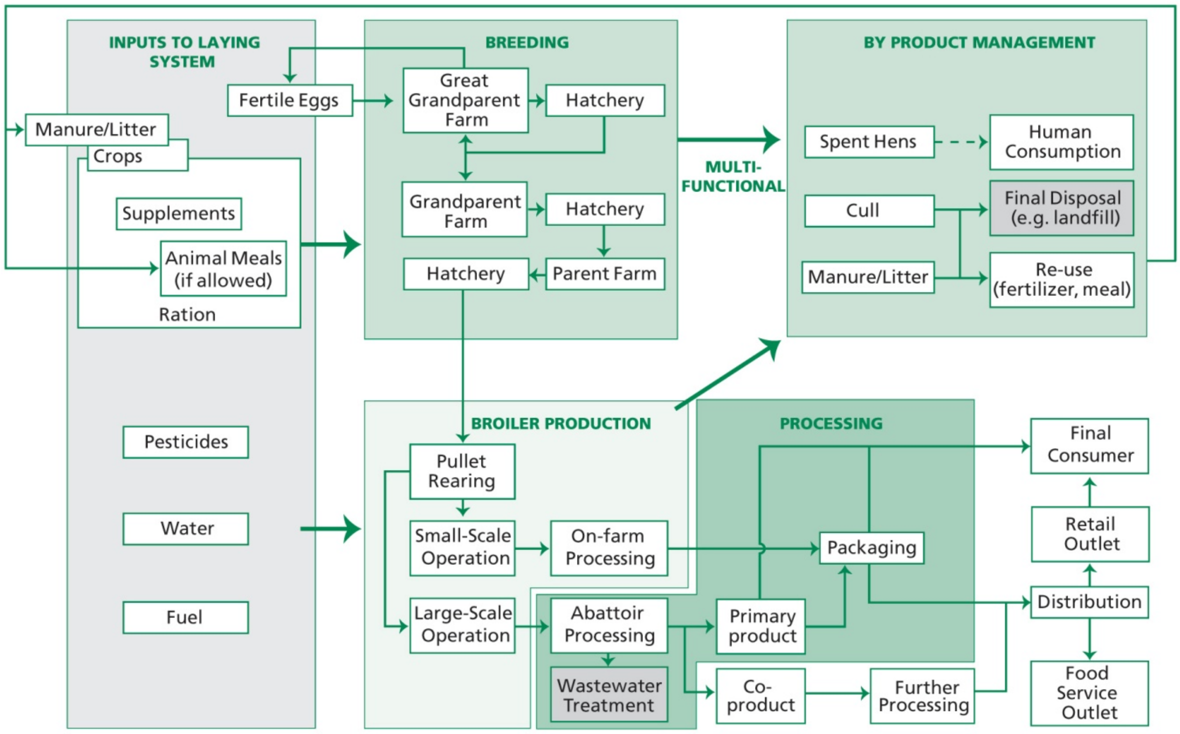
For the meat processing stage, there shall be no differentiation between the various products that are edible by humans therefore impacts are divided evenly by mass over all such products from the poultry supply chain because there are no significant biophysical or nutritional differences between them (Section 11).

The primary processing stage is limited to animal slaughter (backyard, village slaughter unit and abattoir) for meat processing to produce the functional unit. For shelled eggs, if they are washed, packaging and refrigeration until the time of shipment is included. For other egg products, processing includes all necessary steps required to produce the functional unit, for example dried whole eggs would include all the packaging as well as the energy required to pasteurize, and / or dry, and refrigerate the eggs. All transportation steps within and between the cradle-to-primary-processing-gate are included.

8.4.3 MATERIAL CONTRIBUTION AND THRESHOLDS

In determining whether to expend resources and effort to include specific inputs, a 1 percent cut off threshold for mass and energy should be adopted; larger thresholds shall be explicitly documented and justified by the project goal and scope definition. Inputs to the system that represent less than 1 percent of the mass or less than 1 percent of the energy required for a specific unit process (activity) in the system can be excluded from the analysis. Instead, a scoping analysis (Section 8.2) can be used to provide an estimate. An exception to this exclusion is made in cases where significant environmental impact is associated with a small mass input (e.g. some material may be present in small quantities, yet still have a relatively large environmental impact; these should be included). A minimum of 95 percent of the impact for each category shall be accounted for.

FIGURE 11: SCHEMATIC OF BROILER AND TURKEY PRODUCTION SYSTEM



Note: processes outside of the dashed line are excluded from the recommended system. Grey shading indicates waste treatment for which emissions shall be included in the system calculations. When manure has significant economic value for the farmer, it is considered a co-product. See Section 9.3.3 for detailed explanation.

It should be noted that if data are readily available, the cut-off rules are not intended to justify exclusion of these inputs.

8.4.4 TIME BOUNDARY FOR DATA

Documentation for temporal system boundaries shall describe how the assessment deviates from the one-year time frame. By how many years is the temporal scope extended for the model parameters?

The time boundary for data shall be representative of the time period associated with the average GHG emissions for the products. For poultry products, a period of 12 months shall be used, since it is a reasonable time frame to capture seasonal fluctuations.

In some cases where there may be considerable inter-annual variability in inputs, production and emissions, it may be necessary for the one-year time boundary to be determined using data averaged over 3 years to meet criteria of representativeness. An averaging period of 3 to 5 years is commonly used to smooth the impact of seasonal and market variability on agricultural products.

8.4.5 Capital goods

The production of capital goods (buildings and machinery) with a lifetime greater than one year may be excluded in the life cycle inventory; however, the operation or occupation of, or other activities utilizing capital goods shall be accounted. However, for studies in which the goal and scope include assessment of alternate systems for which there may be significant differences in infrastructure requirements, capital goods production shall be included.

8.4.6 Ancillary activities

Emissions from ancillary inputs, e.g. servicing, employee's commutes, executive air travel or accounting or legal services may be included if relevant. To determine if these activities are relevant, an input-output analysis can be used as a scoping analysis.

8.4.7 Delayed emissions

All emissions associated with products to the primary processing stage are assumed to occur within the time boundary for data, generally of one year (Section 8.4.4). Delayed emissions from soil and vegetation may be considered in the LEAP Animal Feed Guidelines. The PAS 2050:2011 provides additional guidance regarding delayed emissions calculations for interested practitioners (PAS 2050, 2011).

8.4.8 Carbon Offsets

Offsets shall not be included in the carbon footprint. However they may be reported separately as "additional information".

8.5 Impact categories

These guidelines are primarily based on assessment of GHG emissions. The total GHG emissions for individual gases are summed along the system boundary. Individual gases are then multiplied by the relevant characterization factor to convert them all into a common unit of carbon dioxide equivalents (kg CO_2eq). The characterization factors shall be based on the global warming potentials of the specific gases over a 100-year time horizon using the most recent IPCC factors which can be found in the latest IPCC guidance documentation. Because characterization factors change as our understanding evolves, it is important to note in the report documentation what specific sources were used for them.

The fossil energy demand should also be calculated, since all inputs of fossil fuels have to be determined as part of the data collection requirements for assessing GHG emissions. This is captured in the impact category called Cumulative Energy Demand and sub-category of non-renewable energy resources, and uses the Lower Heating Value of the fuel for its characterization factor (Huijbregts et al., 2006). It shall account for the embodied primary energy for the production and combustion of the various energy sources and may draw on recognised databases such as EcoInvent (Frischknecht and Rebitzer, 2005). Fossil energy demand for the production and use of electricity, which will be specific for a particular country, shall also be included.

The LCA of products should account for a range of resource use and environmental impact categories. It is intended that in future these guidelines be updated to include multiple categories (Section 5.3).

9 MULTI-FUNCTIONAL PROCESSES AND ALLOCATION

One of the challenges in LCA has always been associated with proper assignment (allocation) of shared inputs and emissions to the multiple products from multi-functional processes e.g. live birds and eggs at a backyard farmgate; or energy, water use and emissions allocated between several dissimilar products produced at a manufacturing plant. The choice of the method for handling co-production often has a significant impact on the final distribution of impacts across the co-products. Whichever procedure is adopted shall be documented and explained, including sensitivity analysis of the choice on the results. As far as feasible, multi-functional procedures should be applied consistently within and among the data sets. For situations where system separation or expansion is not used, the allocated inputs and outputs should equal unallocated inputs and outputs.

9.1 General principles

The ISO 14044 standard gives the following guidelines for LCA practitioners with respect to practices for handling multi-functional production:

Step 1: Wherever possible, allocation should be avoided by:

- Dividing the unit process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes; or
- Expanding the product system to include the additional functions related to the co-products.

Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them: i.e. they should reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system.

Step 3: Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to their economic value.

Where allocation of inputs is required, for example allocation of process energy between poultry meat and other products not meant for human consumption, the allocation procedures should follow the ISO 14044 allocation hierarchy. When allocation choices significantly affect the results, a sensitivity analysis shall be performed to ensure robustness of conclusions.

Below is a list of commonly used procedures for addressing multi-functional processes, as stated, for example, in ISO 14044:2006, Section 9. Allocation can be based on other relationships such as:

- Bio-physical causality, arising from underlying biological or physical principles such as material or energy balances;
- Physical properties such as mass, or protein or energy content;
- Economic value (revenue share) based on market prices of products.

Avoided burden or system expansion can be based on:

- Displacing the average product that is equivalent to a co-product;
- Displacing the marginal product that is equivalent to a co-product;
- Differentiating whether one is dealing with a determining or non-determining product flow, or an avoided burden followed by sharing of credit.

9.2 A decision tree to guide methodology choices

A decision tree diagram to help decide on the appropriate methodology for dealing with co-products is given in Figure 12. This involves a three-step approach and the principles involved in working through it are as follows:

Step 1: Avoid allocation by subdividing the processing system into three categories.
A production unit is defined here as a group of activities (and the necessary inputs, machinery and equipment) in a processing facility or a farm that are needed to produce one or more co-products. Examples are the crop fields in a farm, the different animal herds (poultry, fattening pigs, sows, piglets), or the individual processing lines in a manufacturing facility.

In the first step (ISO step (1a) subdivision) all processes and activities of a farm/processing facility are divided into three categories: the condition is that inputs/emissions are easily divided over the processes and that enough information about the inputs/emissions is available.

flow 1.a. Inputs/activities that should be directly assigned to a single co-product, e.g. packaging and post-processing storage for meat products, or rendering energy requirements in the post-exsanguination phase at the processing plant.

flow 1.b. Inputs/activities that should be assigned to production units that can provide single or multiple co-products e.g. input of pesticides or energy inputs of operations of a barn or manufacturing facility, or feed for a specific bird type at a poultry farm. This would also cover layer operations with eggs and spent hens as main products.

flow 1.c. Inputs/activities of a nonspecific nature in a farm or processing facility such as heating, ventilation, climate control, internal transport in a manufacturing facility or farm that cannot be directly attributed to production units. For example energy to pump drinking water for multiple animal species in a small-scale, multi-species operation.

Step 2: Attribute joint production to production units.

In theory, all joint production systems are separable where sufficiently detailed data exist and they should normally follow path (1a). Nevertheless, situations exist where this is impractical, and in the next step, (step 2 in Figure 12) the nonspecific processes should be attributed to production units on the basis of the ISO steps (1b), (2) and (3). We will discuss these steps and the conditions we applied in selecting the allocation method. Where this led to explicit allocation rules on how to decide in the stepwise approach we underlined the text. For example in backyard systems it may be that poultry, cattle, sheep and swine are all raised in a single production unit. In this situation, farm overhead operations that cannot be explicitly assigned to an individual species should be handled using the criteria in Box/Step 2. For most large-scale poultry production systems, the (1b) path to Box 3 will be followed, as the inputs and outputs in single-species systems are clearly assigned to the single production unit and its activities/operations and products.

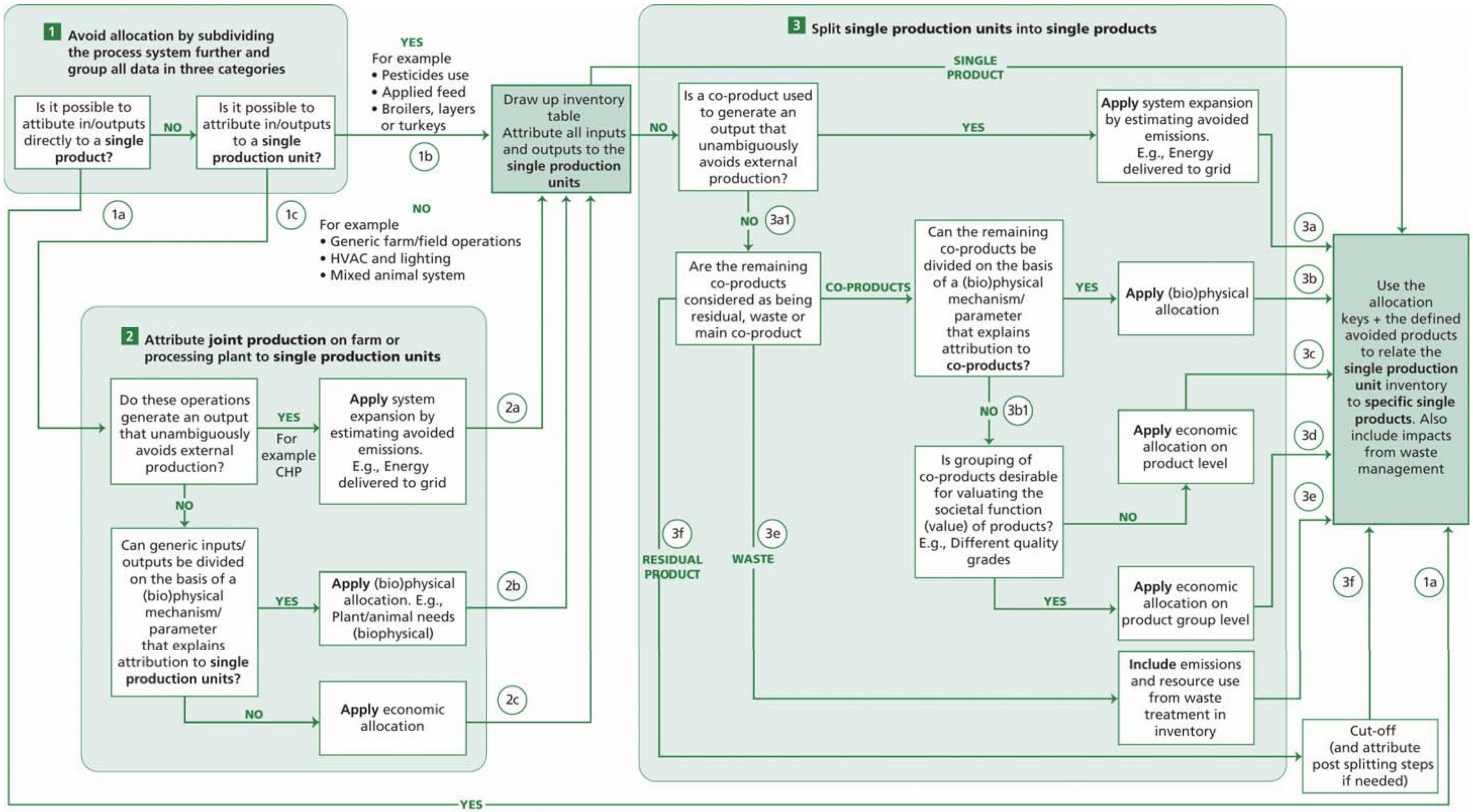
System expansion: ISO step (1b) should only be applied in situations where the avoided production system can be unambiguously determined and there is little interference with other feed or animal production systems (flow (2a) in Figure 12).

