MiLCA

Protocol for including Mitigation actions in Agricultural Lifecycle Assessment

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MiLCA Project Partners

The MiLCA initiative has been financed and driven by the dedication of the following organizations in a collaborative effort to identify a conservative and science-based solution to this complex and absolutely essential opportunity.

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Additionally, the Partners and research team would like to thank all stakeholders who took the time to review the proposed protocol and provide feedback on its science and practical application. The Partners are hopeful that you find this final version of the protocol, one you can actively embed into your climate mitigation quantification actions, enables the contribution made by new technologies to now be captured and reported with confidence.

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FOREWARD FROM THE PROJECT PARTNERS

Adopted in 2015, the Paris Agreement is a landmark international treaty where countries committed to limiting global warming to well below 2 degrees Celsius, with efforts to limit it to 1.5 degrees Celsius. Achieving net zero emissions by mid-century is crucial to meeting these targets. To support this, there is significant investment in research and grassroots practice change to achieve the emissions reductions required. At the same time, dairy organisations worldwide are quantifying and reporting their value chain carbon footprints to identify the most impactful mitigation opportunities and implement them in partnership with their supplying farmers.

While a range of mitigation strategies and technologies exists, credible integration of impacts into carbon footprint calculations or inventories remains challenging—particularly for new technologies entering the market.

Although there are existing protocols for calculating the carbon footprint of dairy production, two key gaps have hindered the sector's ability to incorporate new technologies effectively:

- Robust scientific evidence standards: Clear criteria are needed to validate the efficacy and emissions reduction claims of existing and emerging technologies—i.e., what level of scientific proof is required before a mitigation tool is recognised as contributing to carbon footprint reduction.
- Credible integration of outcomes: A consistent and transparent methodology is necessary to include the impact of applied technologies in carbon footprint calculations.

These gaps have resulted in a lack of ability to make reliable assessments, compare results, identify best practices and allocate resources efficiently. Closing these gaps would enhance trust among stakeholders, and ultimately drive more effective climate action.

The MiLCA project brought together academic and dairy industry partners to address these challenges and support the sector's global and organisational GHG reduction goals. Success depends on incorporating proven technologies into the mitigation toolbox—and on having a robust, science-based methodology for quantifying and responsibly reporting their impacts.

The MiLCA project team has reviewed existing science and GHG reporting frameworks to develop, test, and validate a protocol tailored to on-farm GHG mitigation technologies, starting with methane inhibitors. The MiLCA approach is grounded in science and takes a conservative stance to reflect the inherent variability in biological systems. While methane-inhibiting feed additives served as the initial test case, the underlying principles and methodology are applicable across a wide range of mitigation technologies and agricultural commodities.

Feedback from a six-week public consultation on the draft protocol was invaluable. It confirmed the importance of this work and the need for a scientifically rigorous approach to emissions reporting. Given the emerging nature of this field, dairy sector partners were honoured to collaborate directly with the climate and modelling scientists who developed the protocol—fostering greater alignment between science and industry in pursuit of robust and practical, implementable solutions.

A critical component of MiLCA's success has been building on the foundational work of the Global Research Alliance, which was closely involved in the protocol development. Recognising the complexity of implementation, the protocol includes a decision tree to guide users step-by-step through the process.

The consortium behind this pioneering work fully acknowledges that this is just the beginning. MiLCA offers a responsible and robust starting point for integrating new mitigation technologies into the dairy sector's foot printing activities. As new science emerges, the protocol will evolve to further, enhance its accuracy and utility. What matters most is that the sector now has a more robust framework to align with.

More than just a methodology, the MiLCA project delivers:

- A checklist of criteria that new technologies should meet before adoption;
- Guidance to foster scientifically sound and globally applicable innovation;
- Clear direction on the role of high-quality data and rigorous science in maximising mitigation benefits;
- And, of course, the protocol itself.

The MiLCA protocol brings the sector a step closer to responsibly capturing the impact of all tools in the emissions mitigation toolbox.

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1. INTRODUCTION

Both supply chains and consumers recognise the need to address climate change and are demanding safe foods that have a low **carbon footprint (CF)**. The dairy industry is responding to these demands by adopting technologies that reduce on-farm **greenhouse gas (GHG) emissions**; and it is expected that new technologies will continue to be developed. Acceptance of a **GHG mitigation technology** by policy-makers, supply chains and consumers relies upon their confidence in the robust quantification of **GHG emissions reduction**s. This confidence can be provided by the global dairy industry adopting a consistent approach to objectively assessing the robustness of **GHG** mitigation technologies; and a **conservative** approach to estimating the **emissions reduction**s that occur upon adoption. This protocol is a technical document that provides criteria and methods that, when applied to a **GHG mitigation technology**, will provide confidence that the claimed **GHG emissions reduction**s are robustly quantified and that dairy products are safe to consume.

The protocol also provides guidance on determining whether a **mitigation technology** has adequate **evidence** to support its adoption by the dairy industry, and the integration of its associated **GHG emissions reduction** into a **CF** calculation. The approach to assessing the robustness of mitigation technologies and estimating the **GHG emissions reduction** that can be claimed is a foundation upon which a standardised approach to generating robust **GHG emissions reduction**s claims could be developed for all livestock sectors.

This protocol integrates concepts of **technology** efficacy with the quantification of an **emissions reduction** associated with the implementation of the **technology,** drawing on the knowledge provided by members of other **GHG emissions reduction** frameworks to identify areas of complementarity. The protocol is a live document that will be updated as initiatives deliver relevant results that, when integrated, improve its robustness.

The protocol consists of the main document plus Appendices, which include a worked example relating to an existing **GHG mitigation technology**. It is suitable for assessing technologies described in the definitions listed in Section 4. The protocol does not include guidance on incorporating **carbon sequestration** in the **CF** of milk production as guidance for this is provided in the C-Sequ **LCA** guidelines (IDF, 2022a). This protocol can be applied by people with a moderate level of statistical knowledge, however, in some instances the services of a qualified statistician may be required.

2. NORMATIVE REFERENCES

The following terminology, consistent with terminology used by the International Organization for Standardization (ISO, 2016a), is used throughout and is applicable to the requirements with which protocol users need to comply:

- “shall” is used to indicate a requirement (mandatory).
- “should” is used to indicate a recommendation.
- “may” is used to indicate permission.
- “can” is used to indicate possibility.

3. PROTOCOL SCOPE AND USE

The protocol provides guidance and requirements for businesses or organisations in the global dairy sector to quantify **CF** that can be claimed when an on-farm **GHG mitigation technology** is implemented in a dairy **system**. The protocol is applicable to mitigation technologies that can be implemented on dairy farms, targeting **GHG source**s such as **enteric methane**, fertiliser use and effluent management.

The **CF** that can be claimed is calculated by applying a **GHG adjustment factor** generated by the application of this protocol to the **GHG emissions sources** targeted by the **technology**. The protocol was designed to be used in conjunction with the International Dairy Federation global **Carbon Footprint** Standard (IDF standard) for the dairy sector (IDF, 2022b). The IDF standard makes provision for the inclusion of mitigation technologies in **CF** calculations, recognising the need for **evidence** of efficacy and specific guidance on quantification. This protocol is designed to address that need, yet the adjustment can also be applied to **CF**s calculated using other approaches. The calculation should be done on a regular (e.g. annual) basis to take account of new **evidence** and/or data available.

The application of the protocol shall address five elements:

i. Description of the **technology** and implementation **context** (Section 6) including the type, name and use of the **technology**.
ii. Demonstration of product safety (Section 7) including regulatory approvals and consideration of the potential for any adverse environmental, animal welfare, dairy **product quality** or human health consequences from the production or use of the **technology**.
iii. Collation of **pieces of evidence** to support the **technology**'s use as an efficacious **GHG emissions reduction** strategy (Section 8)
iv. Assessment of the quality of the data used to estimate **GHG emissions reduction**s (Section 8)
v. Selection of **evidence** that is relevant to the **system**(s) being assessed for use in the calculation of a **GHG adjustment factor** (Section 10).

A flow chart of the application of the protocol is provided in APPENDIX A.

4. GLOSSARY: TERMS, DEFINITIONS AND ABBREVIATED TERMS

Terms defined in the glossary are bolded throughout the document for reference. Note that where "in this protocol" follows a term, the definition is relevant within this protocol, but other definitions may exist outside the document.

Abatement

GHG removals by **sink**s and/or reduction in **GHG emissions** by **source**s.

Baseline (in this protocol)

Also known as the reference case, the **baseline** provides the basis for comparison. In this protocol it refers to the **system** without use of the **mitigation technology**.

Biomass

Organic material excluding material that is fossilised or embedded in geological formations, including living and dead organic matter (trees, crops, grasses, plant litter, algae, animals, manure, and waste of biological origin).

Carbon

The chemical element with the symbol C.

Carbon credit

Tradeable certificate representing one tonne of **carbon dioxide equivalent**s **(CO_2-e)** in **GHG emission reductions**, or **GHG removals**. **Carbon credit**s are generated by **GHG abatement** projects and quantified relative to a **baseline**. **Carbon credit**s are commonly purchased to offset **GHG emissions** of the purchasing entity.

Carbon crediting scheme

Buying and selling **carbon credit**s generated by activities that reduce **GHG emissions** or achieve **GHG removals**. **Emissions** trading can occur in government markets (state, **regional** or national) and on the voluntary market. **Carbon credit schemes** commonly apply integrity criteria to ensure that the credits represent the stated **GHG abatement**. Integrity criteria commonly include, but are not limited to, the avoidance of double counting and **leakage**, use of appropriate **baseline**s, additionality, and permanence or measures to address impermanence.

Carbon dioxide (CO_2)

A naturally occurring **GHG**, that is also a by-product of burning fossil fuels (such as oil, gas and coal); of burning **biomass**; of land use change; and of industrial processes (e.g. cement production). It is the principal anthropogenic **GHG** that affects the Earth's radiative balance. It is the reference gas against which other **GHG**s are measured and therefore has a **global warming potential (GWP_{100})** of 1 (Cowie et al., 2023).

