Scottish Natural Heritage
Archive Report No. 024

Life cycle assessment of Scottish wild venison

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ARCHIVE REPORT

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Life cycle assessment of Scottish wild venison

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This report should be quoted as:

Natural Capital Ltd. 2009. Life cycle assessment of Scottish wild venison. *Scottish Natural Heritage Archive Report No. 024.*

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ARCHIVE REPORT

Summary

Life cycle assessment of Scottish wild venison

Archive Report No. 024
Funded by the Deer Commission
Contractor: Natural Capital Ltd.
Year of publication: 2015

Keywords

Deer; venison; carbon; footprint; carbon footprint.

Background

This report was originally commissioned by the Deer Commission for Scotland prior to merger with Scottish Natural Heritage. Its aim is to explore the carbon footprint of venison, breaking it down into its constituent parts.

In recent years a number of carbon footprint studies have been carried out for food products. Research has also been carried out by researchers in New Zealand to determine the carbon footprint of delivering agricultural products to UK markets.

The study represents the first steps in:
- scoping out the carbon footprint of wild venison
- carrying out some initial calculations to establish a footprint using the PAS 2050 methodology

In brief, the assessment covers the following stages of the life cycle of venison:
- production at the estate level
- transport to the processing plant
- processing
- this study does not extend to an assessment of the GHG emissions after the processing stage

Main findings

- The results indicate that wild venison compares very favourably with agricultural meat produce. It is estimated that the carbon footprint of wild venison is approximately 38% lower than beef and 49% lower than lamb.
- From the data collected in the present study the total average footprint of wild venison was calculated to be 12,523 kgCO_2e/tCW. Approximately 93% of the total footprint can be attributed to the estate stage. This is primarily because deer produce large quantities of methane.
- Emissions of methane (associated with digestion and the decomposition of manure) appear to make up the greatest proportion of the overall footprint, accounting for approximately 76% of overall emissions.

- At the estate level, direct fuel use for vehicles and machinery accounts for 15% of the footprint.
- On average, upland deer management estates appear to have a lower carbon footprint per tonne of carcass weight produced compared to woodland estates.

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1 EXECUTIVE SUMMARY

1.1 INTRODUCTION

The Deer Commission Scotland recognises the increasing importance of the need to address climate change issues and in particular the significance of the recent Climate Change (Scotland) Act, the ambitious target set of achieving an 80% reduction in greenhouse gas emissions by 2050, and the duty on public bodies to contribute towards these reductions and play a leadership role.

With environmental issues now high on the public agenda, consumers are increasingly demanding information over the products they buy. By demonstrating the sustainability merits of their products, companies can improve consumer satisfaction.

Carbon footprinting is a method used to measure the total amount of carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions for which a product is responsible. Measuring the carbon footprint of wild venison is the first step towards identifying opportunities for reducing its environmental impact and contribution to climate change.

In recent years a number of similar carbon footprinting studies have been carried out for food products, including a study commissioned by HIE into the carbon footprint of Highland and Island agricultural produce (milk, beef, and lamb). Research has also been carried out by researchers in New Zealand to determine the carbon footprint of delivering agricultural products to UK markets.

The British Standards Institute has recently developed a carbon footprinting standard (PAS 2050) to allow a consistent method for assessing the life cycle greenhouse gas emissions of products. The present study represents the first steps in:

- scoping out the carbon footprint of wild venison;
- carrying out some initial calculations to establish a footprint using the PAS 2050 methodology; and
- making recommendations for both reducing the footprint and for further follow up research.

1.2 SCOPE OF THE FOOTPRINT

In brief, the assessment covers the following stages of the life cycle of venison:

- Production at the estate level
    - Includes for example: fuel use for vehicles and machinery; energy use in buildings; cold storage in larder; and methane production
- Transport to the processing plant
    - Fuel use associated with the collection of carcasses from various estates across Scotland and transportation to the processing plant
- Processing
    - Production of the final venison product involves: energy use in lighting and buildings; water consumption; cold storage; disposal of waste

This study does not extend to an assessment of the GHG emissions after the processing stage, and does not therefore include emissions associated with the distribution of the product to wholesalers or retailers or emissions associated with transport to end consumer and use.

1.3 METHODS USED

Four deer management estates were surveyed as part of this scoping study, including two upland estates and two woodland estates. The survey also included a venison processor to gather data covering haulage of carcasses to the processing plant and production of the final venison product.

Emission factors were used to convert activity data from the cases studies (e.g. kWh of electricity used) into the resulting GHG emissions. These factors were obtained from a variety of sources, including DEFRA, Water UK, National Atmospheric Emissions Inventory, and the Carbon Trust. The equation for carbon footprinting is the sum of all materials, energy, waste, and other processes across all activities in the product's life cycle multiplied by their emission factors.

