Food and Agriculture Organization of the United Nations

VERSION 1

Greenhouse gas emissions and fossil energy use from poultry supply chains

Guidelines for assessment

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APPENDICES

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 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 sector, which includes chicken, turkeys, guinea fowl, geese, quails, ducks and pigeons, is dynamic and growing. In 2011, global poultry production of meat and eggs was estimated to be 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 (FAO, 2012). Expanding populations, greater 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 put 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 (Macleod *et al.*, 2013). Globally, poultry-related emissions account for about 600 million tonnes of CO_2 equivalent per year, with about half coming from feed production (Macleod *et al.*, 2013). There is 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 founded 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; and
- to identify the principal areas where ambiguity or differing views exist as to the right approach.

These guidelines underwent a public review. The purpose of the review was to strengthen the advice provided and ensure it meets the needs of those seeking to improve performance through sound assessment practice. The present document is not 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 viewed as a critical next step.

The strength of the guidelines developed within the LEAP Partnership for 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.

Rogier Schulte, Teagasc - The Agriculture and Food Development Authority, Government of Ireland (2015 LEAP chair)

Lalji Desai, World Alliance of Mobile Indigenous People (2014 LEAP chair)

Frank Mitloehner, University of California, Davis (2013 LEAP chair)

Henning Steinfeld, Food and Agriculture Organization of the United Nations, (LEAP co-chair)

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AUTHORSHIP AND DEVELOPMENT PROCESS

These guidelines are a product of the LEAP Partnership. Three groups contributed to their development: an *ad hoc* Technical Advisory Group (TAG), the LEAP Secretariat and the LEAP Steering Committee.

The 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 Council, United Kingdom), Jason Gittins (ADAS, United Kingdom) and Jamie Burr (Tyson Foods Inc., United States).

The LEAP Secretariat coordinated and facilitated the work of the TAG, guided and contributed to content development and ensured coherence among the various guidelines. The LEAP secretariat, hosted at the Food and Agriculture Organization (FAO) of the United Nations, was composed of: Pierre Gerber (Coordinator), Alison Watson (LEAP Manager until Dec 2013), Camillo De Camillis (LEAP manager since Feb 2014), Carolyn Opio (Technical officer), Félix Teillard (Technical officer) and Aimable Uwizeye (Technical officer).

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

Monikka Agarwal (World Alliance of Mobile Indigenous People, in LEAP since Oct 2014), Douglas Brown (World Vision), Giuseppe Luca Capodieci (The European Livestock And Meat Trading Union, International Meat Secretariat), Camillo De Camillis (FAO, LEAP manager since Feb 2014), Richard de Mooij (The European Livestock And Meat Trading Union, International Meat Secretariat), Elsa Delcombel (Government of France), Lalji Desai (World Alliance of Mobile Indigenous People, 2014 LEAP Chair), Pierre Gerber (FAO, LEAP secretariat coordinator until Jan 2015), Mathias Ginet (Government of France, in LEAP since Oct 2014), Jan Grenz (Bern University of Applied Sciences, Government of Switzerland, in LEAP until Mar 2014), Vincent Guyonnet (International Egg Commission), Dave Harrison (International Meat Secretariat), Matthew Hooper (Government of New Zealand), Hsin Huang (International Meat Secretariat), Delanie Kellon (International Dairy Federation), Lionel Launois (Government of France), Pablo Manzano (International Union for Conservation of Nature), Nicolas Martin (European Feed Manufacturers' Federation, The International Feed Industry Federation), Ian

McConnel (World Wide Fund for Nature, in LEAP since Jan 2015), Paul Melville (Government of New Zealand), Paul McKiernan (Government of Ireland), Frank Mitloehner (University of California, Davis, The International Feed Industry Federation, 2013 LEAP Chair), Anne-Marie Neeteson-van Nieuwenhoven (International Poultry Council), Frank O'Mara (Teagasc - The Agriculture and Food Development Authority, Government of Ireland), Antonio Onorati (International Planning Committee for World Food Sovereignty) Carolyn Opio (FAO, LEAP secretariat coordinator since Jan 2015), Lara Sanfrancesco (International Poultry Council), Fritz Schneider (Bern University of Applied Sciences, Government of Switzerland, in LEAP until Feb 2015), Rogier Schulte (Teagasc - The Agriculture and Food Development Authority, Government of Ireland, 2015 LEAP chair), Henning Steinfeld (FAO, LEAP Partnership co-chair), Nico van Belzen (International Dairy Federation), Elsbeth Visser (Government of the Netherlands), Alison Watson (FAO, LEAP manager until Dec 2013), Bryan Weech (World Wide Fund for Nature, in LEAP until 2014), Geert Westenbrink (Government of the Netherlands) and Hans-Peter Zerfas (World Vision).

Observers and advisers

Alejandro Acosta (FAO, Global Agenda For Sustainable Livestock, in LEAP since Feb 2015), Rudolph De Jong (International Wool Textile Organization, in LEAP until Oct 2014), Jeroen Dijkman (FAO, Global Agenda For Sustainable Livestock, in LEAP until Jan 2015), Matthias Finkbeiner (International Organization for Standardization), Neil Fraser (FAO, Global Agenda For Sustainable Livestock), Michele Galatola (European Commission, Directorate-General for Environment), James Lomax (United Nations Environment Programme), Llorenç Milà i Canals (United Nations Environment Programme), Paul Pearson (International Council of Tanners, in LEAP since Feb. 2015), Erwan Saouter (European Commission, Joint Research Centre), Sonia Valdivia (United Nations Environment Programme) and Elisabeth van Delden (International Wool Textile Organization).

Although not directly responsible for the preparation of these guidelines, the LEAP TAGs on feed and small ruminants indirectly contributed to this technical document.

MULTI-STEP REVIEW PROCESS

The initial draft guidelines developed by the TAG over 2013 went through an external peer review before being revised and submitted for public review.

Laura Drauker (World Resource Institute), Christel Cederberg (SIK and Chalmers University of Technology, Gothenburg) John Kazer (Carbon Trust, London) peer reviewed these guidelines in late 2013.

The LEAP Secretariat reviewed this technical guidance before its submission for both external peer review and public review. The LEAP Steering Committee also reviewed the guidelines at various stages of their development and provided additional feedback before clearing their release for public review.

The public review was announced at the 1st Annual Meeting of the LEAP Partnership on 6 March 2014 and lasted until 31 July 2014. The review period was also announced to the public through an article published on the FAO website. The scientific community working on the accounting of greenhouse gas (GHG) emissions from livestock was alerted through the Livestock and Climate Change Mitigation in

Agriculture Discussion group on the forum of the Mitigation of Climate Change in Agriculture (MICCA) Programme. Experts in life cycle assessment (LCA) were informed through an issue of the United Nations Environment Programme (UNEP)/ Society for Environmental Toxicology and Chemistry (SETAC) Life Cycle Initiative newsletter and through announcements and reminders circulated via the mailing list on LCA held by PRé Consultants. The LEAP Secretariat also publicized the 2014 LEAP public review through oral speeches in the Product Environmental Footprint (PEF) World Forum and other regional conferences. The following have participated in the public review and contributed to improving the quality of this technical document: Anne-Marie Neeteson on behalf of the International Poultry Council, Xavier Vergé and Raymond Desjardins (University of Guelph, Canada, Agriculture and Agri-Food Canada), Michael Binder International Feed Industry Federation/EU Association of Specialty Feed Ingredients and their Mixtures), Vincent Guyonnet on behalf of the International Egg Commission, Bo Weidema (2.-0 LCA consultants, Denmark), Florence Scarsi on behalf of the French Ministry of Ecology, Sustainable Development and Energy, Adrian Leip, Hanna Tuomisto, Luca Zampori, Erwin Schau, Erwan Saouter and David Pennington (European Commission, Joint Research Centre).

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Last but not least, the LEAP Partnership is also grateful for the advisory provided by the International Organization for Standardization (ISO), UNEP and the European Commission, and is glad to network with the World Organisation for Animal Health and the Global Agenda for Sustainable Livestock.

Abbreviations and acronyms

CFP	Carbon footprint of a product
CHP	Combined heat and power
CO2e	Carbon dioxide equivalent
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse Gas
GWP	Global Warming Potential
ILCD	International Reference Life Cycle Data System
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardisation
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LEAP	Livestock Environmental Assessment and Performance Partnership
LUC	Land-Use Change
ME	Metabolizable Energy
PAS	Publicly Available Specification
PCR	Product Category Rules
PEF	Product Environmental Footprint
PDF	Probability Density Functions
SETAC	Society for Environmental Toxicology and Chemistry
TAG	Technical Advisory Group
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development
WRI	World Resource Institute
VS	Volatile solids

Glossary

Terms relating to feed and food supply chains

Annual forage	Forage established annually, usually with annual plants, and generally involves soil disturbance, removal of existing vegetation, and other cultivation practices.
Animal by-product	Livestock production output classified in the European Union in three categories mostly due to the risk associated to the bovine spongiform encephalopathy.
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.
Cropping	Land on which the vegetation is dominated by large-scale production of crops for sale (e.g. maize, wheat, and soybean production).
Crop product	Product from a plant, fungus or algae cultivation system that can either be used directly as feed or as raw material in food or feed processing.
Crop residues	Materials left in an agricultural field after the crop has been harvested.
Crop rotation	Growing of crops in a seasonal sequence to prevent diseases, maintain soil conditions and optimize yields.
Cultivation	Activities related to the propagation, growing and harvesting of plants including activities to create favourable conditions for their growing.
Retail packaging	Containers and packaging that reach consumers.

Feed (feeding stuff)	Any single or multiple materials, whether processed, semi-processed or raw, which is intended to be fed directly to food producing animals. - Codex Alimentarius, Code of practice on good animal feeding CAC/RCP 54 (FAO/WHO Codex Alimentarius, 2008).
Feed additive	Any intentionally added ingredient not normally consumed as feed by itself, whether or not it has nutritional value, which affects the characteristics of feed or animal products. Note: Micro-organisms, enzymes, acidity regulators, trace elements, vitamins and other products fall within the scope of this definition depending on the purpose of use and method of administration. - Codex Alimentarius, Code of practice on good animal feeding CAC/RCP 54 (FAO/WHO Codex Alimentarius, 2008).
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 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.
Feed ingredient	A component part or constituent of any combination or mixture making up a feed, whether or not it has a nutritional value in the animal's diet, including feed additives. Ingredients are of plant, animal or aquatic origin, or other organic or inorganic substances. - Codex Alimentarius, Code of practice on good animal feeding CAC/RCP 54 (FAO/WHO Codex Alimentarius, 2008).
Fodder	Harvested forage fed intact to livestock, which can include fresh and dried forage.
Forage crop	Crops, annual or biennial, grown to be used for grazing or harvested as a whole crop for feed.
Conserved forage	Conserved forage saved for future use. Forage can be conserved in situ (e.g. stockpiling) or harvested, preserved and stored (e.g. hay, silage or haylage).
Medicated feed	Any feed which contains veterinary drugs as defined in the Codex Alimentarius Commission Procedural Manual. - Codex Alimentarius, Code of practice on good animal feeding CAC/RCP 54 (FAO/WHO Codex Alimentarius, 2008).

Natural or cross ventilation	Limited use of fans for cooling; frequently a building's sides can be opened to allow air circulation.
Natural pasture	Natural ecosystem dominated by indigenous or naturally occurring grasses and other herbaceous species used mainly for grazing by livestock and wildlife.
Packing	Process of packing products in the production or distribution stages.
Primary packaging materials	Packaging in direct contact with the product. See also: Retail packaging
Production unit	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 an arable farm, the potential multiple animal herds that are common in small holder operations (sheep, goats deer, dairy cattle, suckling cattle or even rearing of heifers, production of milk, etc.), or the individual processing lines in a manufacturing facility.
Raw material	Primary or secondary material used to produce a product.
Secondary packaging materials	Additional packaging, not contacting the product, which may be used to contain relatively large volumes of primary packaged products or transport the product safely to its retail or consumer destination.
Silage	Forage harvested and preserved (at high moisture contents generally greater than 500 g kg-1) by organic acids produced during partial anaerobic fermentation.
Volatile solids	Volatile solids (VS) are the organic material in livestock manure and consist of both biodegradable and non-biodegradable fractions. VS are measured as the fraction of sludge combusted at 550 degrees Celsius after 2 hours.

Terms relating to poultry supply chains

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.
Chicken meat processing	A general term for further processing needed after dressing (e.g. cutting, selection, cooking)
Cull birds	Birds that are euthanized before the end of the normal productive period. These may include birds that are diseased, injured, defective (e.g. physical abnormalities,) or those that do not conform to the expected breed or production standards (e.g. birds with stunted growth, non-laying hens). These animals are disposed of after euthanasia and do not enter the human food supply.
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.
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 indoor floor space, nest space, and perches.
Gutted chicken	A bird whose viscera (excluding kidneys), cloaca, trachea, and oesophagus have been removed. Inclusion of caudal portion is arbitrary.
Layer / Laying hen	Bird kept for production of eggs intended for human consumption.
Volières systems	Systems offering the hens a relatively complex environment where they can move very freely. The layers can move to several open stories in the system where they can find food, water, nests and perches, and of course there is a large open space on the floor for scratching.

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.
Repackaging facility	A facility where products are repackaged into smaller units without additional processing in preparation for retail sale.
Retail cuts	Cuts of meat for retail sale (e.g. breast/thigh meat, wings, livers).
Rendering	A process that converts animal tissue, bones and blood into stable, value-added materials.
Spent hen	Adult female poultry at the end of their productive life.
Stocking density	Area available to poultry, normally defined as birds per square meter, or on a weight basis as kg per square meter.
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, 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. Birds may also be fed compound feed/concentrate rations.
Tunnel ventilation	Fans located at the building ends provide axial airflow.

Terms relating to environmental accounting and environmental assessment

Acidification	Impact category that addresses impacts due to acidifying substances in the environment. Emissions of nitrogen oxides (NOx), ammonia (NH3) and sulphur oxides (SOx) lead to releases of hydrogen ions (H+) when the gases are mineralized. The protons contribute to the acidification of soils and water when they are released in areas where the buffering capacity is low. Acidification may result to forest decline and lake acidification. - Adapted from Product Environmental Footprint (PEF) Guide (European Commission, 2013)
Activity data	Data on the magnitude of human activity resulting in emissions or removals taking place during a given period of time (UNFCCC, n.d.).
Allocation	Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems. - ISO 14044:2006, 3.17 (ISO, 2006c)
Anthropogenic	Relating to, or resulting from the influence of human beings on nature.
Attributional modelling approach	System modelling approach in which inputs and outputs are attributed to the functional unit of a product system by linking and/or partitioning the unit processes of the system according to a normative rule. - Global Guidance Principles for Life Cycle Assessment Databases (UNEP/SETAC Life Cycle Initiative, 2011)
Background system	The background system consists of processes on which no or, at best, indirect influence may be exercised by the decision maker for which an LCA is carried out. Such processes are called "background processes." - Global Guidance Principles for Life Cycle Assessment Databases (UNEP/SETAC Life Cycle Initiative, 2011)
Biogenic carbon	Carbon derived from biomass. - ISO/TS 14067:2013, 3.1.8.2 (ISO, 2013a)

Biomass Material of biological origin excluding material embedded in geological formations and material transformed to fossilized material, and excluding peat.
- ISO/TS 14067:2013, 3.1.8.2 (ISO, 2013a)

Capital goods Capital goods are final products that have an extended life and are used by the company to manufacture a product; provide a service; or sell, store, and deliver merchandise. In financial accounting, capital goods are treated as fixed assets or as plant, property, and equipment. Examples of capital goods include equipment, machinery, buildings, facilities, and vehicles.
- Technical Guidance for Calculating Scope 3 Emissions, Chapter 2 (WRI and WBCSD, 2011b)

Carbon dioxide equivalent (CO2e) Unit for comparing the radiative forcing of a greenhouse gas (GHG) to that of carbon dioxide.
- ISO/TS 14067:2013, 3.1.3.2 (ISO, 2013a)

Carbon footprint of a product (CFP) Sum of greenhouse gas emissions and removals in a product system, expressed as carbon dioxide equivalents (CO2e) and based on a life cycle assessment using the single impact category of climate change.
- ISO/TS 14067:2013, 3.1.1.1 (ISO, 2013a)

Carbon storage Carbon removed from the atmosphere and stored as carbon.
- ISO 16759:2013, 3.1.4 (ISO, 2013b)

Characterization Calculation of the magnitude of the contribution of each classified input/output to their respective impact categories, and aggregation of contributions within each category. This requires a linear multiplication of the inventory data with characterization factors for each substance and impact category of concern. For example, with respect to the impact category ‘climate change’, CO2 is chosen as the reference substance and kg CO2-equivalents as the reference unit.
- Adapted from: Product Environmental Footprint (PEF) Guide (European Commission, 2013)

Characterization factor Factor derived from a characterization model that is applied to convert an assigned life cycle inventory analysis result to the common unit of the category indicator.
- ISO 14044:2006, 3.37 (ISO, 2006c)

Classification Assigning the material/energy inputs and outputs tabulated in the Life Cycle Inventory to impact categories according to each substance's potential to contribute to each of the impact categories considered.
- Adapted from: Product Environmental Footprint (PEF) Guide (European Commission, 2013)

Combined production A multifunctional process in which production of the various outputs can be independently varied. For example in a back-yard system the number of poultry and swine can be set independently.

Comparative assertion Environmental claim regarding the superiority or equivalence of one product versus a competing product that performs the same function.
- ISO 14044:2006, 3.6 (ISO, 2006c).

Comparison A comparison of two or more products regarding the results of their life cycle assessment as according to these guidelines and not including a comparative assertion.

Consequential data modelling System modelling approach in which activities in a product system are linked so that activities are included in the product system to the extent that they are expected to change as a consequence of a change in demand for the functional unit.
- Global Guidance Principles for Life Cycle Assessment Databases (UNEP/SETAC Life Cycle Initiative, 2011).

Consumable Ancillary input that is necessary for a process to occur but that does not form a tangible part of the product or co-products arising from the process
Note 1: Consumables differ from capital goods in that they have an expected life of one year or less, or a need to replenish on a one year or less basis (e.g. lubricating oil, tools and other rapidly wearing inputs to a process).
Note 2: Fuel and energy inputs to the life cycle of a product are not considered to be consumables.
- PAS 2050:2011, 3.10 (BSI, 2011).

Co-production A generic term for multi-functional processes; either combined- or joint-production.

