Effects of discolouration losses in meat chain

Adrian Williams, Cranfield University

December 2011

Table of Contents

Table of Figures

Table of Tables

Introduction

Losses occur in the meat cold chain from the point packaging through to retail. This study aims to quantify the environmental and economic impacts of such losses for beef and lamb. The main perspective is from retail back to farm production.

The study builds on previous work for WRAP (Whitehead et al., 2011) and a LINK research project on better packaging.

The environmental burdens considered are cumulative energy use and greenhouse gas (GHG) emissions (GHGE). The study uses the principles of Life Cycle Assessment (LCA) to derive the values reported here. These are thus cumulative values including all preceding steps at each stage. Hence, losses at retail require more farm production etc to replace losses.

Scope

The scope includes all activities up to the point of sale. How shoppers buy, store, cook and dispose of waste from the products was outside the scope Figure 1. The environmental burdens are related to 1 kg packed meat at the RDC. Beef and lamb were included using the same model, but with specific parameter values.

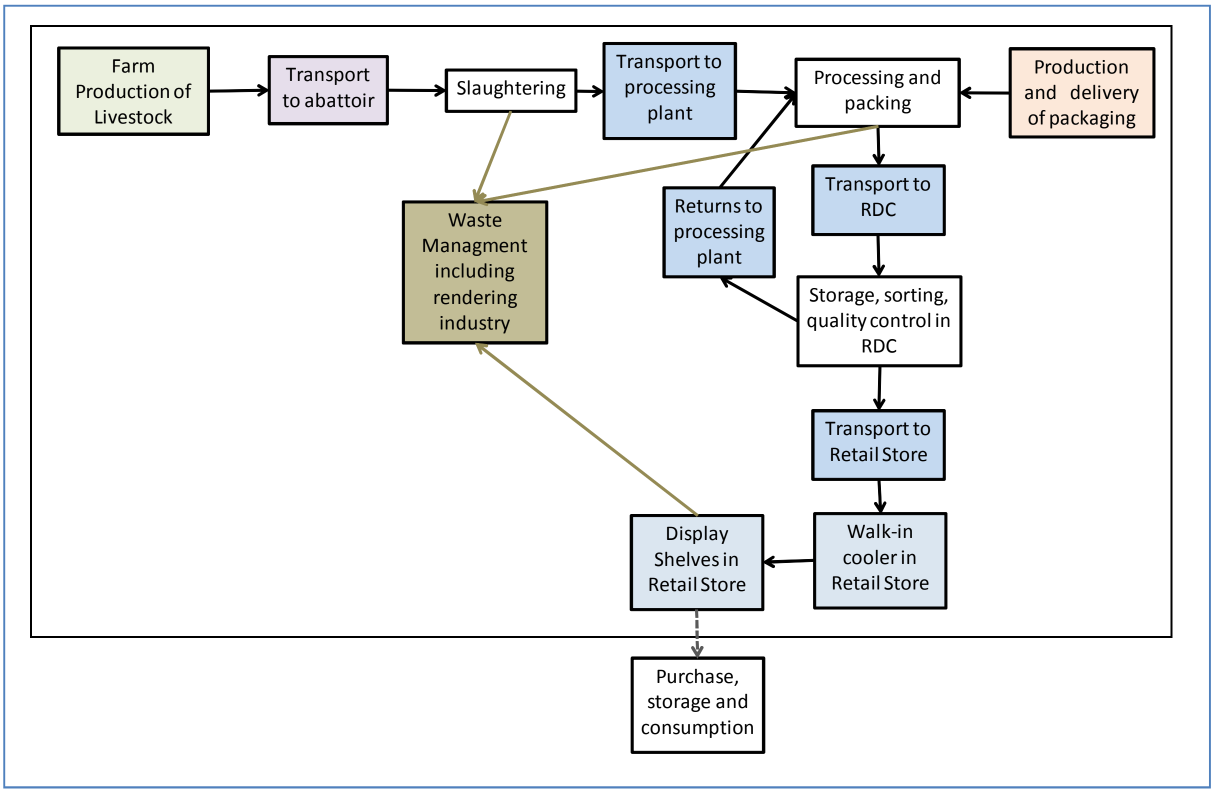

Figure 1 Boundaries of the study showing the processes included

Data sources

Data on farm production was from the Cranfield Agricultural and Horticultural Life Cycle Inventory, CAHLCI, (Williams et al., 2006[i]). Data on slaughtering, processing and packaging came from Whitehead et al. (2011), which was partly based on data and development of Cahlci). Energy use and GHGE from the RDC and retail stored were from the Brunel report for Defra on project FO0405 (Tassou et al., 2008[ii]). Wastage rates, prices, packaging weights and reasons for wastage came from the project team and were from a major retailer.