1.4 RESULTS

An overall summary of results is captured in the following table:

Table 1.4 Summary of Emissions at each Stage of the Life Cycle

Life Cycle Stage	Carbon Emissions ($kgCO_2e$/t CW[1])	Proportion of Footprint
Estate level	11,716	93%
Transport to Processor	327	3%
Processing	480	4%
Total Footprint	**12,523**	**100%**

The total average footprint of wild venison is estimated from data generated in this study to be 12,523 $kgCO_2e$/tCW. Approximately 93% of the total footprint can be attributed to the estate stage, 3% to the transportation stage, and 4% to the processing stage.

It is emissions of methane, produced as a by-product of digestion (enteric fermentation) and the decomposition of manure, that make up the greatest contribution to the carbon footprint of venison, accounting for approximately 76% of overall emissions.

At the estate level, direct fuel use for vehicles and machinery was also found to account for a not-insignificant proportion of the footprint (15%).

At the processing stage, it is the consumption of electricity that accounts for the majority of greenhouse gas emissions (approximately 83%). Natural gas, used for heating, is also a significant contributor, making up around 9% of the footprint during processing, while the generation and disposal of waste is estimated to account for 7% of emissions at this stage.

1.5 RECOMMENDATIONS

This study is the first attempt at establishing a carbon footprint for wild venison in Scotland and as such provides a useful start in:

- establishing boundaries and the scope of the footprint;
- obtaining preliminary data from representative estates;

[1] CW = Carcass Weight

- gaining insights into the composition of the footprint and areas for attention;
- establishing some initial thoughts on ways of reducing the footprint.

Some of the potential options for mitigating the impact of greenhouse gas emissions generated during the process stages investigated in this study include:

- improved energy management (e.g. use of renewable energy);
- reducing emissions from fuel use and improved fleet management;
- management of land for carbon sequestration;
- reducing emissions of methane;
- improved waste management and resource efficiency (e.g. reducing packaging materials);
- implementation of water efficiency measures; and
- supply chain management and good communication between dealers and estates.

Although it is beyond the scope of this study to cover in detail activities at the estate level that relate more to the wider issues of stalking and deer management (rather than food production) a number of suggestions have been put forward for reducing fuel use, including:

- encouraging a return to the traditional use of ponies to extract deer from the hillside;
- reducing the use of helicopters for deer counting and counting on foot instead; and
- generally using more fuel-efficient vehicles.

2 INTRODUCTION

2.1 DEER COMMISSION SCOTLAND

The Deer Commission for Scotland (DCS) is a Non–Departmental Public Body established by the Deer (Scotland) Act 1996. DCS is charged with furthering the conservation, control and sustainable management of wild deer in Scotland, and keeping under review all matters relating to deer, including their welfare. The management of deer is complex and multi-faceted, interacting with all principal rural land uses.

2.2 BACKGROUND TO CLIMATE CHANGE

Climate change is increasingly recognised as a major challenge. It is widely accepted that the greenhouse gas emissions caused by humans are having a negative impact on the environment.

The most important greenhouse gas arising from human activity is carbon dioxide (CO_2). Virtually all human activities cause CO_2 emissions that lead to climate change. By using electricity generated from fossil fuel power stations, burning gas for heating, or driving a petrol or diesel car, every person is responsible for CO_2 emissions. Furthermore every product or service that humans consume indirectly creates CO_2 emissions in that energy is required for their production, transport and disposal. These products and services may also cause emissions of other greenhouse gases. Understanding and addressing the full range of our impact is crucial for the effects of climate change to be minimised.

2.3 WHAT IS CARBON FOOTPRINTING?

The term **carbon footprint** is commonly used to describe the total amount of CO_2 and other greenhouse gas (GHG) emissions for which an activity or product is responsible. This is usually measured in units of carbon dioxide equivalent (CO_2e) to allow for easy comparison with other products.

The full footprint of a product encompasses a wide range of emissions sources from direct use of fuels to indirect impacts such as emissions from other organisations up and down the supply chain. When calculating a product's footprint it is important to try and quantify as full a range of emissions sources as possible in order to provide a complete picture of the product's impact.

The British Standards Institute has recently developed a carbon footprinting standard (PAS 2050)[2] for DEFRA and the Carbon Trust to allow a consistent method for assessing life cycle GHG emissions of goods and services. Natural Capital adheres to the standard for our carbon footprint and accounting projects.

2.4 WHY ASSESS THE CARBON FOOTPRINT OF WILD VENISON?

DCS recognises the importance of addressing climate change and in particular the significance of the recent publication of the Climate Change (Scotland) Bill and the ambitious target set of achieving an 80% reduction in greenhouse gas emissions by 2050. DCS also recognises its responsibilities as a public body to show leadership in the way that it can contribute to the sustainability agenda.