If an output generated by the production unit unambiguously avoids external production, apply substitution (system expansion). There is one important condition for system expansion: that the avoided co-product shall be fully equivalent. This means that you shall be very certain and clear about the avoided production and that there should be no, or minimal interference with other production systems. The result of this step will be an avoided product in the inventory for the unit process; however, at the inventory level there is no corresponding reduction in the emissions or exchanges with the environment. The credit for the substitution will arise in subsequent calculations. For backyard or other diversified systems which produce more than one animal species, system substitution of the co-produced species shall not be used. More specifically, if cattle and poultry are raised in the same field, where poultry may consume undigested grain from the cattle manure, using a substituted cattle production system to calculate the poultry system impacts shall not be permitted within these guidelines.

When system expansion is not possible, the second question is whether a physical allocation is possible. The condition here is that the products should have similar physical properties and serve similar goals or markets, or that known processing or biophysical relationships can be used to assign inputs and outputs of a single production unit to each product. For example, if feed is provided to multiple animal species, the animal growth requirements may be used to apportion the shared feed between the species. The result of this step will be a splitting of some inventory flows between the production units, and if the resultant unit process is multifunctional, these inventory flows will be allocated to single co-products in the next step of the procedure (Box 3 in the Figure 12).

If inputs in a multiple production system benefit all products and cannot be specifically assigned to production units, the allocation should be preferably based on a physical property or mechanistic algorithm (flow (2b) in Figure 12).

FIGURE 12: MULTI-FUNCTIONAL OUTPUT DECISION TREE



Note: The choice of method for handling multi-functional outputs for each stage or process in the supply chain shall be based on this decision algorithm.

When physical allocation is not possible or allowed, the last option is economic allocation. As with physical allocation, the result of this step will be a splitting of some inventory flows between the production units, and if the resultant unit process is multifunctional, these inventory flows will be allocated to single co-products in the next step of the procedure (Box 3 in the Figure 12).

Step 3: Split single production units into individual co-products

After performing steps 1 and 2, all inputs and operations will have been attributed to the single production unit, or already to a single product. An inventory table is made for the production unit. Step 3 guides the assignment of inputs and emissions from a single production unit to each co-product produced by the unit. If there is only a single product at this stage, the process is complete. In the case of a multifunctional production unit, the first approach is to employ system expansion. The same rule holds as the one defined above for production units, so only in very clear situations of avoidance, such as connection to an electricity grid, system expansion should be applied. Any flow arising from (2a) will follow this path. When system expansion is not possible, the remaining outputs must be classified as co-products, residual products or wastes. Existing standards state that a footprint should not get a credit for sold electricity (or natural gas) that is incorporated into grid factors (PAS 2050, 2011; WRI/WBCSD, 2011). Therefore it is not valid, according to these existing standards, to provide a credit using system expansion (or other method) for sold electricity/gas. Further, system expansion does not provide a footprint for the avoided product that can be used in another LCA (for a downstream system). This guidance strongly encourages other methods for allocation, in particular when there is a danger for improper interpretation at policy level when several LCAs are combined to obtain an aggregated view of the larger system; specifically, if an animal production system uses system expansion, and a later crop production analysis assumes the credit for use of manure, there will be a ‘double credit’ in the combined system.

Outputs of a production process are considered as residual flows if (3f):

- They are sold in the condition in which they are created in the process and contribute very little to the turnover of the company (total value of the flow less than 1 percent);
- The upstream and production process that produce the outputs are not deliberately modified for the outputs, and has a subsequent use. There may be value-added steps beyond the boundary of the poultry system under study, but these activities do not impact the poultry system calculations in these guidelines.

Residual products will not receive any allocated emissions, nor will they contribute emissions to the main co-products of the production unit. However it is useful to track residual flows for the purpose of understanding the mass balance for the production unit.

An output of a production process shall be considered as waste if it carries no economic value or if the production unit incurs a cost for treatment or removal. Waste has to be treated and/or disposed of and these emissions shall be included in the inventory. For the poultry sector, the most common process in this category is wastewater treatment at manufacturing facilities, and in some cases litter sent to a landfill. Litter/manure is discussed below (Section 9.3.3).

All other co-products are subject to allocation, leading to flows (3b), (3c), and (3d) in the diagram. Assignment to these flows depends upon whether physical, biophysical or mechanistic allocation is possible (3b), or whether an economic allocation at a single product (3c) or product group level (3d) is applied.

The condition for determining whether physical allocation is appropriate is that the products should have similar physical properties and serve similar functions or markets, or a straightforward mechanistic algorithm can be identified, or that biophysical relationships can be used to assign inputs and emissions to each product. When physical allocation is not feasible (interactions too complex to accurately define a mechanistic relationship) or is not allowed (dissimilar properties or markets), the last option is economic allocation.

In the case of economic allocation, one option (flow 3d) is grouping a number of co-products and performing the allocation with some co-products at the group level instead of the single product level. This option is relevant for the various edible meat components (e.g. carcass cuts and edible offal) which can be grouped before allocation between them and other inedible co-products such as hide, blood and renderables.

9.2.1 ALLOCATION OF TRANSPORT

Estimating environmental impacts of transportation entails two allocation issues: allocation of empty transport distance covered by transport means and allocation of the load fraction of transportation means. The allocation of empty transport distance is often already included in the models used when the secondary life cycle inventory (LCI) data for transportation were created. However if primary data for transport are derived, the LCA practitioner shall make an estimate of the empty transport distance. In the absence of other information, a worst-case estimate should be applied here, meaning inclusion of 100 percent extra transport for empty return. Allocation of empty transport kilometres shall be done on the basis of the average load factor for the transport under study. If no supporting information is collected, it shall be assumed that 100 percent extra transport is needed for empty return.

If products are transported by a vehicle, resource use and emissions of the vehicle shall be allocated to the transported products. A means of transport has a maximum load. This maximum load is expressed in tonnes. However the maximum weight can only be achieved if density of the loaded goods allows it. Therefore allocation of transport emissions to transported products shall be done on the basis of mass share ***unless*** the density of the transported product is significantly lower than average so that the volume restricts the maximum load.

9.3 Application of general principles for poultry systems and processes

To make these general ISO requirements operational for allocation in the poultry production life cycle we applied the ISO steps on these situations: 1) combined joint production processes, such as farms and food processing plants that have multiple products 2) the allocation procedures for transport and 3) for manure.

Allocation procedures shall be uniformly applied to similar inputs and outputs of the system under consideration. For example, if allocation is made to usable products (e.g. intermediate or discarded products) leaving the system, then the allocation procedure shall be similar to the allocation procedure used for such products entering the system. A decision tree is presented below (Figure 12) which can be applied to determine the assignment of individual flows from a unit process data set to multiple products that may be produced. For example in a backyard poultry system where other animal species are also present, the unit process created will very likely have an output product identified for each of the animal species and it is necessary to assign the inputs and emissions of this joint production system separately to each species (product of the farm). The decision tree provides guidance on methodological approaches suitable for assigning inputs and emissions of the overall unit process to the individual products. Where choice of allocation can have a significant effect on results, more than one method shall be used to illustrate the effects of choice of allocation methodology.

9.3.1 Meat production

For broilers, there are two points of separation into multiple products: the breeding stage where spent hens are sent to processing for human consumption or cull hens sent to the pet food sector, and hatchlings that are grown out as broilers. However, the primary point of separation of multiple products is at the processing stage, where chicken meat, bone and feather meals as well as tallow and rendering products are generated. As indicated above, there are several approaches for handling this multi-functionality. As discussed below, the recommendation of this guidance is to choose economic or revenue allocation as the default method for allocation at the processing facility. However, because of the potential sensitivity to this methodological choice, if information is available, system expansion as well as a mass allocation should also be examined to determine the robustness of the results to the choice of allocation methodology. If the breeding stage is considered as a background system, for which secondary data is used, then the first multifunctional issue will already have been accounted for in the secondary data. For situations in which breeding is within the foreground system, the application of system expansion for spent hens should be used. In this guidance, we require functional substitutes for application of system expansion. It is acknowledged that from a consumer perspective, there is a difference between a spent layer or breeding hen and a broiler; however, from a nutritional perspective, there is little difference, and both serve the function of providing an equivalent nutritional value. Therefore, to provide consistency with the decision to treat various meat cuts which may be products from a processing facility as equivalent, we treat all products edible by humans from the supply chain as equivalent. As mentioned in the discussion of functional unit, this applies to delicacies such as chicken feet as well.

9.3.2 Egg production

For egg production systems, eggs and spent layers represent the primary co-products of the laying system. As with breeding phase, the preferred approach for handling this co-production is to use system expansion of a broiler system from the same region to account for the reduction in broiler production realized by utilization of the spent hens as a source of protein for human consumption. Previous studies have shown that the choice of allocation method for spent hens from laying systems has only a minor effect on the reported environmental impacts of egg production (Leinonen et al., 2012b; Wiedemann and McGahan, 2011). Alternate methodological approaches for handling co-production at this stage include: economic or revenue allocation; protein mass for products edible by humans; carcass and egg mass.

For situations where poultry litter may be used in energy generation equipment, an avoided burden of electricity or heat production may accrue at the farmgate. However, all emissions from combustion of the litter within the system being analysed shall be accounted prior to application of credits for avoided emission through substitution.

TABLE 2: RECOMMENDED METHODS FOR DEALING WITH MULTI-FUNCTIONAL PROCESSES AND ALLOCATION BETWEEN CO-PRODUCTS FOR THE CRADLE-TO-PRIMARY-PROCESSING-GATE STAGES OF THE LIFE CYCLE OF POULTRY PRODUCTS

Source/stage of co-products	**Recommended method***	**Basis**
Animal species (within farm backyard system)	Separate farm activities Biophysical causality	First, separate activities specific to an animal species. Then, determine emissions specific to feeds relating to the poultry under study. Then, for remaining non-feed inputs, use biophysical allocation based on the proportion of total feed energy requirement for each of the different animal species.
Spent birds (within farm)	System expansion Biophysical causality	Substitution of relevant broiler production should be used. If not available, then use biophysical allocation based on the proportion of total energy requirements for growth and egg/hatchling production.
Cull birds (within farm)	System expansion Biophysical causality	Substitution of relevant avoided pet food product, if used in pet food supply; however, if disposed by rendering, composting or incineration, treat as a waste, not a co-product.
Meat processing (meat & non-meat products)	System separation Revenue	First, separate activities specific to individual products where possible. Then use allocation based on the relative revenue derived from each of the products.
Egg processing (shells/wasted and broken eggs)	Revenue Residual Waste	Use allocation based on the relative revenue derived from each of the products. If the economic value is zero or negative and the material has a subsequent use, it is residual and receives no allocated burden. If the economic value is zero or negative and the material has no subsequent use, it is waste and emissions from waste treatment should be added to the inventory of the remaining co-products.

* Where choice of allocation can have a significant effect on results, more than one method shall be used to illustrate the effects of choice of allocation methodology.

9.3.3 ALLOCATION OF MANURE / LITTER

This discussion follows the decision tree presented above. Unless a system separation approach is adopted for manure, i.e. following flow (1a), or substitution (following flow 3a), a decision associated with the classification of manure as either a co-product, waste or residual must be made in Box 3 of the decision algorithm (Figure 12). It is the strong recommendation of this guidance that the default manure method should be to consider it as a residual at the farmgate. This results in a clean separation of the system where all post-farm emissions from use of the manure are assigned to that use, while all on-farm management is assigned to the main product from the farm (live birds, eggs, or both).

Substitution: When manure is used to directly produce energy, system expansion may be used to unambiguously substitute for the energy displaced from the external economy. The primary question will be whether marginal or average energy products are substituted.[6] For purposes of this guidance, if system expansion/substitution is used, then the average energy product (e.g., national electricity grid mix of primary energy sources) shall be substituted. Combustion ash must also be evaluated as a potential co-product, residual or waste, and associated emissions properly accounted. In addition, clear documentation of the substitution shall be included in the report, and, following other extant standards if energy is sold, then no credit as a substitute product is allowed. However, in the latter case, the energy shall be considered a co-product and an appropriate allocation chosen through use of the decision tree.

For substitution as fertilizer, it may not be clear which specific inorganic fertilizer products are substituted. Utilization of manure as fertilizer also results in different emissions from the field than from inorganic fertilizers. Therefore substitution shall require assignment of the field emissions to the animal product, with a subsequent substitution credit of both the production and field emissions associated with the substituted inorganic fertilizer. However, when an unambiguous substitution is identified (e.g., 1 kg manure substitutes 0.27 kg ammonia nitrate and 0.36 kg potash), the specific products shall be specified and justification provided to document the equivalence of the substitution.

Co-product: When manure is a valuable output of the farm, and if the system of manure production cannot be separated from the system of animal production, then the full supply chain emissions to the farmgate shall be shared by these two co-products. In this case, physical allocation based on physical parameters is clearly not appropriate. Thus an economic allocation shall be adopted. There shall be no credit for avoided fertilizer production in this situation, because the option for system substitution is path (3a), not (3c).

Residual: When manure has essentially no value at the system boundary (from the point of view of the bird, this is at the point of excretion). This is equivalent to system separation, in that activities associated with conversion of the residual to a useful product occur outside of the system boundary for the poultry production system. The fundamental question is: at what point does the manure/litter become a residual material? It may be at the point of excretion, or at the point it is applied in the field.

Separation at point of excretion: In this case, all post-excretion emissions associated with on-farm manure management are fully attributed to the manure, and follow the manure to its subsequent use as a fertilizer. The principal difference between this scenario and the case of a co-product is that none of

[6] Blonk et al (2010) show that, in practice, this is not immediately obvious for an electricity grid. The grid is fed by multiple production units and how should the avoided production /consumption mix be determined if your type of electricity production is a part of the mix. In BSI PAS2050-2011 a practical approach has been defined by simply stating that the average country production mix should be applied.

the production of the poultry rations is assigned to the manure, nor are any of the emissions associated with the on-farm manure management assigned to the animal. Thus this is a system separation for the production of the two products: meat and manure. This is equivalent to path (1a).

Separation at field application: In this case, all on-farm emissions associated with manure storage and management are assigned to the animal live bird product and all post-farm, field emissions are assigned to the subsequent use for crop production. There shall be no credit for avoided fertilizer production in this situation, because the option for system substitution is path (3a), not (3f).

Waste: this is the status quo approach to manure in LCA. In this case, despite the value of manure as a fertilizer after the farmgate, all of the emissions associated with on-farm manure management are assigned to the live bird at farmgate, and a credit (via substitution) is taken based on the argument that the manure substitutes inorganic fertilizers in the crop production. In spite of the terminology used in the extant literature, this approach is classified in this guidance as residual with separation at field application as described above. However, if manure is classified as a waste – only in situations where it is disposed of by landfill, incineration without energy recovery, or sent to a treatment facility – then all on-farm emissions shall be assigned to the animal live bird product. Emissions associated with the final disposition of litter are within the system boundary and must be accounted and assigned to the animal live bird product. In the case of manure as a waste, there shall be no substitution credit for its use as fertilizer since that is path (3a), not (3e).

