Final report

UHF Feasibility Study

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Abstract

Ultra-high frequency (UHF) is a Radio Frequency Identification (RFID) technology that has been researched globally as an alternative traceability technology for livestock supply chains. UHF has gained interest due to its potential to provide value (cost savings, data collection capabilities) over the dominant traceability technology in livestock, Low frequency (LF) RFID. This project aimed to investigate the technical viability of Ultra High Frequency (UHF) RFID technology in relation to its alignment with the demands of livestock supply chains. Additionally, the study examined the economic implications and advantages linked with the adoption of this technology.

Project research indicated that there has been substantial UHF technology progress in livestock settings, with a number of challenges previously associated with UHF being overcome. However, further research and development is required to deliver a range of commercially available products suitable for the Australian livestock industry. The economic analysis showed that transitioning from a LF system, to a UHF system, would deliver benefits to both cattle and sheep supply chains. UHF livestock tags and readers that are fit for purpose and cost effective, could lead to the capturing of major industry benefits and reduce the cost burden of traceability on livestock industries. UHF technology also provides greater potential opportunities for additional supply chain value creation when compared to current LF systems.

Executive Summary

Background

The objective of this project is to evaluate the technical and economic viability of Ultra High Frequency (UHF) technology within the context of the National Livestock Identification System (NLIS). The project aims to determine if UHF technology is suited for implementation in commercial settings within Australian red meat supply chains. While Low-Frequency (LF) Radio Frequency Identification (RFID) is the prevailing technology globally and in Australia for livestock tracking and tracing, UHF RFID technology offers an alternative traceability solution that potentially delivers added benefits beyond LF technology. The significance of this project lies in ensuring that the Australian livestock industry can access traceability technologies that are both suitable and advantageous. It seeks to identify areas where industry investments could be directed to expedite and harness innovation. A key focus of this project is to communicate the advantages and challenges linked to UHF technology to stakeholders in the Australian livestock industry, especially those engaged in the national traceability system. The outcomes of this project will serve to facilitate industry dialogues about the potential of UHF technology and the enthusiasm of industry to advance further research into UHF technology.

Objectives

The objectives of this project were as follows:

1. Investigate and understand whether UHF technology works in commercial settings and is practically sound for implementation in Australia.
2. Conduct a cost-benefit analysis for cattle, sheep and goat industries in the adoption of UHF technology for traceability purposes, including providing an analysis of:
    a. UHF as the only identification technology for traceability purposes
    b. Dual technology approach (both LF and UHF)
    c. Cost of implementing UHF versus remaining with current LF technology
3. Determine the impact on the current NLIS software (i.e. changes required for the NLIS database, implications for integrated systems and software (e.g. government and commercial) and hardware (i.e. identification of device or chip availability; scanners and dual readers), including the cost and time required to upgrade or integrate changes in the entire supply chain for UHF adoption.
4. Propose the best pathway forward for adoption of UHF technology.
5. Identify any adaptability possibilities for other cloven-hoofed species (pigs, camelids, deer etc.) for future inclusion in NLIS.

The original project objectives were modified to exclude the requirement to account for the costs associated with the introduction of LF (2c) since all industry supply chains nationally would have adopted LF RFID before potential adoption of UHF could occur. Therefore, a comparison to ongoing costs of LF systems was more relevant. Additionally, goats were not included in the CBA analysis due to insufficient data availability. All remaining objectives were achieved.

Methodology

The project methodology used includes the following:

- Desktop research assessing previous trials and academic papers regarding UHF use in livestock settings. Assessing current UHF livestock products on the market.

- Interviews with technology providers and global UHF livestock experts, including representatives involved in UHF adoption in livestock settings internationally.
- Supply chain data collection.
- Validation conversations with industry stakeholders including processors, feedlots, saleyards.

Results/key findings

- UHF is estimated to be a minimum of 4 years from being available for adoption in cattle, sheep and/or goat supply chains, mainly due to the need for further industry-focused research, in-field technology trials, regulatory guidance, and the potential establishment of new Australian interim standards (in lieu of defined international standards) per the accelerated approach. Therefore, LF RFID systems will be implemented nation-wide in cattle, sheep and goat supply chains before a UHF alternative is ready for potential adoption.
- The principal benefits of a UHF or Dual UHF-LF RFID system compared to the LF RFID system were estimated in the CBA for the beef cattle and sheep industries, and included:
  - Lower costs associated with UHF-based tags and reader infrastructure compared to LF technology.
  - Reduced labour requirements throughout the supply chain associated with UHF technology compared to LF technology, due to:
    - The ability to read individual or multiple animals, at higher speeds, and at a larger distance.
    - The ability to store and access animal information (e.g. health records) via the physical tag.
- Transitioning directly to UHF from an LF RFID system has the potential to provide significant financial benefits (net cost savings compared to LF) for both cattle ($360.1 million total accumulated value over a 20-year analysis period, in present value terms) and sheep ($897.8 million total accumulated value over a 20-year analysis period, in present value terms) supply chains.
- The principal sources of benefits (cost savings) associated with a direct transition to UHF from a LF RFID system are lower tag costs in sheep (71.7% of the net benefits) and lower infrastructure costs in cattle (50% of net benefits).
- Transitioning to UHF using dual technology (tags with both LF and UHF components) would provide lower positive net benefits for cattle ($305.1 million, present value terms, 20-year analysis period) and sheep ($604.5 million, present value terms, 20-year analysis period). This option may be preferred to provide better stakeholder support during a system transition.

Benefits to industry

This project is a significant first step in the evaluation of the suitability of alternative traceability technologies for Australian livestock supply chains. Its timing is important, aligning with the impending national implementation of mandated LF RFID for sheep and goats. By exploring technologies that could offer long-term advantages to the Australian industry, this project identifies and guides future research and development to prepare the industry for technology alternatives and new innovations.

The project underscores the potential of UHF to maintain the integrity of the Australian livestock traceability system, while simultaneously delivering value-added benefits to commercial stakeholders across the supply chain, particularly through cost savings and data collection endeavours. Additionally, the project estimates the costs and time associated with transitioning to UHF, equipping the industry with the insights needed to understand the implications of transitioning to an alternative traceability technology.

Future research and recommendations

The findings of this project provide strong evidence of the technical capabilities and economic advantages of UHF technology. However, it is highly recommended to conduct further research and development to validate UHF technology's readiness and deliver additional data on its performance in use. This subsequent phase of research should centre on comprehensive technology testing and trials, engaging with supply chain participants to gain a deeper insight into the benefits, and establishing significant communication with UHF technology providers to gauge global commercial interest.

Table of contents

1. Document Background

1.1 Project Background

This project explored the technical and economic feasibility of Ultra-High Frequency (UHF) technology for use in Australian livestock. UHF is a Radio Frequency Identification (RFID) technology used in various industries, including retail, pharmaceuticals, and logistics/ asset tracking. There has been increasing interest in UHF from livestock industries internationally as a possible alternative to the dominant low frequency (LF) option for animal identification. In Australia, LF tags are currently used in the national cattle supply chain and sheep and goat supply chains in Victoria only. However, the 2022 national mandate will make electronic tagging of sheep and goats compulsory across all remaining states and territories from 1 January 2025. It is highly likely that these remaining states and territories will adopt LF technology systems.

The fundamental difference between UHF and LF technologies is the frequencies at which they operate (LF 125 – 135 kHz, UHF 868-915 MHz), which translates into different technical capabilities and limitations. UHF has gained attention in livestock industries due to a few key perceived benefits, primarily regarding the lower cost of tags and scanning infrastructure, the capability to scan multiple tags/animals simultaneously and at a greater distance, and the capacity to store additional data on the tag itself.

This report provides an initial scoping evaluation of the feasibility of utilising UHF as a livestock traceability technology in Australia. The technology review presents an introductory level understanding of the technology itself, as well as its capability and limitations when compared to LF. The Cost-Benefit Analysis (CBA) presents important economic information to assist individuals and industry groups determine net benefit of various UHF adoption scenarios in comparison to maintaining a status quo. The CBA has been limited in scope and is not intended to be a comprehensive costing exercise that can serve as the foundation of a UHF technology adoption plan without further work. Moreover, the current CBA does not include costs associated with software upgrades in all state jurisdictions, as well as a number of potential UHF benefits due to their difficulty in quantification (e.g. value of on-farm data collection opportunities). Further work on a detailed costing is required as part of the next phase of investigating the suitability of, and potential adoption planning for, UHF in the Australian livestock industry. A number of distinct project limitations must also be taken into account when reviewing this report, including:

- **Limited recent independent UHF field trials |** A number of field trials utilising UHF technology in livestock settings globally were conducted between 2008-2016, however there has been a paucity of academic papers and scientific trials more recently (see Appendix 11.1 for an overview of UHF trials). Over the past 5 years, from the trial data obtained and the interviews conducted, it appears that the capability of UHF technology in terms of read rate and tag performance, has improved when compared to earlier studies. In the absence of recent field data collected in Australian livestock settings, this report presents a collective view from UHF technology experts as a representation of the current status of the limitations and capability of UHF technology and its supporting devices and software.
- **Limited supply chain interviews & validation |** While livestock technology providers and global UHF experts were consulted in this project, there was limited scope for extensive additional supply chain stakeholder engagement. CBA assumptions should be further validated by extensive supply chain engagement and a future detailed costing exercise.
- **Limited UHF technology manufacturer information |** While UHF livestock technology providers were engaged in this project, engagements were often stymied by commercial in-confidence conversations, meaning that the level of detail provided to us was limited. The

project team were unable to interview UHF component manufacturers more broadly due to this same challenge. Desktop research into UHF products currently available and their claimed performance revealed only basic product details. Further work on the technical feasibility of UHF technology must include appropriate time and resources to explore more substantive engagements with UHF technology providers globally.

1.2 Stakeholder Map

Figure 1 shows the various stakeholder segments and organisations or individuals identified in this project. Nine livestock technology experts were consulted in this project, including LF and UHF technology providers and experts, many of whom have conducted trials and research on UHF technology. Additional stakeholders in these segments were identified, but not consulted due to project scope limitations. Future work should include engagement with all stakeholders identified on this map.

Australian livestock industry stakeholders and government bodies have been included in this map as they play a critical role in facilitating the selection and adoption of new traceability technologies in livestock. Learnings from engagements with these stakeholders in previous livestock projects conducted by TGD were leveraged throughout this project, and additional engagements with saleyards, feedlots and processors in this project were conducted to fill knowledge gaps specific to UHF.

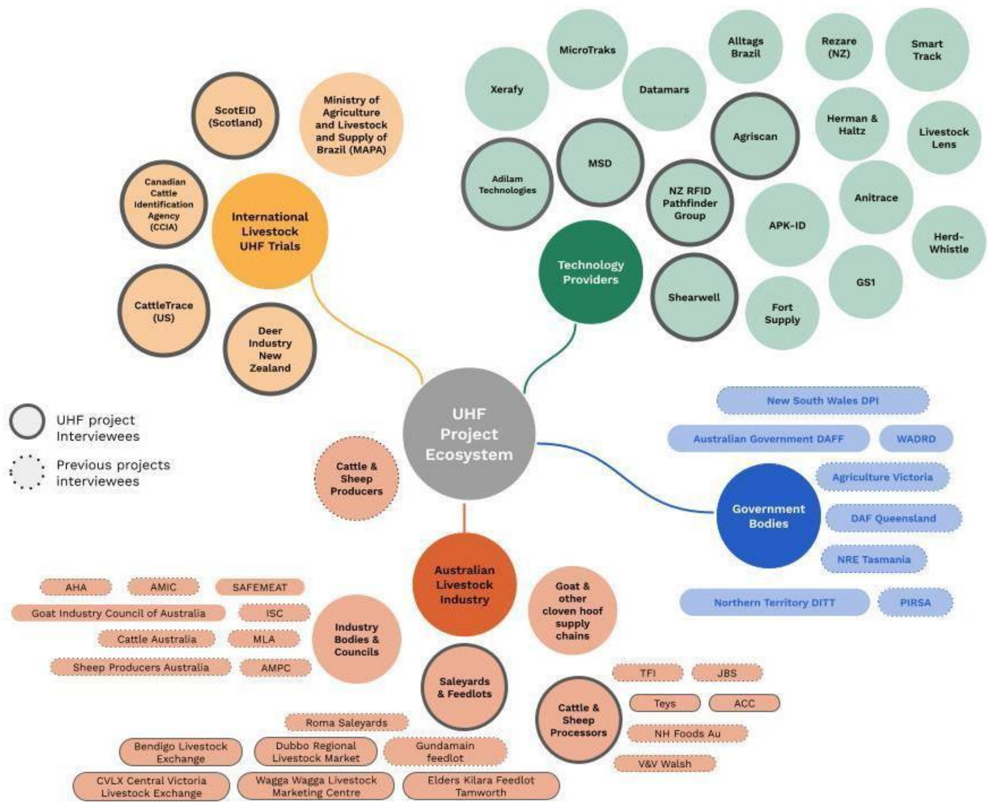

Figure 1. Stakeholder Map

2. UHF Technology Review

This section provides an overview of UHF technical components and their application in livestock settings, and includes the following;

- **Technology Capabilities |** An overview of UHF technology, including an outline of the UHF transponder configuration, and the hardware components required for a UHF system.
- **UHF livestock products |** A list of UHF hardware currently available for use in livestock settings.
- **UHF benefits for livestock |** Primary benefits of UHF technology as an alternative traceability technology for livestock supply chains, including a comparison between LF and UHF technical capabilities on parameters such as read range, read rate, costs, tag weight and more.
- **Progress on addressing UHF technical issues |** Key technical challenges that have been experienced when applying UHF to livestock settings, and an exploration of advancements in the technology and/or workarounds identified in international pilots.

2.1 Technology capabilities

2.1.1 What is UHF RFID technology?

UHF technology is a wireless communication technology that operates in the frequency range of 300 MHz to 3 GHz to transfer bits of data. UHF tags and readers commonly available are UHF Gen 2/ ISO 18000-6C compliant, the international standard defining the physical and logical requirements for a UHF system operating at a frequency of 860-960 Mhz. UHF is widely used in applications that require wireless data transfers, such as RFID systems, television broadcasting and radio communications. UHF has become an important technology in the telecommunications, logistics, healthcare, manufacturing, and agriculture sectors. Understanding the capabilities and limitations of UHF is essential for understanding how to leverage its potential in the Australian livestock context.

2.1.2 How does UHF RFID work?

UHF RFID is a system that involves three critical components that combine hardware and software elements (Nikitin, Lazar & Rao, 2007; Rajiv, 2022). The components are:

1. Transponder: Tags
2. Transceiver: Reader
3. Antenna

This section will give a basic overview of how each component works and how data is transferred.

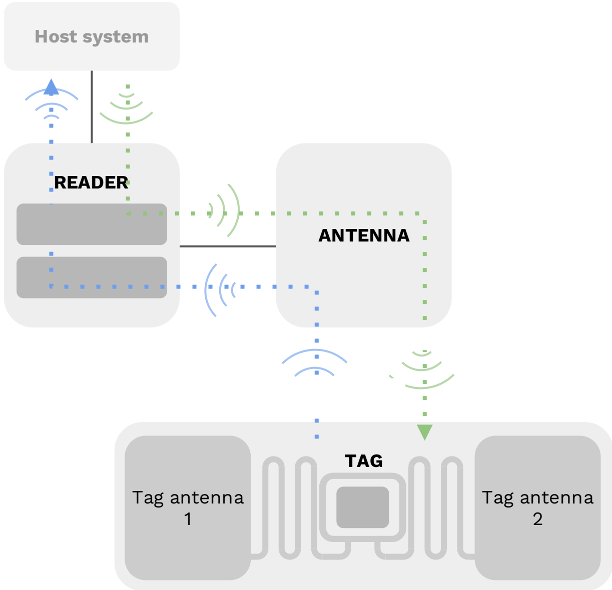

Figure 2. Basic UHF RFID system component overview

Transponder (Tag): RFID tags consist of an integrated circuit (or RFID chip), antenna/s, inlay and carrier. There are also two main types of RFID tags; active and passive.

In this context and scope of the project, only passive tags will be discussed. Active RFID tags have their own power source, typically a battery, that increases the weight and cost of the RFID tags. Active tags are therefore primarily used for high-value asset management purposes, and are unlikely to be suitable as a primary technology in the livestock industry.

- Integrated circuit (IC): The IC is the chip part of an RFID tag that stores and processes data, manages the power source of the tag, and controls communication between the tag and the reader. The complexity of the IC can vary depending on the requirements of the specific RFID application. There are three main chip manufacturers globally, Alien, NXP and Impinj (Anderson, 2016).
- Tag antenna: The tag antenna is a conductive element in the transponder that allows the tag to receive and transmit radio signals. The antenna captures energy from the RFID reader's electromagnetic field and uses it to power the IC, sending the tag's data back to the reader via the antenna. The design and size of the antenna can vary depending on the desired operating frequency, read range, and form factor of the RFID tag. Antennas can be printed on the substrate or attached to the tag separately. Furthermore, it should also be noted that while damage to the antenna may detune the tag, it often remains functional with a reduced signal strength and read distance.
- Inlay: Typically a plastic substrate, the inlay of an RFID tag is the material that provides support and structure for the integrated circuit (IC) and antenna. Depending on the intended use and environment, it can be made of various materials, including paper, plastic, or other materials. The inlay protects the IC and antenna from physical damage and environmental factors such as moisture, heat and cold.
- Carrier: The package or casing the inlay is placed in. For example, in livestock, this is the plastic tag that houses the inlay.

Transceiver (Reader): The reader component of a UHF RFID system is a crucial hardware component that enables the reading of information from the RFID tags and devices. The reader is designed to communicate with the tags through radio waves and transfer this information to a network to be stored in a database. UHF readers can work in close proximity to each other and also near to LF readers without interference, however, UHF devices cannot be read using LF readers.

Antenna: RFID antennas emit and receive radio waves to detect RFID chips. As an RFID tag enters the antenna's field, it becomes activated and emits a signal. The antennas generate diverse wave fields that cover varying distances and can be adjusted to send/receive signals in all directions or be directional, as seen in Figures 3 and 4. A typical antenna for a portal is 600x900 mm. Antennas of different sizes can be swapped without re-tuning the readers.

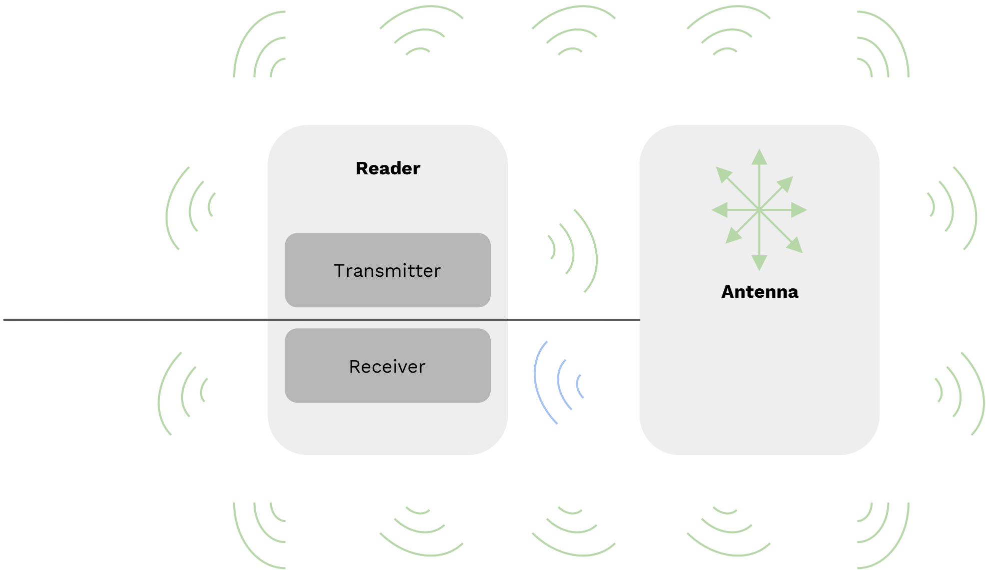

Figure 3. Reader and antenna with an omni-directional configuration.