Co-products Any of two or more products coming from the same unit process or product system.
- ISO 14044:2006, 3.10 (ISO, 2006c)

Cradle to gate	Life-cycle stages from the extraction or acquisition of raw materials to the point at which the product leaves the organisation undertaking the assessment. - PAS 2050:2011, 3.13 (BSI, 2011)
Critical review	Process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment. - ISO 14044:2006, 3.45 (ISO, 2006c)
Critical review report	Documentation of the critical review process and findings, including detailed comments from the reviewer(s) or the critical review panel, as well as corresponding responses from the practitioner of the LCA study. - ISO 14044:2006, 3.7 (ISO, 2006c)
Cut-off criteria	Specification of the amount of material or energy flow or the level of environmental significance associated with unit processes or product system to be excluded from a study. - ISO 14044:2006, 3.18 (ISO, 2006c)
Data quality	Characteristics of data that relate to their ability to satisfy stated requirements. - ISO 14044:2006, 3.19 (ISO, 2006c)
Dataset (both LCI dataset and LCIA dataset)	A document or file with life cycle information of a specified product or other reference (e.g. site, process), covering descriptive metadata and quantitative life cycle inventory and/or life cycle impact assessment data, respectively. - International Reference Life Cycle Data System (ILCD) Handbook: General guide for Life Cycle Assessment - Detailed guidance (European Commission, 2010b)
Delayed emissions	Emissions that are released over time, e.g. through prolonged use or final disposal stages, versus a single, one-time emission. - Adapted from: Product Environmental Footprint (PEF) Guide (European Commission, 2013).
Direct Land-Use Change (dLUC)	Change in human use or management of land within the product system being assessed. - ISO/TS 14067:2013, 3.1.8.4 (ISO, 2013a)
Direct energy	Energy used on farms for livestock production activities (e.g. lighting, heating).

Downstream Occurring along a product supply chain after the point of referral.
- Product Environmental Footprint (PEF) Guide (European Commission, 2013)

Drainage basin Area from which direct surface runoff from precipitation drains by gravity into a stream or other water body.
Note 1: The terms 'watershed', 'drainage area', 'catchment', 'catchment area' or 'river basin' are sometimes used for the concept of 'drainage basin'.
Note 2: Groundwater drainage basin does not necessarily correspond in area to surface drainage basin.
Note 3: The geographical resolution of a drainage basin should be determined at the goal and scope stage: it may regroup different sub drainage basins.
- ISO 14046:2014, 3.1.8 (ISO, 2014)

Economic value Average market value of a product at the point of production possibly over a 5-year time frame.
- Adapted from: PAS 2050:2011, 3.17 (BSI, 2011)
Note 1: Where barter is in place, the economic value of the commodity traded can be calculated on the basis of the market value and amount of the commodity exchanged.

Eco-toxicity Environmental impact category that addresses the toxic impacts on an ecosystem, which damage individual species and change the structure and function of the ecosystem. Eco-toxicity is a result of a variety of different toxicological mechanisms caused by the release of substances with a direct effect on the health of the ecosystem.
- Adapted from: Product Environmental Footprint (PEF) Guide (European Commission, 2013)

Elementary flow Material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation.
- ISO 14044:2006, 3.12 (ISO, 2006c).

Emission factor Amount of GHG emitted, expressed as carbon dioxide equivalent and relative to a unit of activity (e.g. kg CO2e per unit input) (Adapted from: UNFCCC, n.d.).
Note: Emission factor data is obtained from secondary data sources.

Emissions Release of substance to air and discharges to water and land.

Environmental impact Any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's activities, products or services.
- ISO/TR 14062:2002, 3.6 (ISO, 2002).

Eutrophication Excess of nutrients (mainly nitrogen and phosphorus) in water or soil, from sewage outfalls and fertilized farmland. In water, eutrophication accelerates 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. In soil, eutrophication favours nitrophilous plant species and modifies the composition of the plant communities.
- Adapted from: Product Environmental Footprint (PEF) Guide (European Commission, 2013)

Extrapolated data Refers to data from a given process that is used to represent a similar process for which data is not available, on the assumption that it is reasonably representative.
- Product Environmental Footprint (PEF) Guide (European Commission, 2013).

Final product Goods and services that are ultimately consumed by the end user rather than used in the production of another good or service.
- Product Life Cycle Accounting and Reporting Standard (WRI and WBCSD, 2011a).

Foreground system The foreground system consists of processes that are under the control of the decision maker for which an LCA is carried out. They are called 'foreground processes'.
- Global Guidance Principles for Life Cycle Assessment Databases (UNEP/SETAC Life Cycle Initiative, 2011)

Functional unit Quantified performance of a product system for use as a reference unit.
- ISO 14044:2006, 3.20 (ISO, 2006c).
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.

GHG removal	Mass of a GHG removed from the atmosphere. - ISO/TS 14067:2013, 3.1.3.6 (ISO, 2013a)
Global Warming Potential (GWP)	Characterization factor describing the radiative forcing impact of one mass-based unit of a given GHG relative to that of carbon dioxide over a given period of time. - ISO/TS 14067:2013, 3.1.3.4 (ISO, 2013a)
Greenhouse gases (GHGs)	Gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. - ISO 14064-1:2006, 2.1 (ISO, 2006d)
Human toxicity – cancer	Impact category that accounts for the adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin insofar as they are related to cancer. - Product Environmental Footprint (PEF) Guide (European Commission, 2013)
Human toxicity – non-cancer	Impact category that accounts for the adverse health effects on human beings caused by the intake of toxic substances through inhalation of air, food/water ingestion, penetration through the skin insofar as they are related to non-cancer effects that are not caused by particulate matter/respiratory inorganics or ionizing radiation. - Product Environmental Footprint (PEF) Guide (European Commission, 2013)
Indirect Land-Use Change (iLUC)	Change in the use or management of land which is a consequence of direct land-use change, but which occurs outside the product system being assessed. - ISO/TS 14067:2013, 3.1.8.5, ISO (2013a)
Impact category	Class representing environmental issues of concern to which life cycle inventory analysis results may be assigned. - ISO 14044:2006, 3.39 (ISO, 2006c).
Impact category indicator	Quantifiable representation of an impact category. - ISO 14044:2006, 3.40 (ISO, 2006c)
Infrastructure	Synonym for capital good.

Input	Product, material or energy flow that enters a unit process. - ISO 14044:2006, 3.21 (ISO, 2006c)
Ionizing radiation, human health	Impact category that accounts for the adverse health effects on human health caused by radioactive releases. - Product Environmental Footprint (PEF) Guide (European Commission, 2013)
Intermediate product	Output from a unit process that is input to other unit processes that require further transformation within the system. - ISO 14044:2006, 3.23 (ISO, 2006c)
Joint production	A multi-functional process that produces various outputs, such as meat and eggs in backyard systems. Production of the different goods cannot be independently varied, or only varied within a very narrow range.
Land occupation	Impact category related to use (occupation) of land area by activities, such as agriculture, roads, housing and mining. - Adapted from: Product Environmental Footprint (PEF) Guide (European Commission, 2013)
Land-use change	Change in the purpose for which land is used by humans (e.g. between crop land, grass land, forestland, wetland, industrial land). - PAS 2050:2011, 3.27 (BSI, 2011)
Life cycle	Consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal. - ISO 14044:2006, 3.1 (ISO, 2006c)
Life Cycle Assessment (LCA)	Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle. - ISO 14044:2006, 3.2 (ISO, 2006c)
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. - PAS 2050:2011, 3.30 (BSI, 2011)
Life Cycle Impact Assessment (LCIA)	Phase of LCA aimed at understanding and evaluating the magnitude and significance of the potential impacts for a product system throughout the life cycle of the product. - Adapted from: ISO 14044:2006, 3.4 (ISO, 2006c).

Life Cycle Inventory (LCI) Phase of LCA involving the compilation and quantification of inputs and outputs for a product throughout its life cycle.
- ISO 14046:2014, 3.3.6 (ISO, 2014)

Life Cycle Interpretation Phase of LCA in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations.
- ISO 14044:2006, 3.5 (ISO, 2006c)

Material contribution Contribution from any one source of GHG emissions of more than 1 percent of the anticipated total GHG emissions associated with the product being assessed.
Note: A materiality threshold of 1 percent has been established to ensure that very minor sources of life cycle GHG emissions do not require the same treatment as more significant sources.
- PAS 2050:2011, 3.31 (BSI, 2011)

Multi-functionality If a process or facility provides more than one function, i.e. if it delivers several goods and/or services ('co-products'), it is 'multi-functional'. In these situations, all inputs and emissions linked to the process must be partitioned between the product of interest and the other co-products in a principled manner.
- Product Environmental Footprint (PEF) Guide (European Commission, 2013)

Normalization After the characterization step, normalization is an optional step in which the impact assessment results are multiplied by normalization factors that represent the overall inventory of a reference unit (e.g. a whole country or an average citizen). Normalized impact assessment results express the relative shares of the impacts of the analysed system in terms of the total contributions to each impact category per reference unit. When displaying the normalized impact assessment results of the different impact topics next to each other, it becomes evident which impact categories are affected most and least by the analysed system. Normalized impact assessment results reflect only the contribution of the analysed system to the total impact potential, not the severity/relevance of the respective total impact. Normalized results are dimensionless, but not additive.
- Product Environmental Footprint (PEF) Guide (European Commission, 2013)

Offsetting	Mechanism for compensating for all or for a part of the carbon footprint of a product through the prevention of the release of, reduction in, or removal of an amount of greenhouse gas emissions in a process outside the boundary of the product system. - ISO/TS 14067:2013, 3.1.1.4 (ISO, 2013a)
Output	Product, material or energy flow that leaves a unit process. - ISO 14044:2006, 3.25 (ISO, 2006c)
Ozone depletion	Impact category that accounts for the degradation of stratospheric ozone due to emissions of ozone-depleting substances, for example long-lived chlorine and bromine containing gases (e.g. chlorofluorocarbons, hydrochlorofluorocarbons, Halons). - Product Environmental Footprint (PEF) Guide (European Commission, 2013)
Particulate matter	Impact category that accounts for the adverse health effects on human health caused by emissions of particulate matter (PM) and its precursors (NOx, SOx, NH3). - Product Environmental Footprint (PEF) Guide (European Commission, 2013)
Photochemical ozone formation	Impact category that accounts for the formation of ozone at the ground level of the troposphere caused by photochemical oxidation of Volatile Organic Compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NOx) and sunlight. High concentrations of ground-level tropospheric ozone damage vegetation, human respiratory tracts and man-made materials through reaction with organic materials. - Product Environmental Footprint (PEF) Guide (European Commission, 2013)
Primary data	Quantified value of a unit process or an activity obtained from a direct measurement or a calculation based on direct measurements at its original source. - ISO 14046:2014, 3.6.1 (ISO, 2014)
Primary activity data	Quantitative measurement of activity from a product's life cycle that, when multiplied by the appropriate emission factor, determines the GHG emissions arising from a process. Examples of primary activity data include the amount of energy used, material produced, service provided or area of land affected. - PAS 2050:2011, 3.34 (BSI, 2011)

Product(s)	Any goods or service. - ISO 14046:2014, 3.5.9 (ISO, 2014)
Product category	Group of products that can fulfil equivalent functions. - ISO 14046:2014, 3.5.9 (ISO, 2014)
Product category rules (PCR)	Set of specific rules, requirements and guidelines for developing Type III environmental declarations for one or more product categories. - ISO 14025:2006, 3.5 (ISO, 2006a)
Product system	Collection of unit processes with elementary and product flows, performing one or more defined functions, and which models the life cycle of a product. - ISO 14044:2006, 3.28 (ISO, 2006c)
Proxy data	Data from a similar activity that is used as a stand-in for the given activity. Proxy data can be extrapolated, scaled up, or customised to represent the given activity. For example, using a Chinese unit process for electricity production in an LCA for a product produced in Viet Nam. - Product Life Cycle Accounting and Reporting Standard (WRI and WBCSD, 2011ba)
Reference flow	Measure of the outputs from processes in a given product system required to fulfil the function expressed by the functional unit. - ISO 14044:2006, 3.29 (ISO, 2006c)
Releases	Emissions to air and discharges to water and soil. - ISO 14044:2006, 3.30 (ISO, 2006c)
Reporting	Presenting data to internal management or external users, such as regulators, shareholders, the general public or specific stakeholder groups. - Adapted from: ENVIFOOD Protocol (Food SCP RT, 2013).

Residue or Residual

Substance that is not the end product (s) that a production process directly seeks to produce.
- Communication from the European Commission 2010/C 160/02 (European Commission, 2010a)
More specifically, a residue is any material without economic value leaving the product 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 product system calculations.
Note 1: Materials with economic value are considered products.
Note 2: Materials whose economic value is both negligible relative to the annual turnover of the organization, and is also entirely determined by the production costs necessary not to turn such materials in waste streams are to be considered as residues from an environmental accounting perspective.
Note 3: Those materials whose relative economic value volatility is high in the range of positive and negative value, and whose average value is negative are residues from an environmental accounting perspective. Materials economic value volatility is possibly calculated over a 5-year time frame at the regional level.

Resource depletion

Impact category that addresses use of natural resources renewable or non-renewable, biotic or abiotic.
- Product Environmental Footprint (PEF) Guide (European Commission, 2013)

Secondary data

Data obtained from sources other than a direct measurement or a calculation based on direct measurements at the original source.
- ISO 14046:2014, 3.6.2 (ISO, 2014)
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.

Sensitivity analysis

Systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a study.
- ISO 14044:2006, 3.31 (ISO, 2006c)

Sink

Physical unit or process that removes a GHG from the atmosphere.
- ISO 14064-1:2006, 2.3 (ISO, 2006d)

Soil Organic Matter (SOM)	The measure of the content of organic material in soil. This derives from plants and animals and comprises all of the organic matter in the soil exclusive of the matter that has not decayed. - Product Environmental Footprint (PEF) Guide (European Commission, 2013)
System boundary	Set of criteria specifying which unit processes are part of a product system. - ISO 14044:2006, 3.32 (ISO, 2006c)
System expansion	Expanding the product system to include additional functions related to co-products.
Temporary carbon storage	Phenomenon that occurs when a product "reduces the GHGs in the atmosphere" or creates "negative emissions", by removing and storing carbon for a limited amount of time. - Product Environmental Footprint (PEF) Guide (European Commission, 2013)
Tier-1 method	Simplest method that relies on single default emission factors (e.g. kg methane per animal).
Tier-2 method	A more complex approach that uses detailed country-specific data (e.g. gross energy intake and methane conversion factors for specific livestock categories).
Tier-3 method	Method based on sophisticated mechanistic models that account for multiple factors such as diet composition, product concentration from rumen fermentation, and seasonal variation in animal and feed parameters.
Uncertainty analysis	Systematic procedure to quantify the uncertainty introduced in the results of a life cycle inventory analysis due to the cumulative effects of model imprecision, input uncertainty and data variability. - ISO 14044:2006, 3.33 (ISO, 2006c)
Unit process	Smallest element considered in the life cycle inventory analysis for which input and output data are quantified. - ISO 14044:2006, 3.34 (ISO, 2006c)
Upstream	Occurring along the supply chain of purchased goods/services prior to entering the system boundary. - Product Environmental Footprint (PEF) Guide (European Commission, 2013)

Waste	Substances or objects that the holder intends or is required to dispose of. - ISO 14044:2006, 3.35 (ISO, 2006c) Note 1: Deposition of manure on a land where quantity and availability of soil nutrients such as nitrogen and phosphorus exceed plant nutrient requirement is considered as a waste management activity from an environmental accounting perspective. Derogation is only possible whereas evidences prove that soil is poor in terms of organic matter and there is no other way to build up organic matter. See also: Residual and Economic value.
Water body	Entity of water with definite hydrological, hydrogeomorphological, physical, chemical and biological characteristics in a given geographical area (e.g. lakes, rivers, groundwater, seas, icebergs, glaciers and reservoirs). Note 1: In case of availability, the geographical resolution of a water body should be determined at the goal and scope stage: it may regroup different small water bodies. - ISO 14046:2014, 3.1.7 (ISO, 2014)
Water use	Use of water by human activity. Note 1: Use includes, but is not limited to, any water withdrawal, water release or other human activities within the drainage basin impacting water flows and/or quality, including in-stream uses such as fishing, recreation and transportation. Note 2: The term 'water consumption' is often used to describe water removed from, but not returned to, the same drainage basin. Water consumption can be because of evaporation, transpiration, integration into a product, or release into a different drainage basin or the sea. Change in evaporation caused by land-use change is considered water consumption (e.g. reservoir). The temporal and geographical coverage of the water footprint assessment should be defined in the goal and scope. - ISO 14046:2014, 3.2.1 (ISO, 2014)
Water withdrawal	Anthropogenic removal of water from any water body or from any drainage basin, either permanently or temporarily. - ISO 14046:2014, 3.2.2 (ISO, 2014)

Weighting

Weighting is an additional, but not mandatory, step that may support the interpretation and communication of the results of the analysis. Impact assessment results are multiplied by a set of weighting factors, which reflect the perceived relative importance of the impact categories considered. Weighted impact assessment results can be directly compared across impact categories, and also summed across impact categories to obtain a single-value overall impact indicator. Weighting requires making value judgements as to the respective importance of the impact categories considered. These judgements may be based on expert opinion, social science methods, cultural/political viewpoints, or economic considerations.
- Adapted from: Product Environmental Footprint (PEF) Guide (European Commission, 2013)

Summary of Recommendations for the LEAP guidance

ENVIRONMENTAL PERFORMANCE OF POULTRY SUPPLY CHAINS: GUIDELINES FOR QUANTIFICATION

The methodology developed in these guidelines aims to introduce a harmonised 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 methods, metrics and data.

The table below summarises the major recommendations of the technical advisory group for performance of lifecycle assessment to evaluate environmental performance of poultry supply chains. It is intended to provide a condensed overview and information on location of specific guidance within the document.

LEAP guidance uses a precise language to indicate which provisions of the guidelines are requirements, which are recommendations, and which are permissible or allowable options that intended user may choose to follow. The term "shall" is used in this guidance to indicate what is required. 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. In addition, as general rule, assessments and guidelines claiming to be aligned with the present LEAP guidelines should flag and justify with reasoning any deviations.

Topic	Summary recommendation	Section
DEFINITION OF THE PRODUCT GROUP		7
Product description	Poultry products include meat products, with possible co-products of skin, tallow, feathers, renderable material and inedible offal, and eggs or egg products, including shelled eggs and processed products.	7.1
Life cycle stages: modularity.	The guideline support modularity to allow flexibility in modeling systems. The 3 main stages are feed production, animal production, and primary animal processing.	7.2
GOAL AND SCOPE DEFINITION		8
Goal of the LCA study	The goal shall define: the subject, purpose, intended use and audience, limitations, whether internal or external critical review is required, and the study commissioner.	8.1
Scope of the LCA	The scope shall define: the process and functions of the system, the functional unit and system boundaries, allocation principles and impact categories. The recommended scope is cradle to dressed carcass for meat products, and cradle to packaged product for egg products.	8.2
Functional unit and Reference flows	Both functional units and reference flows shall be clearly defined and measurable, including specification of live weight, or product weight for meat products, with specified carcass or edible yield, respectively. For egg products the quantity including packaging and shell percent is recommended for the reference flow.	8.3
System boundary		8.4
General / Scoping analysis	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. Scoping analysis may use input-output data and should cover impact categories specified by the study goal.	8.4.1
Criteria for system boundary	The recommended system boundaries start with the great grandparent generation, and end with dressed carcass or eggs ready for transport to customers or storage.	8.4.2
Material boundaries	A material flow diagram should be produced and used to account for all of the material flows for the main transformation steps within the system boundary.	8.4.2
Spatial boundaries	Feed production and live animal rearing are explicitly included; details on feed production are provided in the LEAP feed guidelines.	8.4.2
Material contribution and threshold	Flows contributing less than 1% to impacts may be cut off, provided that 95% of each impact category is accounted, based on a scoping analysis.	8.4.3
Time boundary for data	A minimum period of 12 months should be used, to cover all life stages of the animal. The study should use an 'equilibrium population' which shall include all animal classes and ages present over the 12-month period required to produce the product. In case of significant inter-annual variability, the one-year time boundary should be determined using multiple-year average data to meet representativeness criteria.	8.4.4
Capital goods	May be excluded if the lifetime is greater than one year.	8.4.5
Ancillary activities	Veterinary medicines, accounting or legal services, etc. should be included if relevant, as determined by scoping analysis.	8.4.6
Delayed emissions	All emissions are assumed to occur within the time boundary for data. The feed guidelines address land-use and land use change related emissions	8.4. 7
Carbon offsets	Shall not be included in the impact characterisation, but may be reported separately.	8.4. 8
Impact categories and characterisation methods	Climate change (IPCC - GWP100) and Fossil Energy Demand (ReCiPe) are covered by these guidelines.	8.5

(Cont.)

