final report

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Live Animal Objective Measurement - ex-ante impact assessment

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Executive Summary

The measurement of traits related to consumer and carcase value are applied to animals at different points in the livestock supply chain to support determination of value and pricing. On the assumption that current or future Objective Measures (OM) will be more accurate than subjective assessment methods currently in use, this report has modelled the benefit that improved measurement accuracy has on decision making and supply chain productivity.

Previously, benefits have been based on measurement post-slaughter only. This report deals with live animal applications for measurement of these same carcase traits. Its purpose is to quantify where in the supply chain additional value may be extracted through on-farm and Point of Sale (POS) live animal measurements.

The approach taken for each applicable impact scenario was as follows:

- Model the likely adoption and benefit if lower accuracy live animal OM was used instead of higher accuracy carcase based OM.
- Compare the benefits for live animal versus carcase based OM and likely industry adoption of both approaches in order to calculate an attribution percentage (see table 28) for each scenario that may be complementary (i.e. both OM measurements may be used) or where only one or the other OM measurement will be preferred.

The benefits of live animal OM for each impact scenario is as follows:

- Scenario 1 – Genetic trait selection for increased LMY whilst maintaining eating quality.

  The most benefit will be achieved by OTH sales due to higher carcase OM accuracy and implementation of VBP system. Additional live animal OM based benefits are expected to be achieved for animals sold on the hoof (e.g. via sale yards and online auctions), primarily where this live animal data is used for purchasing decisions and/or by smaller processors that do not have carcase based OM systems.

- Scenario 2 - Genetic trait selection for increased LMY & reduced dark cutters (northern beef).

  This mirrors Scenario 1 but for northern cattle.

- Scenario 3 - Genetic trait selection for increased marbling & improved feed conversion (longer fed feedlot cattle).

  Currently this is only based on genetic gain of feedlot cattle sold directly to plant and thus no additional benefit can be achieved through live animal OM. There are likely to be benefits in live animal measurement for feedlots, but this area has been excluded from this model and will be addressed in a future update.

- Scenario 4 - Improving on-farm animal health from processor feedback.

  As this currently relies on manual disease inspection post slaughter, no additional benefit has been included for live animal or carcase based OM.

- Scenarios 5 & 6 are based on optimization of product throughput and customer specification driven purchasing/sales/boning schedule decisions that maximize the value of carcases purchased.
  These benefits can only be achieved within the processing plant by measuring all carcases with high accuracy and thus live animal OM will not provide any additional benefit.
- Scenario 7 - Enhanced on-farm decision making to better manage live animal impact on yield.

  These benefits can only be achieved through live animal OM as the scenario involves changing management decisions on live animals on-farm.

Table 1: Likely net benefit for each scenario through the adoption of live animal and carcase based objective measurement technologies, achieved by 2030 and 2045

	Beef ($'000,000)		Sheep ($'000,000)	
Scenario	2029-2030	2044-2045	2029-2030	2044-2045
1	$6.49	$14.37	$1.70	$5.88
2	$2.26	$4.70	$-	$-
3	$7.82	$12.43	$-	$-
4	$16.84	$28.71	$2.41	$5.40
5	$0.66	$4.75	$0.85	$2.23
6	$10.60	$78.21	$6.27	$21.52
7	$5.58	$31.35	$1.23	$7.37
Total	$50.25	$174.53	$12.45	$42.41

The proportion of the above benefits attributed to live animal OM are shown in Table 25 and as per below. This indicates that, apart from scenario 7, there are limited supply chain benefits for live animal measurement as compared to more accurate carcase based measurement.

Table 2: Likely net benefit attributed to live animal based objective measurement technologies, when coupled with carcase based objective measurement technologies.

Scenario	**Beef ($'000,000)**		**Sheep ($'000,000)**	
	2029-2030	2044-2045	2029-2030	2044-2045
1	$0.15	$0.41	$0.19	$0.96
2	$0.04	$0.14	$-	$-
3	$-	$-	$-	$-
4	$-	$-	$-	$-
5	$-	$-	$-	$-
6	$-	$-	$-	$-
7	$5.58	$31.35	$1.23	$7.37
Total	$5.77	$31.90	$1.41	$8.33

Industry benefit

This report includes a 2020 revision of the adoption rates for objective measurement (OM) technologies first reported in 2015 (MLA V.MQT.0071 report) and which estimated that over $420 million of potential gross benefit per annum existed from the further adoption of objective measurements, information transfer and associated pricing signals by 2040.

Since 2015 there have now been three revisions to the adoption rates and benefits associated with OM technologies, with the results summarised as follows:

1. **2020 Results** (V.MQT.0002 current update) - The annual cattle and sheep net benefit achievable from the likely adoption of both carcase and live animal based objective measurements is $62.7 million in 2030 and $216.9 million in 2045, with the majority of benefits derived from cattle OM ($50.2 million in 2030 and $174.5 million in 2045). This is estimated to bring $1.3[1] billion net benefit value to the red meat industry over the period 2025 to 2045.
2. **2019 Results** (V.MQT.0002) - A net benefit of $40 million per annum is likely to be realised by 2023 (beef and sheep including mutton) while around $186 million net benefit per annum could be realised by 2040, providing a total net present value[2] benefit of $1.066 billion between 2020 and 2040.
3. **2018 Results** (V.MQT.0001) – A net benefit of less than $31 million per annum was estimated to be realised by 2020 (beef and sheep excluding mutton) while around $222 million benefit per annum could be realised by 2040. The adoption rates were subsequently revised via feedback from an industry workshop to provide the 2019 results.

The 2018, 2019 and 2020 numbers have been revised down from the 2015 forecasts of around $250 million gross benefit per annum of likely benefit by 2030, with the largest driver being slower than planned adoption of DEXA measurement systems by industry across both beef and lamb sectors as well as delays in rolling out feedback mechanisms and value-based pricing grids.

The numbers contained in this report now include benefits from 2025 to 2045 for both live animal and carcase based OM, and as it is now anticipated that the benefits will only start to flow back to the production sector by 2024, this has now been used as the adoption starting point. These changes result in similar overall benefits to those modelled in 2019 for the carcase only OM program.

Recommendations

As yield is only one determinate of value, it is recommended that future work examines the potential benefits of eating quality (EQ) and genomic objective measures as additional areas to drive industry benefit. The following summaries additional work which could further increase the value proposition for OM technologies:

[1] Net present value discounted at 5%, with 2025 as the base year
[2] Net present value discounted at 5%, with 2020 as the base year

- Only objective measures of yield at two points of the supply chain have been considered in this report however there is significant scope to consider the following:
    - Genomic measures for the prediction of commercial value drivers to assist with management decisions on farm, within both the seedstock and commercial production sectors. This would facilitate earlier intervention for future markets and thus management strategies.
    - The use of objective measures of eating quality as the primary driver of consumer value. This would reduce the number of eating quality issues across industry by allowing early intervention to ensure livestock met their full potential thereby increasing value of the national herd.
    - Utilising genomic, yield and eating quality objective measures in the feedlot sector of the industry. Feedlots operate at low margins per head currently and with increasing costs of production this margin will continue to be eroded. The potential of a combination of live animal and carcase-based OM technologies would ensure that the maximum potential of every animal is reached at the best resource efficiency rate.
- Adoption rates of OM yield-based technology will be impacted by a range of factors including:
    - The cost of entry to the OM technologies
    - Ease of use of the technologies
    - Ability for integration with current systems such as crush side weigh scales and walk-over-weighing systems
    - The presence and size of accompanying market signals
    - The acceptance of on farm-based OM data by processors and feedlots for payment through VBP/VBM models
    - The development of associated feedback mechanisms to producers to drive improvement
    - The understanding and provision of extension programs detailing how to drive yield changes on farm through genetic selection and management interventions by producers
- As yield is only one driver of market value, extension services will be critical to ensure to correct selection pressures are applied in genetic decisions to ensure limited detriment to eating quality, fertility and other significant consumer and production factors
- It is recommended that MLA undertake extensive consultation with producers to better understand the appetite for the adoption of yield-based OM technologies in the live animal.

Consultation and modelling are also required to determine the best decision points in the value chain to implement OM technologies as true value realisation is linked to the adoption of VBM/VBP payment models

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1 Background

1.1 Objective Measurement impacts in the Australian red meat industry

1.1.1 History

The previous reports considered all objective measurements and were technology agnostic in assessing the potential value of yield and/or eating quality based objective measurement (OM) technologies to the red-meat industry. The potential value of OM technologies to the industry is still a significant opportunity. Previously forecasted potential value benefits have been adjusted over the last 4 years as required where new research and development activities have occurred throughout industry as part of the ALMTech program and adoption assumptions updated. The following is the revision history of the likely benefits:

1. Original 2015 report (project V.MQT.0071) comprising all benefit scenarios and assumptions.
2. 2018 revision (project V.MQT.0001) of adoption timeline and rates.
3. 2019 revision (project V.MQT.0002) with further reduced adoption rates after feedback from an industry consultation workshop held 13 June 2019. Adoption rate profiles for benefit scenario were also changed to better reflect likely early, medium and late adopters over the period. These estimates are documented further within this report.
4. 2020 revision (project V.MQT.0002) included for the first time potential benefits from live animal measurements. A new on-farm scenario was added, and the effect of combined live animal and carcase measurements were included in several of the earlier scenarios. All adoption and impact data was extended to 2045, so as to be aligned with MLA's current impacts assessment framework. This latest revision has been fully documented in this report.

Accurate objective measurements of carcase value (driven by tools such as DEXA with support from other objective measurement tools for assessment of eating quality) are key enablers of new value-based payment systems. At the time of writing the 2015 report a Federal government program was being discussed with industry to support the fast tracking of DEXA systems in most Australian processing plants. That initiative has not proceeded to date, so adoption of processing sector OM technologies coupled with new value-based pricing mechanisms has not been as fast as anticipated. This is a primary driver for the much lower rate of adoption (and hence benefits) as compared to the first 2015 estimates.

When adjusting adoption rates and realising OM benefits, the following factors have been considered:

1. Availability, costs and precision/accuracy of potential OM technologies to measure and capture data, noting that assumptions have been made that these may change over time as new technology options are made available.
2. Discerning what new data means to all participants in the chain,
3. How to communicate new information through feedback mechanisms, availability of IT systems that will support this information sharing as well as supporting new payment systems required to incentivise changes in production practices and quality of outputs.

4. Willingness and ability of processors to move to new value-based pricing (VBP) payment system for OTH purchases, given current supply side constraints
5. Rate of cultural change required across industry for new payment methods to become effective.

Description of benefit scenarios

Scenarios 1-6 were developed as published in the 2015 reports by the ALMTech Steering Committee to enable quantification of the value propositions of objective measurements in the Australian red meat industry. Previous reports have examined these scenarios and quantified the benefit to industry if a carcase based objective measurement technology was to be implemented in the appropriate area of the processing sector.

This latest report has examined the additional benefits from live animal objective measurement (primarily on farm) for the six previously assessed scenarios. Modelling live animal OM measurements as a direct replacement for carcase measurements showed that industry benefits would be lower (primarily because of lower accuracy levels) and hence live animal measurement benefits been included where they will increase or supplement carcase based measurement, rather than replace them.

Given progress being made within the ALMTECH R&D program on live animal measurement, a new seventh scenario has been included in this report so as to examine the impacts of on-farm objective measurement to drive increased lean meat yield and the resulting enhanced on-farm decision making to manage live animal impact on yield.

Re-forecasted carcase OM based likely benefits - for the beef and sheep industries are summarised in the following through benefit scenario for 2025 and 2045. These revised values are the result of feedback from an industry workshop that updated adoption rates in alignment with R&D outcomes.

1.1.2 Opportunity for objective measurement on farm

The six original and one new key benefit scenarios can be quantified as directly resulting from carcase traits measured either live or on the carcase. Of these seven scenarios, four apply to on-farm or at Point of Sale (POS) to capture the financial benefit from the objective measures. Note that OM is not applied in the same way across the industry, and so each scenario covers different traits, animal types or management decisions that generate the projected benefit. Each scenario and its scope will be detailed in the discussion.

For the purposes of this report, only scenarios 1, 2, 6 and 7 have been included in delivering additional value through on-farm OM applications. Benefits for scenarios 3 and 5 do not benefits from on farm OM, or in the case of scenario 4 (Animal Health feedback), benefits are not dependent on OM measurements.

Scenario Number	Scenario Title	Scenario Description	% of species it applies to	Live animal OM benefits
1	**Genetic trait selection for increased LMY whilst**	Together Lean Meat Yield (LMY) and Eating Quality (EQ) largely	This scenario applies to 100% of **sheep** production and 60% of **beef** production where	**In** Includes benefits for processors without carcase OM measurement, as improved

	maintaining eating quality	determine total carcase value.	reliable environment and broad market access reward a mix of quality and yield.	purchasing decisions for non OTH sourced animals
2	**Genetic trait selection for increased LMY & reduced dark cutters (northern beef)**	'Dark cutters' impose significant discounts on beef carcases[3]	This scenario applies primarily to 30% of beef production in more unreliable northern environments where conditions make it more difficult to get a return on investment in EQ in Scenario 1.	In Includes benefits for processors without carcase OM measurement, as improved purchasing decisions for non OTH sourced animals
3	**Genetic trait selection for increased marbling & improved feed conversion (longer fed feedlot cattle)**	Increasing growth rates in feedlots reduces the overall cost of feeding but must maintain meat quality.	This scenario applies to feedlot animals (10% of beef production) destined for high quality markets where marbling (MB) has a greater impact on finished product value than lean meat yield, but more efficient feed conversion (negatively correlated to MB[4,5,6]) is required for higher profitability.	Out There are likely to be benefits in live animal measurement for feedlots, but this area has been excluded from this model. This will be addressed in a future update.
4	**Improving on-farm animal health from processor feedback**	This scenario considers the value opportunity for managing animal health issues that impact both the production and		Out Because this is about feedback of manually collected data from processors to producers, it is not a live animal OM application, and so is excluded from this report

[3] McGilchrist P (2012). Beef CRC Fact Sheet: Producers can eliminate 'Dark Cutting'. *CRC for beef genetic technologies*.
[4] Ewers (et. al.) (1999) Saleable beef yield and other carcass traits in progeny of Hereford cows mated to seven sire breeds
[5] Cartens G, Genho P, Miller R, Moore S, Pollak J, Tedeschi L (2005). Determine the genetic and phenotypic variance of meat quality traits and their interrelationships with economically important traits in bos indicus type cattle. *National Cattlemens Beef Association*. The Beef Checkoff. Page 4.

[6] Arthur J, Herd R (2008). Residual feed intake in beef cattle. *Revista Brasileira de Zootecnia* (37). ISSN 1806-9290.

		processing sectors across the beef and lamb industries by the provision of animal health feedback from processors to producers.		
5	**Improved processor boning room efficiencies**	Benefit of improved carcase sortation to customer specifications using accurate carcase objective measures to increase productivity within the processing plant.		Out Live animal OM is not expected to change the efficiency of the boning room e.g. throughput.
6	**Customer specification driven livestock purchase and processing allocation decisions to maximise carcase sale value**	Objective measures of live animals that enable more accurate processor purchase pricing decisions and support boning schedules to extract increased value from carcases. Included in this benefit scenario is the influence of better producer decision making of which sales channel to operate in, aligning with processor markets.	This applies to 100 % of **lamb** production and 100 % of **beef** production	In Where live animal OM data is available (for a subset of the total animals purchased and OM measured post slaughter), animals can be purchased that are more closely aligned with customer specifications. This will increase the per head benefits for that subset of animals.
7	**Enhanced on-farm decision making to better manage live animal impact on yield.**	Adoption of OM technology to select and manage animals for an increase in LMY whilst on-farm, to maximise	This applies to 100 % of **lamb** production and 100 % of **beef** production	In NB: EQ was considered for this scenario however the impact of changing the carcase weight on EQ was unknown, and therefore was excluded.

	SMY at point of sale.	

JT comment:

The results of the CRC showed that increases in carcass weight (i.e. going from domestic to Korean or to Japanese endpoints) resulted in an improvement in EQ.

Also the MSA model quantifies the benefit of increased carcass weight while holding other traits (e.g. marbling, ossification, rib fat and hump) constant.

1.2 Scope

Under project V.MQT.0071, Greenleaf developed an Excel based series of models as well as a related, detailed report that estimated, on an ex ante basis, the productivity-based impacts of the OM program. The modelling was subsequently updated in 2018 and 2019 under project V.MQT.0001 and V.MQT.002 (the current project) as it had become evident that both the development of OM technology and adoption rates within industry have been slower than originally anticipated. Further activity relating to the above is planned under this project as follows.

- Part 1 of this project funded an ALMTECH evaluation workshop to review the results of the updated model, so that these can be used for the evaluation of the ALMTECH RRnD4P project, as well as MLA's impact assessments.
- As a result, Part 2 and 3 of this project for the first time, expanded the existing modelling so as to estimate the productivity impacts of live animal OM on the supply chain value propositions from V.MQT.0071 and V.MQT.0001, as well as creating an additional model for on-farm productivity benefits.

<u>Project part 1 – Live animal measurement </u>- pre-sale measurement - Producers decision to sell will not change.

Updating the existing modelling from V.MQT.0001 to include any additional benefits from live animal pre-sale measurement for benefit scenarios 1, 2 and 6.

This is a version of the current OM modelling (around the benefit scenarios) that includes presale live animal LMY measurement (and assumes that EQ is maintained).

Assumptions include:

- Inclusion of animals being sold using OM descriptions through the following pathways - OTH, feedlot, saleyard and electronic (e.g. Auctions Plus). Hence the main effect is around adoption and improved price signalling.
- Assumption is that producers could not change their decision on where to sell animals because of these OM details.
- Agreement was made that all data and assumptions will be provided for this scenario from MLA & ALMTech and not be required to be collected by Greenleaf.
- Carcase OM feedback would only be provided post sale for all animals sold.

<u>Project part 2 - Live animal measurement</u> – on-farm measurement – informing producers decision to adjust management practices as well as alternative sales decisions

A new model was built based on live animal OM informing producers decision to adjust management practices as well as alternative sales decisions, now known as scenario 7. This is new modelling, involving a complex set of decisions and practice changes that would relate to on farm use of LMY (separate benefits to the above).

It reviewed the financial implications of live animal objective measurement on-farm, quantifying the benefits from the following scenarios:

- Animal management and productivity changes on farm, from on-going measurement of live animals from birth to turn off. Includes managing changes in turnoff times and growth rates to maximise the values of animals when sold.
- Live animal measurement informing genetic selection, similar to LMY feedback from processors. Main benefit might be timing (earlier information). Includes feedback mechanisms from all data collected back to the seedstock sector to increase genetic gain.

2 Methodology

2.1 Total benefit model development

The model is effectively a 5-dimensional matrix where a combination of elements describes the detail within a benefit scenario. The elements of the matrix are explained in the next sections and include:

- Scenario overview
- Trait
- Benefit
- Measurement sector
- Behaviour / reward sharing relationship
- Benefitting sector

The model was updated from the previous report to accurately represent current inputs. It was then populated through research, industry consultation and the team's experience. The variation of each element was found and modelled across the combination of elements as an integrated projection based on improving technology accuracy and adoption rate. Value gains between 2025 and 2045 were generated based on assumed adoption rates. A number of assumptions were made and these are addressed below.

For each combination of factors, maximum, potential and likely benefits were calculated.

2.2 Scenarios

Table 3 shows the scenarios which benefits for the Australian sheep & beef value chains are attributed. The scenarios applicable to this project are 1, 2, 6 and 7.

Table 3: Objective scenarios for benefit to the Australian red meat industry and their inclusion in the on-farm and if they are applicable to this body of work.

Scenario	Applicable to live animal assessment
1 - Genetic trait selection for increased LMY while maintaining or increasing eating quality	Yes
2 - Genetic trait selection for increased LMY & reduced dark cutters (northern beef)	Yes
3 - Genetic trait selection for increased marbling & improved feed conversion (longer fed feedlot cattle)	No
4 - Improving on-farm animal health from processor feedback	No
5 - Improved processor boning room efficiencies	No
6 - Customer specification driven livestock purchase and processing allocation decisions to maximise carcase sale value	Yes
7 - Enhanced on-farm decision making to better manage live animal impact on yield.	Yes

2.3 Traits

As with any product, animals and meat products have attributes or characteristics that determine their value to the various sectors of the value chain and ultimately the consumer. These characteristics impact upon either product quality or quantity. The transmission of information along the value chain about these characteristics relies on (i) the ability to measure the characteristic in question, preferably objectively (objective measurement – 'OM'); (ii) the existence of a sufficiently comprehensive 'language' with its associated standards and definitions; and (iii) a transparent and efficient exchange of ownership process.

In relation to meat characteristics, the red meat language spans all sectors from genetic selection to final consumer purchase. The three key stages are the livestock language (prior to slaughter), the meat language (abattoir and wholesale) and the consumer language (retail).

Each stage uses several objective measurements and / or subjective assessments to describe the product and place a value on it. The accuracy of these objective measures and subjective appraisals varies, as does their influence on product quality and quality. The current level of measurement accuracy for many of the existing characteristics is well known for beef.

2.3.1 Traits Defined

The following traits are keystones to the benefit scenarios covered in this report.

- **Lean Meat Yield (LMY)**
  - The percentage of lean meat, or saleable meat, on the carcase. The calculation used to calculate lean meat yield in beef carcases is below:
    - $LMY = 68.22 - 0.394 * Fat\ Depth + 0.102 * Eye\ Muscle\ Area$
- **Eating Quality (EQ)**
  - Determined by grade of meat, and reflected in the customer's enjoyment
- **Meat Colour (MC)**
  - The colouration of the cut of meat when it sits on the retail shelf, reflected in the consumer's tendency to purchase it
  - It's controlled by the management of animals' pre-slaughter to maximise glycogen stores post-slaughter reducing pH below 5.7 and producing meat with a cherry-red appearance
- **Hot Standard Carcase Weight (HSCW)**
  - The fundamental unit of 'over the hooks' selling and is the weight within two hours of slaughter of a carcase with standard trim (all fats out)
- **Saleable Meat Yield (SMY)**
  - Saleable Meat Yield, SMY, is the total value/quantity of meat in cuts and offcuts that can be sold, after offal and excess fat is removed. Lean Meat Yield, LMY, differs from this in that it is the percentage of carcass weight that is lean meat. SMY is typically applied to the individual animal, whereas LMY is more useful on a herd average basis. This application of OM looks at the value to be gained from the individual, through informing growth decision-making, and so is considered per individual animal.
  - *JT comment: Not sure I agree with this. LMY has less noise and so is a more useful measurement at the individual animal than SMY*
  - Equation 2 has been used to calculate the saleable meat yield of carcases included in the population used for the analysis
    - Equation 1: Saleable Meat Yield calculation

$$SMY = HSCW * LMY$$

- **Intramuscular fat (IMF)**
  - Fat within a muscle, commonly known as marbling, quantified as a percentage of total muscle mass
- **Marbling (MB)**
  - Refers to the intramuscular fat content of beef. Usually evaluated in the rib eye between the twelfth and thirteenth ribs.

