DEFRA and Welsh Government Bovine Electronic Identification (BEID) Pilot Projects: Joint Final Report

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EXECUTIVE SUMMARY

The English and Welsh Governments aim to introduce the mandatory electronic identification (EID) of cattle in England and Wales in the near future. This will require farmers to fit a statutory EID tag in the ears of calves born after the implementation date. There are two different types of radio frequency identification (RFID) technologies that can be used with cattle: low frequency (LF) and ultra-high frequency (UHF). LF is a long established animal ID technology and is already mandated for use in sheep in the UK and many other parts of the world including the EU, whereas the use of UHF for animal ID is comparatively new. UHF EID tags provide additional functionality over LF tags as they have a longer read range and multiple UHF tags can be read at once.

To help inform decision making at DEFRA and in the Welsh Government, they both commissioned Harper Adams University to carry out pilot projects (one in England and one in Wales). The DEFRA pilot project looked at both LF and UHF technology on five commercial cattle farms, two markets and an abattoir. The Welsh pilot project included three beef farms and an abattoir. The Welsh pilot project focussed on LF technology and did not include UHF. Decisions about UHF in Wales are being informed by evidence from the DEFRA-funded English trials. This Joint Final Report covers both the Welsh and English pilot projects.

Generally, with static (fixed) readers, UHF performed better than LF. UHF read 99.6% of tagged, free moving animals in a 2.75m wide alleyway, and 100% in a single cow width raceway. Low frequency alleyway readers are not yet available in the UK, although an LF panel reader in a raceway read 99.4% of moving tagged animals. Retro-fitting a UHF reader to a cattle crush is easier than retro-fitting LF readers, although replacement EID doors (where the LF antennas are incorporated into a crush door) are available for some popular types of crush, and worked very well on one of the pilot farms. Identifying animals in a crush or whilst being held in a raceway using hand-held EID readers was on average about three times faster and more accurate than manual identification.

It was difficult to read a number of cattle in a pen with hand-held readers, irrespective of tag frequency. When the target pen was surrounded on three sides by pens occupied by non-target animals, the UHF hand-held reader had an accuracy of 67%, i.e. non-target animals were read on average on 33% of occasions instead of target animals. This was less of a problem when the immediately adjacent pens were empty and only the pens on the diagonals were occupied, which achieved a UHF hand-held accuracy of 96%. Non-target animal reading is a concern with UHF hand-held readers as misidentification poses a risk to traceability and food safety. Misidentifying an animal when it has been treated with a veterinary medicine could result in it going to slaughter during the withdrawal period. Due to the shorter read range, non-target animal reading is less of a concern with LF hand-held readers.

The English farmers gained experience with both LF and UHF equipment as part of the DEFRA pilot project. They showed a preference for UHF for a number of reasons, including being able to identify animals at a distance and read a group of moving animals in an alleyway. They also liked that UHF was WYSIWYG ('what you see is what you get' – i.e. the number on the display matches the visual identifier printed the ear tag) without the complications of 'tag bucket files' (which link the EID number on the tag's chip with the animal's full herd number and individual identifier as printed on the ear tag). The UHF hand-held reader used in the pilot also had greater functionality. Note that the last three benefits (WYSIWYG, no tag buckets and reader functionality) are not related to tag frequency. Non-WYSIWYG EID reading is seen as a barrier to adoption and should be avoided. Should the mandated tags be required to follow either ISO 11784 for LF or ISO 6881 for UHF, then both LF and UHF will be WYSIWYG without the need for tag bucket files.

Electronic identification (both LF and UHF) should improve both human health and safety, and farm animal welfare. In order to accommodate the larger antenna, UHF tags have to be 'flag' tags whereas LF tags can be smaller 'button' or metal 'fold-over' tags. Non-EID flag tags have a lower tag retention rate (i.e. are more likely to be lost) than non-EID button tags, so fewer EID tags should be lost if LF was mandated rather than UHF. No problems with interference or incompatibility with existing on-farm RFID systems were detected with either UHF or LF in these pilot projects. If LF were to be mandated, the statutory LF EID tag could replace the functionality currently provided by LF management tags on many farms. Some existing equipment on farms that utilises LF RFID requires the EID tag to be in a specific ear. Farmers buying cattle born and tagged on other farms will need a derogation to allow them to swap the statutory EID tag to the appropriate ear where needed.

Currently there are at least six companies providing LF bovine EID equipment in the UK compared to just one for UHF. There are concerns about the ability of a single UHF supplier to meet the demands for tags and readers following the introduction of mandatory BEID in England and Wales, and concerns about the implications should this one supplier fail.

The use of LF in animal identification is covered by a range of ISO standards whereas there is only one (currently) for UHF. ISO standards are important as they help ensure the interoperability of tags and readers from different manufacturers, and help ensure EID equipment meets minimum specifications and functionality. These ISO standards are also important for international trade, and demonstrating robust traceability is easier if the underpinning technologies meet agreed international standards. EU member states can voluntarily adopt EID, but if they do it must comply with ISO11784 and ISO11785 and so must be LF. The Republic of Ireland has mandated LF EID for cattle born on or after 1 July 2022.

An important consideration is that even if EID can read 100% of tagged animals, it will never be able to read 100% of all animals. Although farmers should replace lost EID tags before animals leave their holding, some EID tags will be lost during transport. A bigger problem will be with farmers that do not use EID on their farm. They will not know whether an EID tag has stopped working due to the electronics failing, so will send animals to markets and abattoirs that cannot be read electronically. Consequently, animals will still need to be held, ideally in a cattle crush, to allow animals with non-functioning EID tags to be read manually.

In summary, the following challenges are lower (i.e. easier to overcome) if ultra-high frequency (UHF) technology is mandated for bovine electronic identification in England and Wales:

1. Reading a group of moving animals in an alleyway (static reader).
2. Retrofitting a static EID reader in a crush.
3. Read range.

The following challenges are lower (i.e. easier to overcome) if low frequency (LF) technology is mandated for bovine electronic identification in England and Wales:

4. Reading through flesh.
5. Accidentally reading a non-target animal (hand-held readers).
6. EID tag retention (assuming UHF tags have to be flag tags).
7. Availability of EID equipment and supplier diversity (short term).
8. ISO standards for tags, readers etc. (short to medium term).
9. Compatibility of hand-held readers with the UK sheep EID standard.
10. Compatibility with the type of EID used in the EU (inc. Republic of Ireland).

Currently, challenge number 8 (lack of ISO standards for UHF BEID technology) is arguably the most significant challenge with mandating UHF BEID in England and Wales, and will likely remain a challenge for a number of years.

The overall conclusions of the English and Welsh BEID pilot projects are:

- From the stakeholders consulted in this pilot, there is general support for implementing mandatory bovine EID across the English and Welsh cattle industry at the earliest opportunity.
- Electronic identification is quicker and more accurate than manual ID tag reading and recording.
- Although there are some benefits from using UHF tags on larger farms, the benefits are less clear on smaller farms, in markets and in abattoirs.
- Overall, there are fewer challenges (especially in the short term) with mandating the use of LF tags compared to UHF tags.
- If and when some of the current challenges with UHF tags are resolved, dual tagging (i.e. each individual animal would have both a UHF and a LF transponder fitted) could be an option.

1. Introduction

DEFRA and the Welsh Government aim to introduce the mandatory electronic identification (EID) of cattle in England and Wales in the near future. There are two different radio frequency identification (RFID) technologies that can be used with cattle: low frequency (LF) and ultra-high frequency (UHF). Low frequency EID has two variants: HDX and FDX-B. To help inform decision making at DEFRA and support DEFRA's Traceability Design Users Group (TDUG), they commissioned Harper Adams University to carry out two pilot projects. The DEFRA phase 1a pilot (February - April 2023) focused on the technical aspects of LF *vs* UHF and included economic and practical considerations associated with the introduction of mandatory bovine EID in cattle in England (Rutter *et al.*, 2023). The phase 1a pilot concluded that although LF was a tried and trusted technology, the read range was shorter than UHF, and, unlike UHF, LF cannot identify more than one animal at a time. The UHF tags tested were also WYSIWYG (i.e. the reader displays the same number as printed on the tag), but this is also possible with LF tags. UHF signals are more easily blocked, meaning the group reading of animals in a pen was generally unreliable with a UHF hand-held reader. We were not able to test the ability of UHF to read a group of animals moving down an alleyway.

Recommendations for further research included conducting tests of LF and UHF EID technologies on commercial farms, including the use of static readers in alleyways and raceways.

The DEFRA phase 2 pilot reported here aimed to understand the experiences of English cattle farmers from different sizes and types of holdings in the use and their experiences of bovine electronic identification (BEID). The project also included visits to markets and an abattoir to better understand the challenges and opportunities associated with the introduction of mandatory bovine EID in those parts of the UK cattle industry. The phase 2 pilot also evaluated both low frequency (LF) and ultra-high frequency (UHF) RFID (radio-frequency identification) technologies (ear tags and readers) on farms, in markets and at an abattoir.

The Welsh Government commissioned a similar pilot project which included three Welsh beef farms and a Welsh abattoir. This focussed on LF technologies and did not include UHF. Decisions about UHF in Wales are being informed by evidence from the DEFRA-funded trials in England (and included in full in this joint report).

To try to ensure the people we consulted in these pilots felt able to talk to us as freely and openly as possible, we guaranteed their identities would remain confidential. Consequently, we are unable to acknowledge individuals by name, but we would like to thank everyone who gave their time to talk to us and participate in this work.

2. The farm trials (in both England and Wales)

Five English farms (three beef and two dairy) and three Welsh beef farms were recruited to the pilot. As well as the on-farm EID equipment trials, the farmers also participated in questionnaires and an interview, and the anonymised results from these are summarised in sections 2.6 and 2.10.

2.1 English beef farm 1

English beef farm 1 was the largest beef farm in the pilot with approximately 2100 head of cattle. This farmer was familiar with LF BEID technology so we did not require them to revert to manual reading, and the study on this farm focussed on static readers, with UHF and LF in a crush, and UHF in an alleyway. This was something that was not fully investigated in the phase 1a pilot and was therefore an important goal for the phase 2 pilot.

2.1.1 English beef farm 1 crush reading

A UHF antenna and reader were fitted above the farm's weigh crush, and LF EID panels were fitted either side of the crush (see Figure 2.1). When the LF panels were installed in the crush, there were a limited number of places to locate them to avoid blocking one of the doors on the side of the crush. The ideal location would have been nearer the front of the crush as this would have been nearer the animal's head whilst it was being weighed. After installation, the farm staff found LF panel partially blocked the line of sight of the crush operator, although this could to some extent be resolved by cutting a hole in the middle of the panel. In contrast, the UHF antenna was located out of the way above the crush. Both the UHF and LF readers were successfully integrated into the bespoke animal liveweight recording software used at the farm.

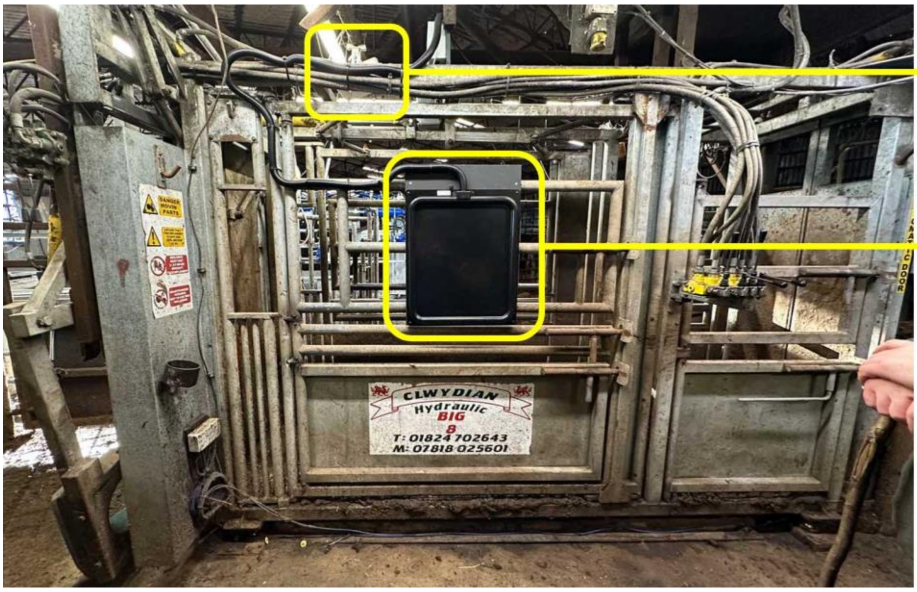

Figure 2.1. UHF (top) and LF (middle) static readers as installed in the weigh crush on English beef farm 1.

A total of 132 cattle were put into the crush and weighed. The first 66 were identified using the LF panels and the second 66 were identified using the UHF reader. When using LF, three of the 66 animals were not initially identified i.e. they managed to pass between the two LF panels without their LF tag being read. This was immediately apparent to the operator and was resolved quickly (requiring an average of 7 seconds per animal). This required the operator at the front of the crush to step towards the animal and encourage it to take a step back, at which point the tag was read by an LF panel. When using UHF, all 66 animals were identified on first entering the crush. The challenge of retro-fitting LF panels in cattle crushes is discussed further in section 6.2.

2.1.2 English beef farm 1 alleyway reading

A four-antenna UHF reader was set up over a 2.75m wide alleyway (Figure 2.2). The UHF antennas were at a height of 2.82m and directed into the area between them. A group of 132 cattle fitted with UHF flag tags (and subsequently counted through a crush) were run to-and-fro under the UHF antennas a total of six times. The numbers of cattle identified on each run is presented in Table 2.1.

Figure 2.2. Photograph (left) showing the four UHF antennas (circled in yellow) above the 2.75m wide alleyway, and a video still (right) showing cattle moving under the UHF antennas during the trial. Note that wire mesh (visible in the still on the right) had been installed above the antennas after the photograph on the left was taken. This mesh is believed to help read tags in animals in the UHF 'tunnel', and reduce the risk of accidentally reading any animals adjacent to the tunnel.

Table 2.1. Results from running a group of 132 UHF tagged cattle through the alleyway reader a total of six times (three times in each direction). The one animal that was missed in run 5 was different to the two missed in run 3. Durations are from the time interval between the first and last UHF tag to be read.

Run	Duration (min:sec)	Number of animals read	Read rate	Total number of animals read	Overall read rate
1	1:20	132/132	100.0%	789/792	99.6%
2	0:52	132/132	100.0%		
3	1:07	130/132	98.5%		
4	1:24	132/132	100.0%		
5	1:27	131/132	99.2%		
6	1:19	132/132	100.0%		

In four out of the six runs, all 132 cattle were read i.e. a 100% read success rate. The reasons for two animals being missed in run 3 and one in run 5 are not clear. Run 5 was the slowest, but only by three seconds. The fact we did not always achieve a 100% read rate for UHF-tagged cattle in the alleyway is in line with a ScotEID report (ScotEID, 2023) which states that, under commercial conditions, '*a few missed reads do occur*' with the caveat that '*this is nearly always due to missing ear tags*' (paragraph 98). We are confident the missed reads in this study were not due to missing tags because after the six runs through the UHF alleyway tunnel, the same group were run through a race and all 132 counted, and the final and an intermediate run (run 4) also read all 132 animals.

Even though a read rate of less than 100% was recorded on two of the six runs, the fact this static multi-antenna UHF system was able to read a large group of fast-moving cattle in close proximity to each other is very impressive. This is one area where UHF has a very significant advantage over LF and observing this (especially on the majority of occasions when it achieved a 100% read rate) was one of the highlights of the phase 2 pilot.

2.2 English beef farm 2

English beef farm 2 was intermediate in size (i.e. between English beef farms 1 and 3 in the pilot) with approximately 1000 head of cattle. Hand-held UHF and LF readers were provided to the farmer. The identification of cattle using manual (visual ear tag) as well as LF and UHF EID reading were video recorded. The videos were analysed to determine the time taken for each identification method, and the results are summarised in Table 2.2. All animals were correctly identified.