9.3.4 MULTIFUNCTIONAL MANUFACTURING FACILITIES

In commercial processing of poultry products (i.e. a single production unit and so follows steps 1b, 3a1 and 3b in Figure 12), the main meat products have a different function and market then than the remaining co-products that are not edible by humans. Therefore allocation based on physical attributes (e.g., mass, protein or fat content) is not appropriate and shall not be employed. In addition, the systems can be quite complex so that creating mechanistic models for the allocation is generally impractical. Therefore, unless detailed material and energy balance process models of the facility exist, economic or revenue allocation shall be applied for the multiple co-products from meat processing. Furthermore, there shall be no differentiation between edible products or other co-products which serve a common market (for example, chicken feet in Asia serve the food sector/market as does chicken meat). These shall be grouped together for the economic allocation calculations. For example meals (blood, bone, and feather) shall be combined and treated as a single commodity.

TABLE 3: EXAMPLE OF MEAT PROCESSING ALLOCATION ASSUMPTIONS APPLIED THROUGHOUT THE SUPPLY CHAIN

Slaughter products	Mass allocation factors	Economic allocation factors	System expansion substitution products
Carcass weight	90.2 - 92.0%	97 - 98.1%	
Edible offal	1.6 - 2.3%	0.3 - 0.5%	
Secondary rendering products			
Poultry oil	1.1-2.0%	0.4-0.6%	Canola oil
Blood meal	0.3-0.4%	0.1-0.2%	Soymeal and sorghum– on protein and energy equiv. basis
Pet food slurry	0-10.5%	0-1.1%	Soymeal and sorghum– on protein and energy equiv. basis
Pet food digest	0-1.1%	0-0.3%	Soymeal and sorghum– on protein and energy equiv. basis
Poultry meal	1.3-2.0%	0.4-0.6%	Soymeal and sorghum– on protein and energy equiv. basis
Feather meal	2.2-3.5%	0.4-0.5%	Soymeal and sorghum– on protein and energy equiv. basis

Source: (Poad et al., 2012)

10 COMPILING AND RECORDING INVENTORY DATA

10.1 General principles

The compilation of the inventory data should be aligned with the goal and scope of the life cycle assessment. The LEAP guidelines are intended to provide LCA practitioners with practical advice for a range of potential study objectives. This is in recognition of the fact that studies may wish to assess poultry supply chains ranging from individual farms, to integrated production systems, to regional or national scale, or to a sector level. When evaluating the data collection requirements for the project, it is necessary to consider the influence of the project scope. In general these guidelines recommend collection of primary activity data (Section 10.2.1) for foreground processes, those processes generally being considered as under the control or direct influence of the study commissioner; however, it is recognized that for projects with larger scope, such as sectoral analyses at the national scale, the collection of primary data for all foreground processes may be impractical. In such situations, or when an LCA is conducted for policy analysis, foreground systems may be modelled using data obtained from secondary sources such as national statistical databases, peer-reviewed literature or other reputable sources.

An inventory of all materials, energy resource inputs, outputs (including products, co-products and emissions) for the product supply chain under study shall be compiled. The data recorded in relation to this inventory shall include all processes and emissions occurring within the system boundary of that product.

As far as possible primary inventory data shall be collected for all resource use and emissions associated with each life cycle stage included in the defined system boundaries. For processes where the practitioner does not have direct access to primary data (i.e. background processes), secondary data can be used. Data collected directly from suppliers should be used for the most relevant products supplied by them when possible. If secondary data are more representative or appropriate than primary data for foreground processes (to be justified and reported), secondary data shall also be used for these foreground processes.

For agricultural systems, two main differences exist compared to industrial systems. Firstly, production may not be static from year to year, and secondly, some inputs and outputs are very difficult to measure. Consequently, the inventory stage of an agricultural LCA is far more complex than most industrial processes, and may require extensive modelling in order to define the inputs and outputs from the system. For this reason agricultural studies often rely on a far smaller sample size and are often presented as 'case studies' rather than 'industry averages'. For agricultural systems, many foreground processes must be modelled or estimated rather than measured. Assumptions made during the inventory development are critical to the results of the study and need to be carefully explained in the methodology of the study. In order to clarify the nature of the inventory data, it is useful to differentiate between 'measured' and 'modelled' foreground system LCI data. For a layer operation, measured foreground system data may include fuel use and bird numbers, while modelled foreground system data may include manure quantity and characteristics.

The LCA practitioner shall demonstrate that the following aspects in data collection have been taken into consideration when carrying out the assessment (adapted from ISO14044:2006):

- **Representativeness**: qualitative assessment of the degree to which the data set reflects the true population of interest. Representativeness covers the three following dimensions:
  a) time-related representativeness: age of data and the length of time over which data was collected;
  b) geographical representativeness: geographical area from which data for unit processes was collected to satisfy the goal of the study;
  c) technology representativeness: specific technology or technology mix;

- **Precision**: measure of the variability of the data values for each data expressed (e.g. standard deviation);
- **Completeness**: percentage of flow that is measured or estimated;
- **Consistency**: qualitative assessment of whether the study methodology is applied uniformly to the various components of the analysis;
- **Reproducibility**: qualitative assessment of the extent to which information about the methodology and data values would allow an independent practitioner to reproduce the results reported in the study;
- **Sources** of the data;
- **Uncertainty** of the information (e.g. data, models and assumptions).

For significant processes, LCA practitioner shall document the data sources, the data quality, and any efforts made to improve data quality.

10.2 Requirements and guidance for the collection of data

Two types of data may be collected and used in performing LCAs:

- Primary data: defined as directly measured or collected data representative of processes at a specific facility or for specific processes within the product supply chain.
- Secondary data: defined as information obtained from sources other than direct measurement of the inputs/outputs (or purchases and emissions) from processes included in the life cycle of the product (PAS 2050:2011, 3.41). Secondary data are used when primary data are not available or impractical to obtain. Some emissions, such as methane from litter management, are calculated from a model, and are therefore considered secondary data.

For projects where significant primary data is to be collected, a data management plan is a valuable tool for managing data and tracking the process of LCI data set creation, including metadata documentation. The data management plan should include(WRI/WBCSD, 2011):

- Description of data collection procedures;
- Data sources;
- Calculation methodologies;
- Data transmission, storage and backup procedures;
- Quality control and review procedures for data collection, input and handling activities, data documentation and emissions calculations.

The recommended hierarchy of criteria for acceptance of data is:

- Primary data collected as part of the project and that have a documented Quality Assessment (Section 10.3);

- Data from previous projects that have a documented Quality Assessment;
- Data published in peer-reviewed journals or from generally accepted LCA databases that are regarded as reliable sources of information;
- Data presented at conferences or otherwise publicly available (e.g., internet sources);
- Data from industrial studies or reports can be considered.

10.2.1 Requirements and guidance for the collection of primary data

In general, primary data shall, to the fullest extent feasible, be collected for all foreground processes and for the main contributing sources to GHG emissions. Foreground processes, here defined as those processes under the direct control of, or significantly influenced by, the study commissioner, are depicted in Figure 10 and Figure 11 within the boundaries denoted as a *Production*, *Processing* and *By-product management*. Some foreground processes are impractical to measure for an LCA; for example, methane emission from litter management. In cases like this, when a model is used to estimate the emission, the input data used for the model shall be measured. In practice, this means that for farm-level studies the ration and its characteristics as well as the observed feed conversion ratio are required to provide estimates of the volatile solids and nitrogen content of the litter, which in turn can be used to estimate the methane and nitrous oxide emissions from litter management.
For most large-scale systems, the production of the ration may be considered a background process, while for many small-scale systems it may be fully integrated into the production system. In addition, the breeding system, from great-grandparents through parents, may be considered a background operation for most production systems. In Appendix A, we have provided secondary data from the literature for the background breeding system. Clearly, for analyses of the breeding system itself these operations would be considered in the foreground, and primary data shall be obtained.

The practicality of measured data for all foreground processes is also related to the scale of the project. As an example, if a national-scale evaluation of the poultry sector is planned, it is impractical to collect farm-level data from all poultry producers. In these cases, aggregated data from national statistical databases or other sources (e.g., trade organizations) may be used for foreground processes. In every case, clear documentation of the data collection process and data quality documentation to ensure compatibility with the study goal and scope shall be incorporated into the report.

It is known from prior work (Appendix A) what the hotspots are, thus secondary data for these stages of the supply chain should not be used. Specifically in the poultry sector, the major cereal and protein grains shall be representative of the actual production used for the region under study. Macleod et al. (2013) report that, globally, for chicken meat, feed production contributes 78% of emissions, direct on-farm energy use 8%, post-farm processing and transport of meat 7% and manure storage/processing 6%. They report that for eggs, feed production contributes 69% of emissions, direct on-farm energy use 4%, post-farm processing and transport of meat 6% and manure storage and processing 20%. The local conditions relevant to manure management emissions shall be considered. Workbooks that provide a template for primary data collection are included as Appendix A.

10.2.2 Requirements and guidance for the collection and use of secondary data

Secondary data refers to life cycle inventory data sets generally available from existing third-party databases, government or industry association reports, peer-reviewed literature, or other sources. It is normally used for background system processes, such as electricity or diesel fuel which may be consumed by foreground system processes. When using secondary data it is necessary to selectively choose the data sets which will be incorporated into the analysis. Specifically, life cycle inventory for goods and services consumed by the foreground system should be geographically and technically relevant. An assessment of the quality of these data sets (Section10.3.) for use in the specific application should be made and included in the documentation of the data quality analysis.

In all cases, given the known importance of the contribution of the ration to the environmental impacts of poultry production, it is imperative that secondary data used for the ration be relevant to the supply chain under study. For this, for example in evaluating a broiler production system in China, the use of proxy LCI for maize produced in the United States would only be suitable as secondary data if it is known that the operation being studied imports its maize from the United States.

Secondary data should only be used for foreground processes if primary data are unavailable, if the process is not environmentally significant, or if the goal and scope permit secondary data from national databases or equivalent sources. All secondary data should satisfy the following requirements:

- They shall be as current as possible and collected within the past 5-7 years.
- They should be used only for processes in the background system. When available, sector-specific data shall be used instead of proxy LCI data.
- They shall fulfill the data quality requirements specified in this guide (Section 10.3.).
- They should, where available, be sourced following the data sources provided in this guide (e.g. Section 11.2. for animal assessment and in appendix A).
- They may only be used for foreground processes if specific data are unavailable or the process is not environmentally significant. However, if the quality of available specific data is considerably lower and the proxy or average data sufficiently represents the process, then proxy data shall be used.

An assessment of the quality of these data sets for use in the specific application should be made and included in the documentation of the data quality analysis.

10.2.3 Approaches for addressing data gaps in LCI

Data gaps exist when there is no primary or secondary data available that is sufficiently representative of the given process in the product's life cycle. LCI data gaps can result in inaccurate and erroneous results (Reap et al., 2008). When missing LCI is set to zero, the result is bias towards lower environmental impacts (Finnveden et al., 2009; Huijbregts et al., 2001).

Several approaches have been used to bridge data gaps, but none are considered standard LCA methodology (Finnveden et al., 2009). As much as possible, the LCA practitioner shall attempt to fill data gaps by collecting the missing data. However, data collection is time-consuming and expensive, and is often not feasible. The following sections provide additional guidance on filling data gaps with proxy and estimated data.

The use of proxy data sets – background LCI data sets which are the most similar process/product for which data is available – is common. This technique relies on the practitioner's judgment, and is therefore, at least arguably, arbitrary (Huijbregts et al., 2001). Using the average of several proxy data sets has been suggested as a means to reduce uncertainty compared to the use of a single data set

Milà i Canals et al., (2011) also suggest that extrapolation from one data set to bridge the gap may also be used. For example, data from broiler production could be extrapolated to turkey production based on expert knowledge of differences in feed requirements, feed conversion ratios, and excreta characteristics. They showed the use of proxy data sets is the simplest solution but also of has the highest uncertainty. Extrapolation methods require expert knowledge, and are more difficult to apply, but provide more accurate results.

For countries where environmentally extended economic input-output tables have been produced, a hybrid approach can also be used as a means of bridging data gaps. In this approach the monitor value of the missing input is analysed through the input-output tables and then used as a proxy LCI data set. This approach is of course subject to uncertainty and has been criticized (Finnveden et al., 2009).

Any data gaps shall be filled using the best available secondary or extrapolated data. The contribution of such data (including gaps in secondary data) shall not account for more than 20 percent of the overall contribution to each emission factor impact category considered.

In line with the guidance on data quality assessment, any assumptions made in filling data gaps, along with the anticipated effect on the product inventory final results, shall be documented. If possible, the use of such gap-filling data should be accompanied by data quality indicators, such as a range of values or statistical measures that convey information about the possible error associated with using the chosen method.

10.3 Data quality assessment

LCA practitioners shall assess data quality by using data quality indicators. Generally, data quality assessment can indicate how representative the data are as well as their quality. Assessing data quality is important for a number of reasons: improving the inventory's data content, for proper communication and interpretation of results, as well as informing users about the possible uses of the data. Data quality refers to characteristics of data that relate to their ability to satisfy stated requirements(ISO 14040:2006). Data quality covers various aspects, such as technological, geographical and time-related-representativeness, as well as completeness and precision of the inventory data. This section describes how the data quality shall be assessed.

10.3.1 Data quality rules

Criteria for assessing LCI data quality can be structured by representativeness (technological, geographical, and time-related), completeness (regarding impact category coverage in the inventory), precision/uncertainty (of the collected or modelled inventory data), and methodological appropriateness and consistency. Representativeness addresses how well the collected inventory data represents the "true" inventory of the process for which they are collected regarding technology, geography and time. For data quality, the representativeness of the LCI data is a key component and primary data gathered shall adhere to the data quality criteria of technological, geographical, and time-related representativeness. Table 4 presents a summary of requirements for data quality. Any deviations from the requirements shall be documented. Data quality requirements shall apply to both primary and secondary data. For LCA studies using actual farm data and targeted at addressing farmer behaviour, ensuring that farms surveyed are representative and the data collected is of good quality and well managed is more important than detailed uncertainty assessment.

Table 4: Overview of requirements for data quality

Indicator	Requirements/data quality rules
Technological representativeness	The data gathered shall represent the processes under consideration.
Geographical representativeness:	If multiple units are under consideration for the collection of primary data, the data gathered shall, at a minimum, represent a local region such as EU-27. Data should be collected respecting geographic relevance to the defined goal and scope of the analysis.
Temporal representativeness	Primary data gathered shall be representative for the past three years and 5-7 years for secondary data sources. The representative time period on which data is based shall be documented.

10.3.2 DATA QUALITY INDICATORS

Data quality indicators define the standard for the data to be collected. These standards relate to issues such as representativeness, age, system boundaries, etc. During the data collection process, data quality of activity data, emission factors, and/ or direct emissions data shall be assessed using the data quality indicators. WRI/WBCSD has published additional guidance on quantitative uncertainty assessment[7] which includes a spreadsheet to assist in the calculations.

Data collected from primary sources should be checked for validity by ensuring consistency of units for reporting and conversion as well as material balances to ensure that, for example, all incoming materials are accounted in products leaving the processing facility.

Secondary data for background processes can be obtained from, for example, the EcoInvent database. In this situation, the data quality information provided by the database manager should be evaluated to determine if it requires modification for the study underway – for example, if use of European electricity grid processes in other areas will increase the uncertainty of those unit processes.