Carbon dioxide equivalent (CO_2-e)

Unit for comparing the radiative forcing of a **GHG** to that of **carbon dioxide**. The **carbon dioxide** equivalent is calculated as the mass of a given **GHG** multiplied by its **global warming potential (GWP_{100})** (Cowie et al., 2023).

Carbon footprint (CF)

The sum of **GHG emissions** minus **GHG removals** of the subject expressed as **carbon dioxide equivalent**s **(CO_2-e)**. The subject could be a product, process or an organisation. Where the subject is an organisation, such as a company, the **carbon footprint (CF)** often includes **indirect emissions** also known as **scope 2** and **scope 3 emissions**. Where the subject is a product, the **CF** includes the **GHG emissions** and **GHG removals** across the product life cycle (Cowie et al., 2023). For farm products, a partial **CF** is often calculated, covering the life cycle stages up to the farm gate, or factory gate in the case of dairy products.

Carbon sequestration

The process of removing **carbon dioxide** from the atmosphere and transferring it to a **carbon** pool such as vegetation, soil, ocean or geological formation (Cowie et al., 2023).

Claimable emissions reduction

Reduction in **GHG emissions** that can be claimed due to implementation of a **technology.** Calculated by subtracting the adjusted **GHG emissions** calculated by this protocol from the estimated **GHG emissions** without the implementation of the **technology**.

Confidence interval

A range of values that is likely to contain the true mean of a population for a given variable for a given level of confidence.

Conservative (in this protocol)

A **claimable emissions reduction** that is less than the mean **GHG emissions reduction** reported in experimental results.

Context (in this protocol)

The **system** in which the **technology** is intended to be applied, including the geography and feeding pattern (e.g. total mixed ration or pasture-based **system**).

Data quality

Relevance of the **primary** or **secondary data** used in **emissions reduction**s calculations to the **system** being assessed. Includes the source of the **primary** or **secondary data**, **system** representativeness, temporal suitability, and geographical suitability.

Emissions

See **Greenhouse gas emissions.**

Emissions reduction

A decrease in **GHG emissions** when compared to the business-as-usual or **baseline** situation.

Enteric methane

Methane (CH_4) formed during the digestion process of ruminant animal species such as cattle, sheep and goats. Microorganisms (bacteria, archaea, fungi, protozoa and viruses) present in the reticulorumen and rumen breakdown plant **biomass** to produce substrates that can be used by the animal for vital processes (maintenance, growth, pregnancy and lactation), with **enteric methane** emitted as a by-product. End-products of rumen fermentation such as hydrogen, **carbon dioxide**, formate and methyl-containing compounds are important substrates for the production of **methane** by the rumen's **methane**-forming archaea (methanogens).

Estimation

A value that has been obtained without measurement. A qualified **estimation** is one that has been made by a person with relevant expertise in the form of formal qualifications and experience. An unqualified **estimation** is one that has been made by a person without the relevant expertise (formal qualifications and experience).

Evidence

See **Piece of evidence.**

Experiment (in this protocol)

An activity that generates a set of results that compares the impacts of a **technology** on the **GHG emissions** from a **farming system**. An **experiment** where a control is compared to a treatment or combination of treatments constitutes one **experiment**; more than one **experiment** can be included in a single publication. A treatment may be applied to a group of animals, an area of land or other similar experimental unit depending on the **technology**.

Farming system (in this protocol, also '**system**')

The set of components, management and processes that produce dairy products, including the facilities, crops, animals, and feed, as listed in Section 6.1.3.

Fat- and protein-corrected milk (FPCM)

A method of standardising milk production for comparison, adjusting milk weight and composition to a standard energy content, based on a specific fat and protein percentage, e.g. 3.5% fat and 3.2% protein.

Global warming potential (GWP)

An index measuring the radiative forcing following an emission of a unit mass of a **GHG**, accumulated over a chosen time horizon, relative to that of the reference substance, **carbon dioxide**. The **GWP** represents the combined effect of the differing times that **GHG**s remain in the atmosphere and their different effectiveness in causing radiative forcing, that is, in heating the Earth's atmosphere. **GWP** is measured in units of **carbon dioxide equivalent**s **(CO_2-e)**. The most common time horizon is 100 years (**GWP_{100}**). Parties to the United Nations Framework Convention on Climate Change (UNFCCC) have agreed to use **GWP_{100}** values from the **IPCC**'s Fifth Assessment Report (AR5; IPCC, 2013) or **GWP_{100}** values from subsequent **IPCC** Assessment Reports to report aggregate **emissions** and **removals** of **GHG**s under the Paris Agreement.

$GHG_{adjt(0.7)}$ adjustment factor (GHG adjustment factor)

A decimal number between 0 – 1, calculated via the protocol, that is used to generate a **conservative** estimate of the **GHG emissions reduction** attributable to implementation of a **technology**. The factor is multiplied by the **baseline GHG emissions** for the relevant **source** (as calculated using a relevant existing **GHG accounting** framework) to estimate the **GHG emissions** for that **source** when the **technology** is implemented in a dairy system.

Greenhouse gas (GHG)

Gaseous constituent of the atmosphere, either natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, by the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), **carbon dioxide (CO_2)**, nitrous oxide (N_2O), **methane (CH_4)**, and ozone (O_3) are the primary **GHG** in the Earth's atmosphere. Human-made **GHG**s include sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), chlorofluorocarbons (CFCs) and perfluorocarbons (PFCs).

Greenhouse gas accounting (GHG accounting)

The process of compiling an inventory of **GHG emissions** and **removals** for key **GHG source**s and **sink**s over a specified period, typically one year.

Greenhouse gas emissions (GHG emissions; Emissions)

The release of a **GHG** into the atmosphere. **GHG emissions** originate from a **GHG source**.

Greenhouse gas emissions reduction (GHG emissions reduction)

The decline in **GHG emissions** from a **source** resulting from implementation of a **technology**.

Greenhouse gas removals (GHG removals)

Anthropogenic activities that remove **carbon dioxide** from the atmosphere and durably store it in geological, terrestrial or ocean reservoirs, or in products. Effective **carbon dioxide** removal methods can include afforestation, reforestation, biochar, bioenergy with **carbon dioxide** capture and storage (BECCS), soil **carbon sequestration**, enhanced weathering, direct air **carbon** capture and storage (DACCS), ocean alkalinisation and ocean fertilisation. A **carbon dioxide** removal activity initiates a **sink** process that leads to **GHG removals**.

Indirect emissions

GHG emissions that are a consequence of the organisation's activities, but that arise from **GHG sources** that are not owned or controlled by the organisation. **Indirect emissions** may occur upstream and/or downstream of the farm, across the value chain, and include **emissions** from manufacture of inputs (e.g. fertiliser), and from product processing (e.g. abattoir operations or feed milling). **Indirect emissions** also include **emissions** outside the value chain that are induced by change in demand for (or supply of) products produced or sourced by the organisation.

Intergovernmental Panel on Climate Change (IPCC)

An intergovernmental body of the United Nations established in 1988 to provide scientific information on anthropogenic climate change, including the impacts, risks, and response options. The **IPCC** does not conduct original research but rather undertakes periodic, systematic reviews of published literature. **IPCC** reports are prepared by thousands of scientists and other experts who volunteer to assess the science related to climate change. The **IPCC** is governed by its member states through an elected bureau of scientists, who select the authors for each report from nominations received from governments and observer organisations.

Leakage

An increase in **GHG emissions** that results indirectly from mitigation actions. **Leakage** can include increased **GHG emissions** upstream or downstream in the value chain (e.g. increased **emissions** associated with the implementation of a **technology**), or through market-mediated effects (e.g. indirect land use change to produce a commodity elsewhere, in response to a decline in production in the system being assessed).

Life cycle assessment (LCA)

Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle. Life cycle refers to "cradle-to-grave" – the consecutive and interlinked stages, from raw material acquisition or generation from natural resources to final disposal or recycling. In **LCA** of farm products, partial **LCA** is common, often covering the cradle to the farm gate or factory door.

Meta-analysis (in this protocol)

A statistical analysis of the results of several **experiment**s.

Methane (CH_4)

A potent **GHG** with short atmospheric lifetime, **methane** is the major constituent of natural gas. Livestock production and paddy rice are significant global **methane source**s. **Methane** is also produced naturally when organic matter decays under anaerobic conditions, such as in wetlands and from human activities such as natural gas exploitation.

Mode of action (in this protocol)

The physical, biological and/or chemical process(es) that result in a reduction in **GHG emissions**.

Piece/s of evidence for this protocol

Can refer to either results from an **experiment**; a **meta-analysis** of a **technology**'s use and impacts; or an existing methodology from an ICROA-endorsed **carbon crediting scheme**. It should be noted that where a research publication that meets the criteria described in section 8.2 includes results from multiple **experiment**s, each set of experimental results that are reported in the research publication represents one **piece of evidence**.

Prediction interval

The estimate of an interval (i.e. upper and lower values) within which a prediction for a variable generated by populating an equation will fall, for a given probability.

Primary data

A quantitative measurement from the system or set of systems for which a **GHG emissions reduction** is being estimated.

Product quality (in this protocol)

The quality of milk that is produced in a dairy in which a **technology** has been implemented. Quality refers to debris and sediment, flavour, colour and odour, bacterial count, existence of introduced chemicals, composition and acidity.

Regional

Pertaining to a geographic area that has definable characteristics. Definable characteristics for dairy production systems include housing type and duration, pasture type/s, climate and soil types.

Reporting period (in this protocol)

The period for which the **carbon footprint (CF)** of the **farming system** is being calculated.

Scope 1, 2 and 3 emissions

Terminology developed by the **Greenhouse Gas** Protocol (**GHG** Protocol, 2011) and now adopted broadly across the globe. **Scope 1 emissions** are direct **emissions** arising from **source**s within the control of the reporting organisation. **Scope 2 emissions** are **indirect emissions** from the generation of purchased or acquired electricity, steam, heating or cooling, that are consumed by the reporting organisation. For farms, this predominantly refers to electricity use. **Scope 3 emissions** are **indirect emissions** other than **scope 2 emissions** that occur within the value chain as a consequence of the organisation's activities. For farms, **scope 3 emissions** occur pre- and post-farm including, for example, those arising from the manufacture of urea and herbicides, abattoir processes, and produce transport.