Topic	Summary recommendation	Section
MULTI-FUNCTIONAL PROCESSES AND ALLOCATION		9
General principles	Follow ISO 14044 standard (section 4.3.4) – with restrictions on application of system expansion. The application of consequential modeling is not supported by these guidelines. System expansion may be used in the context of including expanded functionality. For example, calculating whole farm impacts of egg production without separately assigning impacts to eggs and meat from spent hens as co-products.	9.1
Methodological choices	Guidance for separation of complicated multifunctional systems and application of bio-physical or economic allocation when process separation is not feasible. A decision tree is presented to facilitate division of complicated processes into separate production units, and subsequently into individual products.	9.2
Meat production	The primary point for multi-functionality is in meat processing, where multiple edible and inedible products are generated. Causal reasoning is recommended to subdivide combined production, and to use economic allocation for joint production. Default allocation fractions are given in an appendix.	9.3.1
Egg production	Spent hen and eggs are the primary co-products; biophysical reasoning is recommended as a basis for allocation.	9.3.2
Allocation of manure	First the determination of whether the litter is classified as a co-product, residual or waste is made on the basis of revenue generation for the operation. <u>Co-product</u>: use biophysical reasoning (an example provided). <u>Residual</u>: the system is cut-off at the boundary and no burden is carried to downstream use of the litter. <u>Waste</u>: emissions from subsequent activities are assigned to the main co-products.	9.3.3
Multifunctional manufacturing facilities, primary processing	These guidelines do not support differentiation of edible products. Revenue based allocation is recommended for products which serve different markets (e.g., edible products vs. rendering products).	9.3.4
COMPILING AND RECORDING INVENTORY DATA		10
General principles	Inventory should be aligned with the goal and scope, shall include all resource use and emissions within the defined system boundaries that are relevant to the chosen impact categories. Primary data are preferred, where possible. Data sources and quality shall be documented.	10.1
Collection of data	Primary and secondary data are described. A data management plan is recommended which should address: data collection procedures; data sources; calculation methodologies; data storage procedures; and quality control and review procedures	10.2
Primary activity data	To the full extent possible, primary data are recommended for all foreground processes, those under control of the study commissioner.	10.2.1
Secondary and default data	Data from existing databases, peer-reviewed literature, may be used for background processes, or some foreground processes that are minor contributors to total emissions.	10.2.2
Addressing LCI data gaps	Proxy data may be used, with assessment of the interviews uncertainty. Environmentally extended input-output tables may also be used where available.	10.2.3
Data quality assessment	LCI data quality address representativeness, consistency, completeness, precision/uncertainty, and methodological appropriateness.	10.3
Uncertainty analysis	Uncertainty information should be collected along with a primary data. If possible, the standard deviation should be estimated, if not a reasonable range should be estimated.	10.4
LIFE CYCLE INVENTORY		11
Overview	Inventory should be aligned with the goal and scope, shall include all resource use and emissions within the defined system boundaries that are relevant to the chosen impact categories and shall support the attribution of emissions and resources use to a single production unit and co-products. Primary data are preferred, where possible. Data sources and quality shall be documented.	11.1

(Cont.)

Topic	Summary recommendation	Section
Cradle-to-farm gate	Data shall be collected for feed production (FEED guidelines), grand-parent and parent hatchery, broiler and layer hen production, manure production and emissions.	11.2
Feed assessment	The type, quantity and characteristics of feed produced and consumed must be documented. Because ration characteristics and environmental conditions can affect feed conversion ratio primary data on feed consumption is critical.	11.2.1
Animal population and production	A full accounting of breeding poultry or broiler replacement in each production cycle and spent hens is required, and must be connected to the reference flows of relevant products.	11.2.2
Manure production and management	Estimates of volatile solids and nitrogen excretion based on daily feed intake and properties of the feed are recommended. Procedures for calculating housing emissions of methane and direct and indirect nitrous oxide are provided.	11.2.3
Emissions from other farm-related inputs	The total use of fuel (diesel, petrol) and lubricants (oil) associated with all on-farm operations, including provision of water, shall be estimated.	11.2.4
By-products and waste	Mortality management as well as disposal of broken or damaged eggs, packaging or other solid waste shall be included in the inventory.	11.3.5
Transportation	The load factor shall account for empty transport distance, maximum load (mass for volume limited), and use physical causality (mass or volume share) for simultaneous transport of multiple products.	11.3
Biogenic and soil carbon sequestration	This relates only to the feed production stage, the specific methods are covered in the LEAP Animal Feed Guidelines.	11.5
Primary processing stage	This stage includes slaughter, removal of blood, feathers, feet and head, evisceration, washing and cooling, cutting and packaging and production of byproducts such as feather and bone meal in addition to the main meat products.	11.6
INTERPRETATION OF LCA RESULTS		12
Identification of key issues	The practitioner shall evaluate the completeness (with respect to the goal and scope); shall perform sensitivity checks (methodological choices); and consistency checks (methodological choices, data quality assessment and impact assessment steps)	12.1
Characterising uncertainty	Data uncertainty should be estimated and reported through formal quantitative analysis or by qualitative discussion, depending upon the goal and scope.	12.2
Conclusions, Recommendations and Limitations	Within the context of the goal and scope, the main results and recommendations should be presented and limitations which may impact robustness of results clearly articulated.	12.3
Use and comparability of results	These guidelines support cradle-to-gate LCA and do not include guidance for post-processing, distribution, consumption or end of life activities.	12.3.1
Report elements and structure	The following elements should be included: Executive summary summarizing the main results and limitations; identification of the practitioners and sponsor; goal and scope definition (boundaries, functional unit, materiality and allocation); lifecycle inventory modeling and life cycle impact assessment; results and interpretation, including limitations and trade-offs. A statement indicating third-party verification for reports to be released to the public.	12.5

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 LCA. The main purpose of the guidelines is to provide a 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 range 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; and
- policy makers interested in developing accounting and reporting specifications for livestock supply chains.

The benefits of this approach include:

- the use of a recognized, robust and transparent methodology developed to take account of the nature of poultry supply chains;
- the identification of supply chain hotspots and opportunities to improve and reduce environmental impact;
- the identification of opportunities to increase efficiency and productivity;
- the ability to benchmark performance internally or against industry standards;
- the provision of support for reporting and communication requirements; and
- awareness raising 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 use. This document does not provide support for the assessment of comprehensive environmental performance, nor the social or economic aspects of poultry supply chains.

The LEAP Animal Feed Guidelines cover additional impact categories: acidification, eutrophication, phosphorus depletion 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, if enough reliable data become available to justify the changes.

In the LEAP Animal Feed Guidelines, GHG emissions from direct land-use change is analysed and recorded separately from GHG emissions from other sources. There are two reasons for doing this. The first relates to the time frame, as 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 about follow-on impacts on soil degradation, biodiversity, carbon sequestration or loss, water depletion. 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 strives for a pragmatic balance between flexibility and rigorous consistency across scales, geographic locations 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 14025:2006 (ISO, 2006a) for more information and guidance on comparative claims of environmental performance.

These LEAP guidelines are 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 a full LCA. 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 World Trade Organization requirements.

3. Structure and conventions

3.1 STRUCTURE

This document adopts the main structure of ISO 14040:2006 (ISO, 2006b) and the four main phases of LCA: 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 practices in reporting.

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

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 and published in 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, and permissible or allowable options users may choose to follow.

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

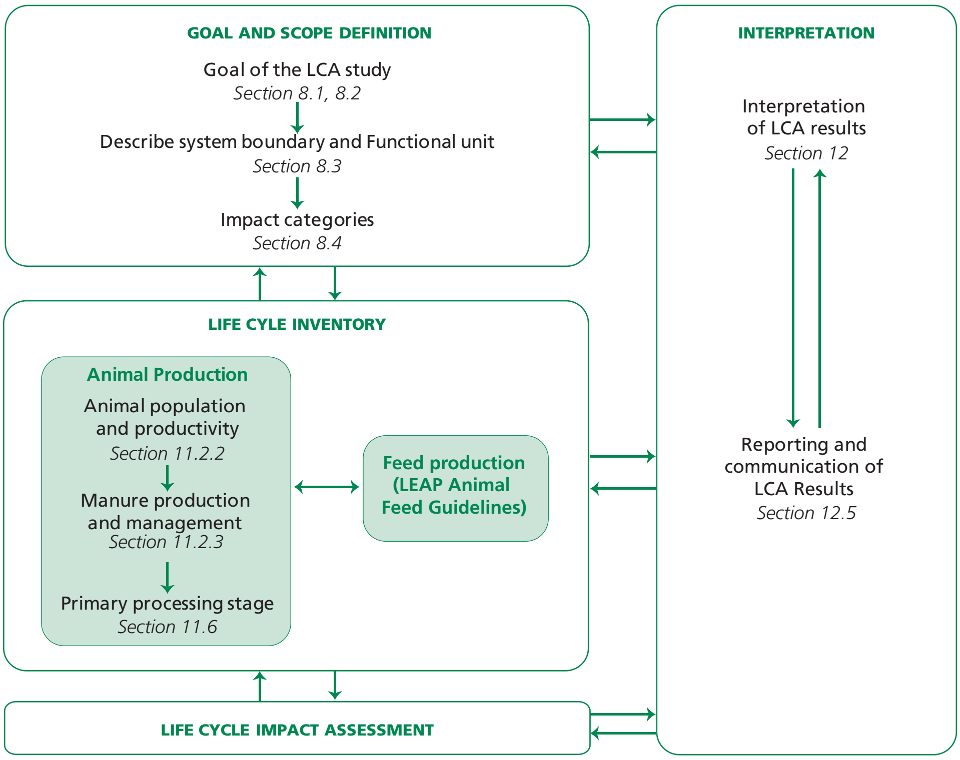
The term “should” is used to indicate a recommendation, but not a requirement.

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.

Figure 1
Main life cycle steps in the poultry supply chain



4. Essential background information and principles

4.1 A BRIEF INTRODUCTION TO LCA

LCA is recognized as one of the most complete and widely used methodological frameworks for assessing 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 reducing environmental impacts. According to ISO14040:2006, LCA consist of four phases (Figure 1):

- goal and scope definition, including appropriate metrics (e.g. GHG emissions, water consumption, hazardous materials generated and/or quantity of waste);
- life cycle inventories (LCIs), i.e. the collection of data that identify the system inputs and outputs and discharges to the environment;
- performance of impact assessment, i.e. the application of characterization factors to the LCI emissions that normalizes groups of emissions to a common metric, such as global warming potential reported in carbon dioxide equivalents (CO_2 e); and
- analysis and interpretation of results.

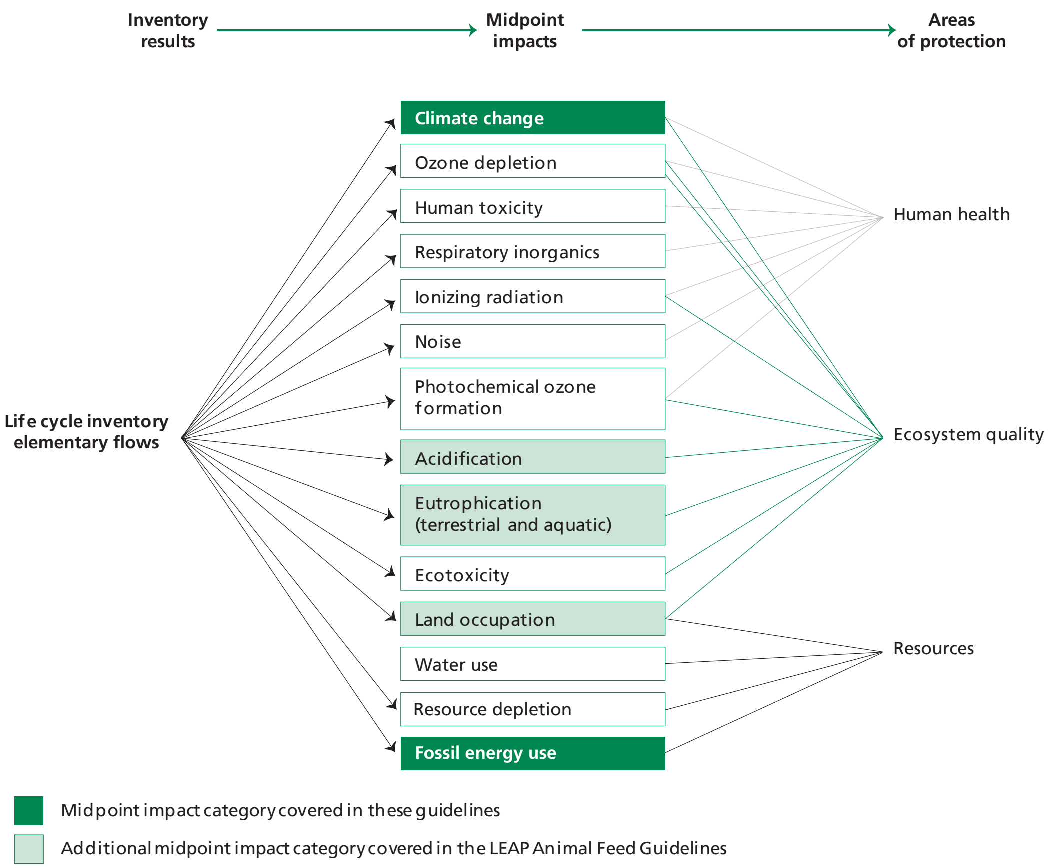
4.2 ENVIRONMENTAL IMPACT CATEGORIES

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 LCI to midpoint and endpoint impact categories (Figure 2).

A distinction must be made between midpoint impacts, which characterize impacts 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 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 LCI are the amounts of GHG emissions per functional unit. Based on a radiative forcing model, characterization factors, known as global warming potentials, specific to each GHG, can be used to aggregate all of the emissions to the same midpoint impact category indicator, (kg of CO_2e per functional unit).

Figure 2
Environmental cause-effect chain and categories of impact



Source: adapted from from the International Reference Life Cycle Data System (ILCD) Handbook (European Commission 2010b, 2011).

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* (ISO, 2006b)
  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 defines the generic steps that 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).

- ISO14044:2006 *Environmental management – Life cycle assessment – Requirements and guidelines* (ISO, 2006c)
  ISO 14044:2006 specifies requirements and provides guidelines for LCA including: definition of the goal and scope of the LCA, the LCI, the LCIA, the life cycle interpretation, 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.

4.4 NON-NORMATIVE REFERENCES

- ISO 14025:2006 *Environmental labels and declarations – Type III environmental declarations – Principles and procedures* (ISO, 2006a)
  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 series of standards 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/TS 14067:2013 *Greenhouse gases – Carbon footprint of products – Requirements and guidelines for quantification and communication* (ISO, 2013a)
  ISO/TS 14067:2013 specifies the principles, requirements and guidelines for the quantification and communication of the carbon footprint of a product. It is based on ISO 14040:2006 and ISO 14044:2006 for quantification, and ISO 14020:2000 (ISO, 2000), ISO 14024:1999 (ISO, 1999) and ISO 14025:2006, which deal with environmental labels and declarations, for communication.
- *Product Life Cycle Accounting and Reporting Standard* (WRI and WBCSD, 2011a)
  This standard from the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) 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 puts more emphasis on analysis, tracking changes over time, reduction options and reporting. Like PAS2050:2011 (see below), this standard excludes impacts from the production of infrastructure, but whereas PAS2050:2011 includes 'operation of premises', such as retail lighting or office heating, the *Product Life Cycle Accounting and Reporting Standard* does not.
- *ENVIFOOD Protocol, Environmental Assessment of Food and Drink Protocol* (Food SCP RT, 2013)
  The Protocol was developed by the European Food Sustainable Consumption Round Table to support a number of environmental instruments for use in communication and the identification of environmental improvement options. The Protocol might be the baseline for developing communication methods, product category rules (PCRs), criteria, tools, datasets and assessments.
- *International Reference Life Cycle Data System (ILCD) Handbook: - General guide for Life Cycle Assessment - Detailed guidance* (European Commission, 2010b).
  The *ILCD Handbook* was published in 2010 by the European Commission Joint Research Centre and provides detailed guidance for LCA based on ISO

14040:2006 and 14044:2006. It consists of a set of documents, including a general guide for LCA, and specific guides for LCI and LCIA.

- *Product Environmental Footprint (PEF) Guide* (European Commission, 2013)
  This Guide is a general method to measure and communicate the potential life cycle environmental impact of a product, developed by the European Commission primarily to highlight the discrepancies in environmental performance information.
- *BPX-30-323-0 General principles for an environmental communication on mass market products - Part 0: General principles and methodological framework* (AFNOR, 2011)
  This is a general method developed by the ADEME-AFNOR stakeholder platform to measure and communicate the potential life cycle environmental impact of a product. It was developed under request of the French Government, again with the purpose of highlighting the discrepancies in environmental performance information. Food production specific guidelines are also available, along with a large set of product specific rules on livestock products.
- *PAS 2050:2011 Specification for the assessment of life cycle greenhouse gas emissions of goods and services* (BSI, 2011)
  PAS 2050:2011 is a Publicly Available Specification (PAS), i.e. a not standard specification. An initiative of the United Kingdom sponsored by the Carbon Trust and the Department for Environment, Food and Rural Affairs, PAS 2050:2011 was published through the British Standards Institution (BSI) and uses BSI methods for agreeing on a PAS. It is designed for 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).

4.5 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 ISO 14040:2006, the *Product Environmental Footprint (PEF) Guide,* the *Product Life Cycle Accounting and Reporting Standard*, PAS 2050:2011, the *ILCD Handbook* and ISO/TS 14067:2013, and are intended to guide the accounting and reporting of GHG emissions and fossil energy use.