Specifically, the consumer value measures are SMY, EQ and Meat Colour. These are derived from HSCW and LMY, from MB and pH, and from visual inspection (influenced by pH) respectively.

2.4 Benefit

Each trait or combination of traits measured enables specific benefits. While the range of benefits is many and varied, the value generated fits into one of the following categories:

- Process improvement – decreasing the costs associated with product throughput through increasing the consistency of products
- Market alignment – obtaining more information or other enabling capabilities to better align existing product to the highest value markets
- Product value - Increasing the value the customer is willing to pay per unit (increased eating quality, longer shelf life, shape/size etc.). This represents an increase in the TOTAL value generated by the supply chain
- Productivity - A change in the amount of output per unit of input. This may result in more product at the same cost or the same amount of product at a reduced cost, e.g. Increasing the volume of units sold (LMY for same feed inputs; genetic gain), improving yield in boning room, reducing disease load to improve feed conversion, and decreasing costs associated with product throughput by increasing input consistency

Benefits in these categories may come about through the introduction of new information, new technology or new processes.

2.4.1 Prioritising benefits in each scenario

Although the focus of a benefit scenario is a few key traits that could be measured by OM technologies, how those measures are enacted across industry is much broader. Within each benefit scenario we have grouped the resultant benefits across industry to aid communication as follows.

Primary benefits are the focus of each scenario (e.g. LMY and EQ, Animal Health, Marbling and Meat Colour).

Secondary benefits were also considered. These are more specific and do depend where the trait is measured and where benefit is attributed to. For example, an objective measure of lean meat yield in the live animal may increase rate of genetic gain for the whole supply chain but may also save drafting costs or feed costs for the live animal. These have a big impact on adoption of OM measures.

Specific benefits

A list of benefits considered while developing the final benefit scenarios is included here:

- Yield increase (meat)
- Labour saving
- Reduced dark cutters
- Improved value of meat
- Improved decision-making regarding marketing and animal production management
- Increased weight at sale
- Increase value
- Reduced mortality

- Increase number of units for sale
- Increase feed conversion efficiency

2.5 Measurement sector

Consideration is given to whether the trait could be measured at each sector in the chain and a subsequent total potential realisable value is calculated based on the following factors:

- Ease to implement – a percentage rating of how easy it is for the measurement to be implemented. These was determined in previous projects as part of the ALMTech program.
- Technical likelihood – a percentage rating of how likely it is to be able to undertake this measurement in this sector. This was set at 100% to demonstrate the full value assuming it could be measured at that point. It could be adjusted in future modelling to estimate the risk/return ratio for future R&D investment
- Accuracy of measurement – the degree of accuracy (5 confidence limits) of this measurement in this sector
    - Will be greatest in the carcase post-slaughter; however, it will be less useful to a producer as they cannot change sale or management decisions past this point.
- Likely Benefit Percentage – when measured at this sector and the measurement is fully used, the percentage of the total potential benefit that can be realised from that data. For example, measuring estimated LMY on-farm gives the producer more ability to change the LMY and value than if it is measured at the saleyard.

Technology throughput - will need to be developed that support a range of environmental needs, such as high throughput numbers in saleyards and crush-side in feedlots and properties, while lower throughput rates for auto drafting in-paddock may be easier to develop. The technologies will be fit for purpose to scan the live animal or carcases and understandably will have an impact on the system accuracies.

Technology Costs - The capital and operational costs of OM measurement technologies costs may have a significant impact on system adoption but are difficult to estimate given that many of these are not yet commercially available. Hence gross and net benefits have been included, with a small allowance for most OM measurement technologies on the assumption that these will be relatively low cost. The exception is DEXA type measurements where a larger cost has been assumed.

Adoption rates leading to increased value - depend on selection pressure being applied by the seedstock sector. The downstream chain, linking the customer to the producer via processor actions needs to place new pressure on the chain to change the status quo. The adoption rate modelling has been detailed in the discussion for each scenario.

There are many factors within the production sector and a few interactions between the processing and production sectors that impact on likely adoption. For example:

- Producer adoption of OM for LMY will be limited without significant incentive, given many do not have scales and thus the installation of potential objective measurement tools is a larger barrier both culturally and as an investment in capital wise
- Pricing signals and feedback mechanisms need to be developed to incentivise adoption of new measures.
- Processors are reluctant to implement pricing methods that disrupt the status quo and risk reduced supply volumes. It has been assumed that only 30% of processors will

adopt processor sector OM combined with VBP. However this may cover up to 75% of the national slaughter of beef and lamb. Note that a much larger number of processors may adopt carcase OM technologies is these are lower in cost and also focussed on processor specific value propositions (scenarios 5 and 6).
- It has been assumed that a larger group of producers that sell to multiple processors would adopt on-farm OM if there were mechanisms like such as online marketing tools such as online auction platform where producers were able to publish livestock measurement results as part of their sale details as a marketing mechanism
- It has been assumed that a higher percentage of processors would adopt LMY pricing (even if indirectly) if they were able to purchase livestock with known OM results prior to slaughter. This would be due to increased certainty of the animals they were purchasing and therefore more accurate processing plans to meet order specifications.

Measurement location considers the sector to which OM is applied, and sector which uses the resulting data. This report is considering the use of objective measurement on farm and thus the likely benefit is greatest when OM is applied to the live animal because producers can make management and sales decisions to improve either traits or the chosen market for the product. Secondary benefits in the model are not costed which make the values conservative. The limitations of pre-slaughter measurement locations are outlined below and summarised in the final dot-point. These limitations are pertinent to OM as a whole. The measurement location of each scenario differs, with the illustrating the potential data collection used in each of the scenarios included:

- Scenarios 1 and 2 could have data to support the benefits collected either on-farm or at live animal point of sale (specifically online auctions & saleyards)
- Scenario 6 requires data to be collected at live animal point of sale (specifically online auctions & saleyards), which would limit the overall pool of animals included.
- Scenario 7 requires data to be collected on animals on-farm to enable a change in management decision to increase value at sale.

Decision making within the feedlot sector is not accounted for in this model however is recommended as further research due to the high-risk environment of fed animals and the potential margin differences in animals of differing performance metrics. Measurement at processing will not only inform the producer for future livestock management but also indicates how well they have managed the genetics to its potential.

- If genomic tests become cost effective, commercial producers could select animals for the most suitable production pathways. The benefits of this genomic testing and subsequent decision making are out of scope of this report.

Behaviour / reward sharing relationship. The last step in the modelling considers the sector in which the value will be realised. In undertaking this assessment, consideration is given to the behaviour/reward sharing relationship between the ‘buyer’ and ’seller’ at the point the measurement is taken, and value transferred.

The behaviour / reward sharing relationships considered include:

- Auction system
- Forward selling
- Over the hooks (OTH) of Value-based pricing (VBP)
- Integrated supply chain and other retained ownership models
- Value-based marketing (VBM)

Current pricing structures are closer to average cost pricing than value-based pricing/marketing because the use of HSCW, fat depth and meat colour which are inaccurate methods to determine consumer led carcase value. With the application of OM, it is expected that objective measures of value, such as LMY and eating quality will enable more accurate selection and allocation to market value. In addition, where producers can evaluate live animals, they are able to dictate animal management strategies, genetic selection and VBM strategies to align stock with the optimal end markets.

The opportunity with VBM over VBP is that the buyer does not need to commit to buy product they do not really want. They know what they are getting before they commit to it. Furthermore, the seller may choose to sell the livestock to another market that is better suited to handle their now-known product, or they may choose to keep it for longer to add some additional value that will make it more marketable and more profitable.

3 Discussion

The results present in this section of the report are specifically related to the adoption of live animal OM technologies. Only scenarios 1, 2, 6 & 7 have been including as they could be achieved using live animal-based measurements. Details on scenarios 3, 4 & 5 can be found in the V.MQT.001 report. The results presented are based on the potential value created through only using live animal technologies. The combined benefits of utilisation of live animal and carcase-based technologies are included in Section 4 of this report.

3.1 Scenario 1 Genetic trait selection for increased LMY whilst maintaining eating quality

3.1.1 Description

- The two factors that generally have the largest impact on the value of each carcase are LMY and EQ
- Increasing LMY reduces fat and waste that will be trimmed from a carcase to meet end customer requirements. Doing this while maintaining EQ is critical to maintain consumers' willingness to pay
- LMY and EQ[7,8] is negatively correlated, so care must be taken not to drive strong gains in one trait at the expense of the other. The European pork industry made this mistake 25 years ago and is now having to undo all the years of selection of lean meat and muscle growth at the expense of eating quality.

JT comment: Also quote the work of Bonney et al for beef.

- Specifically, lambs are primarily valued for their weight and fat cover / score
  - IMF has a significant impact on the flavour, juiciness, tenderness and overall EQ of lamb[10]
- This scenario examines how using OM data on beef and lamb pre-sale for genetic selection will improve carcase value.

3.1.2 Industry Application

This scenario applies to:

- 60% of beef production where reliable environment and access to a range of markets make a mix of quality and yield the most profitable outputs for the supply chain
- 100% of lamb production
- 35% of mutton product resulted from increased LMY in lambs

[7] Mortimer S. et. al, (2010) Preliminary estimates of genetic parameters for carcass and meat quality traits in Australian sheep. Animal Production Science, 2010, 50, 1135–1144.
[8] AGBU, (2016). Genetic Models.

3.1.3 Traits included for Beef and Lamb

The traits measured in this scenario are summarised here in Table 4, Table 5 and Table 5.

Table 4: Beef and Lamb LMY and maximum benefits

Lean meat yield – Beef and Lamb	
Value Proposition	Increasing the lean meat yield of carcases will increase the proportion of lean-to fat, increasing the effectiveness of live animal input costs and reducing trimming of waste in the carcase, resulting in higher returns. A maximum genetic gain in LMY is expected to be 2%[9] per generation for both Beef and Lamb[10].

Table 5: Beef MSA EQ descriptions and maximum benefits

Beef Eating Quality - MSA Existing	
Value Proposition	Increasing the number of livestock graded MSA is the assumed measure here of an increase in eating quality. The price premium for MSA is assumed as the increase in value or consumer willingness to pay for the eating quality increase. Although a range of brand attributes besides EQ are involved in establishing consumer value, MSA willingness to pay data indicates consumers will pay 50% more for better than every day and 100% more for premium. No reduction in MSA value/kilogram has been factored as a result of increased supply. The rate of increase in livestock graded MSA could occur faster. But producers are already paid a premium and some still opt not to become MSA accredited. It is unlikely that significant improvements in MSA will occur unless price incentives for MSA increase.
	JT comment: Not sure of the logic used here.
	• No increase in accuracy of EQ grade has been assumed. • If the standard of EQ grading accuracy were to improve through OCM technologies, there would be an increased rate of EQ growth at the industry level. • Increasing the average eating quality (MSA index) of the population would elevate consumer value from ‘every day’ to ‘better than every day’ and ‘premium’. This value opportunity has not been factored as the scenario is about maintaining eating quality.

[9] Expressed as 2% increase on current LMY levels, not as a portion of 100% meat. Note that single trait selection is not commercially realistic, and rate of Maximum benefit stated here is reduced to Potential Benefit through multi train selection and accuracy levels, and then to Likely Benefit through adoption rates.

[10] Personal communication

Table 6: Lamb IMF description and benefits

Lamb Eating Quality - IMF	
Value Proposition	Intramuscular Fat (IMF) is not measured in lamb carcases currently. A commercial method for measurement of IMF does not yet exist. This contrasts with the beef industry where approved measures of marbling are undertaken (with subjective assessment) and payments are already being made based on these measures. Although IMF in lamb is not graded, industry has maintained an acceptable range in IMF between 7-12% to ensure eating quality. Increased carcase weights (and fat) in recent years without selecting for leanness have maintained IMF levels. The seedstock sector currently uses ultrasound scanning for eye muscle area and IMF approximation but have a very low accuracy. An objective measure of IMF in lamb is under development with commercialisation targeted for 2030. The benefits associated with IMF value in lambs has not been included in this scenario.

3.1.4 Lean meat yield assumptions

Table 7 shows the assumptions used to calculate the maximum increase in benefit per head resulting from LMY[11] for the three livestock types for single trait selection.

- This is based on current pricing and value of saleable lean meat on a carcase weight basis was assumed at $11.36/kg for lamb, and $8.48/kg for beef.
- This equates to an increase of $2.82, $0.56 and $10.91 benefit per head for lamb, mutton and beef respectively, achieved cumulatively across all generations between 2025 and 2045.

Table 7: Assumption details, calculating LMY Benefit for Scenario 1

LMY Benefit			
Factor	Lamb	Mutton	Beef
Single trait rate of gain	2%	2%	2%
Generation interval (yrs)	4	8	5
Gain per year	0.5%	0.3%	0.4%
Annual Increase	0.11%	0.05%	0.08%
Max increase by 2040	1.05%	0.53%	0.84%
Saleable meat yield (kg/hd)	23.60	23.60	153.20
Saleable meat yield ($/kg)	$ 11.36	$ 4.52	$ 8.48
Max value per head ($/hd) (increase)	$ 2.82	$ 0.56	$ 10.91

[11] Expressed as 2% increase on current LMY levels, not as a portion of 100% meat. Note that single trait selection is not commercially realistic, and rate of Maximum Benefit stated here is reduced to Potential Benefit through multi train selection and accuracy levels, and then to Likely Benefit through adoption rates.

3.1.5 Eating quality assumptions

The value of eating quality increase is based on the benefits achieved over and above the MSA grading system. For Scenario 1a, it is anticipated eating quality will only increase slightly. Eating quality value opportunity has not been factored as the scenario is about maintaining eating quality.

3.1.6 Beef Value Proposition

The rate of genetic increase in LMY that could be achieved across the Australian herd can increase at a much faster rate than currently occurs. The following numbers are based on live animal OM measurements.

Maximum Benefit - is estimated at $225 million (per annum gross benefit)

This is based on the genetic rate of gain that is practically possible without limitation from measurement accuracy and information transfer.

Potential Benefit - reduces to $61 million based on the industry supply chain’s ability to measure (accuracy) and drive change.

Likely Benefit – further reduces to $8.18 million by 2045 when implementing objective measurements and associated pricing signals. This represents about 13% of potential benefit by 2045 based on assumed adoption rates and information transfer.

The opportunity for genetic gain achieved by testing animals for EQ and LMY at point of sale has been limited to animals sold through online auction or sale yard pathways, hence the 34% adoption rate demonstrated in Figure 1. Benefits achieved through this scenario is through increasing the availability of information to make more informed purchasing decisions, such as for animals sold through sale yards and electronic auctions.

Genetic gain already included in the previous carcase based OM report reflects an increase in LMY through genetic gain only, and over the longer-term generation interval. Measurement in the live animal enables enhanced decision-making on the specific animals being measured. This additional benefit is addressed in scenario 7.

3.1.6.1 Accuracy of technology systems

LMY technologies to predict LMY% in beef carcases can range from simple regression models that predict yield to state-of-the-art computer tomography (CT) scanners[6]. Accuracy of these technologies will vary, most likely in accordance with the investment. At present only a few of these technologies are available for commercial installation.

Technology options either currently available or likely in future include:

Current

- Yield equations utilising current grading traits
- Ultrasound
- Video Image Analysis (VIA)
- Dual Energy X-ray Absorptiometry (DEXA)

Future

- Computer Axial Tomography (CT)
- RGBD technology (Wii cameras)
- Microwave driver technologies

The lack of technology means less accurate proxies for LMY are the only option. With these current measures, accuracy is assumed as 40 % for live animal OM technologies.

Beef Eating Quality measurement using Australia's unique beef grading scheme, Meat Standards Australia (MSA), can predict eating quality of a cooked meal outcome for individual cuts in the carcase. The inputs used for the MSA prediction model are collated or measured on the carcase at grading. Studies have shown that the MSA grading model correctly classifies between 50 and 70% of the samples into their correct grade[12]. This is an order of accuracy greater than is possible by just using other carcase grading systems. Other systems available to measure eating quality include the TenderTec Probe, colorimeters, Beef Cam, slice shear force tests and NIR but all have been found to have limitations.

It is assumed that new OM technologies will increase accuracy of eating quality measurements and thus increase genetic selection for this trait. However, existing subjective based MSA measures are assumed until 2030, given that OM technologies for measuring eating quality are too far from commercialisation. It is assumed that OM technologies for EQ measurement will be commercially available after 2030, including an increased accuracy leading to increased value through improved customer satisfaction.

The accuracy of the technology will impact on the benefit per head included within this Scenario, as can be seen in Table 8 below. The accuracy assumed from current LMY prediction equations is optimistically for live animal OM technologies 40%, which equates to a gross benefit of $2.94/hd for cattle.

Table 8: Benefit per head for different accuracies as at 2032-33, Scenario 1, beef

System Accuracy	20 % (Sub-Optimal)	40 % (Projected)	60 % (Optimal)
Benefit $/hd	$ 1.47	$ 2.94	$ 4.41

3.1.6.2 Live animal adoption curve

The net benefit ($/year) line shown on Figure 1 reflects industry adoption rates and net benefit of live animal OM technologies. The per head benefit resulting from an increased LMY at a constant EQ has been multiplied by the number of head this scenario applies to. Note the net benefit is first recorded in the evaluation model for the year 2025-2026 which allows for development of the technology.

[12] Watson R, Polkinghorne R, Thompson J (2008). Development of the Meat Standards Australia (MSA) prediction model for beef palatability. *Australian Journal of Experimental Agriculture,* (48), p 1368-1379.

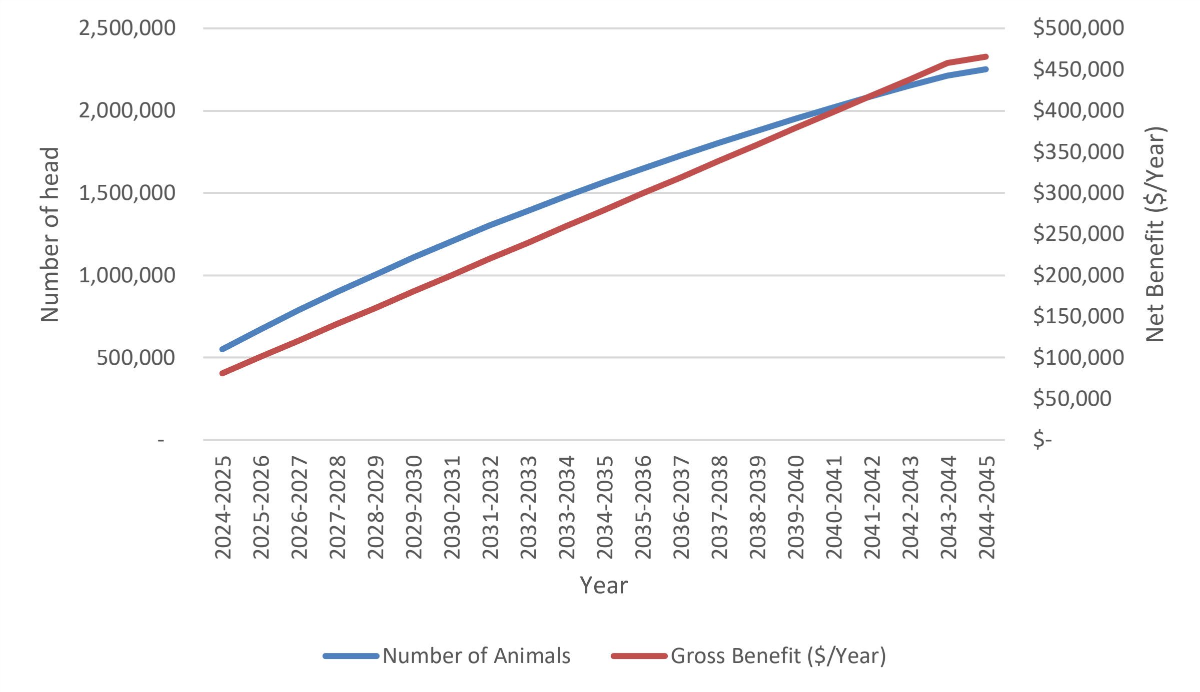

Figure 1: Beef adoption rates and net benefit achieved by Scenario 1a.

In Figure 1, as adoption rates increase over time, there is a slight increase in the net benefit per head (the lines converge around the year 2037). This is because the OM measurement accuracy and genetic selection process used to increase average LMY and eating quality is expected to become more accurate.

3.1.7 Lamb value proposition

Only limited genetic increase in LMY has occurred in the Australian flock but could increase at a much faster rate. The opportunity assumes that:

- Improvement in LMY will occur at a rate that allows current IMF levels to be maintained.
- The likely benefit has only been applied to the portion of animals sold through saleyards as this generates increased benefit in genetic gain over above the previous project.

No eating quality benefits have been included due to the following:

- Industry consultation confirmed that the EQ in lamb is at a good standard and requires a focus on maintaining, rather than increase EQ
- There are currently no pricing mechanisms in the sheep industry that support a further increase in value for an increasing EQ. Given high lamb prices are continuing to increase, it is unlikely a further premium would be achievable for an already consistent product

<u>Maximum Benefit</u> - is estimated at $72 million

<u>Potential Benefit</u> - reduces to $21 million based on the industry supply chain’s ability to measure (accuracy) and drive change.

Likely Benefit – reduces to $3.84 million assuming adoption rates and information transfer of about 18% of potential benefit by 2045 based on implementing objective measurements and associated pricing signals.

The maximum benefit could be achieved through either live animal or carcase objective measurements and is the same maximums benefit achievable in both instances. The potential benefit considers the accuracies of the system used, thus the live animal and carcases based objective measurement values will vary due to different levels of accuracy and finally the likely benefit is a benefit per head achieved through the adoption of the technologies.

3.1.7.1 Accuracy of technology systems

The accuracy of the technology will impact on the benefit per head included within this scenario, as can be seen in Table 9 below.

DEXA measures of LMY have already been commercialised to an accuracy of R2 >0.8 for lamb carcases. The key difference is that live animal measurement systems will have lower accuracies as discussed previously in Scenario 1.a) for beef livestock.

The likely accuracy of live animal measurement systems is 40% and delivers a potential gross benefit of $0.34/hd.

Table 9: Projected benefits for varying system accuracies as at 2032-33, Scenario 1, sheep

System Accuracy	20 % (Sub-Optimal)	40 % (Projected)	60 % (Optimal)
Net benefit $/hd/per year	$ 0.17	$ 0.34	$ 0.51

3.1.7.2 Adoption curve for live animal OM

The adoption of technology at point of sale is considered important to enable value-based marketing. As can be seen in Figure 2, the adoption of the technology is expected to occur rapidly once it becomes available to support value based marketing. It has been assumed that the live animal measurements are taken at point of sale either through, sale yards of electronic auctions, which in both instances will be completed by a third party.

It was anticipated at the time of writing that there would be a lamb EQ tool available in 2023. Adoption rates for both LMY and EQ reflect commercial availability of EQ measures in 2-3 years allowing for industry confidence in new objective measurements.