10.4 Uncertainty analysis and related data collection

Data with high uncertainty can negatively impact the overall quality of the inventory. The collection of data for the uncertainty assessment and understanding uncertainty is crucial for the proper interpretation of results (Section 12) and reporting and communication (Section 12.5).

The following guidelines shall apply for all studies intended for distribution to third parties, and should be followed for internal studies intended for process improvement:

- Whenever data is gathered, data should also be collected for the uncertainty assessment.
- Gathered data should be presented as a best estimate or average value, with an uncertainty indication in the form a standard deviation (where plus and minus twice the standard deviation indicates the 95% confidence interval if data follow a normal distribution.
- When a large set of data is available, the standard deviation should be calculated directly from this data. For single data points, the bandwidth shall be estimated. In both cases the calculations or assumptions for estimates shall be documented.

[7] http://www.ghgprotocol.org/calculation-tools/all-tools

10.4.1 Secondary activity data

See Section 10.2.2 and Appendix A.

10.4.2 Default/proxy data

See Section 10.2.2 and Appendix A.

10.4.3 Inter- and intra-annual variability in emissions

Agricultural processes are highly susceptible to variations in weather patterns year-to-year. This is particularly true for crop yields, but may also affect feed conversion ratios when environmental conditions are severe enough to have an impact on an animal's performance. Depending on the goal and scope definition for the study, additional information may be warranted such that either seasonal or inter-annual variability in the product system efficiency can be captured and identified.

11 LIFE CYCLE INVENTORY

11.1 Overview

The Life Cycle Inventory (LCI) analysis phase involves the collection and quantification of inputs and outputs throughout the life cycle stages covered by the system boundary of the study. This typically involves an iterative process (as described in ISO 14044: 2006), with the first steps involving data collection using principles as outlined in the previous section. The subsequent steps in this process involve recording and validating the data; relating the data to each unit process and functional unit (including allocation for different co-products); and aggregating data, ensuring all significant processes, inputs and outputs are included within the system boundary. The system boundary has pre- and post-farmgate stages (Figure 10 and Figure 11). Workbooks that provide a template for primary data collection are included as Appendix A. Figure 13 provides a guide to the procedure for determining the carbon footprint of poultry products for the cradle-to-farmgate stage.

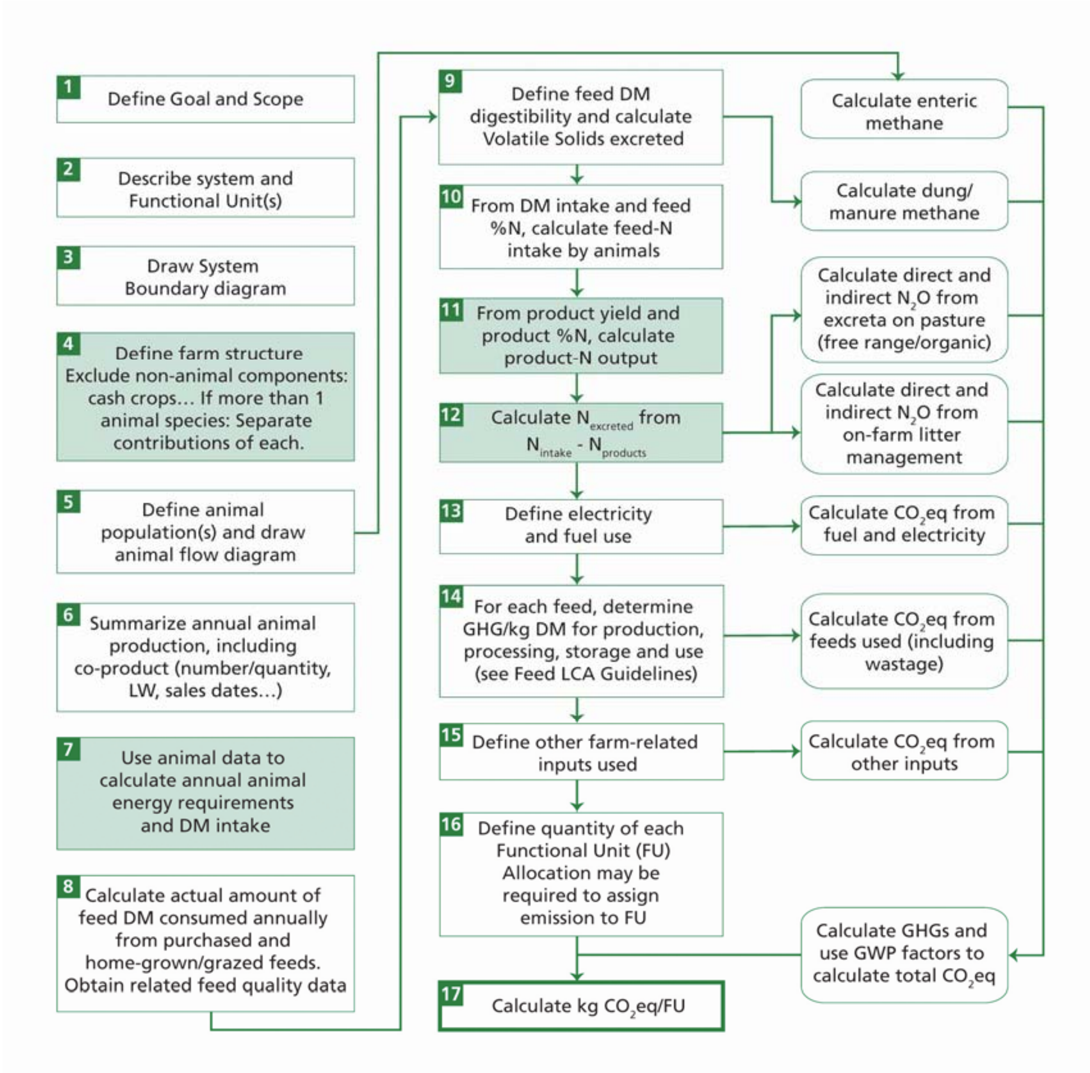
Given the recommended system boundary, there are specific processes for which data are required to compute the life cycle assessment. These are listed in brief below and are discussed in detail in the Box 1.

Box 1: Data requirement for specific processes necessary for LCI of poultry supply chain

- Feed production (on-farm or purchased, including minerals and other supplements) including upstream fertilizer manufacture, delivery and application, diesel used in cultivation, and nitrous oxide emissions from soil. The LEAP Animal Feed Guidelines provides detailed information for calculation of the contribution of feed/animal rations to the environmental footprint.
- Parent and grandparent hatchery data to calculate the upstream impacts of broiler and layer chick production. When this is a foreground system, the quantity and type ration, energy use, and manure management shall be fully accounted. For situations in which this stage is a background system, default life cycle inventory is provided in this document (Appendix A).
- Broiler and layer hen production primary data shall include a precise description of the production system and its targets. For example growth rate, number of eggs, final weight, actual performance, product and market specifications. The systems may be quite different in various countries or regions. Primary data regarding heating and ventilation, lighting, and other energy uses associated with feed and water management shall also be collected.
- Estimation of manure production and emissions associated with on-farm manure management. See section11.2.3 for specific guidance on this topic.
- Post-farm transportation and resource consumption at processing facilities, including types and quantities of co-products produced, such as blood, feather or bone meal.

11.2 Cradle-to-farmgate

FIGURE 13: FLOW DIAGRAM AS A GUIDE TO THE PROCEDURE FOR DETERMINING THE CARBON FOOTPRINT OF POULTRY PRODUCTS FOR THE CRADLE-TO-FARMGATE STAGE



Note: Content within the shaded boxes relate to allocation decisions, while rounded boxes are GHG calculation steps

The cradle-to-farmgate stage can be separated into three main processes of raw material acquisition, water and feed production, and use for animal production. Most raw material acquisition is associated with the production of feeds. Note that these guidelines provide limited information related to poultry feeds because they are covered in LEAP Animal Feed Guidelines. Thus, poultry feed information presented in this document is largely for context and also because of the strong linkage between feeds and animal production. For animal feeds derived from annual and perennial plant types, the inputs of fertilizers, manures and lime are often significant sources of GHG emissions. When annual crops are used for feed, the fuel (e.g. for tillage, harvest and transport), crop residues (that produce N_2O emissions) and land-use change components are also important contributors to GHG emissions. For highly processed feeds (e.g. compound feed/concentrates) there may also be significant energy use and emissions during their processing and storage. Readers are referred to the LEAP Animal Feed Guidelines for detailed guidance on estimating the cradle-to-beak impact of the ration.

Water supply to animals is important for their survival and energy inputs are often required for the provision (e.g. for pumping and reticulation) and/or transport of water. Background processes from existing databases can be used when water is purchased from a municipal source. If local well water is used, the pumping power can be estimated with the following equation:

$$P_h = q\rho g h/(3.6e6) \quad (1)$$

Where P_h = fluid power (kW), q = pumping rate (m^3/h), ρ = fluid density (1000 kg/m^3 for water), g = gravity (9.8m/s^2), h = differential head (m), which is approximately the depth of the well plus the additional elevation necessary to deliver the water to the birds. The power required for the motor is the fluid power divided by the motor efficiency, η, typically 60-70%:

$$P = P_h/\eta \quad (2)$$

For electric pumps, the total energy consumption is estimated as *P*pumping hours.*

There is also a small contribution to resource use and GHG emissions associated with the production and provision of animal health inputs, which may include treatments for infectious diseases, internal and external parasites, reproductive diseases, metabolic diseases, and mineral deficiencies. These materials are likely below the materiality cut-off, but can be estimated using secondary, or proxy data from extant databases.

To assist the user in working through the process of calculating the carbon footprint of products for the cradle-to-farmgate stage, a flow diagram illustrating the various steps involved is presented in Figure 13.

At the cradle-to-farmgate stage, previous research has shown that the largest source of GHG emissions is feed production (Leinonen et al., 2012a, 2012b; Poad et al., 2012; Wiedemann and McGahan, 2011). Manure management may also contribute to emissions; however, as it is frequently utilized as a substitute for inorganic fertilizers, it is possible for a net credit to the system to result for manure. Clearly, an important first step is to define the feed types used and their feed quality characteristics.

11.2.1 Feed assessment

This section refers to identifying the type, quantity and characteristics of feed, which relates to both upstream impacts (the domain of the LEAP Animal Feed guidelines) but also downstream impacts from manure management, which is the domain of this methodology. While information on most of the rations used in large-scale commercial operations is confidential, it remains important to obtain primary data on the ration. For many regions, much of the ration may be imported; for instance in Senegal, most of the corn, the wheat and other low-volume ingredients (lysine, methionine) come from abroad. In addition, there is a great diversity between industries, within broiler or egg production (starter, grower and laying diets), in the presentation (meal, mash, crumbles, pelleted diets) and a shift, for example, in Northern Europe toward the use of entire cereal grain in broiler diets.

Because of the diversity of rations and the fact that rations production contributes significantly to environmental impacts, the ration shall be carefully evaluated and accurately represented in the analysis and assessment of poultry supply chains. In addition, different production systems result in different environmental conditions for the animals (e.g., temperature) that can affect the maintenance energy needs and thus the feed conversion ratio, further underscoring the need for primary data on feed consumption. Characteristics of the ration which are important to include are the energy content, crude protein (or amino acid) contents, and ash. These are used with physiology models to predict the quantity and character of excreta because measurements are not typically available. Recommended Brazilian backyard or organic ration primary nutrient requirements for broilers and layers are shown in Table 5 and Table 6. The breeds (Empraba 041 and 051) are hybrid, slower growing, hardy animals well suited to backyard or organic production systems.

The LEAP Animal Feed Guidelines, which provides support for environmental life cycle assessment from the cradle-to-beak, shall be referred to in this assessment. In practice, there is wastage of feed at various stages between harvest and feeding and this shall be accounted for. For example, if there is 10% wastage between harvesting maize and consumption by animals, the emissions from crop inputs should be based on the crop harvested and not the final amount eaten – this source is treated fully in the LEAP Animal Feed Guidelines. At the farm, a significant component of the wastage occurs during feeding. This waste feed may end up in the manure management system and its contribution to subsequent methane and N_2O should be accounted for and included with the manure emissions estimation (Section 11.2.3).

TABLE 5: NUTRITIONAL REQUIREMENTS TO BROILER IN A BACKYARD OR ORGANIC PRODUCTION SYSTEM (EMBRAPA 041 BRAZILIAN BREEDING)

Nutrients	**1-28 days**	**29-60 days**	**61-91 days**
Metabolizable Energy Kcal/kg	2800	2900	2900
Crude Protein %	19,5	17,5	16,5
Calcium %	1,0	1,0	0,95
Total Phosphurus%	0,71	0,67	0,61

TABLE 6: NUTRITIONAL REQUIREMENTS TO LAYERS IN A BACKYARD OR ORGANIC SYSTEM (EMBRAPA 051 BRAZILIAN BREEDING)

Nutrients	1-6 weeks	7-18 weeks	19-45 weeks	>46 weeks
Metabolizable Energy Kcal/kg	2,850-2,900	2,700-2,750	2,800-2,850	2,800-2,850
Crude Protein %	20-25	14-14.5	15.5-16	15-15.5
Calcium %	0.75-0.80	0.85-0.90	3.4-3.6	3.7-3.8
Available Phosphurus %	0.42	0.36	0.42	0.42

(Avila and de Soares, 2010)

a) Feed milling

One area of particular importance in poultry production systems is when the ration is formulated in a feed mill using least-cost formulation algorithms to select the raw input for the ration. Least-cost formulations can change on a weekly or monthly basis, and therefore, to accurately account for the environmental footprint of the ration, an annual average ration is necessary.

In addition, poultry nutritionists require specific nutrient composition of the ration. Milling processes can change characteristics of feeds, specifically, digestibility and potentially crude protein content. It is therefore important to determine that the ration specified in the life cycle assessment matches both the poultry nutrition requirements and that the milling process model, chosen from LEAP Animal Feed Guidelines is appropriate to provide the required ration characteristics. Careful reference to the LEAP Animal Feed Guidelines is important to assure that appropriate feed burdens are captured for the system under study. It may occur that a more expensive formulation results in lower excretion and GHG emissions and the cost of environmental management will be decreased.

b) Computing emissions

Emissions from the ration should, to the extent feasible, be calculated based on guidance in the LEAP Animal Feed Guidelines. For most large-scale operations, rations represent a significant fraction of the environmental footprint and therefore it is critical that the emissions accurately represent the actual production practices followed for their creation. Specifically, the source of the feed (local, regional, or imported) must be representative of the feeds provided. When feeds are imported, it is necessary to follow the protocol in the LEAP Animal Feed Guidelines to calculate the environmental burden of production and delivery to the exporting country port. The estimate of specific transport distances, from the exporting to importing country shall be accounted as specified in the LEAP Animal Feed Guidelines documentation. These emissions can be combined directly with production and post-farm emissions to calculate the supply chain totals. In practice, most diet decisions are based on least-cost formulation, however an LCA could illustrate the emission impacts made by changes to rations. In some cases it is more cost effective to have a slightly less efficient feed conversion.

11.2.2 Animal population and production

Most models used for calculation of feed requirements derive intake from the energy requirements for growth, reproduction, egg production and maintenance. This requires data on relevant animal numbers and productivity. Information regarding mortality losses as well as the number of live birds or eggs produced over a year is necessary for baseline evaluation. Specific information requirements will depend on the facility type under analysis – grandparent/parent/production as well as the specific type of production under study: large-scale versus small-scale or caged versus free range.