Table 2.2. Summary of the timing and accuracy results from English beef farm 2.

ID method	Manual	LF	UHF
Time per animal (seconds)	7.6	3.7	3.0
Animals correctly identified	20/20	16/16	40/40
Accuracy	100%	100%	100%

This farm had the slowest speed of identification of animals by LF of any of the timing measurements recorded in this pilot. This was attributed to the animals being identified as they stood in a raceway, but they were at a low stocking density, so animals were inclined to move backwards when approached by the operator with the LF stick reader. It therefore took longer to scan the LF tag. Consequently, manual identification took about twice as long as electronic identification on this farm, which is a smaller differential than found on the other farms.

2.3 English beef farm 3

Beef farm 3 was the smallest beef farm in the English pilot with approximately 200 head of cattle. Hand-held UHF and LF readers were provided to the farmer. The identification of cattle using manual (visual ear tag) as well as LF and UHF EID reading were video recorded. This was done by the farmer themselves as research staff were delayed due to traffic. Consequently, we do not have any records of accuracy for this farm. The videos were analysed to determine the time taken for each identification method, and the results are summarised in Table 2.3.

Table 2.3. Summary of the timing results from English beef farm 3.

ID method	Manual	LF	UHF
Time per animal (seconds)	8.4	2.6	3.0
No. of animals identified*	7	9	8

*Read accuracy was not checked on this farm. This is the number of animals that contributed to the average time taken to identify individual animals.

The identification timing results from this farm are very similar to the other farms, with manual identification taking about three times longer than electronic identification.

2.4 English dairy farm 1

English dairy farm 1 was the larger of the two dairy farms involved in the pilot, milking approximately 650 cows. The cows are milked in a rotary parlour, and most of the time they exit via one raceway. This is not always the case, as cows that need attention are put in a side pen and exit via a different route. There is a HerdVision (https://herd.vision/) automated body condition scoring (BCS) and mobility scoring system located at the end of the main exit raceway. This incorporates two LF static panels on either side of the race way (Figure 2.3 right). HerdVision were able to share the raw data collected by this LF reader. On the same raceway (nearer the parlour), four UHF antennas were installed as shown in Figure 2.3 (left). The ID data from these panels were uploaded to the ScotEID database where they could be accessed by research staff. This meant that the majority of the cows passed under both the UHF antennas and through the LF panels at every milking. There was no opportunity for a cow to leave the raceway between the UHF and LF readers, so any cow detected by one should also be detected by the other. Most of the cows in the herd already had LF button tags in their ears so they could be identified by the HerdVision system. Just over sixty cows had a UHF EID ear tag fitted. The farmer was also provided with UHF and LF hand-held readers.

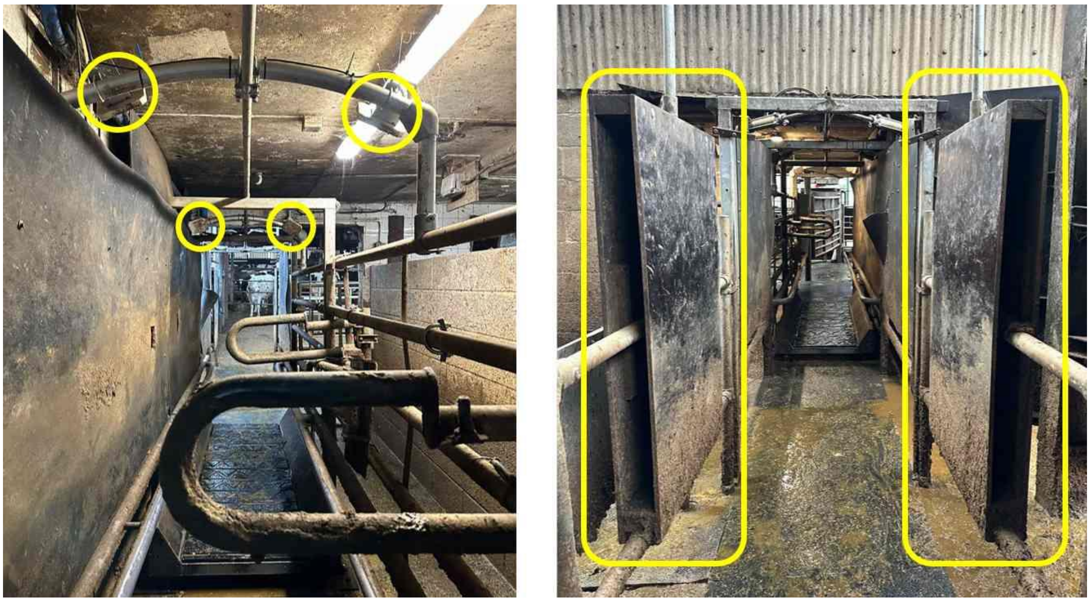

Figure 2.3. The four-antenna UHF static reader (left, antennas circled in yellow) and the HerdVision LF EID panels (right, within the yellow boxes) installed on the main parlour exit race. Cows exiting from the parlour pass the UHF antennas followed by the HerdVision system. The photograph on the left shows the cow's view when exiting, and the photo on the right is looking back up the race towards the rotary parlour.

A researcher visited and manually recorded the ID of cows as they passed the UHF antennas whilst exiting the parlour. A total of 481 cows were recorded, although some data were missing manual ID due to the freeze band numbers not always being clear to the researcher.

Although access to the UHF data was requested at the end of January, it was not made available until early March. This delayed data analysis, and by the time both the UHF and HerdVision data were available, our contact at HerdVision stated that the farmer had retagged about 200 cows (replacing missing or old LF management tags) in late February. Consequently, the current tag bucket data (linking EID to animal visual and UHF ID) would have a lot of new LF ID information added since we observed cows in January. It was therefore decided not to analyse the animal IDs that were recorded manually in late January.

Fortunately, there is an alternative method to check UHF and LF read reliability. Any cow detected by the UHF reader should also be detected by the LF reader and *vice versa*. If a cow was in the UHF list but not the LF list, then the LF system had missed a cow. Conversely, if there was a cow in the LF list that was not in the UHF list, then the UHF system had missed a cow. Any of the 60 UHF-tagged cows that were missed by both the UHF and LF panels likely bypassed the exit race after that milking. The most recent seven-day period (ending 13 March) was chosen as it was believed to have the most reliable LF tag bucket list. UHF data were downloaded from ScotEID and HerdVision supplied the LF data.

The LF reader raw data included multiple reads for each tag, so over a quarter of a million records had to be processed (removing duplicates) and sorted to get a HerdVison EID list for each milking. These EID records then needed to be matched to the LF EIDs in the 60+ UHF tagged cows. This was done using ‘tag bucket’ data generated by the farm’s Uniform Agri management software. Then any missing records in the LF data were indicative of a likely missed read. Conversely, occasions where a UHF tag was not recorded were then checked to see if the corresponding LF records were also missing. It is believed that there are a couple of cows where the LF tag bucket data is not quite up-to-date, so these data should be regarded as being broadly indicative and not absolute. A summary of the analysis is given in Table 2.4.

Table 2.4. Summary of the read reliability results from the UHF and LF static readers in the main parlour exit raceway. Challenges around tag replacements and out-of-date tag bucket information for some cows mean these results should be treated as being broadly indicative and not absolute. The read rates given are rounded to the nearest percent.

Date and	7/3/24		8/3/24		9/3/24		10/3/24		11/3/24		12/3/24		13/3/24	
milking	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm	am	pm
UHF records	58	59	59	59	60	60	60	60	60	60	60	60	60	60
UHF missing	0	0	0	0	0	0	0	0	0	0	0	0	0	0
UHF read rate %	100	100	100	100	100	100	100	100	100	100	100	100	100	100
LF records	57	59	59	59	60	60	60	60	59	60	60	58	60	59
LF missing	1	0	0	0	0	0	0	0	1	0	0	2	0	1
LF read rate %	98	100	100	100	100	100	100	100	98	100	100	97	100	98

With a total of 835 records, the overall read rate for LF was 99.4%. There were no missing reads for UHF, so the overall read rate for UHF was 100%.

The identification of cows using manual (visual ear tag) as well as LF and UHF EID hand-held reading were video recorded. The videos were analysed to determine the time taken for each identification method, and the results are summarised in Table 2.5.

Table 2.5. Summary of the timing and accuracy results from English dairy farm 1.

ID method	**Manual**	**LF**	**UHF**
Time per cow (seconds)	6.4	2.7	2.5
Animals correctly identified	11/12 *	12/12	12/12 †
Accuracy	91.7%	100%	100%

*The farmer read out the visual EID number (last 4 digits) and the researcher wrote this down. The researcher misheard one number, so it was classed as an incorrect identification.

† On two occasions the UHF hand-held reader identified the cow behind the one in the crush and not the target cow. The farmer was diligent enough to spot this mistake on both occasions and

rectified the problem. As this was corrected at the time, this was classed as an accurate identification.

The EID identification timing results from this farm are very similar to the other farms. This farmer was one of the quickest with manual identification, but it still took more than twice as long as electronic identification.

2.5 English dairy farm 2

English dairy farm 2 was the smaller of the two dairy farms, milking approximately 140 cows. The milking parlour has four stalls on each of the two sides i.e. eight stalls in total. Cow IDs are currently read and entered manually into the parlour software (with a keypad at each stall). Each milking stall had a UHF antenna fitted above it (see Figure 2.4, left) i.e. eight UHF antennas in total. A single LF panel was installed on the righthand side of a narrow race through which cows could exit (Figure 2.4, right). The cows on this farm had dual LF/UHF tags fitted in their right ear. Approximately half of these where LF-HDX and half LF-FDX-B (the two types of LF transponder). The farmer was also provided with UHF and LF hand-held readers.

Figure 2.4. One of the UHF antennas in one of the eight milking stalls (left, circled in yellow), and the LF static panel reader (right, in the yellow box) on the narrow exit raceway.

Unfortunately, there were a lot of issues with the equipment installed on this farm. These issues only really became apparent during or sometime after a researcher visited the site in late January 2024. Firstly, the narrow raceway where the LF panel had been installed was not the main exit route from the parlour. Cows normally bypassed this narrow raceway, and it was only used for animals that needed attention. The narrow raceway was used to identify individual cows on the day the researcher visited, and it was noticed that the LF panel was registering some cows when they walked past on the other side of the wall i.e. some of the LF tags were being read through the concrete wall. This highlights the need to fully test static readers once installed to ensure that they can only read target animals. It is believed this would require a sheet of metal (a bit larger than the LF panel) to be screwed to the wall to fix this problem.

There were also significant problems trying to get access to the UHF data. When the researcher visited, they recorded the entry time and stall number of cows being milked. About halfway through milking, the tablet PC that was logging the UHF data automatically performed a Microsoft Windows software update. This was noticed, but observations continued in the hope the UHF reader might buffer the data. At the end of January, the researcher contacted the UHF installer and requested access to the logged data (in part to see if the Windows update had resulted in partial or total data loss). The plan was that once UHF data logging was confirmed, the research team would revisit this farm. However, the UHF installer had problems accessing the data themselves as the 3G data modem kept running out of data. Access for the researcher to the UHF data was finally established on 13 March which was too late to be able to make another farm visit. On checking the ScotEID database for this farm, no data from the UHF reader in the parlour were recorded between 19 December 2023 and 4 March 2024. The reason for this is unclear.

We had also intended to compare LF-HDX and LF-FDX-B on this farm, but as the LF panel was not installed on the primary exit race we were not able to collect sufficient data to make a valid comparison. HDX *vs* FDX-B performance warrants further investigation in the future.

When the research team attempted to analyse the video recorded of the farmer using different methods of ID (manual, LF and UHF) it was apparent there were a number non-target cows being identified, both with the LF panel reader and the UHF hand-held reader. It appears the issue of non-target LF reading was not detected when the LF panel was installed and, it is believed, user inexperience with the UHF hand-held reader. As such the test conditions did not meet our requirements i.e. professionally installed <u>and tested</u> panels and users to be familiar with the equipment before being observed. Therefore, these results are not presented.

2.6 Summary of English farmer questionnaire responses

The full results from the analysis of pilot farmer questionnaire responses are given in Appendix 1. The feedback from the five farm owners or managers provides insight into their experiences and views regarding the trial use of EID tag technology in cattle management. The main challenges faced or anticipated by the farms before the trials included difficulty in integrating with other systems, technical problems during use, steep learning curves for staff, and data privacy and security concerns. However, after the trials, most of these concerns decreased. The farms unanimously agreed that EID tags enhance the effectiveness and efficiency of cattle management and that the long-term benefits outweigh the initial costs and challenges. The most important factors influencing the adoption of EID tags were reliability and accuracy, ease of use, and interoperability with current systems. Potential obstacles to implementation included financial costs and technical complexities, although these were considered moderate obstacles. The use of EID tags significantly improved the accuracy of record-keeping by eliminating manual errors and enhancing data management. The farms identified several potential opportunities associated with EID tag integration, such as future technological advancements, enhanced compliance with industry standards, improved herd management, and better marketing and sales opportunities due to improved traceability.

All four of the farmers that completed the second questionnaire expressed a preference for UHF EID over LF. The main reasons cited were:

- The UHF hand-held reader used in the pilot automatically shows the animal visual tag number (i.e. it is ‘WYSIWYG’) but the LF stick readers used in the pilot requires much more complicated tag bucket lists to achieve the same thing. Note that should EID be mandated in England then the tags will be WYSIWYG without the need for tag bucket files.
- The LF stick readers used in the pilot were more complicated to set up and needed to be connected to a PC to upload tag bucket lists and access data, and this connection was a technical challenge.
- The UHF hand-held reader has an easier user interface with easy access to previous records whereas the LF stick reader has very basic functionality.

- UHF technology can read a group of animals at once and has a much longer read range.
- Longer read range is believed to be better for farmer health and safety and animal welfare.

The following caveats should be kept in mind when interpreting these results. Some of the biases against LF were associated with issues unrelated to the limitations of tag frequency i.e. non-WYSIWYG requiring tag bucket files and our choice to use rather basic LF stick readers in the pilot. It was clear that at least one farmer had a pre-existing bias in favour of UHF EID technology, and this bias was reflected in their responses. Also, the five farmers that participated in the pilot were not chosen at random, and their views may not be representative of English cattle farmers in general.

2.7 Welsh beef farm 1

Welsh beef farm 1 was the largest of the three Welsh beef farms in the pilot with approximately 370 head of beef cattle. This farmer had not previously used BEID. This farm purchases cattle to finish prior to slaughter. This farmer uses red management tags (Figure 2.5, left) with a three digit identifier that is linked to the animal's full 12 digit UK identifier in the farm management software. By fitting these numbered management tags in sequence, the farmer can quickly and easily visually identify any animals that are not performing as well as their peers. This farmer has developed a manual ID recording system that works very well for them. The cattle are weighed on a sophisticated hydraulic 'squeeze' crush (Figure 2.5, right) which can be controlled remotely from a few feet away.

Figure 2.5. Photographs showing on the left the red management ear tags (note that the animal IDs on the yellow statutory ear tags have been blurred) and on the right the hydraulic 'squeeze' crush used on Welsh beef farm 1.

The farmer was supplied with a number of LF button EID tags which had been printed with herd and individual animal identification numbers. The EID tag supplier also provided 'tag bucket files' that linked the tag's EID number with the animal's visual identifier (VID) as printed on the tag. The farmer fitted these EID tags in the animals they had selected.

A UK livestock EID equipment manufacturer was engaged to investigate options for fitting LF EID panels and a reader in the crush. This proved challenging for a number of reasons:

a) The doors at the front of the crush open inwards, so neck EID panels on or near the yoke were not viable.
b) The sides of the crush can be moved in and out depending on the size of the animal being weighed. Although a pair LF antennas (one on either side of the crush) can be 'tuned' to optimise performance, this is influenced by the distance between the two antennas. As the

distance between the antennas can change in a squeeze crush, it is difficult to optimise antenna performance for all possible crush widths.

c) The farmer operates the crush remotely from a few feet away and did not want to have to move nearer to the crush to encourage an animal to move back if it had been missed by the LF reader when it first entered the crush.