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

Life cycle perspective

"LCA considers the entire life cycle of a product, from raw material extraction and acquisition, through energy and material production and manufacturing, to use and end of life treatment and final disposal. Through such a systematic overview and perspective, the shifting of a potential environmental burden between life cycle stages or individual processes can be identified and possibly avoided" (ISO 14040:2006, 4.1.2).

Relative approach and functional unit

LCA is a relative approach, which is structured around a functional unit. This functional unit defines what is being studied. All subsequent analyses are then relative to that functional unit, as all inputs and outputs in the LCI and consequently the LCIA profile are related to the functional unit (ISO 14040:2006, 4.1.4).

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

Quantification of the product environmental performance shall include all environmentally relevant material/energy flows and other environmental interventions as required for adherence to the defined system boundaries, the data requirements, and the impact assessment methods employed (*Product Environmental Footprint (PEF) Guide*).

Consistency

Data that are consistent with these guidelines shall be used throughout the inventory to allow for meaningful comparisons and reproducibility of the outcomes over time. Any deviation from these guidelines shall be reported, justified 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.

Iterative approach

LCA is an iterative technique. The individual phases of an LCA use results of the other phases. The iterative approach within and between the phases contributes to the comprehensiveness and consistency of the study and the reported results (ISO 14040:2006, 4.1.5).

Transparency

"Due to the inherent complexity in LCA, transparency is an important guiding principle in executing LCAs, in order to ensure a proper interpretation of the results" (ISO 14040:2006, 4.1.6).

Priority of scientific approach

"Decisions within an LCA are preferably based on natural science. If this is not possible, other scientific approaches (e.g. from social and economic sciences) may be used or international conventions may be referred to. If neither a scientific basis exists nor a justification based on other scientific approaches or international conventions is possible, then, as appropriate, decisions may be based on value choices" (ISO 14040:2006, 4.1.8).

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 FAO, 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 year until 2050, driven by global population growth and increasing wealth and urbanization (Alexandratos and Bruinsma, 2012). According to Poultry International and Egg Industry, the demand for poultry products is projected to grow by 1.9 percent per year until 2022 (WATT, 2014). 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 resources 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. There is also 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 for 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 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 for 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 LCA and livestock supply chains.

The benefit of a sector-specific approach is that it gives guidance on the application of LCA 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, PCRs or product environmental footprint (PEF) 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 small ruminants, poultry and animal feeds. 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 POULTRY TAG AND THE PREPARATION PROCESS

The poultry TAG of the LEAP Partnership was formed at the start of 2013. The team included nine selected 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 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 the assessment of GHG emissions from livestock supply chains and identify gaps and priorities for further work;
- develop methodologies and sector specific guidelines for the LCA of GHG emissions from poultry supply chains; and
- provide guidance on future work needed to improve the guidelines and encourage greater uptake of LCA 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 purpose was to determine the range of methodological choices that have been used. The intention was to carry out the broadest possible evaluation, and for this reason peer-reviewed articles, theses and dissertations, and conference proceedings were included in the process. These sources allowed for an evaluation of the methodological consistencies and differences for global systems. A review of these studies can be found in Appendix 2. After the evaluation, it was concluded that no existing approach or study set out comprehensive guidance for quantifying GHG emissions and fossil energy demand across the supply chain and that the TAG would need to undertake further work to reach consensus on more detailed guidance. The Japanese Carbon Footprint Product Category Rules, 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

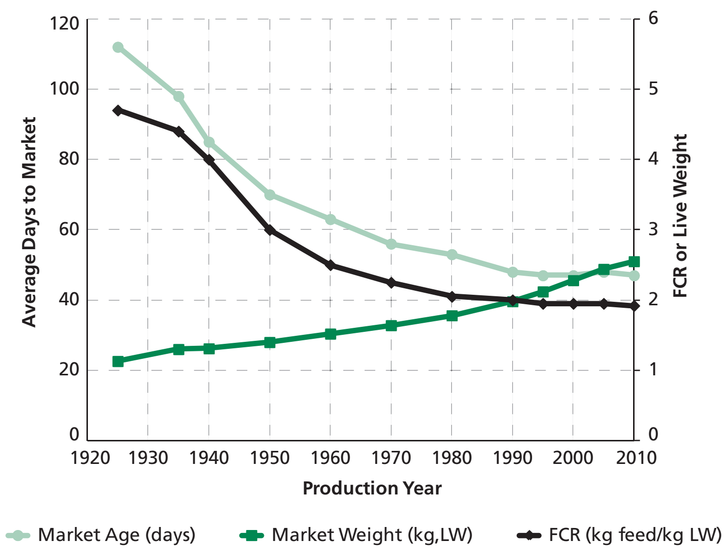
It is intended that these guidelines will be periodically reviewed to ensure the validity of information and methodologies on which it relies. Because there is not currently a mechanism in place to ensure such review, users are invited to visit the LEAP website (www.fao.org/partnerships/leap) for the 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). Quail eggs are also produced, mainly in Latin America, Asia and Europe. Poultry breeding has been done on a commercial scale since the 1870s, and today poultry is a rapidly expanding livestock sector (Figure 3). 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. Figure 4 shows the significant growth in the poultry sector, in terms of both meat production and egg production.

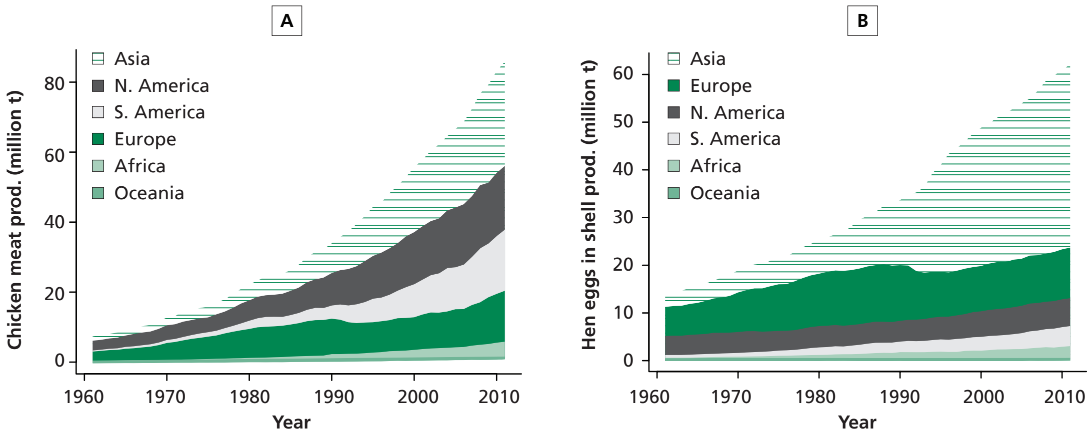
Figure 3
Historical performance improvement in US broiler production efficiency



Source: National Chicken Council, 2010.

Figure 4

Trends in global production from the poultry sector: (a) chicken meat and (b) hen eggs



Source: FAO, 2012.

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.

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 (e.g. organic production systems).

6.2 DIVERSITY OF POULTRY PRODUCTION SYSTEMS

Poultry production systems can be classified on the basis of scale, type of housing, feeding systems, animal genetics, and health provisions and, in some cases, certification programmes (systems prescriptions). Feed represents a major component of poultry supply chains. The possibility of producing feed far from poultry production sites and shipping it by energy-efficient sea transport has enabled many poor agricultural regions to develop their poultry sector. These production practices first arose in Europe and the United Sates and they are now contributing to growth of the agriculture sector in developing economies.

Examples of the diversity of poultry primary processing systems and products are given below.

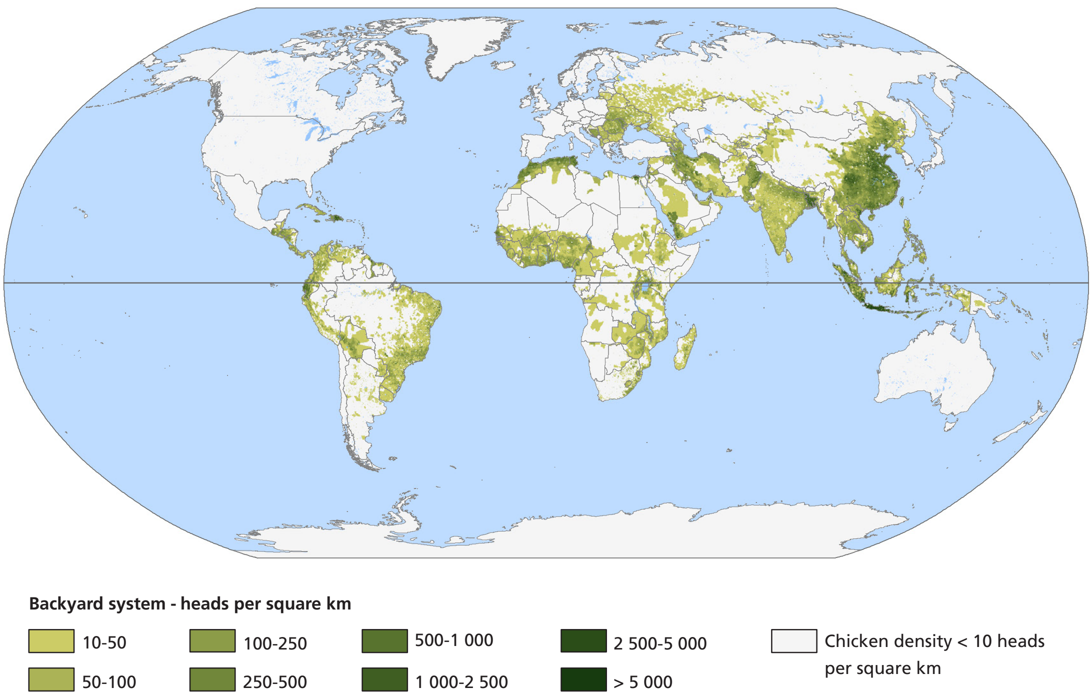
6.2.1 Backyard production

Backyard production systems can be divided into subsistence-driven (in developing and developed economies); 'specialty' production, in which small-scale farms produce for private consumption, local markets or specialty restaurants or food chains; and 'hobby' production. In developed countries, production is aimed not only at local markets but also at specific high-priced outlets, which account for up to 5 percent of the market for backyard and intermediate systems. Animal performance in backyard production systems is generally 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. Poultry production is often family-based. The number of poultry held is largely determined by what is needed to provide a family, or a few families, with an income. Figure 5 shows the global distribution of poultry in backyard systems.

6.2.2 Intermediate production

Intermediate production systems are market-oriented 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 for chicks at an early age, vaccination against prevalent diseases and deworming. Interestingly, in emerging economies, farmers often move from private subsistence production to somewhat

Figure 5
Global distribution of backyard chicken production



Source: Macleod *et al.*, 2013.

larger systems using modern breeds, selling their products either on the local markets or through (sometimes jointly organized) distribution and 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 lower level of performance compared with high-level intensive systems.

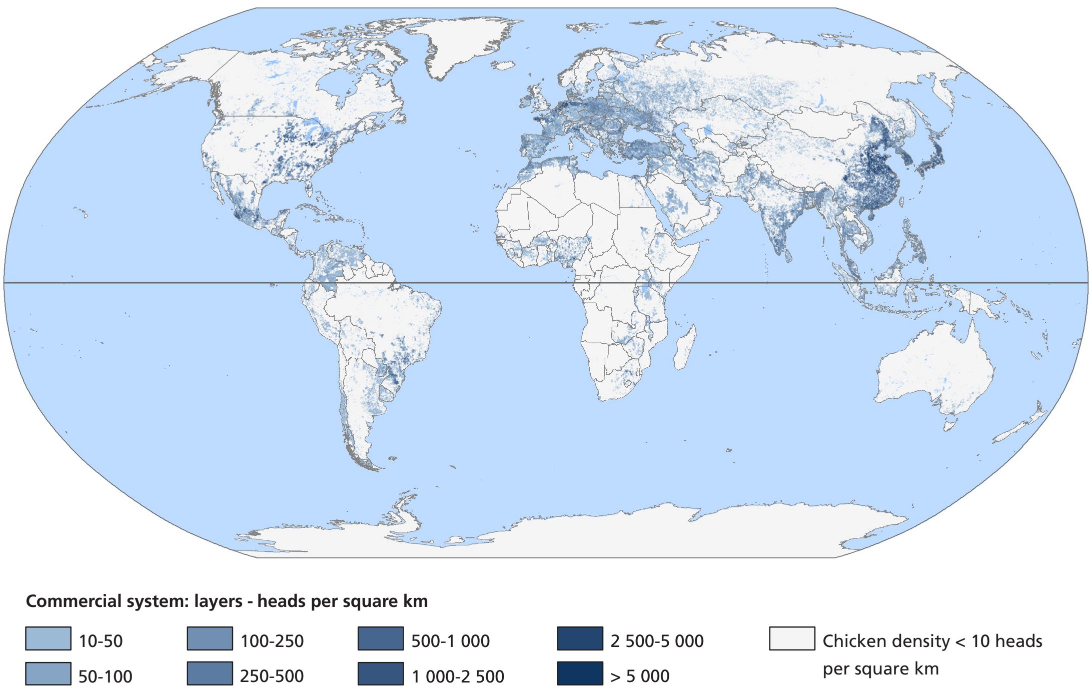
6.2.3 Large-scale production

Larger-scale poultry production systems usually have 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. These 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.

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 year in some cases. Dual-purpose chickens lay fewer eggs. In backyard or diversified systems,

Figure 6
Global distribution of chicken – Layers



Source: Macleod *et al.*, 2013.

which often have high mortality rates for day-old chicks from disease and predation, surviving hens 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 breeds that produce only in the warmer months, LCIA shall account for the non-productive months too.

Examples of laying systems include:

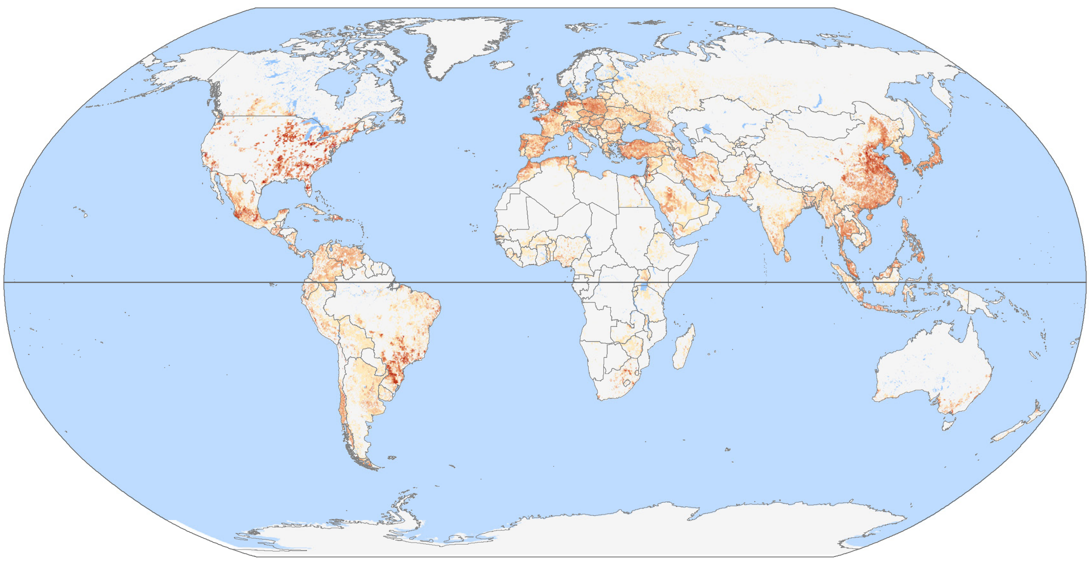
- **Backyard systems:** Backyard systems can best be described as a small farming system in which a sufficient number of hens are raised to provide eggs for a single family or to sell at local farmers' markets. The system is typically similar to the free-range laying hen system below, but on a smaller 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 that 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. In some cases, birds may be housed 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.
- **Post-farm processes:** These are carried out in egg packing and grading plants where shell eggs may be washed, categorized by weight and packed, and egg processing plants that produce a wide range of egg products, liquid and dry powders.

6.2.4 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, broiler 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 that grow more slowly than those in intensive production and reach slaughter weight no sooner than eight weeks of age.
- **Organic broiler chickens:** Organic broilers can be raised either in the back-yard or free-range systems described above. Regulations are region-specific but all require that feed is produced according to relevant organic standards (FAO/WHO Codex Alimentarius Commission, 2001), 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

Figure 7
Chicken Population density – Broilers



Commercial system: broilers - heads per square km

10-50 | 50-100 | 100-250 | 250-500 | 500-1 000 | 1 000-2 500 | 2 500-5 000 | > 5 000 | Chicken density < 10 heads per square km

Source: Macleod *et al.*, 2013.

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 or fully enclosed barns, some of them up to 182 meters long and 20 meters wide. Some modern broilers are also grown in multi-tier, large group colony units in which the broilers are kept on a mesh or plastic floor from one day old until time of slaughter. (Manure is removed via belts underneath the colony units.). 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 to closely control the environment inside the barn. Older barn houses are equipped with curtain walls that 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 barn to maintain fresh air and control temperature. A wide variety of management systems are used, with low- to high-level optimization of living conditions.
- **Post-farm processes:** These are carried out in 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) and material for rendering (for fertilizer).

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.

6.3 MULTI-FUNCTIONALITY OF POULTRY SUPPLY CHAINS

Farmers keep poultry 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 the 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 similar humble origins and by following similar poor-to-rich trajectory, the poultry 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.

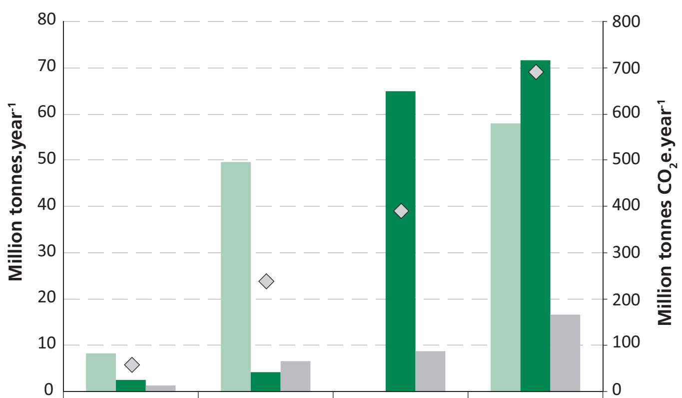
6.4 OVERVIEW OF GLOBAL EMISSIONS FROM POULTRY SUPPLY CHAINS

According to one global analysis (Macleod *et al.*, 2013), the production of poultry meat and eggs is estimated to account for 8 percent of the global annual emissions of GHGs 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. 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 the adoption of the most efficient production practices. These practices include the improvement of feed conversion, optimal manure management, the reduction of animal mortality in backyard systems and improved animal health care. However, as the poultry sector is expected to grow in coming years, mitigation options will need to address both the reduction of emission intensity, as well as emissions generated 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_2e.year^{-1}	52.4	210.3	343.3	606.1

Source: Macleod *et al.*, 2013.