Secondary data

Data that are not directly collected or measured, so are not **primary data**, but are instead sourced from a third-party database (e.g. data for farm inputs obtained from a lifecycle inventory database) or **GHG accounting** framework (e.g. an **emissions** factor from a national **GHG** inventory). Note that **secondary data** are used when **primary data** are not available or where it is impractical to obtain **primary data**.

Sink

A process, activity or mechanism that removes a **GHG**, an aerosol or a precursor to a **GHG** from the atmosphere. A pool (reservoir) is a **sink** for atmospheric **carbon** if, during a given period, more **carbon** is moving into it than is flowing out.

Source

A process, activity or mechanism that releases a **GHG**, an aerosol or a precursor to a **GHG** into the atmosphere. Forests and agricultural lands are reservoirs; they can be either a **GHG source** or a **sink**.

Technology (in this protocol, also referred to as **mitigation technology**)

A product that reduces **GHG emissions** from a dairy **farming system**. The product can reduce **GHG emissions** via biological or chemical processes or can be a device. Examples of technologies include, but are not limited to, supplements to reduce **enteric methane** production; additives to reduce **GHG emissions** from effluent systems; and coatings to reduce on-farm **emissions** associated with N fertiliser use. It specifically excludes products designed to sequester atmospheric **carbon** or the introgression of low-**methane** genetics into dairy herds.

Use (of the **technology**, in this protocol)

The process that is used to implement the **technology**, for example, the rate and the frequency with which the **technology** is implemented and/or the period of time during the year that the **technology** is implemented.

5. ALIGNMENT WITH EXISTING STANDARDS

This protocol uses terminology and concepts that are consistent with **GHG** reporting and **accounting** at the corporate level, including for mandatory reporting, voluntary target-setting, environmental claims and the voluntary **carbon** market.

The IDF standard (IDF, 2022b) provides comprehensive guidance on quantifying the **CF** of dairy products in accordance with the ISO standards 14040 and 14044 for **LCA** (ISO, 2006a; b). Topics covered include setting the system boundary, choosing the functional unit, handling co-products (allocation), data collection, and land use change, all of which are complex topics in the dairy sector, requiring tailored guidance.

Although this protocol has been designed to be integrated into **CF** calculations undertaken using the IDF Standard (IDF, 2022b) it can also be applied to **CF** used for **GHG emissions reduction**s claims for **scope 3 emissions** provided to the supply chain under the Science-based Targets Initiative (SBTi, 2023). It also fulfils the principles of **conservative**ness required to make **GHG emissions reduction**s claims under Article 6.4 of the Paris Agreement (UNFCCC, 2024).

This protocol also generates qualitative information and data that could be used to support a product-based environmental claim such as those governed by the ISO 14021 (Environmental labels and declarations – Self-declared environmental claims; ISO, 2016b); or the ISO 14025 (Environmental labels and declarations – Type III environmental declarations – Principles and procedures; ISO, 2006c) standards .

6. TECHNOLOGY AND IMPLEMENTATION CONTEXT

How and where the **technology** was implemented needs to be clearly stated to ensure information provided in the latter sections of the protocol is relevant to the **technology** and the specific implementation of the **technology** being assessed. The statements that fulfil these requirements shall be made in a report as described in Section 12.

6.1. SCOPE

The scope of the **emissions reduction** assessment shall be defined by unambiguously describing the following:

i. The **technology** (Section 6.1.1)

ii. The intended **use** of the **technology** (Section 6.1.2)

iii. The system(s) in which the **technology** was implemented (Section 6.1.3)

iv. The time period over which the **technology** was implemented (Section 6.1.4)

6.1.1. TECHNOLOGY

A report prepared in accordance with this protocol shall unambiguously identify the **technology**. Identification of the **technology** shall include, where applicable, the following: the product name, trade name, manufacturer, active ingredient(s), conditions and/or limitations on **use**, and, where known, the **mode of action.**

6.1.2. USE

The **use** of the **technology** shall be described. This description shall contain the following information, where applicable: targeted **GHG source**, concentration or dosage of the **technology**, animal categories receiving the **technology**, method of **use**, any specific diet composition required, storage conditions and frequency of **use.** Where applicable, any requirements set out by the manufacturer with regards to the **use** of the **technology** to achieve **emissions reduction**s (Section 6.1.1) shall both be attached to the report and included in the description of **use**.

6.1.3. SYSTEM

The system in which the **technology** was implemented shall be described. This description shall contain, where applicable, the following information:

i. **Regional** location, including climate and soil type;
ii. Breed(s), including weight of mature animals;
iii. Whether herd numbers are maintained by breeding replacement animals or through purchase;
iv. Productivity (e.g. annual **fat and protein-corrected milk** production, **FPCM**);
v. The proportion of the year that the animals are housed and the type of housing employed;
vi. The type of manure management system employed (only required for manure management technologies);
vii. The composition of the diet as varied by season or month (i.e. the relative proportions of pasture, grain, silage and/or supplements within the dry matter intake or DMI);
viii. The nutritional composition of the diet;
ix. Any other information that the protocol user deems relevant to the description.

If any of this information changes during the year due to seasonal conditions or the availability of inputs (e.g. a change in the quality of supplied feed), points (i) through (viii) shall be documented on a seasonal basis and/or for each change.

6.1.4. IMPLEMENTATION PERIOD

The proportion of the **reporting period** (i.e. the period for which the **CF** is being calculated) during which the **technology** was implemented and for which a **GHG emissions reduction** is being estimated shall be documented. For example, the **reporting period** might be annual (12 months), yet the **technology** only used for 9 months.

7. SAFETY

*Acceptance of mitigation technologies by policy makers, supply chains and consumers is reliant upon users demonstrating that the **technology** is safe to **use** with respect to human health, animal health and the environment. This section describes the minimum criteria that must be met to provide confidence that the implementation of the **technology** will have minimal adverse impacts. The assessment of environmental impacts under Section 7.2 has been adapted from global frameworks on **LCA** including ISO 14044 (Environmental management — **Life cycle assessment** — Requirements and guidelines; ISO, 2006b)*

7.1. REGULATORY APPROVALS

Written **evidence** of regulatory approval for the **technology** (Section 6.1.1) **used** as described (Section 6.1.2) in the system (Section 6.1.3) shall be attached to the report. This includes approvals by the appropriate governmental or other organisations for commercial **use** of the **technology**, as well as occupational health and safety regulations for the **technology**.

7.2. ENVIRONMENTAL AND HUMAN HEALTH IMPACTS

Results shall be presented from a **LCA** of the manufacture and described **use** of the **technology** (Section 6.1.2) in a system that shares the characteristics documented in Section 6.1.1. The **LCA** shall be compliant with ISO 14044, including an independent review by an external expert. The **LCA** shall provide the impacts as absolute values (characterisation) relative to the current production system without **use** of the **technology**.

The **LCA** shall include a comprehensive set of environmental indicators including, but not limited to, **GHG emissions**. The selection of environmental indicators shall be relevant to the product system. For example, if the **technology** affects productivity, then water scarcity (Boulay et al., 2018) and land use impacts on soil quality (Bos et al., 2020; Brandão et al., 2011) would be necessary for inclusion. If the **technology** emits ozone-depleting substances, then ozone depletion (World Meteorological Organization (WMO), 2014) would be required. Any **technology** based on a chemical additive shall include human toxicity (cancer and non-cancer) indicators (Fantke et al., 2021). A list of recommended indicators for different technologies are included in Table D.1 in APPENDIX D.

All indicators are not equally important; therefore it is impractical to set thresholds of impact increases in non-**GHG** indicators which can be tolerated in a **GHG abatement technology**. What **LCA** can provide however, is transparent information on relative changes in impacts to ensure unintended consequences can be identified and assessed by the users of the **technology**. As such, the risk of adverse environmental consequences shall be discussed as part of the protocol.

7.3. IMPACTS TO THE FARMING SYSTEM

Given that minimum health and safety standards for both humans and animals have been addressed in Section 7.1 and that the decisions regarding appropriate trade-offs vary according to **context**, there is no threshold associated with **farming system** impacts. Instead, a disclosure of the known information citing original peer-reviewed research and identification of knowledge gaps regarding impacts on production, **product quality**, and animal health and welfare are required. A list of all peer-reviewed, original literature (i.e. not review papers or press articles) on these topics, plus the databases and search terms used to find these articles shall be included.

This section shall review the consequences of using the **technology** on animal welfare, **product quality** and milk production. If any of this information is not available, the information gap shall be acknowledged. Where the implementation of a **technology** results in a decrease in milk production, then the magnitude of the reduction shall be reported, due to the risk of associated **leakage.** For example, if a **technology** causes a reduction in **FPCM** production, milk supply may be maintained by an increase in production in other **regions** or systems.

8. DEMONSTRATING THE EFFICACY OF A TECHNOLOGY

*Acceptance of **claimable emissions reduction**s is dependent upon confidence that implementation of the **technology** will result in a consistent and reliable reduction in **GHG emissions**. Confidence is achieved by providing **evidence** – either the results from a minimum of three scientific **experiment**s that have demonstrated effectiveness of the **technology**, a **meta-analysis** of experimental results or as a methodology approved under an existing accredited **carbon crediting scheme**. These forms of **evidence** have minimum requirements to ensure that **evidence** is robust, and these requirements are described in this section.*

*The more **pieces of evidence** supplied, the greater the confidence in the assessment of a **technology.** It is therefore imperative that as many **pieces of evidence** as possible are provided to support assessment of **technology**'s efficacy. However, experimental results are not always published or made available in the public domain. The authors acknowledge that this protocol is limited by the fact that only **experiment**s showing a statistically* *significant positive or negative effect of a treatment are usually published in scientific journals, and that some experimental results are kept confidential, especially if commissioned by commercial companies.*

8.1. DEMONSTRATED REPEATABLE REDUCTIONS

A consistent reduction in **GHG emissions** associated with implementation of the **technology** shall be demonstrated using one of the following:

i. A **meta-analysis** demonstrating a statistically significant (P ≤ 0.05) **GHG emissions reduction** associated with the **use** of the **technology**, that meets the requirements for experimental settings and scientific publications specified in Section 8.2. A copy of the publication shall be attached to the report if it is not open-access; if it is open access, the digital object identifier (DOI) shall be provided.

ii. A minimum of three (3) **experiment**s that:

    a. Demonstrate a statistically significant (P ≤ 0.05) reduction in **GHG emissions** associated with the **use** of the **technology**, and

    b. Meet the requirements for experimental settings and scientific publications specified in Section 8.2.