Assumptions

A variety of assumptions were needed to make the study feasible. These included the following.

- The uncertainties over the rendering industry as a whole are considerable. In Whitehead et al. (2011) it was considered that the industry as whole was neutral with respect to GHGE. This means that the net GHGE incurred from transport and processing are not statistically significantly different from the net benefits of the outputs, such as biofuels, pet food, oils and aggregates. The assumption about energy neutrality has been extended to the present study. The implication of this is that a small change in the total wastage that enters the national rendering stream is insignificant, except for an extra transport step.
- Average transport distances are assumed for all locations of the plants, centres and stores.
- All electricity used comes from the average national grid mix.
- The residence times for meat products in the RDC were those given by Tassou et al. (2008).
- The refrigerant used in mobile units and for retail display shelves is R404a (Tassou et al., 2008).
- Transport of animals and wastes is at ambient temperature, while transport from the abattoir onwards and returns from the RDC to the packing plant are refrigerated.
- No rejects of whole animals occur in abattoirs.

- The values for beef are based on the national mix of calves from the dairy and beef herds.
- The values for lamb are based on UK lamb only

Effects of rejects at the RDC

Is assumed that rejects are returned to the packing house and go into alternative sale or existing waste management steams. This is part off the baseline emissions from the whole rendering industry.

The reject rate (J) at the RDC (R) rate is J_R

J_R has two components of proportionality: discolouration (J_{RD}) and other reasons (J_{RO})

These can be classified in two parts: waste (J_{RW}) and resale (J_{RR}), i.e. J_{RW}=1-J_{RR}, through other routes.

More primary production is needed to supply needs where waste occurs, so all burdens nominally up to RDC are increased by a factor of 1+(J_R J_{RW})

Returns to packing house are assumed to be negligible with respect to transport burdens, because they are not waste and can be reloaded on to delivery vehicles.

The cost implications: borne by pack house, not retail, so the change in value cased by rejects at the RDC does not affect them.

Retail store rejects

If entering the waste stream, then all is assumed to go to the rendering industry. The only impact included is the transport of collection, which is a relatively small term. Other rejects are sold at a range of discount rates, and are assumed not to be wasted.

The reject (J) rate at the retail store (S) is J_S

J_S has two components: discolouration (J_{SD}) and other reasons (J_{SO})

These can be classified in two parts: waste (J_{SW}) and discounted resale (J_{SR}) (i.e. J_{SW}=1-J_{SR}) at the store. More primary production is needed to supply needs where waste occurs, so all burdens nominally up to retail store are increased by 1+(J_S J_{RW}). Transport for waste collection per unit weight of waste is scaled by (J_S J_{RW}).

The costs to the retailer and the loss of full price income from the fraction that is sold, but discounted and all the revenue of the fraction wasted plus the cost of paying the contractor to take it away.

The rejection rates were determined by the project team. At the RDC, the overall rejection rate is 4%, with an equal attribution to discolouration and other reasons. Expert opinion suggested that a further 2% was wasted in retail stores. From a survey of one week that was conducted by the project team, it was estimated that the wastage rates (J_{SW}) for beef and lamb were 0.8% and 1.7% respectively. These two values were used in baseline assessments. It is evident, however, that the variation across stores is considerable Table 1.

Table 1 Mean and range of wastage rates derived from a one week survey of seven stores in March 2011

	Beef	Lamb
Mean wastage rate, %	0.8%	1.7%
Range of 95% confidence interval (Assuming a normal distribution)		
Lower confidence limit (2.5%) *	-0.08%	-1.20%
Upper confidence limit (97.5%)	1.68%	4.60%

* Negative wastage rates are clearly impossible, this indicates the scatter in the data.