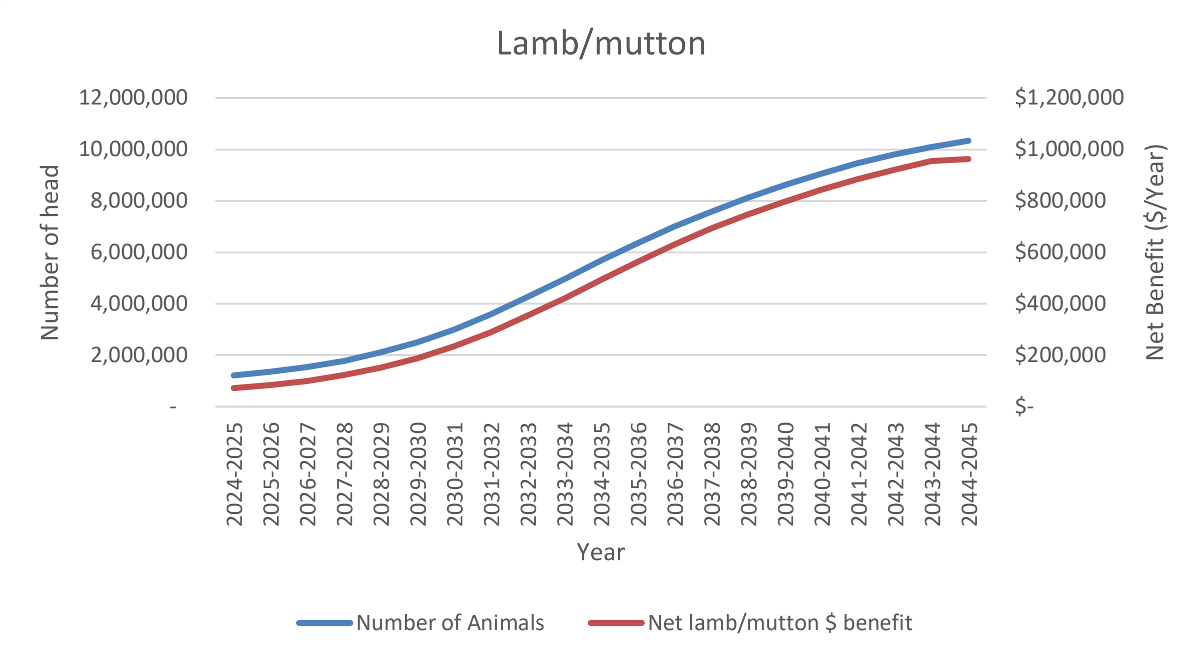

Figure 2: Lamb and Mutton adoption rates and net benefit achieved through Scenario 1b.

*** Note that benefit per head is constant, so gross benefit increases with the number of head*

3.1.8 Industry application considerations

Change of payment processes from the current livestock cost averaging to value-based pricing and value-based marketing transactions will be required to obtain the greatest increase in value. However, it will take several years to realise the potential benefit from increasing the average lean meat yield. This will be enabled by:

- Gathering data to provide detailed feedback to producers on livestock performance
- Providing pricing incentives to producers so they take advantage of the data (i.e. higher $/kg, higher producer booking priority

For Beef:

- The challenge (and focus) will be establishing an effective for aligning payment of LMY to customer value that integrates with a functioning EQ system
- Pre-slaughter attributes like breed, marbling, growth rate (proxy for age) are already available in EBV's that producers select for and are paid for via MSA grade. Measurement pre-slaughter is unlikely to increase selection pressure or enable interventions to improve resultant EQ grade in this scenario for Northern cattle that are not already available.

For Lamb:

- The biggest impact on genetic improvement in both LMY and IMF will be made by increased selection pressure for the right genetics, driven by value-based transactions at processing.
- Measurement of commercial lambs to drive decision making will be minimal as the value in decision making rests at genetic selection.

- There is potential to increase processor-based selection/pricing for live animal measures of LMY and IMF, but this is about marketing higher value livestock at POS than about genetic selection pressure. This is considered more in scenario 6.
- Seedstock measurement of LMY and IMF is currently being done but there is no selection pressure on LMY increases from their customers (commercial producers). As a result, increases in genetic potential for LMY are limited in favour of other traits.
- Measurement at processing is required to value differences to support value-based transactions.
- If genomic tests become cost effective, commercial producers could identify ram sires that should be replaced for herd improvement without requiring individual sheep identification[13].

[13] Personal communication who with???

3.2 Scenario 2 - Genetic trait selection for increased LMY & reduced dark cutters (northern beef)

3.2.1 Description

- As in Scenario 1, Scenario 2 involves an improvement in genetic selection to increase lean meat yield balanced with meat colour (MC).
- This scenario is applied to 30% of beef production. This percentage covers cattle produced in northern pastural regions. The conditions these cattle are exposed to make it difficult to increase LMY without sacrificing MC.
- A negative correlation between LMY and MC means great care must be taken not to drive strong gains in LMY at the expense of MC.
- Dark-cutting meat imposes a significant discount on beef carcases. The Beef CRC estimated that dark cutting costs Australian beef producers in excess of $35 million annually[2]. Objective measures of meat colour support selection for improved meat colour but also consider the value of early identification of at-risk livestock prior to shipment and sale, reducing incidence and lost value.
- By gaining access to genetic selection data, producers will be able to select bulls with the appropriate genetics to balance meat colour with a higher LMY.

3.2.2 Traits included

The traits measured in this scenario are summarised here in Table 10.

Table 10: LMY and Meat Colour/pH descriptions and maximum benefits

Lean meat yield	
Value Proposition	Increasing the lean meat yield of carcases will increase the proportion of lean-to fat, increasing the effectiveness of live animal input costs and reducing trimming of waste in the carcase, resulting in higher returns. A maximum genetic gain in LMY is expected to be 2% per generation (personal communication).

Meat colour/pH	
Value Proposition	Improving meat colour (MC) will increase the value of meat processed, the processing and production sectors would both benefit. MC is affected by genetics, feeding and other on-farm management practices prior to slaughter, sudden changes in air temperature and pre-slaughter stresses such as transport and handling as well as carcase chilling[10]. Current measurement post slaughter does nothing to reduce the incidence of poor meat colour. Given many variables impact MC, measurement prior to slaughter that allowed intervention would have the largest impact. BACKGROUND: Ultimate pH is one of the important factors that impact on changes in meat colour in beef. High pH meat is often associated with darker meat and is often referred to as 'dark firm and dry' or DFD meat. Such carcases are heavily discounted in the marketplace.

3.2.3 Value created

The rate of genetic increase in LMY that could be achieved across this portion of the Australian beef herd can increase at a much faster rate than currently occurs. It is also assumed that a measure for pH_u can be used to prevent reduction in eating quality.

Given this scenario is about maintaining EQ, not increasing it, LMY increase is the only source of value creation in this scenario.

Maximum combined benefit - is estimated at $104 million (per annum gross benefit). This is based on the genetic rate of gain that is physically possible without limitation from measurement accuracy and information transfer.

Total Potential Benefit - reduces to $11 million based on the industry supply chains ability to measure (accuracy) and drive change.

Total Likely Benefit - estimated at $3.07 million in per annum gross benefit or 27% of potential benefit by 2045 based on assumed adoption rates and information transfer.

3.2.3.1 Measurement method and location

Meat colour and pH - Management techniques for reducing the incidence of dark cutters are known but they are not highly correlated to achieving desired meat colour. Furthermore, recent studies have shown that the relationship between meat colour scores at grading and later at retail display is poor at best. As a result, there is some question across industry whether meat colour at grading is a useful trait for inclusion in the beef language.

The MSA grading system has moved from meat colour to pH level as a more accurate predictor of retail value. Like with meat colour, many variables between live animal measurement and retail POS influence final pH results. Considering measurement in the live animal introduces additional variables that further reduce the predictive capability for pH_u[14] meat colour at carcase grading and retail display, technology is this area is well underway in the development process.

Lean Meat Yield - The hardware to create value increase from Scenario 2 has already been installed in one northern plant for carcase-based OM. It is currently being commissioned to start sharing OM feedback to producers. This will begin the identification of value opportunities along the supply chain.

Measurement location considers the OM application location (genotypic and phenotypic variation).

- A pre-slaughter measure of stress could estimate risk of poor meat colour and could allow ‘at risk’ animals to be held back from shipment or slaughter. Producers with flexibility to draft multiple directions may do this but many do not even have scales so this reduces adoption rates. An objective measure is unlikely in the short-term and has not been included in the model as a benefit in 2025. It has been assumed that live animal measurements would be available by 2045 with adoption rates at 35% of the production sector.
- Seedstock selection genetically for meat colour is possible but only contributes a small amount to variation relative to environmental factors[2]

[14] Ultimate pH post rigor.

- Measurements and pricing incentives are already in place in the processing sector to pay for improved meat colour.

3.2.4 Accuracy of systems/Likely Benefit

Because of adoption rates, the benefit per head can only be attributed to those animals which are affected. Given that an accuracy of 40 % is projected onto whatever system is implemented, that benefit per head is $2.87. Despite these low adoption rates, it is also projected that once the first adopters have proven the concept to the rest of the industry, adoption rates will rise steadily and continuously.

Table 11: Benefits relating to varying system accuracy projections as at 2024-25, Scenario 2

System Accuracy	20 % (Sub-Optimal)	40 % (Projected)	60 % (Optimal)
Benefit $/hd	$ 1.44	$ 2.87	$ 4.31

3.2.5 Adoption curve

This scenario is most relevant to producers in extensive northern regions. Genetic selection is still a viable and effective improvement strategy by itself. But introduction of value-based payment or marketing methods will drive some that have options for both live export and boxed markets to focus on live export which this scenario does not benefit. The point here is that alternative commodity markets will limit the adoption of VBP and therefore improvement in Lean meat yield (productivity) addressed in this scenario.

As in Figure *3* below, adoption will be low, on the order of hundreds of thousands, rather than millions as with other scenarios, due to a relatively low number of northern cattle sold through saleyards annually. And, with the initial focus on live export, the net benefit will also be lower. As technology is adopted, the genetic increases will filter through the national herd and total benefits will increase.

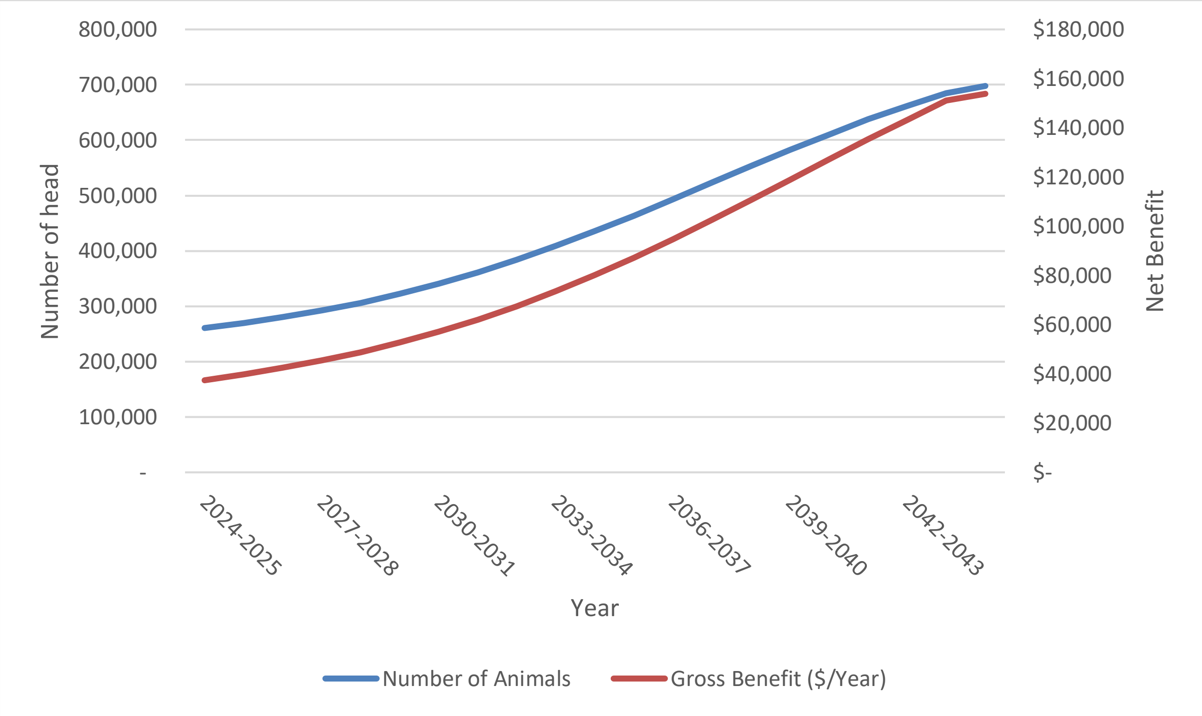

Figure 3: Number of animals and benefit associated with an increase LMY and reduction in the level of dark cutters in the northern beef herd.

3.2.6 Limitations and important assumptions

Adoption Considerations - to facilitate industry transition include:

- Feedback signals will be required to inform producers about new LMY pricing signals
- Extension activities will be required with producers including metrics to improve LMY and how selection for LMY can be done in conjunction with pH and dark cutting management

The opportunity is not being realised by industry. A number of reasons for this include:

- LMY assumptions discussed previously in Benefit Scenario 1 also apply here.
- A negative correlation between yield and quality of 20% has been assumed which is reflected as a reduction in the rate of LMY increase while meat colour is maintained. This has not been accounted for in the model.

Meat Colour:

- Value of Meat Colour has an impact of $50/head with an incidence rate of 8.1%[15] giving an average cost per head processed of $4.17. It is assumed that technology interventions to improve meat colour would reduce incidence by 8% of the existing incident rate per annum.

- Measurement accuracy is greatest post-slaughter but due to a wide range of live animal variables, a lot of effort is required to understand the interactions to change future supply based on information. Recent research from Murdoch University (project B.SBP.0110) has done a lot to understand these variables and points to inaccuracies in current measurements which could be overcome by new technologies.

[15] Jose C, McGilchrist P, Perovic J, Gardner G, Pethick D, (2015). The economic impact of dark cutting beef in Australia. *61st International Congress of Meat Science and Technology*. Clermont-Ferrand, France.

3.3 Scenario 6 – Customer specification driven purchase and processing allocation decisions to maximise carcase sale value

3.3.1 Description

- Increasing primal cut value through more accurate description and alignment of live animals to end customer specifications with improved carcase utilisation. This will drive the management of traits associated with customer specifications rather than less accurate current descriptors.
- Objective measures that enable more accurate processor purchase pricing decisions and support boning schedules to extract increased value from carcases will enable better producer decision making on which sales channel to operate in, aligning with processor markets.
- The higher the technology accuracy, the better live animals will translate to in-specification carcases. This will drive the ability to sort animals more accurately pre-sale to align with customer specifications. The accuracy of LMY live-animal assessment will impact the ability of processors to purchase animals that specifically meet their customer specifications.
- This will enable producers to utilise VBM to choose where to sell their animals, departing from commodity-based livestock cost averaging.
- Objective measures for LMY and EQ will enable more accurate purchase pricing decisions linking to alternative boning specifications and production schedules. Improved boning allocation will also help increase carcase utilisation within the markets they are supplying to, thus enabling processors to extract increased value from carcases, emulating ideal sales pricing scenarios

3.3.2 Traits included

LMY technologies used to predict the optimum cut breakdown and allocation to markets based on saleable meat yield, relative to consumer willingness to pay, will increase the value received by the supply chain for the finished product.

The traits measured and their individual maximum benefit are summarised here in Table 12 and in Figure 4.

Table 12: LMY and EQ descriptions and maximum benefits

Enhanced Make/Sell decisions	
Value Proposition	Lean Meat Yield used to describe and quantify animal quality. Variable inaccuracy in SMY prediction means some carcases are not boned to optimum market specifications. The benefit here is increase in average carcase purchase, and therefore sales, value. Allows more accurate purchase pricing decisions linking to alternative boning make schedules, which make sales pricing more valuable.

Scenario 6 differs from previous discussions of Scenario 6 by aligning carcase processing to customer specifications pre-point of sale/purchase (live animal in Figure 4), rather than post-sale (carcase in the right side of the figure).

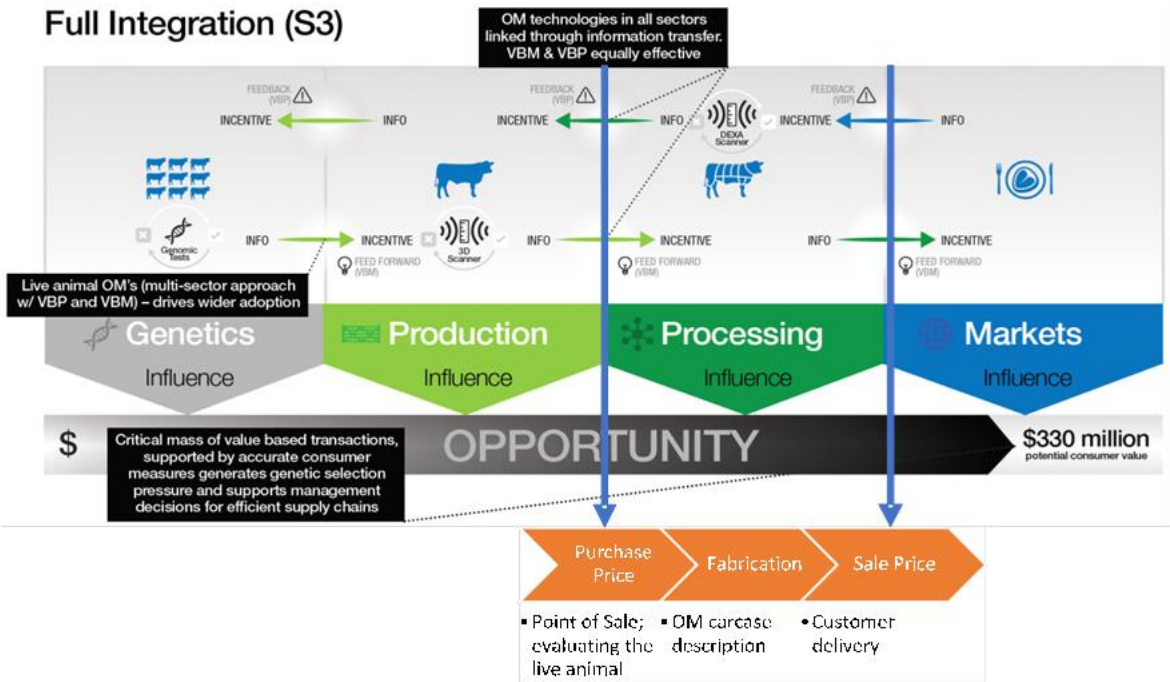

Figure 4: Value Chain and points of Purchase, Fabrication and Sale

3.3.3 Beef value proposition

<u>Value of buy/make/sell</u> improvement is based on a carcase value of $5.60 per kilogram. The livestock cost price has been used rather than a sales price. The assumption is that a 1% increase in total carcase yield will result from improved allocation of cuts to markets.

- This is not the way the market prices, but to cost out the market opportunity, it is the simplest given the wide variation in markets, customer specifications and product availability
- In-plant trials undertaken in unrelated work indicates larger opportunities, so this figure is considered conservative

<u>Maximum benefit</u> - is estimated at $154 million (per annum gross benefit). This value was developed in the previous report detailing benefits from OM for carcase traits. The carcase trait report then quantified a subset of this maximum value that could be achieved through carcase-based OM technologies. This report now considers what additional potential value could be realised with live-animal OM that is not already considered.

<u>Potential Benefit</u> - reduces to $86M based on the industry supply chains ability to measure (accuracy) and drive change.

<u>Total Likely Benefit</u> - estimated at $66 million in per annum benefit or 77% of potential benefit by 2045 based on assumed adoption rates and information transfer. This assumes that live animal carcase measurements are used not carcase-based OM. The attribution of these numbers is covered in section 4.

3.3.4 Lamb value proposition

<u>Maximum benefit</u> - is estimated at $64 million (per annum gross benefit).

Value of buy/make/sell improvement was estimated at $0.12 per kilogram on 16 kilograms of saleable meat per carcase.

Potential Benefit - reduces to $39M based on the industry supply chains ability to measure (accuracy) and drive change.

Total Likely Benefit - estimated at $32 million in per annum benefit or 82% of potential benefit by 2045 based on assumed adoption rates and information transfer. This assumes that live animal carcase measurements are always used instead of carcase-based OM. The attribution of these numbers is covered in section 4.

3.3.4.1 Accuracy of systems / Likely Benefit

A 40 % projected accuracy of an objective technology has been assumed in Table 13 and Table 17 for beef and lamb and is a marked improvement over what is available now. This goes some way to improving market alignment between processors and producers, but it will not always be the optimal decision compared with current historical data. Accuracy and confidence in the measures relative to current systems will have an impact on adoption.

Table 13: Beef increases per head as at 2024-25

System Accuracy	20 % (Sub-Optimal)	40 % (Projected)	60 % (Optimal)
Benefit $/hd	$ 4.43	$ 8.74	$ 12.94

Table 14: Lamb increases per head as at 2024-25

System Accuracy	20 % (Sub-Optimal)	40 % (Projected)	60 % (Optimal)
Benefit $/hd	$ 1.05	$ 1.22	$ 1.54

3.3.4.2 Adoption curve

Because, primarily, this affects the point of sale of live animals limiting the number of animals can be brought into the value stream. The projected benefits below (per head) are for this limited adoption. This increase was not included in the assumptions as a number of other factors towards supply alliances are driving sales channels in the opposite direction.

3.3.5 Assumptions

Processors are adopting technology to better optimise the breakdown of carcases, however the technology needs to improve the maximus the value created. This has been due in part to inability to measure and differentiate carcase composition to the level required. These systems require good mass balance of product through the boning room, accurate yield standards and ability to measure performance to standards. Other more significant opportunities have needed to be addressed.

- As measurement technologies become available and are integrated into company systems, the opportunities in this scenario will become more achievable.

The key value of Scenario 6 for processors is centred around improved decision-making, informing the selection of each animal through prediction of how it will be fabricated as a carcase and allocated to the market they are optimised for.

Genetic increase in LMY in Benefit scenario 1 provides some value to the whole chain however this scenario focuses on enabling processors to realise the maximum value of existing carcases through better market alignment.

It is important to note that mixing of animals' pre-sale can have adverse effects upon EQ and dark cutter traits in the carcase. So, there will be limited ability to pre-sort and group different animal lots.