PART 2

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

7. Definition of products and production systems

7.1 PRODUCTS DESCRIPTION

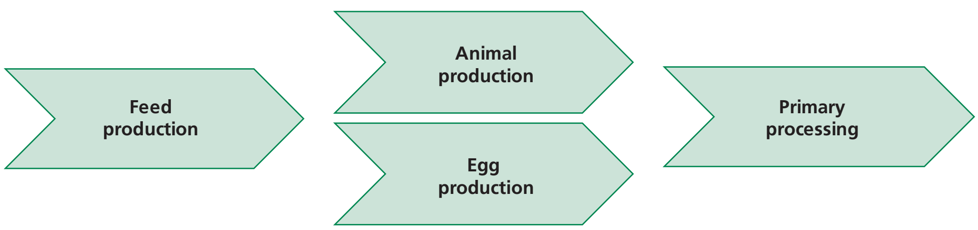
These guidelines cover the supply chain from cradle to primary processing gate. The main products may comprise:

- meat products, with possible co-products of skin, feathers, blood, bone and inedible offal; and
- 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 LCA studies, not specific to the poultry sector. See ISO 14025:2006 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 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, for example, to serve the goal of GHG emission management by determining the carbon footprint of products and understanding the GHG emission hotspots to prioritize emission-reduction opportunities along supply chains. However, LCAs can go beyond a carbon footprint and include other environmental impact categories, such as eutrophication, and provide detailed information on a product's environmental performance. They can also serve performance tracking goals and set progress and improvement targets. LCAs could also be used to support reporting on the environmental impacts of products. However, these guidelines are not intended for the comparison of products or labelling of environmental performance.

It is 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 (*ILCD Handbook*):

- subject of the analysis and properties of the assessed system: organization, location(s), dimensions, products, sector and position in the value chain;
- purpose for performing the study and decision context;
- intended use of the results: will the results be used internally for decision making or shared externally with third parties?
- limitations due to the method, assumptions and choice of impact categories, particularly those related to broad study conclusions associated with exclusion of impact categories;
- target audience of the results;
- comparative studies to be disclosed to the public and need for critical review; and
- commissioner of the study and other relevant stakeholders.

8.2 SCOPE OF THE LCA

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 LCI, 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_2e; and fossil energy use, reported in megajoules (MJ). The guidelines therefore should not be used to provide an indicator of overall environmental effects of the production systems and products. Care is 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 UNITS AND REFERENCE FLOWS

Both functional units and reference flows provide references to which input and output data are normalized in a mathematical sense. Both functional units and reference flows shall be clearly defined and measurable (ISO 14044: 2006). A functional unit describes the quantified performance of the function(s) delivered by a final product. Reference flows provide a quantitative reference for intermediate products.

Livestock products are characterized by a large variety of uses (see *ENVIFOOD Protocol,* 6.2.2.2) and the functions they deliver change according to their use In addition, many livestock products might be both intermediate products and final products. For example, farmers can distribute eggs directly to consumers or supply them for processing. For these reasons, and to ensure consistency across assessments conducted at the sectorial level, livestock products are not classified in final and intermediate products in these guidelines, and accordingly, no differentiation is made between functional units and reference flows.

Recommended functional units/reference flows for different main product types are given in Table 1. Where meat is the product type, the functional unit/reference flow when the bird leaves the farm is live weight, and when the product leaves the meat processing plant it 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 generally refers to the weight of the carcass 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 countries) that are increasingly being captured and should be included in the edible yield where they are destined for human consumption. 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 1). No distinction is made between different cuts of meat, meat products, and other edible parts, and it is recommended that they be 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, as mentioned above. An example of the relative content by weight of different meat cuts and co-products is given in Appendix 1.

For purposes of this guidance document, the preferred functional unit/reference flow is a specified quantity of the product ready for shipping (or sale) at the processing facility dock (or farm gate for backyard systems). An example of a functional unit/reference flow for meat products would be 1 000 kg of edible 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 parts 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. The qualifying characteristics shown in Table 1 shall be defined in the study to ensure sufficient information is available to perform harmonization of studies in the future. To take a specific example, if a practitioner wishes to compare published studies of liquid eggs with shelled eggs, the shell mass is an important parameter for harmonizing functional units/reference flows and enabling the comparison.

An appropriate functional unit for eggs would be 1 000 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.

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 farm gate (Boggia *et al.*, 2010; Leinonen *et al.*, 2012a). As farm gate assessments do not include the burdens of the post-farm gate processing, results of such analyses should be disseminated together with a discussion of possible allocations of total emissions to co-products. For informational purposes, the dress-out fractions should be specified, i.e. live to carcass weight and carcass weight

Table 1. Recommendations for choice of functional units/reference flows

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

to edible weight. However, without knowledge of post-farm processing burdens and co-product allocation, it is not appropriate to report farm gate burdens on, for example, a carcass weight or edible weight basis. The appropriate functional unit at the farm gate is animal live weight because use of carcass yield at the farm gate is doubly mistaken: first. None of the burdens of the post-farm gate 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. If the available data do not support the farm gate boundary, the iterative nature of the LCA should lead to a revision of the boundary to match the available data, and the cut-off criteria applied (and justified) if the data at the processor are unavailable for the necessary allocation.

8.4 SYSTEM BOUNDARY

8.4.1 General / Scoping analysis

The system boundary shall be defined following general supply chain logic and include 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 an LCA, which are outlined in Section 4. It should be emphasised 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.

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 TAG agreed that the breeding system should extend to the great grandparent generation based on previous studies, which show the breeding system contributes between seven and 8 percent of life cycle impacts (Wiedemann *et al.*, 2012; Leinonen *et al.,* 2012b)from cradle to gate, to quantify the environmental burdens per 1,000 kg of eggs produced in the 4 major hen-egg production systems in the United Kingdom: 1. To assess the time unit of 12 months of operation, data should be collected for the operation over a year's time. As there will be a non-integer number of bird generations in this time frame, the rolling flock average and annual live weight production can be used to calculate the total inputs and emissions. 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. The dressed carcass is a necessary stage in both consumption and post-farm processing. 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 PCR for Chicken (JEMAI, 2011a).

Frequently a scoping analysis based on a relatively rapid assessment of the system can provide valuable insight into areas that may require additional resources to establish accurate information for the assessment. A scoping analysis can be conducted using secondary data to provide an overall estimate of the system's impact. Furthermore, based on existing literature reviews relating to the poultry sector (Appendix 2), it is relatively clear that for production systems the following factors are extremely important to assess with high accuracy: the ration, the feed conversion efficiency and 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 boundaries. A flow diagram of all assessed processes should be drawn that indicates 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 boundaries: The cradle-to-farm-gate stage includes feed and animal components. The LCA of feeds is covered in detail in the 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. The LEAP Animal Feed Guidelines covers all emissions associated with land use and land-use change.

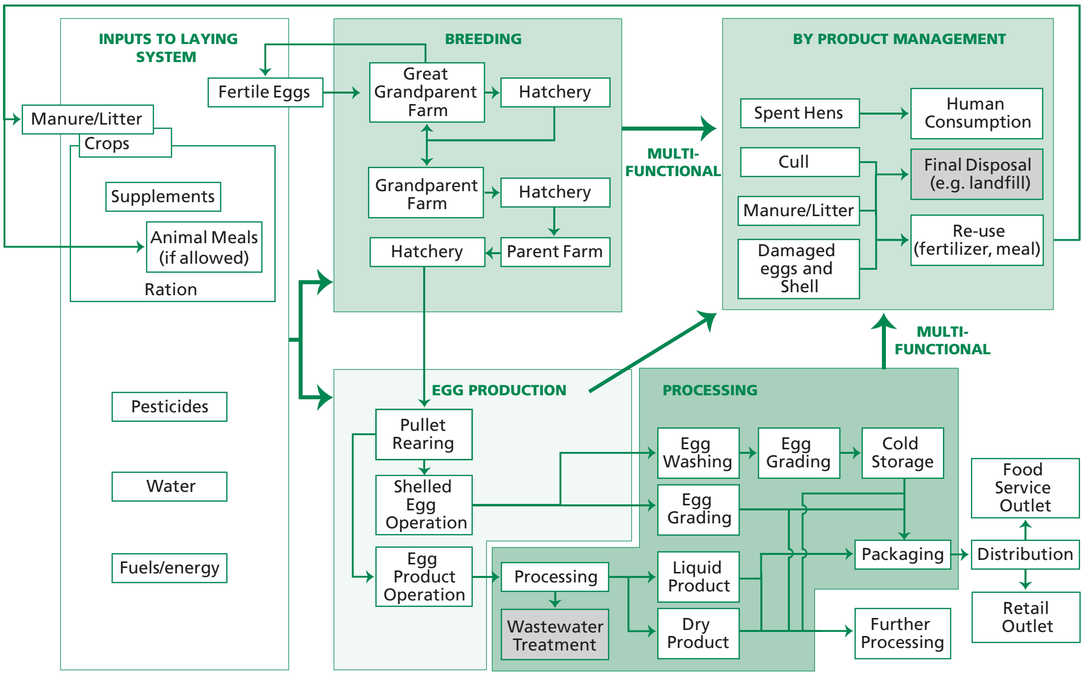
These guidelines cover all inputs and emissions in the poultry supply chain not covered by the LEAP Animal Feed Guidelines, i.e. emissions associated with poultry production and management. Management includes accounting for the utilization of excreta, where it is important to avoid double counting, if excreta represent a direct input for feed production. The estimation of manure emissions from transport and application is included in the LEAP Animal Feed Guidelines. These guidelines include 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 processing.

The primary processing stage is limited to animal slaughter, which may be done in the backyard, village slaughter unit or 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 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

LCA requires tremendous amounts of data and information. Managing this information is an important aspect of performing LCAs, and all projects have limited resources for data collection. In principle, all LCA practitioners attempt to include all relevant exchanges in the inventory. Some exchanges are clearly more important in their relative contribution to the impact categories of the study, and significant effort is required to reduce the uncertainty associated with these exchanges. In determining whether or not to expend significant project resources to reduce the uncertainty of small flows, cut-off criteria may be adopted (Section 8.2).

Figure 10
Schematic of egg and egg products production system



Source: 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.

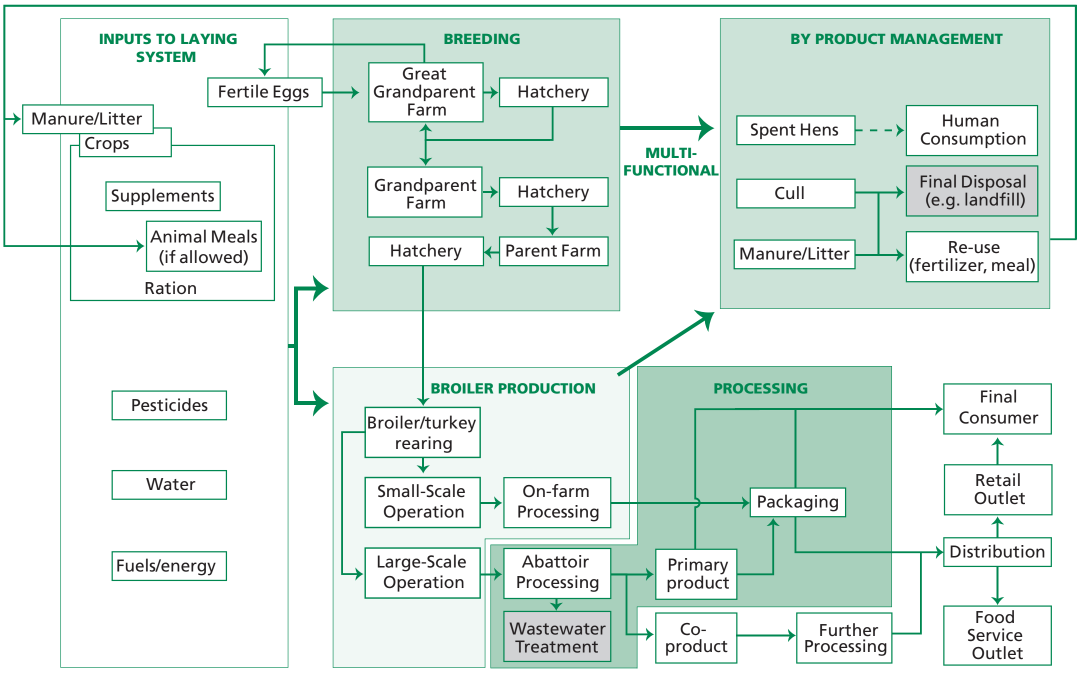
Exchanges that contribute less than 1 percent of mass or energy flow may be cut off from further evaluation, but should not be excluded from the inventory. Larger thresholds shall be explicitly documented and justified by the project goal and scope definition. A minimum of 95 percent of the impact for each category shall be accounted for. Inputs to the system that contribute less than 1 percent of the environmental significance for a specific unit process (activity) in the system can be included with an estimate from a scoping analysis (Section 8.2). The scoping analysis can also provide an estimate of the total environmental impact to evaluate against the 95 percent minimum.

For some exchanges that have small mass or energy contributions there still may be a significant impact in one of the environmental categories. Additional effort should be expended to reduce the uncertainty associated with these flows. Lack of knowledge regarding the existence of exchanges that are relevant for a particular system is not considered a cut-off issue but rather a modelling mistake. The application of cut-off criteria in an LCA is not intended to support the exclusion of known exchanges, it is intended to help guide the expenditure of resources towards the reduction of uncertainty associated with those exchanges that matter the most in the system.

8.4.4 Time boundary for data

For poultry products, a minimum period of 12 months should be used, if this is able to cover all life stages of the animal through to the specified endpoint of the analy-

Figure 11
Schematic of Poultry Meat production



Source: processes outside of the shaded boxes are excluded from the recommended system. Dark 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.

sis. To achieve this, the study shall use an 'equilibrium population' that shall include all animal classes and ages present over the 12-month period required to produce the given mass of product.

Documentation for temporal system boundaries shall describe how the assessment deviates from the one-year time frame. The time boundary for data shall be representative of the time period associated with the average environmental impacts for the products.

In extensive production systems it is common for important parameters to vary between years. For example, reproductive rates or growth rates may change based on seasonal conditions. In these cases where there may be considerable inter-annual variability in inputs, production and emissions, it is necessary for the one-year time boundary to be determined using data averaged over 3 years to meet representativeness criteria. An averaging period of 3 to 5 years is commonly used to smooth the impact of seasonal and market variability on agricultural products.

It is important to state that in this section the time boundary for data is described, and not the time boundary of a specific management system. When the specific management system or additional system functions, such as wealth management or the provision of draught power, influence the life cycle of the animal this needs to be clearly stated. However, this would in general not influence the time boundary for the data being 12 months.

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 LCI. All consumables and at least those capital goods whose life span is below one year should be included for assessment, unless it falls below the 1 percent cut-off threshold noted in Section 8.4.3.

8.4.6 Ancillary activities

Emissions from ancillary inputs (e.g. veterinary medicines, servicing, employee commutes, executive air travel, accounting or legal services) may be included if relevant. To determine if these activities are relevant, an input-output analysis can be used as part of 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 are considered in the LEAP Animal Feed Guidelines. The PAS 2050:2011 provides additional guidance regarding delayed emissions calculations for interested practitioners.

8.4.8 Carbon Offsets

Offsets shall not be included in the carbon footprint. However, they may be reported separately as 'additional information'. If reported, details for the methodology and assumptions need to be clearly documented.

8.5 IMPACT CATEGORIES

These guidelines are primarily based on an 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_2e). 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 Intergovernmental Panel on Climate Change (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 use should also be calculated, since all inputs of fossil fuels shall 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 higher heating value of the fuel for its characterization factor (Frischknecht, Heijungs and Hofstetter, 1998). It shall account for the embodied primary energy for the production and combustion of the various energy sources and may draw on recognized 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 will be updated to include multiple categories.

9. Multi-functional processes and allocation

One of the challenges in LCA has always been associated with the 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 farm gate; 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, and include a 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 14044:2006 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:

a. 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

b. 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. In other words the allocation should reflect the way in which the inputs and outputs are affected 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 (e.g. the allocation of process energy between poultry meat and other products not meant for human consumption), the allocation procedures should follow the ISO 14044:2006 allocation hierarchy. When allocation choices significantly affect the results, a sensitivity analysis shall be performed to ensure the robustness of conclusions.

Below is a list of commonly used procedures for addressing multi-functional processes in attributional studies:

- biophysical causality, arising from underlying biological or physical relationships between the co-products, such as material or energy balances;
- physical properties, such as mass, or protein or energy content; and
- economic value (revenue share) based on market prices of the products.

9.2 A DECISION TREE TO GUIDE METHODOLOGY CHOICES

A decision tree diagram to help with decisions on the appropriate methodology for dealing with co-products is given in Figure 12. It uses a three-stage approach, and the principles involved in working through it are as follows:

Stage 1: Avoid allocation by subdividing the processing system.
A production unit is defined here as a group of activities (along with the 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 stage (ISO step 1a subdivision), all processes and activities of a farm/processing facility are subdivided based on the following characteristics:

- flow 1.a. Inputs/activities that *can be directly assigned to a single co-product should be assigned to that 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 *can be assigned to single production units* and that may provide multiple co-products should be assigned to the specific production unit (e.g. input of pesticides for corn are assigned to the 'corn production unit' of a farm with multiple crops; or energy inputs for a specific barn operation or manufacturing facility; or feed for a specific animal, which may yield multiple products, in a farm operation with several species).
- flow 1.c. Inputs/activities of a *non-specific nature in a farm or processing facility,* such as heating, ventilation, climate control and internal transport in a manufacturing facility or farm that cannot be directly attributed to specific production units. For example, energy to pump drinking water for multiple animal species in a small-scale, multispecies operation would be categorized as non-specific. It may be possible for these inputs to be assigned to each production unit in proportion to the causal relationship that determines increased need for each input, such as weight, volume or area (transport, roads, buildings) or revenue (office and accounting).

Stage 2: Attribute combined production to separate production units.
In theory, all combined 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 stage, (stage 2 in Figure 12) the non-specific processes should be attributed to production units on the basis of the ISO steps 1b, 2 and 3. 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 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 multiple products.

System expansion: ISO step 1b: As part of the harmonization effort behind these guidelines, the range of allocation options in the application of LCA are restricted to poultry systems and exclude the application of system expansion by means of substitution. Furthermore, its use is limited to situations in which "expanding the product system to include the additional functions related to the co-products" is acceptable within the goal and scope of the study (ISO 14044:2006). This implies, for laying operations for example, that the GHG emissions can only be attributed to the combined multiple outputs of spent layers (as meat) and eggs, and that neither product receives a separately identified impact. For benchmarking operations, this is an entirely appropriate perspective; the overall reduction of impacts for the multifunctional system can be easily monitored and managed. The alternative, the consequential use of system expansion using an avoided burden calculated through substitution is not compliant with these guidelines.

Allocation: ISO step 2: When system expansion is not possible, the second question is whether a physical allocation is possible. The condition imposed by these guidelines here is that the products should have similar physical properties and serve similar goals or markets. Alternatively, known processing or biophysical relationships can be used to assign inputs and outputs of a single production unit to each product (ISO 14044:2006, 4.3.4.2, Step 2). 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 stage will be a splitting of some inventory flows between the production units, and if the resultant process is multifunctional, these inventory flows will be allocated to single co-products in the next step of the procedure (Box 3 in 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 mechanistic algorithm or physical property (flow 2b in Figure 12).