The reasons for waste are summarised in Table 2 and show that discolouration is a major factor, but stock being out of date was the largest single factor. Discolouration accounted for about a quarter of rejects.

Table 2 Reasons for waste from retail stores as % by weight

Reasons	Beef	Lamb
Not Discoloured		
Out of date	58%	44%
Out of temperature	2%	10%
Damaged	3%	6%
Sub-total	**64%**	**60%**
Discoloured		
No other factor	28%	24%
Out of date	7%	17%
Damaged	1%	0%
Sub-total	**36%**	**40%**

The combination of these two sets of values gives the parameter values for rejection (Table 3).

Table 3 Retail store reject parameter values

	Beef	Lamb
Reject for discolouration (J_{SD})	0.29%	0.69%
Reject for other reasons (J_{SO})	0.51%	1.01%
Reject rate to waste at shop is J_{SW}	0.80%	1.70%

No data were provided on the actual mark down rates used to sell "surplus" meat that is near its sell by date. As a starting point, it was assumed that was the same as the actual wastage rates and the effects of variation are examined later. Hence, the starting value for the values of J_{SR} were the same as for J_{SW} in Table 3, but this does not affect the environmental analysis anyway.

Results

Baseline burdens

The baseline analysis shows what the burdens are up the RDC and then to retail, assuming that no losses occur after packing the meat (Table 4). Activities up to the retail store dominate the burdens when no losses in the chain occur. These are broken down further in Figure 2 in which it is clear that primary production, i.e. farming, dominates the whole chain. Note that with the assumption of energy and GHGE neutrality in the whole rendering sector, this term exists, but has the value of zero.

Table 4 Baseline environmental analysis in which the energy use and GHGE are related to 1 kg meat sold

	Energy MJ/kg		GHGE, kg CO_2e/kg	
	Beef	**Sheep**	**Beef**	**Sheep**
Up to and including RDC,	49.2	34.4	18.7	17.8
Delivery to and activities in retail store,	4.3	4.3	0.7	0.7
Total energy	**53.5**	**38.7**	**19.5**	**18.5**

The baseline values were scaled by the annual UK sales to show the current annual total energy use and GHGE for lamb and beef (Table 5).