Improvement in processing related costs could be achieved as a secondary yet significant benefit from installation of OM technologies for pre-slaughter assessment scenarios. Depending on OM system accuracy and adoption of decision support and processing aids, the likely industry benefits will be much less than the maximum opportunity. The assumptions used to underpin the maximum value opportunity were validated in the original report

3.4 Scenario 7 - Enhanced on-farm decision making to better manage live animal impact on yield

3.4.1 Description

- Adoption of OM technology to select and manage animals for an increase in LMY whilst On-Farm that will maximise SMY at point of sale.
- This scenario captures benefits summarised in **Error! Reference source not found.** and enables livestock managers to:
  - Sell existing livestock to a different market – By reporting measurement outcomes at point of sale will help maximise value of increased SMY and better alignment to market specifications to support productivity improvement on farm.
  - Sell earlier or later – by measuring animals at different points throughout their life, allowing enhanced management of inputs and growth patterns.
- This scenario only includes an increase in value for existing animals by changing their SMY, reducing input costs, or aligning them to more appropriate markets as a result of more timely objective information. Creation of value is driven within the current population and excludes any genetic improvement as that value is captured in other scenarios.
- There will be some benefit from more timely feedback for genetic selection and increased response per generation, but this has not been considered to avoid duplication included in other benefit scenarios.

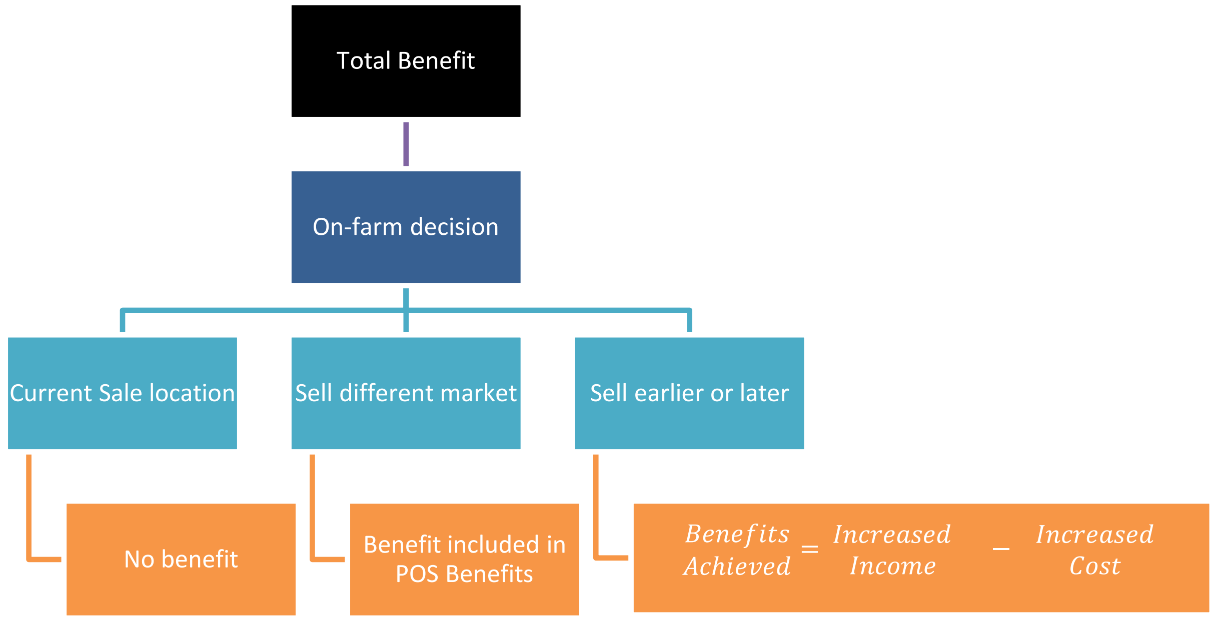

Figure 5: Decision-making, informed by the fallout of Scenario 7, sheep

Benefits in these scenario categories may come about through the introduction of new information, new technology or new processes.

3.4.2 Traits included

LMY (Lean Meat Yield) and HSCW (Hot Standard Carcase Weight) are measured to determine SMY (Saleable Meat Yield).

3.4.2.1 Measurement Accuracies for LMY, by system

Technical papers produced for the Beef Language White Paper noted that technologies to predict LMY in beef carcases can range from simple regression models to state-of-the-art computer tomography (CT) scanners. Accuracy of these technologies vary, most likely in accordance with the investment. There should be an option for processors to state what the accuracy of their yield prediction technology is.

Technology options include:

- Yield equations utilising current grading traits
- Ultrasound2
- Video Image Analysis (VIA)
- Dual Energy X-ray Absorptiometry (DEXA)
- Computer Axial Tomography (CT)
- RGBD technology (Wii cameras)
- Calculating LMY with relative accuracies

As shown in Table 15 below, accuracy varies between systems. The CT Scan is the gold standard while LMY prediction equations are approximations based on a number of indirect measures. As accuracy improves, the confidence of decisions improves. The selection of method for calculating LMY comes down to a trade-off between system costs and the level of accuracy necessary to achieve the desired outcome.

Table 15: Relative accuracy of LMY calculation methods (Obtained from P.PSH.0417)

System	R^2
Equation 1	0.19
VIAScan	0.49
DEXA	0.8
CT Scan	0.95

Equation 1[16]

$$LMY = 68.22 - 0.394 * Fat\ Depth + 0.102 * Eye\ Muscle\ Area$$

[16] Source ????

3.4.3 Beef

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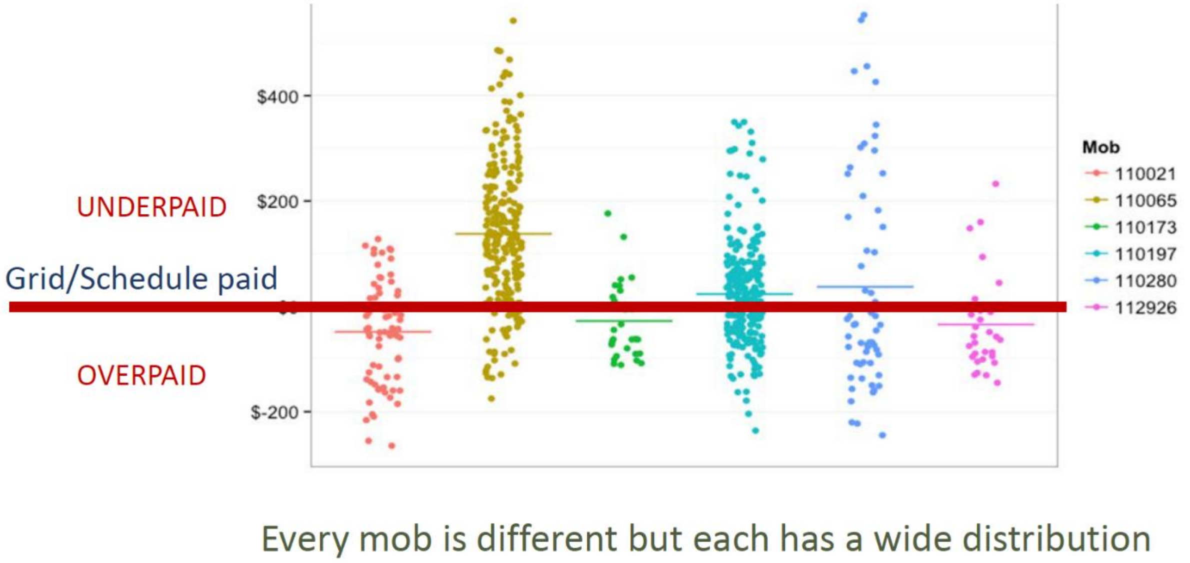

Figure 6: Variation in mobs of cattle and impact of the lost value through paying across a standard carcase grid[17]

The costing model in this project required baseline data to estimate the maximum benefit opportunity for industry. An MSA data set for one processing specification had the required data to make these calculations and showed producer compliance to target specification. The size of the dataset was considered representative of the entire industry for the purpose of this activity. Change in production outputs and market value was then calculated based on value impact that live animal OM could have on better alignment of livestock to markets.

Assumptions on industries magnitude of change and likely adoption rates were considered and are discussed below.

3.4.3.1 HSCW

Animal weights currently drive transfer price between sectors. Other measures, such as Animal health, average daily gain (ADG) and feed conversion all impact the weight of animals. The following are a list of factors which impact producers' ability to weigh animals and utilise the information for change management practices for optimum value:

- Environmental conditions and market conditions makes producers sell before OM data would suggest is good timing. Wet season response sees producers make use of available forage to grow animals beyond OM data recommendations
- Natural variance within a livestock cohort reduces value if sold together due to market misalignment. Value loss can be reduced by reducing population variation or drafting population subsets. However, inability or cost to weigh and draft multiple times, may limit return on investment and on adoption.
- Turnoff time can be moved increase rate of compliance. Increased value would offset labour increases from more intensive management but would still limit adoption.

[17] Source: Teys Australia (needs a better citation)

- There is potential to incorporate walk-over-weigh stations with body composition measurement will enable closer management of animal turnoff, reduce labour costs and avoid animal stress.

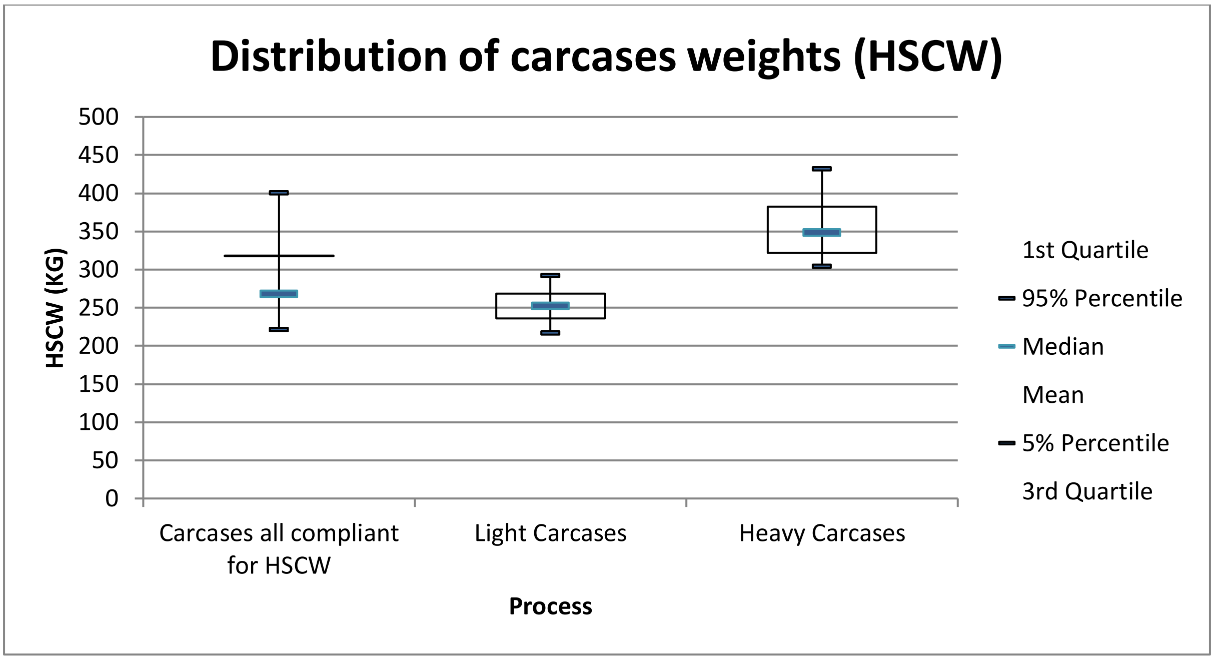

Figure 7: Distribution of non-compliant cost to HSCW for animals' complaint for current HCSW grids, animals discounted for being light and animals discounted for being heavy.

The separation of animals in Figure 14, into compliant, light and heavy carcasses has been used to demonstrate the proportion of animals which could have been weight-managed to better meet market specifications.

The target weight range was 260-300kg. Variance from target weight was calculated as either under-weight (Light Carcases) or over-weight (Heavy Carcases). A histogram of non-compliant animals within the data set is shown in Figure 8. The change in turnoff weights for both these groups to become compliant is captured in the two populations in the far right of Figure 7.

It has been assumed that more accurate live animal assessment of LMY in conjunction with HSCW would increase the overall value of beef produced in Australia. The net benefit of growing out Light Carcases and of selling Heavy Carcases earlier to meet weight compliance was calculated and is discussed in the section on value created.

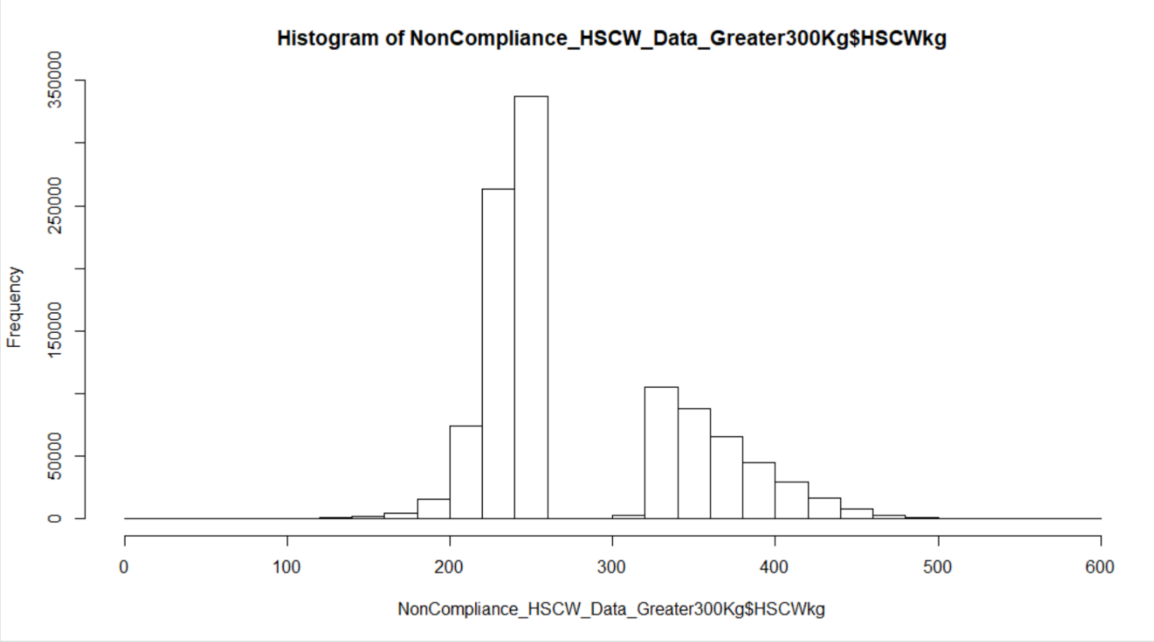

Figure 8: Graphing Non-Compliant animal distribution vs. Weight for Beef

3.4.3.2 LMY and SMY

Lean meat yield distribution in beef has been calculated using Equation 1 (discussed earlier) and applied to the MSA data set. The distribution of LMY for animals in the following 4 categories are displayed in Figure 9:

1. All animals within the MSA dataset used to complete the analysis
2. Animals compliant for HSCW
3. Animals non-compliant for HSCW and lighter than 260kg
4. Animals non-compliant for HSCW and heavier than 300kg
5. *JT comment: Mean not shown in legend*

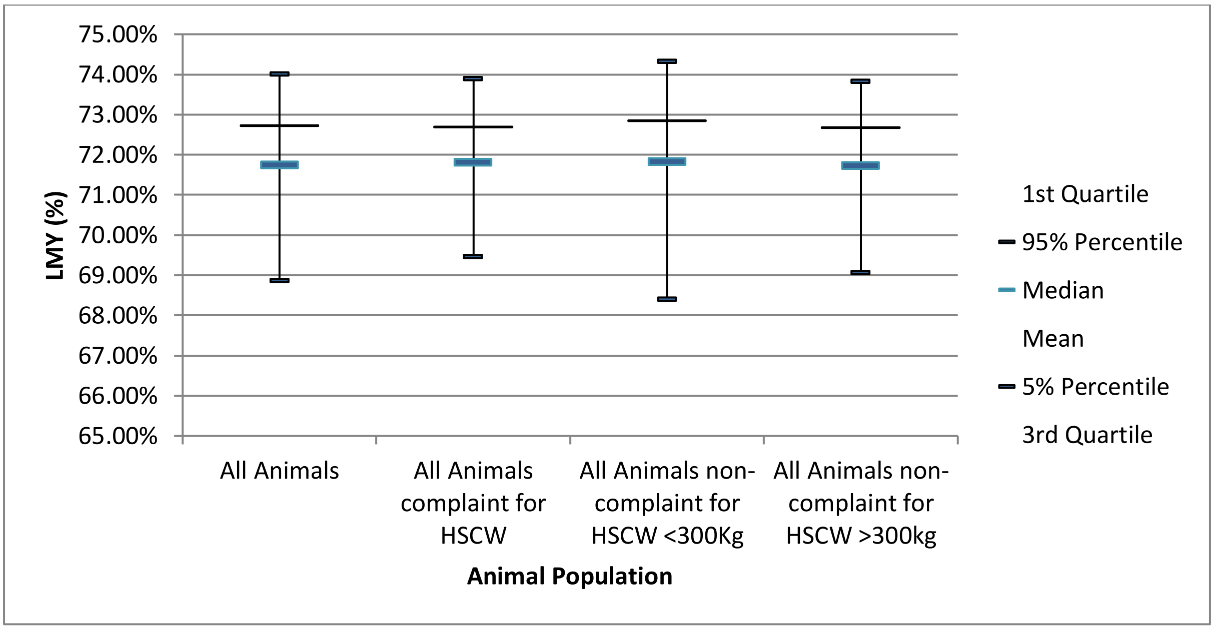

Figure 9: Distribution of LMY % in the current cattle population processed within the MSA program, this has been calculated using equation 1.

OM looks at the value to be gained from a more individual analysis of each animal to increase value by managing SMY throughout the animal's growth trajectory to meet market specifications at sale. Saleable meat yield was calculated using the following calculation:

$$SMY = HSCW * LMY$$

Saleable meat yield was then calculated to determine the increase in value of meat sold through interventions from the baseline population. Figure 10 shows the distributions of 1) animals within the current ideal weight range, 2) animals that are currently discounted from being too light and 3) animals which are heavier than ideal. These three groups of animals have been used to calculate the financial opportunity. Changes in volume of meat sold have been calculated by shifting the mean of light animals to the same mean as animals currently compliant for HSCW and decreasing the distribution of heavy animals. Benefits have then been calculated by considering the change in meat value and costs of making the changes.

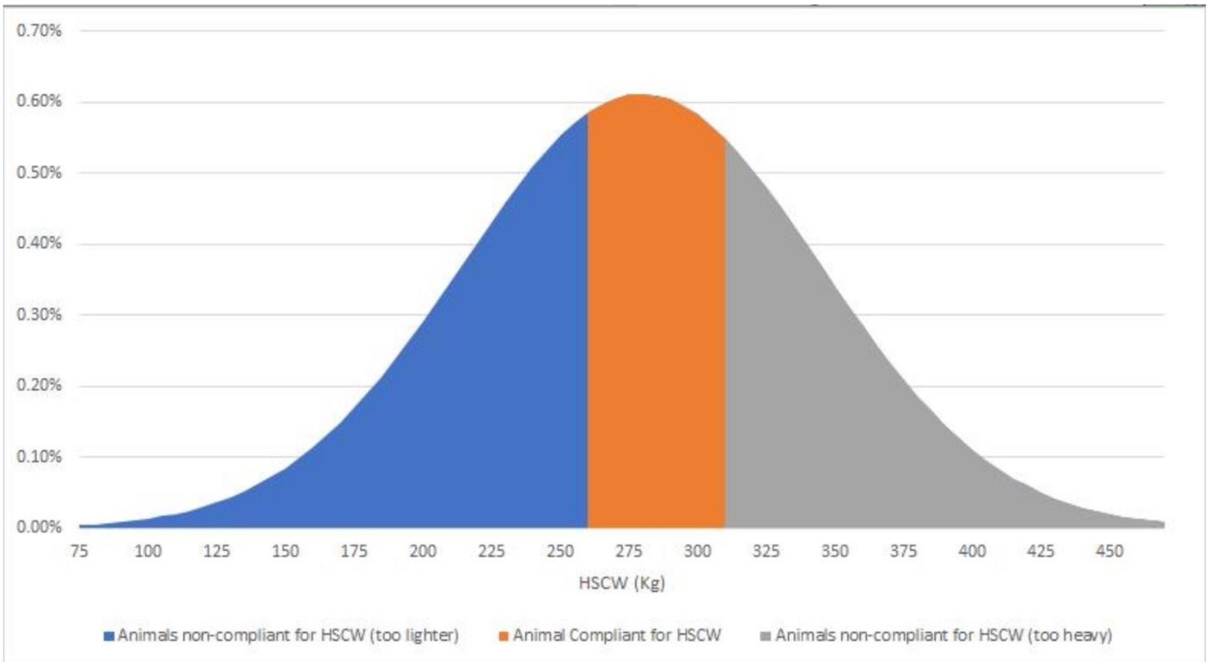

Figure 10: Distributions of Light to Heavy animals, accounting for SMY, by population percentage

3.4.3.3 Value created

The benefits associated with increasing or decreasing the SMY of the population of animals shown in Figure 10 are shown in Table 16. The calculations shown in this table are as follows:

- Light animals will have a 11.18kg increase and heavy cattle will have a 57.6kg reduction in SMY to meet target HSCW specification.
- The sales value of SMY has been assumed at $5.70/kg to value change in carcase weight. The increase in weight gain for light animals to meet specification is a $63.74 increase in value. Heavy animals reduce weight by being sold earlier which equates to a $328.3 decrease in value for heavy animals.
- There is an additional gain by eliminating the discount for being out of specification. The average cost of discounts saved on light animals is $33.08 and $84.40 on heavy animals.

- The gross benefit for changing carcase weight is $96.83 for light animals that increase weight. There is a significant loss in value for heavy animals that are sold earlier of $243.50 ($84.80-$328.30).
- However, when considering net benefit below, both heavy and light animals receive an increase in value.
- To account for the increase or decrease in weight gain on farm, the cost of gain at $5.36/kg SMY has been removed from the gross benefits. Understandably these costs and the ability for producers to increase growth of animals will be affected by seasonality and each production system.
    - The additional costs for the light animals are $59.95/hd, giving a net benefit of $36.88.
    - For heavy animals there is a reduction in feed costs of -$308.7/hd. Heavy animals still have a net increase in value after considering feed costs. But the $84.80 discount makes it a net loss to grow heavier out-of-spec animals, giving a net benefit on reducing the weight of heavy animals by $65.20/hd based on this data set.
- Compliant livestock represented 32% of the population, while light animals and heavy animals were 46% and 21% respectively. This breakdown was based off 1,500,000 cattle processed through the dataset. These distributions were assumed as representative across the 9.2 million head of cattle processed in Australia annually.
- These assumptions result in a total benefit of $370.3 Million annually shown in Table 16 when applied across the population, or $16.06/hd on average.