    Three **experiment**s are considered to be the minimum number required to provide confidence that the **GHG emissions reduction**s associated with the **use** of the **technology** are repeatable. Copies of the scientific publication(s) containing the results of these **experiment**s shall be attached to the report if they are not open access; if they are open access, the DOI shall be provided.

iii. An existing methodology from a **Carbon crediting scheme** that meets the minimum requirements set out in Section 8.2.2.

A statement shall be made for each **piece of evidence** outlining how the requirements in Section 8.2 are met.

8.2. REQUIREMENTS FOR PIECES OF EVIDENCE

8.2.1. EXPERIMENTAL SETTINGS AND SCIENTIFIC PUBLICATIONS

Where a **meta-analysis** (8.1 option (i)) or set of experimental results (8.2 option (ii)) are used as **evidence**, the protocol user shall justify that the experimental results are applicable to a commercial dairy situation (e.g. lab based **experiment**s shall not be extrapolated to a commercial situation).

Only experimental results or a **meta-analysis** published in a journal classified as a level 1 or 2 journal on the Norwegian Register For Scientific Journals, Series and Publishers (*https://kanalregister.hkdir.no/*) at the time of publication shall be used as **evidence**. Documentation showing that the journal was a level 1 or 2 journal at the time of publication shall be attached to the report (e.g. timestamped screenshot of the journal listing on the Register).

Results from **experiment**s that do not include an appropriate control group shall not be used.

8.2.2. EXISTING METHODOLOGIES

Calculations from a **carbon crediting scheme** methodology may be used to calculate the **claimable emissions reduction** (see 8.2.2), if:

i. that methodology is from a standard endorsed by the International Carbon Reduction and Offsetting Accreditation (ICROA) program (ICROA, 2025);

ii. it provides a **conservative** estimate of the **GHG emissions reduction** by using statistical uncertainty to adjust the **GHG emissions reduction**; and if the estimate calculated using the methodology is as **conservative** as that calculated using this protocol; or if an adjustment such that the estimate of **GHG emissions reduction** can be made so that estimated **GHG emissions reduction** is as **conservative** as that calculated using this protocol; and

iii. the methodology was intended to be applicable to the system for which a **GHG emissions reduction** will be claimed.

9. QUALITY OF DATA

The calculation of a ***claimable emissions reduction*** *associated with the implementation of a* ***technology*** *requires data obtained from, or representative of, the system being assessed. Definitions of data-related terms are available in the glossary. Using lower quality data (e.g.* ***secondary data*** *instead of* ***primary data****) to calculate a* ***GHG emissions reduction*** *reduces the accuracy of the calculation so the* ***claimable emissions reduction*** *for any dairy system is adjusted for the quality of data used. Adjusting a claim for the quality of data is an acknowledgement by the dairy sector that using lower quality data can negatively impact confidence in the claim associated with the implementation of a* ***technology****. A* ***data quality*** *adjustment also has several other benefits, including incentivising the collection of high-quality data by dairies to maximise the* ***claimable emissions reduction****.*

The approach to ***data quality*** *used in the protocol is adapted from the data pedigree matrix approach used by the global* ***LCA*** *community (Ciroth et al., 2016). A* ***GHG adjustment factor*** *with which to modify the* ***GHG emissions reduction*** *to determine the* ***claimable emissions reduction*** *is calculated based on the quality of data collected from the dairy, with the greatest* ***claimable emissions reduction*** *achieved when the highest quality data are used. Incorporating* ***data quality*** *into the calculation in this way ensures that the* ***claimable emissions reduction*** *calculated using the protocol is credible.*

The quality of the data used to calculate an **emissions reduction** is determined according to the following four categories:

i. RELIABILITY
This criterion evaluates the **data quality** based on the method of obtaining the data. It assesses whether the data are obtained via direct measurements, a calculation or a qualified estimate.

ii. COMPLETENESS
This criterion assesses the extent to which the data used to estimate the **emissions reduction** represent the system being assessed. Data that are obtained from the system being assessed are considered higher quality than **secondary data** that are obtained from other systems in the same region or **regional** averages. Where data are obtained from a system other than the system being assessed, **FPCM** (kg/head/day) is used to determine the completeness of data used to calculate a **GHG emissions reduction**. FCPM is used because it reflects the system with respect to feed use, feed quality and/or livestock movement (e.g. barn systems with total mixed rations and limited cow movement are likely to have higher productivity than a pasture-based system where cows walk further to graze, therefore using more energy).

iii. TEMPORAL CORRELATION
This criterion evaluates the extent to which data are up-to-date and applicable and, therefore, relevant to the **reporting period** covering relevant events and trends. For example, do the data represent the activities of the year for which the **CF** is being assessed or the activities that occurred between 1-3 years prior?

iv. GEOGRAPHICAL CORRELATION
Geographical suitability examines whether the data's geographic scope match the area of interest for the system being assessed. This ensures that the data are applicable to the specific location or **region** of concern. For example, data relating to British dairy production systems might not be suitable for evaluating the impact of the **technology** in Australian systems.

9.1. DATA QUALITY ASSESSMENT

The values for each level for each **data quality** category are presented in APPENDIX B and the equations for calculating the **data quality** adjustment are shown in Sections 10.2.1 and 10.2.2. The data source and relevant **data quality** modification factor for each of the variables required to calculate **emissions reduction**s shall be documented in a table.

10. CALCULATION OF CLAIMABLE EMISSIONS REDUCTION

*Providing confidence that the **claimable emissions reduction** associated with the implementation of a **technology** is robust is achieved using the following four strategies:*

1. *The use of robust scientific results from **evidence** that is most relevant to the system under study as the basis for **GHG emissions reduction** calculations. The scientific **evidence** must meet requirements described in Section 8.2 and be relevant to the **technology** and **context** as described in Section 6.*

2. *The calculation of a **conservative** estimate of the **GHG emissions reduction**. Using a **conservative** estimate for a **GHG emissions reduction** claim is a key principle in **GHG emissions reduction** frameworks, e.g. Article 6.4 of the Paris Agreement (UNFCCC, 2024). The method to calculate a **conservative** estimate in the protocol is based on statistical uncertainty and adjusts the magnitude of the **emissions reduction** according to the uncertainty of the experimental results so that the **claimable emissions reduction** is reduced accordingly. This provides an incentive to **technology** developers and researchers to generate and publish high quality experimental results. Adjusting **GHG emissions reductions** based on statistical uncertainty is a relatively common approach to ensure the integrity of **GHG emissions reduction** claims – it is a basic principle of the Verra Carbon Standard (Verra, 2022) and is also included in government **carbon credit** methodologies (Australian Government, 2021). In this protocol, the **claimable emissions reduction** is the value for which there is 70% chance of exceedance, meaning it is possible to claim that GHG abatement at the level claimed is likely to have occurred. A 70% chance of exceedance aligns with the statement from the guidance note on uncertainties for lead authors of the **Intergovernmental Panel on Climate Change** (Mastrandrea et al., 2010) that **GHG abatement** was 'likely to have occurred'.*

3. *The adjustment of the calculated **GHG emissions reduction** for the quality of data that are used to calculate the **emissions reduction** (see Section 9).*

4. *The re-calculation of the **GHG adjustment factor** on an annual basis or whenever new information that improves the estimate of **GHG emissions reduction** becomes available.*

10.1. EVIDENCE USED FOR CALCULATIONS

The **evidence** used for calculations shall be one of either:

i. A **meta-analysis** that meets requirements set out in Section 8.1.i;

ii. The provision of experimental results that demonstrate a significantly significant ($P \leq 0.05$) reduction in **GHG emissions** when compared to a control for the **technology** (Section 6.1.1) when **used** (Section 6.1.2) in a system as described in Section 6.1.3. These **experiment**s must meet the requirements set out in Section 8.1.ii.

iii. Where more than one set of experimental results have equal relevance to the system being assessed, as described above in 10.1.ii. and it is statistically appropriate to average the experimental results as determined by a qualified statistician, then the results shall be averaged and the average used to calculate an **emissions reduction**;

iv. An existing methodology from a **GHG abatement** scheme that meets the minimum requirements set out in Section 8.2.2.

Where multiple **pieces of evidence** are available, the **evidence** that is the most relevant to the system being assessed shall be used, and written justification provided in the report (see Section 12).

If unrestricted online access is available, the DOI or other permanent digital identifier for the relevant document(s) shall be provided. Otherwise, a copy of the relevant document(s) shall be provided.

Where multiple sets of experimental results are averaged, a report from a statistician detailing the method used to derive the average shall be provided.

A **claimable emissions reduction** calculated using **evidence** shall meet these criteria:

The implementation of the **technology** in the **evidence** used to calculate **claimable emissions reduction** shall be consistent with the implementation **context** described in Section 6.1.2. The protocol shall not be used to assess the implementation of a **technology** where **uses** are inconsistent. This includes, where relevant, the concentration of the **technology** used in the system, as declared under Section 6.1.2;

i. Where the **evidence** used to calculate an **emissions reduction** is a regression equation, the values of data used to populate the equation to estimate the **emissions reduction** shall not exceed the range of values for the relevant variable used to develop the equation;
ii. Where the **GHG emissions reduction** is dependent on environmental conditions that change over time (e.g. on a seasonal basis), then a **GHG emissions reduction** shall only be calculated where the environmental conditions declared in Section 6.1.2 are the same as those under which the **evidence** used to support calculation under Section 10.1 were obtained;
iii. Claims for a **GHG emissions reduction** should not exceed the maximum duration of the **experiment** in the **evidence** used as a basis for **GHG emissions reduction**s calculation. It is common for biological systems and processes to adapt to changes, e.g. using a chemical to change the activity of one group of microbes in an environment with a diversity of microbe groups. It is also likely that indications of adaptation will be observable over a period of months, as opposed to years. If the period of claim exceeds the maximum duration, then the longer period of claim shall be justified. Justifying a longer period shall rely on published scientific literature, considering the **mode of action** for the **technology**, the vulnerability of the **technology** to adaptation, and the absence of adaptation in **experiment**s of a duration in which adaptation could be expected to occur;
iv. If the **evidence** comes from **experiment**s conducted in a different system, or in the same system under different diet compositions (Section 6.1.3), the user shall justify that the **evidence** used in calculation of **claimable emissions reduction** is applicable to the system under study. Justification is qualitative and shall address the following components (where relevant to the declared **technology**): animal mass, milk production, diet type, diet quality, climate, and soil type (as described using the surface soil texture). The justification shall also describe the proportion of the year in which changes in any of these components occurs.