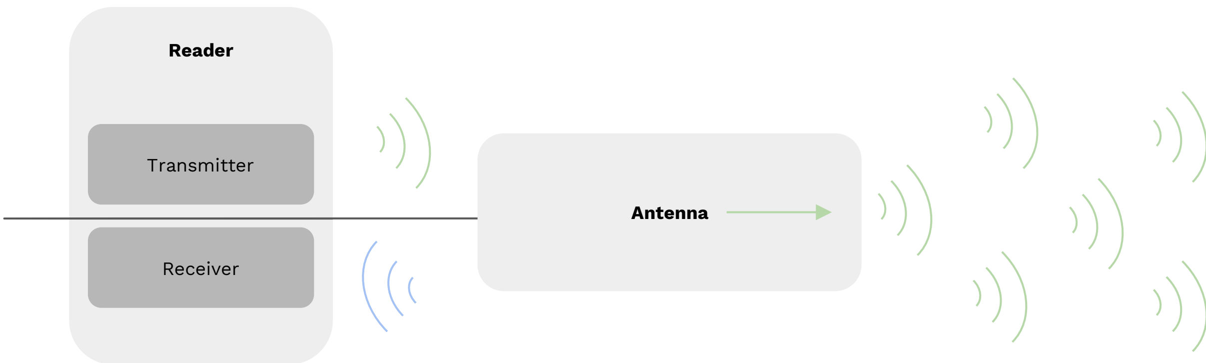

Figure 4. Reader and antenna with a directional configuration.

2.2 UHF Livestock products

UHF technology has been researched and field trialled primarily in sheep, pig, deer and cattle contexts (see Appendix 11.1 for trial/ research summary). In particular, two cattle supply chain pilots have been conducted in Scotland (2012 - ongoing, by ScotEID) and in the US (2018-2020, by CattleTrace). These pilot trials and other related diligence work has led to UHF becoming the technology of choice for both Scotland and US cattle industries. Commercially, UHF is also used in other livestock settings, including wool tracking in Australia, and tracking deer velvet in New Zealand. Engagement with the above-mentioned international groups, as well as desktop research, highlighted a range of commercially available UHF products that are reported to be suitable for use in livestock contexts. These products are explored in the following sections.

2.2.1 Commercially available tags

Several ear tags are currently available for purchase directly from specialist livestock tag companies or generic tags available from online consumer shopping sites such as Amazon and Alibaba. Generic tags were found to be of lower cost than branded options from well-known device manufacturers. No testing or performance data was available on the durability or performance of different tag brands since the International Committee for Animal Recording (ICAR) does not currently accredit UHF tags. Tags approved for use within Australia would also be required to pass rigorous laboratory and field-testing regimes specified by the NLIS. Five livestock manufacturer tags were routinely mentioned in interviews as being robust and currently used in livestock environments such as Scotland and the United States (US). These tags and companies are included below:

- APK-ID
- Fort Supply
- MS Chippers
- Herd Whistle
- Anitrace

As cattle have been the primary species involved in global pilots, there is greater certainty regarding the suitability of their design and use in livestock settings. The majority of tags used in these settings are the cattle ‘flag’ tags, which is a less popular tag design in Australia as it has been previously associated with retention issues. There are also examples of button, strip and wrap-around tags for cattle, sheep, goats and pigs. However, there is a lack of available data regarding the effectiveness of these different tag designs. Strip tags are ideal for UHF technology, as they can include an air pocket inside the tag for the UHF transponder to sit. Table 1 provides an overview of available tag designs.

Table 1: UHF tag designs

Flag tag: APK-ID  *Source: https://www.uscattletrace.org/tagstore*	Strip tag: Fort Supply  *Source: https://fort-supply.com/uhf-tags/*
Button Tag: Laipson  *Source: https://www.laipsontag.com/products_show/um401_1.html*	Wrap-around Tag: Laipson  *Source: https://www.laipsontag.com/products_show/p84.html*

Dual tags | Dual tags include both UHF and LF components in the tag. This tag can be scanned using either UHF or LF scanning equipment, and, therefore is ideal in supply chain scenarios where different stakeholders may be using different technologies or when transitioning an industry from one technology to another. There are currently limited dual tags on the market, with only one manufacturer (APK-ID) selling dual tags to US stakeholders through the CattleTrace online tag store. Research by ScotEID has established that these technologies can function in the same tag effectively, however, the design and placement of the components inside the tag is critical to dual tag performance (ScotEID, 2015a).

2.2.2 Available readers and antenna

Handheld Readers | UHF handheld readers currently used in livestock settings are developed by a range of companies, including the following:

- Fort Supply (US) is one of the leading companies designing handheld readers specifically for livestock applications. These readers function with their unique Fort Supply App designed to support data collection and interpretation.
- Zebra Technologies is a UHF company originally designing readers for multi-industry use. Collaboration with the Deer Industry NZ developed a reader suitable for livestock settings.
- Chainway readers are designed for asset management applications and warehousing and are considered suitable for various applications. These readers are widely used by cattle producers and other supply chain stakeholders in Scotland.

Fixed Readers & Antennas | Fixed readers and antennas currently used in livestock are primarily products developed for other industries. For example, ScotEID uses readers developed by UHF manufacturers Impinj, Motorola, and CAEN. In Australia, a fixed UHF scanner specifically designed for local livestock conditions has been developed by Agriscan.

Dual Readers | Dual readers can read both LF and UHF tags. Dual readers may play a role in a scenario where an industry desired stakeholders to be equipped to use LF or UHF tags. However, in this scenario, or a transition to UHF scenario, UHF readers could be installed alongside LF readers without interference. For example, if the Australian cattle supply chain transitioned to UHF, LF readers would already be installed, and therefore UHF readers would simply need to be installed alongside the LF readers, making dual readers unnecessary.

2.3 Comparison between UHF and LF

2.3.1 Technology Comparison

The table below compares physical design, performance, and economic data between UHF and LF technology options. Cells shaded in green indicate the potential of higher suitability to the Australian livestock industry. Conversely, cells shaded in yellow indicate the potential of lower suitability to the Australian livestock industry when compared to the alternative.

Table 2: UHF and LF technology comparison

	UHF	LF
Tag Components	Flexible flat printed circuit with antenna.	Chip and copper wire air coil antenna.
Tag Design	1 or 2 piece flag tag, strip tag, wrap-around and button.	1 or 2 piece flag tag, wrap-around, button.
Frequency	868-915 MHz	125 – 135 kHz

	UHF	LF
Industries using technology	Numerous.	Limited (primarily livestock).
Read Range	Approx. 3-9 m. Read range is typically shorter with hand-held readers (approx 4 m). Read-range is adjustable.	Approx 80-140 cm. Read range can be shorter with hand-held readers (approx. 20-60 cm).
Anti-collision technology	Yes. One or multiple animals can be read at one time. Unconfined animals (eg. paddocks) can also be scanned.	Current readers installed in supply chains do not have anti-collision technology. One manufacturer is currently developing an LF reader with anti-collision technology.
Read Rate / Scanning speed	150 - 500 reads per second.	20 reads per second.
Tag Costs	Cattle: $1 - $3.35 Sheep: $1 - $2.00	Cattle: $2.75- $4.07 Sheep: $1.99- $2.10
Tag Weight	2-16 grams (approx.)	3 -10 grams (approx.)
Reader Costs	Fixed: $1500-$4000 Hand-held: $600-1600	Fixed (inc antenna): $3299 - $18000 Hand-held: $750-8000
Reader Size	Readers: Wide-range, smallest being matchbox size. Phone readers available (direct interaction with tag).	Readers: Usually small or large sizes, smallest approx 50x50cm (small). Phone apps available to transfer information from a stick reader.
Information storage	Multiple memory banks.	1 memory bank (Limited by ISO standard and data speed).
Data integrity/ security	Unique identifier means tags cannot be replicated, additional levels of security and anti-counterfeiting available.	Unique identifier means tags cannot be replicated.
Liquid interference	Medium (cannot read through a body of water).	No interference.
Tissue interference	Medium-high (cannot be used as bolus technology). Tag needs to be line-of-sight to the reader (i.e. not covered by another animal/ flesh)	No interference (can be used as bolus).
Metal interference	High metal interference. Can be minimised/ removed through reader set-up.	Moderate metal interference, with improvements over the last few years.
Conflicts	These technologies do not conflict with each other. This means that readers can be placed next to each other and read tags without interference. Or, both technologies can be in an ear tag, and there is no interference when read.	

LF technology delivers major benefits to livestock industries and has historically played a key role in improving traceability systems, allowing these systems to shift from mob-based to individual animal tracking. LF technology has been adapted and designed specifically for livestock supply chains and has been proven to provide a reliable long-term traceability option for various livestock settings. At points in the supply chain where animals are handled individually, LF scanning can be relatively seamless. Technical factors such as tissue or flesh not interfering with tag readings are also major benefits of this technology. Although data cannot be stored on the LF tag itself, stakeholders in livestock supply chains have utilised software to collect and store tag-related data off the tag, enabling the analysis of individual animal data (e.g. breeders). In many situations that require animals to be handled on an individual basis (i.e. scanning at feedlots), there are negligible advantages of UHF when compared to

LF technology. Significant advantages of UHF can occur, however, in animal management scenarios where UHF's adjustable read range and capability to scan multiple animals at once is useful. Additionally, UHF technology appears to provide a lower price point than LF. Details regarding these benefits are explored in more detail in the following section.

2.4 UHF benefits for livestock

The perceived benefits of UHF technology can be viewed from three perspectives; the traceability system, stakeholder value-add and future innovation opportunities.

The traceability system

- **Hardware cost |** UHF tags and readers are currently available at a lower retail cost than LF options. The large number of highly competitive UHF manufacturers globally could result in even lower UHF hardware costs, particularly if the sizable Australian red meat industry paved the way for widespread adoption. It is unknown whether the costs associated with future research and product development deemed necessary to meet hardware performance criteria for accreditation would be absorbed by the technology company or passed onto the industry in the form of higher hardware costs. The impact of various tag cost scenarios can be seen in a sensitivity analysis in Section 4.
- **Increased reading speeds & anti-collision technology |** The cost burden of compliance to a National traceability program can potentially be offset through higher scanning speeds and/or scanning multiple animals at the speed of commerce. If realised, improved scanning efficiency will have the likely effect of a reduction in the labour requirement. UHF anti-collision capabilities (reading multiple tags at once), read speeds up to 2,000 tags per minute, and read ranges in the order of 6 meters (Ahmed Bhatti et al., 2012) would reasonably translate into supply chain efficiencies observable at the following points in the supply chain:
    - **Producers |** Reduced time scanning during property-to-property (P2P) transfers by enabling individual or multiple animal scanning via fixed or handheld readers.
    - **Saleyards |** Although animals are handled individually at saleyards through drafters, the typical LF scanning process can add additional time in drafting (e.g. due to scanning speed). The so-called 'mop up' phase or second pass can also add additional time, where agents re-tag and/or re-scan animals in pens to rectify data anomalies. The performance of UHF technology in an Australian saleyard is uncertain, however it is expected that the ability to scan individual or groups of animals (adjustable read-range) and higher read speed offered by UHF could be practically arranged to deliver improved saleyard efficiencies when compared to LF technology. *Note: Best practice reader set-up in these environments would need to be designed and trialled in future research.*
- **Increased and/or improved animal movement data |** According to a trial by ScotEID (2021), UHF technology provides new possibilities to increase supply chain data volume and integrity. This could be achieved by installing reader(s) on livestock transport trucks to scan multiple animals simultaneously, thus reducing the reliance on producers and agents to scan during P2P transfers. UHF readers could also be installed at additional points in high contact locations to passively gain more detailed movement data (e.g. additional UHF readers installed at different points of saleyards collecting additional animal movement data).

Stakeholder value-add opportunities include:

- **Property data collection opportunities |** Due to the lower relative cost of UHF readers, producers could position readers at key locations throughout a property to monitor animal movements. Producers could collect and process data that captures information on animal location, behaviours and productivity metrics by using suitable software applications. Other stakeholders, such as feedlots, could also collect property data, such as how much feed an individual animal consumed. Additionally, tags can be used to store this data, meaning readers do not need to be connected to the internet to capture and communicate this data.[1]

- **Data storage |** Using the data storage capabilities of UHF tags, information could be shared between supply chain segment groups. For example, with suitable supporting software, feedlots could access animal health information via animal tags, rather than manually following up on this information. Principles surrounding data ownership and data alterability need to be assessed in future development research.

Innovation opportunities include:

- **Benefitting from global investment and innovations |** The majority of global investment in RFID technologies is now in HF (High frequency) and UHF, with numerous companies developing UHF transponders and reading equipment globally[2]. With a smaller number of LF tag and reader manufacturers in Australia and globally, the innovation potential of LF would appear constrained, and there is low market competition to encourage reductions of costs in the long term. As UHF is heavily invested in globally, innovations are occurring frequently in this space, with the technology's capabilities and range of products available growing yearly. These innovations range from increases in read range to smaller readers and tags. While there are currently only a limited number of UHF livestock tag suppliers globally, findings from this project indicate that several UHF manufacturers are involved in developing UHF tags suitable for long-term livestock applications. It is worth noting that no Australian companies developing UHF livestock tags were identified.

2.5 Progress on addressing UHF technical issues

Key areas that stakeholders identified as being of high importance in the assessment of UHF technology were tag durability and retention, interference, and data security and policy. The suitability of UHF readers and antenna for livestock environments was also of high importance.

2.5.1 Tag Retention

The ability of a tag to be physically attached to an animal is a fundamental requirement of any tag used for the purpose of livestock traceability. There are a variety of practical challenges that result in lost or missing tags which include; the natural behaviours of livestock such as sheep putting their heads through fences and tags being caught and ripped out, on-farm and supply chain processes such as the act of shearing, human factors which rely on producers or agents to apply tags correctly all of the time, and harsh Australian environmental conditions such as UV exposure that can lead to plastic tags becoming brittle and breaking off. Overall, achieving the highest possible levels of tag retention is a key challenge that is equally applicable to all forms of RFID that involve the physical attachment of a tag to an animal for its lifetime.

To date, UHF livestock tags have been primarily designed for short-term use scenarios such as in feedlots in the US. This has meant that most of the commercially available UHF tags have been designed to be applied to cattle on induction and therefore only need retention for 60-100 days on feed. However, a USDA UHF cattle demonstration project in 2016 reported excellent retention (100%)

[1] In this scenario, readers could be powered by solar panels.

[2] Research and Markets report "RFID Market with COVID-19 Impact Analysis by Product Type (Tags, Readers, and Software and Services), Wafer Size, Tag Type (Passive Tags and Active Tags), Frequency, Applications, Form Factor, Material, and Region - Global Forecast to 2026" shows the UHF tags segment of the RFID market is projected to register the highest compound annual growth rate (CAGR) during the forecast period of all RFID technology types.

over 6 months to 1.5 year trial periods (USDA, 2016), suggesting a higher retention level is possible with current UHF tags.

There is limited data concerning livestock traceability systems worldwide that have sought to use UHF for lifetime traceability. ScotEID has worked directly with providers to develop long-term tags and has had two officially approved for use in traceability systems. Anecdotal evidence suggests these tags have been on some cattle for 10+ years. Similarly, long-term tags have been designed by AniTrace and are currently used in the US. However, these tags are available at a retail cost of ~USD $3.50, similar or slightly higher to that of LF tags in Australia. Tag retention represents a key issue and will require minimum performance levels to be demonstrated before being accredited for use.

2.5.2 Tag Electrical Durability

One of the most common concerns regarding UHF tags is the potential for internal components to be damaged. The origin of this concern can be attributed to how the transponder electrical components are arranged within the tag, discussed in Section 2.1.2. In some UHF tag configurations, the transponder has the chip component and antenna component connected via a small wire. This particular transponder configuration is cost-effective and simple to manufacture, however has been reported to be susceptible to breakage.

This issue has been reportedly overcome by inductive coupling or improving the tag casing design/material. While both approaches would provide a more robust transponder design, this could increase the cost of the tags. Inductive coupling removes the need for a physical connection between the chip and the antenna within the transponder (the common breakpoint), allowing the tag to be flexed without breaking the connection or detuning (Moraru, Ursachi, & Helerea, 2020). Inductive coupling, and a more robust tag design, have already been applied to the design of livestock tags used in Scotland. Recent UHF transponders also can house two antennas, providing redundancy in the case of breakage and a more durable transponder. Designing transponder tag casings specifically for UHF technology, with reinforced casings, protective coatings, and tamper-resistant features, can further enhance their durability. Fort Supply's strip tag, for example, is specifically designed for UHF, and involves an 'air-pocket' that the UHF transponder sits in, allowing the tag to bend and flex without damaging the electrical components.

2.5.3 Animal Flesh/ Liquid Interference

Liquids (or flesh) between the transponder and transceiver have previously been reported to reduce UHF RFID performance by absorbing radio waves, which can result in signal attenuations (signal loss or distortion). The amount of signal loss depends on several factors, such as the dielectric constant (electrical permeability of a material), conductivity, and viscosity of the liquid (Benelli & Pozzebon, 2013). In livestock settings, animal flesh (or blood) is the main element that can interfere with tag reads.

Several factors have been considered to optimise UHF RFID performance around flesh, including the frequency used, the antenna design, and/or the positioning of the tag and reader. For example, placing readers that allow for a direct line-of-sight between the tag and the reader is required to achieve high read rates. This has been experimented with in various trials, including the USDA demonstration project, where readers were placed above the animals (as opposed to on the side of a race) (USDA, 2016). Another set-up that reduces the impact of flesh is the use of a metal arch to reflect the radio waves, essentially "bouncing" the antennas activating radio waves around the areas animals are moving through. This set-up has been used in Scotland, and has reduced the potential of a tag being missed due to animal flesh interference.

2.5.4 Metal interference

Metal can reflect UHF radio waves, causing multipath interference, where the reflected waves interfere with the original signal, leading to signal loss or reduced read range (Aroor & Deavours, 2019). Factors that affect the extent of metal interference include the composition of the metal, and the size, shape, and proximity of the metal object to the tag and reader.

Strategies to minimise the impact of metal interference on UHF systems include enhanced tag designs, and techniques that adjust the power and frequency of the RFID reader to minimise signal loss and interference. For example, tags can be designed with specialised shielding or antennas, improving performance around metal. These strategies would be essential to ensure UHF tags are consistently readable in high metal livestock environments, such as processors.

There is also concern that metal could interfere with reading accuracy in complex livestock environments. For example, if a signal is reflected on metal, the reader could pick up a tag/animal that was not intended to be scanned. Future UHF trials would need to assess the accuracy of UHF in complex environments, where scanning the correct animal(s) is critical.

The proper design of UHF systems can also utilise metal to support and/or improve tag reads, as described in the Scotland saleyard example in the previous section of this report, where metal archways were used to contain UHF signals, and improve read rates. A 2019 UHF sheep trial in France showed that read rates were higher in areas in closer proximity to metal fences, rather than wooden fences (Duroy et al., 2019).

2.5.5 UHF Reader Durability and Usability

High durability of UHF readers and a simple user experience are also critical requirements for any radio frequency-based identification system used in an Australian livestock environment. There are currently a limited number of UHF readers available that are specifically designed for livestock environments, however, durable off-the-shelf readers designed for use in other industries such as logistics, have been successfully adapted and used in livestock settings.

Fixed Readers & Antenna | Australian technology company, Agriscan, has developed a purpose built UHF reader for livestock management that is reported to be highly durable, and the associated software allows the reader performance to be customised to different scenarios. Fixed readers and antennas installed in Scotland and the US have been off-the-shelf, originally designed for various industries and environments different to those experienced in livestock, including warehouse systems where the hardware is exposed to extreme temperatures (e.g. cold storage) and other environmental conditions (e.g. collisions and water cleaning).

Handheld readers | As identified in Section 2.2.2, handheld readers supplied by livestock companies and off-the-shelf readers designed for other industries are currently being used in livestock settings. Software included within these readers can range from basic to advanced functionality and usability. Stakeholders consulted in this project indicated that the usability and durability of both fixed and handheld readers used in their livestock environments were fit for purpose.