Table 16: Table of Maximum potential benefits from Scenario 7, beef

Changing turnoff weight On-farm to better match markets				
	Benefit from increase weight on farm for light animals		Benefit through reducing weight of heavy animals on-farm	
Weight variation prior to slaughter		11.18	-	57.59
Reduced cost of discounts	$	33.08	$	84.8
Increase carcase value	$	63.74	-$	328.3
Opportunity cost by variation in carcase weight	**$**	**96.83**	**-$**	**243.5**
Cost of increase weight gain	**$**	**59.95**	**-$**	**308.7**
Net benefit per head	**$**	**36.88**	**$**	**65.2**
Benefit per hd processed	$	25.27	$	14.9
Benefit per kg	$	0.13	$	0.08
Annual opportunity	$	233,180,840	$	137,146,778

Table 17: Beef value created through better alignment with carcase grids.

Scenario 7 - Beef industry benefit		
Maximum gross benefit	$	370,327,618
Potential benefit @ 40% accuracy	$	148,131,047
Average likely benefit per head	$	16.06
2024-25 Likely Gross Benefit		
Gross benefit	$	1,002,832
Adoption		0.70%
2039-40 Likely Gross Benefit		
Gross benefit	$	31,050,503
Adoption		20.10%

3.4.3.4 Assumptions

The following list of assumptions were included in the calculations for this scenario:

- Pricing assumptions
  - Average feeder price = $3.00
  - Average sale price = $5.70
  - Cost of weight gain = $5.36
  - Number of head processed = 9,226,100
- For light animals
  - An additional $96.83/ head can be gained from increasing the weight of light animals when slaughtered.
  - Cost of feed to increase these animals weight is estimated at $59.95/ head. Resulting in a net benefit of $36.88/ head. Resulting in a total benefit of $25.27/head per animal slaughtered.
- For heavy animals
  - The costs associated with reducing the weight of heavy animals on-farm is $243.50/head reducing the overall weight of the animal, minus the current deductions given on those animals ($328-$84.40). The estimated reduction in feed costs through this action is $308.70 resulting in a net benefit of $65.20/ head through an increased ROI on feed costs. Thus, the overall result is a benefit of $14.90/head slaughtered.
- Combining compliance benefits from underweight and overweight livestock provides a maximum benefit of $370 million.
  - The total potential benefit for an OM system with 40% accuracy is then $148 million, which is divided amongst 9,226,100 head of cattle, giving a benefit of $16.06/head slaughtered.
  - The adoption curve then dictates the likely benefit for industry.

3.4.3.5 Accuracy

Measurement accuracy is greatest in the carcase post-slaughter. However, current predictive measures are not much more accurate than live animal assessment. Until technologies such as DEXA with accuracies above 60% are available, location of measurement in the live-animal sector has limited impact on measurement accuracy. The likely accuracy of objective measurement technologies for live animal assessment of 40% has been used in this scenario, however the benefit per head for different accuracies are displayed in Table 18.

Table 18: Beef benefit achieved through Scenario 7 for varying accuracies

	On-Farm Decisions		
	Scenario 1 20% Accuracy	Scenario 2 40% Accuracy	Scenario 3 60% Accuracy
Magnitdue of Change	$ 8.03	$ 16.06	$ 24.08

3.4.3.6 Adoption curve

Adoption rates of OM for SMY are expected to be low at present for producers, given many don't even have scales. Adoption in this scenario links with the two benefit scenarios 1 and 2 that objectively measure LMY to all extensive beef production and require selection pressure to be placed on seedstock sector for genetic gain. There are trade-offs between the processing and production sectors that will impact on likely adoption rates in those scenarios but the same technology in those scenarios will also deliver the direct benefits for existing livestock in this scenario so is assumed to have similar adoption rates as summarised in Figure 11.

A higher percentage of processors would adopt value-based transactions (supporting benefit scenario 1 and 2) if they were able to purchase livestock with known OM results (such as on Auctions Plus) without having to initiate VB transactions themselves. Price differences would be less direct than processor-based pricing grids and would be open to market supply and demand. But this would significantly lower barriers to adoption compared with processors having to implement value-based pricing. Initially, when there are few early producer adopters, there will be little pressure from processors but an increased willingness to engage in value-based purchasing. Once adoption has increased, processors are expected to take more public approaches to value based pricing.

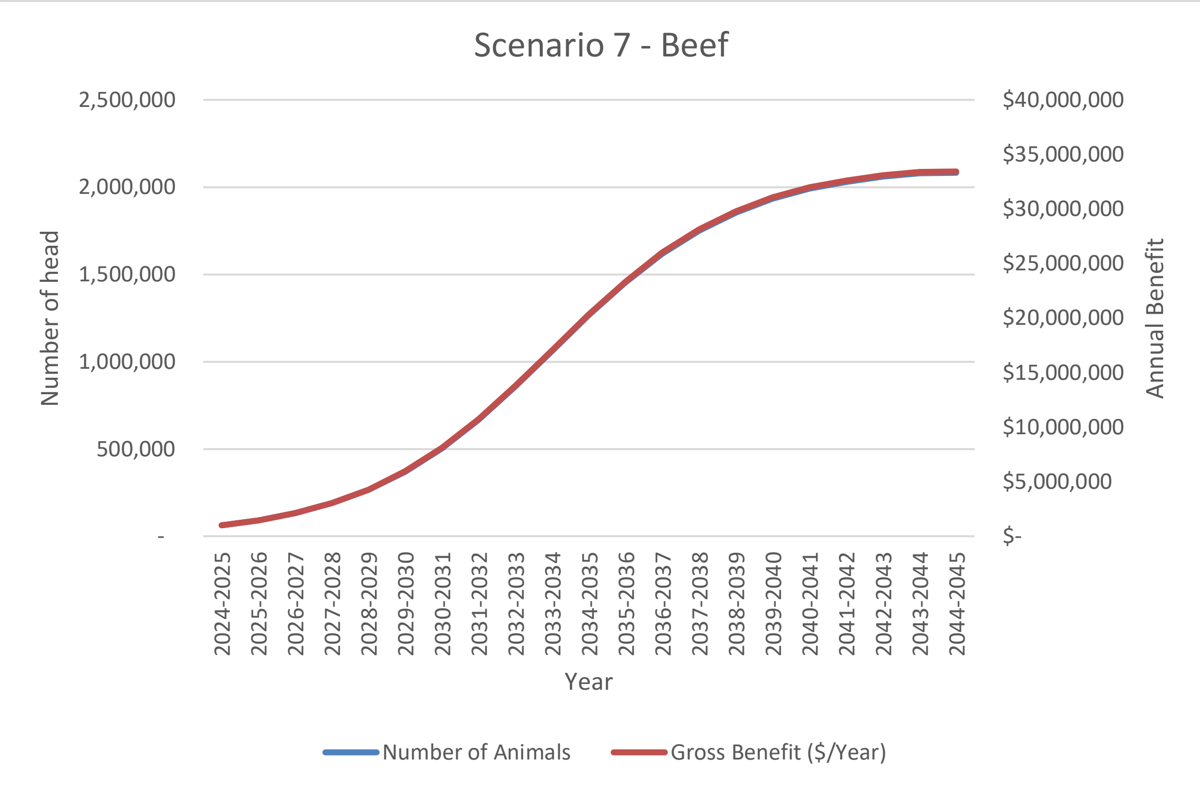

Figure 11: Adoption rate through time, for Scenario 7, beef

Key drivers of adoption in this scenario include:

- Accuracy of live-animal OM – if it is not much more accurate than visual impaction and historic producer data, processors are unlikely to use these measures to influence payment value.
- Cost Benefit ratio for a producer on cost to scan (including extra labour and support costs), relative to the increased value they will realize.
- Ease of scanning – if live animal OM was able to be administered by livestock assessors via portable OM system that is part of live animal assessment, the rate of adoption would be significantly greater.
- If OM is fixed location at a sale yard for example, adoption would be limited. A generalization is that a smaller percentage of sale yard transactions would be interested in carcase feedback and sales decisions than OTH transactions. Furthermore,
    - the variation in price received at sales is impacted more by supply and demand on the day than on objective results of carcase confirmation

  - Many livestock traded through sale yards are not destined for slaughter. The value of OM for LMY on those animals is less valuable and further diminishes value increases.

3.4.4 Sheep

LMY, HSCW and SMY are processed as demonstrated above in Section 4.7.a) Beef.

3.4.4.1 LMY

LMY percentage used for the sheep analysis was 58.6% LMY which was the CT LMY in industry previously and will be used as a standard in the calcs (obtained from P.PSH.0417). At the time of completing this report there was limited data available on LMY compliance in the sheep industry for analysis like the beef analysis in the previous section.

3.4.4.2 HSCW

There are three distributions of HSCW;

- HSCW between 20 and 30kg
- lighter that 20kgs
- greater than 30kg

The distributions of HSCW, shown in Figure 12, are based in a data set of 1.6 million animals, of which 5 % were over 30 kg, and 16 % were below 20 kg. The 16 % underweight, when brought up to ideal weight will create most of the value, whereas the 5 % overweight will cause a loss, due to the current flat pricing grid structure.

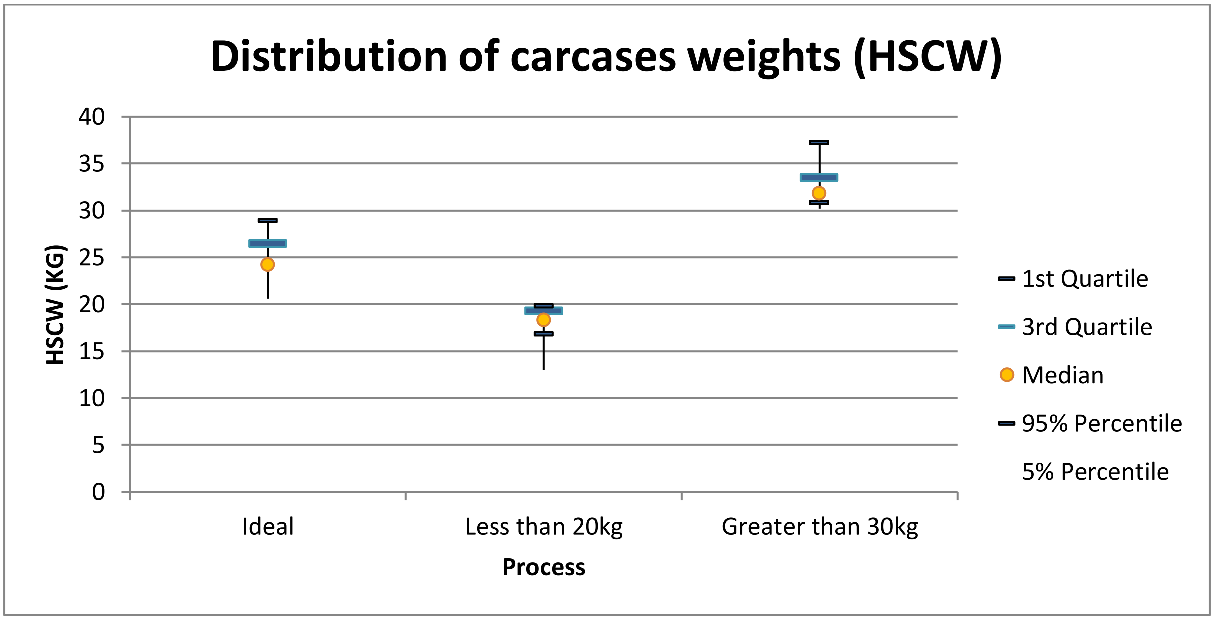

Figure 12: Distributions of carcase weight for varying weight categories, sheep

- Increasing the weight of light animals and developing new markets for heavier animals will maximise benefit for industry.
- Some animals will not have the genetic ability to increase HCW without running to fat. New LMY grids will be required to reward genetics with a higher LMY % at a higher carcase weight. Some additional products will need to be developed to manage higher carcases weights. The selection of animals for sale based on a combination of HCW and LMY will increase the value of products sold BUT need to be managed to ensure that the eating quality of products is not decreased.

- HSCW has been used to show the change in value at farm gate as a proxy for value of SMY at exit of the plant. This has limitations but is the best proxy population dataset available.
- Scenario 6 would provide additional value as OM systems can be developed to process larger numbers of animals and limits the issues associated with producers not adopting technology as can be seen by the adoption of scales in the industry.
- The adoption of technology with limited benefits is going to be the greatest limitation to adoption and utilisation of technology through the current Scenario.
    - It also limits the cost of which the system can be sold to at or the business models which are required for the systems to be utilised by the sheep industry.
    - Dataset of -

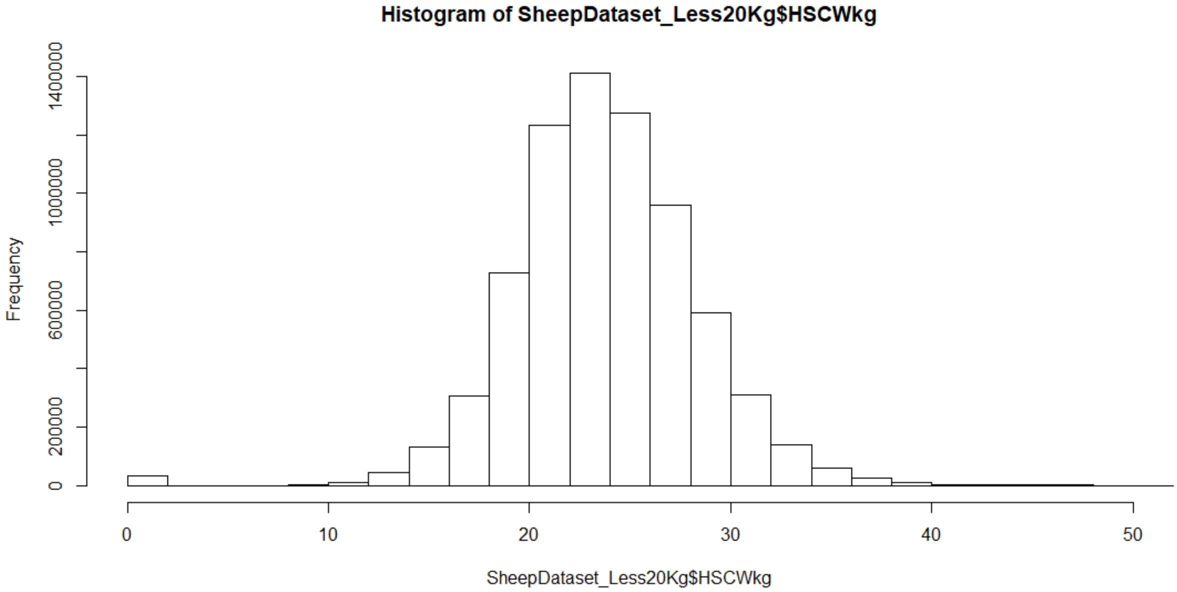

Figure 13: Data of all animal weights measured, informing ideal distributions

3.4.4.3 SMY

The SMY has been calculated the same way as beef summarized in Table 19. This has resulted in a total increase of SMY for light animals to be 2.28kg SMY per head. Increases to SMY through genetic development have been accounted for in previous scenarios and will not be double counted here.

As can be seen in Table 19 below the maximum increase in value is estimated at $11.69 million annually across the sheep flock. The maximum benefit has been calculated using the following assumptions:

- 16 % or 3.6 million lambs which are currently under-weight, and 5 % currently overweight animals will have their sales value affected by the adoption of SMY identification on-farm
- The value of $5.60/kg of SMY was used for the increased value. This is conservative when compared to the current sales price of lambs in Australian
- The cost of weight gain has been included at $4.17/kg per kilogram gained

Table 19: Total potential benefit for Scenario 7, sheep

Changing turnoff weight On-farm to better match current markets		
	Increasing weight on-farm	Reducing weight of heavy animals
Increase HCW @ Slaughter	3.89	- 8.85
Increased SMY @ slaughter	2.28	- 5.18
Reduced cost of discounts	$ -	$ -
Increase value of carcases	$ 28.62	-$ 65.11
Total opporunity cost by increasing carcase weights	$ 28.62	-$ 65.11
Cost of weight gain	**$ 16.20**	**-$ 36.86**
Net benefit per head	**$ 12.42**	**-$ 28.25**
Overall Benefit		
Benefit per hd processed	$ 1.99	-$ 1.41
Benefit per kg	$ 0.09	-$ 0.07
Annual opportunity	$ 44,207,792	-$ 31,430,671

3.4.4.4 Likely Benefit

The likely benefit is estimated at $3.27/head per animals affected with an assumed accuracy of 40% increase in value in association with the new scenario. It is expected that $1.30 million annual gross benefit will occur by 2030. The increased value achieved will be affected by the accuracy of systems used, as can be seen in Table 20. Adoption strategies for the technology will also impact the benefit shown in Figure *14*, which is dependent on producer response to incentives and selection pressure.

Table 20: System accuracies, and their associated benefits, for Scenario 7, sheep

On-Farm Decisions			
	Scenario 1 20% Accuracy	Scenario 2 40% Accuracy	Scenario 3 60% Accuracy
Magnitude of Change	$ 2.61	$ 3.27	$ 3.92

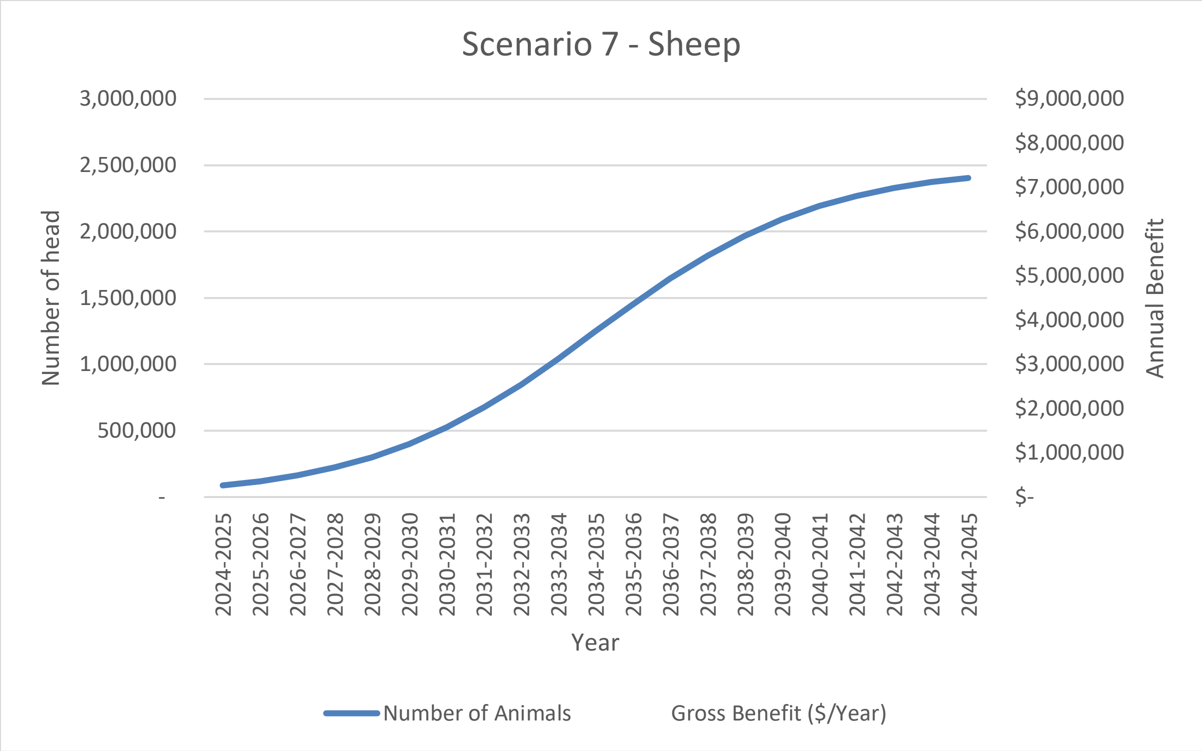

Figure 14: Estimated adoption curve for on-farm selection of animals for sale through the development of OM Technologies.

4 Conclusions

For each scenario, the maximum possible benefits are reduced to generate the likely benefit (what is expected) after adoption rates, accuracy of technology, and industry factors are considered for each scenario. The following sections summaries that gross and net benefit for the 7 scenarios included and the adoption considerations that will impact on value realized. The benefits for carcase and live animal based objective measurements from 2025 to 2045 have been calculated. The specific value created throughout this section summarizes the benefits which can be achieved through the following applications:

- Live animal based only objective measurement
- Carcase based only objective measurement
- A combined model of both live animal and carcase based assessment, based on the likely adoption of live animal and carcase based animal assessments within each scenario.

4.1 Live animal only objective measurements

The benefit from implementation of live animal objective technologies for each scenario through the adoption of live animal objective measurement technologies is shown in Table 21. As can be seen in Table 21 the most benefit will come from Scenarios 6 & 7 for the live animal assessment of objective measurements. The annualized expected gross benefit and adoption curves for the 20 year from 2025 to 2045 can be seen in appendix 6.1 for beef and 6.4 for sheep. It is likely that the below benefits will not be achieved in isolation from the carcase based objective measurements, given that for most scenarios a carcase only or a hybrid OM approach maximises industry benefit. Thus, this expected combined net benefit is show in section 4.3 and is seem as the most realistic impact estimate.

Table 21: Likely net benefit for each scenario through the adoption of only live animal objective measurement technologies, achieved by 2030 and 2045

	Beef ($'000,000)		**Sheep ($'000,000)**	
Scenario	2029-2030	2044-2045	2029-2030	2044-2045
1	$3.05	$8.18	$0.75	$3.84
2	$0.89	$2.72	$-	$-
3	$-	$-	$-	$-
4	$-	$-	$-	$-
5	$-	$-	$-	$-
6	$12.77	$64.39	$4,63	$29.75
7	$5.57	$31.305	$1,22	$7.37
Total	$22.39	$106.65	$5.60	$40.97

4.2 Carcase objective only measurements

The benefit attributed to each scenario through the adoption of carcase assessment using objective measurements technologies for the years 2030 and 2045 shown in Table 22. As can be seen the Table 22 the most benefit will come from Scenarios 3, 4 & 6 for carcase based objective measurements alone. The annualized net benefit and adoption curve for carcase based objective measurements are included in appendix 6.2 for beef and 6.5 for sheep. The benefits achieved through only carcase based objective measurements will not cover the entire industry with the current sale methods. Thus, live animal based objective measurements will be complementary to the following benefits in scenarios 1 and 2.

Table 22: Likely Net Benefit for carcase based objective measurements for each scenario, by species, achieved by 2045

	Beef ($'000,000)		**Sheep ($'000,000)**	
Scenario	2029-2030	2044-2045	2029-2030	2044-2045
1	$6.33	$13.96	$1.52	$4.92
2	$2.21	$4.57	$-	$-
3	$7.82	$12.43	$-	$-
4	$16.84	$28.71	$2.41	$5.40
5	$0.66	$4.75	$0.85	$2.23
6	$10.60	$78.21	$6.27	$21.52
7	$-	$-	$-	$-
Total	$44.47	$142.63	$11.04	$34.07

4.3 Combined live animal and carcase based assessments

The benefits achieved through investment into live animals and carcase based objective measurements will be complementary. However, it is expected that the most benefits will be achieved through the utilization of carcase based objective measurements for scenarios 1 to 6. Hence an attribution percentage shown in Table 23 has been estimated for each scenario.