The only viable location for static LF EID panels was on the sides of the crush close to the middle (i.e. about half way between the front and back of the crush). However, even after trying to tune the panels, a proportion of cattle (about one in five) were still being missed when they first entered the crush, and this did not meet the requirements of the farmer. The EID equipment manufacturer believed that a much higher read reliability rate should be possible if bespoke doors incorporating EID antennas were manufactured for near the front of the crush. However, the project timescale was too short for this option, so it was decided not to implement BEID on this farm in the pilot. The farm still provided tagged animals for the Welsh abattoir to read.

2.8 Welsh beef farm 2

Welsh beef farm 2 was intermediate in size i.e. between the other two Welsh beef farms in the pilot with approximately 270 head of beef cattle. This farmer had tried using LF BEID tags before the pilot, but had experienced problems due to the unreliability of the Bluetooth wireless connection between an LF stick reader and the weigh head attached to the crush. It was therefore decided to investigate the use of a fixed panel reader installed in their weigh crush to facilitate a cable connection to the weigh head. Some of the cattle on this farm already had LF EID management ear tags. Those that did not (but were likely to go to the abattoir during the project) were fitted with EID tags which had been printed with herd and individual animal identification numbers. The corresponding tag bucket files were also supplied.

One UK livestock EID equipment manufacturer was engaged to fit static panels in the front of the crush, but after a site visit it was determined that their panels were too wide for the intended location, so a second UK livestock EID equipment manufacturer was approached. This second company already have 'off-the-shelf' EID doors they have developed for this particular model of crush so they were commissioned to install these EID doors (see Figure 2.6).

Figure 2.6. Welsh beef farm 2 had off-the-shelf EID doors (solid green panels with a grey box at the top) fitted on either side at the front of their existing weigh crush.

The installer helped the farmer integrate the EID reader with their weigh head. The farmer was very pleased with the performance of the EID doors and reported that the animals were reliably identified and the wired connection to the weigh head was very stable and always remained connected. HAU staff visited the farm and video recorded a group of animals being weighed. The timings from the analysis of this video recording are given in Table 2.6.

Table 2.6. Summary of the timing and accuracy results from Welsh beef farm 2.

ID method	Manual	LF
Time per cow (seconds)	4.2	4.5
Animals correctly identified	10/10	18/18
Accuracy	100%	100%

This farmer was very quick with manual reading (but only needed to enter the last four numbers of the ear tag on the weigh head). The LF reading time in Table 2.5 includes the time taken to manually confirm the animal weight on the weigh head. In practice the static LF read time was nearly instantaneous.

2.9 Welsh beef farm 3

Welsh beef farm 3 was the smallest of the three Welsh beef farms in the pilot with approximately 250 head of beef cattle. This farmer had not used BEID before the pilot project. Although this farmer had an electronic weigh head for their weigh crush, it was not EID compatible, so the farmer was provided with a new EID compatible weigh head and a hand held LF stick reader as part of the project. The farmer was also provided with a number of LF button EID tags which had been printed with herd and individual animal identification numbers as well as the corresponding ‘tag bucket files’. Once the farmer was familiar with using the EID equipment, HAU staff visited and made a video recording of cattle being weighed. The timings from the analysis of this video recording are given in Table 2.7.

Table 2.7. Summary of the timing and accuracy results from Welsh beef farm 3.

ID method	Manual	LF
Time per cow (seconds)	8.9	2.0
Animals correctly identified	15/15	15/15
Accuracy	100%	100%

The timings for this farmer are comparable to those achieved elsewhere in the project.

As is normal practice, the new weigh head and stick reader were shipped to the farmer, i.e. they were not visited by an installer to help set up the equipment. Although the farmer managed to get the new weigh head and EID stick reader connected to each other and working, they had not managed to upload the tag bucket files when HAU staff visited to observe them. The farmer observed that the Bluetooth connection between the weigh head and stick reader would occasionally be lost, but worked out that switching the stick reader off and then back on restored the connection. However, the farmer did not feel that they were getting the most from the weigh head and requested some help. The equipment manufacturer provided some over the phone help and the farmer was then happier that they were making effective use of the equipment. This kind of one-to-one support will be important if farmers are to be encouraged to adopt EID readers and make the best use of BEID once it is mandated. This will be particularly important for hand-held readers which are not typically supplied with on-site support as part of equipment installation.

2.10 Summary of Welsh farmer questionnaire responses

The feedback from the three Welsh farm owners provides insight into their experiences and views regarding the trial use of LF EID in cattle management. The detailed responses can be found in Appendix 1. Of the three Welsh farms, one had previously used LF EID in their routine management of cattle and two had no prior experience. Overall, the one who had previously used the EID was positive about the trial and the potential benefits of adopting the technology. The novice users were less positive and more concerned with the challenges. The main challenges anticipated by the farms before the trials included a high steep learning curve for staff if implementing EID. After the trials, the Welsh farmers experienced varying levels of challenges in integrating EID tags with other systems, technical problems during use, maintenance and replacement costs, and a steep learning curve for staff.

The two novice users were less enthusiastic about the potential benefits of EID technology compared to their English counterparts, particularly in terms of effectiveness and efficiency enhancement. The most important factors influencing the adoption of EID tags for the Welsh farmers were reliability and accuracy, ease of use, and interoperability with current systems, while cost was seen as less important. The impact of EID tags on the accuracy of record-keeping varied among the Welsh farmers, with one reporting significant improvement, one being neutral, and one indicating that accuracy was somewhat worsened due to the EID tags having to compete with a refined manual management tagging system.

The Welsh farmers only tested LF EID and were more satisfied with the technology than their English peers. However, they gave similar ratings for ease of implementation as English farmers. The overall feelings about using EID tags were less positive among the Welsh farmers compared to their English counterparts, with concerns about the technology not being robust, user-friendly, or accurate enough.

The two novice users were less likely to recommend using EID compared to their English peers, with one being neutral, and one probably not recommending it due to concerns about read reliability and the system not being user-friendly. But the one who had previously used LF EID would definitely recommend it. Regarding the likelihood of adopting EID tag technology in the next two years, one farmer indicated that they are very likely to adopt LF EID due to operability and compatibility across software and hardware, one is likely to adopt, and one is unlikely to adopt.

The following caveats should be kept in mind when interpreting these results. The sample size of Welsh farmers was also very small, and their views may not be representative of Welsh cattle farmers in general. Additionally, the Welsh farmers only tested LF EID technology, so their opinions on UHF EID technology were not captured in this study.

3. The English market trials (findings are also applicable in Wales)

3.1 Market operating procedures

Based on visits to two markets and discussions with industry representatives, there is considerable variation in the scale, layout and operating methods between different livestock markets. There are however some common features:

1. Markets invariably have several loading bays, and many do not have a 'central' point through which all cattle are run.
2. Most markets sell cattle in 'lots', with one or more animals per lot.
3. To assist operations, cattle are given a clearly visible mark (either an individual animal or a lot number).
4. Individual cattle IDs are read (currently their visual tag) and the appropriate lot number is then added to the animal (see Figure 3.1). This ties together the animal's UK ID number (and therefore their passport) and the auction lot number.
5. Thereafter, the animal is identified just by the lot number.
6. The clearly visible lot number makes it easy to identify the animals when taken to the sale ring, when in the ring, and then when the buyers need to find their animals after the sale.
7. Many auctioneers will likely keep lot numbers even when BEID is introduced.

Figure 3.1. At the small market (left), animals are identified in a raceway and lot numbers painted on their backs. At the large market, animals are identified in pens (centre), and paper lot numbers stuck on their backs (right).

3.2 Closed market trial: Raceway reading test

The smaller of the two markets in the pilot have two side-by-side raceways in which cattle are identified and the lot numbers added (painted on – Figure 3.1, left). A raised platform on one side of the raceway allows market staff to see across taller animals to see their tags.

As part of the pilot, a trial was conducted when the market was closed. This allowed several different tests to be conducted (including replication i.e. repeats to improve the validity of the results) without interfering with the operation of a 'live' market. Forty cattle (all with both LF and UHF tags) were used in the closed market trial and divided into file 'lots' of eight animals per lot. The first three lots were identified manually (noting both herd and individual animal numbers), using a hand-held UHF reader and using an LF stick reader. This was carried out by Harper Adams research staff and not market staff. This process was video recorded (Figure 3.2) to determine the time taken to identify the animals, and the accuracy of the recorded IDs were also checked. The results are summarised in Table 3.1. There was one error in the manually recorded IDs i.e. a 23/24 or 96% accuracy. There were no errors in either the UHF or LF hand-held EID reads i.e. both were 100% accurate.

Figure 3.2. A video still showing manual ID of the cattle in the raceway.

Table 3.1. Summary of the timing results from the closed market raceway reading.

Replicate	Manual		LF		UHF	
	Per eight min:sec	**Per animal** sec	**Per eight** min:sec	**Per animal** sec	**Per eight** min:sec	**Per animal** sec
1	02:56	22.0	00:15	1.9	00:19	2.4
2	02:35	19.4	00:16	2.0	00:17	2.1
3	02:05	15.6	00:21	2.6	00:18	2.3
Mean		**19.0**		**2.2**		**2.3**

The manual reading time improved over the three replicates, suggesting the research staff were getting better with experience, and it is likely experienced market staff would be quicker. However, based on observations of lotting in the live market, manual reading cannot achieve the very quick times obtained with both LF and UHF identification. EID identification was also more accurate than manual identification, largely due the challenge of reading dirty tags (Figure 3.3) and/or tags in hairy ears.

Figure 3.3. Photograph illustrating the challenge of manual identification when the tag is dirty. Note that the herd mark has been blurred for anonymity.

3.3 Closed market trial: Pen reading tests

The accuracy of reading a group of cattle in a pen was tested under three scenarios. In the first (pen test 1, Figure 3.4, left), the 8 cattle in the target pen were surrounded on three sides by pens also occupied by eight cattle in each. In pen test 2 (Figure 3.4, right), the pens on the diagonals were occupied (eight cattle in each) and the immediately adjacent pens empty. In pen test 3 (not illustrated), the target pen was surrounded by empty pens (or the raceway) on all sides. All the pens were 3.2m by 3.9m.

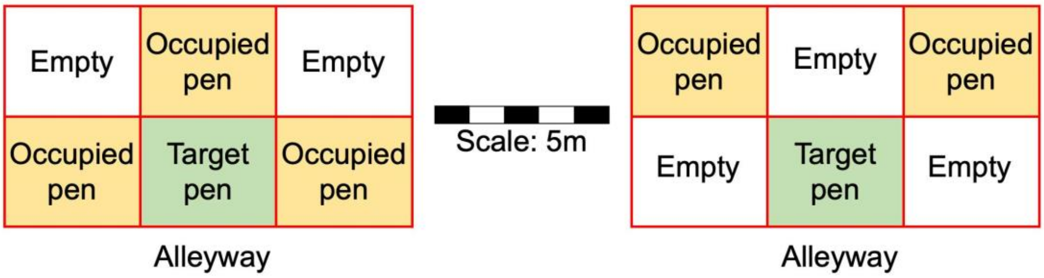

Figure 3.4. A plan illustrating the layout of the target and occupied pens for pen test 1 (left) and pen test 2 (right).

The protocol used in all three pen tests with the UHF hand-held reader was to scan the target pen until eight animals had been registered. The UHF reader operator tried to avoid scanning non-target animals by climbing on the railings of the target pen so as to aim the scanner down as much as possible, and also to try to read over any cattle that might be obscuring the animals behind them (Figure 3.5). This has health and safety implications, and other solutions (e.g. a pole-mounted UHF reader) need to be considered. Once eight IDs had been recorded, this list was then compared to the known list of animals in the target group (recorded earlier in the raceway reading test in section 3.2). Any non-target animals were noted. This was repeated another two times (giving three replicates for each pen test arrangement). The results are given in Table 3.2.

Figure 3.5. The pen with the target animals (on the right) being scanned with the UHF hand-held reader in pen test 2. Note that the operator is trying to use the scanner as high as possible to avoid scanning non-target animals in other pens and to scan 'over' animals in front of them to read those behind.

Table 3.2. The results from the closed market pen tests 1, 2 and 3 for the UHF hand-held reader. Rep. = replicate number.

Pen test	Rep.	Target scanned	Accuracy	Non-target scanned	ID(s) of target animals missed (last 4 digits)	ID(s) of non-target animals scanned
1	1	6/8	67%	2	1469, 1621	1581, 1594
	2	5/8		3	1504, 1621, 1639	1523, 1579, 1609
	3	5/8		3	1504, 1543, 1641	1579, 1600, 1608
2	1	7/8	96%	1	1606	1602
	2	8/8		0		
	3	8/8		0		
3	1	8/8	100%	0		
	2	8/8		0		
	3	8/8		0		

In pen test 1, non-target animals were accidentally scanned in all three replicates, with an overall identification accuracy of 67%. Two animals (1504, 1621) were missed on two occasions, and one non-target animal (1579) was scanned on two occasions, otherwise the missed target and non-target animals were different in the three replicates. The results were better for pen test 2, with just one animal incorrectly identified in one replicate. There were no errors in the three replicates for pen test 3. However, across all three UHF pen tests, the problem of some animals being obscured by others was a major issue, and it generally required a second person to encourage the cattle to move about in the pen before all eight were scanned. The results from these pen tests very much support the findings for phase 1a i.e. that a UHF hand-held scanner struggles to read any tags obscured by other animals, and the accidental reading of non-target animals is a problem, especially when they are in adjacent pens. This issue is discussed further in section 6.5.

Pen reading with an 80cm long LF stick reader was also attempted (without replication), but this also proved challenging. Only target animals were scanned in the three LF tests that were conducted (i.e. 100% accuracy), but LF scanning also required a second person to help push animals towards the person with the stick reader. Smaller pens and/or a longer stick reader (which is already available on the international BEID market, see section 5.6) would probably help, but overall, and irrespective of EID technology, pen reading is a challenge.

3.4 Live market trial: Pen reading

A group of five dairy calves from one of the two English dairy farms in the pilot were sold at the large market. The time taken to identify the animals manually (by market staff), using an LF stick reader and a UHF hand-held scanner are summarised in Table 3.3. Two tests were carried out with the UHF hand-held scanner, one on the maximum power setting (for attempted group reading of all the calves in one go) and then on a lower power setting (for individual calf scanning). The results are presented in Table 3.3.

Table 3.3. Summary of the timing and accuracy results from the live market trial. 'UHF (group)' were scanned at the maximum power setting and 'UHF (individual)' at a reduced power.

ID method	**Manual**	**LF**	**UHF (group)**	**UHF (individual)**
Mean time per calf (sec)	6.3	2.0	1.0	4.4
Animals correctly identified	5/5	5/5	5/5	5/5
Accuracy	100%	100%	100%	100%
Replication (no. of tests)	1	2	4	2

The average manual identification times in this test are much quicker than those from the closed market raceway reading test (section 3.2), but these young calves had clean ear tags so were much easier to read, and they were identified by experienced auction staff. LF scan times were nearly identical to those from the closed market raceway reading test (section 3.2) and were three times quicker than manual reading.

The UHF scan times were mixed. UHF group reading was quicker than individual reading (LF and UHF) but getting the small hand-held UHF reader to read individual animals took twice as long as doing this using an LF stick reader. Group reading with the UHF hand-held took half the time of LF identification. However, when the UHF tags on the trial animals were read in the market, none of the other animals on the site had UHF tags, so there was no risk of accidentally reading a non-target animal in an adjacent pen. In practice, if UHF were adopted for mandatory BEID in England, the rest of the cattle in the market would also have UHF tags. This would almost certainly result in the same problem with non-target animal reads that was identified in the closed market pen trial (section 3.3) and would require hand-held UHF readers to be used in the low power (individual animal) mode.