2.5.6 Read rate comparison

The requirement of any traceability system to achieve a high read rate (the percentage of animal tags read during a transfer) is critical to ensuring system accuracy and efficiency. Commercially available LF tags used for traceability purposes in Australian livestock supply chains must be ISO compliant (ISO 11784 specifies the animal radio-frequency (RF) identification code structure, ISO 11785 specifies how a transponder is activated and how the stored information is transferred to a transceiver) and NLIS accredited (LF readers only need to be ISO compliant). NLIS accreditation involves lab testing and field-based trials. This process is designed to ensure that the industry has access to technology that is fit for purpose. In a perfect system, tag read rates of 100% would be achieved. However, livestock industries globally have accepted lower performance targets and monitor the system performance accordingly.

It is commonly accepted that several events can occur within any radiofrequency system that have the potential to reduce the scan read rate of animals, including;

1. Lost tags (tags become detached from the host animal).
2. Reader malfunction (e.g. disconnection from power).
3. Incorrect reads. For example, an animal is being scanned at drafting, the scanner identifies a different animal. Or the tag is tuned to a broader bandwidth than the reader.
4. Transponder failure (the transponder inside the tag stops working due to manufacturing error or tag damage).

In regards to current Australian LF system read rates, there is limited data available. The Victorian Government stated in a 2020 report that sheep saleyards are regularly reporting read rates in excess of 99% (Agriculture Victoria, 2020). Engagements in this project and prior TGD livestock traceability projects indicate that LF read rates can vary substantially. A significant time inefficiency identified at saleyards concerning LF technology is known as the "mopping up" period, adding anywhere between 2 to 6 hours on sale days. Animals are initially scanned upon drafting, and an additional second scan is required to reach an acceptable read rate.

Table 3 summarises the reported UHF technology read rate performance in various trial scenarios.

Table 3: UHF trials - read rate summary

Trial Details	Trial Description	Trial Details	Read Rate results
Ultra-High Radio Frequency Identification Demonstration Project **Year |** 2014 **Species |** Cattle	UHF demonstration projects in 8 different states in the US, assessing UHF potential for collecting animal identification and animal health information to support traceability/ disease response.	Project coordinators reported on tag readability for both 118mm and 77mm length tags. 66,015 tags were applied across the 8 states.	Performance summary: ● 100% readability if tags and readers were installed correctly. ● No reports that size of tag impacted readability.

Trial Details	Trial Description	Trial Details	Read Rate results
In field assessment of UHF technology for sheep electronic identification (France). **Year |** 2019 **Species |** Sheep	Trials were conducted at locations with wood or metal portal set-ups.	Total number of animals involved in trial unavailable. Number of animals per reading passes: ● Wood fences | Batches of 50, 70 and 110 ewes. ● Metal fences | Batches of 50, 90 and 130 ewes.	Performance summary: ● Wood fences | 99.1% average read rate across 28 single pass readings. ● Metal fences | 99.8% average read rate across 19 single pass readings.
CattleTrace Inc. Pilot Project Findings: August 1, 2018 – June 30, 2020 (US). **Year |** 2020 **Species |** Cattle	This pilot was conducted across the cattle supply chain, to understand the infrastructure required for a traceability system, and to evaluate UHF technology.	Number of animals in pilot: ● Cow/Calf Facilities: 235 ● Backgrounder Facilities: 23,542 ● Livestock Market Facilities: 34,222 ● Feedyard Facilities: 431,592 ● Packer Facilities: 99,877 Total Reads: 589,465	Performance summary: ● Cow/ Calf: 99% ● Livestock Market / Saleyard: 95.18%, 97.73% ● Feedlot: 89.57% (alleyway), 92.46% (single file) ● Packer/ Processor: 88.9% (alleyway), 84.07% (single file)

These trials demonstrate that a high UHF read rate for sheep and cattle is possible in a single pass (e.g. without 'mopping up' after the first scan). In the USDA demonstration project, it was found that UHF tag readability was 100% when readers were in correct set-ups (above the area animals are moving through, creating line-of-sight between the reader and tag). When comparing UHF and LF read rates, it is important to note that these UHF trials are conducted under controlled environments and do not necessarily indicate the read rates of tags used in the long term (as with LF tags currently in the Australian system). While the 2020 CattleTrace trial could provide a possible comparison, the reasons behind lower read rates are unknown, and several variables (e.g. incorrect reader setup, the brand of tag) limit the ability to form a fair comparative conclusion.

Available UHF studies measured read rates under different conditions, using different UHF system setups, and showed that UHF was fit for purpose in most cases. They compared well to the current level of scan read rates reported in the current working LF systems in Australia.

It is recommended that future time-in-motion activities and read rate studies be conducted to form a body of evidence regarding read rates in LF systems in cattle, sheep and goat supply chains, including the initial 'first pass' read rates versus the 'mopping up' period at saleyards. This will be critical in creating robust, future comparisons between LF and UHF read rates.

2.5.7 Standards, accreditations and regulations barriers

One of the most significant barriers to the immediate adoption of UHF technology in livestock is the absence of International Standard Organisations (ISO) standards, which set standards around RFID technology in livestock internationally. The main standards for RFID in livestock currently apply to low-frequency RFID technology only (ISO 11784 & ISO 11785).

ISO 11785 is the standard that primarily impacts the use of UHF in livestock. The ISO-approved frequency standard is 134.2 kHz, whereas UHF devices can operate between 300MHz- 3GHZ (see diagram below), with Gen 2 UHF devices operating at 860 MHz - 960 MHz. A recent ISO committee meeting was held to discuss ISO standards for encoding UHF tags for livestock. A draft ISO standard for UHF is currently available and the finalised standard is likely to be ISO 6881: Radio-frequency identification of animals – Code structure ultra high frequency transponders.

Despite this positive progress on ISO standards, without final UHF ISO standards, it is doubtful whether the required flow-on activities in research and development would occur. Figure 5 demonstrates this situation, showing a system that relies on international standards (1) and accreditation (2) to ultimately inform Australian and NLIS standards (3 & 4) surrounding device accreditation (5) and RFID numbers (6). It is worth noting that following ICAR certification, devices must be approved for use in NLIS through ISC. NLIS accreditation trials last for three years (often lasting longer due to trial challenges e.g. droughts) and, if results are strong after six months, the NLIS provides for conditional device approval.

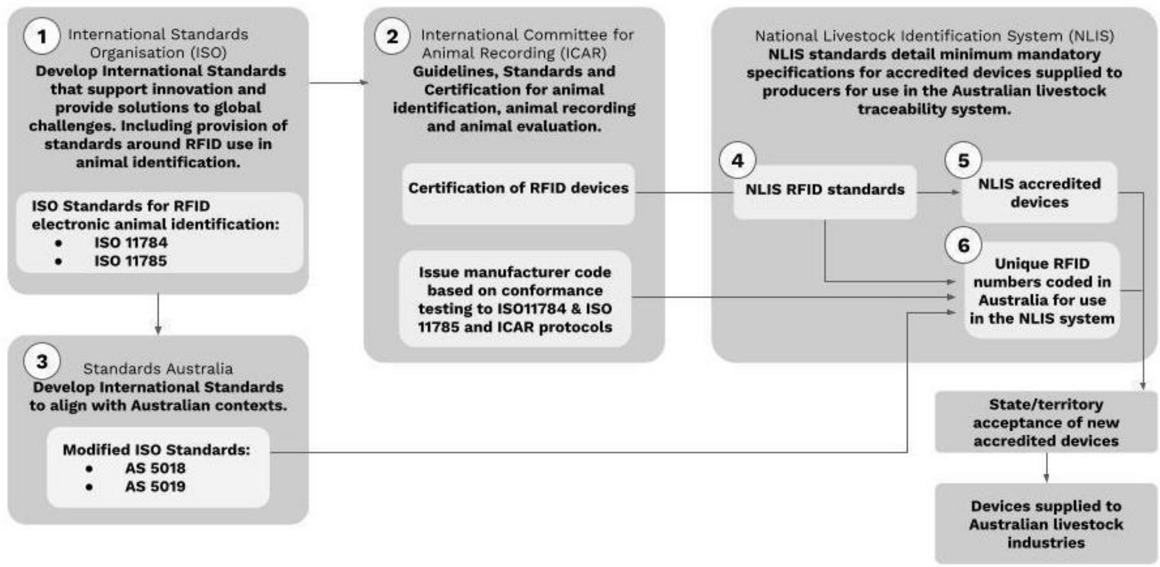

Figure 5. Australian technology & device accreditation system

Without ISO standards in place, and with national and state regulations locking supply chains into LF technology, there are limited incentives for major livestock technology companies to invest in R&D regarding UHF technology, as there is little to no current demand to supply life-time UHF tags/ readers to Australian livestock industries. For progress to be made in UHF technology in lieu of international standards, industry intervention is likely required to develop the technology further and demonstrate value. Section 3.2.2 explores opportunities to overcome this regulatory barrier through the use of interim standards.

2.6 UHF technology capabilities review takeaways

Positive progress has been demonstrated through global UHF technology pilots in the areas of tag retention, durability, and the affect of metal and liquid interference on the tag performance. However, it is anticipated that further research and product development will be required to deliver the standard of reliable technology performance that the Australian livestock industry will require for its traceability system.

While UHF is likely to be technically feasible for use in Australian livestock commercial contexts, further research and trials are required to validate current capabilities of UHF and identify areas that could be overcome through technology development opportunities. The current barrier to UHF development appears to be the absence of ISO standards, and in lieu of commercial incentives for LF livestock technology providers to develop UHF offerings, UHF development will likely need to be progressed and funded via industry R&D funds in the short term.

3. Development Timeline & Adoption Pathways

3.1 Overview

This section provides insight into potential adoption pathways for UHF in an Australian livestock setting. The two components of this section are:

1. Timelines indicating when UHF technology would feasibly be available to Australian livestock industries based on the need to conduct field trials, develop standards, and adjust regulations.
2. Adoption pathways for UHF technology when the technology has been sufficiently proven to fulfil or improve traceability, there are clearly demonstrated benefits for industry stakeholders, and there is industry and government buy-in. These pathways informed the structure of the CBA analysis.

These timelines and adoption pathways play a pivotal role in framing the CBA analyses. The timelines and adoption pathways demonstrate that it would be a minimum of 4+ years before UHF would be available for widespread implementation in cattle, sheep and/or goat supply chains. Future UHF work should adapt and build upon these outputs as additional information becomes available.

3.2 Technology development & standards timeline

Gaining insight into the likely timelines associated with UHF technology development is crucial for shaping adoption strategies and conducting CBA analyses. It offers valuable context regarding the Australian livestock industry and technology landscape around the anticipated adoption period of UHF.

Two technology development timelines are presented in this section. The first adheres to past approaches of integrating new technologies into the NLIS in a linear fashion, while the second explores potential modifications of the traditional pathway to expedite the adoption of UHF. These timelines are approximations based on input from experts and key industry stakeholders. They illustrate that technology development timelines consist of both fixed and adaptable components. Depending on the industry's aspirations and financial resources, timelines can be subject to adjustments. By understanding these timelines, stakeholders can make informed decisions regarding the optimal adoption pathways and assess the potential economic benefits of implementing UHF in the livestock sector.

3.2.1 Timeline 1: Traditional Approach

In Timeline 1, the initial phase involves the establishment of global standards and accreditations specific to UHF technology as a first step. This sequential approach mirrors the standard procedure for implementing novel electronic animal identification technologies in Australia. A similar process was successfully undertaken during the implementation of Low Frequency (LF) animal identification for the Australian cattle supply chain (see Figure 5 for reference).

Shifting focus to the present state of UHF international standards development, currently only draft UHF ISO standards are available, with an anticipated publication date of two years from now (2025). Figure 6 demonstrates that these standards serve as a pivotal barrier to UHF development since they act as a foundational point for other system activities, such as ICAR (International Committee for Animal Recording) certification. Any changes to the ISO publication schedule could either expedite or delay the progress of technology development and adoption. Future consideration of UHF as a possible technology for use in Australian livestock must involve direct engagement with the ISO standards committee to gain a clearer understanding of the timeline concerning standard development and ICAR certification. A proactive approach will provide valuable insights and enable better planning for UHF implementation, ensuring a smoother and more efficient technology transition.

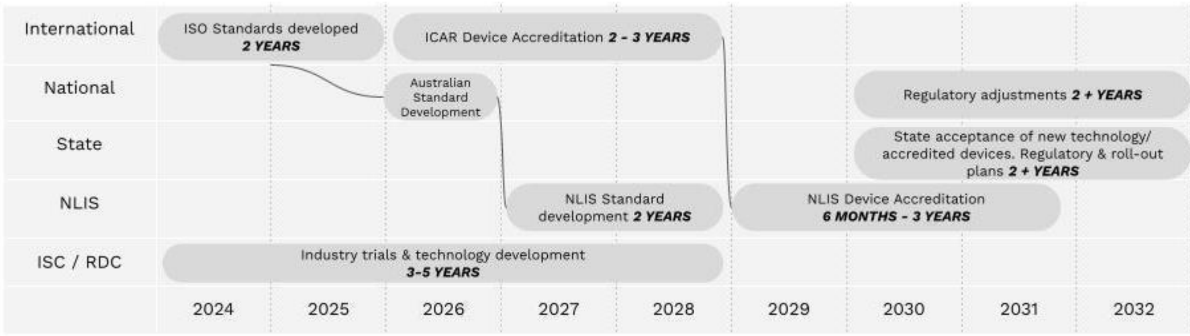

Figure 6. Timeline 1: Traditional Approach

3.2.2 Timeline 2: Accelerated Approach

Timeline 2 (Figure 7) explores the possibility of implementing interim National standards to expedite NLIS accreditation and UHF adoption in the supply chain. Drawing inspiration from Scotland and the US, this approach has been successfully utilised to advance the adoption of UHF technology for traceability purposes while awaiting international standards. By studying the experiences of these countries and collaborating with ISO/ICAR to understand the likely framework of international standards, Australia can proactively introduce UHF technology to the livestock supply chain within a shorter time frame of 4-7 years, as opposed to the 7-9 years required by the traditional pathway.

Figure 7. Timeframe 2: Accelerated Approach

To achieve this accelerated timeline for UHF technology adoption, a combination of the following measures are recommended by various stakeholders ;

1. RDC's and peak bodies: Dedicate industry funds to conduct the next stage of UHF technology research and trials.
2. Standards Australia & ISC: Develop interim standards to signal the intention to adopt UHF technology and the need for new product offerings from technology companies. Conduct NLIS accreditation trials for UHF technology.

3. NLIS and state government agencies: Assess impact of interim standards on databases, estimate the costs of transitioning, and required industry and governance support. State Governments should also review UHF research and development trial results, NLIS device accreditation field trial results, and adjust regulations accordingly to accredit UHF devices.
4. Technology companies: Contribute to the execution and planning of UHF technology trials, and provide input to interim standard and regulatory adjustments as requested. Conduct further research and development to deliver new UHF based technology offerings suitable for Australian livestock settings.

To justify the development of interim Australian standards in the accelerated timeline approach, confidence in the performance of UHF technology and its ability to meet industry requirements is essential. There are also inherent risks associated with the development of interim Australian standards before the completion of international standards currently under consideration. If interim standards are developed that deviate substantially from the international standards concurrently in development, it could necessitate significant financial resources and time to make necessary revisions. To mitigate this risk, Standards Australia and the NLIS must prioritize open communication with their international counterparts and take proactive steps to collaborate closely with manufacturers and the broader industry. This collaboration should aim to devise Australian standards that align effectively with the needs of the Australian red meat industry and seamlessly harmonize with forthcoming international standards.

Further research and carefully designed field trials are necessary to gain industry buy-in and assess the technology's technical viability in use. The accelerated timeline suggests UHF could be available for national traceability by 2027/28. This assumption informs adoption pathways and CBA scenarios, considering that LF RFID systems will remain in use in cattle, sheep and goat supply chains until UHF's potential widespread adoption.

3.3 Adoption pathways

3.3.1 Overview

The time frames presented in the preceding section indicate that the implementation of UHF technology is presumed to take place in a future scenario where the livestock supply chains of cattle, sheep, and goats are currently utilizing LF technology.

Shifting from LF to UHF technology presents a distinctly different challenge for stakeholders compared to transitioning from visual tags to electronic tags (i.e. moving from low technology to electronic technology). The latter requires extensive stakeholder engagement to develop technology literacy and support technology adoption throughout the supply chain. However, when moving from one type of RFID to an alternative, challenges related to stakeholder technology literacy would likely be reduced as experiences with LF technology are somewhat transferable to UHF technology use. Nonetheless, the main challenge lies in the lack of interoperability between the technology reading systems and associated software. LF tags cannot be read using UHF readers, and UHF tags cannot be read with LF readers. This creates a significant interoperability hurdle that necessitates careful management through a well-structured adoption pathway.

Below is a summary of considerations for the development of detailed adoption pathways:

1. **Ensuring traceability system integrity:** Maintaining the reliability of the Australian traceability system is crucial during the transition to a new technology.
2. **Assume widespread multi-species LF technology usage:** Given the 4-9 year development timeline, it is assumed that cattle, sheep, and goat supply chains will be using LF technology. All players in these supply chains will already have LF scanning technology in place.

3. **Differing tag lifespans:** Tags remain in different species' supply chains for varying timeframes, ranging from a few weeks to several years. Transition planning must account for existing LF tags and ensure compatibility with the next-generation technology for seamless traceability. Estimated times per species are as follows; Lambs 1-1.5 years, Sheep 3-6 years, Goats weeks - 3 months, Cattle, 1-4 years (meat), 3-8 years (dairy), and 4-8 years (breeders).
4. **Time for trialling and installation:** Trialling and installing technology at critical control points like feedlots, saleyards, and processors can take up to 6 months. Ensuring functional equipment at these points is essential for robust traceability data, necessitating extension activities throughout the supply chain.
5. **Role of agents:** Agents play a critical role in scanning during P2P transfers and need to be equipped and educated with the necessary scanning equipment and software.

Three pathways have been developed for technology transition:

- **Pathway 1:** Shift directly from LF to UHF.
- **Pathway 2:** Use dual tag technology as a 'bridging' technology to transition from LF to UHF.
- **Pathway 3:** Producers are provided the opportunity to adopt dual technology on a voluntary basis to gain on-farm benefits.

Future iterations should build on these pathways as more information is gathered regarding technology costs, benefits, regulations, standards, and industry willingness to embrace change.

3.3.2 Pathway 1: LF to UHF

Overview | The industry undergoes a transition from LF to UHF by gradually introducing UHF tags into the system. During this period, supply chain stakeholders perform scanning for both LF and UHF. UHF tags are introduced into the system through new calves, kids, or lambs, as well as animals preparing for P2P transfers that have not yet been tagged. This gradual introduction continues until the majority of the national herd is tagged with UHF technology, a process that would likely span 3-7 years.

Timeline |

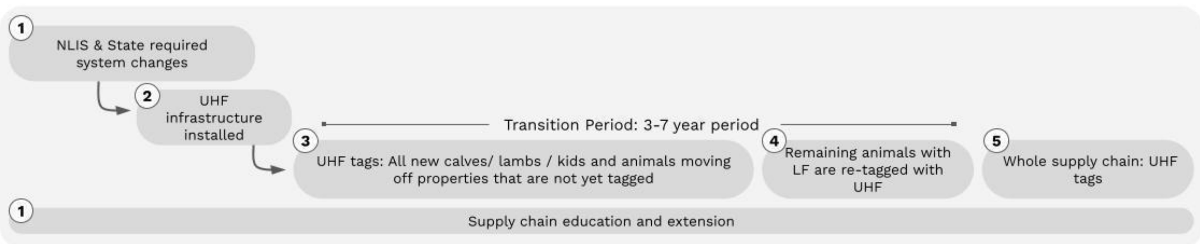

Figure 8. Pathway 1 Timeline

Pathway Features |

1. The NLIS Database, State Government systems, and software/integrations with NLIS undergo upgrades to accommodate UHF tag data. A clear transition plan and timeframe are communicated to supply chain/s, with ongoing education and extension support provided throughout the process.
2. Critical control points (CCP) install UHF readers alongside LF readers before UHF tags are introduced. For processors, this entails placing UHF readers next to LF readers, while saleyards may adopt scanners installed over portals. Trials are conducted to ensure CCPs can scan both UHF and LF tag types once the supply chain starts adopting UHF. Agents and/or producers receive hand-held or fixed UHF scanners for their use.