The benefits of live animal OM for each impact scenario is as follows:

- Scenario 1 – Genetic trait selection for increased LMY whilst maintaining eating quality.

  The most benefit will be achieved by OTH sales due to higher carcase OM accuracy and implementation of VBP system. Additional live animal OM based benefits are expected to be achieved for animals sold on the hoof (e.g. via sale yards and online auctions), primarily where this live animal data is used for purchasing decisions and/or by smaller processors that do not have carcase based OM systems.

- Scenario 2 - Genetic trait selection for increased LMY & reduced dark cutters (northern beef).

  This mirrors Scenario 1 but for northern cattle.

- Scenario 3 - Genetic trait selection for increased marbling & improved feed conversion (longer fed feedlot cattle).

  Currently this is only based on genetic gain of feedlot cattle sold directly to plant and thus no additional benefit can be achieved through live animal OM. There are likely to be benefits in live animal measurement for feedlots, but this area has been excluded from this model and will be addressed in a future update.

- Scenario 4 - Improving on-farm animal health from processor feedback.

  As this currently relies on manual disease inspection post slaughter, no additional benefit has been included for live animal or carcase based OM.

- Scenarios 5 & 6 are based on optimization of product throughput and customer specification driven purchase and processing allocation decisions that maximize carcase sale value.
  These benefits can only be achieved within the processing plant by measuring all carcases with high accuracy and thus live animal OM will not provide any additional benefit.

- Scenario 7 - Enhanced on-farm decision making to better manage live animal impact on yield.

  These benefits can only be achieved through live animal OM as the scenario involves changing management decisions on live animals on-farm.

Table 23: Attribution of adoption rates between live animal and carcase based objective measurements. The percentages are based on the above assumptions of the investment into live animal and carcases based OM.

Scenario	**Sheep**		**Beef**	
	Live animal	Carcase	Live animal	Carcase
1b - Genetic trait selection for increased LMY while maintaining eating quality	25%	100%	5%	100%
2 - Genetic trait selection for increased LMY & reduced dark cutters (northern beef)			5%	100%
3 - Genetic trait selection for increased marbling & improved feed conversion (longer fed feedlot cattle)				100%
4 - Improving on-farm animal health from processor feedback		100%		100%
5 - Improved processor boning room efficiencies		100%		100%
6 - Customer specification driven livestock purchase and processing allocation decisions to maximise carcase sale value		100%		100%
7 - Enhanced on-farm decision making to better manage live animal impact on yield	100%		100%	

4.3.1 Overall Benefit

The annual cattle and sheep net benefit achievable from the likely adoption of both carcase and live animal based objective measurements is $60.7 million in 2030 and $217 million in 2045, with the majority of benefits derived from cattle OM ($48 million in 2030 and $175 million in 2045). The overall benefit for each scenario achievable from development of both carcase and live animal based objective measurements is shown in Table 24,

The benefit attributed to carcase based and live animal OM are shown in Table 25 and Table 26 respectively.

Table 24: Likely net benefit for each scenario through the adoption of live animal and carcase based objective measurement technologies, achieved by 2030 and 2045

	Beef ($'000,000)		Sheep ($'000,000)	
Scenario	2029-2030	2044-2045	2029-2030	2044-2045
1	$6.49	$14.37	$1.70	$5.88
2	$2.26	$4.70	$-	$-
3	$7.82	$12.43	$-	$-
4	$16.84	$28.71	$2.40	$5.40
5	$0.66	$4.75	$0.85	$2.23
6	$10.60	$78.21	$6.27	$21.52
7	$5.58	$31.30	$1.22	$7.37
Total	$50.26	$174.52	$12.45	$42.40

Table 25: Likely net benefit attributed to live animal based objective measurement technologies, when coupled with carcase based objective measurement technologies.

Scenario	**Beef ($'000,000)**		**Sheep ($'000,000)**	
	2029-2030	2044-2045	2029-2030	2044-2045
1	$0.15	$0.41	$0.19	$0.96
2	$0.04	$0.14	$-	$-
3	$-	$-	$-	$-
4	$-	$-	$-	$-
5	$-	$-	$-	$-
6	$-	$-	$-	$-
7	$5.58	$31.35	$1.22	$7.37
Total	$5.78	$31.89	$1.41	$8.33

Table 26: Likely net benefit attributed to carcase based objective measurement technologies, when coupled with live animal technologies.

Scenario	Beef ($'000,000)		Sheep ($'000,000)	
	2029-2030	2044-2045	2029-2030	2044-2045
1	$6.33	$13.96	$1.52	$4.92
2	$2.21	$4.57	$-	$-
3	$7.82	$12.43	$-	$-
4	$16.84	$28.71	$2.41	$5.40
5	$0.66	$4.75	$0.85	$2.23
6	$10.60	$78.21	$6.27	$21.52
7	$-	$-	$-	$-
Total	$44.47	$142.63	$11.04	$34.07

4.4 Adoption rates

The adoption rates for the live animal scenario for beef and sheep are summarised in Table 27 as a percentage of the population shown in Table 27 for the beef scenarios, and based on 32.3 million head of lamb and mutton slaughtered annually for the sheep scenarios.

Table 28.

Table 27: Population beef carcases used in each scenario

Scenario	Population	Rational
1	5,535,660	Southern grass-fed cattle (60% beef slaughtered)
2	2,767,830	Northern grass-fed cattle (30% beef slaughtered)
3	922,610	Grain-fed cattle (10% beef slaughtered)
4	9,226,100	Entire slaughter
5	9,226,100	Entire slaughter
6	9,226,100	Entire slaughter
7	9,226,100	Entire slaughter

Table 28: Combined live animal and carcases based objective measurement adoption rates

Scenario	Beef		Sheep	
	2029-2030	2044-2045	2029-2030	2044-2045
1	19%	37%	17%	44%
2	14%	25%	0%	0%
3	14%	23%	0%	0%
4	37%	65%	12%	20%
5	12%	47%	14%	39%
6	12%	47%	14%	39%
7	3%	23%	1%	7%

4.5 Attribution of benefits

Modelling by MLA of second round benefits[18] from OM requires an estimate of the attribution of benefits between cost reduction and productivity increases for each scenario, as well as an allocation of those benefits between producers and processors in each farming zone.

These estimates are shown in the table 29.

Table 29: Allocation of benefits by type and industry sector

Scenario	Benefit type		Sector benefitting	
	Cost reduction	Productivity Increase	Producer	Processor
1	0%	100%	80%	20%
2	0%	100%	80%	20%
3	0%	100%	80%	20%
4	0%	100%	80%	20%
5	100%	0%	0%	100%
6	0%	100%	40%	60%
7	0%	100%	60%	40%

4.6 Adoption considerations

Accurate objective measurements of carcase value (driven by DEXA with support from other objective measurement tools for assessment of eating quality) have been considered key enablers of new value-based payment systems over the past 5 years.

The previous OM report considered a range of technologies being developed that could be applied across all benefit scenarios. However, the key drivers required to deliver enhanced feedback systems across the industry are a combination of yield and quality measures. Slower than expected commercialisation of OM's for beef yield and lamb eating quality have limited the rate of information flow and capability building across industry to convert that information into enhanced decision making. Adoption for all other OM technologies has been slower as a result.

When establishing adoption rates and realising OM benefits, the following factors have been considered:

1. Installation of OM systems to capture data
2. All chain participants discernment of new data,
3. How to communicate new information through feedback mechanisms, and
4. IT systems that will support information sharing and new payment systems required to incentivise changes in production practices and quality of outputs
5. Willingness and ability of processors to move to new value-based pricing (VBP) payment system for OTH purchases, given current supply side constraints. Willingness and ability of producers to use OM to inform their production process and increase alignment to pricing grids, and where they sell their animal to

[18] MLA uses the GMI/IF partial equilibrium model of the red meat industry to model the second round benefits (benefits retained long term within the red industry and redistributed between red meat sectors) arising from the annual first round costs reduction and/or productivity shocks modelled in this report.

6. Rate of cultural change required across industry for transaction methods to become effective

In the promotion of OM information, two things need to be understood; production rewards, and pricing rewards. It is not enough for the producers and processors to know that they can get information out of the process. They need to know what improvements it can inform.

The use of OM On-Farm can limit out of spec cattle, raise LMY and target weak points in the growth process. It can determine which animals are most desirable for a processor's customer base, which animals hold the best value for money. There would need to be education on each technology's applications to encourage adoption and improvements.

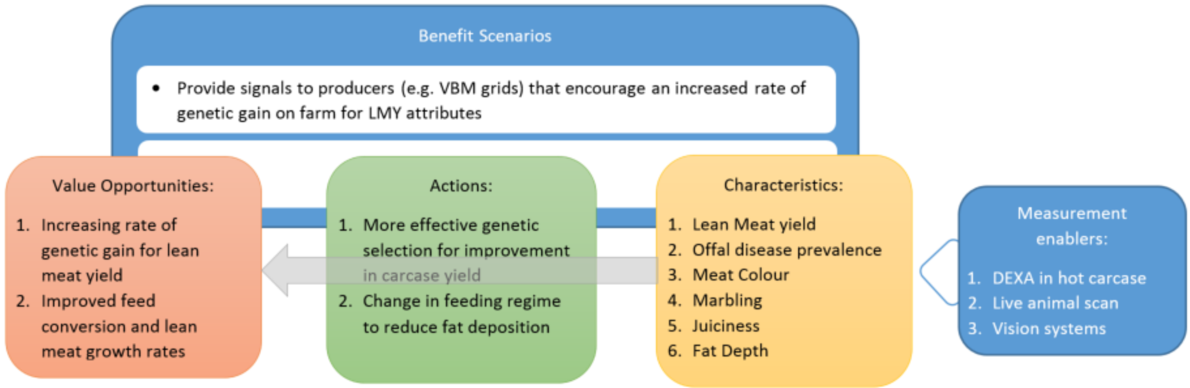

Figure 15: The necessity of understanding applications, to justify adoption

Adoption comes first, but once applied to the relevant characteristics, in the above Figure 15, better actions can be taken, and value opportunities are maximised.

To increase the adoption of technology across the beef and sheep industry, the compatibility of systems so they can be used on both sheep and cattle would increase their adoption as multi-species producers would be able to further justify the purchase of equipment. How feasible this is will need to be investigated through R&D investment.

4.6.1 Barriers to adoption

Objective measurement technology adoption risk

Existing measures for payment estimate the value of the finished product, though with low accuracy. There are already prediction equations for LMY using existing measures as well as objective systems like ViaScan that are more accurate than current payment measures. These are claimed to give accuracies of around R2 ~0.5-0.6 but have not been adopted. The main barrier to adoption of objective technologies is value-based payments, not accuracy of OM's.

There is a risk that producers don't want to 'overwrite' familiar production and sales system processes with alternative decision processes, even if they are more accurate.

Finding ways to integrate live animal OM into existing processes could enable broader early awareness and faster adoption. For example, OM integration to current paddock assessments through online auctions is an easy way to educate. Integration of OM to automatic walk-over-weighing if low enough cost engages wider sectors of industry in raising awareness and increases likelihood of broad adoption. Trialing OM at saleyards increases awareness and engages the agent sector of industry in communicating use of data.

JT comment: Saleyards have been poor adopters of technology. The use of liveweight selling is an example

These existing and trusted relationships could be a key to broader awareness and industry acceptance. There is a good portion of the producer sector that do not use existing systems such as scales and will not adopt. This subset of the population has not been considered part of adoption and will diminish over time.

<u>VBP Adoption risk</u>
In the processing sector there is a real risk that VBP will not be adopted broadly enough to generate the critical mass needed to be a sustainable trading method. Availability of livestock is a key focus for processors and impacts on allocation of fixed cost. Some processors are concerned that if they pay less for lower LMY livestock (to help pay for higher value livestock), suppliers that are worse off could shift supply to competitors.

<u>Resistance of producers to continue with VBM</u>
Increased understanding of the value opportunities from OM has short and long-term implications to VBP and VBM. There is a perception among some producers that they will automatically receive more money for livestock. In the short-term there will be a balance between “winners and losers” while the incentives to improve drive longer-term opportunity for gain to all producers. Live animal OM benefits that come from better sales decisions will take time to emerge given confidence in data accuracy is required from the buyers (finishers as well as processors). If the transition period (years) is not managed well (education and knowledge transfer) finishers will lose confidence in the measurements and processors that introduce VBP could have reduced livestock supply if communication with producers is not well managed. Both these situations could revert to current inaccurate methods of attributing value.

<u>Limitations of incentives to encourage change</u>

- If no buying signals incentivise for higher LMY, the technologies will not drive improvement.
- Quality attributes in the form of MSA are being rewarded and have driven adoption of improved on-farm management practices. It should be noted that not all producers will be incentivised by pricing signals given a percentage of producers have not registered for MSA and would receive a price premium by simply filling out the paperwork.

4.6.2 Future enablers / opportunities

Live animal measurement of LMY prior to sale will be a way to engage the broader processing sector in adopting LMY measures. Rather than rely on a processor to send pricing signals at the risk of losing supply, processors would be free to utilise the objective results accompanying livestock as part of their purchasing decisions. A wider group of processors would use the information from this VBM approach compared to those leading a VBP approach. However, cost of live animal measures on property would have low adoption considering many producers do not have scales for basic weighing. Accuracy of on-farm measures would be low compared with carcase measures. Increased sales through online auction platforms could be further increased if live assessment with objective measurements increased accuracy over subjective visual assessment.

Installing OM technologies like 3D scanning at saleyards would encourage wider adoption of OM without relying on producer investment in on-farm systems. There are several factors that would need to be considered carefully for this option including:

- Challenges of live animal scanning at saleyards, cost of infrastructure and labour for extra work, reliability of systems etc.
- Implication of saleyards becoming a preferred method of sale when research has shown the negative impacts on eating quality as well as barriers to information transfer between producers and end customer.

Market reporting of objective measures would increase awareness and use of technologies. This should be a key initiative for industry (MLA) to drive. There is a trade-off in agendas here. If processors are measuring on carcase they will be reluctant to report results publicly. Adoption then looks very different to the national wool launch which had rapid and broad industry adoption. On the other hand, processors need a national accreditation system to demonstrate the OMs they are using are accurate and reliable. There could be a middle ground between accreditation, reporting and company privacy.

4.6.3 Alternative measurement locations and business models

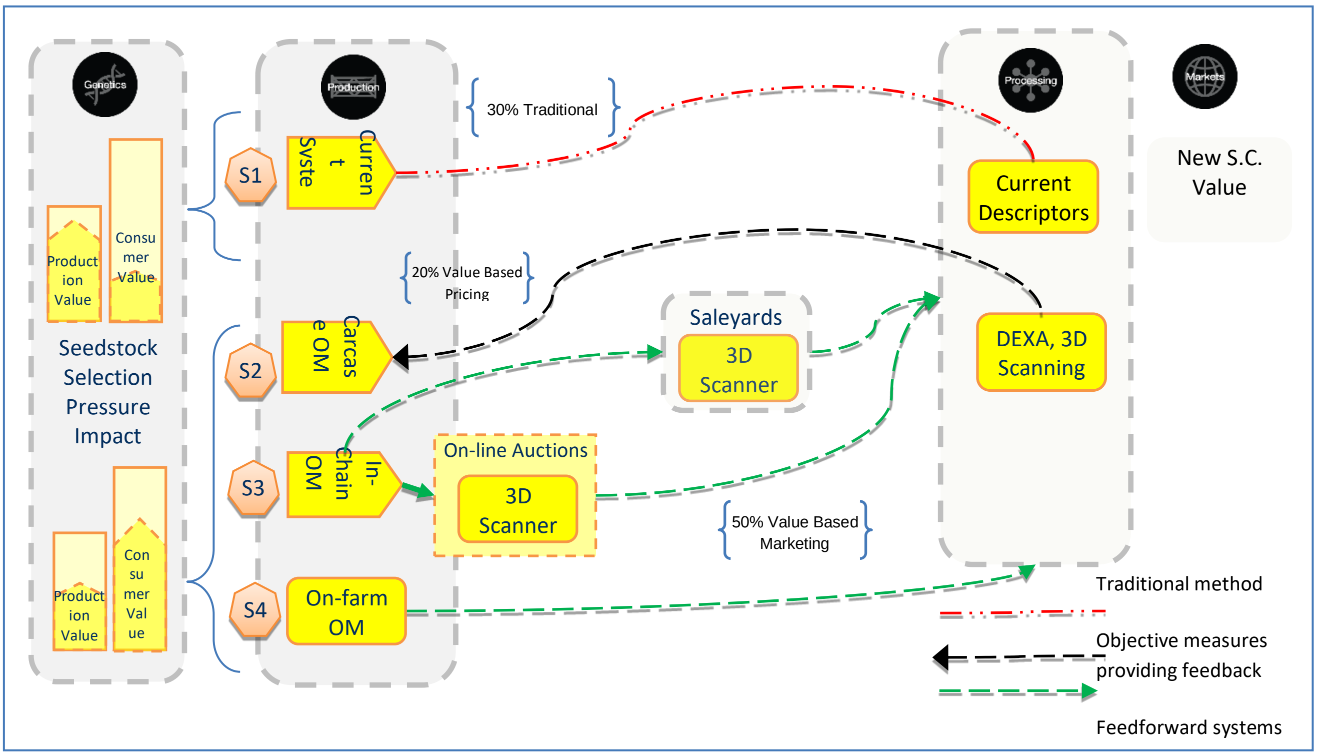

Figure 16: Multiple measurement locations with feed forward and feedback of information supports wider industry adoption and value increases

Objective measurement systems in Figure 16 identify measurement locations that determine sale value. This will either be directly in the case of parameters for a pre-determined price, or indirectly in an auction type environment where parameters differentiate value but no pre-determined value.

5 Key Messages and Recommendations

- Live animal and carcase based objective measurement is estimated bring $1.27[19] billion (NVP) benefit to the red meat industry over the period 2025 to 2045.
- Benefits of implementing yield-based OM on-farm in combination with carcase based OM for the scenarios impacted by live animal OM include:
    - Scenario 1: Genetic selection for increased LMY and maintenance of EQ
        - This involves using yield objective measurement data to make selection decisions in future generations
        - Selection decisions would be made to drive the increase of LMY without detrimental effects to EQ
        - Essentially this method would increase the total number of kg of red meat available for sale at the same eating quality premium
        - Adoption rates of 39% are assumed by 2045
        - Providing a 2045 annual net benefit of $20.24 million for beef and sheep combined.
    - Scenario 2: Genetic selection for increased LMY & reduced dark cutting rates in northern beef enterprises
        - Selection of LMY has the potential to both positively and negatively impact the rate of dark cutting incidence
            - Higher muscling animals (as indicated by EMA) have been shown to have lower incidences of dark cutting (McGilchrist et al., 2009) as there is increased glycogen storage and metabolization capacity
            - However, selection of LMY to the detriment of fat cover (as indicated by rib fat or P8 fat) has been linked to increased incidences of dark cutting as animals are not on a rising plane of nutrition and have lower blood glycogen levels at slaughter
        - Dark cutting costs the northern red meat industry $44.9 million annually
        - The ability to both increase LMY and resultant number of kg of beef, plus decreases discounts by reducing dark cutting rates would provide a $4.85 million annually by 2045
    - Scenario 7: Enhanced on farm decision making to manage live animal impact on yield
        - This scenario examines the use of yield-based OM technologies on farm for incremental management decision support
        - The ability to utilise OM technology at a variety of stages in production would enable producers to better segregate livestock to diversify markets and harness any market premiums available
        - Such technologies will ensure producers are managing livestock to realise their highest potential as well as distribute resources as required

[19] Net present value discounted at 5%, with 2020 as the base year

        - Improved management decisions will maximise the value each animal with an overarching benefit realisation to industry of $38.6 million annually.
- Only objective measures of yield at two points of the supply chain have been considered in this report however there is significant scope to consider the following:
    - Genomic measures for the prediction of commercial value drivers to assist with management decisions on farm, within both the seedstock and commercial production sectors. This would facilitate earlier intervention for future markets and thus management strategies.
    - The use of objective measures of eating quality as the primary driver of consumer value. This would reduce the number of eating quality issues across industry by allowing early intervention to ensure livestock met their full potential thereby increasing value of the national herd.
    - Utilising genomic, yield and eating quality objective measures in the feedlot sector of the industry. Feedlots operate at low margins per head currently and with increasing costs of production this margin will continue to be eroded. The potential of a combination of live animal and carcase based OM technologies would ensure that the maximum potential of every animal is reached at the best resource efficiency rate.
- Adoption rates of OM yield-based technology will be impacted by a range of factors including:
    - The cost of entry to the OM technologies
    - Ease of use of the technologies
    - Ability for integration with current systems such as crush side weigh scales and walk overweight systems
    - The presence and size of accompanying market signals
    - The acceptance of on farm-based OM data by processors and feedlots for payment through VBP/VBM models
    - The development of associated feedback mechanisms to producers to drive improvement
    - The understanding and provision of extension programs detailing how to drive yield changes on farm through genetic selection and management interventions by producers
- As yield is only one driver of market value, extension services will be critical to ensure to correct selection pressures are applied in genetic decisions to ensure limited detriment to eating quality, fertility and other significant consumer and production factors
- It is recommended that MLA undertake extensive consultation with producers to better understand the appetite for the adoption of yield-based OM technologies
- Consultation and modelling are also required to determine the best decision points in the value chain to implement OM technologies as true value realisation is linked to the adoption of VBM/VBP payment models (Greenleaf 2017).