4. The English and Welsh abattoir trials

4.1 Abattoir operating procedures

The operating procedure for the English abattoir in the phase 2 pilot is as follows:

1. An agent visits the farm and identifies animals to be slaughtered a few days before and draws up a list ('kill plan').
2. Animals (and paper passports) arrive at the abattoir a few hours before slaughter – animal ID is <u>not</u> checked on arrival.
3. After lairage, animals walk up a race and are held in a crush a few metres from the point of slaughter.
4. The ear tag is checked against the kill plan and passport.
5. If the tag number can be matched against one of the passports provided, the animal proceeds to be slaughtered in sequence.
6. If a tag does not have the corresponding passport, the animal (and ideally another from the group on welfare grounds) are pulled out of the line and held back.
7. This happens with fewer than 1% of the animals.
8. The abattoir contacts the farmer and gets a copy of the correct passport sent electronically.
9. An animal will not leave the abattoir alive, so if the passport discrepancy cannot be resolved in a timely manner the animal is killed and the carcass disposed of
10. If the discrepancy is resolved, the animal is slaughtered.
11. From the ID crush the animals are in a numbered sequence
12. Shortly after slaughter, the ears (and ear tags) are removed (and are rendered)
13. The sequence number and last three digits of the animal UK ID are written on the carcass with a meat indelible pencil.
14. The MLC grader attaches a tag to each half of the carcass – this includes the animals full 12-digit UK ID number as well as the sequence number.
15. This tag stays on the carcass during chilling and any ageing until it is butchered (when it is scanned into a batch)

The operating procedures in the Welsh abattoir were nearly identical to the English abattoir's procedures with the following exceptions:

a) After step 5, the passport is passed through a hole in the wall to the post-slaughter side of the abattoir where it is again checked against the animal's ear tag just before the ears are removed.
b) At step 14, the carcass has two tags attached to each half of the carcass (one tag per quarter)

Discussions were held with senior managers at both the English and Welsh abattoirs. At the English abattoir, the manager believed that following the introduction of mandatory BEID in England, identifying animals on arrival would be desirable but not essential. In contrast, the manager at the Welsh abattoir stated that identifying animals on arrival was essential once BEID was mandated, arguing that this would be more feasible with UHF technology.

To guarantee 100% reliable traceability, abattoirs require <u>100% accurate animal ID</u>. Because of this, even when BEID is mandated, abattoirs will still need to hold and check animals in a crush prior to slaughter. This is for two reasons: EID tags can be lost and EID tags can fail (i.e. cannot be read due to a failure of the RFID components in the tag). Even if an alleyway or raceway EID reader can achieve a 100% read reliability of <u>tagged</u> animals, 100% accurate automatic ID of <u>all</u> animals can never be achieved. Animals with missing or non-functioning EID tags will always require manual identification in a crush, so realistically all animals will need to go through a crush and be held until the presence or otherwise of a functioning EID tag can be determined. This is discussed more in section 5.8.

However, this does not mean that BEID will not be of benefit in abattoirs. Static EID readers (either LF or UHF) in the pre-kill crush would be able to read the majority of cattle, with manual tag ID reading being used for cattle with missing or non-functioning EID tags. Also, depending on the layout of an abattoir, including the numbers of animal unloading bays, routes to lairage etc., multi-antenna UHF alleyway readers could be installed to scan animals on arrival. This could help flag up cases where the wrong animal (i.e. not on the kill plan) might have been sent, or where a passport discrepancy needs to be resolved. Although this is still too late to return the animal to the farm, it would give more time to resolve any issues.

4.2 English abattoir lairage tag reading

Twelve cattle from one of the pilot farms were sent for slaughter in the abattoir that was engaged in the pilot. These animals were scanned using a UHF hand-held reader when they were in a pen in the lairage. The researcher initially attempted to scan all twelve animals when standing at ground level in the lairage passageway (Figure 4.1, left). Eight of the twelve were recorded, but four at the back could not be successfully scanned from this position. One of the adjacent pens was empty, so the researcher climbed on the railings of this pen and tried to scan the cattle at the back (Figure 4.1, middle). Two more were picked up from here, but two (laid down at the back) could still not be recorded. Finally, the researcher went into the back of the empty pen and was able to scan the final two animals from there. Identifying the animals using the LF stick reader was not attempted in the lairage as it was recognised this would be likely to stress the animals.

Figure 4.1. Photographs showing trial cattle being scanned with a hand-held UHF reader in the abattoir lairage (left and centre) and with an LF stick reader in the abattoir crush (right). Note that in the crush, the animal's neck is held in the head yoke to restrict head movements. This ensures that the LF stick reader can be used with minimal risk of injury to the operator. In practice, static EID readers (either UHF or LF) would be used in the crush, further reducing injury risk to operators, and could operate without the need to use the head yoke. The head yoke would still be used to restrain any animal requiring manual identification (when the EID tag is missing or not working).

Note that when the UHF tags on the trial animals were read in the abattoir lairage, none of the other animals on the site had UHF tags, so there was no risk of accidentally reading a non-target animal. In practice, if UHF were adopted for mandatory BEID in England, the rest of the animals in the lairage (and the site) would also have UHF tags, and this could result in the same problem with non-target animal reads that was identified in the closed market pen trial (section 3.3).

4.3 English abattoir crush tag reading

The twelve cattle were then moved from the lairage into the pens and then the raceway leading to the kill box. A crush is located a few metres from the kill box. This crush is currently used to identify animals (visually) by reading the herd and individual animal number printed on their ear tag. This is then checked against the animal's paper passport, and if everything is correct the abattoir computer-based record system is updated and the animal proceeds to be slaughtered.

This process continued as normal in this trial, but the researcher also used EID to record the identity of animals when they were in the crush. Six were scanned using the hand-held UHF reader and six with an LF stick reader (Figure 4.1, right). This process was video recorded, allowing the time taken for manual identification, passport checking, LF and UHF identification to be determined. The data from the LF and UHF readers was downloaded and checked to ensure the recorded ID numbers were accurate. The results are presented in Table 4.1.

Table 4.1. Summary of the time taken (and accuracy) of identifying animals in the pre-slaughter crush.

ID method/activity	Manual ID	LF EID	UHF EID	Passport check
Mean time per animal (sec)	7.6	3.2	2.6	20.8
Animals correctly identified	12/12	6/6	6/6*	
Accuracy	100%	100%	100%	

* Initially the UHF hand-held reader identified the target and two other animals behind it in the first scan. The power setting was lowered and a new session started, and subsequently just the individual in the crush was recorded on each scan.

The times taken for manual and EID identification are similar to those presented elsewhere in this report. Note that the time taken to stun and kill an individual animal is greater than the time spent in the crush, so EID will not speed up the processing of animals, but has the potential to make it more accurate. However, the current process of manual tag reading and passport checking is very thorough, so already highly accurate.

This area in an abattoir (near the kill box) has a lot of metal and electrical equipment that might interfere with the reliable reading of EID tags. No problems were encountered, and both the UHF and LF hand-held readers were able to correctly determine the identity of animals both quickly and accurately.

4.4 Welsh abattoir crush tag reading by abattoir staff

Originally it was planned as part of the pilot project to install a static LF reader in the pre-slaughter ID check crush at the Welsh abattoir. A UK livestock EID equipment manufacturer visited the abattoir to investigate options. Unfortunately, the crush currently installed at the abattoir is of a design that would not readily accommodate LF EID panels, and the required modification work was not really feasible within the timescale of the project. It was therefore decided to use a hand-held LF stick reader in the abattoir to read the EID tags of cattle from the three pilot farms prior to slaughter. Two LF stick readers (pre-loaded with most of the relevant tag bucket information) were provided to the abattoir, and abattoir staff scanned a total of 174 cattle on ten occasions as summarised in Table 4.2. The abattoir also provided the kill sequence for all the cattle in these ten batches allowing comparison with the EID scan order.

Table 4.2. Summary of the EID scans of cattle in the pre-slaughter ID crush conducted by staff at the Welsh abattoir.

Date	Numbers of animals				Comments
	In the batch	**Out of sequence**	**Missing an EID tag**	**Extra EID reads**	
1/3/24	14				
6/3/24	31			1	One animal had a second EID tag fitted
8/3/24	11	1			Sequence changed due to a passport discrepancy
15/3/24	14				
18/3/24	14				
20/3/24	14				
21/3/24	14				
21/3/24	18	1[a]	1[b]		[a] Out of sequence due to user error or an animal getting past others in the race? [b] EID tag not fitted for the trial
5/4/24	15			1	Second EID tag had been fitted or animal from next batch read by mistake?
9/4/24	29		1		EID tag was fitted but had been lost
Total	***174***	***2***	***2***	***2***	

There were two occasions (8/3/24 and 21/3/24) when the sequence of EID scans did not match the abattoir's kill sequence. On 8/3/24, one animal was scanned, but the corresponding passport could not initially be found, so the animal was held back. The missing passport was subsequently found (tucked in another passport), so the animal was slaughtered at the end of the batch. Note that by default the LF stick reader used in the abattoir trial only recorded the first scan for any animal in a group. Consequently, although the operator might have re-scanned this animal's EID tag on the second occasion it was in the ID crush, this was not recorded on the stick. On 21/3/24, the third from last animal in the EID scan list appeared last in the kill sequence. The reason for this difference is unclear as the abattoir staff do not recall any passport issues with this batch. It is possible the operator forgot about a passport issue or forgot to scan one animal and subsequently scanned it in the race. Note that once EID is mandated it is likely the abattoir will invest in a static EID reader in the pre-slaughter crush, and this could be setup to ensure only the final EID read is registered for the kill sequence. This would also avoid possible user error associated with the use of a hand-held stick reader. Another possible reason for the sequence discrepancy on 21/3/24 is the third from last animal somehow managed when moving in the race between the ID crush and the kill box to get past the two animals in front of it. This can occasionally happen which is why this abattoir also checks (and corrects) the ID sequence post-slaughter i.e. once the animals are on the processing line. Note that industrial LF EID readers designed to read EID tags in animals post-slaughter are available in international markets and could be used in UK abattoirs after BEID is mandated.

On two occasions (21/3/24 and 9/4/24) animals were noted to be missing an EID tag. On the first occasion this was due to the animal not being tagged as part of the trial i.e. the farmer had not requested a tag for this animal. On the second occasion this was due to the pilot project EID tag being lost prior to arrival in the abattoir lairage. As discussed in section 5.8, EID tags will be lost (or the RFID components in some EID tags will stop functioning), so abattoirs will still need the ability to hold animals in a crush so that their ID can be read manually.

On two occasions there were 'extra' EID reads recorded on the LF stick reader i.e. additional EID tags that were not registered in the project tag bucket files were also recorded. On the first occasion, the operator noticed that the first scan showed the animal's EID and not the UK herd and animal number (VID), so the animal was scanned again. The VID was displayed on the second scan. The LF stick reader recorded these scans as two separate EID tags. The pilot project tag supplier was contacted, and they noticed that the first scan had an EID number associated with a different UK EID tag supplier. This other tag supplier was contacted, and was able to confirm this animal had previously had an EID tag supplied (likely an EID secondary statutory tag). This animal had been purchased as a calf by the pilot farmer for finishing, and it appears the pilot farmer was unaware this animal already had an EID tag when they fitted the EID tag provided as part of the pilot. This will be an important message to get across to farmers once BEID is mandated i.e. that animals should only have one LF tag fitted in their ears (see section 5.4 for further discussion). The reason for the extra EID read on the second occasion is not clear as it was not noticed by the operator at the time. It is possible they accidentally read an EID tag in an animal in the next batch of cattle (which were not from a pilot farm but might have had an existing management EID tag).

4.5 Welsh abattoir ID timings

A member of HAU staff visited the abattoir on the final occasion (9/4/24) cattle from a pilot farm were being slaughtered and a video recording was made to determine the time taken to identify the animals in the pre-slaughter ID crush. The results for the analysis of the time taken to identify cattle manually and using LF EID is given in Table 4.3.

Table 4.3. Summary of the time taken (and accuracy) of identifying animals in the pre-slaughter crush in the Welsh abattoir.

ID method/activity	Manual ID	LF EID
Mean time per animal (sec)	6.7	2.4
Animals correctly identified	25/25	24/24*
Accuracy	100%	100%

*One animal had lost its EID tag so could only be read manually. This did not affect EID read accuracy, but EID read reliability was 96% due to the missing tag.

The ID timings for the Welsh abattoir are broadly comparable to those achieved elsewhere in the project.

5. General considerations (applicable to both England and Wales)

5.1 WYSIWYG tag reading

The farmers in the English pilot had a preference for UHF BEID technology over LF (see section 2.6), and one of the main factors contributing to this was that the UHF tags used in the pilot is 'WYSIWYG'. This means the number displayed on a hand-held reader is identical to the one printed on the animal's ear tag (i.e. 'what you see is what you get'). The UHF tags and readers provided by ScotEID for these trials have this functionality built in. The full 12 digit animal ID is encoded on the UHF chip in the tag. In contrast, LF tags currently available for use with cattle are management tags and the LF chip contains what is effectively a very long random number. In order for an LF stick reader to display the animals 12 digit ID number (as printed on the tag), a 'tag bucket file' needs to be uploaded to the stick first. The tag bucket file provides a lookup table linking the tag's chip number (EID) with the animal's visual identifier (VID) as printed on the ear tag. The results of scanning an LF tag with and without the tag bucket information are shown in Figure 5.1 (left and centre). In practice, tag buckets take time and require some technical expertise to load onto LF sticks, and the farmer survey showed this was another reason English pilot farmers had a preference for UHF BEID technology over LF.

Figure 5.1. Before a tag bucket file is uploaded, LF stick readers can only display the 'random' number encoded on the chips currently used in LF cattle management tags (left). Once the tag bucket is loaded, the stick can display the corresponding VID i.e. the animal number as printed on the tag (centre). UK sheep LF EID tags are WYSIWYG which means the VID is programmed on the LF chip, and the stick can therefore display the VID without needing a tag bucket file (right).

In contrast, mandatory UK sheep LF EID tags are WYSIWYG (Figure 5.1, right). If LF EID is to be mandated for cattle in England and Wales, both DEFRA and the Welsh Government have indicated that the regulations will ensure LF tags are WYSIWYG, addressing some of the reasons farmers expressed a preference for UHF over LF.

5.2 Human health and safety considerations

The manual identification of cattle poses two risks to human health and safety, one direct and one indirect. Manually reading the numbers printed on an ear tag often requires getting close to the animal, especially if any digits are obscured by dirt on the tag or hair on the ear. In this case the animal needs to be restrained in a cattle handling crush, ideally including the use of a neck yoke. In this scenario, the tag needs to be wiped or hair moved away, requiring the human operator to work with their hands close or even touching the animal's head. If the animal suddenly moves its head, there is a direct risk of injury to the person trying to read the tag. The indirect risk associated with manual tag reading is related to errors associated with record keeping. If an animal that is given a medication is misidentified, the treatment is recorded against the wrong animal. It is possible the animal that was actually treated could then be unknowingly sent for slaughter during the withdrawal period for that medication and enter the food chain posing a risk to consumer safety.

Electronic identification should reduce both the direct and the indirect risks identified above as the animal's ear tag can be read without direct contact, and the read accuracy should be higher. Although UHF tags can be read at a greater distance compared to LF tags (i.e. be even safer), this comes at the expense of possible misidentification associated with reading a non-target animal. So whilst the use of UHF tags should reduce the direct risk, reading at too great a distance could result in misidentification which poses an indirect risk as described above.

Overall, the adoption of BEID (either LF or UHF) should reduce risks to human health and safety, both direct and indirect. Given the interaction between increased read range (reducing direct risk) and the possibility of misidentification (increasing indirect risk), the differences in human health and safety benefits between UHF and LF are less clear cut.