3. All new kids, calves, lambs, and/or animals moving to another property or a CCP are tagged with UHF tags if not already tagged. Supply chain stakeholders utilise UHF and LF scanning equipment to ensure all tags are effectively read.
4. Over a span of 3-7 years, as most animals in the system become tagged with UHF as their first tag, the remaining animals would have LF tags removed and replaced with UHF tags. Supporting systems and software may be required to link removed LF tags to new UHF tags in the NLIS system, maintaining lifetime traceability.
5. Throughout the supply chain, benefits from UHF technology are effectively captured. LF readers are no longer used and are removed from CCPs, streamlining the adoption of UHF technology.

Table 4: Pathway 1, Challenges and Solutions

Challenges	Solutions
● Ensuring CCPs and producers/ agents can scan both types of tags. Missed scans due to confusion/ incorrect reading equipment/ issues with running both LF and UHF reading equipment could lead to reduced traceability. ● The extended time of this transition could lead to stakeholder fatigue and dissatisfaction with the transition. ● Places such as saleyards will be unlikely to gain major benefits until the entire supply chain has transitioned to UHF. During the transition, these stakeholders would have to manage scanning both technologies, likely adding more time and costs to sale days. ● Labour associated with re-tagging animals with UHF tags.	● Conduct trials of different scales to understand the complexity of scanning for both tag types. ● Ensure there are robust extension activities and transition communications to reduce scanning errors/ challenges. Stakeholders such as agents are educated on UHF technology to support the transitions. ● Use trial results to create evidence-based and detailed assessments of the time and costs associated with the adoption pathway. Communicate these findings clearly to the industry to ensure that stakeholders supporting/ asking for a transition to UHF understand this transition's short-term time/costs burden.

3.3.3 Pathway 2: Dual technology approach

Overview | The industry makes a gradual transition to UHF technology by using dual tags as a "bridging" technology. This approach allows supply chain stakeholders to adapt to the technology and adopt scanning equipment without compromising national animal traceability.

As discussed in Section 2.2, dual technology transition can be achieved by two technology combination options - a tag with both LF and UHF technology integrated into it, or a reader capable of simultaneously scanning both types of technology. Since LF readers will be already installed in the supply chains, the need to explore dual readers is unnecessary, as UHF readers can be installed alongside LF readers without interference. Dual tags would therefore be the main dual technology used in a transition, ensuring that if stakeholders do not yet have UHF scanners (or there are other complications surrounding adoption), animals can still be scanned using existing LF readers in the system. Dual tagging is available in three main forms:

1. LF tag in one ear, UHF tag in the other.
2. Combined one-piece tag, with both technologies embedded in the same piece.

3. Two-part tag where one part of the tag is UHF, and the other part is LF, secured together through the ear to make one piece (APK-ID currently offers this form of tag, where the UHF male flag is paired with an HDX LF button).

Options 2 and 3 are assumed to be the dual tag technology used in this scenario, as their UHF and LF ID numbers could be linked upon manufacturing, or the same number encoded (allowing stakeholders to scan with either UHF or LF technology, and the same animal being traced in the NLIS system).

Timeline |

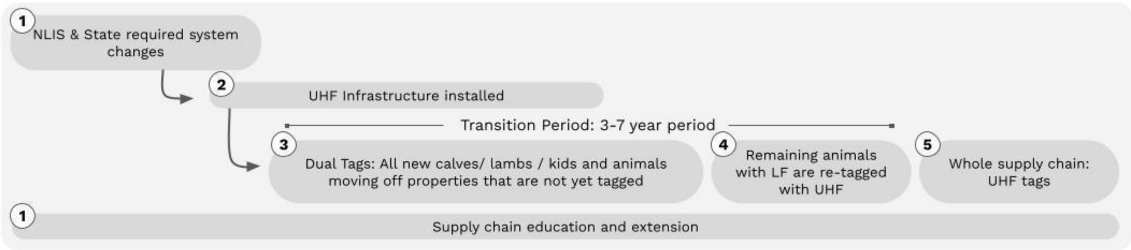

Figure 9. Pathway 2 Timeline

Pathway Features |

1. The upgrade process begins with the NLIS Database, State Government systems, and software/integrations to accommodate UHF tag data. A comprehensive transition plan and timeframe are communicated to all stakeholders within the supply chain(s), with ongoing education and extension support provided throughout the transition period.
2. Clear timelines are provided to CCPs, producers, and agents, outlining the necessary hardware and software adoption requirements. Adequate support and resources are made available to help them to develop a thorough understanding of the UHF technology.
3. The adoption of dual tags is implemented in a phased manner. All new-season kids, calves, lambs, and animals yet to be tagged destined for another property or to a CCP, are tagged with dual tags. This practice continues for 1-2 years, after which all CCPs are required to have UHF readers installed.
4. As the number of LF tags in circulation reduces significantly, the industry initiates a shift from dual tags to exclusive UHF tag applications. Any remaining LF tags are replaced with UHF tags when animals depart a property and are scanned for registering a transfer on the NLIS database. To maintain lifetime traceability, supporting systems and software ensure that these removed LF tags are properly linked to the new UHF tags in the NLIS system.
5. Dual tags and UHF tags coexist within the system, enabling all tags to be read using UHF readers. LF readers become obsolete and removed from CCPs as they are no longer required in the updated technology landscape.

Table 5: Pathway 2, Challenges and Solutions

Challenges	**Solutions**
● Dual tags will likely cost more than LF tags, which could reduce industry appetite for a transition. Therefore, industry buy-in must be high enough to bear this higher cost in the short term. ● Dual tags have not yet been widely developed and require extensive trialling/ testing. A level of technology manufacturer engagement would be	● A cost reduction approach to dual tags and business models that explore novel funding and government support mechanisms to assist with industry transition. ● Conduct trials exploring dual tags currently on the market or developed/researched by UHF technologists (e.g. Agriscan). If there is sufficient

required to support the development of durable dual tags. ● Transitioning mindset. Stakeholders that prefer LF technology will not utilise the dual technology period to adopt the appropriate infrastructure, possibly resulting in traceability challenges when UHF is fully adopted. ● Labour associated with re-tagging animals with UHF tags.	industry and government buy-in for a dual tag transition, RDCs and peak industries should support the development of robust, long-term dual tags. ● State governments conduct compliance exercises (similar to that conducted for LF) to ensure stakeholders have the correct scanning equipment and are uploading UHF data to the NLIS database. ● Ensure sufficient industry buy-in for transition to UHF. Ensure stakeholders understand short-term burdens/ costs involved in transition (e.g. dual tag cost, labour associated with re-tagging animals)/.

3.3.4 Pathway 3: Voluntary adoption

Overview | Producers can voluntarily adopt dual-frequency NLIS-approved devices. This pathway provides an opportunity for producers to receive value from UHF without necessarily shifting entire supply chains to UHF.

Timeline |

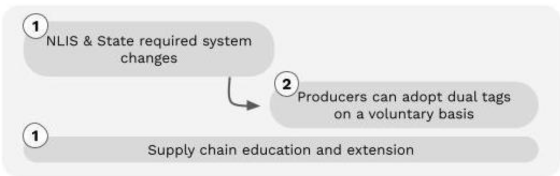

Figure 10. Pathway 3 Timeline

Pathway Features |

1. The process of NLIS accreditation of dual tag devices is initiated, accompanied by appropriate adjustments to the NLIS database to enable producers to upload dual tag movement data, encompassing both LF and UHF animal ID numbers linked to their PIC. State Government systems and software integrations with NLIS are upgraded to seamlessly accept UHF tag data.
2. Producers voluntarily adopt dual tags, allowing them to efficiently collect mob-based and individual data on-farm and conduct P2P transfers with greater ease. Since these devices would be required to be NLIS approved, this option remains available to producers indefinitely. Other points of the supply chain (other producers, saleyards and processors) continue using and scanning for LF technology, as the primary technology in the system (with limited or no software or system changes required).
3. If voluntary adoption of dual tags demonstrates notable UHF benefits that apply to other segments of the supply chain, it could generate significant industry and government support. Such momentum could lead to a broader shift from LF to UHF technology throughout the entire supply chain. A comprehensive whole-of-supply chain adoption pathway would then be collaboratively developed to facilitate a smooth transition to UHF across the industry.

Table 6: Pathway 3, Challenges and Solutions

Challenges	**Solutions**

● Gaining interest from technology providers to develop a robust, lifetime traceable dual tag that may have a smaller producer customer base. ● Saleyards will see limited benefit in a voluntary scenario, as animals arriving at saleyards will have a mixture of LF and dual tags.	● Conduct UHF trials on-farm to understand the benefits of UHF for producers better. Develop an understanding of market size based on these findings and producer interest. ● Upon securing a market that justifies dual tag research & development, collaborate with technology providers to design a robust dual tag. ● Support collaborations between saleyards and producers to encourage dual tag use and allow saleyards to justify UHF reader investment and use for some livestock batches/mobs.

3.3.5 Future pathway development

This section has provided an overview of potential pathways to transition Australian livestock industries to UHF technology, or alternatively, provide the option of voluntary adoption to capture a portion of the benefits UHF presents.

Transitioning directly to UHF (pathway 1), entails significant change management complexity to ensure that all stakeholders can scan both types of technology from the outset. However, initial assessment suggests that this pathway has the potential to compromise animal traceability performance and lead to delays when conducting transfers, if challenges arise during the scanning process. On the other hand, the dual technology pathway (pathway 2) offers a more gradual transition, reducing the risk of compromising animal traceability performance. Stakeholders can rely on their existing knowledge and infrastructure surrounding LF technology throughout the process. The economic analysis in Section 4 explores the relative costs and benefits of these two pathways. Regardless of the chosen pathway, a voluntary adoption period allows the industry to explore additional benefits from UHF without fully transitioning the entire supply chain to UHF technology.

For future adoption pathway development, it will be essential to incorporate the species-specific needs and variables. For instance, the goat supply chain might temporarily transition to dual tag devices for one year, before directly adopting UHF, given the specific tagging and harvesting timelines involved in the goat supply chain. On the other hand, the cattle supply chain may require a longer transition period due to the timeframes that animals and tags remain in the system. Moreover, the decision of whether all species should transition to UHF or only certain species, where the most benefits are observed, warrants careful consideration. This choice could impact stakeholders differently, such as some producers who own both sheep and cattle needing to use both LF and UHF scanning equipment. Therefore, a broad impact assessment is necessary to explore the collective benefits of having a unified livestock supply chain where all species use the same technology. In making such decisions, it is crucial to consult with the respective peak industry bodies and state governments. Their input and involvement are essential in shaping the best course of action for the industry's sustainable progress.

4. Cost- Benefit & Stakeholder Effects Analysis

4.1 Introduction

This CBA was developed to estimate and report the costs and benefits of adoption of UHF-based Electronic ID (EID) technology for animal traceability in cattle, sheep and goats. The CBA assessed the costs of adoption pathway 1 (UHF-only) and 2 (Dual) (Section 3.3), against the cost of maintaining a LF system. The purpose of these analyses is to provide data to inform future decision making in relation to UHF technology research and development activities, and provide visibility on the various adoption pathway options if the Australian livestock industry intended to execute a transition to the UHF alternative. This CBA is not an extensive costing exercise, and should be used as the foundation to conduct more detailed costing.

The CBA analysis is broken down by cattle and sheep species and each industry was analysed independently. Also, while goats were originally scoped to be included in the CBA, there was not enough industry data to support an analysis for this species (e.g., no data on national or state goat herd numbers and supply chain throughput, see Appendix 11.2, Table 27), so goats were excluded from the final CBA. The principal benefits quantified and included in both the sheep and cattle analysis were:

1. Lower costs associated with UHF-based tags and reader infrastructure compared to LF technology.
2. Reduced labour requirements throughout the supply chain associated with UHF compared to LF technology, due to;
   a. The ability to read individual or multiple animals, at higher speeds, and at a larger distance.
   b. The ability to store and access animal information (e.g. health records) via the physical tag.

Additionally, there are potential benefits that were not able to be quantified, but could be incorporated into future analyses that include:

1. Data collection efficiency and supply chain productivity improvements.
2. Animal traceability system performance improvements (e.g. multiple reading points at high contact locations).

4.1.1 Cattle CBA Overview

This analysis focuses on understanding the cost implications of maintaining the current LF EID system versus implementing UHF technology throughout the Australian cattle industry.

Three scenarios were explored in this analysis:

1. The ongoing cost of the national cattle LF system, which includes costs related to LF tags and system maintenance.
2. The cost of implementing UHF tags and the ongoing UHF system costs at a National level (pathway 1, pp. 26-27).
3. The cost of implementing dual tags and the ongoing UHF system costs at a National level (pathway 2, pp. 27-28).

4.1.2 Sheep CBA Overview

Based on the UHF technology development timeline outlined in Section 3.2, the sheep CBA assumes the most feasible scenario in which UHF technology could be adopted is in 4+ years, after which time LF technology has already been adopted within the sheep industry.

The three scenarios explored in this analysis for sheep were the same as those for cattle:

1. The ongoing cost of a national sheep LF system, which includes costs related to LF tags and system maintenance.
2. The cost of implementing UHF tags and the ongoing UHF system costs at a National level (pathway 1, pp. 26-27).
3. The cost of implementing dual tags and the ongoing UHF system costs at a National level (pathway 2, pp. 27-28).

4.2 Approach

The CBA followed a systematic approach, consisting of the following activities:

1. A desktop literature review, project data assessment, and preliminary qualitative analysis to develop a modified logic model and pathways to impact.
2. Creation of an economic model (CBA framework) to estimate the costs and benefits of UHF EID technology for each industry and for each scenario. The model estimated the distribution of benefits among stakeholders and various points along the supply chains.
3. Data gap analysis and consultation with ISC and NLIS personnel to source additional data as required.
4. Assessment of adoption profiles for proposed UHF and dual UHF-LF technology implementation scenarios for cattle and sheep (see Section 4.1).
5. Data synthesis, finalisation of the economic model(s), and estimation of CBA results for each industry and scenario. All data and assumptions used are clearly documented (see Appendix 11.2).
6. Integration of qualitative and quantitative analyses, developing insights that would support stakeholder effects analysis, and preparation of the final written report.

4.3 Key Assumptions & Data

Tables 7-8 report key data and assumptions used to estimate the cost and benefit cash flows for the various LF, UHF, and dual technology EID system scenarios. Data was sourced/ developed through product market reviews, expert consultation, and published literature review. Both hardware costs (Table 8) and labour hours (Table 9) were multiplied by relevant industry data (Table 7) in the analysis. Baseline industry data and a detailed breakdown of relevant data, references, and assumptions can be found in Appendix 11.2.

Table 7: Industry Baseline Data

Variable	Cattle	Sheep
No. of producer enterprises - Australia[(a)]	23,079	14,097
Australian herd / mob (head - 5yr average)[(b)]	22,250,391	70,234,655
No. of calves/ lambs born annually (average)[(b)]	4,450,078	23,177,436
No. feedlots (Australia)[(c)]	750	-

No. saleyards (Australia)[d]	74	39
No. processors (Australia)[e]	381	
No. head slaughtered annually[b]	6,148,000	27,098,600

[a]ABARES 2023, Financial performance of livestock farms: 2020–21 to 2022–23, ABARES, Canberra, June, DOI: https://doi.org/10.25814/s02x-d521. CC BY 4.0 https://www.agriculture.gov.au/abares/research-topics/surveys/livestock#methodology

[b]Australian Bureau of Statistics, Agricultural Commodities, Australia. Statistics on the production of principal agricultural commodities including cereal and broadacre crops, horticulture and livestock. 2021-22 financial year. https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/latest-release#livestock

[c]Feedlot costs were excluded from the Sheep industry analysis as NSW, QLD and SA representatives confirmed that feedlots are not a significant separate entity for their jurisdictions. Sheep and Goat Traceability Task Force (SGTTF) (2022). Livestock Traceability Co -Design - Cost model guide and assumptions. [online] Available at: https://www.agriculture.gov.au/sites/default/files/documents/livestock-traceability-cost-model-guide-and-assumptions.pdf.

[d]National Livestock Reporting Service, 2020-2021, https://www.mla.com.au/contentassets/435cfb49268947dc817e5f57593b041a/2020-2021-saleyard-survey.pdf

[e]Processing enterprise number not species/industry specific. Data sourced/ developed through TGD product market review, expert consultation, and published literature review.

Table 8: Hardware Cost Data

	LF	UHF-only	Dual
Tag costs (Cattle)	$2.75 to $4.07	$1.00 to $3.35	$3.00 to $4.35
Tag costs (Sheep)	$1.99 to $2.10	$1.00 to $2.00	$3.00 to $4.35
Handheld readers (Cattle & Sheep)	$750 to $8,000	$600 to $1,600	
Fixed readers - Producers, Feedlots, and Processors (Cattle & Sheep)	$3,299 to $7,189	$1,500 to $4,000	
Fixed readers - Saleyards (Cattle & Sheep)	$55,000 per unit	$1,500 to $4,000	

Table 9: Labour Hours Data

	Cattle			Sheep		
Enterprise Type	LF	UHF - only	Dual	LF	UHF- only	Dual

Producer[(a)] *Per movement*	1.5 to 2.0 hours	0.5 to 1.25 hours	1.5 to 4 hours	0.5 to 1.25 hours
Feedlot[(b)] *Per movement*	1.0 to 2.0 hours	0.5 to 1.0 hours	-	-
Saleyard[(c)] *Per sale day*	36.5 to 128.5 hours	18.25 to 64.25 hours	37.0 to 130.0 hours	18.5 to 65.0 hours
Processor[(d)]	-	-	-	-

(a) Total approximate labour hours undertaking property to property transfer compliance activities. Reduced through UHF group scanning capabilities (>50%).
(b) Total approximate labour hours involved in retrieving animal history information. Reduced through UHF data storage capabilities (50%).
(c) Total approximate labour hours per sale day undertaking compliance activities. Reduced through UHF individual or group scanning capabilities and high scanning speed (50%).
(d) Processors were not included in labour savings due to scanning systems (i.e scanned in stun box).

As the key quantifiable differences between LF, UHF-only and Dual are cost-based (hardware and labours costs) the benefit analyses in the following sections focus on relative cost savings associated with each scenario (as opposed to additional other benefits i.e. improved efficiencies due to on-farm data collection).

4.4 CBA Results

4.4.1 Overview

The following sections summarise the quantitative findings of the UHF CBA. All benefit and cost cash flows were expressed in real 2022/23 dollar terms. Benefit and cost cash flows were discounted to year zero (the first year of investment) using a discount rate of 7%. The base analyses used the best available estimates for each variable, notwithstanding a level of uncertainty for many of the estimates. All analyses ran for a period of 20 years after the first year of investment. A glossary of economic terms can be found at the end of this report.

Results presented are expressed in present value terms, that is, the values are the sum of the discounted cost and/or benefit cash flows over the 20 year analysis period.

Please Note: Future CBAs regarding UHF must include costs associated with State government systems. State system costs were beyond the scope of this project.

4.5 Cattle Results

4.5.1 Upfront Costs Comparison

Table 10 shows the upfront costs associated with a UHF or dual technology adoption plan in the areas of physical tag costs, reader infrastructure, governance and change management, and additional industry support. The 'Livestock Traceability Co-Design - Cost model guide and assumptions' report (Sheep and Goat Traceability Task Force, 2022) was utilised to identify the cost areas and values that could be used as the basis for cattle implementation costs, with relevant assumptions for this work indicated below the table as footnotes. The upfront costs span a 5 year adoption time-period. The analysis in the next scenario expands on these upfront costs to develop a 20-year cost-benefit analysis period.