The food industry is a significant contributor to carbon emissions and there is an increasing demand from consumers for environmental information about food

[2] Guide to PAS 2050:2008. How to assess the carbon footprint of goods and services. British Standards Institute. October, 2008

production and supply. There is a significant market advantage for companies that can demonstrate the sustainability merits of their products.

An assessment of the carbon emissions associated with wild venison production will provide:

- where appropriate, robust information to allow the industry to promote wild venison as an 'environmentally friendly' food;
- recommendations for improvements to production and supply to reduce environmental impacts.

This carbon footprint study also links with DCS's Wild Deer Strategy – *Scotland's Wild Deer – A National Approach (2008).* This document sets out a vision and objectives for the management of wild deer in Scotland in a way that will contribute to a high quality environment, sustainable economic development and social well-being. There are two strategic objectives in particular that are closely related with this study; these are to:

- **help tackle and adapt to the effects of climate change** – this includes appropriate land management practices to maintain vegetation cover and soil quality in order to enhance carbon storage;
- **develop the market and supply chain for venison** – this includes supporting marketing initiatives to promote venison as a high quality and environmentally-friendly food.

2.5 RECENT SIMILAR CARBON FOOTPRINTING STUDIES

2.5.1 HIE Carbon Footprint of Agricultural Produce

In 2008 Highland and Island Enterprise (HIE) commissioned a study to assess the carbon footprint of three key regional agricultural products – milk, beef, and lamb[3]. The study broadly follows the BSI carbon footprinting methodology (PAS 2050) and covers the following areas of the supply chain: production at the farm level; haulage from farm to processor; processing; and haulage to a centralised depot.

The study found that these three products are each responsible for a significant amount of greenhouse gases. Overall, by far the greatest amount (over 90%) of emissions occurs at the farm stage of each supply chain. The production of milk, beef, and lamb by ruminants results in the production of large emissions of methane and nitrous oxide, which are potent greenhouse gases.

The results of the HIE study are summarised in Table 2-1 below.

Table 2-1 Carbon Footprint of Highlands and Islands Agricultural Produce

Stage	($kgCO_2e$/t milk solids)	($kgCO_2e$/t carcass weight)	
	Dairy	**Beef**	**Lamb**
Farm/Estate level	12,007	20,171	23,583
Transport to processor	57	7	6
Packaging	169	15	15
Processing (incl. waste)	979	204	1,093
Distribution	34	145	17
TOTAL	**13,246**	**20,542**	**25,614**

[3] Bevan, K. (2008) *Comparing the carbon footprint of Highlands and Islands agricultural produce and its domestic and international competition.* Highlands and Islands Enterprise

The study identified a number of options for reducing greenhouse gas emissions from agriculture. These are focused primarily at the farm level and include: improving the productivity of current systems; better energy management; changing systems and livestock numbers; better manure storage and handling; management of carbon sinks and emissions trading.

2.5.2 DEFRA Report on the LCA of Agricultural and Horticultural Commodities[4]

This research commissioned by DEFRA assesses the environmental burdens and resource use involved in producing agricultural and horticultural commodities using the principles of Life Cycle Assessment. The study includes an assessment of the GHG emissions associated with producing agricultural products. The research found that most GHG emissions from agriculture come from Nitrous Oxide (N_2O), with substantial contributions from methane gas. This contrasts with most other industries and domestic activity where CO_2 from fuel use is dominant.

2.5.3 Food Miles and Carbon Footprinting of New Zealand (NZ) Agricultural Produce

In response to consumer concern over food miles and associated environmental impacts, researchers at Lincoln University used life cycle assessment to determine the carbon footprint of delivering agricultural products to UK markets[5]. The study covered emissions from direct energy use on farm-site (e.g. diesel, petrol, electricity, etc), emissions associated with the use of agrichemicals and supplementary animal feed, energy embodied in capital items such as tractors, and emissions associated with shipping produce from NZ to the UK and storage.

The study found that, due to the different production systems, even when shipping was accounted for NZ dairy products used half the energy of their UK counterpart and in the case of lamb a quarter of the energy. In the case of apples the NZ source was 10 per cent more energy efficient. In the case of onions whilst NZ used slightly more energy in production the energy cost of shipping was less than the cost of storage in the UK making NZ onions more energy efficient overall.

2.5.4 PepsiCo and Walkers Crisps

The Carbon Trust has recently developed a Carbon Reduction Label to allow a business to demonstrate its commitment to reducing the carbon emissions of products as well as helping consumers to make informed decisions about the products that they buy. Companies are required to follow the BSI standard for carbon footprinting (PAS 2050).