5.3 Animal welfare considerations

The ability to automatically read the identity of cattle using BEID is already bringing benefits for animal welfare. It facilitates automated monitoring technologies such as the HerdVision body condition and mobility scoring system used on English dairy farm 1. The regular monitoring provided by this sort of technology can detect changes indicative of injury or disease allowing farmers to take action and thus improve animal health and welfare. The mandatory introduction of bovine EID in England and Wales could help increase the uptake of these monitoring technologies. UHF technology can also identify cattle moving in an alleyway i.e. without them having to go down a raceway. Although this could reduce animal stress levels, there does not appear to be any published literature on this, so further research is needed.

The use of technology in livestock management can also bring some risks to animal welfare (van Erp-van der Kooij and Rutter, 2020). Overreliance on technology could compromise animal welfare when systems fail. For example, automated systems that rely on EID (e.g. robotic milking) need to be 'fail safe' when an animal loses its EID tag e.g. by quickly alerting the farmer that a cow is overdue to be milked. It needs to be clear that these precision technologies are intended to facilitate rather than replace the skills of expert stock keepers.

Overall, the adoption of BEID (either LF or UHF) should improve animal welfare. Although the longer read range and group reading possible with UHF technology could reduce animal stress, there is a greater risk of tag loss with UHF flag tags (see section 6.6). Tag loss can result in damage to ear tissue, causing pain and risking infection. Consequently, the differences in animal welfare benefits between UHF and LF are less clear cut.

5.4 Possible interference or incompatibility with existing RFID equipment on farms

The phase 1a pilot found a potential interference issue with a UHF static reader and a LoRaWAN sensor network at the University. However, further investigation after the pilot had finished determined that this was due to water ingress in one of the LoRaWAN sensors and interference was not the cause of the problem. UHF technology also uses the same part of the radio spectrum as at least one wireless animal-mounted activity sensor of the type commonly used on UK dairy farms. However, none of the farms in this pilot used this type of technology, so we were not able to investigate this as a possible cause of interference during this project.

None of the pilot farmers reported any interference issues with either LF or UHF technologies. Two of the farms in the pilot were already using LF EID technology before the start of the pilot, but the tags they were already using were compliant with the relevant LF ISO standards, so they were compatible with the LF equipment that was supplied as part of the project. Note that UHF technology operates on a different part of the radio spectrum to LF, and as was shown in the phase 1a pilot, there are no interference issues between these two RFID technologies.

Should LF (with or without ISO11784) be the mandated BEID technology, the new statutory LF EID tag will need to replace the function currently provided by LF management tags e.g. as used by HerdVision, robot milkers etc. This is because LF technology does not have the collision avoidance properties found in UHF tags, so two LF EID tags can interfere with each other if they are too close together. Consequently, if LF were to be mandated, cattle should have just one LF ear tag i.e. the statutory one. Fortunately, because ISO standards for LF technology have been around for a number of years, LF readers in systems such as HerdVision usually have ISO compliant readers. These will be able to read the statutory tags as if they were management tags, and so will continue to function as before. Because the use of a statutory LF tag will replace the need to buy a management LF tag, mandatory LF BEID will effectively be cost neutral on these farms. Some systems such as HerdVision can read an LF tag regardless of which ear it is in (left of right) because they have antennas on both sides of the raceway. Consequently, they will work irrespective of which ear the LF tag is fitted. Other systems (including the robotic milking unit on the joint AgriEPI and Harper Adams University facility) require the LF management tag to be in one ear. Any dairy farmer rearing their own replacement cattle can ensure a statutory LF tag is put in the correct ear when the calf is first tagged. However, there will be a potential issue when farmers purchase animals that were born and tagged on another farm i.e. that the statutory LF tag will be in the wrong ear for potentially half the cattle. To address this problem, DEFRA might need to consider providing a derogation to allow farmers to replace both mandatory tags to allow the statutory LF tag to be fitted in the correct ear. Otherwise, farmers will be restricted to buying cattle which have the statutory LF tag in the appropriate ear. This will not be an issue with a statutory UHF tag.

5.5 UK BEID equipment manufacturer diversity

UHF is a relatively new technology for animal EID compared to LF. Consequently there are far fewer manufacturers and suppliers of UHF BEID tags and readers compared to LF. To our knowledge, the only company currently supplying UHF bovine EID tags and readers in the UK is ScotEID, and they supplied and installed the UHF equipment used in this pilot. It appears the UHF tags provided by ScotEID come from one company in India, and the static and handheld UHF readers they use are generic devices manufactured in China (and not specifically designed for use with livestock). In contrast, there are at least six companies supplying either LF tags, readers or both in the UK (Allflex, Caisley, Dalton, Datamars, Nordic Star and Shearwell Data). Some of these companies manufacture both tags and readers in the UK. The current lack of diversity of UK suppliers of UHF BEID tags and readers is a concern should UHF be mandated for BEID in England and Wales. There are inherent risks in relying on the ability of one supplier to meet the demand for tags and readers for the whole of England and Wales, and the negative consequences should this one supplier fail. Although some of the UK suppliers of LF equipment could start supplying their own UHF tags and equipment should UHF be mandated, this is by no means certain. In contrast, the fact there are several UK-based companies already manufacturing and supplying LF cattle tags and readers means there is very likely to be the capacity to meet the demand should LF be mandated, and the consequences of one (or more) companies failing are far less serious.

5.6 International BEID markets

Low frequency EID is already used with cattle more widely in some other countries around the world, and there is a wider range of LF reading equipment in these countries. In particular, Australia has some examples as shown in Figure 5.2. Some of this equipment could help address some of the challenges likely to be faced in different parts of the UK cattle industry should LF be mandated for use in England and Wales. The wider adoption of BEID in the UK would likely result in much of this equipment being imported and sold here, and UK-based companies could also develop similar solutions themselves. Allflex UK can import this equipment to the UK on demand, and we were interested in evaluating some options as part of this pilot. However, the lead time and air freight shipping costs from Australia meant this was not possible in the timeframe of the project.

Figure 5.2. Pictures of some examples of ‘Industrial’ LF reading equipment from Allflex in Australia. On the left is an LF *Multi-Read System* for cattle in alleyways (which range from the two bay version shown here up to six bays). In the centre is a LF *High Flow Lane Reader* for reading cattle at speed. On the right is an extra-long LF stick reader (available up to 3m in length) for reading cattle in pens. Further examples and images from https://www.allflex.global/au/2770-2/

Options for international suppliers for UHF BEID readers are currently much more limited, and HerdWhistle (from Canada; www.herdwhistle.com) is the only one we could find that sell hand held UHF scanners. This reflects the fact that UHF is still a relatively novel technology for livestock identification (compared to LF). However, HerdWhistle manufacture some interesting readers, and two hand-held devices look particularly interesting (Figure 5.3, centre and right). Unlike the generic hand-held UHF scanners provided by ScotEID (Figure 5.3, left) the HerdWhistle hand held UHF scanners look to have been specifically designed and manufactured for use with livestock (and their USD2000 price tag each reflects that). The *LF and UHF Processing Scanner* (Figure 5.3, centre) is designed to scan both UHF and LF tags and help the farmer link together the animal’s visual ID on a flag tag with their EID (whether LF, UHF or potentially both). The LF read range is up to 20cm and the UHF range is up to 1.7m. This relatively short UHF read range would likely reduce the possibility of accidentally reading non-target animals when using UHF. Whether or not this was by design is not known. However, the generic hand-held UHF devices used in this pilot can read tags at a range in excess of 5m (Rutter *et al.*, 2023), so it appears the read range has been restricted by HerdWhistle for some reason.

The second device sold by HerdWhistle is their *UHF field scanner* (Figure 5.3, right). It incorporates a directional 'yagi' aerial and can read tags at up to 30m. Crucially, it is designed to find individual animals and not to identify an unknown animal at a distance. Farmers can select the target animal by scrolling through a list on the built in screen. The scanner then guides the farmer to that specific animal using an audio tone (like radio tracking a wild animal).

Figure 5.3. Three UHF hand-held scanners. On the left is a typical generic UHF hand-held scanner of the type used in this pilot. These generic devices are not specifically designed for use with livestock, and are typically also used in warehouses, retail, stock inventory etc. In contrast, the other two hand-held UHF scanners from HerdWhistle are specifically designed for use with livestock. The device in the middle is an *LF and UHF Processing Scanner* and the device on the right is a *UHF Field Scanner*.

We became aware of HerdWhistle during the phase 2 pilot. Although it would have been interesting to have evaluated the devices, we had no idea if they would work with the UHF tags we were using in the trial as there are no internationally recognised standards for UHF tags or readers (other than the recently published ISO6881 – see section 6.8. This illustrates the importance of international (ISO) standards.

5.7 Static vs hand-held scanner strengths and weaknesses in different enterprises

The phase 1a pilot did not get the opportunity to properly evaluate static EID readers, so the findings were largely based on hand-held readers. We have had better opportunity to evaluate static readers in the current study. English beef farm 1 gave us information on UHF in an alleyway and UHF and LF in a crush, and English dairy farm 1 included UHF and LF in a raceway.

The main advantage of static readers is that they can be operated 'hands-free' i.e. read an animal's EID tag 'automatically' without the need to wave a hand-held reader near the animal. This saves time and avoids any risk of injury to the operator associated with using a hand held device near the animals head. To achieve this, static readers generally have much more powerful radio equipment. Static readers typically also use a cable (rather than wireless) connection to link to weigh heads and other data recording equipment. Cable connections are generally more reliable than wireless (e.g. Bluetooth) connections. The disadvantages of static readers is they are usually more expensive than handheld readers and are physically tied to one location. The costs quickly mount if static readers are needed at multiple locations. As well as being cheaper, hand-held readers are portable and can be used wherever needed. However, capturing an EID with a hand-held reader is slower than a panel, and hand-held readers usually use wireless (e.g. Bluetooth) to connect to other equipment (e.g. weigh heads), and this can be unreliable at times.

Consequently, static readers work better on larger farms where the volume of use justifies the extra expense. However, if a farm has a central crush where the majority of operations requiring animal ID to be recorded take place, then a static reader could be viable even on smaller farms. In abattoirs, static readers would also be appropriate in the 'check' crush just before the kill box. The use of static readers in markets depends on their layout. If a market has one or a small number of locations where the animals all move through, then static readers could be economically viable. However, if the market has multiple unloading/loading bays without central raceways, then the large number of static readers required would likely be prohibitively expensive. Where static readers are not economically viable, hand-held readers are a better option. Even if an enterprise uses one of more static readers, having a hand-held reader as backup is a sensible option in case the static reader stops working.

The UHF static readers in this study out-performed the LF static readers. Consequently, UHF is generally better suited to enterprises where static readers are better suited. Challenges with body blocking and the misidentification of animals with hand-held UHF readers remain a concern. Although the read range of LF hand-held readers is shorter, there is little doubt that the target animal has been read, so they are arguably more reliable than UHF hand-held readers. Consequently, LF is generally better suited to enterprises where hand-held readers are better suited.

5.8 EID will never read 100% of all animals

An important consideration when implementing bovine EID is that even if an EID reader can reliably identify 100% of tagged animals, it cannot read:

a) any animal that has lost its EID tag,
b) any animal where the EID tag electronics have failed.

Before sending animals to markets or abattoirs, farmers should be aware of missing tags (i.e. scenario a above) and replace them. However, if the farmer does not use EID on their farm, they will not know if any of the EID tags in their cattle have stopped working (scenario b). In this case, farmers will be sending animals away from the farm unaware that some of them cannot be identified electronically. Consequently, animals will arrive at markets and abattoirs that cannot be read with EID. These animals will therefore require manual identification e.g. in a pen at a market or in a crush at an abattoir. Anecdotally, 2-3% EID tag failure in sheep after a year, so potentially one in fifty cattle arriving at abattoirs and markets will require manual identification.

6. Summary of the challenges of introducing BEID to England (and Wales): low frequency (LF) *vs* ultra-high frequency (UHF)

Based on the evidence collected during this pilot, it is possible to draw together a summary of the different challenges associated with both UHF and LF in relation to the proposed introduction of mandatory bovine EID in England and Wales. In general, the results from this the phase 2 pilot align with those from the phase 1a pilot. This is that the two different EID technologies have different strengths and weaknesses. This section covers what we consider to be the most important challenges, and how UHF and LF technologies compare in relation to each challenge.

6.1 Reading a group of moving animals in an alleyway (static reader)

English beef farm 1 in this pilot had a four-antenna UHF archway above a 2.75m wide alleyway, and it had a high read reliability (99.6%). Although an LF *Multi-Read System* is available internationally (see section 5.6), the duration of the current project meant this could not be evaluated in this pilot. Unlike the LF *Multi-Read System*, the UHF alleyway reader used in this trial does not require any central panels, so the UHF system is probably better for the free movement of cattle.

With respect to reading a group of moving animals in an alleyway, there are fewer challenges with using UHF compared to LF.

6.2 Retrofitting a static EID reader in a crush

Incorporating LF antennas into the crush on English beef farm 1 proved to be more of a challenge than fitting a UHF antenna. There are solutions available (Figure 6.1) whereby one of more of the doors on an existing crush can be replaced by doors that incorporate LF antennas. These were used on Welsh beef farm 2 and were very effective (i.e. reliably reading all 18 animals run through the crush). These are only available for a limited range of crushes at the moment, but if LF were to be mandated, this could help drive manufacturers to develop these for a wider range of crushes.

Figure 6.1. Photographs showing two options for incorporating EID panels into crush doors. These maintain the operational functionality of the crush (i.e. the doors still work as before) whilst ensuring the LF antennas are well placed to read the ear tag of an animal standing in the crush.

With respect to retrofitting a static EID reader in a crush, there are fewer challenges with using UHF compared to LF

6.3 Read range

The phase 1a pilot showed that, without obstacles, UHF tag read range was over 5m (for both the panel and handheld reader) i.e. at least ten times the range possible with LF tags (Rutter *et al.* 2023).

With respect to read range, there are fewer challenges with using UHF compared to LF

6.4 Reading through flesh

The phase 1a pilot showed that UHF signals are far more prone to being blocked by 'flesh' compared to LF signals (Rutter *et al.,* 2023). This results in 'body blocking' i.e. one animal (or the animal's own head) blocking the 'line-of-sight' between a UHF EID tag and the receiver prevents the tag being read. ScotEID (2023) argue that overcoming the problem of body blocking simply requires '*holding the handheld readers above head height*'. Although we attempted to use this approach in this pilot, we still found body blocking was a problem with UHF tag reading, in both the closed market trial (section 3.3) and the abattoir lairage trial (section 4.2). In contrast, scanning LF tags with either a human or a container of water between the tag and reader had little or no effect on read range (Rutter *et al.,* 2023).

With respect to reading through flesh, there are fewer challenges with using LF compared to UHF.

6.5 Accidentally reading a non-target animal (hand-held readers)

Accidentally reading a non-target animal was a concern highlighted in the phase 1a pilot, and the validity of this as an issue has been supported by evidence collected in the phase 2 pilot. In particular, the closed market pen trails (section 3.3) highlighted this as a problem with hand-held UHF readers. Non-target animal reading compromises accurate record keeping, traceability and food safety (see section 5.2).

Although ScotEID (2023) argue that this '*can be easily addressed*' (paragraph 100), we still believe this is a major problem, especially with hand-held UHF readers. This type of reader is typically used by pointing it at an individual or a group in a pen, when the operator is either at or a bit above the head height of the target animals. The device therefore predominantly scans horizontally, with any animals behind the target individual or group also liable to be scanned. The problem arises if the UHF tag in a target animal is obscured, either by its own head or the body of another animal, then it cannot be read. However, any visible non-target tags behind or alongside the target will be read instead. One solution to this problem is try to get some height above the animal(s), both to see over any obstructing animals and to try to avoid the reader being directed towards non-target animals. One way to try to achieve this in pens is to climb up their railings (e.g. Figure 3.5), but this poses a health and safety risk, especially when the pens are occupied.