If used as **evidence**, an external **GHG abatement** scheme methodology shall be strictly limited to the **use**/system defined within that methodology. A statement shall be provided, outlining how the criteria described in this section are met by the methodology.

10.1.1. ADDITIONAL CONSIDERATIONS

There may be additional considerations required to ensure that the assessment of **GHG emissions reduction**s is credible. An example of an additional consideration is provided in Section C5.2 of APPENDIX C.

10.1.2. UNCERTAINTY ADJUSTMENT

Where a methodology from an existing **carbon crediting scheme** is used, the applied discount for uncertainty shall be no less than that calculated using this protocol. Where the discount for uncertainty is less than that included in this protocol, the calculations contained in the methodology shall be adjusted to ensure alignment with this protocol.

10.2. EQUATIONS

*Statistical knowledge and/or an understanding of **confidence and prediction intervals** may be needed to undertake the calculations specified in this protocol, therefore the input of a statistician may be necessary for its implementation. The equations used to calculate the **GHG adjustment factor** are dependent on the statistical analysis used in the **evidence** (Section 10.1). Where the calculation of **GHG emissions reduction** uses the difference in absolute **GHG emissions** between a control and treatment assessed by a parametric statistical method, a factor with which to calculate a claimable emissions reduction shall be calculated using equations in Section 10.2.1.*

*Where the **GHG emissions reduction** is calculated using an equation developed using a regression approach, a factor with which to calculate a claimable emissions reduction shall be calculated* *using an approach consistent with the equations in Section 10.2.2. It is difficult to provide specific equations for calculating the **claimable emissions reduction** when a regression approach has been used in the **evidence** due to the many different possible approaches. The equations in Section 10.2.2 demonstrate the calculation of a **GHG adjustment factor** for a multiple linear regression equation and demonstrate the principles that shall be followed if a **confidence or prediction interval** is calculated for another type of regression approach. These principles are:*

i. The adjustment shall be made using a t-value where P = 0.7 and the degrees of freedom are calculated appropriately;

*ii. The **data quality** adjustment shall adjust the variance of each explanatory variable;*

*iii. The **data quality** adjustment shall not adjust the regression mean;*

iv. The standard error of the intercept may be assumed to be zero where the regression is not centred, however where the correlations between coefficient estimates are assumed to be zero, the standard error of the intercept may artificially dominate the total variance – especially when the regression is not centred. It shall therefore only be assumed that the standard error of the intercept is zero where the relationship between predictors and outcome is strong;

v. If correlations between regression coefficient estimates are unavailable, it may be assumed that these correlations are zero unless there is a strong reason to believe they are highly positive. They are positive when the predictors themselves are negatively correlated;

*vi. The equations presented in section 10.2.2 calculate a **confidence interval** to be applied to individual herds. The use of a **confidence interval** assumes that the carbon footprints for individual herds will be aggregated at the processor level where the relatively large number of predictions result in the error around the dependent variable becoming negligible. Where the protocol is applied to a single herd without aggregation, or the carbon footprints of a relatively small number of herds are aggregated, then a **prediction interval** should be calculated and applied.*

*Where calculations are done for a regression approach other than linear regression or for a nonparametric statistical analysis, a report shall be prepared by a qualified statistician that provides evidence of their qualification and a justification for the approach used to calculate the **prediction or confidence interval**, including how Principles i – vi in the previous paragraph have been adhered to.*

The protocol generates $\mathbf{GHG_{adjt(0.7)}}$, an **adjustment factor** expressed as a decimal that is used to generate a **conservative** estimate of the **GHG emissions reduction** from the implementation of a **technology**.

For all equations presented in this sub-section:

- Where a mixed model approach was used for statistical analysis in the **evidence** and random effects in the model were statistically significant, then the predicted values for **GHG emissions reduction** shall be used.
- Where a co-variate was included in the statistical analysis in the **evidence** and found to be significant then values adjusted for co-variance shall be used.

A list of variables used in the equations is provided below in Table 1 to allow easy reference of variables, their definitions and the equations they appear in.

Table 1 The description and relevant equation/s for variables used to estimate a ***GHG emissions reduction****.*

Variable	Description	Equation
$GHG_{adj_{t(0.7)}}$	That factor used to adjust the **GHG emissions reduction** based on experimental results for uncertainty and study similarity or **data quality**.	1, 5
$\bar{x}_t;\ \bar{x}_c$	The mean of the treatment and control, respectively.	1, 3
$t_{(0.7,\ df)}$	The critical one-tail value from the t-distribution for p = 0.7 and the relevant df	1
SE_{DQ}	An approximation of the standard error of the difference between the means of the control and treatment adjusted for study similarity	1, 3
$SE_{\bar{x}_t}; SE_{\bar{x}_c}$	The standard error of the treatment and control, respectively.	2, 3
$df_{\bar{x}_t};\ df_{\bar{x}_c}$	The degrees of freedom for the treatment and control, respectively.	2
SS	Study similarity score	4
n	The number of **primary data** sources used to calculate the on-farm **GHG emissions reduction**	4
$R_i,\ C_{i,}\ \ T_i,\ G_i$	**Data quality** values representing reliability, completeness, temporal correlation, geographical correlation	4, 11
$\hat{y}$	The mean **GHG emissions reduction** estimate	5
SE_{adj}	The standard error of the equation used to estimate a **GHG emissions reduction** adjusted **data quality**.	5
df	Degrees of freedom	6
n	The number of cases in the equation used to calculate the mean **GHG emissions reduction**	6
k	The number of explanatory variables in the equation used to calculate the mean **GHG emissions reduction**	6
$SE_{\beta 0}$	The standard error of the regression intercept	7
$SE_{adj_{\beta_i}}$	The standard error of the regression co-efficient for the ith explanatory variable adjusted for **data quality**	7
x_i	Value for the ith explanatory variable	8, 9
SE_{β_i}	The standard error of the regression co-efficient for the ith explanatory variable	8, 9
$S^2{}_{DQ_{ir}}$	The variance of the ith explanatory variable adjusted for **data quality**	8, 9, 10
β_i	The regression co-efficient for the ith explanatory variable	8, 9
x_{0_i}	Value used to centre the regression equation for the ith explanatory variable	9
DQ_i	**Data quality** adjustment for the ith explanatory variable	11

10.2.1. THE DIFFERENCE BETWEEN THE MEAN OF A CONTROL AND MEAN OF A TREATMENT

Where a statistically significant **GHG emissions reduction** is demonstrated between the control and a treatment, the **adjustment factor** $\boldsymbol{GHG_{adj_{t(0.7)}}}$ may be calculated using Equation 1. $GHG_{adj_{t(0.7)}}$ may alternatively be calculated via another method (e.g. Fieller's theorem) if the calculations are done by a qualified statistician. If an alternative method is used, a report shall be prepared by the statistician that provides **evidence** of their qualification, the method used to adjust the **GHG emissions reduction**, a justification for the use of the method and the calculations, including the integration of an adjustment for **data quality** consistent with the approach shown in Equation 3.

Equation 1

$$GHG_{adj_{t(0.7)}} = \frac{\bar{x}_t + t_{(0.7,\, df)} \,.\, SE_{DQ}}{\bar{x}_c}$$

where $GHG_{adj_{t(0.7)}}$ is the value used to adjust the **GHG emissions** for the **baseline emissions source** without **use** of the **technology** as calculated by a relevant existing **CF** methodology; $\bar{x}_t$ is a positive value that represents the treatment mean from the **evidence** declared in Section 10.1; $t_{(0.7)}$ is the critical one-tail value from the t-distribution for p = 0.7 and the relevant df as calculated by Equation 2, based on a 70% confidence level; and SE_{DQ} is an approximation of the standard error of the difference between the means of the control $(\bar{x}_c)$ and treatment, adjusted for uncertainty as calculated using Equation 3.

Equation 2

$$df = \frac{({SE_{\bar{x}_c}}^2 + {SE_{\bar{x}_t}}^2)^2}{(\frac{{SE_{\bar{x}_c}}^4}{df_{\bar{x}_c}} + \frac{{SE_{\bar{x}_t}}^4}{df_{\bar{x}_t}})}$$

where df is the degrees of freedom from the relevant study; $SE_{\bar{x}_c}$ and $SE_{\bar{x}_t}$ are the standard errors of $\bar{x}_c$ and $\bar{x}_t$, respectively, from the **evidence** used to support the calculations in Section 10.1; and $df_{\bar{x}_c}$ and $df_{\bar{x}_t}$ are the degrees of freedom for the control and treatment groups.

Equation 3

$$SE_{DQ} = \sqrt{(e^{SS^2} - 1) \,.\, e^{SS^2} \,.\, (x_t - x_c)^2 + (e^{SS^2/2})^2 \,.\, (SE_t^2 + SE_c^2) + (e^{SS^2} - 1) \,.\, e^{SS^2} \,.\, (SE_t^2 + SE_c^2)}$$

where SS is the adjustment for study similarity as calculated using Equation 4.

Equation 4

$$SS_i = \sqrt{\frac{\sum_{i=1}^{n} (log(R_i)^2 + log(C_i)^2 + log(T_i)^2 + log(G_i)^2)}{n}}$$

where R_i, C_i, T_i and G_i are the **data quality** scores for reliability, completeness, temporal correlation and geographical correlation, respectively, taken from APPENDIX B, for the data representing the ith variable used to calculate the **emissions** from the **GHG source** nominated in Section 6.1.2; and n is the number of variables (e.g. animal weight, animal numbers) that are used to calculate the **GHG emissions** from the nominated **GHG source**.