Table 10: Cattle - Upfront Costs Comparison (UHF vs Dual) (initial fitout)

	Tags	Infrastructure[c]	Governance & Change	Additional industry support
UHF	$22.3m-$74.5m	$12.0m to $49.1m	$8m[a]	$53m[b]
Dual	$66.8m- $96.8m	$12.0m to $49.1m	$8m[a]	$53m[b]

(a) assumes the same level of governance required compared to the SGTTF cost model (Sheep and Goat Traceability Task Force, 2022). Upfront costs in the National model included; National system governance arrangement costs, updating legislation and establishing compliance monitors, communications, education, training and technical support, and designing of the potential provision of grants / subsidies.

(b) assumes the same level of additional industry support compared to the SGTTF cost model (Sheep and Goat Traceability Task Force, 2022). Upfront costs in the National model included upskilling across the supply chain to adopt new EID and change support from key industry associations to support the adoption.

(c) includes initial infrastructure fit out and first capital expenditure for adoption of new handheld and fixed reader hardware.

4.5.2 Scenario costs

The total undiscounted annual cost cash flows for each adoption scenario (existing LF, UHF only, and dual technology) are presented in Figure 11 below. The cost cash flows represent the total costs for the Australian beef cattle industry. Ongoing system infrastructure and other periodic costs (e.g., hardware such as handheld and fixed readers that must be periodically replaced based on its useful life; does not include initial fit out/setup capital costs) have been annualised to show the relative difference in total expected annual costs for the beef cattle industry across the three scenarios evaluated over the 20 year analysis period.

Considering the 20 year analysis period, Figure 11 demonstrates that the long-term, average annualised ongoing costs of maintaining the existing LF technology EID system for the beef cattle industry are higher than the long-term, average annualised costs for the UHF-only and dual EID technology scenarios. The annualised ongoing costs for the dual technology adoption pathway remain higher than the UHF only adoption scenario, despite the eventual transition to UHF from dual EID, because of the higher costs over the first 5-10 years and annualisation of costs over the 20 year analysis period. Using a longer time horizon the ongoing annualised costs for the dual adoption pathway would become similar to the UHF only adoption pathway.

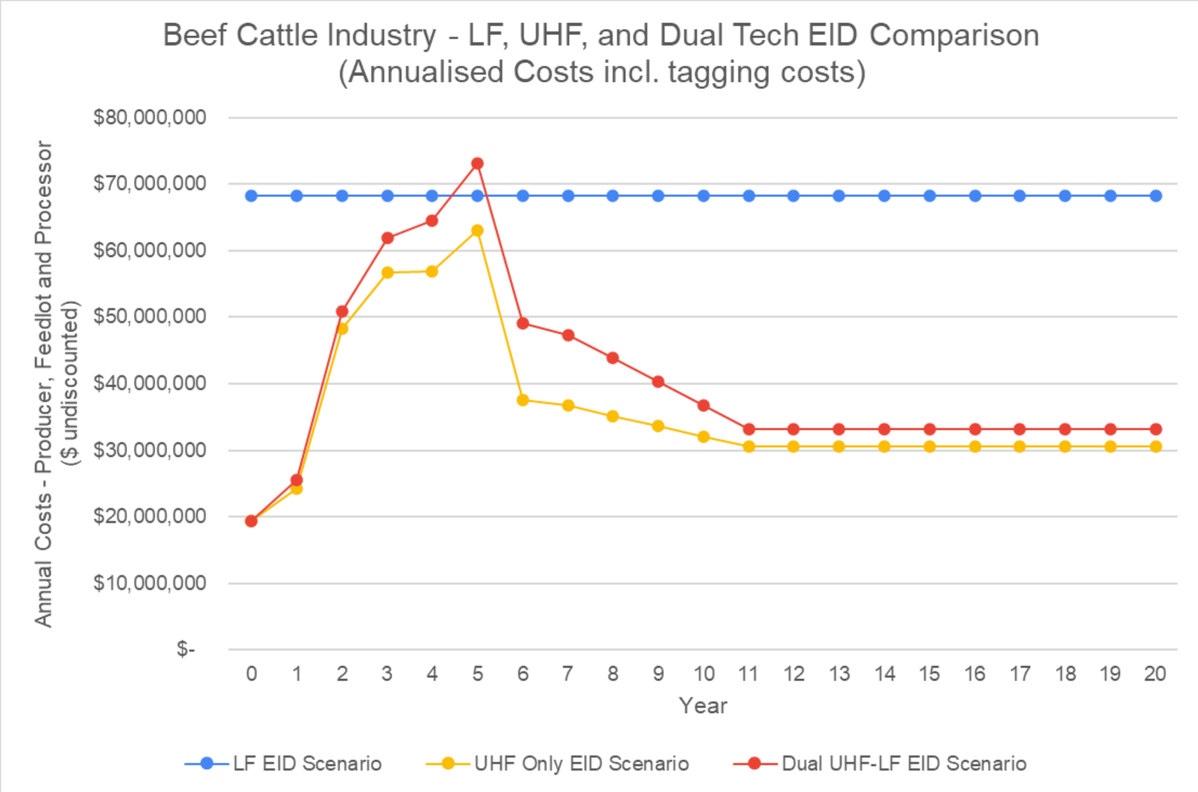

Figure 11. Cattle Industry - LF, UHF, and Dual Tech EID Comparison (Annualised Costs incl. tagging costs)

Total cost for each scenario over the 20 year analysis period is broken down by industry supply chain (stakeholder) segment below.

Table 11: Cattle - Estimated Total Cost (Present Value) over 20 year period across all scenarios

Cattle Industry	Total Costs LF ($m)	Total Costs UHF-only ($m)	Total Costs Dual ($m)
Producers	541.5	340.1	395.1
Feedlots	41.1	24.8	24.8
Saleyards	166.8	60.5	60.5
Processors	41.6	5.6	5.6
Industry Total	791.1	431.0	486.0

4.5.3 Benefits analysis

The benefits quantified in the analysis were cost savings associated with UHF-based technology compared to LF technology across the different supply chain segments. The cost savings estimated stemmed from

1. Lower cost of UHF tags compared to LF tags.
2. Lower cost of UHF reader infrastructure compared to LF reader infrastructure.
3. Lower labour requirement UHF-based technology use compared to LF technology use throughout the supply chain.

To estimate the expected net benefit of implementing a UHF only or dual EID pathway, the present value of costs for the relevant adoption scenario were compared to the present value of costs for the base LF scenario (or other adoption scenario as in the case of comparing a dual adoption pathway to the UHF only adoption pathway). The total estimated cost saving for UHF and dual pathways were then compared over the 20 year analysis period to assess which pathway would provide the highest benefit. The table below presents these results, and Figure 12 provides a visual explanation of this analysis.

Table 12: Cattle - Estimated Total Benefits (Present Value) over 20 year period across all scenarios

Cattle Industry	NPV ($m) UHF adoption compared to LF EID. Scenario (1)	NPV ($m) Dual technology adoption compared to LF EID. Scenario (2)	NPV ($m) UHF compared to Dual EID technology. Scenario (3)
Producers	201.5	146.4	55.1
Feedlots	16.4	16.4	0.0
Saleyards	106.3	106.3	0.0
Processors	36.0	36.0	0.0
Industry Total	360.1	305.1	55.1

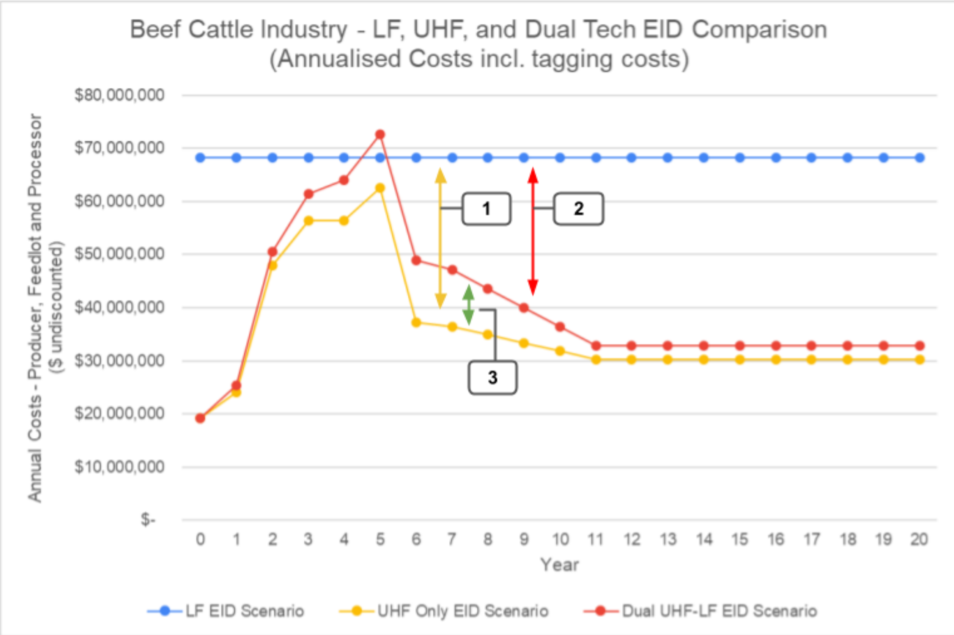

Figure 12. Cattle Industry - Benefit Comparison Visual Explanation

The relative contribution of each source of benefits (cost savings) to the total present value of net benefits (NPV) for each scenario are presented in the table below.

Table 13: Cattle - Source of Benefits

Cattle Industry	UHF adoption compared to LF EID (NPV, $m)	Dual technology adoption compared to LF EID (NPV, $m)	UHF compared to Dual EID technology (NPV, $m)
Tag costs	58.6 (16.3%)	- 2.3 (- 0.8%)	55.1 (100.0%)
Infrastructure costs	180.8 (50.2%)	184.3 (60.4%)	0.0 (0.0%)
Labour costs	120.7 (33.5%)	123.1 (40.3%)	0.0 (0.0%)
Total Scenario NPV	360.1 (100.0%)	305.1 (100.0%)	55.1 (100.0%)

4.5.4 Sensitivity analysis

Sensitivity analyses were carried out on variables that were (a) considered key drivers of the investment criteria and/or (b) considered the most uncertain. The analyses were performed for the cattle industry as a whole and with costs and benefits taken over the 20 year analysis period. This table demonstrates that if key variables shift, UHF-only or Dual technology pathways will still provide significant value to the beef industry.

Table 14: Cattle - Sensitivity Analysis

Cattle Industry (Beef)	NPV ($m) UHF adoption	NPV ($m) Dual technology	NPV ($m) UHF compared to

	compared to LF EID	adoption compared to LF EID	Dual EID technology
Baseline analysis (NPV, $m)	360.1	305.1	55.1
UHF/ Dual Tag Cost 20% higher (NPV, $m)	337.7	271.6	66.1
UHF/ Dual Tag Cost 20% Lower (NPV, $m)	382.6	338.5	44.0
Labour 20% Higher (NPV, $m)	339.1	284.1	55.1
Labour 20% Lower (NPV, $m)	381.1	326.1	55.1

4.5.5 Cattle CBA insights

The key advantages of UHF-based EID technologies primarily revolve around cost savings. These savings encompass reduced infrastructure and hardware expenses, more affordable tag costs, and decreased labour expenditures due to enhanced and/or efficient EID scanning, management, and maintenance operations. The outcomes detailed in the preceding sections illustrate that, on average, the costs linked to adopting and implementing UHF-only technologies are lower than the cumulative ongoing expenses associated with existing LF EID systems or the phased transition from dual technology to UHF technology adoption pathway for the Australian beef cattle industry across all supply chain segments.

The principal source of these benefits stems from the cost savings related to EID system infrastructure, constituting roughly 50% of the benefits in the UHF-only analysis over the LF base case and about 60% of the benefits in the dual pathway analysis over the LF base case (measured in present value terms).

In the scenarios involving dual UHF-LF EID technology, the adoption costs at the enterprise level for producers from year 0 to year 5 are greater than those of the LF EID base case. This is primarily attributed to higher tagging expenses, as dual tag technologies incur costs comparable to the existing LF tag costs.

The CBA and comparative analysis for the Australian beef cattle industry key takeaways:

- The cumulative cost of maintaining the current LF EID system was estimated at $791.1 million over 20 years, in present value terms (including hardware/equipment costs but excluding initial infrastructure setup/ fit out costs).
- Excluding modifications to the NLIS platform, the calculated present value cost of implementing a UHF-only EID system for the entire Australian beef cattle industry was $431.0 million over a 20-year period. In contrast, the estimated cost for implementing a dual EID system was $486.0 million over the same period. This analysis underscores that a direct

adoption pathway to UHF-only technology is more cost-effective than the dual LF-UHF adoption approach.

- Opting for a direct adoption pathway to UHF-only technology resulted in the highest net benefits (cost savings compared to the existing LF NLIS system) for all segments of the beef cattle supply chain, amounting to $360.1 million over a 20-year period, in present value terms.
- The net benefits (potential cost savings) of the dual adoption pathway was only $55.1 million less than a direct to UHF-only adoption pathway over the 20 year period of the analysis (present value terms).
- The main sources of benefits (cost savings) for the UHF-only adoption pathway for the beef cattle industry were infrastructure costs (50% of net benefits), followed by labour costs (33.5%), then tag costs (16.3%).

4.6 Sheep Results

4.6.1 Upfront Costs Comparison

Table 15 shows the upfront costs associated with a UHF or dual technology adoption plan for sheep in the areas of physical tag costs, reader infrastructure, governance and change management, and additional industry support. The upfront costs span a 5 year adoption time-period. The analysis in the next scenario expands on these upfront costs to develop a 20-year cost-benefit analysis period.

Table 15: Sheep - Upfront Costs Comparison (UHF vs Dual) (initial fitout)

	Tags	Infrastructure [c]	Governance & Change	Additional industry support
UHF	$70.2m to $105.4m	$7.0m to $29.1m	$8m [a]	$53 m [b]
Dual	$210.7m to $305.5m	$7.0m to $29.1m	$8m [a]	$53 m [b]

(a) assumes the same level of governance required compared to the SGTTF cost model (Sheep and Goat Traceability Task Force, 2022). Upfront costs in the National model included; National system governance arrangement costs, updating legislation and establishing compliance monitors, communications, education, training and technical support, and designing of the potential provision of grants / subsidies.

(b) assumes the same level of additional industry support compared to the SGTTF cost model (Sheep and Goat Traceability Task Force, 2022). Upfront costs in the National model included upskilling across the supply chain to adopt new EID and change support from key industry associations to support the adoption.

(c) includes initial infrastructure fit out and first capital expenditure for adoption of new handheld and fixed reader hardware.

4.6.2 Scenario costs

The total undiscounted annual cost cash flows for each adoption scenario (existing LF, UHF only, and dual pathway) are presented in Figure 13 below. The cost cash flows represent the total costs for the Australian sheep industry. Ongoing system infrastructure and other periodic costs (e.g., hardware such as handheld and fixed readers that must be periodically replaced based on its useful life; does not include initial fitout/setup capital costs) have been annualised to show the relative difference in total expected annual costs for the sheep industry across the three scenarios evaluated over the 20 year analysis period.

Considering the 20 year analysis period, Figure 13 demonstrates that the long-term, average annualised ongoing costs of maintaining the expected mandatory LF technology EID system for the sheep industry are higher than the long-term, average annualised costs for the UHF-only and dual EID technology scenarios. The annualised ongoing costs for the dual technology adoption pathway remain higher than the UHF only adoption scenario, despite the eventual transition to UHF from dual EID, because of the higher costs over the first 5-10 years. Using a longer time horizon the ongoing annualised costs for the dual adoption pathway would become similar to the UHF only adoption pathway.

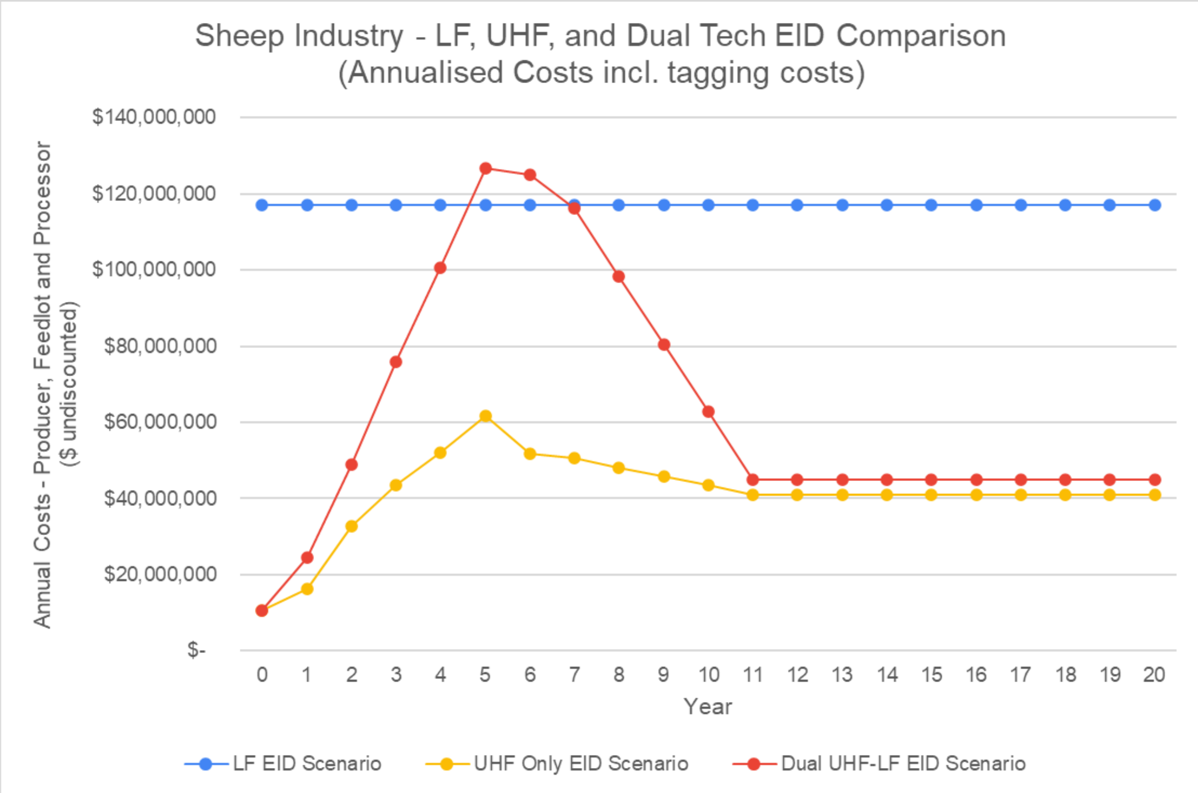

Figure 13. Sheep Industry - LF, UHF, and Dual Tech EID Comparison (Annualised Costs incl. tagging costs)

Total cost for each scenario over the 20 year analysis period is broken down by industry supply chain (stakeholder) segment below.

Table 16: Sheep - Estimated Total Cost (Present Value) over 20 year period across all scenarios

Sheep Industry	Total Costs LF ($m)	Total Costs UHF-only ($m)	Total Costs Dual ($m)
Producers	1,218.2	422.8	716.1
Feedlots(a)	n/a	n/a	n/a
Saleyards	99.4	33.0	33.0
Processors	41.6	5.6	5.6

Sheep Industry	Total Costs LF ($m)	Total Costs UHF-only ($m)	Total Costs Dual ($m)
Industry Total	1,359.2	461.4	754.8

n/a: not applicable
(a) Feedlot costs were excluded from the Sheep industry as data was unavailable.

4.6.3 Benefits analysis

The benefits quantified in the analysis were cost savings associated with UHF-based technology compared to LF technology across the different supply chain segments. The cost savings estimated stemmed from:

1. Lower cost of UHF tags compared to LF tags.
2. Lower cost of UHF reader infrastructure compared to LF reader infrastructure.
3. Lower labour requirement UHF-based technology use compared to LF technology use throughout the supply chain.

To estimate the expected net benefit of implementing a UHF only or dual LF-UHF EID system the present value of costs for the relevant adoption scenario were compared to the present value of costs for the base LF scenario (or other adoption scenario as in the case of comparing a dual adoption pathway to the UHF only adoption pathway). The total estimated cost saving for UHF and dual pathways were then compared over the 20 year analysis period to assess which pathway would provide the highest benefit. The table below presents these results, and Figure 14 provides a visual explanation of this analysis.