To some extent, the problem of non-target animal reading with a UHF hand-held receiver in both the phase 1a and phase 2 pilots is related to the design of the device. The UHF hand-held receivers used in this pilot are generic UHF readers that have not been specifically designed for use identifying livestock. Consequently they are arguably too powerful, and possibly lack a narrow enough angle of reading. Although requiring further research, it appears that HerdWhistle (see section 5.6) might have created bespoke animal UHF scanners that help avoid (or at least reduce) non-target animal reading. This illustrates that the use of UHF technology in animal EID is still relatively new. Further research is needed to develop UHF hand-held readers for livestock identification that are specifically designed to maximise all the benefits of UHF technology without the potential problems identified in this pilot.

Note that non-target animal reading in this pilot was not restricted to the UHF hand-held reader. The LF panel installed on English dairy farm 2 was found to be reading the LF tags in animals on the other side of a concrete wall. It is understood this could be rectified by fitting a metal sheet on the wall, but this illustrates the need to properly test static EID readers during installation to avoid such problems.

With respect to accidentally reading a non-target animal, there are fewer challenges with using LF compared to UHF.

6.6 EID tag retention (assuming UHF tags have to be flag tags)

One concern highlighted in the phase 1a pilot was that the UHF flag tags currently supplied by ScotEID are quite stiff and inflexible compared to standard (non-EID) flag tags. This stiffness is believed to be in part due to the manufacturing process and in part to reduce the risk of damage to the antenna and chip which are in the flag part of the tag. The concern is this reduced flexibility increases the risk that when a tag gets caught on something it will be more likely to be pulled out of the animal's ear compared to a more flexible non-EID flag tag (or a LF button tag).

In order to achieve the long (greater than 5m) read range possible with UHF tags, they require a large antenna which occupies most of the space in the flag part of a UHF tag. This means UHF tags have to be flag tags. In contrast, LF antennas can be very small, meaning LF BEID tags can be a lot smaller than UHF flag tags (Figure 6.2).

Figure 6.2. Comparative sizes of a UHF flag tag (left) with an LF button tag (upper right) and an LF metal tag (lower right). The UHF flag tag is 60mm wide (and should be about 1:1 scale at A4).

Published literature cites annual retention rates of 98% for non-EID button tags (Kellom *et al.,* 2006; Ribo *et al.,* 2001) and 89% for non-EID flag tags (Seroussi *et al.,* 2011). The 11% annual losses of flag tags reported by Seroussi *et al.* (2011) were in dairy cattle where feed yokes can catch tags, and losses could be lower in other systems, but further research is needed. Assuming the EID equivalents of flag and button tags have similar retention rates to the published figures given above, UHF flag tags are about five times more likely to be lost than LF button tags. This is probably the best case scenario for UHF flag tags i.e. it is based on the UHF tag flexibility concerns raised earlier in this section having no impact on tag retention.

With respect to EID tag retention, there are fewer challenges with using LF compared to UHF.

6.7 Availability of EID equipment and supplier diversity (short term)

As covered in section 5.5, there is (as far as we are aware) currently just one company supplying BEID UHF tags and receivers in the UK, compared to at least six for LF. There are therefore concerns that there will not be the capacity to meet demand should UHF be mandated for BEID in England and Wales, and there will be a severe negative impact should this one company fail.

With respect to the availability of EID equipment and supplier diversity, there are fewer challenges with using LF compared to UHF.

6.8 ISO standards for tags, readers etc. (short-medium term)

The International Organization for Standardization (ISO) is an independent, non-governmental international organization with a membership of 170 national standards bodies (including the British Standards Institute or BSI). ISO standards cover a wide range of products and are intended to ensure that goods are reliable, of good quality and safe. There are already a range of ISO standards covering the use of low frequency (LF) technology for the identification of animals (Table 6.1). In contrast, there is only one specific ISO standard related to the use of ultra high frequency (UHF) technology for the identification of animals (*ISO 6881:2023 Radiofrequency identification of animals – Code structure ultra high frequency transponders*), introduced after the pilot began.

One challenge with implementing ISO11784 for LF (or ISO6881 for UHF) is that the amount of memory space allocated on the EID chips to hold the national unique animal identification code cannot accommodate the full twelve digits currently used in the UK. However, DEFRA have proposed a solution to this, and this is covered in Appendix 2.

Beyond ISO11784, the other ISO standards published for LF (Table 6.1) are important as they facilitate the interoperability of tags and readers from different manufacturers. They also give users greater confidence that ID tags and reading equipment will not only meet their requirements but will also meet minimum standards of functionality. These ISO standards are also important for international trade, and demonstrating robust traceability is much easier if the underpinning technologies meet agreed international standards i.e. ISO. The current lack of similar ISO standards for UHF tag technologies is a significant barrier to the adoption of UHF as the mandated BEID technology in England and Wales, and will likely remain a barrier for a number of years.

With respect to ISO standards for tags, readers etc, there are (in the short to medium term) fewer challenges with using LF compared to UHF.

Table 6.1. A list of the ISO standards already available for the use of low frequency (LF) in the identification of animals

Standard	Title	Description
ISO 11784	Radiofrequency identification of animals – Code structure	Defines how numbers are stored on an animal identification device ('tag').
ISO 11785	Radiofrequency identification of animals – Technical concept	Defines how numbers are transmitted between tag and reader.
ISO 24631-1	Radiofrequency identification of animals Part 1: Evaluation of conformance of RFID transponders with ISO 11784 and ISO 11785 (including granting and use of manufacturer code)	Defines how to test a tag to make sure it conforms to minimum requirements. Also, defines who controls approval of tags.
ISO 24631-2	Radiofrequency identification of animals Part 2: Evaluation of conformance of RFID transceivers with ISO 11784 and ISO 11785	Defines how to test a reader to make sure it conforms to minimum requirements.
ISO 24631-3	Radiofrequency identification of animals Part 3: Evaluation of performance of RFID transponders with ISO 11784 and ISO 11785	Defines how to test a tag to see how well it performs (for comparison to other tags).
ISO 24631-4	Radiofrequency identification of animals Part 4: Evaluation of performance of RFID transceivers with ISO 11784 and ISO 11785	Defines how to test a reader to see how well it performs (for comparison to other readers).
ISO 24631-5	Radiofrequency identification of animals Part 5: Procedure for testing the capability of RFID transceivers of reading ISO 11784 and ISO 11785 transponders	Defines a simplified test for evaluating reader capabilities.
ISO 24631-6	Radiofrequency identification of animals Part 6: Representation of animal identification information (visual display/data transfer	Defines how tag numbers should be displayed and transferred from readers to external devices.
ISO 24631-7	Radiofrequency identification of animals Part 7: Synchronization of ISO 11785 identification systems	Defines how readers should be synchronized when many are used in close proximity.
ISO 14223-1	Radiofrequency identification of animals – Advanced transponders – Part 1: Air interface	Defines how additional animal information stored on an advanced transponder is transmitted to a reader (physical layer).
ISO 14223-2	Radiofrequency identification of animals – Advanced transponders – Part 2: Code and command structure	Defines how additional animal information stored on an advanced transponder is transmitted to a reader (command layer).
ISO 14223-3	Radiofrequency identification of animals – Advanced transponders – Part 3: Applications	Defines how the data stored on an advanced transponder is formatted.

6.9 Compatibility of handheld readers with UK sheep EID standard

Low frequency has been mandated for use with sheep in England and Wales since 2010. One advantage of mandating LF for use in cattle is that any farmers, markets and abattoirs handling both sheep and cattle that are already using LF hand-held readers for sheep can also use the same equipment for cattle i.e. without the need to purchase new UHF readers. Note that static LF panel readers designed for and installed in sheep raceways are not appropriate for use with cattle, so this would really only benefit users that already have and use LF hand-held readers.

Also, should LF be mandated for cattle, farmers managing both sheep and cattle might decide it is worth the time and cost of investing in an EID stick reader. So a possible positive outcome of mandating LF for cattle is greater use of EID technology in managing sheep.

With respect to compatibility of handheld readers with the UK sheep EID standard, LF is compatible whereas UHF is not.

6.10 Compatibility with EID used in the EU (inc. Republic of Ireland)

EU member states can voluntarily adopt EID, but if they do, it has to conform to ISO standards 11784 and 11785 (see section 6.8) which only apply to LF. These are covered in Commission Delegated Regulation (EU) 2019/2035 and Commission Implementing Regulation (EU) 2021/520. The Republic of Ireland has mandated LF EID technology for the statutory identification of cattle born on or after 1 July 2022. Mandating tags that conform to ISO standards 11784 and 11785 (i.e. LF) in England and Wales would mean alignment with EU and Republic of Ireland bovine EID standards, and this should facilitate easier cross-border trade in the future.

With respect to compatibility with EID used in the EU (inc. Republic of Ireland), LF is compatible whereas UHF is not.

6.11 Using a hand-held reader to read stationary animals in a pen

The use of hand-held readers (either UHF or LF) was found to be a challenge in the closed market trial (section 3.3). This is a particular challenge if the pen has a high stocking density and one or more of the animals stand with their heads down (as is often the case). Although a long LF stick reader (section 5.6) could be of use here, we were not able to test this in this pilot. More work is needed to understand the easiest and safest way to achieve EID in pens, especially when adult cattle are lotted in pens in markets.

The use of a hand-held reader to read stationary animals in a pen is a challenge with both LF and UHF technology.

6.12 Overall summary of the different challenges of UHF vs LF

This section has covered a total of 11 different challenges as summarised in Table 6.1.

Table 6.1. A summary of all the challenges covered in this section.

	Challenge	**Degree of challenge or *compatibility*** LF	UHF
1	Reading a group of moving animals in an alleyway (static reader)	More	Less
2	Retrofitting a static EID reader in a crush	More	Less
3	Read range	More	Less
4	Reading through flesh	Less	More
5	Accidentally reading a non-target animal (hand-held readers)	Less	More
6	EID tag retention (assuming UHF tags have to be flag tags)	Less*	More*
7	Availability of EID equipment and supplier diversity (short term)	Less	More
8	ISO standards for tags, readers etc. (short to medium term)	Less	More
9	*Compatibility of handheld readers with UK sheep EID standard*	***Compatible***	*Not compatible*
10	*Compatibility with EID used in the EU (inc. Republic of Ireland)*	***Compatible***	*Not compatible*
11	Using a hand-held reader to read stationary animals in a pen	Difficult	Difficult

*Based on literature on flag tag retention. Requires a long-term study.

The challenges in Table 6.1 are not presented in any particular order other than to group together areas where we believe UHF is less of challenge and areas where LF is less of a challenge with respect to the introduction of mandatory bovine EID in England and Wales. The degree of importance of the different challenges will vary depending on user or stakeholder interests, and some of the challenges will likely diminish over the next few years. Over time, evidence relating to long-term UHF tag retention will become available, and this will inform the assessment of the degree of challenge number 6. Currently, challenge 8 (lack of ISO standards for UHF) is arguably the most significant challenge with mandating UHF BEID in England and Wales.

6.13 Are dual tags the answer?

There is an argument that mandating dual LF/UHF tags would allow different users to utilise which ever RFID technology (LF or UHF) works best in different scenarios. However, there are some potential issues with this approach. Firstly, challenges 6, 7 and 8 from Table 6.1 (i.e. concerns over UHF tag retention, UHF tag/equipment availability and current lack of UHF ISO standards) remain an issue. Even if these three challenges are all resolved, the cost per animal would almost certainly be higher than if a single EID technology was mandated, and this additional cost would more than likely have to be carried by cattle farmers.

Dual LF/UHF tags are available commercially from ScotEID, and were used in the current study on pilot farms that were not already using LF EID. In a dual tag, the male part (which hangs on the back of the animal's ear) is a UHF flag and the female part (inside the ear) can be either an LF button or a LF flag. The dual tags used in the pilot were UHF flag and LF flag tags. However, as can be seen from Figure 6.3, a dual LF/UHF tag (on the right) is bulkier and heavier than standard (non-EID) or UHF (only) flag tags. This additional bulk and extra weight could have a detrimental impact on tag retention, but this requires further long-term research. There is another issue with having both the LF and UHF transponders together in a single two-part tag. If this one tag is lost, both EID transponders are lost, leaving just a visual tag in the other ear. This would result in a higher replacement cost compared to having the two different technologies in different ears.

Standard (non-EID) flag tag	UHF (only) flag tag	Dual LF/UHF flag tag
Weight: **10.9g**	Weight: **14.6g**	Weight: **22.4g**

Figure 6.3. A comparison of standard (non-EID), UHF (only) and dual LF/UHF flag tags.

If animals are to be fitted with both LF and UHF transponders in the future, it might be better to opt for a UHF flag tag in one ear and an LF button (or metal) tag in the other ear (i.e. 'dual tagging') as shown in Figure 6.4. As well as avoiding one of the animal's tags being bulky and heavy, replacement costs should be lower i.e. dual tagging spreads the weight and the cost across both ears.

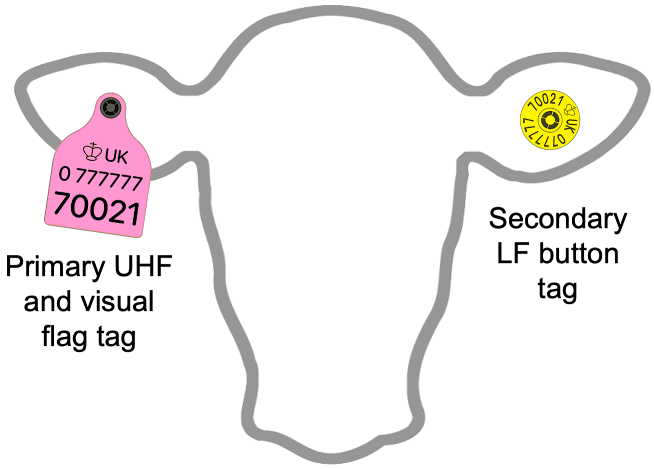

Figure 6.4. If both technologies were to be mandated in the future, using 'dual tagging' i.e. where the UHF and LF transponders are in separate tags in different ears could avoid possible retention issues with a dual LF/UHF tag, and potentially help reduce replacement costs.

7. Conclusions (applicable to both England and Wales)

- From the stakeholders consulted in this pilot, there is general support for implementing mandatory bovine EID across the English and Welsh cattle industry at the earliest opportunity.
- Electronic identification is quicker and more accurate than manual ID tag reading and recording.
- Although there are some benefits from using UHF tags on larger farms, the benefits are less clear on smaller farms, in markets and in abattoirs.
- Overall, there are fewer challenges (especially in the short term) with mandating the use of LF tags compared to UHF tags.
- If and when some of the current challenges with UHF tags are resolved, dual tagging could be an option.

8. References

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Appendix 1 – Analysis of the English and Welsh farmer interviews and questionnaires

This section presents the results from questionnaires completed by the five English farm owners or managers and three Welsh farm owners, focusing on their experiences and views regarding the trial use of electronic identification (EID) tag technology in cattle management. The farmers provided insights into their current uses of bovine EID, challenges faced before and after the trials, and their thoughts on the potential benefits of integrating EID tags and key decision making factors regarding adopting or switching to a new EID system.

For the first questionnaire, the questions were asked by a researcher and the session was recorded. A transcription was made from this recording, and some of the quotes are from this transcription. This was completed by all five English farmers and all three Welsh farmers. A shorter follow-up questionnaire was completed online. Four out of the five English farmers and all three Welsh farmers completed the second questionnaire.

1. Farm characteristics and current use of BEID Technology

The English farms vary in size, with land areas ranging from 103 to 550 hectares. The number of beef cattle ranges from 200 to 2,100 (up to 4,000), while the number of dairy cows ranges from 140 to 650. Four out of the five respondents indicated that the cattle enterprise is their main farm enterprise by financial return. One farm routinely used low frequency (LF) EID tags in their cattle management. Two farms had tried LF EID tags but did not currently incorporate them into their routine management. One farm had not used EID tags at all. Peer usage of EID tags was limited. The farms indicated that some or few of their peers or neighbouring farmers currently use EID.