10.2.2. REGRESSION APPROACH

When a regression approach has been used to estimate a **GHG emissions reduction**, the equation used to adjust the **GHG emissions reduction** will generate two results (as demonstrated in Section C5.3). The result that generates the most **conservative GHG emissions reduction** relative to the **baseline emissions** for the nominated **source** shall be used.

Equation 5

$$GHG_{adj_{t(0.7)}} = \hat{y} \pm t_{(0.7,\ df)} \cdot SE_{adj}$$

where $GHG_{adj_{t(0.7)}}$ is the value that represents a factor used to adjust the **GHG emissions** for the nominated **source** as calculated without the **technology**; $\hat{y}$ is the **GHG emissions reduction** calculated using the equation from the **evidence**; $t_{(0.7)}$ is the critical one-tail value from the t-distribution for the for p = 0.7 with the appropriate number of degrees of freedom as calculated using Equation 6 ; and SE_{adj} is the standard error adjusted for **data quality** as calculated by Equation 7.

Equation 6

$$df = n - (k + 1)$$

Where n is the number of observations used in the analysis and k is the number of explanatory variables in the model.

Equation 7

$$SE_{adj} = \sqrt{SE_{\beta_0}{}^2 + \sum_{i}^{n} SE_{adj_{\beta_i}}{}^2}$$

where SE_{β_0} is the standard error of the regression intercept (noting that where the regression is not centred this value can be 0); and $SE_{adj_{\beta_i}}$ is the SE of the regression co-efficient for the ith explanatory variable adjusted for **data quality** calculated using Equation 8 for a centred regression Equation 9 when the regression equation is not centred.

Equation 8

$$SE_{adj_{\beta_i}}{}^2 = x_i{}^2 . SE_{\beta_i}{}^2 . S^2{}_{DQ_i} + x_i{}^2 . \beta_i{}^2 . S^2{}_{DQ_i} + SE_{\beta_i}{}^2 . (x_i \cdot e^{\frac{DQ_i}{2}} - x_{0_i})^2$$

Equation 9

$$SE_{adj_{\beta_i}}{}^2 = x_i{}^2 . SE_{\beta_i}{}^2 . S^2{}_{DQ_i} + x_i{}^2 . \beta_i{}^2 . S^2{}_{DQ_i} + x_i{}^2 . SE_{\beta_i}{}^2 . (e^{\frac{DQ_i}{2}})^2$$

where, for the ith explanatory variable in the equation from the **evidence**; x_i is the value for variable used to populate the equation from the **evidence**; $SE_{\beta i}$ is the standard error of the regression co-efficient; $S^2{}_{DQ_{ir}}$ is the variance adjustment for **data quality** as calculated using Equation 10; β_i is the regression co-efficient and x_{0_i} is the centring value.

Equation 10

$$S^2{}_{DQ_i} = (e^{DQ_i} - 1) . e^{DQ_i}$$

where DQ_i is the **data quality** modification factor for the ith explanatory variable calculated using Equation 11.

Equation 11

$$DQ_i = (\log(R_i)^2 + \log(C_i)^2 + \log(T_i)^2 + \log(G_i)^2)$$

where R_i, C_i, T_i and G_i are the **data quality** scores for reliability, completeness, temporal correlation and geographical correlation, respectively, taken from APPENDIX B, for the data representing the ith independent variable in the regression equation used to calculate the **emissions** from the nominated **source**.

10.3. CALCULATION FREQUENCY

The calculation shall be reviewed annually or more frequently when data used to calculate a **claimable emissions reduction** changes or experimental results that improve the robustness of the **GHG adjustment factor** are made available via publication in a relevant scientific journal (see Section 8.2).

11. MULTIPLE TECHNOLOGIES

Where multiple technologies are implemented within the same system and each **technology** reduces **emissions from** a different **source** (e.g. **methane** from enteric fermentation and **methane** from manure), then the protocol shall be applied to each **technology** individually and each **GHG emissions source** adjusted using the relevant protocol output. Where multiple technologies are implemented within the same system and the technologies reduce the same **emissions source**, then Sections 6 to 8 shall be completed for each **technology**. Sections 9 and 10 shall also be completed for the technologies combined, i.e. the **evidence** used to calculate **GHG emissions reduction** shall be from **experiment**s that implemented the relevant technologies simultaneously.

12. REPORT

To ensure transparency, a report shall be generated that provides the required information as outlined in Sections 6 to 10. An example report is presented in APPENDIX C. Where the $GHG_{adj_{t(0.7)}}$ is incorporated in a **CF** calculator or calculation, the developer of the **CF** calculator shall make the report available to the reviewer of the **CF** calculator or calculation.

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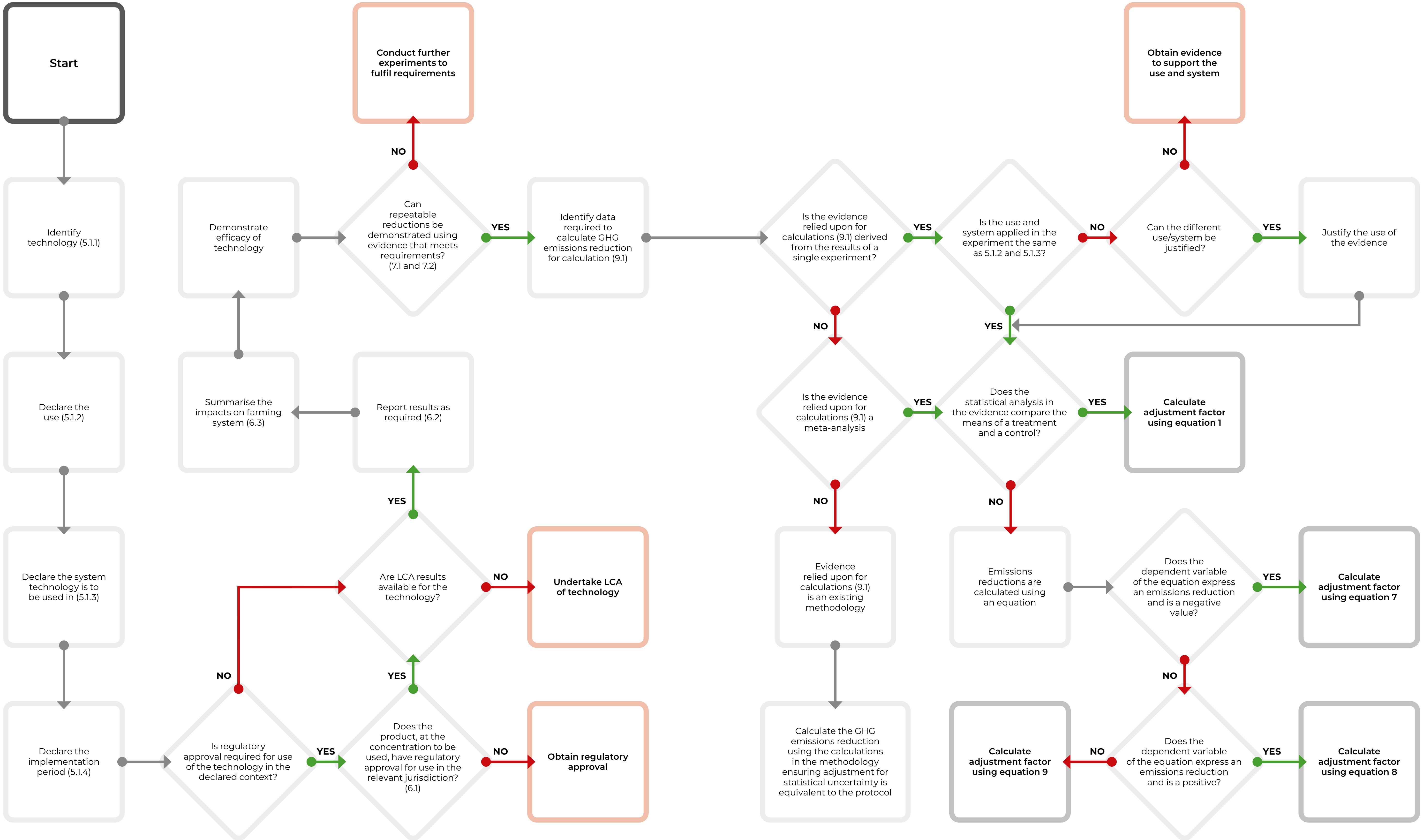
APPENDIX A

Figure 1



APPENDIX B

*Table B.1 **Data Quality** Matrix with the **data quality** factors applied to each parameter used to calculate **GHG emission reductions**.*

Data quality category	Description	*DQ*
Reliability	Directly measured	1
	Calculated **primary data** based on measurements	1.54
	Calculated **secondary data** based partly on assumptions	1.61
	Qualified **estimation** (by experts)	1.69
	Non-qualified **estimation**	Not acceptable
Completeness	**Primary data** from the system being assessed	1
	Secondary data from a system or systems where the **FPCM**+ is +/- 5% of the FCPM of the system being assessed	1.03
	Secondary data from a system or systems where the **FPCM**+ is +/- 10% of the FCPM of the system being assessed	1.04
	Secondary data from a system or systems where the **FPCM**+ is +/- 20% of the FCPM of the system being assessed	1.08
	Secondary data from a system with unknown **FPCM**	Not acceptable
Temporal correlation	Less than 1 years old	1
	1 – < 3 years old	1.03
	3 - <6 years old	1.10
	More than 6 years old	Not acceptable
Geographical correlation	**Primary data** from the **system** being assessed (location-specific)	1
	Secondary data from the same **region** as the system being assessed	1.04
	Secondary data from a **region** with similar production conditions	1.08
	Secondary data from a **region** with somewhat similar production conditions	1.11
	Secondary data from unknown **region** or **region** with distinctly different production conditions	Not acceptable

+ More information on the use of **FPCM** to determine completeness is available in section 9.