Table 17: Sheep - Estimated Total Benefits (Present Value) over 20 year period across all scenarios

Sheep Industry	NPV ($m) UHF adoption compared to LF EID. Scenario (1)	NPV ($m) Dual technology adoption compared to LF EID. Scenario (2)	NPV ($m) UHF compared to Dual EID technology. Scenario (3)
Producers	795.4	502.1	293.3
Feedlots	n/a	n/a	n/a
Saleyards	66.4	66.4	0.0
Processors	36.0	36.0	0.0
Industry Total	897.8	604.5	293.3

n/a: not applicable
(a) Feedlot costs were excluded from the Sheep industry as data was unavailable.

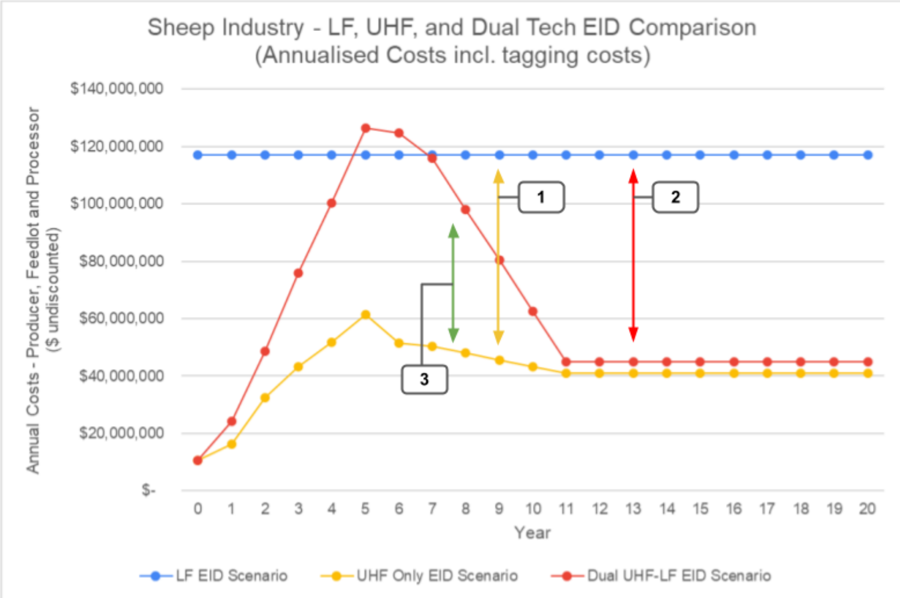

Figure 14. Sheep Industry - Benefit Comparison Visual Explanation

The relative contribution of each source of benefits (cost savings) to the total present value of net benefits (NPV) for each scenario are presented in the table below.

Table 18: Sheep - Source of Benefits

Sheep Industry	UHF adoption compared to LF EID (NPV, $m)	Dual technology adoption compared to LF EID (NPV, $m)	UHF compared to Dual EID technology (NPV, $m)
Tag costs	644.1 (71.7%)	355.5 (58.8%)	293.3 (100.0%)
Infrastructure costs	123.7 (13.8%)	121.4 (20.1%)	0.0 (0.0%)
Labour costs	130.1 (14.5%)	127.6 (21.1%)	0.0 (0.0%)
Total Scenario NPV	897.8 (100.0%)	604.5 (100.0%)	293.3 (100.0%)

4.6.4 Sensitivity analysis

Sensitivity analyses were carried out on variables that were (a) considered key drivers of the investment criteria and/or (b) considered the most uncertain. The analyses were performed for each industry as a whole and with costs and benefits taken over the 20 year analysis period. Similar to the cattle analysis, this table demonstrates that if key variables shift, UHF-only or Dual pathways will still provide significant value to the sheep industry.

Table 19: Sheep - Sensitivity Analysis

Sheep Industry	NPV ($m) UHF adoption	NPV ($m) Dual technology	NPV ($m) UHF compared to

	compared to LF EID	adoption compared to LF EID	Dual EID technology
Baseline analysis (NPV, $m)	897.8	604.5	293.3
UHF/ Dual Tag Cost 20% Higher (NPV, $m)	841.1	489.1	352.0
UHF/ Dual Tag Cost 20% Lower (NPV, $m)	954.5	719.9	234.7
Labour 20% Higher (NPV, $m)	885.8	592.5	293.3
Labour 20% Lower (NPV, $m)	909.8	616.4	293.3

4.6.5 Sheep CBA insights

Similar to the findings for the beef cattle industry, the principal benefits of UHF-based EID technologies are associated with cost savings including cheaper infrastructure and hardware costs, cheaper tag costs, and labour savings from more efficient and/or effective EID scanning, management, and maintenance operations. The results presented in the previous sections demonstrate that, on average, costs associated with the adoption and implementation of UHF only technologies are lower than the cumulative ongoing costs of existing LF EID systems or the phased dual technology to UHF technology adoption pathway for the Australian sheep industry across all segments of the supply chain. However, unlike in the beef cattle industry CBA, the primary source of benefits were the cost savings associated with EID system tags which made up approximately 72% of the benefits in the UHF only over LF base case analysis and approximately 59% of the benefits in the dual over LF base case analysis (in present value terms).

For the dual UHF-LF EID technology scenarios the enterprise level adoption costs for producers over year 0 to year 5 are higher than the LF EID base case and the UHF only scenario for the sheep industry. This was largely because of the higher initial tagging costs where dual tag technologies have costs higher than existing LF tag costs.

The CBA and comparative analysis for the Australian sheep industry key takeaways:

- The cumulative cost of maintaining the expected mandatory LF system was estimated at $1,359.2 million over 20 years (present value terms) including hardware/equipment costs but excluding initial infrastructure setup/ fit out costs for states/territories where the LF system is not yet in place.
- The estimated cost of implementing a UHF-only EID system for the entire Australian sheep industry over a 20-year period was $461.4 million (present value terms). The estimated cost of implementing a dual LF-UHF EID system was $754.8 million over the same period (present

value terms). This underscores the cost-effectiveness of a direct adoption pathway to UHF-only technology compared to a dual LF-UHF adoption approach.

- Opting for a direct adoption pathway to UHF-only technology yielded the most substantial net benefits (cost savings compared to LF EID) across all segments of the sheep supply chain, totalling $897.8 million over a 20-year period (measured in present value terms).
- The net benefits (potential cost savings) resulting from the adoption of dual LF-UHF technology remained substantial, at approximately $604.5 million. Nevertheless, the direct adoption pathway to UHF-only technology yielded extra benefits of $293.3 million over the 20-year analysis period (measured in present value terms).
- The principal sources of benefits (cost savings) for the sheep industry in the UHF-only adoption pathway were tag costs, constituting 71.7% of the net benefits, followed by labour costs at 14.5%, and infrastructure costs at 13.8%.

4.7 CBA Conclusion

The economic analysis underscored that adopting UHF technology would bring potential advantages to all stages of the supply chain in both the beef cattle and sheep industries. Furthermore, the CBA indicated that, on an industry-wide scale, the primary beneficiaries are producer and saleyard enterprises, with the magnitude of benefits diminishing as one progresses up the supply chain, to feedlot and processor enterprises.

The CBA findings indicated that, under the assumptions considered, directly transitioning to UHF-only technology would yield the most substantial benefits compared to the existing LF system for both beef cattle and sheep. Nonetheless, a dual LF-UHF technology adoption pathway would also be economically viable, generating cost savings for all segments of the Australian beef cattle and sheep supply chains.

4.8 Stakeholder effects analysis

The economic analysis demonstrates that a transition to UHF would benefit all segments of the supply chain for both the beef cattle and sheep industries. The CBA also demonstrates that, at an industry level, benefits accrue primarily to producers and saleyards, with benefits lessening further up the supply chain (feedlots and processors). This information, and the benefits and costs that shaped the development of the CBA analyses, have been used to clearly define the effects a transition would have on each stakeholder group (below). The ‘interest’ column has been developed based on the assumption that the NPV attributed to each stakeholder group will influence the stakeholder group's appetite for a transition to UHF. ISC and state governments have also been included in the analysis to understand how these entities would influence and be affected by UHF adoption.

Table 20: Stakeholder effects analysis

Stakeholder	Influence	Interest	Benefit	Change required
Producers (Cattle, Sheep & Goats)	Medium	High	• Reduced tag cost (long-term) • Low-touch/ effort animal transfers • Reduced labour/cost associated with P2P transfers • On-farm data collection opportunities (profit and improved efficiency benefits)	• Purchase and install new fixed or hand-held scanning infrastructure • Increased upfront investment and tag cost during transition • If already using LF software provider on-farm (e.g. pregnancy scanning), updating current software, or transferring to new software designed for UHF • Upskilling in technology
Saleyards (Cattle & Sheep)	Low-Medium	High	• Increased speed of scanning (close to BAU) • Reduced labour required • Reduced animal and staff welfare impacts • Lower cost scanners • Lower cost replacement tags	• Purchase and install of new fixed and hand-held scanning infrastructure • Retro-fitting saleyard • Adjusting saleyard software and systems • Upskilling workers in technology
Feedlots	Medium	Low	• Opportunities for increased efficiencies • Data to support efficiencies at feedlot (e.g. recording animals at	• Purchase and install of new fixed (at weigh bridges) and hand-held scanning infrastructure • Retro-fitting feedlot

Stakeholder	Influence	Interest	Benefit	Change required
			feeding troughs) • Additional data included on tag (e.g. health record) • Lower cost scanners • Lower cost replacement tags	• Adjusting feedlot software and systems • Upskilling workers in technology
Processors	High	Med	• Lower cost scanners • Lower cost replacement tags • Additional data included on tag (e.g. health record) • Opportunities for increased supply chain compliance (e.g. Lower time/cost involved in correctly undertaking P2P transfers, scanning on trucks)	• Purchase and install of new fixed and hand-held scanning infrastructure • Time and cost of adjusting processor software systems and processes • Upskilling workers in technology
ISC	Med	Med	• Opportunities to increased transfer uploads/ human-free system uploads (e.g. trucks scanning animals)	• Cost of incorporating UHF data into NLIS system • Trialling technology (NLIS approval process) • NLIS standard development

Stakeholder	Influence	Interest	Benefit	Change required
State Departments	High	Low	• Opportunities to increase movement data (e.g. additional points at saleyards) • Opportunities for increased supply chain compliance • Lower time/cost involved in correctly undertaking P2P transfer • Human-free system upload (e.g. trucks scanning animals)	• Cost of adapting state systems (auditing, disease surveillance and response work) to allow UHF data • Supporting industry transition to UHF (communications, extension, education, change management) • Updating legislation • State coordination/ governance & designing of the potential provision of grants / subsidies

This analysis indicates that a shift to UHF will likely be driven by producers and saleyards, as key players with the highest interest and potential benefit from UHF technology. Other stakeholders with more influence and/or power (e.g. state governments) would need to be heavily engaged in the preparation and execution of the transition process.

5. NLIS Review

5.1 Including UHF tag data in the current NLIS database

The adoption of UHF technology to collect animal movement data will have implications for the NLIS database. At a minimum, the existing database currently records two essential numbers which are linked to the animal; 1) A unique 64-bit RFID number encoded within each LF transponder must be unable to be reprogrammed and commence with a 3-character numeric prefix code issued by ICAR, and 2) a 16-bit NLIS number is also generated and linked with the RFID number of the LF transponder inside the device (see Figure 15 below). The NLIS number is printed on the outside of an ear tag and is read visually. These numbering schemas provide essential information to ISC, state departments of agriculture (SDA's), NLIS users, and auditors, and allow for the recording of individual animal movements throughout livestock supply chains, and have been designed in accordance with international (ICAR, ISO) and national (Australian Standards) LF numbering standards.

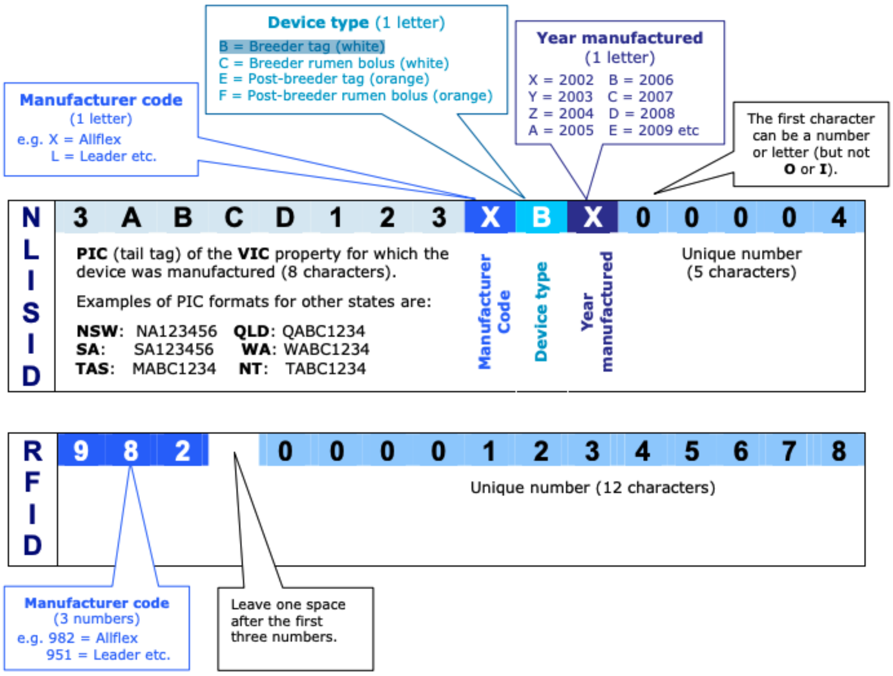

Figure 15. RFID and NLIS ID numbering schemas

These numbers and associated information (mainly the PIC) play a crucial role in a range of functions within the NLIS system. These functions encompass providing state compliance data and powering the NLIS website user dashboards, as illustrated in Figure 16 below.

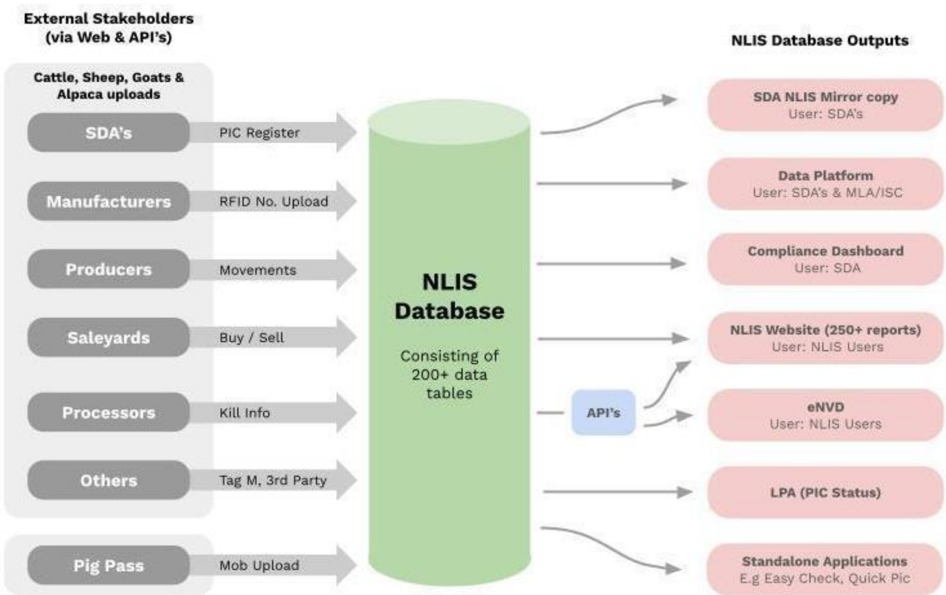

Figure 16. Overview of NLIS Database

The impact of a decision to adopt UHF on the current NLIS database depends on the RFID numbering schema associated with the device. Two scenarios are considered below;

Scenario 1 - The numbering schemas remain unchanged (i.e. schemas follow the same or similar NLIS ID and RFID structures outlined above as used with LF devices. This would have minimal or no changes to the database and is reflected in the CBA analyses in Section 4 as zero NLIS costs.

Scenario 2 - Numbering schemas are altered due to international and national standards, which necessitate significant change to the NLIS database and the associated 200 + data tables. Consultation with NLIS representatives has estimated this scenario to cost $7.1 million over a 4 year period. To assess the economic viability of transitioning to UHF technology in Scenario 2 an additional CBA has been included below (Tables 21-22). This analysis considers the combined benefits for cattle and sheep assuming that both industries undergo a simultaneous transition to UHF technology.

The estimated additional NLIS costs for Scenario 2, equivalent to $8.5 million in present value terms (over 4 years and incurred prior to initial implementation of UHF or dual adoption pathways), had a minimal effect on the overall costs and benefits estimated for the different scenarios for beef cattle and sheep over the 20 year analysis period. Also, the benefits of a UHF or Dual LF-UHF adoption pathway (industry wide system cost savings compared to ongoing annual LF costs) would more than cover the estimated NLIS costs within five years of implementation (positive NPV greater than $8.5m).

Table 21: Cost comparison (Present Value, 20 years)

Combined Cattle & Sheep Industry	Total Costs Maintaining LF ($m)	Total Costs UHF-only ($m)	Total Costs Dual ($m)
Industry Total combined (Scenario 1)	2,150.3	892.4	1240.8
Industry total combined (Scenario 2)	2,150.3	900.9	1249.3

Table 22: Benefits comparison (Present Value, 20 years)

Combined Cattle & Sheep Industry	NPV ($m) UHF only compared to LF EID adoption scenario	NPV ($m) Dual technology compared to LF EID adoption scenario	NPV ($m) Dual compared to UHF only EID technology adoption scenario
Industry Total combined (Scenario 1)	1,257.9	909.6	348.4
Industry total combined (Scenario 2)	1,249.4	901.0	348.4

ISC has recently been awarded an Australian Government grant to develop a new and advanced livestock traceability platform. Given this funding, it appears likely that the current NLIS traceability platform will be different by the time UHF technology could be ready for system-wide adoption (approximately 2028). A re-designed traceability platform holds the potential to be highly flexible, accommodating various technologies for use by supply chains, including potential changes associated with new technology (such as a new numbering schema, for example).

The high-level analysis conducted in tables 21 and 22 highlights that without database flexibility in the traceability platform re-design, adopting new technologies like UHF would be more costly. The industry may remain reliant on LF technology, even as newer technologies like facial recognition emerge. The re-designed traceability platform's significance lies in its adaptability to embrace emerging technologies, keeping the industry innovative and competitive. A versatile system that ensures the efficient adoption of new technologies without prohibitive upgrade costs or outdated options, will enhance innovation in resilience and traceability of the Australian livestock landscape.

5.2 Future NLIS database and integrated system costings

Understanding the numbering schema for UHF tags is a critical component of future UHF research and system costs. The ISO committee is currently developing the UHF numbering schema, but there is also an opportunity to design a schema that works specifically for the Australian context. The US devised an interim standard in lieu of an international one, the NZ RFID pathfinder group and Agriscan have also conducted extensive work on UHF schemas for livestock. Engaging these experts in future work can help design a schema that benefits national livestock supply chains and align with the international livestock community and systems.

Future iterations of UHF research, especially after a numbering schema standard is finalised, should focus on a detailed cost assessment of introducing UHF into the NLIS databases and understanding its impact on other stakeholder systems (e.g. state departments of agriculture). This comprehensive approach will ensure a well-informed integration of UHF technology into the livestock industry, enhancing its traceability and efficiency while considering broader stakeholders' interests.