Allocation: ISO step 3: 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 still multifunctional, these inventory flows will be allocated to single co-products in the next stage of the procedure (Box 3 in Figure 12).

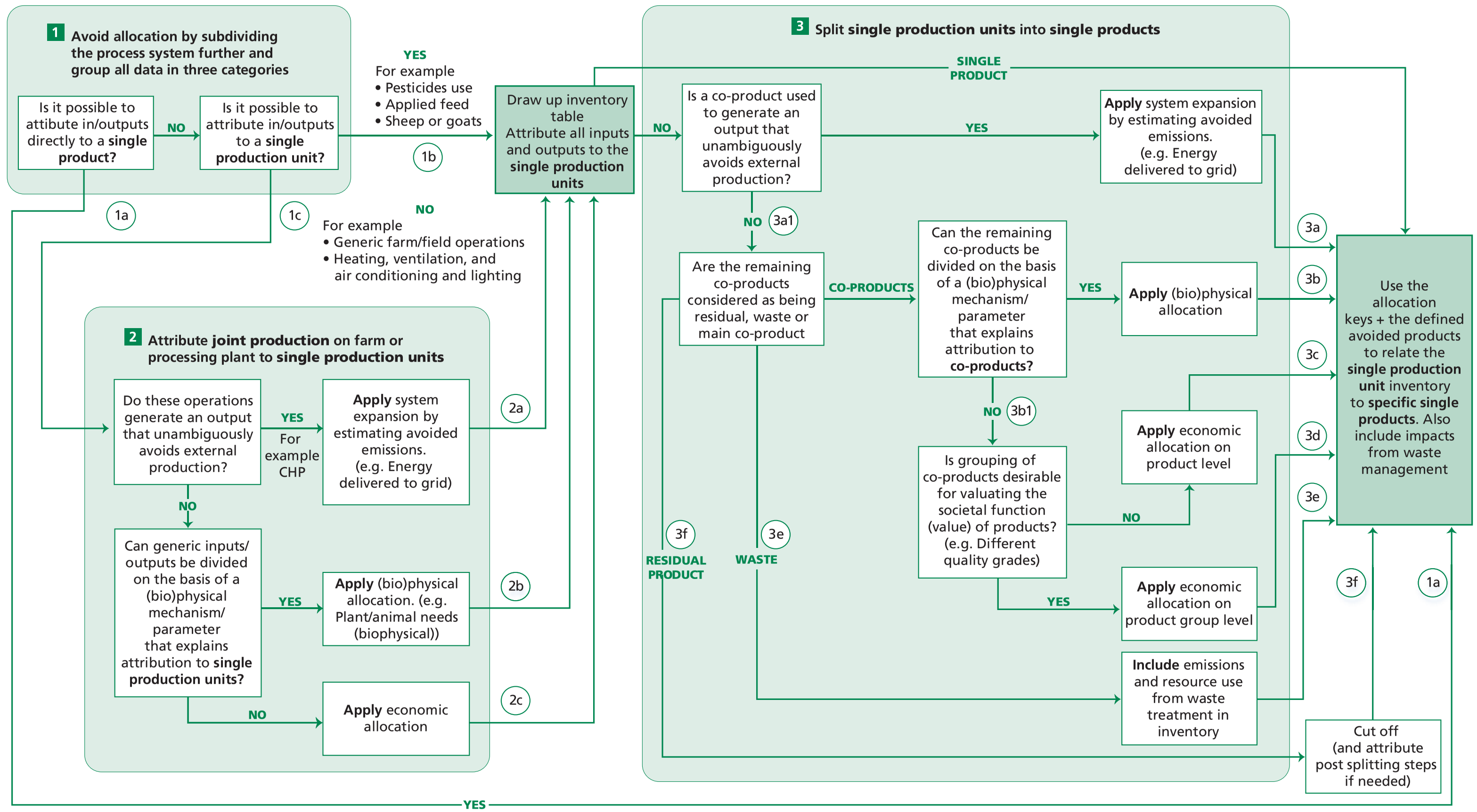
Stage 3: Split single production units into individual co-products.

After stages 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. Stage 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. The same rule holds as the one defined above for production units, so system expansion (without substitution) should be applied in situations where supported by the goal and scope definition. Any flow arising from 2a will follow this path. When system expansion is not used, the remaining outputs shall be classified as co-products, residual products or wastes.

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

- they are sold in the condition in which they are created in the process and do not contribute revenue to the owner;
- they are included in 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.

Figure 12
Multi-functional Output Decision Tree



Note: The choice of method for handling multifunctional outputs for each stage or process in the supply chain shall be based on this decision algorithm. Allocation keys used in the right-most box refer to the factors derived during application of the decision tree that are used to allocate inputs among multiple functions. For example, if economic allocation is used (e.g. to arrive at 3c), the allocation key for that stage is the ratio of the revenue of the co-product of interest to the total revenue for the activity.

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 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).

Co-products, i.e. not residual or waste, are subject to allocation, leading to flows 3b, 3c and 3d in Figure 12. Assignment to these flows depends upon whether biophysical or mechanistic allocation or an allocation based on physical characteristics, is possible or allowed under these guidelines (3b), or whether an economic allocation at a single product (3c) or product group level (3d) is applied.

Following the ISO standard, the preferred approach is to identify a straightforward mechanistic algorithm (e.g. when energy inputs in the process are directly correlated with mass flow), or biophysical relationship that can be used to assign inputs and emissions to each co-product. The condition for determining whether physical characteristic-based allocation (e.g. energy or protein content) is appropriate is that the products should have similar physical properties and serve similar functions or markets. When physical allocation is not feasible (interactions are 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 shall be grouped before allocation between them and other inedible co-products, such as renderables.

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, the ISO steps were applied in these situations: combined and joint production processes, such as farms and food processing plants that have multiple products and for manure. Table 2 summarizes the allocation procedures supported by this guidance.

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. 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 combined 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 apply causal reasoning for all situations of co-production, i.e. subdivision according to physical causalities for combined production and economic allocation for joint production. However, because of the potential sensitivity of this methodological choice, if information is available, system expansion and 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 multi-functional issue will already have been accounted for in the secondary data. For situations in which breeding is within the foreground system, the application of biophysical allocation for spent hens based on the proportion of total energy requirements for growth and egg/ hatchling production should be used.

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 biophysical allocation for spent hens based on the proportion of total energy requirements for growth and egg production. 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 (Wiedemann and McGahan, 2011; Leinonen *et al.*, 2012b)from cradle to gate, to quantify the environmental burdens per 1,000 kg of eggs produced in the 4 major hen-egg production systems in the United Kingdom: 1. Alternate methodological approaches for handling co-production at this stage include: economic or revenue allocation; protein mass for products edible by humans; and carcass and egg mass.

9.3.3 Allocation of manure / litter exported off-farm

This discussion follows the decision tree presented above. The first determination that shall be made is the classification of manure as either a co-product, waste or residual. This results in a 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(s) from the farm (live birds, eggs, or both) for which the previous allocation procedures apply.

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 farm gate shall be shared by all the co-products. Following the recommendations provided in Figure 12, the first method for allocation is to apply a biophysical approach based on the energy for digestion

Table 2: Recommended methods for dealing with multifunctional 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)	System separation 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 (common overhead. such as provision of water, or heating of a barn with multiple species), use biophysical allocation based on the proportion of total feed energy requirement for each of the different animal species.
Spent birds (within farm)	Biophysical causality	Use biophysical allocation based on the proportion of total energy requirements for growth and egg/hatchling production.
Cull birds (within farm)	Biophysical causality	Use biophysical allocation based on the proportion of total energy requirements for growth and egg/hatchling production. However, if disposed by rendering, composting or incineration, treat as a waste, not a co-product.
Meat processing (meat and non-meat products)	System separation Economic	First, separate activities specific to individual products where possible. Then use allocation based on the relative revenue derived from each group of products.
Egg processing (shells/wasted and broken eggs)	Economic	Use allocation based on the relative revenue derived from each of the products.
	Residual	If the economic value is zero or negative, and the material has a subsequent use, it is residual and receives no allocated burden.
	Waste	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. Specifically, it is recommended that biophysical causality and economic allocation are used in the sensitivity assessment, and that market price fluctuations be included as a tested parameter in all economic allocation (*ENVIFOOD Protocol*).

that must be expended by the animal in order to utilize the nutrients and create the manure. This is calculated as the heat increment for feeding of the diet. It represents the energy expended by the end associated with the process of feeding and digestion, and is distinct from maintenance energy requirements (Emmans, 1994; Kaseloo and Lovvorn, 2003). This situation may occur in any poultry system. There may be several co-products: spent hens, hatchlings or eggs, cull birds, meat and manure/litter. The allocation fraction assigned to each of the co-products shall be calculated as the ratio of the feed consumed that was required to perform each of the respective functions to the total feed consumed for all of the functions. An example is provided in appendix 3. In situations where energy content of the diet is unknown, the next step in the decision tree results in an economic allocation, because allocation based on physical characteristics parameters is clearly not appropriate, as the functions are different for the product (in the case of manure, fertilizer as opposed to energy). However, it should be noted that in this situation, an inconsistency in methodology arises if biophysical allocation is used for part of the system while economic allocation is used for another part.

Residual: When manure has essentially no value at the system boundary. This is equivalent to system separation by cut off, in that activities associated with conversion of the residual to a useful product (e.g. energy or fertilizer) occur outside of poultry production system boundary. In this recommended approach, as previously stated, emissions associated with litter management up to the point of field application are assigned to the animal system, and emissions from the field are assigned to the crop production system.

Waste: If manure is classified as a waste (generally 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 product(s). Emissions associated with the final disposition of manure/litter as a waste are within the system boundary and shall be accounted and assigned to the animal product(s).

9.3.4 Multi-functional manufacturing facilities

In commercial processing of poultry products, as a single production unit, the edible products have different functions and markets 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. However, for multiple determining edible products (e.g. chicken feet and chicken meat), which serve a common food market, the net induced changes in consumption may be insignificant coupled with the complexity of physical modelling of the processing facility (as the basis of a physical causality relationship), which leads to a simple revenue allocation of the similar products grouped together as one average product. Likewise, secondary rendering products that serve the same purpose in the market (e.g. blood, bone and feather meals that all serve as a protein source) shall be combined and treated as a single commodity. It is recognized that differentiation among products within the average commodity may, in some situations, be desired. However, for purposes of compliance with these guidelines this additional differentiation is not permitted. Table 3 provides an example of allocation factors for meat processing in Australia based on mass and revenue.

Table 3: Example of meat processing allocation factors

Slaughter products	Mass allocation factors	Economic allocation factors
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%
Blood meal	0.3-0.4%	0.1-0.2%
Pet food slurry	0-10.5%	0-1.1%
Pet food digest	0-1.1%	0-0.3%
Poultry meal	1.3-2.0%	0.4-0.6%
Feather meal	2.2-3.5%	0.4-0.5%

Source: Wiedemann *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 LCA. 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, national, or sectoral levels. 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 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 a 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 and 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 resources used and emissions associated with each life cycle stage included within the defined system boundaries. For processes where the practitioner does not have direct access to primary data (background processes), secondary data can be used. When possible, data collected directly from suppliers should be used for the most relevant products they supply. 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. First, production may not be static from year to year, and second, 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 to define the inputs and outputs of 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 shall 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 study methodology. 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 following three dimensions:
  a. *temporal 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, the LCA practitioner shall document data sources, 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 and 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 of higher quality are not available or it is 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 the LCI data set creation, including metadata documentation. The data management plan should include (WRI and WBCSD, 2011b, Appendix C):

- description of data collection procedures;
- data sources;
- calculation methodologies;
- data transmission, storage and backup procedures; and
- 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 that have a documented Quality Assessment (Section 11.3);

- data from previous projects that have a documented Quality Assessment;
- data published in peer-reviewed journals or from generally accepted LCA databases, such as those described by the Database Registry project of the UNEP/SETAC Life Cycle Initiative;
- data presented at conferences or otherwise publicly available (e.g. internet sources); and
- data from industrial studies or reports.

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 of 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 (e.g. methane emissions 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. Appendix 1 provides 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. For 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 2) 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 percent of emissions, direct on-farm energy use 8 percent, post-farm processing and transport of meat 7 percent and manure storage and processing 6 percent. They report that for eggs, feed production contributes 69 percent of emissions, direct on-farm energy use 4 percent, post-farm processing and transport of meat 6 percent and manure storage and processing 20 percent. The local conditions relevant to manure management emissions shall be considered. Workbooks that provide a template for primary data collection are included as Appendix 1.

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

Secondary data refers to LCI 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 that will be incorporated into the analysis. Specifically, LCI for goods and services consumed by the foreground system should be geographically and technically relevant. An assessment of the quality of these data sets (Section 10.2.3) for use in the specific application should be made and included in the documentation of the data quality analysis.

Where primary data are unavailable and where inputs or processes make a minor contribution to total environmental impacts, secondary or default data may be used. However, geographic relevance should be considered. For example, if default data are used for a minor input, such as a pesticide, the source of production should be determined and a transportation component added to the estimated emissions to account for its delivery from site of production to site of use. Similarly, where there is an electricity component related to an input, an electricity emission factor for the country or site of use should be used that accounts for the energy grid mix.

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 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. However, if only older data is available, documentation of the data quality is necessary and determination of the sensitivity of the study results to these data shall be investigated and reported.
- 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 fulfil the data quality requirements specified in this guide (Section 3.4).
- They should, where available, be sourced following the data sources provided in this guide (e.g. Section 11.2.2 for animal assessment and in Appendices 1 and 3.
- 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 are 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 data is set to zero, the result is biased towards lower environmental impacts (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, expensive and often not feasible. This section provides additional guidance on filling data gaps with proxy and estimated data, and is primarily targeted at LCA practitioners. Proxy data is never recommended for use in foreground systems as discussed elsewhere in this guidance.

The use of proxy data sets, i.e. LCI data sets that are the most similar to a process or product for which data is available, is common. This technique relies on the practitioner's judgment, and is therefore, arguably, arbitrary (Huijbregts *et al.*, 2001). Using the average of several proxy data sets, instead of a single data set, has been suggested as a means to reduce uncertainty as has bridging data gaps by extrapolating from another related data set (Mila i Canals *et al.*, 2011). 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. While the use of proxy data sets is the simplest solution, it also 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 to bridge 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 subject to uncertainty and has been criticised (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. When such proxy data are utilized it shall be reported and justified. When possible, an independent peer review of proxy data sets by experts should be sought, especially when they approach the 20 percent cut-off point of overall contribution to each emission factor, as errors in extrapolation at this point can be significant. Panel members should have sufficient expertise to cover the breadth of LCI data that is being developed from proxy data sets.

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. It improves the inventory's data content for the proper communication and interpretation of results, and informs 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 temporal representativeness, as well as the 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 temporal), completeness regarding the impact category coverage in the inventory, precision and 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 temporal representativeness. Table 4 presents a summary of selected 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 a detailed uncertainty assessment.

103.2 Data quality indicators

Data quality indicators define the standard for the data to be collected. These standards relate to issues such as representativeness, age and system boundaries. 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.

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.

Table 4: Overview of selected 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.

Secondary data for background processes can be obtained from different sources (e.g. 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 (e.g. if the 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 12.4). The *Product life cycle accounting and reporting standard* provides additional guidance on quantitative uncertainty assessment that includes a spreadsheet to assist in the calculations.

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:

- small whenever data are gathered, data should also be collected for the uncertainty assessment.
- small 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 percent confidence interval) and an assessment if data follow a normal distribution.
- small 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.

10.4.1 Secondary activity data

See Section 10.2.2 and Appendix 1.

10.4.2 Default/proxy data

See Section 10.2.2 and Appendix 1.

10.4.3 Inter- and intra-annual variability in emissions

Agricultural processes are highly susceptible to year-to-year variations in weather patterns. This is particularly true for crop yields, but these variations 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 to capture and identify either seasonal or inter-annual variability in the efficiency of the product system.

11. Life cycle inventory

11.1 OVERVIEW

The 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 follows an iterative process (as described in ISO 14044: 2006), with the first steps involving data collection adhering to the principles as outlined in Section 10. The subsequent steps in this process involve recording and validating the data; relating the data to each unit process and functional unit, including the allocation for different co-products; and aggregating the data, ensuring all significant processes, inputs and outputs are included within the system boundary. The system boundary (Figure 10 and Figure 11) includes pre- and post-farm gate stages. Workbooks that provide a template for primary data collection are included in Appendix 1.

Given the recommended system boundary, there are specific processes for which data are required to compute the LCA. These are briefly listed in Box 1 and discussed in detail in the following sections.

11.2 CRADLE TO FARM GATE

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

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

- *Feed production (on-farm or purchased feed, 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 of ration, energy use and manure management shall be fully accounted. For situations in which this stage is a background system, a default LCI is provided in Appendix 1).*
- *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 section 11.2.3 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.*

At the cradle to farm gate stage, previous research has shown that the largest source of GHG emissions is feed production (Wiedemann and McGahan, 2011; Wiedemann *et al.,* 2012; Leinonen *et al.,* 2012a; 2012b). Manure management also contributes to emissions, and is directly related to feed quality and the quantity of feed consumed. Clearly, an important first step is to define the feed types used and their feed quality characteristics.

The cradle to farm gate stage can be separated into three main processes of raw material acquisition, water and feed production, and their 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 as these are covered in the LEAP Animal Feed Guidelines. Thus, poultry feed information presented in this document is largely for context and because of the strong linkages 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 nitrous oxide emissions) and land-use change components are also important contributors to GHG emissions. For highly processed feeds (e.g. compound feed and 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 for estimating the cradle-to-beak impact of the ration.