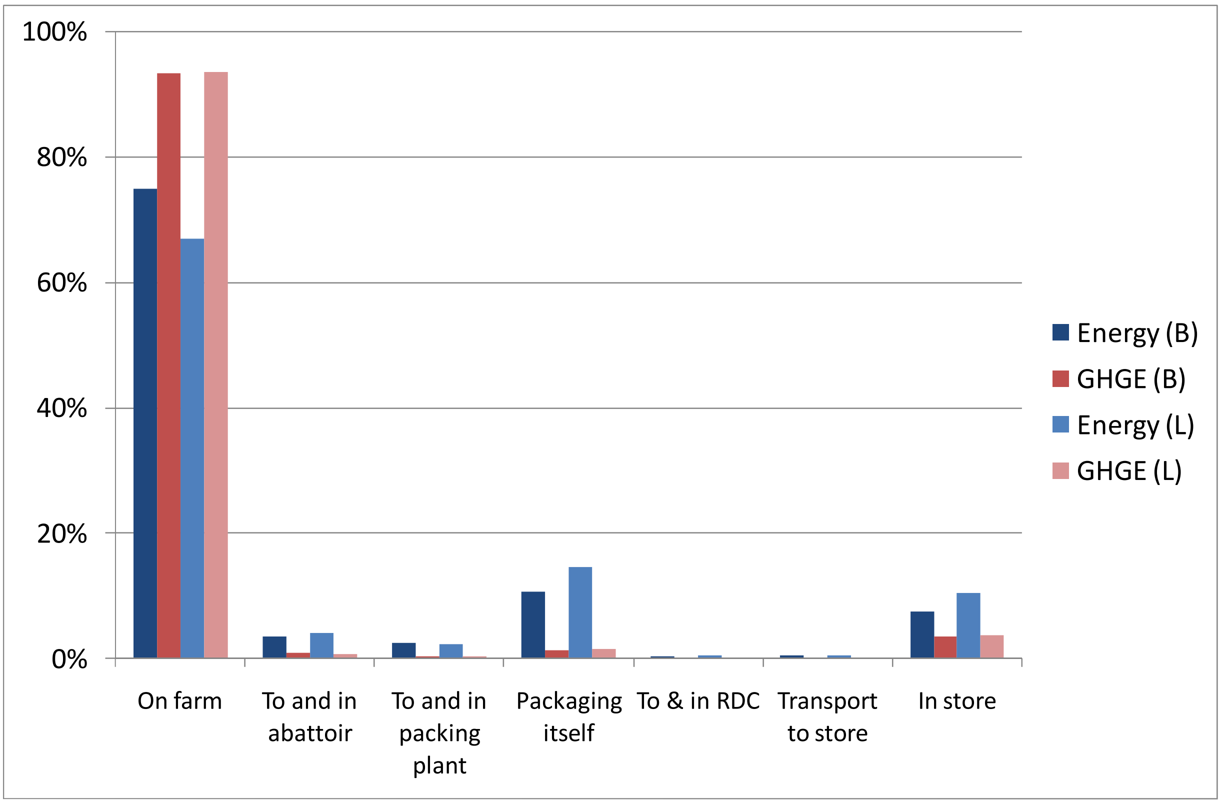

Figure 2 Breakdown of energy use and GHGE from farm to retail per kg meat sold

The breakdown of the embedded packaging energy and GHGE shows that expanded polystyrene base dominates (Figure 3). The same applies to both beef and lamb and is based on the data supplied by the major retailer, which showed that packaging was an average of 5% of the weight of the packed meat.

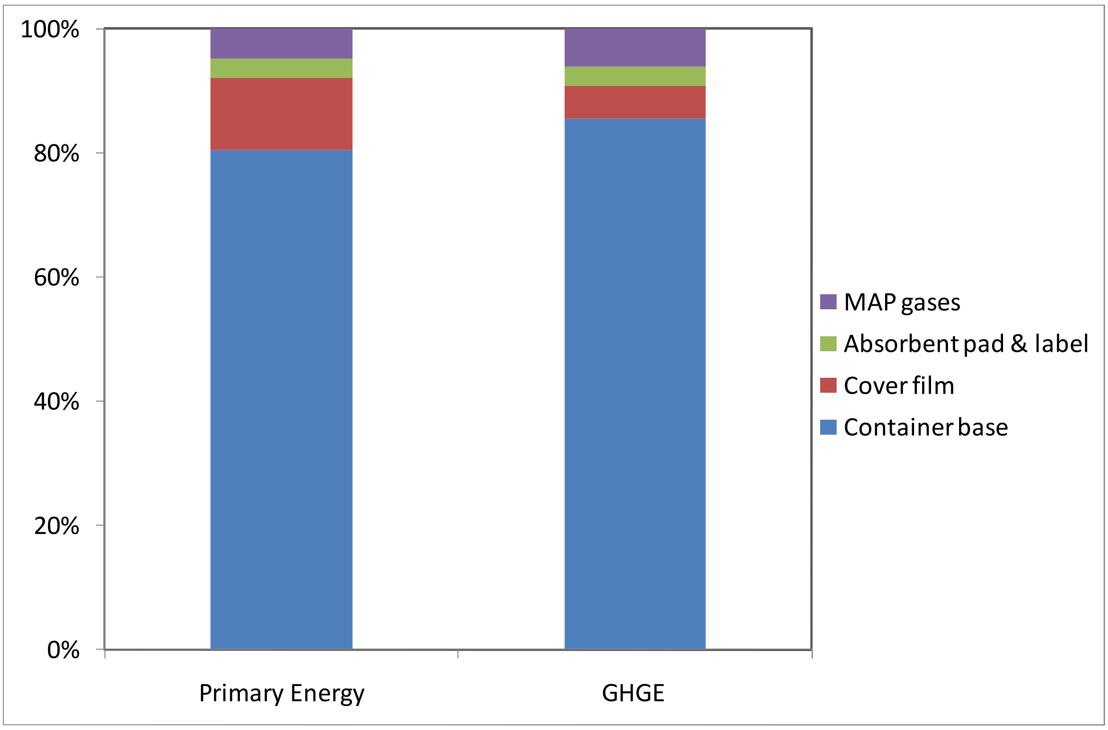

Figure 3 Breakdown on energy use and GHGE from meat packaging.