To account for total GHG emissions over a one-year time period, it is necessary to define the animal population associated with the production of the products. This requires accounting for breeding poultry, pullet or broiler replacement for each barn production cycle, and spent (i.e. not required for maintenance of the flock) hens sold for meat. The benefit of having a methodology and primary seasonal or monthly data is that the effects of improvement in animal productivity on reducing the carbon footprint of products can be determined; e.g. achieving the market weight earlier means less feed is consumed and the maintenance feed requirement is reduced relative to the feed needed to achieve a given level of animal production.

a) Animal enteric methane emissions

According to IPCC (2006), insufficient information exists regarding enteric methane emissions from poultry (Dong et al., 2006). However, two studies, from Taiwan and Malaysia report enteric methane from poultry ranging from 0.015 to 2 g CH_4 /head/year (Wang and Huang, 2005; Yusuf et al., 2012) which should be used as default emission factors.

11.2.3 Manure production and management

a) Biological principles

From an animal physiology perspective, the characteristics of the excreta are defined by the characteristics of the ration and the efficiency of its conversion into the product of interest (meat or eggs). The digestibility and ash content which characterize the fraction of the ration that is not available to support metabolic needs are particularly relevant. The crude protein content of the ration and protein deposition rate define the nitrogen content in the excreta. Poultry litter may have additional material such as straw added (with additional carbon, phosphorus and nitrogen), which affects the emissions from the subsequent management system.

b) Manure production

The first step to estimating manure GHG emissions is to estimate manure excretion, and more specifically the mass of volatile solids (VS) and nitrogen (N) excreted in manure. Manure VS and N excretion may be estimated by using information collected from poultry producers, i.e. daily feed intake and the properties of the diet, or by applying the default excretion values for poultry (ASAE Standards, 2005; Dong et al., 2006).

For meat chickens excretion is calculated by:

$$N_{E-PH} = \frac{FI_{PH}C_{CP}}{6.25}(1 - N_{RF}) \equiv {}^{g\,N}/_{phase} \quad (3)$$

Where: $N_{E\text{-}PH}$ = Nitrogen excretion per bird-phase (grams of nitrogen per bird-phase); FI_{PH} = Feed intake per bird-phase. (as fed); C_{CP} = Concentration of crude protein of total ration (as fed); N_{RF} = retention factor for nitrogen (fraction dietary N retained in bird– broilers: 0.602; turkey toms and hens: 0.588 (ASAE Standards, 2005). Equation 1 shall be summed over all the growth phases over the course of one year's operation.

For laying hens not gaining body weight, nitrogen excretion may be calculated by:

$$N_E = \frac{FI * C_{CP}}{6.25} - \left((0.0182\, EGG_{wt})(EGG_{prod})\right) \equiv {}^{g\,N}/_{day} \quad (4)$$

Where: N_E = total nitrogen excretion per hen per day (grams nitrogen per hen per day); FI = Feed intake per day (as fed); C_{CP} = Concentration of crude protein of total ration (g of protein/ g of feed (as fed)); Egg_{wt} = Egg weight (grams – typical 60g for light layer strains and 63g for heavy layer strains); Egg_{prod} = Number of eggs that are produced per day (eggs / hen / day – typical value, 0.8 (ASAE Standards, 2005). Annual excretion shall be estimated from the animal population, excretion per bird per day and 365 days/year.

Volatile solids excretion may be predicted using the feed intake, digestibility of the diet and ash content in the manure using the formula:

$$VS = FI_{PH}(1 - DMD)(1 - A) \equiv {}^{kg\,VS}/_{phase} \quad (5)$$

FI_{PH} = Feed intake per bird-phase (kg, as fed); DMD = Diet digestibility expressed as a fraction (default value of 80%); A = Ash content of manure (default value approx. 10%). Volatile solids shall be summed across all production phases during one year's operation.

c) Manure management systems

Manure emissions shall be estimated at each point in the manure management system following a mass balance approach. Emission sources are shown in Figure 14 for chicken production utilizing housing systems. Two factors relating to the flow of spent litter are required: i) a partitioning factor between directly applied spent litter and stored spent litter, and ii) a partitioning factor between spent litter applied in regions susceptible to leaching and runoff.

Housing emissions – Methane

Manure methane emissions may be estimated using the following general formula:

$$CH_4 = VS(B_O)(MCF)(\rho) \equiv {}^{kg\ CH_4}/_{day} \quad (6)$$

Where: VS = volatile solids excretion (kg/day); B_o = emissions potential - m^3 CH_4/kg VS (provided in IPCC – (Dong et al., 2006) – 0.36 for developed countries); MCF = Integrated methane conversion factor (default value of 1.5-2% for poultry housed on litter); ρ = density of methane (0.662 kg CH_4/m^3).

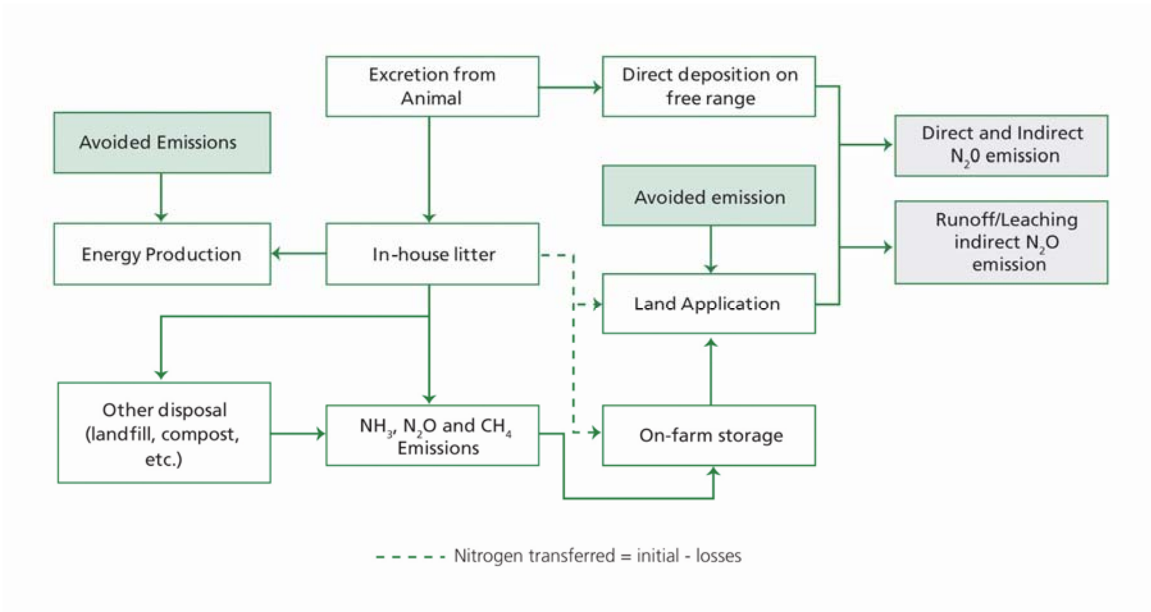
Housing emissions – Nitrous Oxide

Direct nitrous oxide emissions from manure management in the shed can be calculated by:

$$N_2O = N_E(EF_{MMS})\left(\frac{44}{28}\right) \equiv {}^{kg\ N_2O}/_{day} \quad (7)$$

Where: N_2O = Nitrous oxide emissions from manure management (kg/day); N_E = nitrogen excretion (kg/day – if nitrogen excretion is based on equation (3), then the N_2O emissions will be per phase rather than per day); EF_{MMS} = the emission factor for the relevant manure management system; the factor 44/28 is to convert mass of N_2O-N to mass of N_2O. If multiple management systems are used, or if the nitrogen excretion varies significantly throughout the year, then these factors must be accounted in the analysis. This formula is sensitive to the estimated nitrogen excretion and the emission factor applied. Recommended emission factors from the IPCC are reported in Table 7.

FIGURE 14: NITROGEN MASS FLOWS FROM SPENT LITTER



Note: Emissions from land application (orange boxes) fall within the LEAP Animal Feed Guidelines, while emissions from direct deposition (e.g., backyard systems) should be accounted as emissions assigned to the animals as that manure may not be exploited for crop production.

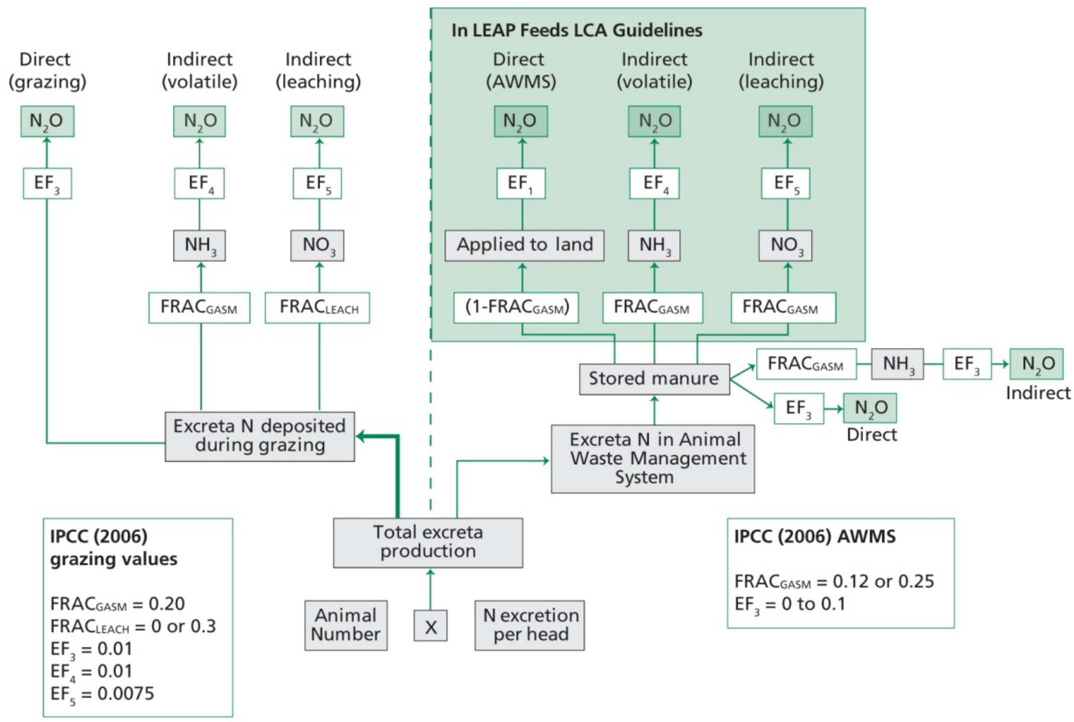
Free-range poultry systems use a different manure management system and require different emission factors. In the free-range system, a proportion of manure is deposited indoors (on litter or slats) and the remainder is deposited outdoors.

TABLE 7: MANURE MANAGEMENT SYSTEMS AND EMISSION FACTORS FOR NITROUS OXIDE

Management system	**IPCC emission factor for nitrous oxide kg N_2O / kg N excreted**
Poultry manure with litter (bedding)	0.001[a]
Poultry manure deposited outdoors (free range and organic supply chains)	0.02 [b]
Poultry manure without litter (majority of egg production systems).	0.001 [a]

[a] IPCC (Dong et al., 2006); [b] (De Klein et al., 2006).

Figure 8: Calculation of N_2O



Note: Summary of approach for calculating N_2O emissions from animal excreta and the waste management system (WMS) using IPCC (2006) activity factors (FRAC refers to fraction of N source contributing) and emission factors (EF in kg N_2O-N/kg N). GASM = gaseous loss as ammonia; FRACgasm and EF1 vary with type of AWMS. For manure, only manure storage losses are included in these guidelines (losses from land application are covered in the LEAP Animal Feed Guidelines).

Indirect Nitrous Oxide Emissions

Indirect N_2O emissions from ammonia loss and N leaching from excreta deposited directly to land during grazing shall be calculated as shown in Figure 15. Country-specific factors that have been published and integrated into the national GHG Inventory shall be used and if not available the IPCC (2006) default factors shall be used. Calculations first require an estimate of the amounts of ammonia loss and N leaching from excreta deposited on land. The default IPCC (2006) loss factor for $FRAC_{GASM}$ is 20% of N excreted and for $FRAC_{LEACH}$ is 30% (for soils with net drainage, otherwise 0%) of N excreted. These are then multiplied by the corresponding IPCC (2006) emission factors of 0.01 kg N_2O-N/kg N lost as ammonia and 0.0075 kg N_2O-N/kg N leached, respectively.

The total N_2O emissions from excreta and manure are calculated by summing the direct and indirect N_2O emissions, after adjustment for the N_2O/ N_2O-N ratio of 44/28.

d) Ammonia volatilization

Indirect emissions of nitrous oxide occur as the result of ammonia volatilisation from the production system and from ammonia volatilisation during manure application. Ammonia emissions are deposited onto land where they contribute to a pool of soil nitrogen, some of which is re-emitted as nitrous oxide. Consequently, the emissions are attributed to the facility responsible for the ammonia emissions.

TABLE 8: AMMONIA EMISSION FACTORS FROM DIFFERENT STAGES OF MANURE MANAGEMENT

Emission source	**Ammonia emission factor (fraction of NH_3-N volatilized)**
Housing (with litter)	0.40[a]
Housing (without litter)	0.55[a]
Manure storage	0.20
Land application	0.20[b]

Indicative ammonia emission factors and total losses (as a percentage of excreted N) are shown in Table 8. Values may be derived from IPCC or local research. Of the nitrogen lost as ammonia (NH_3-N), the IPCC apply an emission factor of 0.01 (1%) to calculate indirect nitrous oxide emissions.

e) Leaching and runoff

Indirect nitrous oxide emissions from nitrogen that is leached or lost from runoff after manure application may be predicted using the following formula:

$$M_L = M_A(Frac_{wet})(Frac_{leach}) \equiv {}^{kg\ N}/_{day} \quad (8)$$

Where: M_L = Mass of manure N lost through leaching and runoff; M_A = mass of manure N stored in a system potentially subject to leaching and runoff; $Frac_{wet}$ = fraction of N available for leaching and runoff; $Frac_{leach}$ = 0.3 (IPCC default fraction of N lost through leaching and runoff); the default nitrous oxide emission factor from manure N lost through leaching and runoff is 0.0125 according to the IPCC (Dong et al., 2006).

11.2.4 EMISSIONS FROM OTHER FARM-RELATED INPUTS

Substantial variation in energy requirements may exist between different types of production operations; however, for intensive systems, there are generally requirements for lighting, ventilation, and heating – depending on the local climate. Extensive systems may not have significant inputs, but fuel for transportation shall be accounted. Where there is a significant use of consumables in farm operations, the GHG emissions associated with their production and use should be accounted. However, in practice these will often be a very minor contribution and relevant data on them may be difficult to access. See Section 8.4.3 on cut-off criteria for exclusion of minor contributors.

The total use of fuel (diesel, petrol) and lubricants (oil) associated with all on-farm operations shall be estimated. This shall be based on actual use and shall include that used by contractors involved in on-farm operations. Where actual fuel use data is unavailable, it should be calculated from the operating time (hours) for each activity involved in fuel use and the fuel consumption per hour (this latter parameter can be derived from published data or from appropriate databases (e.g. EcoInvent). Note that any operations associated with the production, storage and transportation of poultry feeds shall not be included, to avoid double counting, if values for total emissions associated with specific feeds are derived from a feed database where they are already included (e.g. from default values from the LEAP Animal Feed Guidelines). However, they shall include fuel use in transportation from the source of feed storage to the farm, where the point of storage is not on-farm (e.g. for compound feed/concentrates purchased from a local feed merchant). Some of the main processes associated with the use of fuels include water transport, use of vehicles for animal movement, provision of feeds to poultry on-farm and other farm-specific activities.