Supplying water to animals is essential for their survival, and energy inputs are often required for the provision of water (e.g. for pumping and circulation) and/or its transport. 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:

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

Where P_h = fluid power (kW), q = pumping rate (m^3/h), ϱ = fluid density (1 000 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 percent:

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

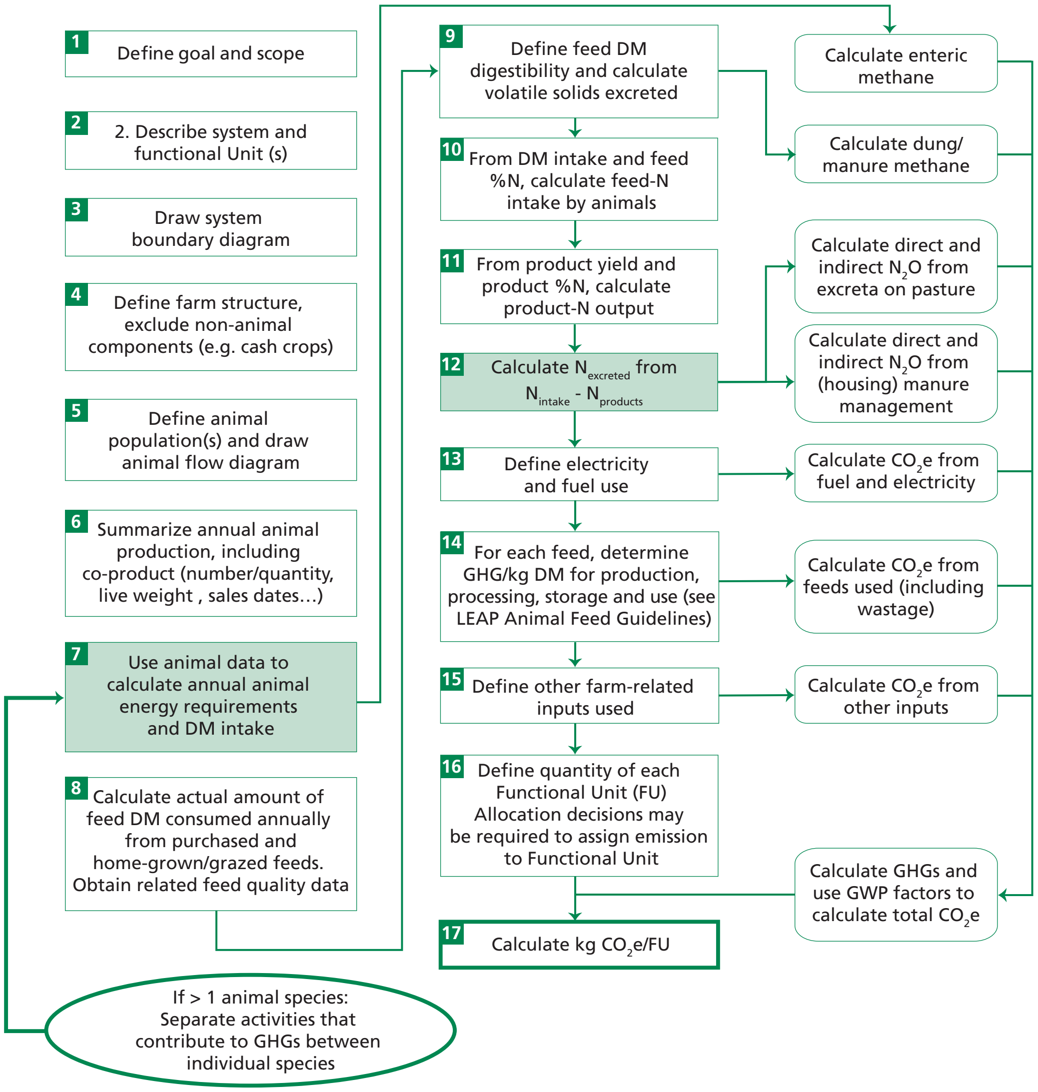
For electric pumps, the total energy consumption is estimated as *P*pumping hours.*

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 and metabolic diseases, and mineral deficiencies. These materials are likely below the materiality cut off and can be estimated using secondary or proxy data from extant databases.

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) and downstream impacts from manure management, which is the domain of this

Figure 13
Flow diagram as a guide to the procedure for determining the carbon footprint of poultry products for the cradle-to-farm-gate stage.



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

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 how the ration is presented (meal, mash, crumbles, pelleted diets). There has been 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 create 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 that 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 hybrids that are slower growing, hardy animals, well suited to backyard or organic production systems.

The LEAP Animal Feed Guidelines, which provide support for environmental LCA 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 percent 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 nitrous oxide should be accounted for and included with the manure emissions estimation.

Feed milling

One area of particular importance in poultry production systems is the period 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.

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	2 800	2 900	2 900
Crude Protein percent	19.5	17.5	16.5
Calcium percent	1.0	1.0	0.95
Total Phosphorus percent	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 percent	20-25	14-14.5	15.5-16	15-15.5
Calcium percent	0.75-0.80	0.85-0.90	3.4-3.6	3.7-3.8
Available Phosphorus percent	0.42	0.36	0.42	0.42

Source: Avila and de Soares, 2010.

In addition, poultry nutritionists require specific nutrient composition of the ration. Milling processes can change characteristics of feeds, specifically, their digestibility and potentially crude protein content. It is therefore important to determine that the ration specified in the LCA 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.

Computing emissions

To the extent feasible, emissions from the ration should 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) shall 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 the 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 and 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, grandparent and parent production, and the specific type of production under study (e.g. 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 hens that are not required for maintenance of the flock and 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.

Animal enteric methane emissions

According to the IPCC, insufficient information exists regarding enteric methane emissions from poultry (IPPC, 2006, Volume 4, Chapter 10). However, two studies, from Taiwan and Malaysia report enteric methane from poultry ranging from 0.015 to 2 g methane/head/year (Wang and Huang, 2005; Yusuf and Noor, 2012), which should be used as default emission factors.

11.2.3 Manure production and management

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 that 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 the 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.

Manure production

The first step to estimating manure GHG emissions is to estimate manure excretion and specifically, the mass of volatile solids (VS) and nitrogen (N) excreted in manure. Manure volatile solids and nitrogen 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, 2005; IPCC, 2006, Volume 4, Chapter 10).

For non-laying hens, nitrogen excretion is calculated by:

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

Where: $N_{E\text{-}PH}$ = Nitrogen excretion per bird-phase, breeding, hatchery, or broiler (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 nitrogen retained in bird– broilers: 0.602; turkey toms and hens: 0.588 (ASAE, 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:

$$N_{E\text{-}PH} = \frac{FI.C_{CP}}{6.25}\big((0.0182\,EGG_{wt})(EGG_{prod})\big) \equiv {}^{g\,N}\!/_{day} \quad (4)$$

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, 2005). Annual excretion shall be estimated from the animal population, excretion per bird per day and 365 days/year.

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

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

Where: FI_{PH} = Feed intake per bird-phase (kg, as fed); DMD = Diet digestibility expressed as a fraction (default value of 0.8); A = Ash content of manure (default value approx. 0.1). Volatile solids shall be summed across all production phases during one year's operation.

<u>Manure management systems</u>
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.

a) Housing emissions – Methane
Manure methane) emissions may be estimated using the following general formula:

$$CH_4 = VS\,(B_O)\,(MCF)\,(\varrho) \equiv {}^{Kg\ CH_4}\!/_{day} \quad (6)$$

Where: VS = volatile solids excretion (kg/day); B_o = emissions potential - m^3 CH_4/kg VS (provided in IPCC – (IPCC, 2006, Volume 4, Chapter 10) – 0.36 for developed countries); MCF = Integrated methane conversion factor (default value of 1.5-2 percent for poultry housed on litter); ϱ = density of methane (0.662 kg CH_4/m^3).

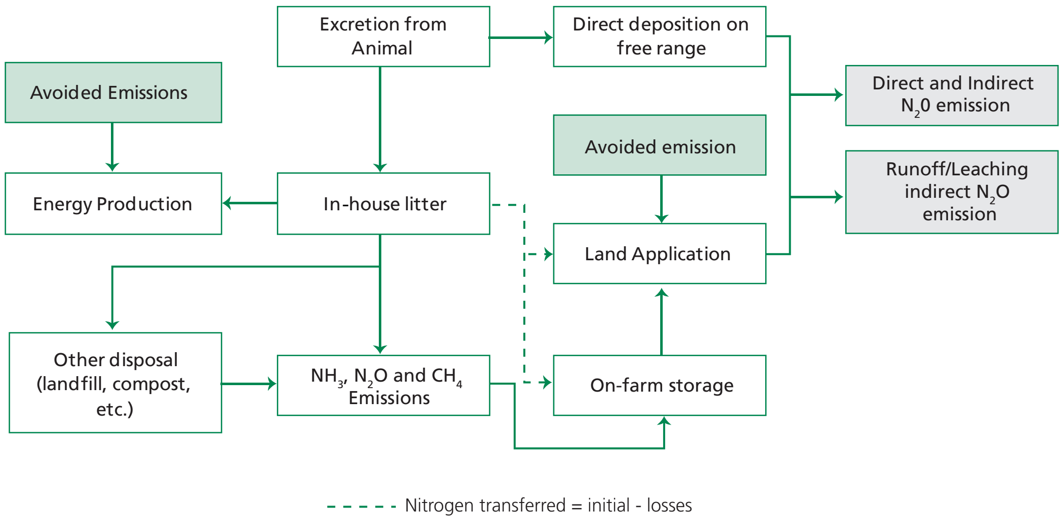
b) Housing emissions – Nitrous Oxide
Direct nitrous oxide emissions from manure management in the shed can be calculated by:

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

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 shall 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.

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.

Figure 14
Nitrogen mass flows from spent litter.



Note: Emissions from land application (green 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.

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*
Poultry manure deposited outdoors (free-range and organic supply chains)	0.02 **
Poultry manure without litter (majority of egg production systems).	0.001 *

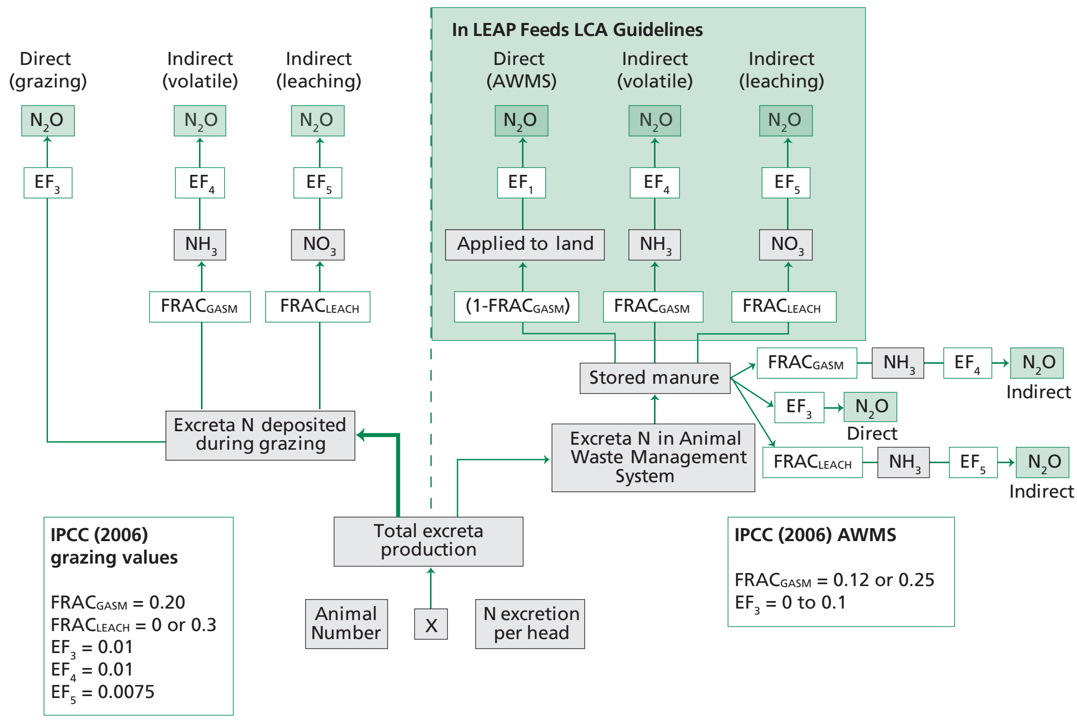
* IPCC, 2006, Volume 4, Chapter 10; ** IPCC, 2006, Volume 4, Chapter 11.

c) Indirect Nitrous Oxide Emissions

Indirect nitrous oxide emissions from ammonia loss and nitrogen 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, Volume 4, Chapter 10) default factors shall be used. Calculations first require an estimate of the amounts of ammonia loss and nitrogen leaching from excreta deposited on land. The default IPCC (2006) loss factor for $FRAC_{GASM}$ is 20 percent of nitrogen excreted and for $FRAC_{LEACH}$ is 30 percent (for soils with net drainage, otherwise 0 percent) of nitrogen excreted. These are then multiplied by the corresponding IPCC (2006, Volume 4, Chapter 10) emission factors of 0.01 kg N_2O-N/kg N lost as ammonia and 0.0075 kg N_2O-N/kg N lost from leaching/runoff, respectively.

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

Figure 15
Summary of approach for calculating Nitrous Oxide emissions from poultry excreta and waste management systems



Note: Summary of approach for calculating N_2O emissions from animal excreta and the animal waste management system (AWMS) using IPCC (2006, Volume 4, Chapter 10) activity factors (FRAC refers to fraction of nitrogen source contributing) and emission factors (EF in kg N_2ON/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).

d) Ammonia volatilization

Indirect emissions of N_2O occur as the result of ammonia volatilization from the production system and from ammonia volatilization 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.

Indicative ammonia emission factors and total losses (as a percentage of excreted nitrogen) 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 recommends an emission factor of 0.01 (1 percent) to calculate indirect N_2O emissions.

e) Leaching and runoff

Indirect N_2O emissions from nitrogen that is leached or lost from runoff after manure application may be predicted using the following formulas:

Table 8: Ammonia emission factors from different stages of manure management

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

* IPCC, 2006, Volume 4, Chapter 10; ** IPCC, 2006, Volume 4, Chapter 11{FormattingCitation}.

$$MN_L = NA\ (Frac_{wet})(Frac_{leach}) \equiv {}^{Kg\ N}/_{day} \quad (8)$$

Where: MN_L = N content of manure (kg) lost through leaching and runoff; N_A = N content of manure (kg) 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 nitrogen lost through leaching and runoff is 0.0125 according to the IPCC (2006, Volume 4, Chapter 10):

$$N_2O_L = 0.0125 MN_L \left(\frac{44}{28}\right) \equiv {}^{Kg\ N_2O}/_{day} \quad (9)$$

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, which will depend 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 treatment 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 fuel and lubricants 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, the 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.

The final on-farm results are calculated on the basis of the cumulative inventory the inputs and emissions each converted the appropriate impact category based on the characterization factors (e.g. for climate change due to electricity, the total annual number of kilowatt-hours of electricity consumed is multiplied by the national emission factor-kilograms CO_2e/kilowatt-hour). Once each of the inventories has been converted to the appropriate impact category metric, they are summed and divided by the total annual production to be reported on a per functional unit basis.

11.2.5 By-products and waste

The 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.

Fuel consumption from transport can be estimated using a) the fuel cost method, b) the fuel consumption method, or c) the tonne-kilometre method (Appendix 1). Transport distances may be estimated from routes and mapping tools or obtained from navigation software. The allocation of empty transport distance (backhaul) 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 provide a best estimate with a corresponding uncertainty, per the requirement in section 10.4.

Allocation of empty transport kilometres 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 percent 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.

Allocations 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.

11.4 INCLUSION AND TREATMENT OF LAND-USE CHANGE IMPACTS

The reader is referred to the LEAP Animal Feed Guidelines for additional detail. GHG emissions associated with land-use change 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 farm gate;
- 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; and
- waste management that has environmental impacts (e.g. landfill disposal of solid waste and wastewater treatment).

<u>Calculating GHG emissions from meat processing</u>

Calculation of GHG emissions shall account for resource use, wastewater 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 wastewater quantity and composition is used with the GHG emission factors for the method of wastewater processing (2006, Volume 4, Chapter 10) to calculate GHG emissions. An example is presented in Box 2. Total GHG emissions shall be allocated between the various co-products as outlined in Section 9.3.4.

Box 2. Example emissions calculation for an average US abattoir.

This facility processes 1.0 million birds per week with an average weight of 2 700 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.

Calculating GHG emissions from egg processing

Calculation of GHG emissions shall account for resource use, wastewater 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.

11.7 MULTI-FUNCTIONAL EXAMPLES

11.7.1 On-site energy generation

In some processing plants, waste material may be used for on-site energy generation. This may simply be used to displace energy requirements within the plant, in which case emissions from the energy generation system are assigned to the main products, and net energy consumption from external sources used as input to the process for the analysis. Where there is a surplus of energy generated within the primary processing system and some fraction is sold outside the system under study, the present guidelines recommend the use of system expansion to include the additional functionality of the sold energy. This is in line with ISO 14044:2006. When this does not match the goal and scope of the study, then the system shall be separated and the waste feedstock to the energy production facility shall be considered a residual from the processing operation as illustrated in box 3. All emissions associated with generation of energy shall be accounted, and the fraction used on-site treated as a normal input of energy (with the calculated environmental burdens). The fraction sold carries the burden associated with its production.

Box 3. Exemple of calculation for on-farm energy generation.

Advanced options for manure management are continually being developed. One technology that holds high promise is biomass enhancement for combined heat and power generation (CHP). In this example we will consider the manure management calculations, following the attributional approach required by these guidelines. We consider a 20 000 head barn (1485 m²) producing 110 000 live broilers for slaughter annually. Each broiler produces approximately 4kg manure (25% solids) resulting in 100 dry tons of litter produced annually, which is used to generate electricity and heat, in a 12.5 kW generator for on-site consumption, with excess electricity sold to the local grid (Reardon et al.*, 2001). Poultry litter has an energy content of approximately 14MJ/kg. Annual electricity consumption is estimated to be 23 000 kWh/yr with heating requirements of approximately 16 000 liters of propane (27MJ/L). Emissions associated with the residence time of the manure in the barn are attributed to the animal system, while the feedstock to the CHP system is considered, for purposed of this calculation, as a residual and carries no burden into the CHP process.*

Typical CHP efficiency ranges between 75 – 85% in overall conversion, with a range of 15 – 30% conversion to electricity and the remainder converted to useful heat energy.

If the house requirement is 23 000 kWh/year for electricity and assuming 15% conversion efficiency to electricity, the quantity of litter required to generate this amount of electricity is:

$$\frac{23000kWh}{0.15} * \frac{kg\ litter}{14MJ} = 39.4t$$

This amount of litter will also generate, assuming 60% conversion efficiency to heat (or a total efficiency of 75% - on the low end of the range):

$$39.4t * \frac{14MJ}{kg\ litter} * 0.6 = 3.31\text{x}10^5 MJ = 12250\ L\ (equivalent)\ propane$$

Thus the CHP system can provide 100% of the electricity requirements and 76.6% of the heating requirements with less than 40t. This leaves approximately 60t of excess litter that could be converted to an additional 18 600L of propane equivalent as heat and 35 000 kWh of electricity. Because the CHP feedstock, litter, is considered a residual, aside from start-up energy required to bring the system on-line, there are essentially no fossil carbon emissions associated production of this electricity, and if the local utility purchases it, the local average emission factor for the grid will be decreased proportionally. Depending on local circumstances, the excess heat may become waste heat to the environment. The operation itself will of course, have essentially no carbon footprint associated with its own energy consumption, and at a minimum, a reduced impact associated with a 40t reduction in the quantity of litter to be disposed.

Table 9: 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%

11.7.2 Effect of mass and economic value of different components of an average US broiler leaving an abattoir on allocation calculations

Data in the Table 9 was based on a summary of the average weight of different meat cuts and co-products from a broiler 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.

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 (*ILCD Handbook*):

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, for example 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, and 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.