Table 5 Total baseline burdens from beef and lamb sales using the annual UK retail sales (Whitehead et al., 2011[iii])

	All UK Sales		10% of market share	
	Beef	Lamb	Beef	Lamb
Annual sales, t	379,000	95,000	37,900	9,500
Energy, TJ	20,295	3,680	2,030	368
GHGE, kt CO_2e	395	68	39	7
Notes: 1 TJ = 10^{12} J				
Source: W:\EBLEX\Packaging_Project\[WRAP_Meat_Main_1_EBLEX.xlsx]Tables for report				

Effects of wastage on environmental burdens

The main effect of wastage, for whatever reason, is the need to produce, process and deliver more meat, with a small extra term for waste collection. This is quantified in next section.

The results in Table 6 show how the current overall wastage rate at the RDC causes a higher increase in burdens than the current wastage rates at retail. The overall impacts for lamb are larger than beef, simply because the wastage at retail is higher. Because the effects of waste are closely related to the early dominant part of supply chain, the overall impacts of waste rates at the RDC or retail are similar to the increase in burdens caused by that rate.

The results in Table 6 are for all reasons of waste arisings, not just discolouration, which enhanced packaging should reduce. The values for wastage through discolouration only are in Table 7 and the effects are about half of the total. It should be noted that an important assumption here is that half of the RDC wastage through discolouration can be sold as human-edible food again. Those with more experience may be able to refine this estimate and hence revise the outcome.

The analysis does broadly indicate how much more burdens could go into packaging before having a negative effect on the whole chain. The current wasted energy from discolouration is about 85% of the current packaging energy for both beef and lamb, while the wasted GHGE are about 30%.

Table 6 Effects of the current rate of waste in the RDC and retail stores on overall burdens in the whole chain

	No waste	At RDC only	At RDC and store	No losses	At RDC only	At RDC and store
Wastage rates		**Beef**			**Lamb**	
Total reject rate at RDC		4%	4%		4%	4%
Rejects to waste		2%	2%		2%	2%
Rejects to resale		2%	2%		2%	2%
Total reject rate at store		0	0.8%		0	1.7%
Reject for discolouration		0	0.3%		0	0.7%
Reject for other reasons		0	0.5%		0	1.0%
Total Effect on whole chain to retail store		**Beef**			**Lamb**	
Total energy, MJ/kg	53.5	54.5	55.0	38.7	39.4	40.1
Total GHGE, kg CO_2e/kg	19.5	19.8	20.0	18.5	18.9	19.2
Increase in energy, MJ/kg		1.0	1.4		0.7	1.4
Increase in GHGE, kg CO_2e/kg		0.4	0.5		0.4	0.7
Increase in energy, %		1.8%	2.7%		1.8%	3.5%
Increase in GHGE, %		1.9%	2.7%		1.9%	3.7%

Source: W:\EBLEX\Packaging_Project\[WRAP_Meat_Main_1_EBLEX.xlsx]Tables for report

Table 7 Effects of the current rate of waste (through discolouration only) in the RDC and retail stores on overall burdens in the whole chain. Values are with respect to kg packed meat sold in retail, but including the weight of packaging.

	No waste	At RDC only	At RDC and store	No losses	At RDC only	At RDC and store
Wastage rates		**Beef**			**Lamb**	
Discolouration reject rate at RDC		2%	2%		2%	2%
Rejects to waste		1%	1%		1%	1%
Rejects to resale		1%	1%		1%	1%
Reject for discolouration at retail		0%	0.30%		0%	0.70%
Total Effect on whole chain to retail store		**Beef**			**Lamb**	
Total energy, MJ/kg	53.5	54.0	54.2	38.7	39.1	39.4
Total GHGE, kg CO_2e/kg	19.5	19.6	19.7	18.5	18.7	18.8
Increase in energy, MJ/kg		0.5	0.6		0.3	0.6
Increase in GHGE, kg CO_2e/kg		0.2	0.2		0.2	0.3
Increase in energy, %		0.9%	1.2%		0.9%	1.6%
Increase in GHGE, %		1.0%	1.3%		1.0%	1.7%