The total amount of use of a particular fuel type is then multiplied by the relevant country-specific GHG emission factor (which accounts for production and use of fuel: see third-party databases for secondary life cycle inventory and in some cases geographically specific data sets). The process for calculating fuel-related emissions also applies to electricity. Thus, all electricity use associated with farm activities (excluding feed production and storage where they are included within the emission factor for feeds) shall be estimated. This includes electricity for water recirculation, ventilation and lighting. Country-specific emission factors for electricity production and use shall be applied according to the electricity source. This would typically be the national or regional average and would account for the mix of renewable and non-renewable energy sources used for the electricity grid mix.

11.2.5 By-products and waste

The on-farm management of wastes other than manure shall also be accounted. In particular, the management of mortalities and broken/damaged eggs should be included in the inventory. Waste materials such as disposed packaging or other solid waste shall also be accounted.

11.3 Transportation

Estimating environmental impacts of transportation entails two allocation issues: allocation of empty transport distance of transport means and allocation of the load fraction of transportation means.

The allocation of empty transport distance is often done already in the background models used for deriving the secondary LCI data for transportation. However, if primary data for transport should be derived, the LCA user should make an estimate of the empty transport distance. It is good practice to apply a worst-case estimate here, meaning inclusion of 100% extra transport for empty return.

Allocation of empty transport kilometres (backhaul) shall be done on the basis of the average load factor of the transport that is representative for the transport under study. If no supporting information is collected, 100% extra transport for empty return should be assumed.

If products are transported by a vehicle, resource use and emissions of the vehicle shall be allocated to the transported products. A means of transport has a maximum load, expressed as tonnage. However the maximum weight can only be achieved if density of the loaded goods allows.

Allocation of transport emissions to transported products shall be performed on the basis of mass share, unless the density of the transported product is significantly lower than average so that the volume restricts the maximum load.

Fuel consumption from transport can be estimated using a) the fuel cost method, b) the fuel consumption method, or c) the ton-kilometre method (Appendix A). Transport distances may be estimated from routes and mapping tools or obtained from navigation software.

11.4 Inclusion and treatment of land-use change (LUC) impacts

The reader is referred to the LEAP Animal Feed Guidelines for additional detail. GHG emissions associated with LUC should be separately accounted and reported. PAS 2050, 2011 provides additional guidance.

11.5 Biogenic and soil carbon sequestration

Biogenic and soil carbon sequestration can be important for some poultry systems. However, since this relates only to the feed production stage, the specific methods are covered in the LEAP Animal Feed Guidelines. As these guidelines note, biogenic and soil carbon sequestration shall be included in the final GHG emissions value. Where no data relating to soil carbon sequestration are available, the LEAP Animal Feed guidelines provide default values for temperate climate. The last option is to assume zero change in soil carbon.

11.6 Primary processing stage

This stage of the poultry value chain includes: slaughter, removal of blood and feathers, feet and head, evisceration, washing and cooling, cutting and packaging as well as production and management of numerous by-products such as feather and bone meal in addition to the main meat products. For operations that include rendering, the energy requirements can be significant. Other inputs that shall be included at this phase are electricity for refrigeration and water and chemicals for equipment cleaning. The following processes shall be evaluated:

- Transport of live birds or eggs (if applicable) to the processing site from the farmgate;
- Production, delivery and consumption of materials used in processing, e.g. cleaning chemicals and packaging materials;
- Other purchased inputs or ingredients;
- Freshwater usage and wastewater treatment (quantity of water, chemicals, energy);
- Releases resulting from background processes, including chemical and ingredients production, refrigerant manufacturing and losses and other emissions sources;
- Energy consumption: electricity, natural gas, on-site energy production;
- Waste management that has environmental impacts (e.g. landfill disposal of solid waste and wastewater treatment).

a) Calculating GHG emissions from meat processing

Calculation of GHG emissions shall account for resource use, waste-water processing and the associated GHG emission factors. Electricity and other energy use shall account for total embodied emissions relevant to the country where the primary processing occurs. Data on waste-water quantity and composition is used with the GHG emission factors for the method of waste-water processing (IPCC 2006) to calculate GHG emissions. Total GHG emissions shall be allocated between the various co-products as outlined in Section 9.3.4.

b) Calculating GHG emissions from egg processing

Calculation of GHG emissions shall account for resource use, waste-water processing, waste egg and shell management using appropriate emission factors. Electricity and other energy use shall account for total embodied emissions relevant to the country where the primary processing occurs.

Box 2: Example of emissions calculation for an average US abattoir

This facility processes 1.0 million birds per week with an average weight of 2700 grams. Data are available for the entire facility on an annual basis:

		Emission Factor*
Water Use (m^3)	1,086,410	0.435 kg CO_2e /m^3
Waste Water Treatment(m^3)	1,093,981	3.99 kg CO_2e /m^3
Electricity (kWh)	57,500,000	0.77 kg CO_2e/kWh
Natural Gas (m^3)	5,012,082	2.5 kg CO_2e/m^3
Meat products (kg)	107,256,236	
Inedible co-products (kg)	33,870,390	

* calculated from EcoInvent processes using SimaPro 7.3®

The facility (unallocated) gate-to-gate GHG emissions are calculated as the sum of the products the inputs and emission factors: 50,365 metric tonnes CO_2e. The calculation of the estimated impact of the meat products is achieved through an economic or mass allocation, as shown in a subsequent example.

11.7 Multifunctional examples

11.7.1 On-site energy generation

System expansion/substitution for energy generated within the system and sold outside the system under study, such as sale of energy generated on farm by litter burning and sold to the grid. For situations where poultry litter may be used in energy generation equipment, an avoided burden of electricity or heat production may accrue at the farmgate. However, all emissions from combustion of the litter within the system, to the point at which energy (i.e., heat or electricity) is substituted, shall be included in the system inventory, including disposition of combustion ash (Section 9). This is in line with ISO 14044 (2006); it is important to know which form of energy is being exported.

The flows are from the animal system to manure and then to primary energy inputs so credits can be assessed by avoided electricity production from the local grid. In addition, the resulting ash must be assessed as a substitute product or classified as a residual, waste or co-product following Section 9. If the use of the ash as a fertilizer can be shown to unambiguously substitute for inorganic fertilizers, an additional substitution should be accounted, otherwise depending on the economic value and final disposition it should be accounted following the decision tree (Section 9.2.).

11.7.2 Replacement of inorganic fertilizer

Box 3: Example of Application of system expansion for manure as a replacement synthetic fertilizer

Poad et al. (2012) used system expansion for manure nutrients and accounted for both the manufacture and application of spent litter and synthetic fertilizer. The calculations included the respective nitrogen emissions that arise from both systems, from production through field emissions. The chicken meat system was credited with both the avoided manufacturing cost of synthetic fertilizer and the emissions that would have arisen from the use of the fertilizer. Specific equivalence factors for substituting nutrients in spent litter are provided in Table 9.

Table 9: Spent litter allocation (system expansion) assumptions

Nutrient	Substitution product	Substitution value of nutrients in spent litter with synthetic fertilizer
Nitrogen:	1 kg of nitrogen as urea applied to land.	0.6
Phosphorus:	1 kg of phosphorus as triple superphosphate	0.6
Potassium:	1 kg of potassium as potassium chloride	1

As discussed in Wiedemann et al. (2010), nutrients in organic by-products may not be directly equivalent to synthetic fertilizer, mainly because of the lower levels of plant availability and greater risk of nutrient loss at the point of application for spent litter.

The calculated substitution values are used as an avoided product flow of synthetic fertilizer in the unit process which produces the manure.

Box 4: Example of Effect of mass and economic value of different components of an average US broiler leaving an abattoir on allocation calculations

Data in the table below was based on a summary of the average weight of different meat cuts and co-products from lamb leaving an average abattoir in the United States. The average economic value of the different components is also given and this is used in calculation of the allocation among co-products. The gross revenue across all edible components was used to calculate the allocation, which results in the same impact assigned to all edible parts. It also illustrates relatively large difference in economic value of the co-products.

Table 10: Economic and mass allocation calculation at an abattoir

	Average mass of component (g)	Component % of total mass	Component as % of total economic value
Live Weight	2500	100	
Meat / Edible Products:			
Dark meat/leg quarter /back half	825	33	35%
Breasts/Boneless Skinless/bone-in	925	37	41%
Wings	150	6	13%
Inedible offal			
Inedible organs / viscera / fat/ giblets	160	6.4	6%
Head, Feet	190	7.6	3%
Blood, Feather	250	10	2%

Thus the economic allocation percentage (EA) for meat relative to the total returns was calculated using: EA (%) = 100 x Σ(meat product revenue contribution) / [Total revenue]

The mass allocation percentage (MA) for meat was calculated using:

MA (%) = 100 x Σ(weight of meat components) / [Σ(weight of meat components + Σ(weight of co-products)]

The results from these calculations for % allocation to meat using economic or mass allocation were 89% and 76%, respectively.

12 INTERPRETATION OF LCA RESULTS

Interpretation of the results of the study serves two purposes (European Commission, 2010):

At all steps of the LCA, the calculation approaches and data shall match the goals and quality requirements of the study. In this sense, interpretation of results may inform an iterative improvement of the assessment until all goals and requirements are met.

The second purpose of the interpretation is to develop conclusions and recommendations, e.g. in support of environmental performance improvements. The interpretation entails three main elements detailed in the following subsections: "Identification of important issues," "Characterizing uncertainty" and "Conclusions, limitations and recommendations".

12.1 Identification of key issues

Identifying important issues encompasses the identification of most important impact categories and life cycle stages, as well the sensitivity of results to methodological choices.

The first step is to determine the life cycle stage processes and elementary flows that contribute most to the LCIA results, as well as the most relevant impact categories. To do this, a <u>contribution analysis</u> shall be conducted. It quantifies the relative contribution of the different stages/categories/items to the total result. Such contribution analysis can be useful for various interests, such as focusing data collection or mitigation efforts on the most contributing processes.

Secondly, the extent to which methodological choices such as system boundaries, cut-off criteria, data sources, and allocation choices affect the study outcomes shall be assessed, especially impact categories and life cycle stages having the most important contribution. In addition, any explicit exclusion of supply chain activities, including those that are excluded as a result of cut-off criteria, shall be documented in the report. Tools that should be used to assess the robustness of the footprint model include (European Commission, 2010):

- <u>Completeness checks</u>: evaluate the LCI data to confirm that it is consistent with the defined goals, scope, system boundaries, and quality criteria and that the cut-off criteria have been met. This includes completeness of process (i.e. at each supply chain stage, the relevant processes or emissions contributing to the impact have been included) and exchanges (i.e. all significant energy or material inputs and their associated emissions have been included for each process).
- <u>Sensitivity checks</u>: assess the extent to which the results are determined by specific methodological choices, and the impact of implementing alternative, defensible choices where these are identifiable. This is particularly important with respect to allocation choices. It is

useful to structure sensitivity checks for each phase of the study: goal and scope definition, the life cycle inventory model, and impact assessment.

- Consistency checks: ensure that the principles, assumptions, methods and data have been applied consistently with the goal and scope throughout the study. In particular, ensure that the following are addressed: (i) the data quality along the life cycle of the product and across production systems, (ii) the methodological choices (e.g. allocation methods) across production systems and (iii) the application of the impact assessments steps with the goal and scope.

12.2 Characterizing uncertainty

This section is related to *Section* 9, data quality. Several sources of uncertainty are present in LCA. First is knowledge uncertainty which reflects limits of what is known about a given datum, and second is process uncertainty which reflects the inherent variability of processes. We can reduce knowledge uncertainty by collecting more data. We may reduce process uncertainty by breaking complex systems into smaller parts or aggregations, but inherent variability cannot be eliminated completely. Third, the characterization factors that are used to combine the large number of inventory emissions into impacts also bring uncertainty into the estimation of impacts. In addition, there is bias introduced if the LCI model is missing processes, or may have larger flows than actually present.

Variation and uncertainty of data should be estimated and reported. This is important because results based on average data (i.e. the mean of several measurements from a given process – at a single or multiple facilities) or using LCIA characterization factors with known variance do not reveal the uncertainty in the reported mean value of the impact. Uncertainty may be estimated and communicated quantitatively through a sensitivity and uncertainty analysis and/or qualitatively through a discussion. Understanding the sources and magnitude of uncertainty in the results is critical for assessing robustness of decisions that may be made based on the study results. When mitigation action is proposed, knowledge of the sensitivity to, and uncertainty associated with the changes proposed provides valuable information regarding decision robustness, as described in Table 11.

At a minimum, efforts to accurately characterize stochastic uncertainty and its impact on the robustness of decisions should focus on those supply chain stages or emissions identified as significant in the impact assessment and interpretation. Where reporting to third parties, this uncertainty analysis shall be conducted and reported.

TABLE 11: GUIDE FOR DECISION ROBUSTNESS FROM SENSITIVITY AND UNCERTAINTY

Sensitivity	Uncertainty	Robustness
High	High	Low
High	Low	High
Low	High	High
Low	Low	High

12.2.1 MONTE CARLO ANALYSIS

In a Monte Carlo analysis, parameters (LCI) are considered as stochastic variables with specified probability distributions, quantified as probability density functions (PDF). For a large number of realizations, the Monte Carlo analysis creates an LCA model with one particular value from the PDFs of every parameter and calculates the LCA results. The statistical properties of the sample of LCA results across the range of realizations are then investigated. For normally distributed data, variance is typically described in terms of an average and standard deviation. Some databases, notably EcoInvent, use a lognormal PDF to describe the uncertainty. Some software tools (e.g. SimaPro, OpenLCA) allow the use of Monte Carlo simulations to characterize the uncertainty in the reported impacts as affected by the uncertainty in the input parameters of the analysis.

12.2.2 SENSITIVITY ANALYSIS

Choice-related uncertainties arise from methodological including modelling principles, system boundaries and cut-off criteria, choice of footprint impact assessment methods, and other assumptions related to time, technology, geography, etc. Unlike the LCI and characterization factors, they are not amenable to statistical description, but the sensitivity of the results to these choice-related uncertainties can be characterized through scenario assessments (e .g., comparing the footprint derived from different allocation choices) and/or uncertainty analysis (e.g. Monte Carlo simulations).

In addition to choice-related sensitivity evaluation, the relative sensitivity of specific activities (LCI datasets) measures the percentage change in impact arising from a known change in input parameter (Hong et al., 2010).

12.2.3 NORMALIZATION

According to ISO 14044, normalization is an optional step in impact assessment. Normalization is a process in which an impact associated with the functional unit is compared against an estimate of the entire regional impacts in that category (Sleeswijk et al., 2008). For example, livestock supply chains have been estimated to contribute 14.5% of global anthropogenic greenhouse gas emissions (Gerber et al., 2013). Similar assessments can be made at regional or national scales, provided that a reasonably complete inventory of all emissions in that region which contribute to the impact category exists. Normalization provides an additional degree of insight into those impacts for which significant improvement would result in a significant improvement for the region in question, and can help decision-makers to focus on supply chain hotspots for which improvement will result in the greatest overall environmental benefit.