6 Appendix

6.1 Beef live animal OM – annual net benefit

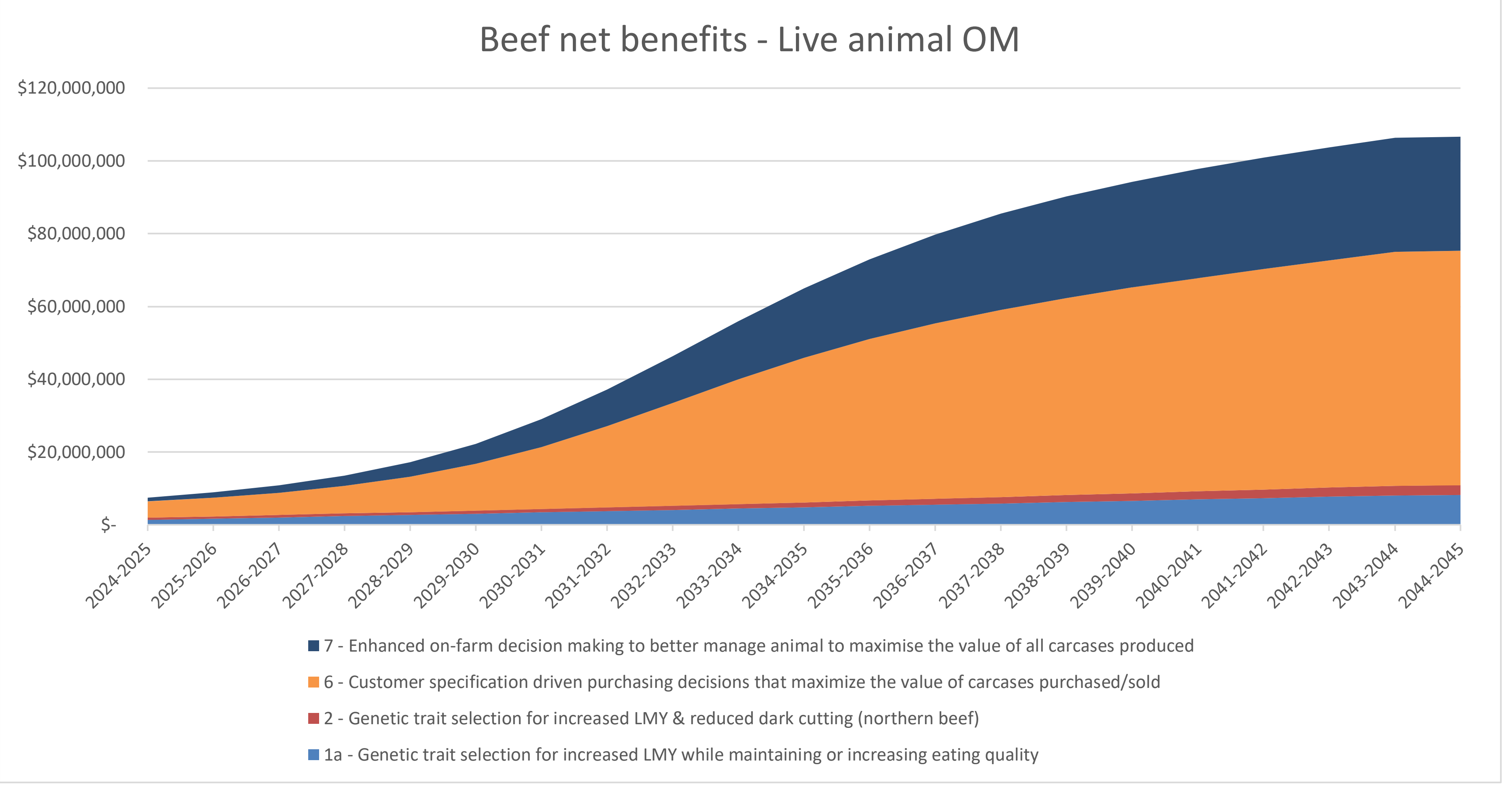

Figure 17: Potential net benefits for live animal objective measurement assessment of cattle, for the years 2025 and 2045

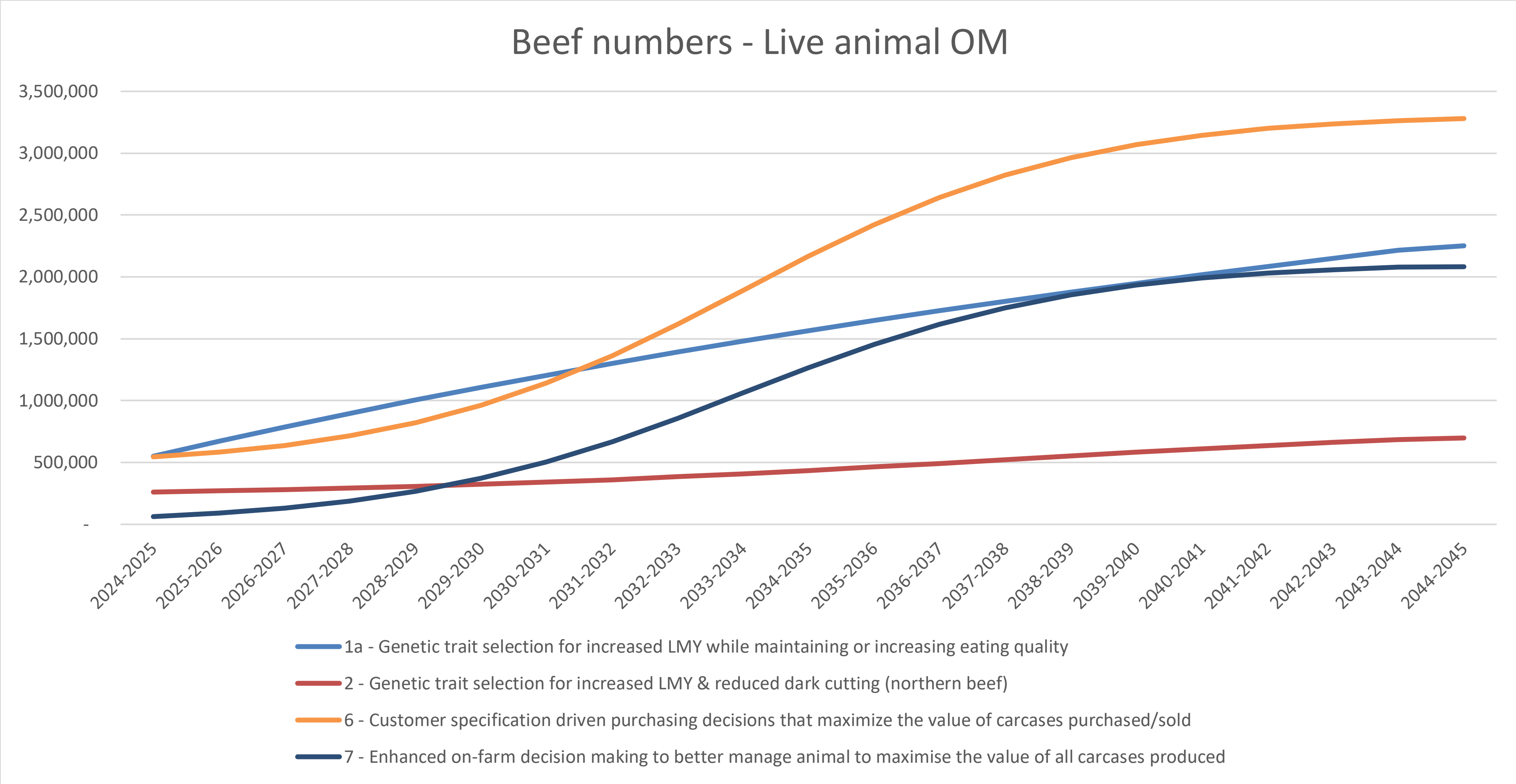

Figure 18: Number of head adopted per scenario, for live cattle assessment

6.2 Beef Carcase OM – annual net benefit

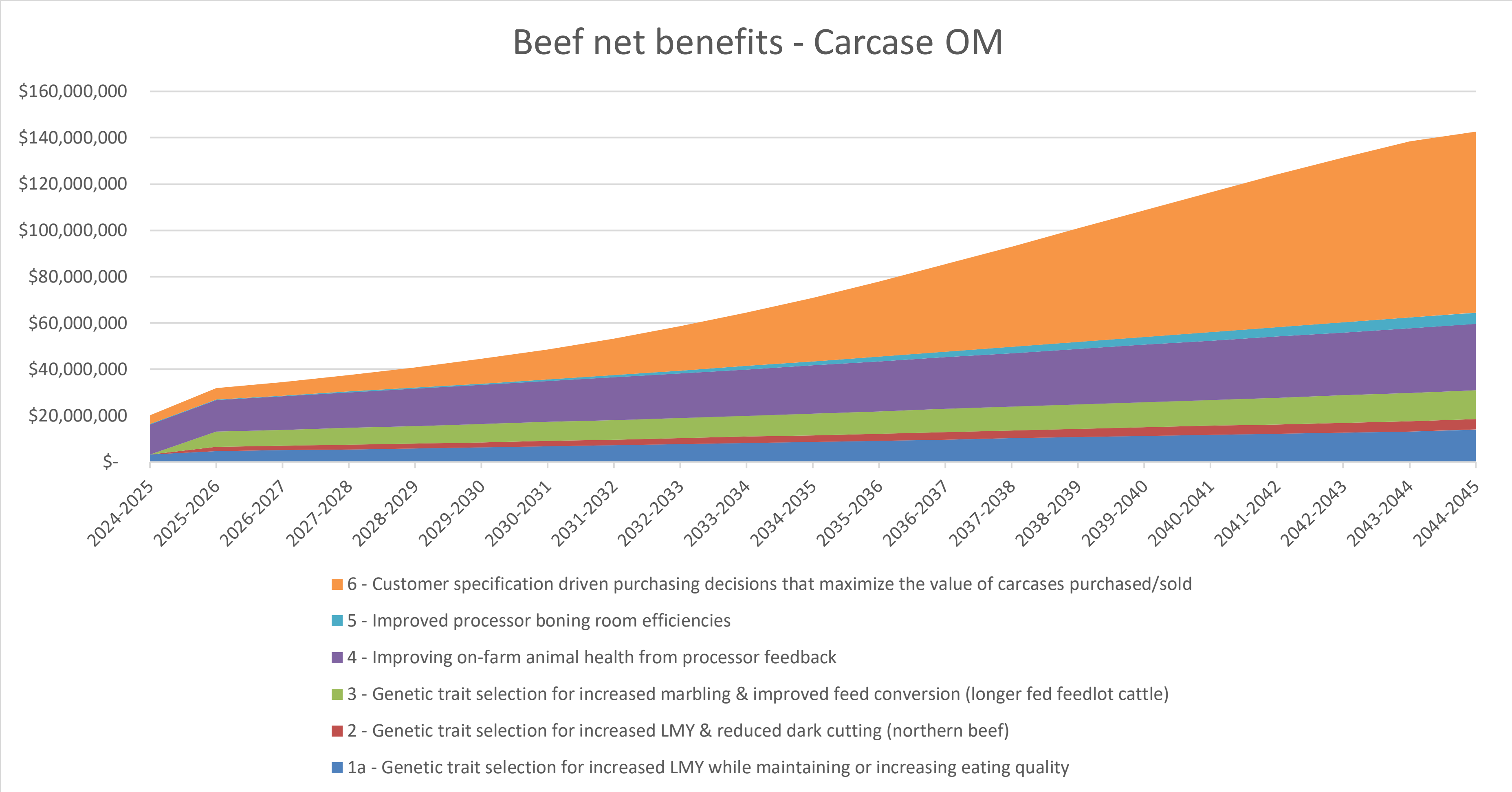

Figure 19: Potential net benefits for objective assessment of beef carcases, for the years 2025 and 2045

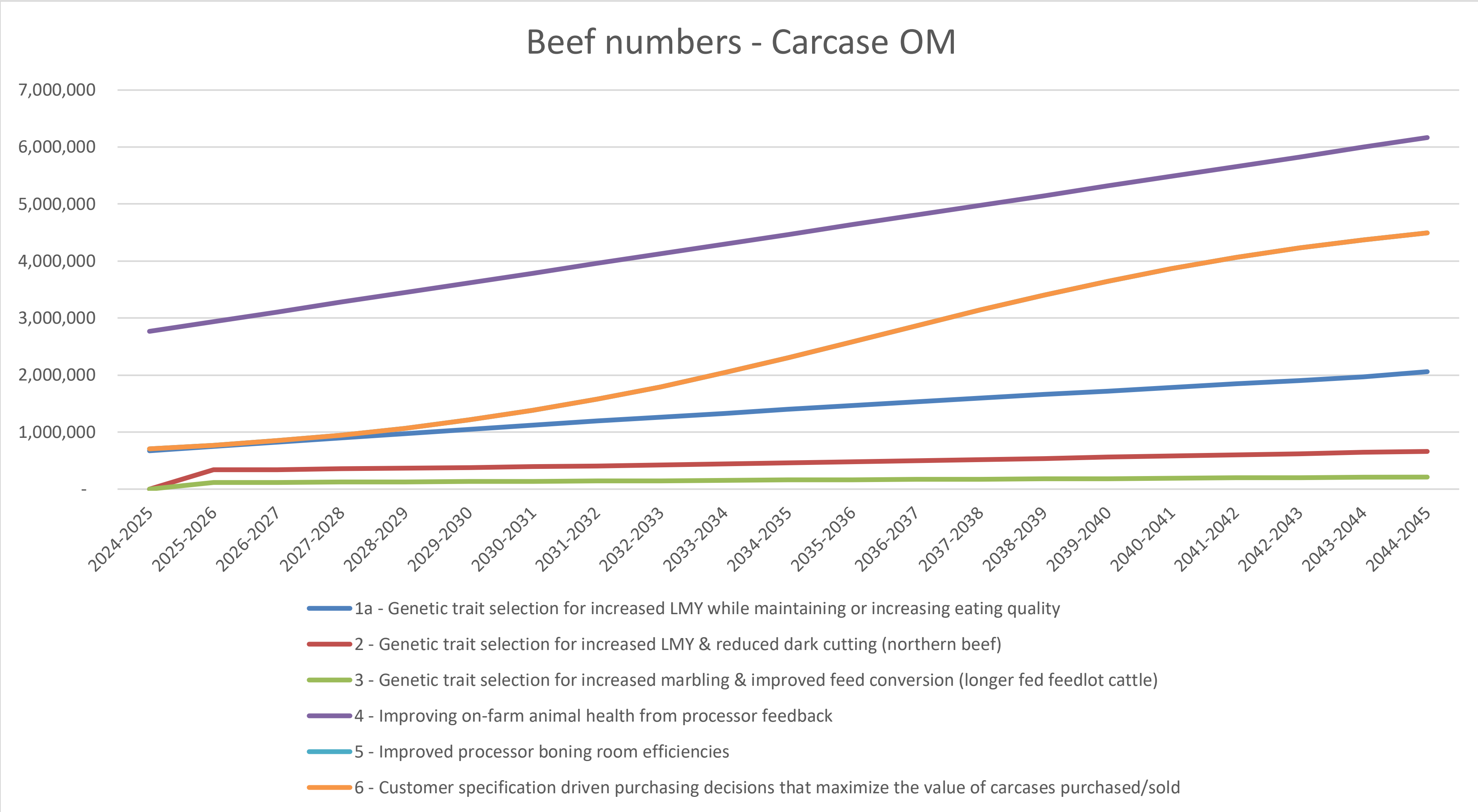

Figure 20: Number of head adopted per scenario, for beef carcase OM assessment

6.3 Beef combined carcase and live animal assessment – annual net benefit

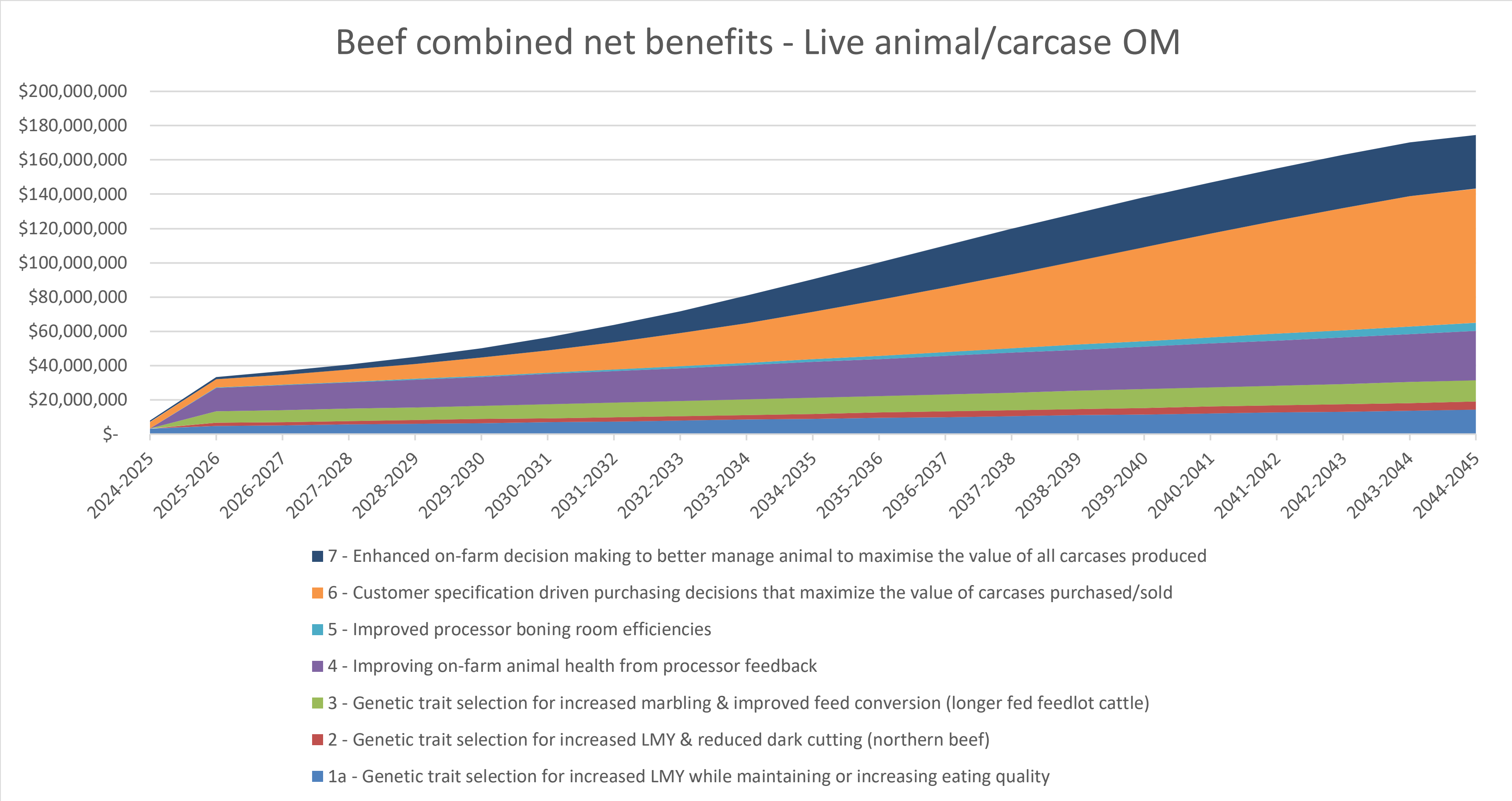

Figure 21: Likely and Potential Benefits for each beef scenario through the addition of both live animal and carcase objective measurement technologies between the years 2025 and 2045

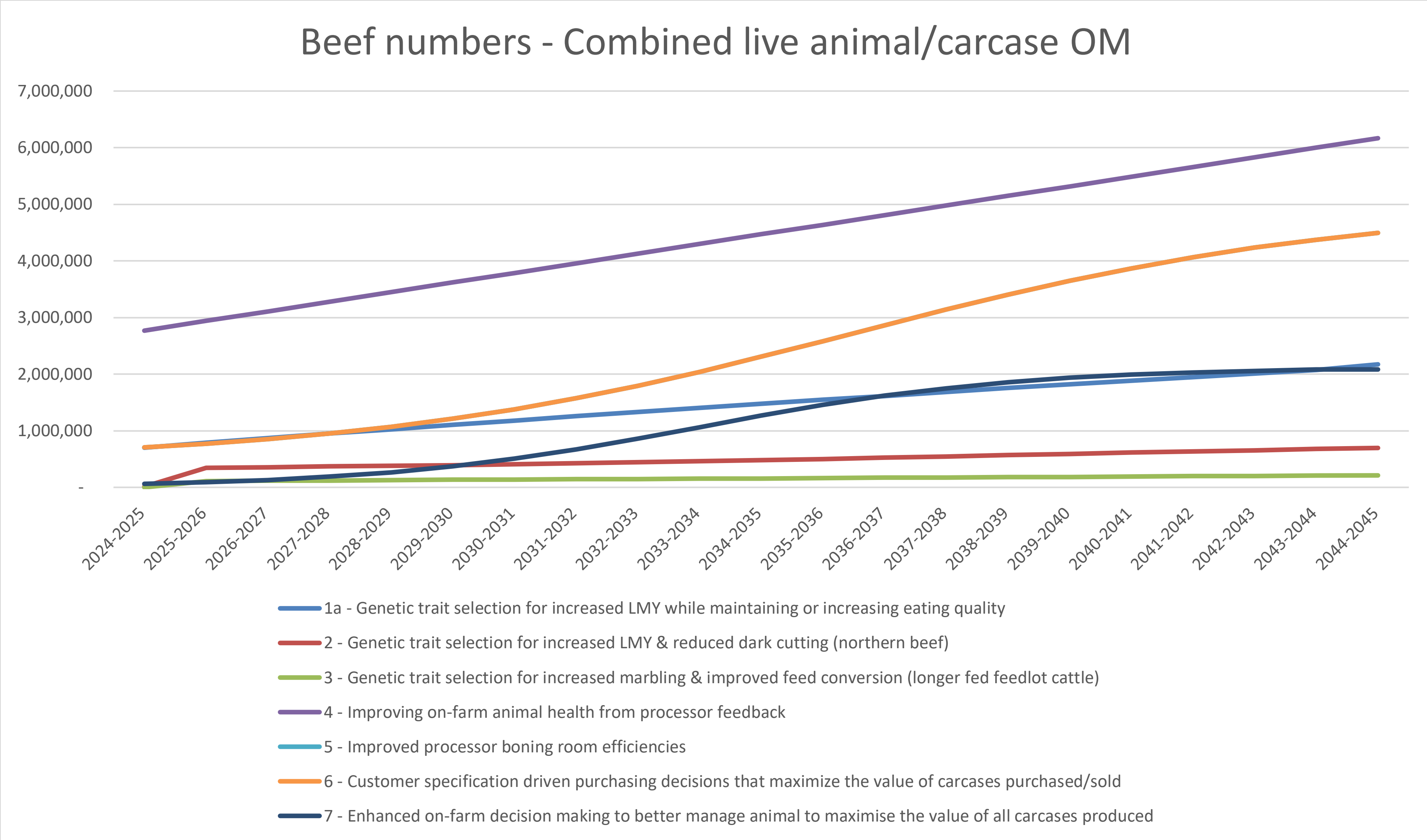

Figure 22: Number of head adopted per scenario, for combined beef carcase and live cattle assessment