Source: W:\EBLEX\Packaging_Project\[WRAP_Meat_Main_1_EBLEX.xlsx]Tables for report

Time on retail shelves

The time during which meat is on display has an impact on the contribution of retail to the whole chain. Tassou et al (2008) suggested that the average residence time for meat on retail shelves was 24 h. If discolouration is reduced and shelf time is extended, then time on shelves or the walk-in cooler may be extended. This will increase energy use and GHGE. The impact of display shelf refrigeration has a relatively high impact on GHGE compared with energy use. This results from the leakage of refrigerant. It has been assumed here that R404a is used and it has the same leakage rates as Tassou et al (2008) noted. The effects differ considerably between time spent in the store's walk-in cooler and display shelves. Display shelves used more energy per unit weight and time than walk-in stores. Walk-in stores also use more benign refrigerants and leak less. The effects show that doubling the residence time on retail shelves has an effect of similar magnitude to the maximum for current waste rates (Figure 4). Hence, if increased residence time is a consequence of better packaging, it needs to be managed carefully and there is scope for optimisation to reduce impacts. The analysis applied here was relatively simplistic in that a uniform stocking and sale rate was assumed. There could be many different rates, which could have contrasting effects.

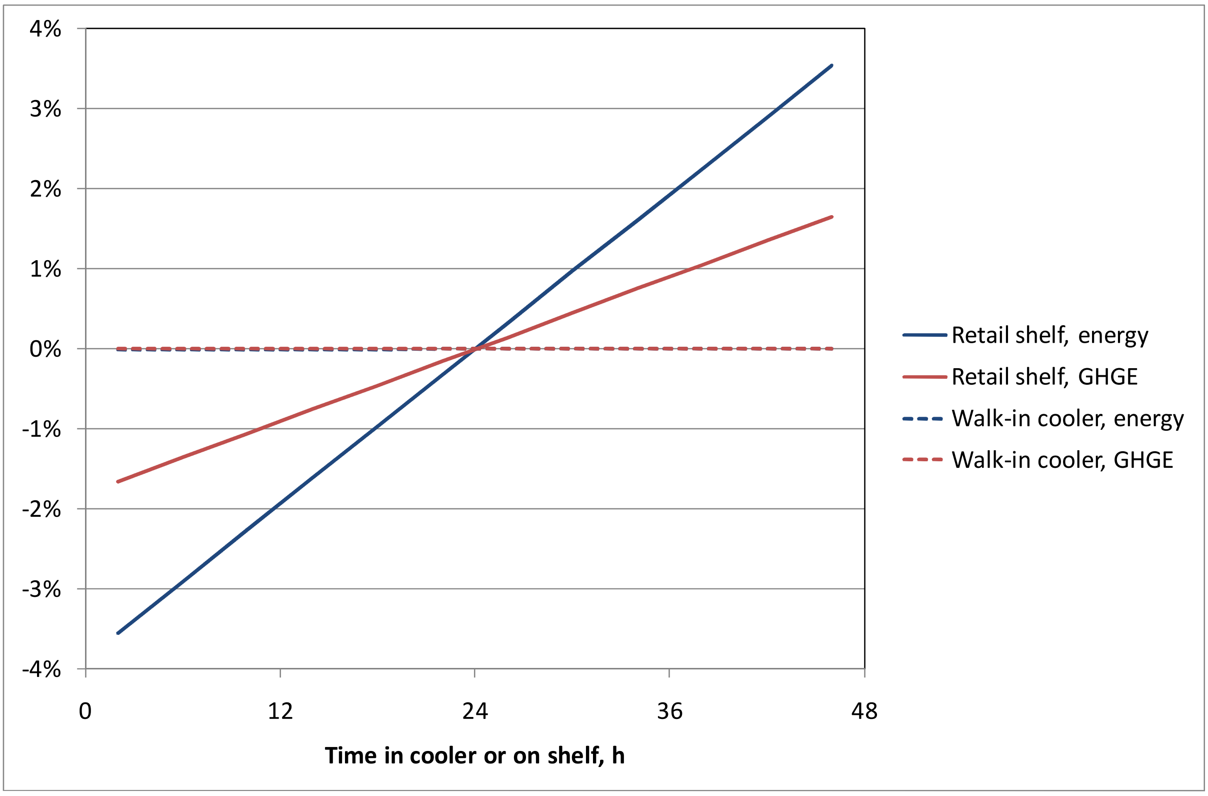

Figure 4 Effect of changing average residence time of meat in a walk-in cooler or a retail display shelf on changes in the overall burdens of the supply chain.