APPENDIX C

WORKED EXAMPLE OF PROTOCOL FOR 3-NITROOXYPROPANOL USE

Preface

This worked example demonstrates the retrospective application of the protocol to the use of 3- nitrooxypropanol (3-NOP) to reduce **enteric methane emissions** from dairy cattle, with data from a relevant **meta-analysis** used to calculate $GHG_{adj_{t(0.7)}}$. Based on current available **evidence**, **GHG emissions reduction**s associated with the use of 3-NOP could not be claimed under the protocol for the system being assessed because there is no **LCA** that is compliant with requirements set out in the protocol. Therefore, the purpose of this worked example is to demonstrate how the requirements set out in the protocol are applied to the **evidence** that demonstrates the efficacy of a **technology** and the application of the equations in the protocol to calculate $GHG_{adj_{t(0.7)}}$.

C1. TECHNOLOGY AND IMPLEMENTATION CONTEXT

C1.1. SCOPE

C1.1.1. TECHNOLOGY

The product is a chemical named 3-nitrooxypropanol (3-NOP), with the Chemical Abstract Service (CAS) number 100502-66-7. This is a proprietary **technology** owned by DSM-Firmenich, who markets the product under the name "Bovaer®" (*https://www.dsm-firmenich.com/anh/products-and-services/products/methane-inhibitors/bovaer.html*). Conditions and limitations of use are detailed in Section C5.2.

C1.1.2. USE

The 3-NOP feed additive was included in total mixed rations at a rate of 80 mg/kg dry matter (DM) and incorporated into the ration during manufacture. Including 3-NOP in the ration reduced **enteric methane** production. It was fed as part of an ad-lib ration to adult dairy cows while housed during the summer period. Research has demonstrated that 3-NOP can be lost during the pelleting process (Bampidis et al., 2021), so the 3-NOP will only be included in a loose mix. That research also demonstrated that 3-NOP degrades in storage so the loose mix will not be stored and was made up when and as needed.

C1.1.3. SYSTEM

This application of the protocol is specific to the **use** of 3-NOP in a commercial dairy that is also used for research and educational purposes. The dairy is located in northern Victoria, Australia and receives an average annual rainfall of 556 mm, most of which falls in winter. The **region** has a Mediterranean climate with hot, dry summers and cool winters. The soils are variable and include loams and clay. The dairy is predominantly a pasture-based system with pellet supplementation and high protein hay/silage for nine months of the year, and a total mixed ration supplied during housing for the remaining three months (summer). The total mixed ration is a mix of commercial dairy pellets and pasture silage. The dairy produces an estimated 109 tonnes of milk solids in 2024 with cows averaging 6 669 litres of **FPCM** per lactation. It is a self-replacing system and over the year the herd contains an average of 285 Holstein-Friesian dairy cattle. Non-milking cows are fed pasture and cereal hay in spring, with pellets added in autumn and winter. As this **technology** does not reduce manure **GHG emissions** the manure management system is not relevant. **Evidence** indicates that the effects of the **technology** are independent of cow breed, age and weight (Kebreab et al., 2023).

C1.1.4. IMPLEMENTATION PERIOD

Supplementation will occur in the summer months (i.e. December, January and February in Australia).

C2. SAFETY

C2.1. REGULATORY APPROVALS

At the time of writing, the **use** of 3-NOP in dairy systems in Australia does not require regulatory approval in Australia under the Agricultural and Veterinary Chemicals Act 1994. This is consistent with the Agricultural and Veterinary Chemicals Code Regulations 1995 where a product is manufactured to the specifications in a relevant QA system, the product label contains specified information, and the label does not include a claim that the product treats a disease, condition or injury. This information can be found at online at *https://www.apvma.gov.au/registrations-and-permits/chemical-product-registration/stockfeed-petfood-regulation*.

The Material Safety Data Sheet for Bovaer®1 bears hazard statements for skin irritation (H315), serious eye damage (H318) and that it is suspected of damaging fertility (H361f). Precautionary statements listed are to obtain special instructions before using (P201); wear protective gloves, protective clothing, eye protection, face protection, or hearing protection (P280); and to wash thoroughly after handling (P264).

C2.2. ENVIRONMENTAL IMPACTS

The European Food Safety Authority concluded that 3-NOP does not have an adverse effect on consumer safety or the environment (European Union, 2022) and there are no concerns if residues are introduced to the environment (Bampidis et al., 2021).

A **LCA** using data from the manufacturer (DSM-Firmenisch) on the climate impacts of 3-NOP production was included in an unpublished analysis (Kebreab, 2021). This analysis reported that the environmental impacts associated with the production and shipping of 3-NOP in California had negligible impact on the total **emissions reduction** achieved by supplementing Californian dairy cow diets with 3-NOP. An analysis using similar methodology, yet covering the entire USA, was published in 2022. Although there was considerable variability in the impacts of 3-NOP **use** between **regions**, 3-NOP **use** reduced **emissions** intensity (kg **CO_2**-e/kg **FPCM**) by 12%, including **emissions** associated with production and transport of feed additives (Uddin et al., 2022).

The text below is an example of how the results of a **LCA** may be reported to meet the requirements of the protocol.

A **LCA** was undertaken on milk production with and without 3-NOP for a generic production system in Europe and it showed that the climate change benefits calculated in the **LCA** were slightly higher than those calculated via the protocol due to the **conservative data quality** corrections included in the protocol. There was no significant change in eutrophication, water scarcity, land use or soil quality impact with 3-NOP **use**. The resource depletion (fossil fuels) impact was 3% higher for the system using 3-NOP due to the impacts conferred by manufacturing the supplement.

C2.3. IMPACTS TO THE FARMING SYSTEM

Several studies have investigated the impact of 3-NOP on milk production, composition, and quality. Limited published information is available on factors specific to animal health or welfare. The summarised literature was based on scientific literature searches using Google Scholar using the terms "3-NOP AND milk quality", or "3-NOP AND dairy AND either health, welfare OR production".

Published literature showed either no effect or minor effects on dairy cow productivity. Two studies reported no impact on either DMI or milk production (van Gastelen, 2020; Van Wesemael, 2019). There was some **evidence** for reduced milk yield (Maigaard et al., 2023) which was observed in dairy cows on a higher 3-NOP dose (60 vs 80 mg/kg DM) (van Gastelen et al.,

2022) or in those fed high concentrate diets (Schilde, 2021b).

In terms of milk composition and quality, 3-NOP is metabolised into endogenous compounds and the presence of exogenous residues in the milk is unlikely (Thiel, 2019). An increase in milk fat has sometimes been observed (van Gastelen et al., 2022) but this effect was not consistent across studies (van Gastelen, 2020; Van Wesemael, 2019). Two studies reported a significant increase in milk urea nitrogen with the **use** of 3-NOP (Melgar, 2021; Schilde, 2021a). A summary of reviewed studies focusing on **use** of the **technology** in dairy cows is provided in Table C.1.

Table C.1 Published peer-reviewed studies on 3-NOP and its impacts on dairy cattle welfare, feed intake/ efficiency, milk production and/or milk composition/quality.

Citation	Animal biology	Feed intake/efficiency	Milk production	Milk composition/quality
Garcia et al. (2022)	Shifted rumen fermentation from acetate to propionate	Not assessed	Not assessed	Not assessed
Jayanegara et al. (2018)	Decreased total volatile fatty acids (VFA) concentration in the rumen	No statistically significant change.	No statistically significant change.	No statistically significant change.
Kim et al. (2020)	Decreased the proportion of acetate and increased valerate in rumen	No statistically significant change.	No statistically significant change.	No statistically significant change.
Kjeldsen et al. (2023)	VFA concentrations in the rumen were negatively affected: decreased acetate and increased concentrations of several alcohols in the rumen.	Statistically significant reduction in DMI.	No statistically significant change.	No statistically significant change.
Maigaard et al. (2023)	No statistically significant change.	Statistically significant reduction in DMI.	Statistically significant reduction in energy-corrected milk.	No statistically significant change.
Melgar et al. (2020a)	Statistically significant decrease in insulin.	No statistically significant change.	No statistically significant change.	Statistically significant increase in short-chain fatty acids, no change in sensory properties of milk or cheese.
Melgar (2021)	No statistically significant change.	No statistically significant change.	No statistically significant change.	Increased milk fat and milk urea nitrogen concentration.
Melgar et al. (2020b)	No statistically significant change.	No statistically significant change.	No statistically significant change.	Increased fat concentration, tended to increase milk urea nitrogen.
Schilde (2021a)	No changes to rumen pH but 3-NOP supplemented with a high concentrate diet resulted in more rumen propionate	No statistically significant change.	Decreased energy-corrected milk (ECM) production in cows on high concentrate diet, but not in other cows.	Increased milk lactose and milk urea.
Schilde et al. (2022)	Improved the energy budget of dairy cows.	No statistically significant change.	No statistically significant change.	No statistically significant change.
van Gastelen (2020)	Increased digestibility of several nutrients; cows supplemented with 3-NOP gained more weight during lactation	No statistically significant change.	No statistically significant change.	No statistically significant change.
van Gastelen et al. (2022)	No statistically significant change.	Statistically significant decrease in DMI.	Statistically significant decrease in ECM production when cows were given 80 mg 3-NOP/ kg DM	Statistically significant decrease in major components of milk when cows were given 80 mg 3-NOP/kg DM

The European Food Safety Authority concluded that 3-NOP supplementation does not have an adverse effect on dairy cows (European Union, 2022). Furthermore, a study assessing 3-NOP supplementation in a commercial beef feedlot evaluated animal welfare using the DART system and found no **evidence** of negative impacts (Alemu et al., 2021); however, similar information for dairy systems has not yet been published. More information on the potential impacts of 3-NOP on rumen parameters in dairy cows is available (Pitta, 2022; Schilde, 2021b).

C3. DEMONSTRATING CONFIDENCE IN TECHNOLOGY

Under the protocol guidance, only one **piece of evidence** is required to demonstrate confidence in the efficacy of 3-NOP when the **piece of evidence** is a **meta-analysis**.