The three Welsh farm sizes range from 200 to 300 hectares. The number of beef cattle ranges from 250 to 370. Two out of the three respondents indicated that the beef cattle enterprise is their main farm enterprise by financial return. One farm routinely used low frequency (LF) EID tags in their cattle management. Two farms had not used EID tags at all. The farms indicated that none of their peers or neighbouring farmers currently use EID.

2. Challenges faced or anticipated with EID tag implementation (before and after the trials):

The Table A1 presents the challenges faced or anticipated by the farms regarding the implementation of EID tags, both before and after trials. The challenges fall into six main areas: difficulty in integrating with other systems, technical problems during use, maintenance and replacement costs, steep learning curve for staff, data privacy and data privacy and security concerns. Farms a-e are English farms and f-h are Welsh farms.

Table A1. Challenges faced or anticipated with EID tag implementation (before and after trials). Green highlight shows where farmer ratings improved over the trial, pink where the rating was lower.

Farmer (randomised order)		**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**
Difficulty in integrating with other systems	Before	5	2	4	3	1	4	5	3
	After	1	3	2	1		1	3	3
Technical problems during use	Before	4	3	3	3	4	3	5	2
	After	1	1*	1	1		2	1	4
Maintenance and replacement costs	Before	2		3	1	3	3	3	3
	After	1	†	3	1		1	2	4
Steep learning curve for staff	Before	3	1	4	2	4	3	1	2
	After	2	1*	4	1		4	2	3
Data privacy and security concerns	Before	4	2	3	1	1	1	2	4
	After	2	2	2	1		1	2	2

**1 for UHF, 5 for LF (1 being negligible and 5 being extreme).* † *'not known'*

Generally, the concerns about the challenges of implementing BEID mostly decreased after the trial. Before the trials, farmers b and h (both had not used BEID technologies at all) anticipated lower levels of challenges before the trials. All three Welsh farmers anticipated high steep learning curve for staff if implementing the EID.

- **Difficulty in integrating with other systems** – Before the trials, two English farmers and two Welsh farmers expected major difficulties in integrating EID tags with other systems (ratings of 4 and 5, respectively), while three English farmers and one Welsh farmer anticipated minor to moderate challenges (ratings of 2, 1, and 3, respectively). After the trials, the perceived challenges decreased for most English farms, with three reporting minor difficulties (ratings of 2, 1, and 1, respectively), except for one who experienced moderate challenges (rating of 3). Of the three Welsh farms, two experienced moderate challenges and one reported negligible challenge.
- **Technical problems during use** - Before the trials, except for farm h (Welsh), all other farmers expected moderate to extreme technical problems during use (ratings of 3, 4 or 5). After the trials, all English farms reported negligible technical problems with BEID tags (rating of 1), but one farmer differentiated between UHF and LF, reporting major problems with LF but negligible problems with UHF. Of the three Welsh farms, two reported negligible or minor challenges and one reported major challenges.
- **Maintenance and replacement costs** – For the English farms, this was a negligible or minor issue. But of the three Welsh farms, one reported an increased level of concern.
- **Steep learning curve for staff** – For the English farms, before the trials, two farmers anticipated a major steep learning curve for staff (rating of 4), while one expected moderate challenges (rating of 3), and two expected minor challenges (ratings of 1 and 2, respectively). After the trials, one still reported major challenges (rating of 4), while one experienced minor challenges (rating of 2), and one had negligible challenges (rating of 1). One farmer again differentiated between UHF and LF, reporting extreme challenges with LF tags (rating of 5) but negligible challenges with UHF tags (rating of 1). All three Welsh farms expressed increased level of concern after the trial.
- **Data privacy and security concerns** – For English farms, data privacy and security was negligible or minor for the two new BEID users and remained so after the trial. This concern was moderate or major for the other three, but decreased to a minor concern

after the trial. Of the three Welsh farms, two remained unchanged and one reported lower concern (reduced from 4 to 2).

- **Other areas of concern** - Before the trials, one farmer anticipated major challenges with read reliability and tag format (rating of 4). After the trials, one farmer reported concerns for accuracy, speed, health and safety, and animal welfare as a key challenge (rating of 5). One Welsh farmer mentioned that compatibility with existing systems was a challenge.

3. Perceptions of EID technology

All five English farms agreed or strongly agreed that EID enhances the effectiveness and efficiency of cattle management as shown in Figure A1. They also agreed that the long-term benefits of EID outweigh the initial costs and challenge. The mean scores of the three Welsh farmers on the three types of benefits were all lower than English farmers, particularly on the efficiency and effectiveness enhancement.

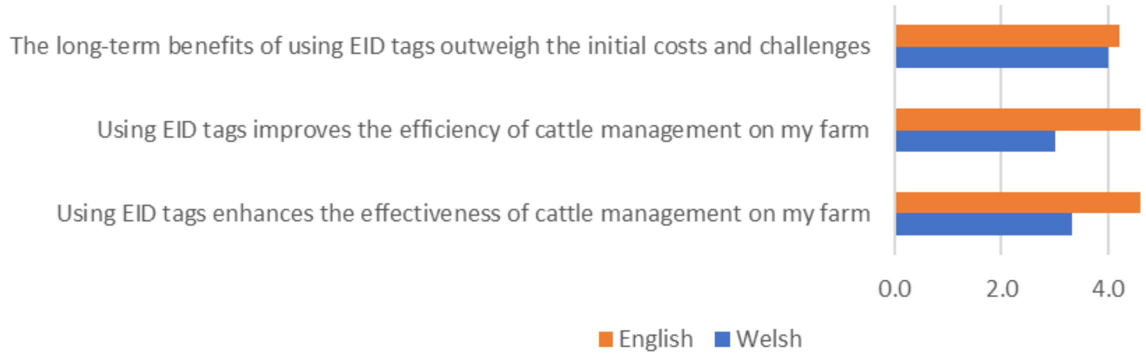

Figure A1. Mean scores of the perceptions of EID technology

4. Factors influencing adoption of EID technology

For English farmers, the most important factors influencing their decision to adopt EID technology (Figure A2) were **reliability and accuracy** (mean of 4.8) with all farmers rating this factor as very important, except for one, which rated it as important (rating of 4); **ease of use** (mean of 4.6), with three farmers rating this factor as very important (rating of 5), while two rated it as important (rating of 4); and **interoperability with current systems** (mean of 4.4), with three rating this factor as very important (rating of 5), while one rated it as important (rating of 4), and one rated it as moderately important (rating of 3).

Other important factors were **training and support availability** (mean of 4.2), **features and capability** of the technology (mean of 4.0) and **cost** (mean of 4.0) were also seen as important. Recommendations from others had the least influence on the farmers' decision to adopt EID tags, with ratings ranging from 2 to 4.

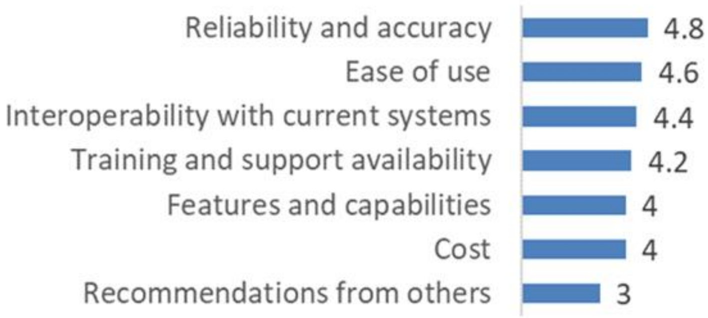

Figure A2. Factors influencing adoption of EID tags (mean score of English farmers)

For the three Welsh farmers, the order of importance of the decision making factors (Figure A3) were similar to the English farmers. The top three influencing factors were also **reliability and accuracy**, **ease of use** and i**nteroperability with current systems with one farmer rated 4 (important) and two farmers rated 5 (i.e. very important)**. Costs were seen as less important with two farmers gaving a rating of “2” (not very important).

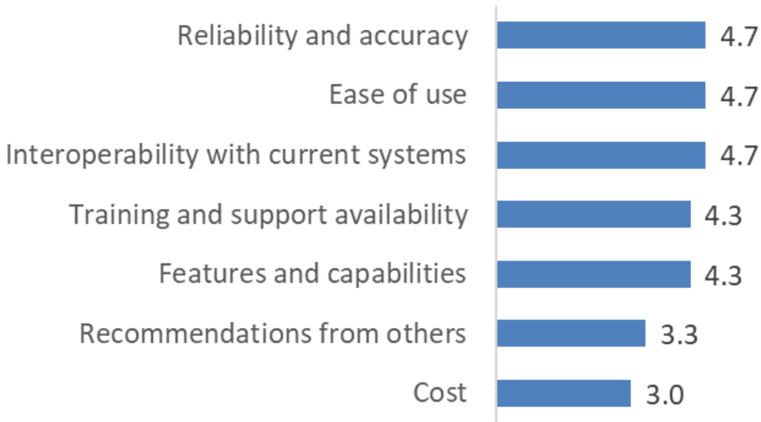

Figure A3. Factors influencing adoption of EID tags (mean score of Welsh farmers)

Further comments from the farmers included:

- **Government policy and regulations** - Example quote: *"Government policy, I guess government policy obviously, but if it meant that we could move away from paper passports, that would be a big bonus"*
- **Depending on the EID tag technology** - Example quote: *"There's currently an option. There's a choice, and there's one which I like and one which I don't like so much. So yes, depending on which system is adopted would be the answer to that"*
- **Time and effort required** can be an influencing factor. This is also related another comment that “swapping sometimes can put people off”.

5. Potential obstacles to implementing and using EID tags

Potential obstacles to successfully implementing and using EID on their farms can be found in Figure A4. Financial costs (mean of 3) and technical complexities were considered moderate obstacles, with ratings ranging from 1 to 4. Lack of knowledge and resistance from staff or management were considered minor to moderate obstacles, with ratings ranging from 1 to 4. Only two Welsh farmers provided answers to this question, all ranging from 1 to 3.

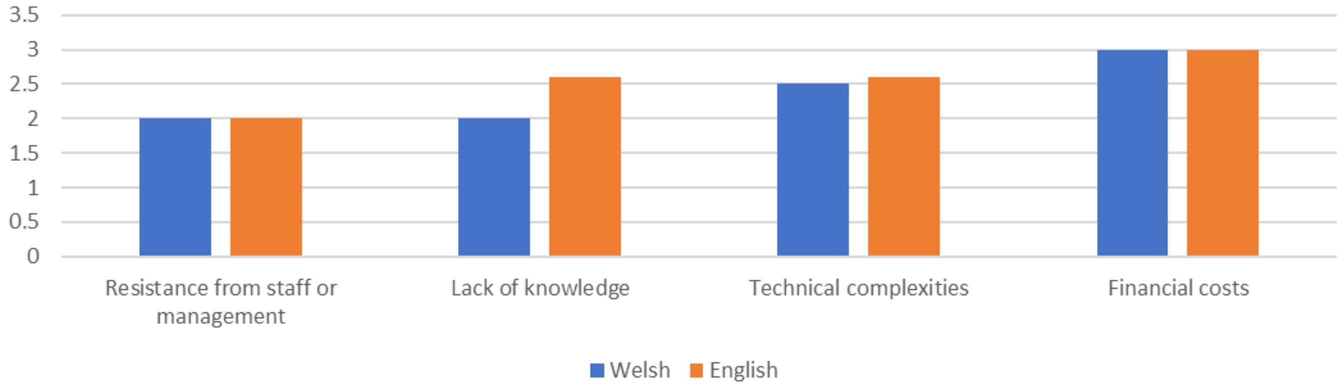

Figure A4. Potential obstacles to implementing and using EID tags (mean score)

The farmers expanded more on these obstacles:

- **Resistance tend to be from old staff** rather than young staff.
- **Simplicity** of technology is important. This is also related to the perceived compatibility of the technology with existing systems.
- LF technology is seen as more challenging, harder and more expensive to implement.

Here are some example quotes:

- *"Resistance from old staff is major and young staff is minor. Other government rules and regulations, simplicity, industry to come together behind EID, and change ASAP"*
- *"Knowing which standard to adopt"*

6. How has the use of EID tags impacted the accuracy of record keeping?

For the English farmers, four out of five farms reported that the use of EID tags significantly **improved the accuracy** of their record-keeping. The reasons for the improved accuracy were attributed to two main themes:

- **Improved accuracy and data management**:

  "*We have used EID management tags for over 12 years - we have found huge benefits to accuracy and therefore the greater ability to collect, store and use data. Looking forward with new technologies coming along. The ability to identify animals electronically automatically and accurately will be central to everything"*
  "The use of the UHF tags has meant that instead of visually checking ear numbers, which can lead to miss identifying of animals either being treated or moved. The [U]HF reader has correctly recorded with ease the cattle ID and number.
  We are naive to using EID, the flexibility and simplicity of [U]HF is a big advantage to record keeping"
- **Elimination of manual errors** - Example quote: *"Using UHF which reads the tag as we see it, and using EID it has removed the inaccuracies from manual reading"*

For the three Welsh farmers, one rated 5 out of 5 which meant that the use of EIG tags significantly improved the accuracy as they have already used LF EID in their routine cattle management. They believed that the EID crush doors provided as part of the pilot worked well. Another farmer was neutral about this (rated 3/5) because they believed that they "had a fool proof [manual] system before". The third one gave a rating of 2/5 which means it was somewhat worsened. The reason given was "T*he EID tags had to compete with a refined management tagging system, mis-reads to any level cause accuracy loses and increased cycle times*".

7. Comparisons of LF and UHF in terms of ease of implementation and levels of satisfaction with

Figure A5 shows that the farmers unanimously found the UHF EID system to be highly satisfactory and easy to implement, with consistent scores of 5 for both satisfaction and ease of implementation. In contrast, the LF EID system received lower and varying scores, ranging from 1 to 3, for both satisfaction and ease of implementation across the same parameters.

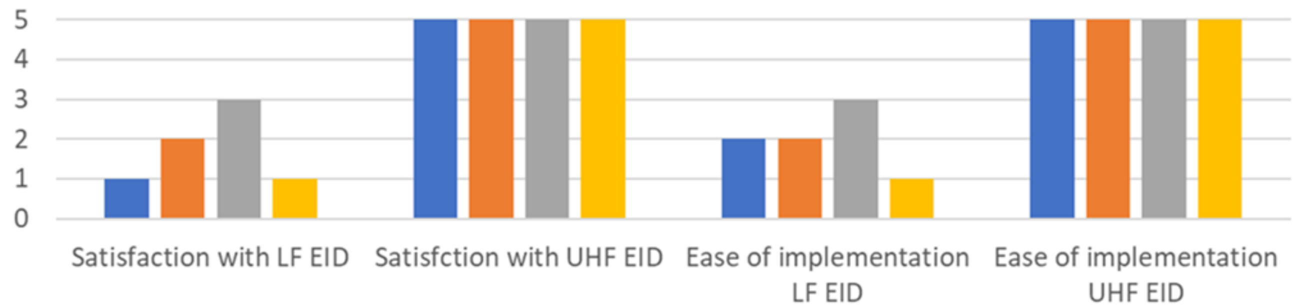

Figure A5. Comparisons of LF and UHF in terms of ease of implementation and levels of satisfaction (rating 1-5). Each bar represents one English farmer.

The three Welsh farmers only tested LF EID. They were more satisfied with the technology than their English peers. One farmer was extremely satisfied and one was satisfied and one was not satisfied. In terms of ease of implementation, Welsh farmers gave similar rating as English farmers (ranging from 1 to 3).