6.4 Live sheep Objective measurement assessment – annual net benefit

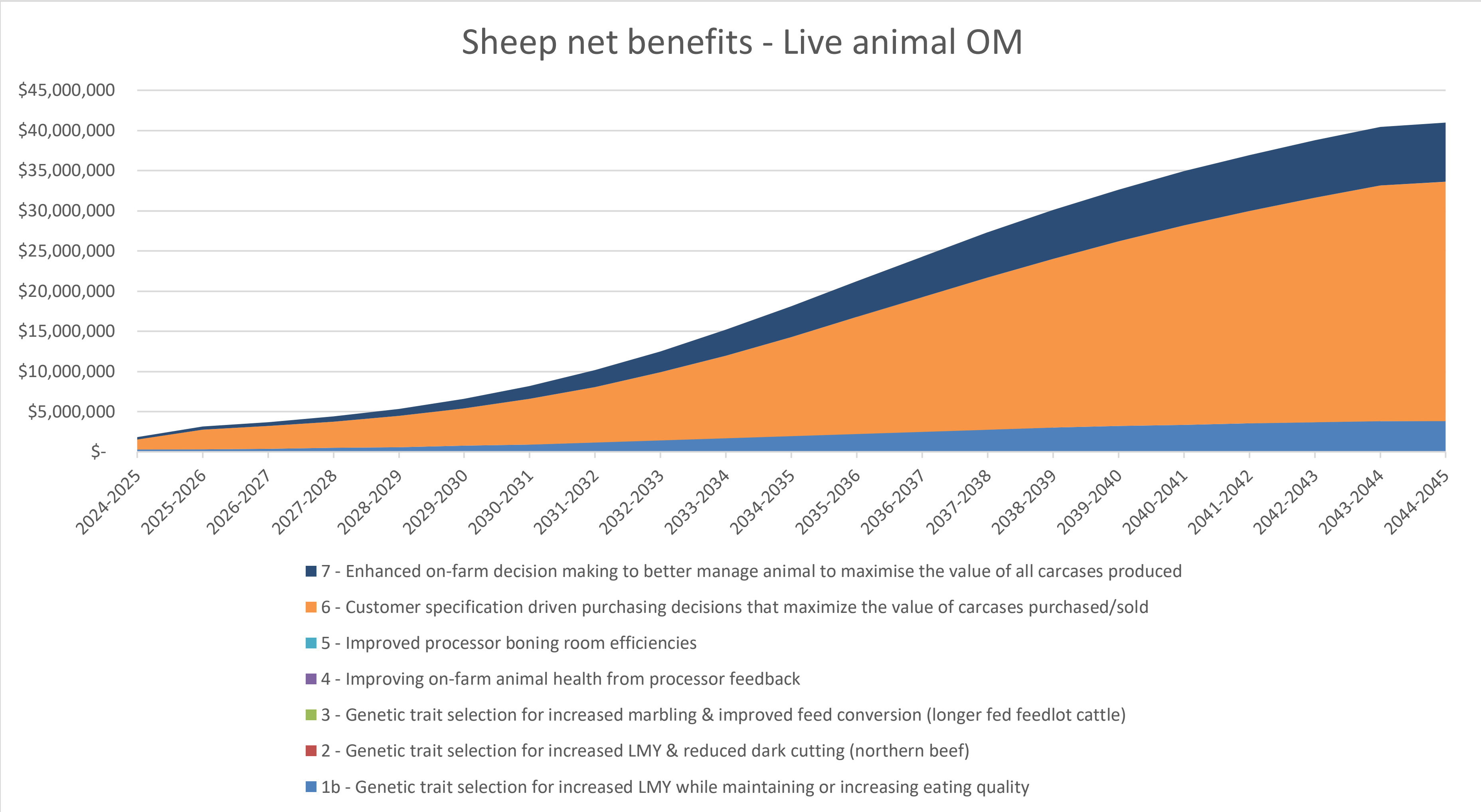

Figure 23: Potential net benefits for live animal objective measurement assessment of sheep, for the years 2025 to 2045

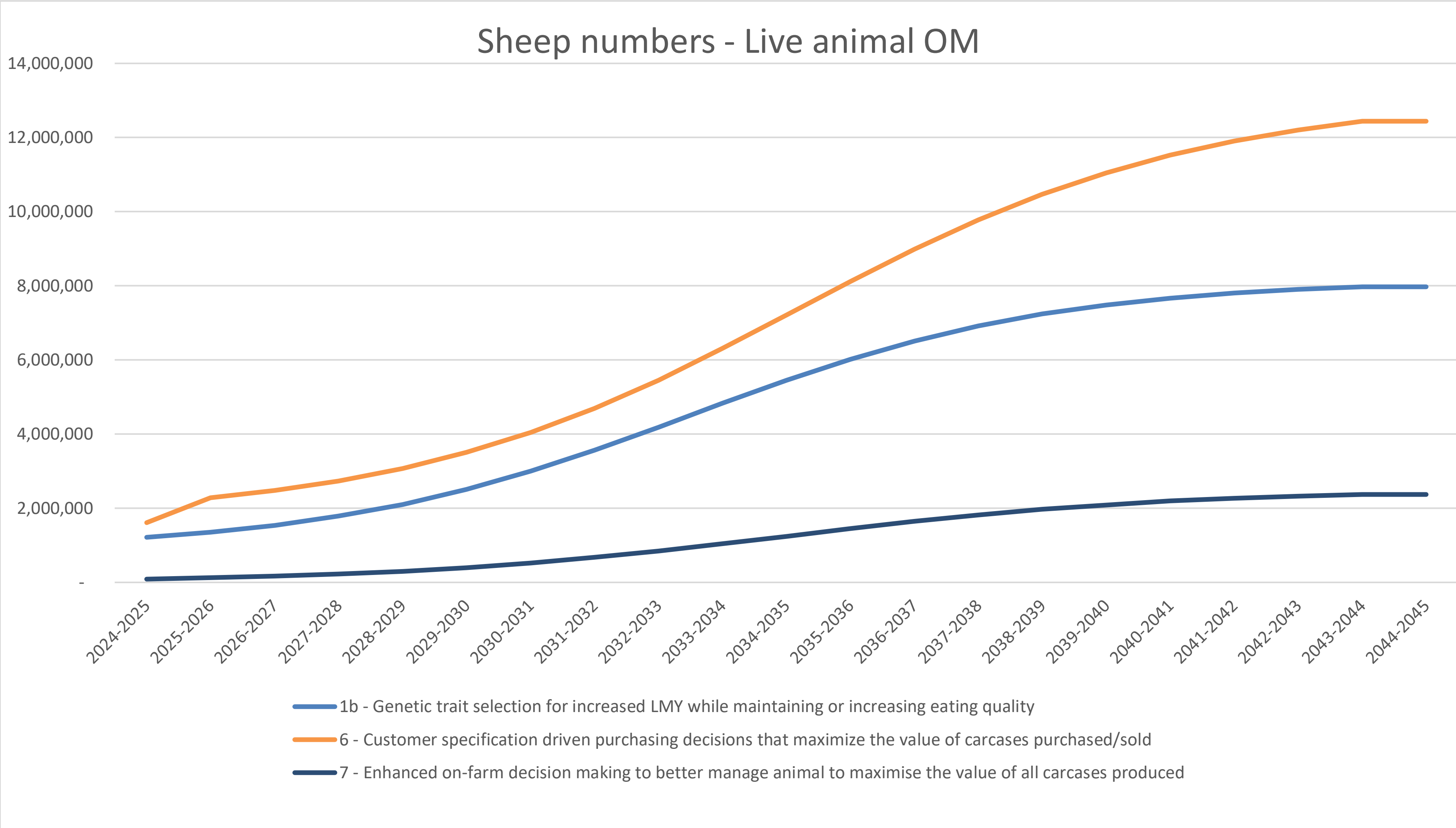

Figure 24: Number of head adopted per scenario applied to sheep

6.5 Lamb & Mutton carcase assessment – annual net benefit

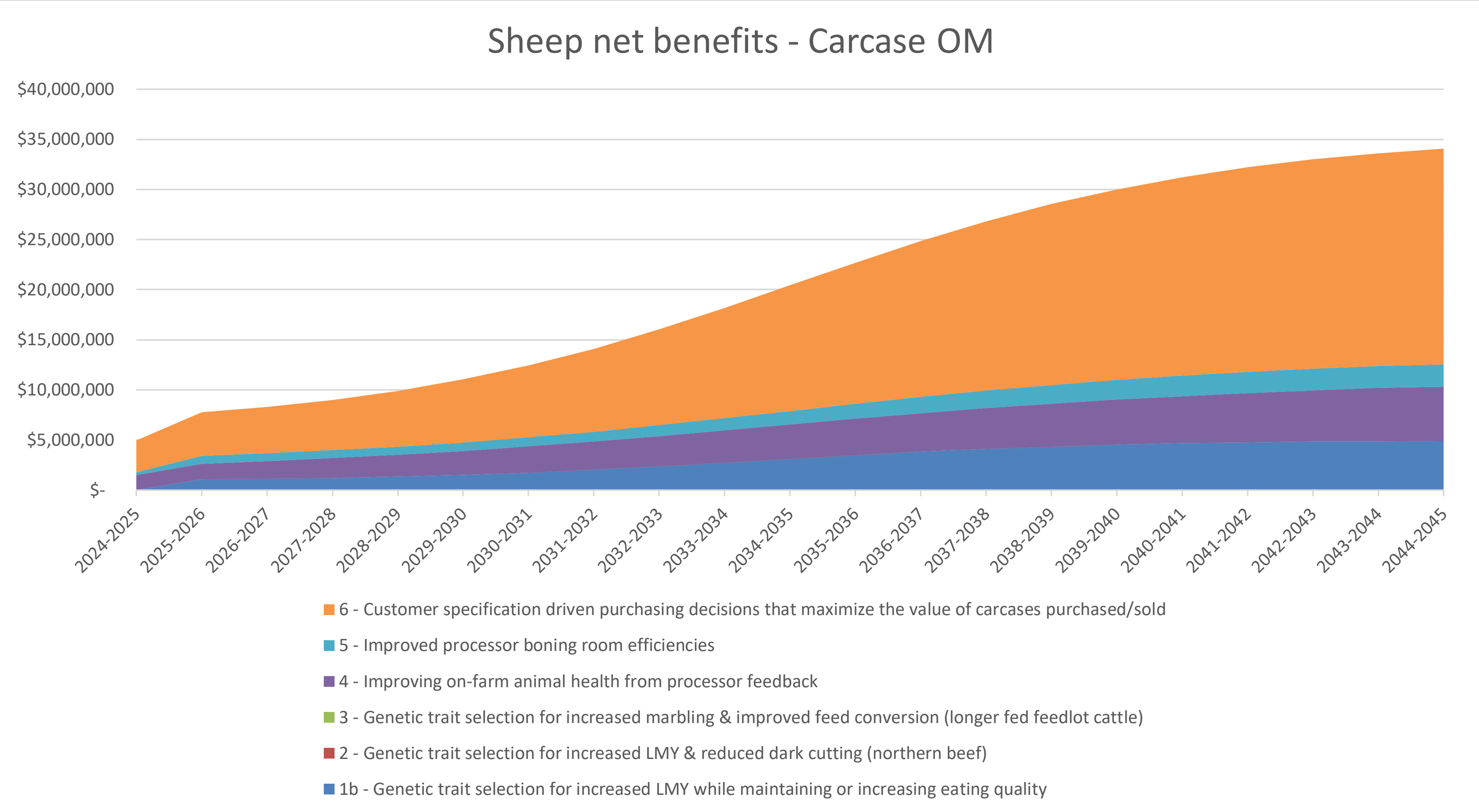

Figure 25: Potential net benefits for objective assessment of sheep and mutton carcases, for the years 2025 and 2045

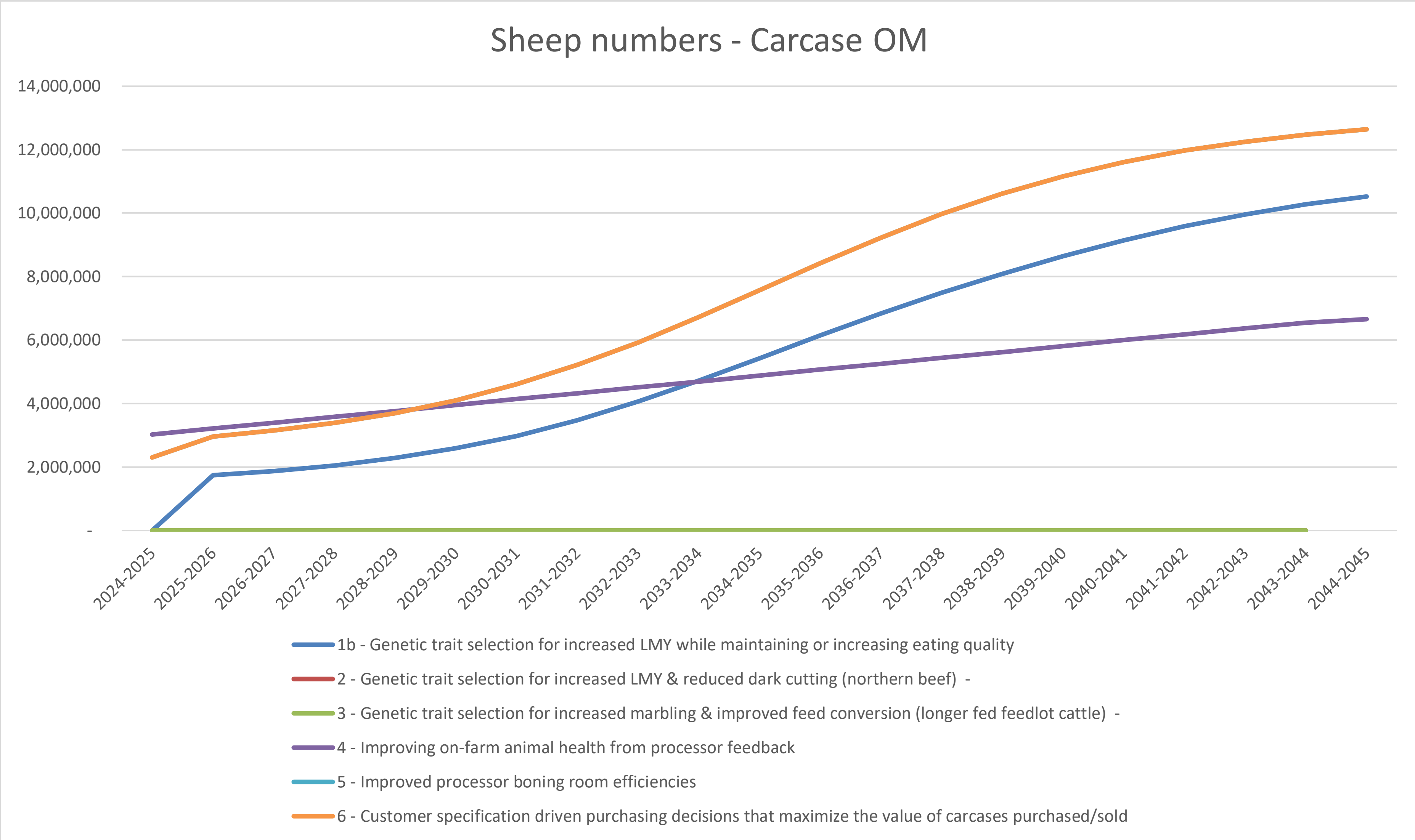
Sheep numbers - Carcase OM
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
-
2024-2025
2025-2026
2026-2027
2027-2028
2028-2029
2029-2030
2030-2031
2031-2032
2032-2033
2033-2034
2034-2035
2035-2036
2036-2037
2037-2038
2038-2039
2039-2040
2040-2041
2041-2042
2042-2043
2043-2044
2044-2045
1b - Genetic trait selection for increased LMY while maintaining or increasing eating quality
2 - Genetic trait selection for increased LMY & reduced dark cutting (northern beef) -
3 - Genetic trait selection for increased marbling & improved feed conversion (longer fed feedlot cattle) -
4 - Improving on-farm animal health from processor feedback
5 - Improved processor boning room efficiencies
6 - Customer specification driven purchasing decisions that maximize the value of carcases purchased/sold

Figure 26: Number of head adopted per scenario, for mutton and lamb carcases assessment using objective measurement technologies

6.6 Combined live animal and carcase assessment – annual net benefit

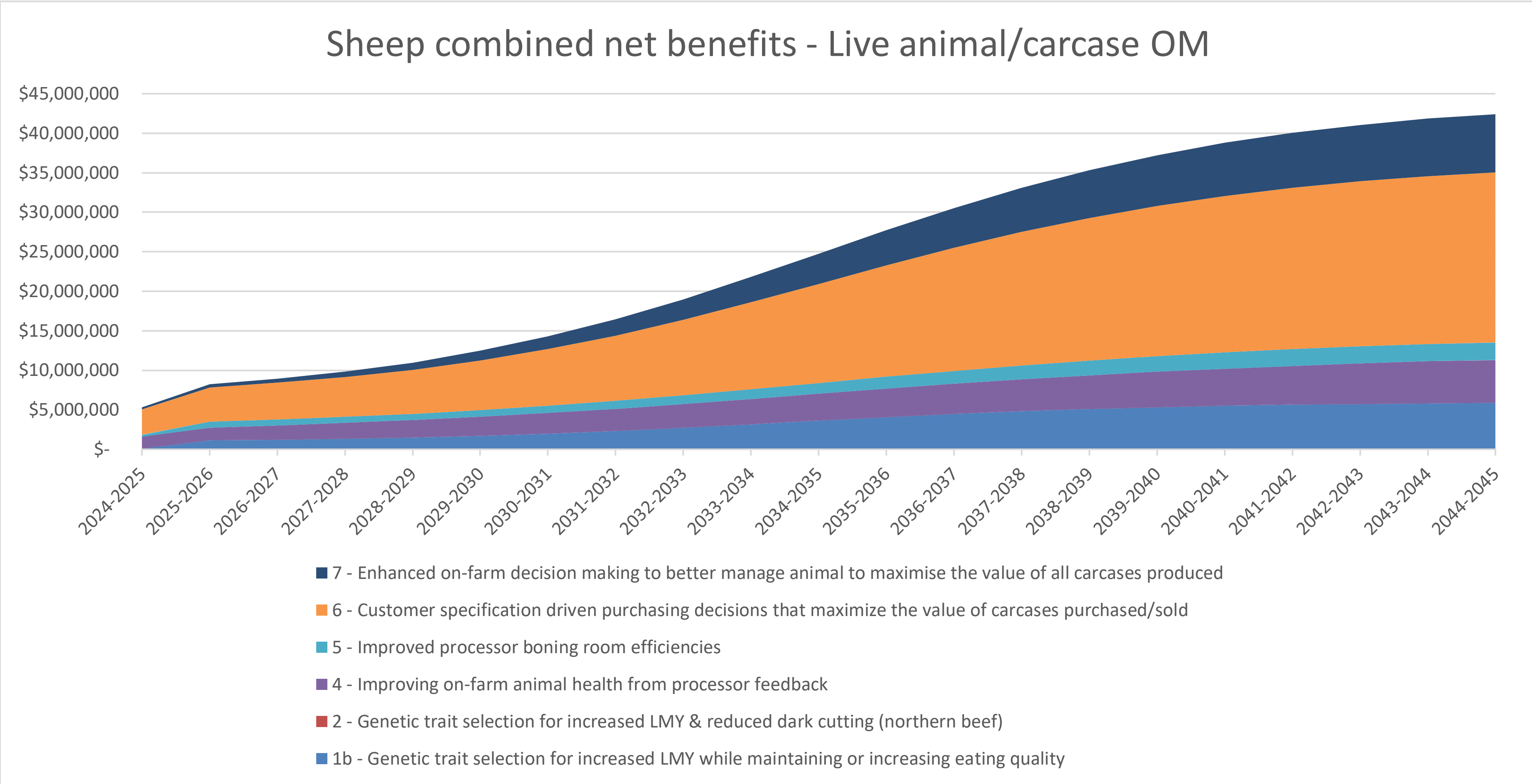

Figure 27: Likely net benefits for each sheep scenario through the addition of both live animal and carcase objective measurement technologies between 2025 and 2045

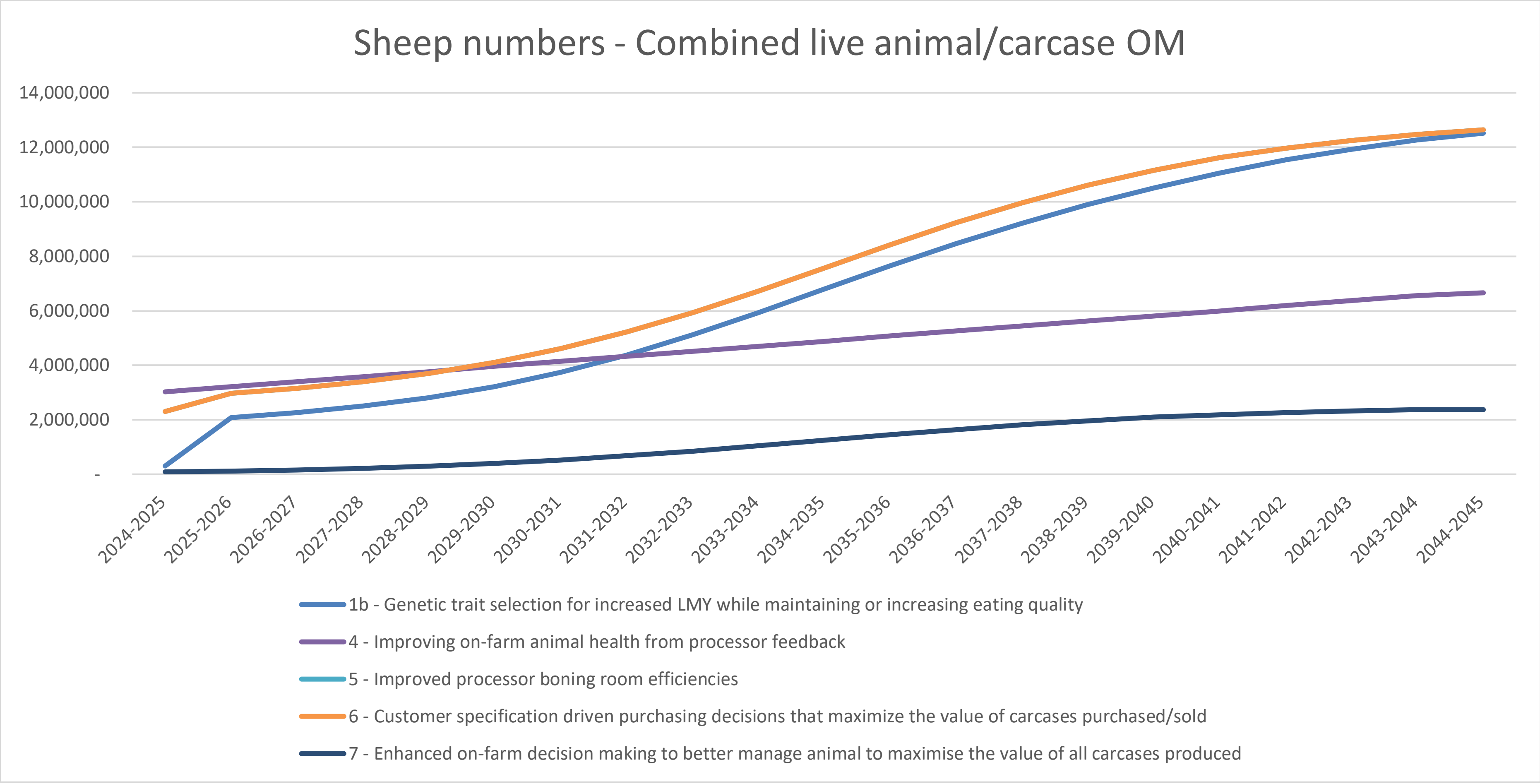

Figure 28: Number of head adopted per scenario, for mutton and lamb carcases assessment using objective measurement technologies