Other databases and software that may be impacted by the adoption of UHF technology include:

- **Producers (including breeders):** Software updates may be required for producers who have already adopted software for collecting on-farm data and/or lifetime data on high-value livestock. The change management process would be led by suppliers of commercial software options and would need to consider how these previous data sets can be seamlessly integrated with new animal identifier information to ensure insights are not lost in the transition.
- **Saleyards, Feedlots, and Processors:** Saleyards and feedlots utilise software solutions like Agrinous and Outcross to integrate with the NLIS system. Processors, on the other hand, not only have integrations for NLIS data uploads but also may establish links between tag and carcase (body) numbers for hook tracking purposes.
- **Manufacturers:** Existing systems currently generate NLIS ID and RFID numbers that comply with mandatory requirements. These systems would need to be updated accordingly.
- **State departments:** In addition to state departments having access to a mirror database, they also have various hardware and software that rely on NLIS data for compliance monitoring and outbreak response. The cost areas related to the Victorian system are outlined below.
    - Upgrade of Victoria’s online tag ordering service, which allows Victorian producers and industry to access the NLIS and procure approved tags.
    - Upgrade of hardware and software used by staff for auditing, disease surveillance, and response work.
    - Upgrade of MAX disease response information system, used for disease surveillance, testing, and vaccinations.
- **Other:** Other stakeholders in the ecosystem utilise LF numbers in their systems. For example, banks use these numbers to monitor high-value animals. In addition to cattle, sheep, and goats, the NLIS database currently includes other cloven-hoofed animals such as pigs and South American camelids. Pig movement information is collected at a mob level and uploaded to PigPass, which is connected to the NLIS database. For alpacas, LF tags are used to collect movement data, and individual animal movements are directly uploaded to the NLIS database. If any of these species were to adopt UHF technology, the numbering schema of UHF would play a significant role in determining its impact on the NLIS system. Future mapping exercises

and stakeholder engagements should be conducted to assess these other stakeholder systems, and the impact UHF data could have on them.

6. Conclusion

6.1 Key findings

The findings from this project demonstrate that UHF is likely to be technically and economically feasible for integration into Australian livestock supply chains in time. Future research and Australian-based field trials are required to create an independent body of evidence that assesses the current state of UHF technology and associated software products, to confirm if key technology challenges have been, or could be resolved, through further research and development.

This review of the technology readiness of UHF technology, and the current status of standard and regulatory development, indicated that UHF is 4+ years[3] away from being suitable for wide-spread adoption in cattle, sheep or goat supply chains. Therefore, all cattle, sheep and goat supply chains will have established LF systems in use by the time that a transition to UHF could be considered. This information provided a contextual backdrop for both the formulation of adoption pathways and the structure of cost-benefit analyses.

Three adoption pathways were developed to understand how these industries could transition to UHF from LF systems:

- **Pathway 1:** Shift directly from LF to UHF technology.
- **Pathway 2:** Use dual tag technology as a 'bridging' technology to transition from LF to UHF.
- **Pathway 3:** Producers are provided the opportunity to adopt dual technology on a voluntary basis to gain on-farm benefits.

Both the shift directly to UHF (Pathway 1) and the use of a dual technology to bridge from LF to UHF (Pathway 2) demonstrated a large positive net benefit to all livestock industries.

The CBA analysis, however, indicates that a dual technology transition (pathway 2) will result in a lower positive net benefit for cattle, when compared to a direct shift to UHF ($305.1 vs $360.1 million, present value terms, 20-year analysis period), respectively. Regarding sheep, the dual technology transition delivers a larger reduction in benefit ($604.5 vs. $897.8 million, present value terms, 20-year analysis period), when compared to transitioning straight to UHF. Despite the direct shift to UHF potentially delivering the largest net benefit to industries, pathway 2 could mitigate risk by better support of compliance data collection and providing stakeholders time to adjust to new technology.

Future UHF research must explore adoption pathways through the lens of change management frameworks. It should identify opportunities to transition to UHF in a manner that upholds compliance with the national traceability system while also optimising industry's net benefits from such a transition.

An analysis of stakeholder effects suggests that the adoption of UHF technology can only be possible with substantial industry impetus, particularly in terms of overcoming the time and financial commitments associated with the transition. Such a shift is likely to be spearheaded by industry representatives and peak bodies. Effective collaboration between the industry, governmental bodies, and the ISC would be pivotal in driving this change, encompassing activities such as updating the NLIS database, amending regulations and standards, and orchestrating change management initiatives.

[3] This would require Australia to adopt an interim UHF standard as described in section 3.2.2 Timeline 2: Accelerated Approach.

6.2 Benefits to industry

This project has provided an initial assessment of the suitability and benefits of UHF technology for the Australian livestock industry. Short-term industry benefits are as follows:

- Industry has clarity around the value UHF technology could provide supply chains, areas that require further research or product development, and estimated timelines regarding key adoption milestones.
- Project findings can inform discourse and decisions surrounding future industry research into the technology, and/or use of industry levy funds.
- Supporting the re-design of the new livestock traceability system through providing key database recommendations that will enable the integration of future traceability technologies in Australian livestock supply chains.

Long-term industry benefits are as follows:

- Access to an alternative technology that maintains or improves traceability data across livestock supply chains, supporting Australia's ability to respond to biosecurity threats.
- Access to an alternative technology that reduces the cost burden of the traceability system.
- Access to an alternative technology that creates additional opportunities to share animal data across the supply chain, and collect on-farm/ property data to support productivity and efficiency gains.
- Access to global technology developments and increased market competition around the supply of technologies to the livestock industry.

7. Future research and recommendations

It is recommended that UHF research and trials be conducted to confirm the technical capabilities of UHF and create a deeper understanding of the benefits UHF could provide stakeholders. The outputs from these activities would be critical in making a comprehensive decision, alongside industry stakeholders, on the next steps for UHF technology in Australian livestock supply chains.

1. **Peak bodies and RDCs will play an important role in progressing UHF development.** Technology companies exhibit a strong responsiveness to market demand. Currently, the limited demand for UHF technology in Australia can be attributed to prevailing regulations that bind industries to LF technology and the absence of global UHF standards. The timelines elucidated in this report propose a UHF technology adoption readiness at 4+ years (section 3.2.2 Timeline 2: Accelerated Approach) and assumes that robust research and development within Australia occurs, as well as interim Australian standards adopted. Without further research and development efforts on the domestic front, Australian industries will have to lean on progress and innovations from other nations. This, in turn, would necessitate extensions to timelines to accommodate requisite Australian standards and NLIS accreditation procedures. Positive interventions from peak bodies and research and development corporations can assist the further assessment of UHF technology and empower stakeholders, mainly producers, to reap benefits from the voluntary adoption of NLIS-approved dual tags.
2. **Conduct Australian-based field trials to validate UHF technology, benefits and costs.** A series of trials are recommended to progress UHF technologies. These trials include assessing the technologies (tags and readers/antenna) currently available on the market and in-field species trials. It is recommended that a tiered approach is taken to these trials, where, if critical requirements are met, follow-on trials are undertaken. An outline of recommended trials and accompanying research required is provided below:

Table 24: Future UHF research opportunities

Trial	Description
UHF technology assessment and trial	● Identify the most promising technology prototypes (tags, readers, antenna, software) through engaging UHF specialists in Australia and globally. Create further detailed cost estimates for both UHF and dual tags. ● Engage UHF manufacturers within Australia and globally to understand the appetite for developing livestock UHF products (e.g. risk appetite if global standards are not yet in place). ● Create further clarity regarding supply chain data-collection opportunities UHF could present by engaging industry stakeholders and livestock data experts. ● Assess previous use of technology (reader and antenna setup) from national and global experts. Design trial set-ups based on these findings. ● Conduct small-scale trials to test the function of technology. ● Identify technology updates required to ensure robust technology can be developed and made available to the industry.
LF research and time-in-motion study	● If initial technology trials show promising results, conduct time-in-motion studies of LF at different points of the supply chains to get accurate data that can be compared to UHF trial results (e.g. time added to saleyard sale days due to LF scanning). This will support the development of a more detailed CBA model that can be used to create a more robust business case for UHF adoption in Australia. ● In addition to comparisons to UHF, this study would also support cattle, sheep and goat supply chains in identifying inefficiencies in the supply chain and opportunities for improvement (if an LF system is maintained). ● As the main benefits associated with UHF are hardware cost and labour related, research should explore if there are opportunities to reduce LF costs and/or improve labour efficiencies. Currently, there is limited evidence that would suggest that LF costs could be reduced in the long-term.
Supply chain/ field trials	● If UHF is proven to be technologically appropriate and benefits are clear, conduct additional assessments of species-specific tags and reader set-ups. ● Conduct supply chain trials, assess function throughout the supply chain, and identify any remaining challenges experienced in-field and less controlled environmental set-ups.
Dual technology assessment and development	● Once UHF has been established as suitable and beneficial for supply chain/s, trials should be conducted to assess available dual tags globally.

3. **Deepen stakeholder engagement and refine business cases and adoption pathways.** For industry stakeholders to justify the expenses and challenges associated with shifting from LF to UHF technology, substantial advantages in UHF technology must be apparent. Effective collaborations among peak bodies, MLA/ISC, and state governments would be imperative to coordinate and fund data collection. Benefits need to be meticulously substantiated and adeptly communicated to the industry, showcasing specific enterprise advantages. Peak industry bodies and state governments will also require compelling evidence of enhanced biosecurity, along with additional supply chain benefits encompassing productivity, efficiency, and cost savings.
4. **A positive technology capability assessment leads to detailed costing exercises and change management plans.** The impending NLIS database platform redesign and the adoption of LF technology by the sheep and goat industry are pivotal developments. As these

transformations unfold, it becomes imperative to reevaluate the adoption pathways and associated costs for UHF technology in light of the evolving landscape. In the event that international standards for UHF remain unresolved, there is merit in exploring the feasibility of establishing interim Australian standards to unlock further progress for the Australian livestock industries.

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9. Appendix

9.1 Global UHF research & trials

UHF technology trials for livestock have been conducted by a range of countries, applying these technologies to a range of species, including cattle, sheep, deer, and pigs. Prominent trials have occurred in Germany, France, England and New Zealand, with the most recent pilots occurring in the US and Scotland. The table below summarises the main trials and pilots that have occurred globally regarding UHF and livestock.

Table 25: Global trial summary

Name	Year	Location	Species	Link
RFID Technical Study: The Application of UHF RFID technology for animal ear-tagging	2008	New Zealand	Deer, Sheep, Cattle	https://meatprojects.com/docs/NewZealand/report-uhf-animal-tag-trials-july08.pdf
Use of UHF Tags in Deer and Sheep	2009	New Zealand	Deer, Sheep	https://www.rezare.com/wp-content/uploads/2016/04/UHF-Tag-Assessment-Report-2010-02-09.pdf
UHF RFID in the Livestock Supply Chain	2010	New Zealand	Cattle, Sheep	https://www.rezare.com/wp-content/uploads/2016/04/UHF-Supply-Chain-Report-2010-07-30.pdf
The use of UHF transponders as a potential replacement for cattle passports	2012	Scotland	Cattle	https://www.scoteid.com/Public/Documents/The_Use_of_UHF_Transponders_for_Cattle_Passportsfinal.pdf
Comparison of different ultra-high-frequency transponder ear tags for simultaneous detection of cattle and pigs	2012	Germany	Pigs, Cattle	https://www.researchgate.net/publication/297890903_Comparison_of_different_ultra-high-frequency_transponder_ear_tags_for_simultaneous_detection_of_cattle_and_pigs
Evaluation of Commercially Available UHF RFID Tag Technology for Animal Ear Tagging.	2013	New Zealand	Sheep, Deer	https://www.youtube.com/watch?v=IPXhdM_QicE
ROXAN & TRUTEST - UHF TagFaster in action	2014	UK	Sheep	https://www.youtube.com/watch?v=IPXhdM_QicE
ROSEI (Robust Sheep Electronic Identification)	2014	EU	Sheep	https://cordis.europa.eu/project/id/315222/reporting/es
Ultra-High Radio Frequency	2016	US	Cattle	https://www.aphis.usda.gov/traceability/downloads/uhrf-id-demo-pro-summary-st-rpt.pdf

Identification Demonstration Summary and State reports				
Evaluating Fort Supply's FaST Track-Monitor animal health and inventory system on feedlot cattle	2019	Australia	Cattle	N/A
On field assessment of UHF technology for sheep electronic identification	2019	France	Sheep	https://www.icar.org/Documents/Prague-2019/Abstracts/S03(T)-OP-4.pdf (Presentation no longer available online)
CattleTrace Inc. Pilot Project Findings: August 1, 2018 – June 30, 2020	2020	USA	Cattle	https://www.uscattletrace.org/_files/ugd/35e859_07ab4b141b3b4c9c90eb975ec4051f6f.pdf
SAC Float Trial	2020	Scotland	Cattle	https://www.scoteid.com/Public/Documents/uhf/ScotEID%20UHF%20Report%20April%2021.pdf
UHF EID in Scotland (pilot)	2012-Ongoing	Scotland	Cattle	https://www.scoteid.com/Public/Documents/uhf/ScotEID%20UHF%20Report%20April%2021.pdf

9.2 CBA Data & Assumptions

9.2.1 Industry Baseline Data

Table 26 shows the baseline industry data that underpinned the analysis of the costs and benefits of the LF base scenario compared to the UHF, and Dual adoption pathways across the different segments of the Australian beef cattle supply chain.

Table 26: Australian Cattle Industry Data

Variable	Value	Source/ Comments
No. of beef and mixed (beef/sheep) enterprises - Australia	23,079	https://www.agriculture.gov.au/abares/research-topics/surveys/livestock#methodology
Australian cattle herd (head - 5yr average)	22,250,391	https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/latest-release#livestock
Average herd size - cattle enterprise (head)	964 head per farm	derived (22.3m/23k)

No. of calves born annually (average)	4,450,078	~20% of national herd (based on 4.9m calves in herd of 22.1m in 2021: https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/2020-21#livestock)
Average calves born annually per enterprise	193 calves born per farm	derived (4.45m/23k)
No. cattle feedlots (Australia)	750	Data sourced/ developed through TGD product market review, expert consultation, and published literature review.
Average annual feedlot throughput (head)	2,740,000	https://www.mla.com.au/news-and-events/industry-news/grainfed-cattle-account-for-almost-half-of-australias-cattle-slaughter/#:~:text=since%20Q4%202018.-,Turn%2Doff,to%20the%20five%2Dyear%20average.
Average throughput (head) per feedlot per annum	3,653 head per feedlot per annum	derived (2.74m/750)
No. beef cattle saleyards (Australia)	74	https://www.mla.com.au/contentassets/435cfb49268947dc817e5f57593b041a/2020-2021-saleyard-survey.pdf
Average annual saleyard throughput (head)	3,700,000	https://www.mla.com.au/news-and-events/industry-news/2022-saleyard-survey-results-released/#:~:text=Saleyard%20throughput%20reduced%20marginally%20by,Wagga%20remains%20Australia's%20largest%20saleyard.
Average throughput (head) per saleyard per annum	50,000 head per saleyard per annum	derived (3.7m/74)
No. processors (Australia)	381	Processing enterprise number not species/industry specific. Data sourced/ developed through TGD product market review, expert consultation, and published literature review.
No. head slaughtered annually	6,148,000	Includes calves: https://www.abs.gov.au/statistics/industry/agriculture/livestock-products-australia/mar-2023
Average no. slaughtered per processor per annum	16,136 head slaughtered per processor per annum	derived (6.1m/381)

Table 27 shows the baseline industry data that underpinned the analysis of the costs and benefits of the LF base scenario compared to the UHF, and Dual adoption pathways across the different segments of the Australian sheep supply chain.

Note: Feedlot data were reported in Table 27; however, feedlot costs were excluded from the Sheep industry analysis because data was not available.

Table 27: Australian Sheep Industry Data

Variable	Value	Source/ Comments
No. of sheep and mixed (beef/sheep) enterprises - Australia	14,097	https://www.agriculture.gov.au/abares/research-topics/surveys/livestock#methodology
Australian sheep herd (head - 5yr average)	70,234,655	https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/latest-release#livestock
Average herd size - sheep enterprise (head)	4,982 head per farm	derived (70.2m/14k)
No. of lambs born annually (average)	23,177,436	~33% of national herd (based on 22.6m lambs marked in herd of 68.0m in 2021: https://www.abs.gov.au/statistics/industry/agriculture/agricultural-commodities-australia/2020-21#livestock)
Average lambs born annually per enterprise	1,644 lambs born per farm per annum	derived (23.2m/14k)
No. sheep feedlots (Australia)	Not available	Insight provided by ISC Feedlots were excluded from the Sheep industry analysis because conversations held with NSW, QLD and SA representatives confirmed that feedlots are not a significant separate entity for their jurisdictions.
No. sheep saleyards (Australia)	39	https://www.mla.com.au/contentassets/435cfb49268947dc817e5f57593b041a/2020-2021-saleyard-survey.pdf
Average annual saleyard throughput (head)	13,000,000	https://www.mla.com.au/news-and-events/industry-news/2022-saleyard-survey-results-released/#:~:text=Saleyard%20throughput%20reduced%20marginally%20by,Wagga%20remains%20Australia's%20largest%20saleyard.
Average throughput (head) per saleyard per annum	333,333 head per saleyard per annum	derived (13.0m/39)

No. processors (Australia)	381	Processing enterprise number not species/industry specific. Data sourced/ developed through TGD product market review, expert consultation, and published literature review.
No. head slaughtered annually	27,098,600	Includes lambs: https://www.abs.gov.au/statistics/industry/agriculture/livestock-products-australia/mar-2023
Average no. slaughtered per processor per annum	71,125 head slaughtered per processor per annum	derived (27.1m/381)

Table 28 shows the baseline industry data that underpinned the analysis of the costs and benefits of the LF base scenario compared to the UHF, and Dual adoption pathways across the different segments of the Australian goat supply chain. Credible baseline data for the Australian goat industry were scarce and insufficient to complete analysis. Therefore, the goat industry was excluded from the UHF economic feasibility analysis. However, it was considered reasonable that enterprise level and animal level costs and benefits likely would be similar to those estimated for the sheep industry.

Table 28: Australian Goat Industry Data

Variable	Value	Source/ Comments
No. of goat enterprises - Australia	12,000	Data sourced/ developed through TGD product market review, expert consultation, and published literature review.
Australian goat herd (head - 5yr average)	Not available	
No. of kids born annually (average)	Not available	
No. feedlots (Australia)	Negligible/ not applicable	
No. goat depots (Australia)	19	https://www.goatindustrycouncil.com.au/wp-content/uploads/2019/06/registered-goat-depots.pdf
Average annual saleyard throughput (head)	Not available	
No. processors (Australia)	381	Processing enterprise number not species/industry specific. Data sourced/ developed through TGD product market review, expert consultation,

		and published literature review.
No. head slaughtered annually	1,671,611	https://www.mla.com.au/globalassets/mla-corporate/prices--markets/documents/trends--analysis/goat-industry-summary/2023-mla-ms_global-goatmeat_f5.pdf
Average no. slaughtered per processor per annum	4,387	derived (1.67m/381)

9.2.2 CBA Cost Assumptions

Table 29: Cost Assumptions

Note: Where a data range has been provided, the average of the low and high cost has been used for the purpose of CBA analysis. All data AUD.

<table>
<tr><th>Variable</th><th>Data/Assumption</th><th>Source/ Comments</th></tr>
<tr><td colspan="3">EID tags</td></tr>
<tr><td>EID tag purchase/ replacement costs (applicable across any/all segments of supply chain e.g., producers, feedlots, saleyards, and/or processors where required)</td><td>Cattle – costs per tag
<table>
<tr><td>Enterprise Type</td><td>LF</td><td>UHF</td><td>Dual</td></tr>
<tr><td>Producer
Feedlot
Saleyard
Processor</td><td>$2.75 to $4.07</td><td>$1.00 to $3.35</td><td>$3.00 to $4.35</td></tr>
</table>
Sheep – costs per tag
<table>
<tr><td>Enterprise Type</td><td>LF</td><td>UHF</td><td>Dual</td></tr>
<tr><td>Producer
Saleyard
Processor</td><td>$1.99 to $2.10</td><td>$1.00 to $2.00</td><td>$3.00 to $4.35</td></tr>
</table></td><td>Data sourced/ developed through TGD product market review, expert consultation, and published literature review.