12.3 Conclusions, Recommendations and Limitations

The final part of interpretation is to draw conclusions derived from the results, pose answers to the questions raised in the goal and scope definition stage, and recommend appropriate actions to the intended audience, within the context of the goal and scope, explicitly accounting for limitations to robustness, uncertainty and applicability.

Conclusions derived from the study should summarize supply chain "hot spots" derived from the contribution analysis and the improvement potential associated with possible management interventions. Conclusions should be given in the strict context of the stated goal and scope of the study, and any limitation of the goal and scope can be discussed *a posteriori* in the conclusions.

As required under ISO 14044:2006, if the study is intended to support comparative assertions (i.e. claims asserting difference in the merits of products based the study results), then it is necessary to fully consider whether differences in method or data quality used in the model of the compared products impair the comparison. Any inconsistencies in functional units, system boundaries, data quality, or impact assessment shall be evaluated and communicated.

Recommendations are based on the final conclusion of the LCA study. They shall be logical, reasonable, plausible founded and strictly relate to the goal of the study. Recommendations shall be given jointly with limitations in order to avoid their misinterpretation beyond the scope of the study.

12.4 Use and comparability of results

It is important to note that these guidelines refer only to a partial LCA and that where results are required for products throughout the whole life cycle then it is necessary to link this analysis with relevant methods for secondary processing through to consumption and waste stages (e.g. EPD 2012; PAS 2395 2013 Draft). Results from application of these guidelines cannot be used to represent the whole life cycle of poultry products. However, they can be used to identify hot-spots in the cradle-to-primary-processing stages (which are major contributors to emissions across the whole life cycle) and assess potential GHG reduction strategies. In addition, the functional units recommended are intermediary points in the supply chains for virtually all poultry sector products and therefore will not be suitable for a full LCA. But they can provide valuable guidance to practitioners to the point of divergence from the system into different types of products.

12.5 Good practice in reporting LCA results

The LCA results and interpretation shall be fully and accurately reported, without bias and consistent with the goal and scope of the study. The type and format of the report should be appropriate to the scale and objectives of the study and the language should be accurate and understandable by the intended user so as to minimise the risk of misinterpretation.

The description of the data and method shall be included in the report in sufficient detail and transparency to clearly show the scope, limitations and complexity of the analysis. The selected allocation method used shall be documented and any variation from the recommendations in these guidelines shall be justified.

The report should include an extensive discussion of the limitations related to accounting for a small numbers of impact categories and outputs. This discussion should address:

- Negative impacts on other (non GHG) environmental criteria;
- Positive environmental impacts (e.g., on biodiversity, landscape, carbon sequestration);
- Multifunctional outputs other than production (e.g., economic, social, nutrition);

If intended for the public domain, a communication plan shall be developed to establish accurate communication that is adapted to the target audience and defensible.

12.6 Report elements and structure

The following elements should be included in the LCA report:

- Executive summary typically targeting a non-technical audience (e.g. decision-makers), including key elements of goal and scope of the system studied and the main results and recommendations while clearly giving assumptions and limitations;
- Identification of the LCA study, including name, date, responsible organization or researchers, objectives of/reasons for the study and intended users;
- Goal of the study: intended applications and targeted audience, methodology including consistency with these guidelines;
- Functional unit and reference flows, including overview of species, geographical location and regional relevance of the study;
- System boundary and unit stages (e.g. to farmgate and farmgate to primary processing gate);
- Materiality criteria and cut-off thresholds;

- Allocation method(s) and justification if different from the recommendations in these guidelines;
- Description of inventory data: representativeness, averaging periods (if used), and assessment of quality of data;
- Description of assumptions or value choices made for the production and processing systems, with justification;
- Feed intake and application of LEAP Animal Feed Guidelines, including description of emissions and removals (if estimated) for LUC;
- LCI modelling and calculating LCI results;
- Results and interpretation of the study and conclusions;
- Description of the limitations and any trade-offs;
- If intended for the public domain the report should also state whether or not the study was subject to independent third-party verification.

12.7 Critical review

Internal review and iterative improvement should be carried out for any LCA study. In addition, if the results are intended to be released to the public, third-party verification and/or external critical review shall be undertaken (and should be undertaken for internal studies) to ensure that:

- The methods used to carry out the LCA are consistent with these guidelines and are scientifically and technically valid;
- The data and assumptions used are appropriate and reasonable;
- Interpretations take into account the complexities and limitations inherent in LCA studies for on-farm and primary processing;
- The report is transparent, free from bias and sufficient for the intended user(s).

The critical review shall be undertaken by an individual or panel with appropriate expertise, e.g. suitably qualified reviewers from agricultural industry or government or non-government officers with experience in the assessed supply chains and LCA. Independent reviewers are highly preferable.

The panel report and critical review statement and recommendations shall be included in the study report if publicly available.

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APPENDICES

Appendix A: LCI data to be collected

Primary data on the following items should be collected when feasible:

1. Inputs for meat production:

a. Background breeding system

Operations with the primary function of providing eggs which can be hatched as chicks those become broilers. If primary data are available they should be used. However, we have provided normative reference information for the life cycle inventory associated with the background production system of broiler and layer chicks. The following information is required:

Inputs:

- Annual quantity of materials and fuels used at parent/grandparent farms;
- Electricity, natural gas and other fuels;
- Water (process water, tap water, well water, etc.)
- Feed rations (type and quantity).

Outputs:

- Annual number of hatchery pullets produced by breeding hens;
- Type and quantity of waste;
- Solid waste to landfill, incineration or recycled.
- Manure / Litter
- Quantity and characteristics (see Section 10.2.3);
- Management technology; if multiple systems exist, include fraction treated by each system;
- Emissions of methane and nitrous oxide arising from litter management;
- Wastewater discharge.

b. Commercial broiler production

Pullets from the breeding system:

Inputs:

- Annual quantity of materials and fuels used at broiler farm;
- Electricity, natural gas and other fuels;
- Water (industrial water, tap water, well-water, etc.);
- Feed rations (type and quantity).

Outputs:

- Annual number and live weight of broilers produced;
- Type and quantity of waste;
- Solid waste to landfill, incineration or recycled;

Manure / Litter

- Quantity and characteristics (see Section 10.2.3);
- Management technology; if multiple systems exist, include fraction treated by each system;
- Emissions of methane and N2O (nitrous oxide) arising from litter management;
- Wastewater discharge.

c. Slaughtering process

Inputs:

- Number and weight of live animals processed;
- Annual quantity of materials and fuels used;
- Electricity, natural gas and other fuels;
- Water (industrial water, tap water, well-water, etc.);
- Chemicals, soaps, disinfectants.

Outputs:

- Annual production of gutted carcasses;
- Annual production of other co-products (non-human edible viscera, etc.)
- Type and quantity of waste;
- Solid waste to landfill, incineration or recycled;
- Wastewater discharge.

d. Dressing process

Inputs:

- Number and weight of whole carcasses processed;
- Annual quantity of materials and fuels used;
- Electricity, natural gas and other fuels;
- Water (process water, tap water, well-water, etc.)
- Chemicals, soaps, disinfectants.

Outputs:

- Weight of “dressed parts” for study functional unit;
- Annual production of all co-products (edible by humans, but not included in functional unit);
- Annual production of other co-products (viscera not edible by humans, etc.)
- Type and quantity of waste;
- Solid waste to landfill, incineration or recycled;
- Wastewater discharge.

2. Calculation method for fuel consumption during transport

a. *Fuel consumption method*

Collect data on “fuel consumption [L]” for each mode of transport. Calculate GHG emissions [kg-CO_2e] by multiplying fuel consumption [L] by “life cycle GHG emissions related to supply and use of fuel” [kg-CO_2e/L] (secondary data – emission factor for each fuel) for each type of fuel.

b. *Fuel cost method*

Collect data on “fuel expense [$/yr]” and “average fuel price [$/L]” for each mode of transport. Calculate GHG emissions [kg-CO_2e] by multiplying fuel consumption [fuel expense/ average fuel price] by “life cycle GHG emissions related to supply and use of fuel” [kg-CO_2e/L] (secondary data– emission factor for each fuel) for each type of fuel.

c. *Tonne-kilometre method*

Collect data on loading ratio [%] and transport load (transport tonne-kilometre) [t-km] for each mode of transport. Calculate life cycle GHG emissions [kg-CO_2e] by multiplying the transport load (transport tonne-kilometre) [t-km] by the “life cycle GHG emissions related to fuel consumption per transport tonne-kilometre” [kg-CO_2e/t-km] (secondary data– emission factor for each fuel) for different transport loads for each mode of transport.

3. Data collection template for farming operations

Draft data collection template – to be modified consistently with specific goal and scope:

Information needed	Explanation
Facility characterization information	Facility location, plant age, current technology used
Raw materials, packaging (primary, 2^{ndary} and tertiary) and auxiliary materials information	Annual amount purchased (in kg or lbs.)
Raw and packaging inbound transportation information, refrigerants losses if available	Means of transportation, distance, pallet patterns, backhaul information
Plant energy, water, refrigerant usage information	Annual energy, water usage, refrigerant loss
Production information	Type of products, and annual production volume
Waste/wastewater/recycling information	Amount generated, treated, discharged, recycled; transportation info if treated offset and to final destination
Raw and packaging outbound transportation information, refrigerants losses if available	Both company-owned and third-party owned: means of transportation, distance, pallet patterns, backhaul information

Plant data collection template	
Facility information	
Please use this survey to gather information regarding the life cycle impacts of the product that you make.	
Company name:	
Facility:	
Location:	
Data period:	Calendar year 20XX

Plant information	
Company name	
Facility name	
Total meat products production (lbs.)	
Total production (lbs.)	
% functional unit production as fraction of plant total	

Annual meat production information

Primary meat products produced in this facility	% lean meat	% of annual meat production (%)	Revenue allocation fraction % of plant revenue for this specific product from facility in calendar year 20XX (%)

Annual non-meat production information

Other co-products	% solids (if applicable)	% of annual co-product production	Revenue allocation fraction % of plant revenue from this specific product from facility in calendar year 20XX
		Economic allocation check (should total 100%)	0%

Purchased inputs

Material purchased	Carcass yield	Lean yield	Mode of transport (truck, rail, air, ship, etc.)	Total mass delivered in calendar year 20XX (kg)	Average distance from producer to processing plant (km)
Live animals					
Products for rendering					
Other – please list					

Chemicals

Chemical description	Chemical abstract number (CAS#)	Concentration (% wt)	Calendar year 20XX annual chemical usage (kg)	Transport distance (km)
Sodium Hydroxide ($NaOH$)				
Nitric Acid (HNO_3)				
Potassium Hydroxide (KOH)				
Phosphoric Acid (H_3PO_4)				
Calcium Hydroxide ($Ca(OH)_2$)				
Acid (other) – please list				
Sanitizers (other) –please list				
Refrigerants – please list				
Other – please list				

Electricity Data

	Electrical Energy (kWh)	Allocation estimate	% kWh
Total annual energy usage		Evisceration	
		Rendering	
		Storage	
		Packaging	
		Other	
		Total processing breakout percentage	0.00%

Fuel data

Fuel type	Total annual fuel usage	Units
Natural gas		
Propane/butane		
Light oil (#2)		
Heavy oil (#5 or #6)		
Coal		
Other -- please list		

Allocation estimation	% of total fuel Energy Natural gas	% of total fuel Energy Propane	% of total fuel Energy Other
Evisceration			
Rendering			
Storage			
Packaging			
Other			
Total processing breakout percentage	0%		

Water data

Water source	Total annual water usage in calendar year 20XX	Allocation estimation	% of total water used
Incoming municipal water		Evisceration	
Other incoming water		Rendering	
Other incoming water		Storage	
Other incoming water		Packaging	
		Other	
		Other	
		Total processing breakout percentage	0%

Packaging

	Material Description	Amount	Unit purchased	Distance from supplier (km)	Mode of transport
Raw and process material inputs	Corrugated/ cardboard boxes		kg / year		
	Corrugated/ miscellaneous		kg / year		
	Shrink wrap		kg / year		
	Stretch wrap		kg / year		
	Plastic bags for boxes		kg / year		
	Other – please list		kg / year		

Packaging waste

Material Description	**Amount**	**Unit**	**% Incinerated**	**% Landfilled**	**% Recycled**
Corrugated/cardboard boxes		kg / year			
Corrugated/ miscellaneous		kg / year			
Shrink wrap		kg / year			
Stretch wrap		kg / year			
Plastic bags for boxes		kg / year			
Masonite (or similar) stiffeners		kg / year			
Other – please list		kg / year			

Distribution

List the products and amounts that were shipped from your facility in calendar year 20XX

	Mass of product shipped from your facility to customer (kg)	**Average container load (kg)**	**Mode of transport (truck, rail, air, ship, etc.)**	**Distance from facility to customer (km)**	**Loading ratio**
Other – please list					

Liquid waste

	Unit	Annual amount
Water flow	Gal	
Ammonia	mg/litre	
BOD's	mg/litre	
TSS	mg/litre	
Phosphate	mg/litre	
Chloride	mg/litre	
Electroconductivity	deciseimens/metre	

% generated in each process step

	Evisceration	Rendering	Storage	Packaging	Other	Total
Water flow						0.00%
BOD						0.00%
TSS						0.00%
Phosphate						0.00%
Chloride						0.00%
Electroconductivity						0.00%

Other solid waste generated		**Solid waste allocation percentage**
Product	**Value**	**Unit of measurement**
Solid waste sent to landfill		
Mixed waste		kilograms
Enter specific materials, if available		kilograms
Materials recycled		
Enter material		kilograms
Materials composted		
Enter material		kilograms
Materials with alternative end-of-life (please specify in comments)		
Enter material		kilograms

Draft Data Collection Template – to be modified according to specific goal and scope

Primary data/ information to be collected for the LCA - based on annual usage/data for consumption of inputs in relation to production outputs

List of information needed	Explanation
Facility characterization information	Facility location, size
Raw materials, packaging (primary, 2ndary and tertiary) and auxiliary materials information	annual amount purchased (in kg)
Feed, packaging and other inputs inbound transportation information	Means of transportation, distance, pallet patterns, backhaul information
Energy, water, refrigerant usage information	Annual energy, water usage, refrigerant loss
Broiler or egg production quantities	Type of product(s) and annual production volume
Manure/litter and other waste/wastewater/recycling information	Amount generated, treated, discharged, recycled; transportation info if treated offset and to final destination
Raw and packaging outbound transportation information, refrigerants losses if available	Both company-owned and 3rd party owned; means of transportation, distance, pallet patterns, backhaul information

Farm Data Collection Template

Please use this survey to gather information regarding the life cycle impacts of the product that you make.