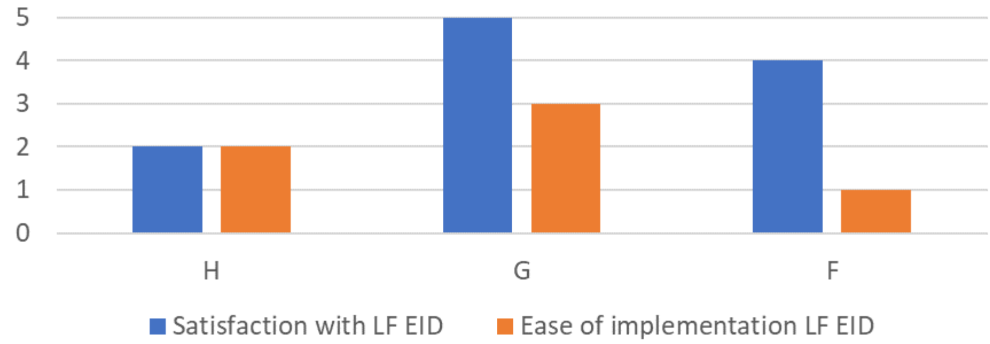

Figure A6. Comparisons of LF and UHF in terms of ease of implementation and levels of satisfaction (rating 1-5). Each bar represents one Welsh farmer.

The reasons for the ease of implementation ratings by the English farmers were attributed to the following themes:

- **Challenges with using LF tags**

  *"LF needing a '**bucket list of tags'** and **having to convert to reading** what we see on the tag has not been at all easy, the **hardware (stick reader) has also been more difficult to set up and connect**"*
  *"LF **handheld complicated** and **not user friendly**"*

- **Advantages of UHF tags such as "no need for bucket list", accuracy of reading large groups from a distance**

  "UHF has been much easier as the tags reads what's on it visually so no need for bucket lists, the reader connected immediately, the technology seems much more advanced and easier to use"

  "Accuracy of reading large groups of cattle from a distance with [U]HF, [U]HF handheld reader easy to use and explain to users"

Of the three Welsh farmers, one rated "satisfied" (4 out 5) and two rated "unsatisfied" (2 out of 5) for LF EID. The reasons for the satisfied farmer was that it was "easy to link" and the reasons for lack of satisfaction were similar to the reasons given by the English farmers. The EID system not being user-friendly was seen as a major barrier to entry although they acknowledged that "*factors concerning linking of equipment and management systems would be easier once a universal standard is established*". This was echoed by the other farmer who commented that "*Despite reading the instructions and being reasonably tech savvy we found the new weigh head and stick reader to be not intuitive as to how to use them. Consequently the trial was a bit unreal as we were not used to the equipment. In my opinion the trial would have been more useful if we had been shown how to use the equipment before start instead of trying to puzzle it out as we went on*".

The reasons for the satisfaction ratings by the English farmers were attributed to two main themes:

- Challenges with LF tags such as missing cows

  "LF works but can miss cows much more easily than UHF. With UHF there is an option to scan a group of cattle in one batch much more easily which is much more efficient, less stressful for the cattle and safer for the cattle handlers"

- Advantages of UHF tags such as reading groups of cattle

  "UHF tags allow for alleyway reading en masse accurately we read 132 animals accurately in about 90 seconds"

Of the three Welsh farmers, one who has used LF in their routine management was highly satisfied (rated 5 out of 5) as they found no misreads at all. Another farmer rated it 4 out 5 and they were *"confident that the equipment is good when the user knows how to use it".* The one who rated it 2 out of 5 (unsatisfied) indicated that the reason for the dissatisfaction was that *"the accuracy did not meet my expectations or commercial practicality".*

8. Overall feelings about using EID tags

All four English farms that provided a response felt very positive about using EID tags in their cattle management, with ratings of 5 out of 5. The reasons for the positive feelings were attributed to two main themes:

- Improved efficiency, accuracy and future proof

  "Greater accuracy, the ability to identify a number of animals speedily (alleyway reader). Getting away from written/paper records equals easier and more accurate. EID also gives the ability to quickly enter accurate data in computers and therefore much improve efficiency. Also for future proofing our business as new technologies arrive"

  "It can't come soon enough, for efficiency on farm, market or processor, reduced errors, real time tractability of cattle"

- Ease of use of UHF tags
    "[U]HF's ease of use"

- Transformative potential for the cattle industry
    "Useful to be able to very quickly and accurately identify the animal in question without number confusions. If it can lead to a fully digital passport system would be a huge leap forward for the cattle industry with an increasingly unreliable postal system causing delays in passport arrivals"

The three Welsh farmers were less positive about using EID with an average score of 3.3 (compared to 5 from their English peers). Two farmers rated 4 out 5 which was "*somewhat positive"* as they believed that the EID technology will *"speed up handling, make it safer and reduce mistakes*" and "*there is potential to benefit from further analysis of the weighing data*". However, one farmer rated EID as "somewhat negative" (2 out of 5) because they believed that the "*technology is not yet robust, user friendly or accurate enough*".

9. Recommendation of EID tags to other farmers

All four English farms that provided a response indicated that they would definitely recommend EID tags to other cattle farmers for improved management, even if they were not mandatory, with ratings of 5 out of 5. The reasons for the recommendation decisions were attributed to:

- Improved accuracy, speed, safety, and welfare
- Easy and cost-effective way to monitor cattle - Example quote: "*Relatively easy and cheap way to monitor and record cattle data*"

One farmer expressed that they would only recommend UHF due to the advantages of UHF tags and unsuitability of LF tags:

> *"I would only recommend HF for others to use. LF is not user friendly or suitable for use in grown cattle due to safety concerns in trying to get a successful read with a handheld reader"*

The three Welsh farmers were less likely to recommend using EID with an average score of 3 (compared to 5 from their English peers) with one indicated "probably will recommend" (4 out of 5), one rated "neutral" as they were "*not knowledgeable enough to see the benefits*" and one "probably not" as they were still concerned with accuracy and the system "*not yet an easier process of use*".

10. Potential opportunities associated with EID Tag integration

The English farmers rated several potential opportunities associated with the integration of EID tags (Figure A7), with ratings ranging from 3 to 5 on a scale of 1 (negligible) to 5 (transformative). The most significant opportunities were "potential for future technological advancements and integrations" (mean of 4.75), with three farmers rating this opportunity as transformative (rating of 5), while one rated it as important (rating of 4); "enhanced compliance with industry standards" (mean of 4.75), with three farmers rating this opportunity as transformative (rating of 5), while one rated it as important (rating of 4); and "improved herd management" (mean of 4.5), with two farmers rating this opportunity as transformative (rating of 5), while two rated it as important (rating of 4).

Other significant opportunities were "better marketing and sales opportunities due to traceability (mean of 4.0)", with one farmer rating this opportunity as transformative (rating of 5), while two rated it as important (rating of 4), and one rated it as moderately important (rating of 3). "Improved decision-making based on real-time data" (mean of 3.75) was rated as transformative by one farmer (rating of 5), while one rated it as important (rating of 4), and two rated it as moderately important (rating of 3).

In line with the overall feel about the technology, the Welsh farmers were less enthusiastic about the potential opportunities, with two believing that the opportunities were negligible or minor.

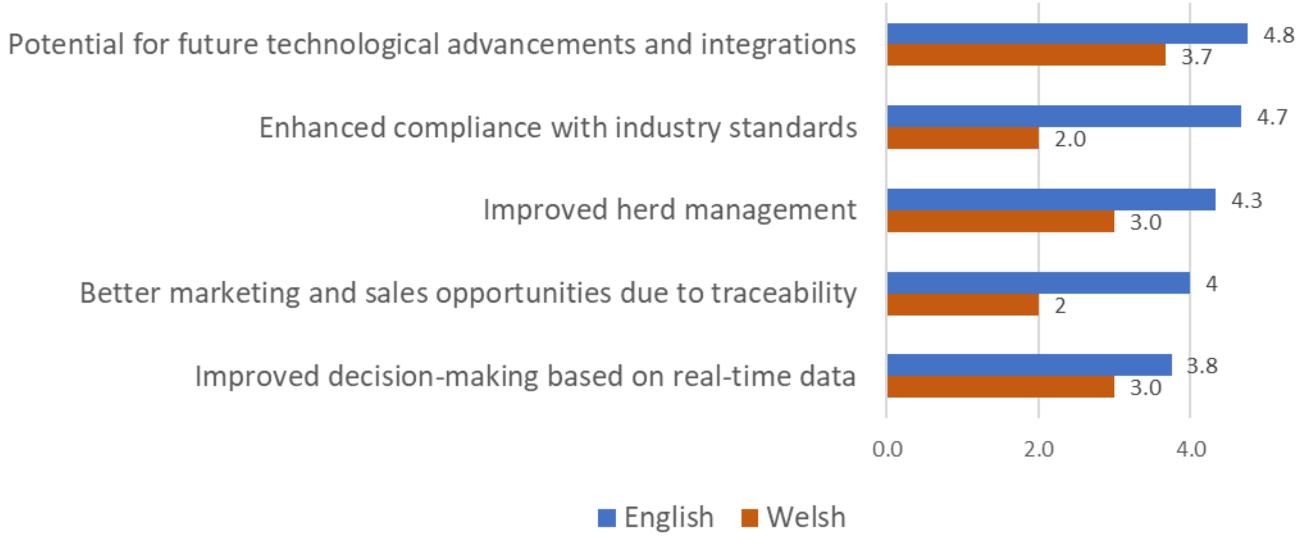

Figure A7. Potential opportunities associated with EID Tag integration (mean scores)

11. Likelihood of adopting EID Tag technology in the next two years

The farmers unanimously expressed a strong likelihood of integrating UHF EID tags into their routine cattle management over the next two years, while three farmers indicated that they were very unlikely to integrate LF EID tags and one is likely to adopt LF as shown in Figure A8.

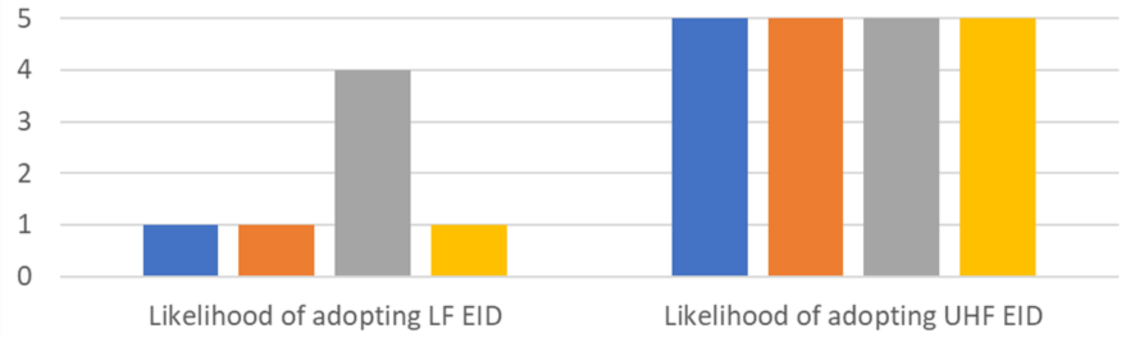

Figure A8. Likelihood of adopting EID Tag technology in the next two years (rating 1-5)

Reasons for not adopting LF:

1. Poor experience with LF tags - The farm has been using LF management tags for several years and is "*well versed in their shortcomings*"
2. LF is considered an "*outdated technology*"
3. Disadvantages of LF tags not being user-friendly, and

4. LF equipment is expensive

The three Welsh farmers only tested LF EID and they were slightly more positive than their English peers. One (farmer G) indicated that they are “very likely to adopt” LF EID due to “*operability and compatibility across software and hardware*” and Farmer F is “likely to adopt”. Farmer H is unlikely to adopt.

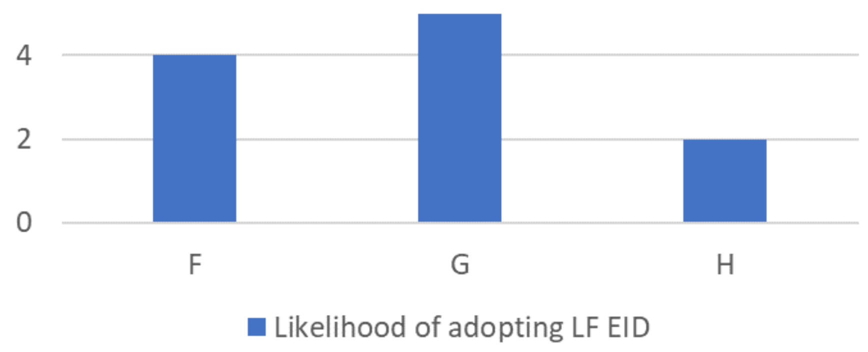

Figure A9. Likelihood of adopting EID Tag technology in the next two years (rating 1-5)

The reasons for **the strong likelihood of integrating UHF EID tag technology** were attributed to the following:

1. Impressed with the options, abilities, and accuracy of UHF tags
2. UHF’s ability to read groups of cattle at a distance
3. UHF tags offer improved health and safety benefits - UHF tags allow keeping a safe distance from cattle when needing to read tags
4. UHF has given a much superior experience overall
5. Cattle handling and stress reduction - Reading UHF tags in groups moving through an alleyway is far less stressful for cattle and handlers compared to putting them into a single raceway
6. UHF tags offer ease of integration and ease of use

Although LF technology is the established system used by two farms already (with one having already used LF for 12 years), the farmers have seen the benefits of UHF and prefers to use UHF as explained by one farmer:

> *"Already have LF technology as it's the established system used by several technology companies. Now that I have seen the benefits of UHF I would be very keen to use that technology instead if it was available"*

The three Welsh farmers only tried LF EID technology and one indicated that they will definitely integrate the technology as they have found good operability and compatibility across software and hardware. One farmer is likely to integrate and will try to hear how to get the most out of the technology. One farmer is unlikely to integrate the technology in their system as they believed that “*a comprehensive management tag system is currently far superior*”.

12. Discussion

The results are discussed in the main report (sections 2.6 and 2.10). This includes two important caveats regarding their interpretation.

Appendix 2 – Overcoming the numbering constraints of ISO 11784 and ISO 6881

One potential issue with adopting ISO11784 for LF (or ISO6881 for UHF) is that the is that the number of bits of data allocated to the national unique animal identification code is 38, and this is not usually sufficient to hold the full UK animal ID.

UK cattle currently have a 12 digit identification number, with the first six digits being the herd mark, there is then a checksum digit, followed by a five digit individual animal number. This 12 digit identification number is printed on the animal's ear tag and passport.

The maximum positive decimal integer (i.e. number) that can be represented with the 38 bits allocated in ISO11784 and ISO6881 is 274,877,906,943. Although this has 12 digits, the first digit can only be a 0, 1 or 2, and if it is a 2, the following digits cannot exceed the number 74,877,906,943. The first two digits in the herd mark were originally based on geographic area codes relating to Animal Health Divisional Offices, the majority of which exceed 27.

DEFRA have proposed a solution that allows the UK code to fit within the 38 bits allocated by the ISO standards. This involves dropping the checksum digit, which was initially added so that manual transcription errors could be more easily detected. This will be less important once EID recording is implemented. Removing the checksum leaves an 11 digit UK animal identification number (a six digit herd mark and five digit individual animal number as before). This 11 digit animal ID can now be held in full in the 38 bits allocated in the ISO standards, with the first ISO digit (i.e. 0, 1 or 2) now being a 'prefix number'. Prefix 0 and 1 both allow all 99,999,999,999 permutations of the 11 digit animal code, and prefix 2 allows numbers up to 74,877,906,943 to be held.

UK sheep LF EID tags also follow ISO11784, and use the prefix number 0 prefix followed by a six digit flock mark and a five digit individual animal number. However, sheep individual animal numbers have been restricted to the range 1-69,999, leaving 70,000-99,999 for use with cattle. Consequently, with a minor modification, UK cattle numbering can be accommodated within the requirements of ISO11784 and ISO6881.