Tag replacement costs incurred by producers and charged by feedlots, saleyards, and/or processors were assumed to be equal to tag cost price. This was because, excluding the base tag hardware cost, any additional charges for tag replacement at different stages of the supply chain were assumed to be similar for LF, UHF, or Dual EID tag technologies.

Subsidies for tag costs were not included. Within a national CBA framework subsidies represent a transfer payment and not a true cost, so the full tag costs were used in the analyses.</td></tr>
<tr><td>Percentage of tags replaced due to loss/damage through the supply chain (tag replacement costs incurred by producers)</td><td>Cattle and Sheep (producers only)
3% to 10% of average annual throughput</td><td>Data sourced/ developed through TGD product market review, expert consultation, and published literature review.

Justification:
· Desktop research: 20% loss on -farm
· Stakeholder interview: 4-5% loss per year
· Stakeholder interview: 9-10% loss
· Stakeholder interview: 1-2%</td></tr>
</table>

<table>
<tr><th>Variable</th><th>Data/Assumption</th><th>Source/ Comments</th></tr>
<tr><td></td><td></td><td>ISC statement: 3%
Assumption between ISC 3% figure and 10% (20% extreme/ regarding tags in animals for 4+ years)</td></tr>
<tr><td colspan="3">Enabling infrastructure</td></tr>
<tr><td>Estimated reader costs by EID technology type - handheld readers</td><td>Cattle and Sheep – costs per handheld reader
<table>
<tr><th>Enterprise Type</th><th>LF</th><th>UHF</th><th>Dual</th></tr>
<tr><td>Producer</td><td rowspan="4">$750 to $8,000</td><td colspan="2" rowspan="4">$600 to $1,600</td></tr>
<tr><td>Feedlot[(a)]</td></tr>
<tr><td>Saleyard</td></tr>
<tr><td>Processor</td></tr>
</table>
(a) Feedlot costs were excluded from the Sheep industry analysis because conversations held with NSW, QLD and SA representatives confirmed that feedlots are not a significant separate entity for their jurisdictions.</td><td>Cost range for handheld readers specifically for livestock (cattle and sheep).

Data sourced/ developed through TGD product market review, expert consultation, and published literature review.</td></tr>
<tr><td>Number of handheld readers required by supply chain enterprise type (producer, feedlot, saleyard, or processor) and EID technology type (LF, UHF, or Dual)</td><td>Cattle – no. handheld readers
<table>
<tr><th>Enterprise Type</th><th>LF</th><th>UHF</th><th>Dual</th></tr>
<tr><td>Producer</td><td>0 to 1</td><td colspan="2">0 to 1</td></tr>
<tr><td>Feedlot</td><td>1 to 3</td><td colspan="2">1 to 3</td></tr>
<tr><td>Saleyard</td><td>6 to 10</td><td colspan="2">6 to 10</td></tr>
<tr><td>Processor</td><td>1 to 2</td><td colspan="2">1 to 2</td></tr>
</table>
Sheep – no. handheld readers
<table>
<tr><th>Enterprise Type</th><th>LF</th><th>UHF</th><th>Dual</th></tr>
<tr><td>Producer</td><td>0 to 1</td><td colspan="2">0 to 1</td></tr>
<tr><td>Saleyard</td><td>6 to 10</td><td colspan="2">6 to 10</td></tr>
</table></td><td>Data sourced/ developed through TGD product market review, expert consultation, and published literature review.</td></tr>
</table>

Variable	Data/Assumption	Source/ Comments
	Processor | 1 to 2 | 1 to 2	
Handheld readers useful life (average replacement period)	*Cattle and Sheep (all enterprise types)* 5 years (handheld)	Based on the NLIS target that specifies the transponder within devices must be reliably machine-readable for a minimum of seven years following the installation of devices in typical Australian field conditions.
Maximum industry adoption of handheld readers by enterprise type	*Cattle – handheld reader adoption* Enterprise Type | Max. Adoption Producer | 15% Feedlot | 85% Saleyard | 85% Processor | 85% *Sheep – handheld reader adoption* Enterprise Type | Max. Adoption Producer | 15% Saleyard | 85% Processor | 85%	TGD assumption inc. 15% producer enterprises adopting handheld readers, based on: · only enterprises conducting P2P transfers needing scanners · producers hiring agents to scan during transfers · some producers collecting on-farm data Max. adoption for feedlots, saleyards, and processors estimated based on outputs from adoption modelling by TGD using CSIRO Adopt[1] Tool.
Estimated reader costs by EID technology type - fixed readers	*Cattle – costs per fixed reader* Enterprise Type | LF | UHF | Dual Producer | $3,299 to $7,189 | $1,500 to $4,000 Feedlot | $3,299 to $7,189 Saleyard(a) | $55,000 per unit	Cost of handheld readers specifically for livestock (cattle and sheep). Data sourced/ developed through TGD product market review, expert consultation, and published literature review.

<table>
<tr><th>Variable</th><th>Data/Assumption</th><th>Source/ Comments</th></tr>
<tr><td></td><td>
<table>
<tr><td>Processor</td><td>$3,299 to $7,189</td><td></td></tr>
</table>
(a) “Unit” incl. 3 panel readers for 3 lane drafter.

Sheep – costs per fixed reader
<table>
<tr><td>Enterprise Type</td><td>LF</td><td>UHF</td><td>Dual</td></tr>
<tr><td>Producer</td><td>$3,299 to $7,189</td><td colspan="2" rowspan="3">$1,500 to $4,000</td></tr>
<tr><td>Saleyard[(a)]</td><td>$55,000 per unit</td></tr>
<tr><td>Processor</td><td>$3,299 to $7,189</td></tr>
</table>
(a) “Unit” incl. 3 panel readers for 3 lane drafter.
</td><td></td></tr>
<tr><td>Number of fixed readers required by supply chain enterprise type (producer, feedlot, saleyard, or processor) and EID technology type (LF, UHF, or Dual)</td><td>
Cattle – no. fixed readers
<table>
<tr><td>Enterprise Type</td><td>LF</td><td>UHF</td><td>Dual</td></tr>
<tr><td>Producer</td><td>0 to 1</td><td colspan="2">0 to 1</td></tr>
<tr><td>Feedlot</td><td>1 to 6</td><td colspan="2">1 to 6</td></tr>
<tr><td>Saleyard</td><td>1 to 7</td><td colspan="2">1 to 7</td></tr>
<tr><td>Processor</td><td>0 to 2</td><td colspan="2">0 to 2</td></tr>
</table>

Sheep – no. fixed readers
<table>
<tr><td>Enterprise Type</td><td>LF</td><td>UHF</td><td>Dual</td></tr>
<tr><td>Producer</td><td>0 to 1</td><td colspan="2">0 to 1</td></tr>
<tr><td>Saleyard</td><td>1 to 13</td><td colspan="2">1 to 13</td></tr>
<tr><td>Processor</td><td>0 to 2</td><td colspan="2">0 to 2</td></tr>
</table>
</td><td>Data sourced/ developed through TGD product market review, expert consultation, and published literature review.

Assumption based on ScotEID setups - https://www.scoteid.com/ Public/Documents/uhf/ ScotEID%20UHF%20Report%20April%2021.pdf

Note: for saleyards handheld readers used by agents primarily when ‘mopping up’.</td></tr>
</table>

<table>
<tr><th>Variable</th><th>Data/Assumption</th><th>Source/ Comments</th></tr>
<tr><td>Fixed readers useful life (average replacement period)</td><td>Cattle and Sheep (all enterprise types)
10 years (fixed)</td><td>Based on NLIS target, the transponder within devices must be reliably machine-readable for a minimum of seven years following the installation of devices in typical Australian field conditions.</td></tr>
<tr><td>Maximum industry adoption of fixed readers by enterprise type</td><td>Cattle – fixed reader adoption
<table>
<tr><td>Enterprise Type</td><td>Max. Adoption</td></tr>
<tr><td>Producer</td><td>15%</td></tr>
<tr><td>Feedlot</td><td>15%</td></tr>
<tr><td>Saleyard</td><td>75%</td></tr>
<tr><td>Processor</td><td>15%</td></tr>
</table>
Sheep – fixed reader adoption
<table>
<tr><td>Enterprise Type</td><td>Max. Adoption</td></tr>
<tr><td>Producer</td><td>15%</td></tr>
<tr><td>Saleyard</td><td>75%</td></tr>
<tr><td>Processor</td><td>15%</td></tr>
</table></td><td>TGD assumption inc. 15% producer enterprises adopting handheld readers, based on:
· only enterprises conducting P2P transfers needing scanners
· producers using agents to scan during transfers
· some producers collecting on-farm data

Max. adoption for feedlots, saleyards, and processors estimated based on outputs from adoption modelling by TGD using CSIRO Adopt Tool.</td></tr>
<tr><td>No. of fixed reader antennae required per fixed reader installed</td><td>Cattle – no. antennae per fixed reader
<table>
<tr><td>Enterprise Type</td><td>LF</td><td>UHF</td><td>Dual</td></tr>
<tr><td>Producer</td><td>0</td><td colspan="2">4</td></tr>
<tr><td>Feedlot</td><td>0</td><td colspan="2">4</td></tr>
<tr><td>Saleyard</td><td>0</td><td colspan="2">4</td></tr>
<tr><td>Processor</td><td>0</td><td colspan="2">4</td></tr>
</table>
Sheep – no. antennae per fixed reader</td><td>For LF, antennae are included in fixed reader infrastructure.

Assumption based on ScotEID setups - https://www.scoteid.com/ Public/Documents/uhf/ ScotEID%20UHF%20Report%20April%2021.pdf</td></tr>
</table>

<table>
<tr><th>Variable</th><th>Data/Assumption</th><th>Source/ Comments</th></tr>
<tr><td></td><td>
<table>
<tr><td>Enterprise Type</td><td>LF</td><td>UHF</td><td>Dual</td></tr>
<tr><td>Producer</td><td>0</td><td colspan="2">4</td></tr>
<tr><td>Saleyard</td><td>0</td><td colspan="2">4</td></tr>
<tr><td>Processor</td><td>0</td><td colspan="2">4</td></tr>
</table>
</td><td></td></tr>
<tr><td>Cost for antennae required for fixed UHF readers</td><td>Cattle and Sheep – all enterprise types
$260 per antennae</td><td>Assumption based on ScotEID setups - https://www.scoteid.com/ Public/Documents/uhf/ ScotEID%20UHF%20Report%20April%2021.pdf</td></tr>
<tr><td colspan="3">Initial system fit out costs (fixed readers)</td></tr>
<tr><td>Initial capital costs for fit out of fixed reader infrastructure (one off, upfront cost)</td><td>Cattle –fixed reader fit out costs
<table>
<tr><td>Enterprise Type</td><td>LF</td><td>UHF</td><td>Dual</td></tr>
<tr><td>Producer</td><td rowspan="4">n/a</td><td colspan="2" rowspan="4">$3,000 to $5,000</td></tr>
<tr><td>Feedlot</td></tr>
<tr><td>Saleyard</td></tr>
<tr><td>Processor</td></tr>
</table>
n/a: not applicable

Sheep – fixed reader fit out costs
<table>
<tr><td>Enterprise Type</td><td>LF</td><td>UHF</td><td>Dual</td></tr>
<tr><td>Producer</td><td rowspan="3">n/a</td><td colspan="2" rowspan="3">$3,000 to $5,000</td></tr>
<tr><td>Saleyard</td></tr>
<tr><td>Processor</td></tr>
</table>
n/a: not applicable</td><td>LF infrastructure is assumed already in place across the cattle and sheep industry for the base case scenario prior to potential UHF or dual LF-UHF EID adoption pathways.

Data sourced/ developed through TGD product market review, expert consultation, and published literature review.</td></tr>
<tr><td colspan="3">Relevant EID system labour costs and other costs</td></tr>
</table>

<table>
<tr><th>Variable</th><th>Data/Assumption</th><th>Source/ Comments</th></tr>
<tr><td>Annual hardware and software maintenance costs</td><td colspan="2">Cattle and sheep – all enterprise types
Not applicable – assumed to be part of normal business operations and is assumed similar for different EID systems. Note: software set up and any software updating costs assumed to be included in handheld and fixed reader enabling infrastructure costs.</td></tr>
<tr><td>Annual industry training and advisory costs (capability and capacity building)</td><td colspan="2">Cattle and sheep – all enterprise types
Not applicable – assumed to be similar for all different EID systems and part of business as usual</td></tr>
<tr><td>EID system costs associated with livestock transport</td><td colspan="2">Cattle and sheep – all enterprise types
Not applicable – EID not used directly on livestock transport. Systems unlikely to change for UHF/ Dual EID adoption pathways unless new readers are installed on trucks for P2P transfers.</td></tr>
<tr><td>Enterprise scanning, mopping up, monitoring, and reporting (NLIS compliance) costs associated with relevant P2P or B2B animal movements/ loads</td><td>Cattle – labour hours per movement/ load
<table>
<tr><th>Enterprise Type</th><th>LF</th><th>UHF</th><th>Dual</th></tr>
<tr><td>Producer</td><td>1.5 to 2.0 hours</td><td colspan="2">0.5 to 1.25 hours</td></tr>
<tr><td>Feedlot</td><td>1.0 to 2.0 hours</td><td colspan="2">0.5 to 1.0 hours</td></tr>
<tr><td>Saleyard[a]</td><td>36.5 to 128.5 hours</td><td colspan="2">18.25 to 64.25 hours</td></tr>
<tr><td>Processor</td><td>0 hours</td><td colspan="2">0 hours</td></tr>
</table>
(a) Based on additional hours for movements of 3 to 6 hours, plus 0.5 hours on arrival (e.g., use of weighbridges or extra holding time in drafter), plus 1 to 2 hours compliance monitoring and reporting plus 4-15 FTE personnel per sale day.

Sheep – labour hours per movement/ load
<table>
<tr><th>Enterprise Type</th><th>LF</th><th>UHF</th><th>Dual</th></tr>
<tr><td>Producer</td><td>1.5 to 4 hours</td><td colspan="2">0.5 to 1.25 hours</td></tr>
</table>
</td><td>UHF and Dual labour hours are estimated at 50% less than current LF system hours for cattle feedlots.
UHF and Dual labour hours for other supply chain segments assumed to be ~50% less than for LF due to scanning multiple animals at once, scanning multiple times throughout saleyard to reduce misreads, anti-collision capabilities, ability to read tags with damaged/ de-tuned electrical components.

Data sourced/ developed through TGD product market review, expert consultation, and published literature review.</td></tr>
</table>

<table>
<tr><th>Variable</th><th>Data/Assumption</th><th>Source/ Comments</th></tr>
<tr><td></td><td>
<table>
<tr><td>Saleyard[(a)]</td><td>37.0 to 130.0 hours</td><td>18.5 to 65.0 hours</td></tr>
<tr><td>Processor</td><td>0 hours</td><td>0 hours</td></tr>
</table>
(a) Based on additional hours for movements of 3 to 6 hours, plus 1 to 2 hours on arrival (e.g., use of weighbridges or extra holding time in drafter), plus 1 to 2 hours compliance monitoring and reporting plus 4-15 FTE personnel per sale day.</td><td></td></tr>
<tr><td>Estimated value of labour for EID use</td><td>Cattle and Sheep – all enterprise types
$36.06 per labour hour</td><td>Based on total average annual family farm income for livestock enterprises of $75,000 per annum over 52 weeks and a 40 hour working week.
https://www.agriculture.gov.au/abares/data/farm-data-portal</td></tr>
<tr><td>No. of animal movements/ loads per annum - where EID use for P2P or B2B movements are applicable</td><td>Cattle and sheep– No. animal movements/ loads per annum
<table>
<tr><th>Enterprise Type</th><th>LF</th><th>UHF</th><th>Dual</th></tr>
<tr><td>Producer</td><td colspan="3">2 to 13 p.a.</td></tr>
<tr><td>Feedlot[(a)]</td><td colspan="3">0 (no data available)</td></tr>
<tr><td>Saleyard</td><td colspan="3">52 p.a.</td></tr>
<tr><td>Processor</td><td colspan="3">not applicable</td></tr>
</table>
(a) Feedlot costs were excluded from the Sheep industry analysis because conversations held with NSW, QLD and SA representatives confirmed that feedlots are not a significant separate entity for their jurisdictions.</td><td>Producer movements:
https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/animal-plant/animal-health/livestock-movement/beef-movement-ead.pdf
Saleyard movements: assumed min. one per week
https://www.agriculture.gov.au/sites/default/files/sitecollectiondocuments/animal-plant/animal-health/livestock-movement/beef-movement-ead.pdf</td></tr>
<tr><td colspan="3">System adoption/implementation assumptions</td></tr>
</table>

Variable	Data/Assumption	Source/ Comments
LF EID base scenario the following adoption profile was assumed for both cattle and sheep industries	Enterprise level implementation ● Initial capital expenditure for fitout/infrastructure investment already completed (sunk cost - government mandated NLIS system) ● Replacement of capital every 5 to 10 years based on useful life ● Producers: 100% of new births NLIS tagged each year Industry level implementation ● Producers: 100% of national herd adopted and NLIS LF tagged at year zero ● Feedlots: 100% outfitted with required NLIS LF infrastructure/capacity at year zero ● Saleyards: 100% outfitted with required NLIS LF infrastructure/capacity at year zero ● Processors: 100% outfitted with required NLIS LF infrastructure/capacity at year zero	
UHF only EID scenario the following adoption profile was assumed for both cattle and sheep industries	Enterprise level implementation ● Initial capital expenditure for fitout/infrastructure investment in year zero ● Replacement of capital every 5 to 10 years based on useful life ● Producers: 100% of existing stock NLIS tagged with UHF in by year five (new adopters) ● Producers: 100% of new births NLIS tagged each year from year one Industry level implementation ● Producers: 100% of national herd adopted and NLIS UHF tagged by year five ● Feedlots: 100% outfitted with required NLIS UHF infrastructure/capacity by year three ● Saleyards: 100% outfitted with required NLIS UHF infrastructure/capacity by year three ● Processors: 100% outfitted with required NLIS UHF infrastructure/capacity by year three	
Dual UHF-LF only EID scenario the following adoption profile was assumed for both cattle and sheep industries	Enterprise level implementation ● Initial capital expenditure for UHF capable fitout/infrastructure investment in year zero ● Replacement of dual and/or capital every 5 to 10 years based on useful life ● Producers: 100% of existing stock NLIS tagged with dual EID technology by year five (new adopters) ● Producers: transition existing stock from dual EID technology to 100% UHF technology from year six to twenty (fifteen year period) ● Producers: 100% of new births NLIS tagged with dual technology each year from year one to year five ● Producers: 100% of new births NLIS tagged with UHF only technology each year from year six to year twenty	

Variable	Data/Assumption	Source/ Comments
	Industry level implementation ● Producers: 100% of national herd adopted and NLIS dual tagged by year five and UHF only tagged by year twenty ● Feedlots: 100% outfitted with required NLIS UHF infrastructure/capacity by year three to accommodate dual technologies and subsequent UHF only transition ● Saleyards: 100% outfitted with required NLIS UHF infrastructure/capacity by year three to accommodate dual technologies and subsequent UHF only transition ● Processors: 100% outfitted with required NLIS UHF infrastructure/capacity by year three to accommodate dual technologies and subsequent UHF only transition	

[1] For more information see: https://adopt.csiro.au

9.3 Glossary of Economic Terms

Cost-benefit analysis:	A conceptual framework for the economic evaluation of projects and programs in the public sector. It differs from a financial appraisal or evaluation in that it considers all gains (benefits) and losses (costs), regardless of to whom they accrue.
Benefit-cost ratio:	The ratio of the present value of investment benefits to the present value of investment costs.
Discounting:	The process of relating the costs and benefits of an investment to a base year using a stated discount rate.
Internal rate of return:	The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.
Investment criteria:	Measures of the economic worth of an investment such as Net Present Value, Benefit-Cost Ratio, and Internal Rate of Return.
Modified internal rate of return:	The internal rate of return of an investment that is modified so that the cash inflows from an investment are reinvested at the rate of the cost of capital (the reinvestment rate).
Net present value:	The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.
Present value of benefits:	The discounted value of benefits.
Present value of costs:	The discounted value of investment costs.