Company name:	
Facility:	
Location	
Data period:	Calendar year 20XX

Inputs

Purchased inputs	Mode of transport (truck, rail, air, ship, etc.)	Number	Weight (kg)	Total mass delivered in calendar year 20XX (kg)	Average transport distance (km)
Eggs				-	
Pullets				-	
Other					

Animal feeds consumed	Mode of transport (truck, rail, air, ship, etc.)	Total mass delivered in calendar year 20XX (kg)	Average transport distance (km)
Corn, grain			
Wheat, Red W.			
Barley			
Wheat middlings			
Soybean meal -48%			
Gluten meal			
Poultry fat			
Menhaden meal			
Gelatine by-prod			
Meat meal			
Alfalfa meal-20			
Whey, dehydrated			
Poultry BP meal			
Limestone			
Defluor. Phos.			
Soft Rock Phos.			
Common Salt			

Primary products produced in this facility	Carcass yield (%)	Lean yield (%)	% of annual production (%)

Other co-products			% of annual co-product production (%)

1

Chemicals

Chemical description	Chemical abstract number (CAS#)	Concentration (% wt)	Calendar year 20XX annual consumption (kg)
Sanitizers / cleaning			
Lime			
Pesticides			
Other – please list			

2

Electricity data		This section is optional	Allocation %
	Electrical energy (kWh)	Ventilation	
Total annual energy usage		Lighting	
		Pumping	
		Feeding	
		Other	
		Total	0.00%

3

Fuel data

Fuel type	Total annual fuel usage	Units	This section is optional	Allocation %
Diesel			Heating	
Gasoline			Farm equipment	
Natural gas			Pumping	
Propane/butane			Litter/manure management	
Light oil (#2)			Other	
Heavy oil (#5 or #6)			Total processing breakout percentage	0.00%
Coal				
Other – please list				

1

Water data

Water source	Total calendar year 20XX water Usage	Units
Incoming municipal water		
On-site well		
Other incoming water		
This section is optional	%	
Cleaning		
Animal consumption		
Other		
Total	0.00%	

2

Packaging

	Material description	Amount	Quantity purchased	Mode of transport (truck, rail, air, ship, etc.)	Approx. distance from supplier (km)
Raw and process material inputs	Corrugated/cardboard boxes		kg / year		
	Egg trays		kg / year		
	Other – please list		kg / year		
Packaging waste	**Material description**	**Amount**	**Quantity Disposed**	**% Landfilled**	**% Recycled**
	Corrugated/cardboard boxes		kg / year		
	Paper bags		kg / year		
	Egg trays		kg / year		
	Primary/secondary packaging for ration		kg / year		
	Other – please list		kg / year		
	Other – please list		kg / year		

3

Spent and cull hens

Quantity (kg)	Disposition (human food, pet food, rendering)	Distance transported (km)

4

1

Distribution

List the products and amounts that were shipped from your facility

	Mass of product shipped from your facility (kg)	Average load (kg)	Mode of transport (truck, rail, air, ship, etc.)	Shipping distance (km)
Broilers				
Eggs				
Other – please list				

2

Other solid waste generated

Product	Quantity (kg)	Allocation Fraction	Distance Transported (km)
Sent to landfill			
Mixed waste			
Enter specific materials,			
Materials recycled			
Enter material			
Materials Composted			

3

Manure/litter management

Disposition	Quantity (kg)	Fraction of annual manure/litter managed	Distance transported (km)
Sent to landfill			
Used as fertilizer			
Used as energy source			
Other			

Enter material

Materials with alternative end-of-life (specify in comments)			
Enter material			
Enter material			

Liquid waste

	Unit	Annual amount
Wastewater flow treated	m^3	
Optional water quality data		
Ammonia	mg/litre	
BOD	mg/litre	
TSS	mg/litre	
Phosphate	mg/litre	
Chloride	mg/litre	
Electro-conductivity	deciseimens/metre	

4. Sources of additional information:

- Agricultural assessment:
- Report of Greenhouse Gas Accounting Tools for Agriculture and Forestry Sectors. Interim report to USDA under Contract No. GS-23F-8182H (Denef et al., 2012). This document describes a large number of calculators, models and agricultural protocols.
- PLANETE (INRA, France): www.solagro.org/site/im_user/286014planeteooct02.pdf
- Fieldprint calculator: http://keystoneftm.zedxinc.com/fieldprint-calculator/
- United Nations Framework Convention on Climate Change: http://www.unfccc.int
- Holos (Agriculture & Agri-Food Canada): http://www.agr.gc.ca/eng/science-and-innovation/science-publications-and-resources/holos/?id=1349181297838
- FAO EX-ACT tool: www.fao.org/tc/tcs/exact/en
- CALM (Country Land & Business Association): www.calm.cla.org.uk/

5. Default data sets and data ranges

Table 12 presents approximate yields for broiler processing. Farmgate burdens (i.e., inputs to the processing facility) should be distributed to the co-products on a mass basis, and processing facility impacts should be allocated to various co-products on the basis of the fraction of revenue derived from the product.

TABLE 12: YIELD RATE OF YOUNG CHICKEN BREED (EXAMPLE)

Category			Weight (g)	Ratio (%)		
Living chicken			2,500	100		
Carcass			2,250	90	100	
	Meat with bone (Gutted chicken, Type III)		1,755	70.2	78	100
		Breast/thigh meat	844	33.8	37.5	48.1
		Skin	47	1.89	2.1	2.7
		Inner fillet	81	3.24	3.6	4.6
		Neck meat	83	3.33	3.7	4.7
		Oil	63	2.52	2.8	3.6
		Wing tip	92	3.69	4.1	5.2
		Wing stick	110	4.41	4.9	6.3
		Bone	434	17.4	19.3	24.7
	Edible organs		101	4.05	4.3	
	Inedible organs		203	8.1	9.0	
	Head, Feet		191	7.65	8.5	
	Blood, Feather		250	10.0		

Notes:
1. As for ratio, the shaded parts are assumed as 100 %.
2. Edible organs: heart, liver, pancreas, and gizzard. Inedible organs: other than edible organs.
3. This yield rate table was created on the basis of case research of the yield rate of ordinary processing in processing site.
4. The Carbon Footprint of Products Calculation and Labelling Pilot Programme.

6. DEFAULT LCI FOR BREEDER AS A BACKGROUND SYSTEM

a) Putting economic allocation into practice

Applying economic allocation on the “valuable” co-products

Economic allocation can be conducted in several ways. Economic allocation should ideally be done at the unit process of separation and based on the prices of products at the point of separation. In practice however, these intermediate prices are often not available (or the determination is very subjective). To make the economic allocation feasible in practice two methods can be applied. The first one, input/output-based, is actually a simplification of the more accurate method described below. Due to practical reasons the first one is most often applied.

Input/Output analysis on processing facility level

The most straightforward and often-encountered simplification is to apply allocation on the basis of an input/output analysis of the overall processing facility or group of facilities (i.e. overall input/output process). This means that the total inputs and related LCI data (at the operation and upstream) are divided over the products on the basis of their relative contribution to the overall revenue. In fact this method is not precise enough because differences in processing after separation can cause differences in resource inputs and emissions and valorisation of the co-products. If the environmental inputs and emissions and the valorisation are similar and especially if the majority of the impacts take place before separation, so that the additional impacts after separation are relatively small, economic-based attribution will not change very much. Under these conditions the input/output analysis on processing facility level gives a rather good estimate for the more precise economic allocation method starting at the specific unit process and then including the life steps afterwards.

Economic allocation at the specific separation process

The method should in principle not be applied if the "after separation processes" differ significantly between the co-products, regarding resource inputs, emissions or valorisation (relatively to pre-processing steps). Here, a more precise economic allocation based on resource inputs and emissions per co-product production route and associated economic valorisation provides significantly different results. Since there is a high need for conducting this allocation of which a part of the data is very hard to obtain, input/output-based data are sometimes suggested.

Appendix B: Literature review

1. Goal and Scope

(Bengtsson and Seddon, 2013; Boggia et al., 2010a; Dekker, 2012; Dekker et al., 2008, 2011, 2013, 2013; JEMAI, 2011a, 2011b; Katajajuuri et al., 2008b; Leinonen et al., 2012a, 2012b; Lesschen et al., 2011; Marino et al., 2011; Pelletier, 2008; Poad et al., 2012; da Silva Júnior et al., 2008; Verge et al., 2009; Weiss and Leip, 2012; Wiedemann and McGahan, 2011; Williams, 2006). The goal and scope of the studies range from hotspot identification (Bengtsson and Seddon, 2013); (Wiedemann and McGahan, 2011; Wiedemann et al., 2012) to commodity analysis (Williams et al., 2006) to benchmarking for understanding and opportunities for improvement (Katajajuuri et al., 2008a; Wiedemann et al., 2012); (Wiedemann and McGahan, 2011), with several studies that targeted a comparison of production methods – including other protein sources as well has organic and free-range production and other alternate production methods (Bengtsson and Seddon, 2013; Boggia et al., 2010b; Leinonen et al., 2012b; Lesschen et al., 2011; Weiss and Leip, 2012);(Dekker et al., 2008, 2011, 2013; Leinonen et al., 2012c). In developing the draft guidance and methodology, it was considered important to allow sufficient flexibility to encompass this range of potential reasons for conducting an LCA of poultry or eggs.

2. Geographic Region

There are a number of studies focused on either individual countries in Europe or the EU27 (Boggia et al., 2010b; Dekker et al., 2008; Katajajuuri et al., 2008a; Leinonen et al., 2012b; Lesschen et al., 2011; da Silva et al., 2012; Weiss and Leip, 2012; Williams et al., 2006), the United States (Pelletier, 2008), Brazil(da Silva et al., 2008a, 2008b), and Australia (Bengtsson and Seddon, 2013; Wiedemann and McGahan, 2011; Wiedemann et al., 2012). In reviewing these publications, there do not seem to be significant differences driven by geographic location, aside from the need for life cycle inventory data that are relevant to that location.

3. Materiality

The question of materiality is related to the cut-off criteria chosen for each study. The ISO 14044, PAS 2050, and Product Category Rules all provide guidance regarding life cycle inventory or emissions impacts which should not be neglected. Only two of the documents reviewed, one for meat (Pelletier, 2008), and one for eggs (Dekker et al., 2008) make specific mention of cut-off criteria. The EPD PCR states that 99% of ingredients must be declared a product declaration. The Japanese PCR

(JEMAI, 2011c) indicates that when cut-off criteria are employed, the cut-off range shall be clearly reported and it shall be stated that cut-off GHG emissions are within 5% of the total life cycle GHG emissions (presumably this also applies to other impact categories, although this is not explicitly stated).

4. Functional Unit

The majority of published studies on poultry meat have specified the functional unit as specified weight chicken meat at the farm or processor gate. Some studies have mixed the system boundary and functional unit by stating a functional unit of a specified weight of edible carcass or simply carcass at the farmgate (Boggia et al., 2010b; Leinonen et al., 2012b; Weiss and Leip, 2012; Williams et al., 2006), although the definition of edible is not unequivocally defined. Two studies and included downstream processing to the point of purchase by the consumer (Bengtsson and Seddon, 2013; Katajajuuri et al., 2008a). The studies from da Silva (da Silva et al., 2008a, 2012) specified a functional unit either a ton of whole chicken, chilled or frozen and delivered to the port of entry. One product category rule refers to 1 kg of meat and associated packaging as the functional unit, specifying "pure" meat exclusive of any inedible portions (Palm, 2010). The other PCR specifies 100 g of product as functional unit, thus allowing flexibility with regard to the inclusion or exclusion of bones, skin, and fat (JEMAI, 2011a).

For eggs, the functional unit for all but one study is a specified mass of eggs at the farmgate; Williams et al. (2006) used 20,000 eggs as a functional unit.

5. System boundaries

The system boundary for most of the meat studies is from cradle to farmgate. The definition of "cradle" is variable; for some studies it includes three generations of breeding stock (Bengtsson and Seddon, 2013; Leinonen et al., 2012b; Williams et al., 2006); the remainder of the studies either did not specify the upstream boundary or included one generation of breeding plus the hatchery.

The EPD PCR defines only three primary stages: upstream, core processes, and downstream. Upstream processes include feed production, breeding farm, including manure management; core processes include production (farms, packaging and distribution); downstream processes include retail, consumer, and EOL for packaging, but not consumer waste. The Japanese PCR (JEMAI, 2011a) is not specific regarding the number of breeding generations to include within the production system boundary. However, it does include analysis of the consumption stage including cooking, dishwashing, food residue and waste container disposal.

6. Ancillary activities

This could include items in the life cycle such as: technical advisors, accounting, legal, corporate overhead (potentially air travel), and workers' commutes. Only one paper was explicit regarding ancillary activities where corporate and overhead burdens were included (Bengtsson and Seddon, 2013) and it included supporting facilities, but not business travel. The EPD PCR requires that maintenance activities with a frequency of less than three years should be included, that business travel may be included, but that workers' daily commutes are excluded. The Japanese PCR does not explicitly mention ancillary activities.

7. Biogenic Carbon/Methane

Few of the studies mentioned biogenic carbon, only one treats biogenic methane differently from fossil methane by assigning global warming potential 24 to account for the fact that the carbon dioxide decay product in the atmosphere was biogenic in origin (Wiedemann et al., 2012). The EPD PCR provides for separate, optional reporting of biogenic carbon dioxide. The Japanese PCR (JEMAI, 2011a) does not mention biogenic carbon.

8. Soil Carbon / Sequestration

Only one study comparing livestock greenhouse gas emissions in Europe included soil carbon sequestration for grasslands and crops (Weiss and Leip, 2012). Lesschen et al. (2011) discussed but did not account for soil carbon sequestration in their analysis. The EPD PCR provides for optional reporting in this category, while the Japanese EPD explicitly excludes soil carbon accounting because it states there is no internationally agreed protocol in this regard.

9. Land Use (direct/indirect/iLUC)

Indirect land-use change was not accounted for in any of the studies; however direct land-use change for recent (less than 20 years) conversion was included on a country specific basis (in particular for palm and soy) in several studies (Leinonen et al., 2012b, 2012c; da Silva et al., 2008b, 2012; Weiss and Leip, 2012). Three studies accounted for land occupation, but did not explicitly mention land-use change (Boggia et al., 2010b; Dekker et al., 2008; Williams et al., 2006). The PAS 2050 method for accounting for land-use change has been adopted by the European Food Sustainable Consumption and Production Round Table (SCP-RT) ENVIFOOD protocol, Environmental Assessment of Food and Drink Protocol (Food SCP RT, 2013).

10. Delayed Emissions

None of the studies mentioned delayed emissions. This refers to activities or materials for which emissions are postponed; sometimes well into the 100-year time horizon that is frequently adopted for greenhouse gas emissions. Examples include packaging disposed in landfills, or materials such as leather (for which there may not be an analogue in the poultry sector).

11. Capital goods

There is a range of approaches in accounting for capital infrastructure. It is either not mentioned or excluded in the majority of studies. Some studies did count, to some extent, infrastructure in the supply chain (Dekker et al., 2008; Leinonen et al., 2012b, 2012c; Williams et al., 2006). The actual extent of inclusion is not completely clear from the studies. For example, one reports inclusion of infrastructure for machinery but not for fertilizer or fuel manufacture and delivery – apparently suggesting that foreground machinery is included, but background system infrastructure is not. The EPD PCR states that if the lifetime of an item is greater than three years, then it is to be excluded from the inventory. The Japanese PCR (JEMAI, 2011a) does not provide specific guidance on infrastructure.

12. Handling multifunctional processes

The two predominant choices for allocation are economic value and system expansion. However some other approaches are taken, including mass allocation, gross chemical energy content, and physical/cost relationships. One study used a reasoned, but arguably arbitrary, system separation (Lesschen et al., 2011).

13. Litter/manure

Most of the studies accounted for an offset credit, based on the available nutrient content of manure as a displacement for inorganic fertilizers. Recent studies (Wiedemann et al., 2012) which included electricity production from litter used system expansion of the grid mix in the UK.

14. Processing

Only the Japanese PCR (JEMAI, 2011a) provides detail regarding this stage. It provides default values for different parts of the chicken. This has been reproduced in Appendix A.

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