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 the 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 *ILCD Handbook*):

- **Completeness checks:** 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.
- **Sensitivity checks:** 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 LCI 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* 10.3 on 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. Knowledge uncertainty can be reduced by collecting more data, but often resource limits restrict the breadth and depth of data acquisition. Process uncertainty can be reduced by breaking complex systems into smaller parts or aggregations, but inherent variability cannot be eliminated completely. The LCIA characterization factors that are used to combine the large number of inventory emissions into impacts also introduce uncertainty into the estimation. In addition, there is bias introduced if the LCI model is missing processes, or otherwise does not represent the modelled system accurately.

Variation and uncertainty of data should be estimated and reported. This is important because results that are based on average data, i.e. the mean of several measurements from a given process at a single or multiple facilities, or on 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 10. 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.

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. 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.

Table 10: Guide for decision robustness from sensitivity and uncertainty

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

12.2.2 Sensitivity analysis

Choice-related uncertainties arise from a number of methodologies, including modelling principles, system boundaries and cut-off criteria, choice of footprint impact assessment methods and other assumptions related to time, technology and geography. Unlike the LCI and characterization factors, they are not amenable to statistical description. However, 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 an input parameter (Hong *et al.*, 2010).

12.2.3 Normalization

According to ISO 14044:2006, 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 percent of global anthropogenic GHG emissions (Gerber *et al.*, 2013). Similar assessments can be made at regional or national scales, provided that there exists a reasonably complete inventory of all emissions in that region that contribute to the impact category. Normalization provides an additional degree of insight into those areas in which significant improvement would result in notable advances for the region in question, and can help decision makers to focus on supply chain hotspots whose improvement will bring about the greatest relative 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, and explicitly accounting for limitations to robustness, uncertainty and applicability.

Conclusions derived from the study should summarize supply chain hotspots 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, allocation, and 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, plausibly founded and strictly relate to the goal of the study. Recommendations shall be given jointly with limitations to avoid their misinterpretation beyond the scope of the study.

12.3.1 Use and comparability of results

It is important to note that these guidelines refer only to a partial LCA, Where results are required for products throughout the whole life cycle, 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: 2014). Results from the application of these guidelines cannot be used to represent the whole life cycle of poultry products. However, they can be used to identify hotspots 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. However, they can provide valuable guidance to practitioners to the point of divergence from the system into different types of products.

12.4 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 minimize the risk of misinterpretation.

The description of the input data and assessment methods 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 non-comprehensive number of impact categories and outputs. This discussion should address:

- possible positive or negative impacts on other (non-GHG) environmental criteria;
- possible positive or negative environmental impacts (e.g. on biodiversity, landscape, carbon sequestration); and
- multi-functional outputs other than production (e.g. economic, social, nutritional);

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.

12.5 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) and including key elements of goal and scope of the system studied and the main results and recommendations, while clearly presenting assumptions and limitations;
- identification of the LCA study, including name, date, responsible organization or researchers, objectives and reasons for the study and intended users;
- goal of the study, its intended applications, targeted audience and 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 farm gate and farm gate 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, its 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 land-use change;
- LCI modelling and calculating LCI results;
- results and interpretation of the study and conclusions;
- description of the limitations and any trade-offs; and
- if intended for the public domain, a statement as to whether or not the study was subject to independent third-party verification.

12.6 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; and
- 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, for example, 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 1
LCI data to be collected

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

INPUTS FOR MEAT AND EGG PRODUCTION:

Background breeding system

For operations with the primary function of providing eggs, which can be hatched as chicks to become either laying hens or broilers, if primary data are available they should be used. However, normative reference information has been provided 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 (e.g. process water, tap water, well water; and
- feed rations (type and quantity).

Outputs:

- annual number of hatched day-old chicks 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; and
- wastewater discharge.

Commercial broiler and egg production

Day-old chicks from the breeding system:

Inputs:

- annual quantity of materials and fuels used at broiler farm;
- electricity, natural gas and other fuels;
- water (e.g. industrial water, tap water, well-water); and
- feed rations (type and quantity).

Outputs:

- annual number and live weight of broilers produced;
- annual number of eggs and weight produced;
- type and quantity of waste; and
- 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; and
- wastewater discharge.

Slaughtering process

Inputs:

- number and weight of live animals processed;
- annual quantity of materials and fuels used;
- electricity, natural gas and other fuels;
- water (e.g. industrial water, tap water, well-water,); and
- 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.

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.

Egg grading and processing*:*

Inputs:

- Number of eggs and weight 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 functional units (eggs and /or egg products);
- Type and quantity of waste;
- Solid waste to landfill, incineration or recycled;
- Wastewater discharge;

CALCULATION METHOD FOR FUEL CONSUMPTION DURING TRANSPORT

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.

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.

Tonne-kilometre method

Collect data on loading ratio [percent] 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.

DATA COLLECTION TEMPLATE FOR FARMING OPERATIONS

Table A1.1: 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, 2ndary 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

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%

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	

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

Table A1.2: 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, 2^{ndary} 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

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

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

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					

Inputs

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%			

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%	

Packaging

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

Chemicals

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

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

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				

Spent and cull hens

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

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				

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			
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	

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			

Sources of additional information

Agricultural assessment:

- **Denef, K., Paustian, K., Archibeque, S., Biggar, S., and Pape, D.** 2012. Report of Greenhouse Gas Accounting Tools for Agriculture and Forestry Sectors. Interim report to USDA under Contract No. GS23F8182H. This document describes a large number of calculators, models and agricultural protocols.
  www.usda.gov/oce/climate_change/techguide/Denef_et_al_2012_GHG_Accounting_Tools_v1.pdf
- PLANETE (INRA, France)
  https://solagro.org/images/imagesCK/files/publications/f56_014planeteooct02.pdf
- Fieldprint calculator
  www.fieldtomarket.org/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/
- AGRIBALYSE®, this is a life cycle inventory database for food and agriculture products (including poultry products) designed for use with the French reporting system.
  www.ademe.fr/en/expertise/alternative-approaches-to-production/agribalyse-program
- The Agri-Footprint project is another lifecycle inventory database containing data on many agricultural products.
  www.agri-footprint.com/
- The US national agriculture Library Digital Commons project is another source of life cycle inventory data sets covering US agricultural production.
  www.lcacommons.gov/

Table A1.3: Yield rate of young chicken breed (example)

Name / 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 percent.

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

Default data sets and data ranges

Table A1.3 presents approximate yields for broiler processing. Farm gate 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.

Default LCI for breeder as a background system

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 (Section 0), is actually a simplification of the more accurate method described below (Section 0). 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 valorization (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 valorization 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 2
Literature review

This document was prepared as part of the UN FAO partnership for Livestock Environmental Assessment and Performance Partnership (LEAP) technical advisory group for poultry. The intention of this document is to provide an overview assessment existing studies and associated methods that have used life cycle assessment for evaluation of poultry meat and egg supply chains. 18 studies have been identified addressing aspects of the poultry supply chain or egg supply chain (Bengtsson & Seddon, 2013; Boggia *et al*, 2010; da Silva *et al*, 2012; da Silva *et al*, 2008a; da Silva *et al.*, 2008b; Dekker *et al*., 2008; Dekker *et al*., 2013; Dekker *et al*., 2011; Dekker, 2012; Ellingsen and Aanondsen, 2006; Katajajuuri *et al*., 2008; Leinonen *et al*., 2012a, 2012b; Lesschen *et al*, 2011; Marino *et al*., 2011; Palm, 2010; Pelletier, 2008; JEMAI 2011a, 2011b; Verge *et al*, 2009; Weiss & Leip, 2012; Wiedemann *et al*, 2010; Wiedemann *et al*, 2012; Wiedemann and McGahan, 2011; Williams *et al*, 2006). In the remainder of this document will identify the common approaches as well as point out differences in methodological and modelling choices.

GOAL AND SCOPE

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*., 2008; 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 (Boggia *et al*., 2010; Lesschen *et al*., 2011; Leinonen *et al*., 2012b; Weiss and Leip, 2012; Bengtsson and Seddon, 2013, Dekker *et al*., 2008, 2011, 2013; Leinonen *et al*., 2012a). 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.

GEOGRAPHIC REGION

There are a number of studies focused on either individual countries in Europe or the EU27 (Williams *et al*., 2006; Dekker *et al*., 2008; Katajajuuri *et al*., 2008; Boggia *et al*., 2010; Lesschen *et al*., 2011; da Silva *et al*., 2012; Leinonen *et al*., 2012b; Weiss and Leip, 2012), the United States (Pelletier, 2008), Brazil (da Silva *et al*., 2008a; b), and Australia (Wiedemann and McGahan, 2011; Wiedemann *et al*., 2012; Bengtsson and Seddon, 2013). 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.

MATERIALITY

The question of materiality is related to the cut-off criteria chosen for each study. ISO 14044: 2006 (ISO, 2006), PAS 2050:2011 (BSI, 2011), and PCRs 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 Environmental Product Declaration PCR states that 99 percent of ingredients must be declared a product declaration (Palm, 2010). The Japanese PCR (JEMAI, 2011b) 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 percent of the total life cycle GHG emissions (presumably this also applies to other impact categories, although this is not explicitly stated).

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 farm gate (Williams *et al*., 2006; Boggia *et al*., 2010; Leinonen *et al*., 2012b; Weiss and Leip, 2012), although the definition of edible is not unequivocally defined. Two studies included downstream processing to the point of purchase by the consumer (Katajajuuri *et al*., 2008; Bengtsson and Seddon, 2013). The studies from da Silva *et al.* (2008b, 2012) specified a functional unit either a ton of whole chicken, chilled or frozen and delivered to the port of entry. The Environmental Product Declaration PCR refers to 1 kg of meat and associated packaging as the functional unit, specifying 'pure' meat exclusive of any inedible portions (Palm, 2010). The Japanese 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 farm gate; Williams *et al*. (2006) used 20 000 eggs as a functional unit.

SYSTEM BOUNDARIES

The system boundary for most of the meat studies is from cradle to farm gate. The definition of 'cradle' is variable; for some studies it includes three generations of breeding stock (Williams *et al*., 2006; Leinonen *et al*., 2012b; Bengtsson and Seddon, 2013)from cradle to gate, to quantify the environmental burdens per 1,000 kg of eggs produced in the 4 major hen-egg production systems in the United Kingdom: 1; the remainder of the studies either did not specify the upstream boundary or included one generation of breeding plus the hatchery.

The Environmental Product Declaration PCR defines only three primary stages: upstream, core processes, and downstream (Palm, 2010). Upstream processes include feed production, breeding farm, including manure management; core processes include production (farms, packaging and distribution); downstream processes include retail, consumer, and end of life 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.

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 Environmental Product Declaration 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 (Palm, 2010). The Japanese PCR does not explicitly mention ancillary activities.

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 Environmental Product Declaration PCR provides for separate, optional reporting of biogenic carbon dioxide (Palm, 2010). The Japanese PCR (JEMAI, 2011a) does not mention biogenic carbon.

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 Environmental Product Declaration PCR provides for optional reporting in this category (Palm, 2010), while the Japanese PCR explicitly excludes soil carbon accounting because it states there is no internationally agreed protocol in this regard.

LAND USE

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 (da Silva *et al*., 2008a, 2012; Leinonen *et al*., 2012a; b; Weiss and Leip, 2012)from cradle to gate, to quantify the environmental burdens per 1,000 kg of eggs produced in the 4 major hen-egg production systems in the United Kingdom: 1. Three studies accounted for land occupation, but did not explicitly mention land-use change (Williams *et al*., 2006; Dekker *et al*., 2008; Boggia *et al*., 2010). The PAS 2050:2011 (BSI, 2011) method for accounting for land-use change has been adopted by the *ENVIFOOD Protocol* (Food SCP RT, 2013).

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).

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 (Williams *et al*., 2006; Dekker *et al*., 2008; Leinonen *et al*., 2012a; b)from cradle to gate, to quantify the environmental burdens per 1,000 kg of eggs produced in the 4 major hen-egg production systems in the United Kingdom: 1. 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 Environmental Product Declaration PCR states that if the lifetime of an item is greater than three years, then it is to be excluded from the inventory (Palm, 2010). The Japanese PCR (JEMAI, 2011a) does not provide specific guidance on infrastructure.

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).

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 United Kingdom.

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 Section 0.

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Appendix 3

Example calculation of allocation for laying operation with manure as a co-product

We consider a laying operation with 1000 layers. The replacement rate for laying hens is 35% such that for a flock average of 1000 birds, 350 are sent to slaughter annually. In this example, we do not consider mortality, as only spent hens are included in calculation of the allocation fraction. In this case there are 3 co-products of the operation: the main product, eggs, spent hens sent to slaughter, and manure which is sold to a nearby power plant as supplemental fuel for electricity production. A biophysical / causal basis for the allocation among the co-products is adopted based on the feed consumed for each activity. Numerous studies have investigated the partitioning of feed energy between growth (meat production) and egg (or hatchling) production (Byerly *et al.*, 1980; de Almeida Brainer *et al.*, 2012; Gous and Nonis, 2010; Keshavarz and Nakajima, 1995; Sakomura *et al.*, 2003; Spratt *et al.*, 1990). The NRC (1994) reports the following equation for metabolizable energy requirement in kcal per hen per day:

$$ME = W^{0.75}\,(173 - 1.95T) + 5.5\Delta\mathbf{W} + 2.07EM \quad (1)$$

Where W is the hen weight (kg), T is the temperature (^{0}C), ΔW is the change in body weight (g/day) and EM is the egg mass produced per day. Thus the ME requirement is partitioned into maintenance, growth and production. There are some reported variations in the partitioning reported in the literature, and if specific relationships exist for the particular genetic line under study, those relationships may be substituted – for example, Romero *et al.* (2009)144 hens were caged and randomly assigned to 1 of 2 feed allocation treatments (72 birds each report a temperature term of (111.95 – 0.36T), gain term of 3.36 (kcal ME/day per g/d of gain) and egg production partition coefficient of 2.10 (kcal ME/day per g/d egg mass).

Emmans (1994) describes an energy partitioning scheme in which the maintenance energy is further partitioned into basal metabolism, feeding and digestion, and protein and lipid synthesis. For purposes of the allocation calculation, in particular regarding manure, the energy of feeding and digestion are relevant. This energy is called the heat increment of maintenance feeding (HIM) and Emmans (1994) demonstrates that it can be shown to be primarily a function of the feed not the animal, and thus the following relationship is applicable across species:

$$HIM\ (kJ) = w_d\, FOM + w_u UN + w_m MTHE \quad (2)$$

Where: HIM= heat increment of maintenance feeding, w_d = 3.8 kJ/g FOM; FOM = faecal organic matter (g/d); w_u = 29.2 kJ/g urine nitrogen; UN = urine nitrogen (g N/day); w_m = 0.616 kJ/kJ methane; MTHE = methane production (kJ/day).

For non-ruminants, the methane term is considered negligible. Note that this is not equivalent to energy content in faeces, but rather an estimate of the utilisation of feed energy for the purpose of processing the feed into useful nutrients and creating the excreta. At a maintenance diet, defined as one in which there is no protein or lipid deposition (i.e. no growth), the quantity of urine nitrogen must be DCP/6.25, where DCP = digestible crude protein, since by definition no nitrogen is retained (there will be catabolic conversion in the animal, rather than simple passing of the dietary protein, but the net retention, at maintenance diet, must be zero). The FOM can be estimated from the organic matter digestibility as: FOM = (1-D) OM, where OM is organic matter in the diet. During growth and production, additional feed will be consumed above that required for maintenance, and the same relationships can be applied as an approximation of the heat increment for feeding. Thus the FOM is derived from organic matter digestibility, and would include passage of undigested proteins in the feed. The estimate of urine nitrogen based on amount of digestible crude protein will also approximate urine protein in the absence of measured values of urea nitrogen in the combined faeces.

Using the NRC relationship for metabolizable energy requirement and a typical production cycle: Phase 1 from first laying to maximum production at 36 weeks (assumed 88% in this example); Phase 2 with declining egg production until forced moulting at 65 weeks, followed by an increased production back to 80% through the productive life of the animal (assumed 100 weeks), when the spent animals are sent for slaughter. Mortality does not enter into the calculation of the allocation fraction, but is accounted in the final calculations as waste stream. For this scenario, the average spent hen weight was 3.3 kg and thus the ME requirement for weight gain is [3300-60 (hatchling weight)]*5.5kcal/g gain = 17820 kcal and the ME requirement for egg mass produced in 100 weeks is [23.3 kg]*2.07kcal/g = 48231 kcal.

The calculation for the heat increment of feeding, in order to determine the allocation to manure, is outlined for the corn grain as follows (the HIF is calculated for each feed ingredient, then summed as indicated in the Table A3.1):

The mass of corn (g/d) consumed per day where DFI is the daily feed intake (g/d) of the ration. The protein (g/d) provided by the corn, is partially digested and in the absence of nitrogen retention information, is assumed to be processed by the animal and excreted in the urine, (g N/day). FOM is calculated as the sum of undigested material (undigested protein + undigested non-protein organic matter):

, where the first term is undigested protein and the second term accounts for 88% digestibility of the non-protein components of the remaining organic matter fraction of the corn grain. The heat increment for feeding, for purposes of these guidelines, is considered the energy required to produce the excreta (physiologically speaking, of course, the purpose is to break down the feed ingredients so that they can be absorbed and used by the animal). The total feed consumed over a full cycle of the barn (100 weeks in this case), is needed so that the ME for the HIF can be calculated on the same basis as the egg and meat production. In this case, the feed consumption per bird over the production cycle is 84 kg (1162178 kJ of ME). The HIF is then 0.091*1162178/4.184 = 25276 kcal (4.184 kJ = 1 kcal). Finally the allocation factors for the three co-products are:

It is important that for cyclic operation that data are collected for a sufficient period that all phases are accounted in the analysis. The allocation factors are used to assign the whole operation emissions to the three co-products.

Table A3.1: Layer ration and characteristics (example only).

Feed ingredient	Ration (%)	Ash (%)	Organic Fraction (%)	Protein (%)	Organic Matter Digestibility (%)	Crude Protein Digestibility (%)	ME (kJ/kg)
Corn grain	30	1.3	98.7	8.2	88	80	14205
Wheat grain	44.8	2	98	14	87	88	13452
Vegetable oil	1.5	0	100	0	100		36961
Soybean meal	18.7	6.2	93.8	45	78	91	13958
Fish meal	3	16	86	63	88	85	14761
Vitamins and minerals	2	77	33	0	88		
						Ration ME (kJ/kg)	13895
Feed ingredient (per 100g/day of feed intake)	**FOM (g)**	**UN (g)**	**FOM Heat Increment (kJ)**	**UN Heat Increment (kJ)**	**Heat Increment of Feeding per 100g (kJ)**	**Total ME per 100g ration (kJ)**	**Fraction of ME required for digestion**
Corn grain	3.75	0.31	14.25	9.19	126.2	1390	9.1%
Wheat grain	5.64	0.88	21.45	25.79			
Vegetable oil	0.00	0.00	0.00	0.00			
Soybean meal	2.76	1.23	10.51	35.78			
Fish meal	0.37	0.26	1.39	7.51			
Vitamins and minerals	0.08	0.00	0.30	0.00			

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