C3.1. EVIDENCE 1

A **meta-analysis** which assessed the reduction in **enteric methane** associated with feeding 3-NOP using data from 13 studies (Kebreab et al., 2023) provides adequate **evidence** for policy-makers, supply chains and consumers to have confidence in the **technology**. The studies that were included in the **meta-analysis** by Kebreab et al. (2023) were appropriate for demonstrating confidence in the **technology** because all studies were conducted in lactating dairy cattle; each study had both a control group and one or more 3-NOP treatment groups; and **enteric methane** was measured directly using either respiration chambers, GreenFeed units or the sulfur hexafluoride tracer gas technique. The publication was published in the Journal of Dairy Science in 2023 – the journal was a Level 2 journal on the Norwegian Register For Scientific Journals, Series and Publishers at the time of publication, as shown in the screenshot in Figure C.1. Kebreab et al. (2023) is an open-access publication with a DOI of *10.3168/jds.2022-22211*.

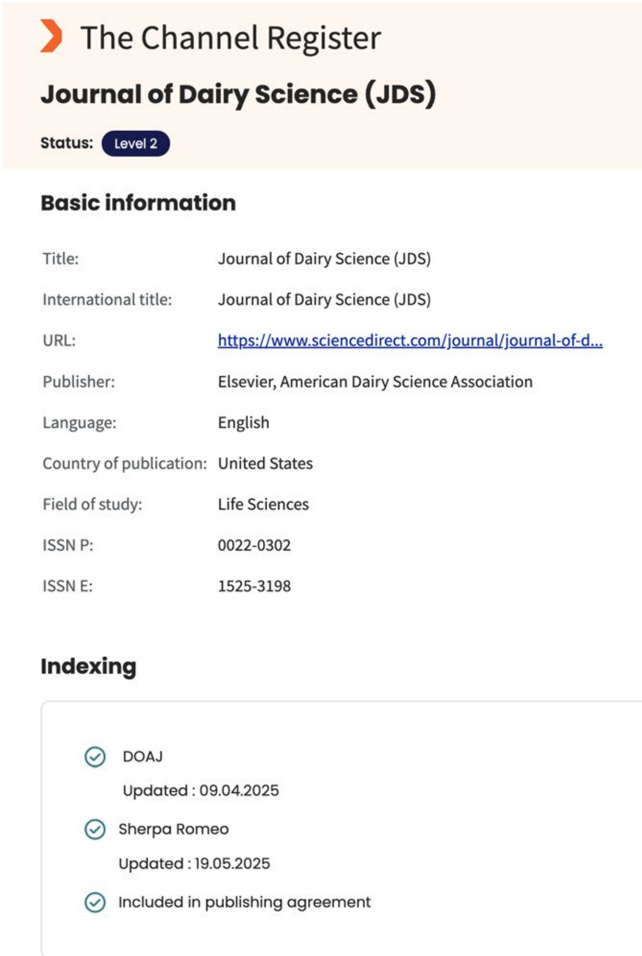


Figure C.2 Screenshot of the Journal of Dairy Science entry in the Norwegian Register For Scientific Journals, Series and Publishers.

C4. DATA QUALITY

The variables required for the **estimation** of **GHG emissions reduction**, their values, units, data sources and **data quality** values are presented in Table C.2.

Table C.2 Variables and their units, data source and the quality of data used for the **estimation** of **GHG emissions reduction**.

Variable	Value	Unit	Data source	Data quality; R, C, T, G)
3-NOP	80	mg/kg DM	Feed supplier	1, 1, 1, 1
Crude fat	2.8	% DM	Feed supplier	1.54, 1, 1, 1
NDF	27.1	% DM	Feed supplier	1.54, 1, 1, 1
Starch	26.5	% DM	Calculated from feed tests	1.61, 1, 1.1, 1

Applying the values for data in Table C.2 to Equation 11 (Section 10.2.2) of the protocol generated DQ_i values of 0, 0.19, 0.19 and 0.24 for 3-NOP, NDF, crude fat and starch, respectively. The application of Equation 11 to the values for Crude Fat from Table C.2 are shown below in Equation C.1.

Equation C.1

$$
\begin{aligned}
DQ_{Crude\ Fat} &= \left(\log(1.54)^2 + \log(1)^2 + \log(1)^2 + \log(1)^2\right) \\
&= 0.43^2 + \ 0^2 + \ 0^2 + \ 0^2 \\
&= 0.19 + \ 0 \ + \ 0 \ + \ 0 \\
&= 0.19
\end{aligned}
$$

C5. CALCULATION OF GHG EMISSIONS REDUCTION

C5.1. EVIDENCE USED FOR CALCULATIONS

The studies used in the **meta-analysis** used respiration chambers, GreenFeed units or the sulfur hexafluoride tracer technique to estimate **enteric methane emissions** from dairy cattle. The known relationships between **DMI** and **enteric methane emissions** provide confidence that the results from the **experiment**s used in the **meta-analysis** are relevant to a commercial dairy. As such, there was a high degree of confidence that the equation from Kebreab et al. (2023) stated in Section C5.3 would be suitable for estimating the reduction in **enteric methane** when implemented in the system being assessed within this example.

C5.2. ADDITIONAL CONSIDERATIONS

Kebreab et al. (2023) did not address whether the effectiveness of 3-NOP as a **mitigation technology** varies according to the duration of supplementation. Other studies have reported that the response of ruminal microorganisms to 3-NOP varies (Duin et al., 2016; Pitta et al., 2021) or have provided **evidence** (Vyas et al., 2018) that the rumen adapts to 3-NOP over time, changing the dominant methanogen species. This can lead to a reduction in the efficacy of 3-NOP in reducing **enteric methane emissions**. Research has yet to determine the factors that regulate rumen adaptation to 3-NOP and **enteric methane emissions** increase relative to the duration of 3-NOP **use**. However, a study by Schilde (2021b) demonstrated that rumen adaptation by dairy cattle did not occur over a 148-day period of feeding. The period for which

3-NOP was fed to housed dairy cattle is the Australian summer period (December – February), a total of 90 days. As this is less than the 148 days cited by Schilde (2021b), a reduction in **enteric methane** is claimed for the entire duration of dairy cattle housing in this instance.

C5.3. EQUATIONS

Kebreab et al. (2023) conducted a meta-regression to examine relationships between feed quality variables, 3-NOP and CH_4 yield and then used leave-one-out cross validation (LOOCV) to determine the model that explained the most variation. The equation from Kebreab et al. (2023) used to calculate $\hat{y}$ for the calculation of a **GHG adjustment factor** was:

Equation C.2

$$\Delta\ CH_4 \text{ yield (\%)} = -30.8 - 0.226 \times (\text{3-NOP} - 70.5) + 0.906 \times (\text{NDF} - 32.9) + 3.871 \times (\text{crude fat} - 4.2) - 0.337 \times (\text{starch} - 21.1)$$

where 3-NOP = 3-nitroxypropanol dose (mg/kg of DM), and NDF, crude fat, and starch are in % DM. Populating the equation with the values from The variables required for the **estimation** of **GHG emissions reduction**, their values, units, data sources and **data quality** values are presented in Table C.2.

Table C.2 Variables and their units, data source and the quality of data used for the **estimation** of **GHG emissions reduction**.

Equation C.3

$$= -30.8 - 0.226 \times (80 - 70.5) + 0.906 \times (27.1 - 32.9) + 3.871 \times (2.8 - 4.2) - 0.337 \times (26.5 - 21.1)$$

The degrees of freedom were calculated using Equation 6 (Section 10.2.2) of the protocol with n = 14 and n = 4. The critical value for $t_{(0.7)}$ was 0.543.

Applying the standard errors from Table 3 of Kebreab et al. (2023) and the DQ_i values from Section C4 of this worked example to Equation 9 (Section 10.2.2) of the protocol generated $SE_{adj_{\beta_i}}$ values of 0.6, 26.3, 5.6 and 6.0 for the variables 3-NOP, NDF, crude fat and starch, respectively.

Populating Equation 7 (Section 10.2.2) with these values and using a value of 1.5 for SE_{β_0} generated a value of 27.5 for SE_{adj}. Thus, Equation 5 (Section 10.2.2) of the protocol was:

Equation C.4

$$GHG_{adjt_{(0.7)}} = -45.4 \pm 0.543 \times 27.5 = (-60.4, -30.5)$$

The protocol requires that the value for $GHG_{adj_{t(0.7)}}$ is **conservative**, hence the relevant value representing a **conservative** estimate of **GHG emissions reduction**s was -30.5, or a 30.5% reduction in **enteric methane**.

C6. APPLICATION OF $GHG_{adjt_{(0.7)}}$

Note that this section is for reference only and is not required to be included in a report produced through using the protocol.

A **CF** of the commercial dairy under study was calculated using the Dairy Greenhouse Gas Accounting Framework tool (Eckard, 2020). A **baseline** total of 6 454 kg **CO_2-e** of **enteric methane** were emitted by all dairy cows housed in the dairy during December, January and February. When 3-NOP was fed to these cattle, a **GHG emissions reduction** of 1 968 kg **CO_2-e** was estimated by the application of the protocol and reduced the **GHG emissions** from **enteric methane** from 6 454 kg **CO_2-e** to 4 486 kg **CO_2-e**.

APPENDIX D

*Table D.1 Impact categories recommended for the **LCA** that provides **evidence** for the efficacy of the **technology**. Other impact categories should be used where they are relevant to the **technology**.*

Impact category	Recommended method	Rationale
Climate change	**IPCC GWP**$_{100}$ AR5 (**IPCC**, 2013) or more recent updates	The basis of the **GHG abatement**
Resource use - fossil	Frischknecht et al. (2003) or similar	Energy required for production of the **technology**
Ozone depletion potential	Chanin et al. (1999)	Included due to the ozone-depleting impact of bromoform (CH3Br)
Freshwater eutrophication	Payen et al. (2021)	Growing Asparagopsis to produce a bromoform based **enteric methane** inhibitor may involve emission of nutrient-rich water from growing systems
Water scarcity	Boulay et al. (2018)	Changes in productivity are possible which may impact water embodied in feed production.
Land use impacts on ecosystem services	Brandão et al. (2011)	Changes in productivity are possible which may affect demand for feed and therefore land use.
Ecotoxicity and Human toxicity	Fantke et al. (2021)	Bromoform has a freshwater ecotoxicity effect and a value for human toxicity – non cancer.

MiLCA

Protocol for including
Mitigation actions in
Agricultural Lifecycle Assessment