Economics at retail

The data from the major retailer were averaged to get the full retail sales price for beef, before any discounting occurred. The average price for beef was about £8.25/kg and £12.70 for lamb. The cost of waste collection was £104/t. The mark down process in store is first a 20% first mark down then a 50% at a second period in the day, stores have the facility to also mark the product down away from the % guidelines. This was implemented with estimates of the distribution of marked down prices (Table 8). The overall effect is a loss of revenue of £7.43 for lamb and £5.31 for beef, of which waste disposal is a small fraction.

Table 8 Mark down rates and effect on loss of income, with worked example for beef, assuming that the wastage rate equals the rate of total marking down

	Mark down rate	Price sold per kg	Lost income per kg	Proportion at each reduced price	Income loss, £
Full retail price, £/kg		£8.25	£0.00		
1st mark down rate	20%	£6.60	£1.65	17%	£0.28
2nd mark down rate	50%	£4.13	£4.13	17%	£0.69
3rd mark down rate	75%	£2.06	£6.19	17%	£1.03
To waste	100%	£0.00	£8.25	50%	£4.13
Waste collection cost (i.e. a negative income loss)			£104.00		£0.05
Total loss per kg marked down or wasted at retail					**£6.17**

It is evident that a more useful result could be obtained with more data on the proportions of mark down rates. These probably vary with the time year and external factors, such as weather. A range may be more suitable.

One feature of waste in the supply chain is that more production is needed and more processing etc. This is bad environmentally, but does provide revenue for the players in the chain, unless some form of penalty is applied. The farmer's share of the retail price is about half (Defra, 2011[iv]). So, in the example in Table 8, the loss at the store of £4.13 is matched by a potential farm income of about £2.06.

Household waste

Although outside the scope of this study, it is worth noting that reducing discolouration is likely to extend the storage life of meat in the home (or indeed the food service sector). The full benefit of this per unit weight not wasted will be greater than at retail, because it will have included the purchase effort (typically some road fuel) and an allocation of refrigeration energy. A separate study on understanding the reasons for domestic waste of meat and quantifying the arisings would be needed to deliver reliable results.

Conclusions

These are provisional conclusions.

- The effects of wastage of beef and lamb at the RDC and retail stores have been estimated.
- The effects have been quantified as wasted total energy and greenhouse gas emissions per unit weigh sold. The loss of revenue has also been estimated.
- The wastage rates are relatively low, especially at retail, particularly for waste through discolouration, which was a reason for the study.
- Various assumptions were needed to produce the baseline estimates and explore some scenarios. Feedback on these is requested, so that more reliable calculations can be made.

- No alternative techniques have been suggested yet, so these can only be analysed with more data on the alternatives.
- The embedded energy in packaging materials is quite high. Light-weighting may be beneficial if current discolouration rates are not made worse.

References

[i] Williams, A.G., Audsley, E. & Sandars, D.L. (2006) Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Final report on Defra funded project IS0205, www.agrilca.org Accessed 4-Nov-2011

[ii] Tassou, S. et al. (2008) Greenhouse Gas Impacts of Food Retailing. Final report to Defra on Project FO0405. http://preview.tinyurl.com/6hbmbzz Accessed 4-Nov-2011

[iii] Whitehead, W. ., Palmer, M., Mena, C., Williams, A.G., Walsh, C (2011) Resource Maps for Fresh Meat across Retail and Wholesale Supply Chains. Final report to WRAP on Project RSC009. http://preview.tinyurl.com/3pronn2 Accessed 4-Nov-2011

[iv] Defra (2011) Agriculture in the United Kingdom 2010 Table 7.2, http://preview.tinyurl.com/63mtf9b Accessed 4-Nov-2011