In 2006, the Carbon Trust worked with a variety of companies to test the Label and inform its development, as well as assess the impact product carbon footprinting can have on businesses' commercial and environmental goals. Walkers were one of the first companies to undertake a study of the carbon footprint of a product (crisps) across the entire product life cycle, from raw materials to manufacture and packaging through to disposal of the crisp bag. The life cycle of the product was broken down into the following stages:

1. raw materials: potatoes, sunflowers and seasoning;
2. manufacture: producing crisps from potatoes;
3. packaging of crisps;

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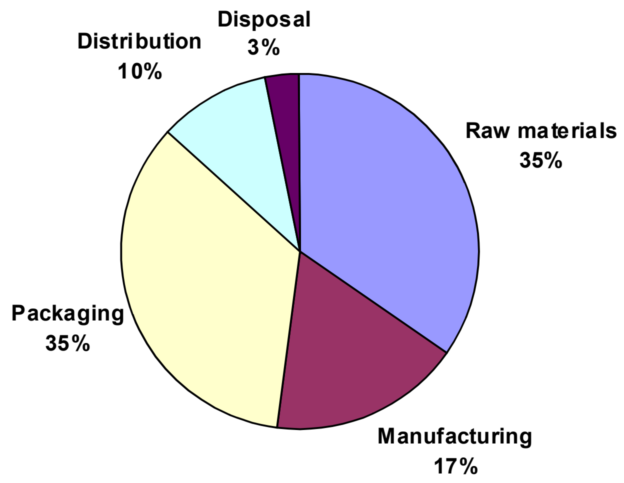
[4] Williams, A.G., Audsley, E. and Sandars, D.L. (2006) Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main Report. DEFRA Research Project IS0205. Bedford: Cranfield University and DEFRA. Available on www.silsoe.cranfield.ac.uk, and www.DEFRA.gov.uk

[5] Saunders, C., Barber, A., & Taylor, G. 2006. Food Miles – comparative energy/emissions performance of New Zealand's agricultural industry

4. distribution to customer; and
5. disposal of the empty packs.

This study found that the majority of Walkers crisps footprint lay outside of its direct control, primarily in raw materials. Figure 2-1 shows the percentage of the carbon footprint expended at each stage of the product life cycle. This understanding has led to a series of initiatives with suppliers and distributors to identify the root causes of high emissions and opportunities to reduce them. Over the past two years, Walkers have achieved a 7% reduction in the amount of CO_2 produced per standard bag (a standard bag of Walkers crisps is 80 gCO_2)[6].

Figure 2-1 Walkers Crisps: the Percentage of the Carbon Footprint Expended at Each Stage[5]



Walkers also commissioned customer research to test consumer reactions to the Carbon Reduction Label. It was found that consumer awareness is rising and attitudes toward the Label are generally positive. Of those surveyed:

- 79% agree with the statement: "it makes me more aware of the environmental impact of the products and services I choose to buy";
- 71% agree that the Carbon Reduction Label: "helps me to reduce the carbon footprint of my regular shopping items"[10].

2.5.5 Example Carbon Footprints

- in 2006 the UK produced 554 million tonnes of CO_2 - around 9 tonnes for every person[7]. In comparison emissions in India are about 1 tonne of CO_2 per person[8];
- an average household uses about 4,300kWh of electricity each year. This results in emissions of over 2 tCO_2 per household, or 750kg per person[9];
- the carbon footprint of a return flight from Edinburgh to London generates approximately 420 $kgCO_2$[10] per passenger;
- a return trip by train from Edinburgh to London generates approximately 80 $kgCO_2$ per passenger;
- the carbon footprint of Tesco 100% Pure Squeezed Orange Juice is 360g CO_2 per 250ml serving[11].

[6] http://www.walkerscarbonfootprint.co.uk/walkers_carbon_trust.html (accessed 5/05/09)
[7] Energy Saving Trust http://www.energysavingtrust.org.uk/
[8] CAT Centre for Alternative Technology http://www.cat.org.uk
[9] CAT Centre for Alternative Technology http://www.cat.org.uk
[10] http://www.co2balance.com/

3 METHODOLOGY

3.1 INTRODUCTION

The methods used in undertaking this carbon footprinting exercise were based on PAS 2050 (see Section 2.3) and followed a structured sequence of stages as follows:

- defining the functional unit;
- building a process map;
- setting the boundary and scope of the footprint;
- data gathering;
- calculating the footprint.

3.2 DEFINING THE FUNCTIONAL UNIT

The appropriate functional unit is determined by how the product is typically consumed by the end user (e.g. 250 ml of a soft drink or 1,000 hours of light from a light bulb). To express the environmental impact of wild venison a suitable functional unit must be used. In this case the functional unit must cover both the production and processing stages of the chain. For this study it was decided that the carbon footprint of wild venison would be expressed per tonne of dressed carcass weight (t CW).

3.3 BUILDING A PROCESS MAP

In order to calculate the carbon footprint of a product it is necessary to first build a process map of the product's life cycle. The goal of this step is to identify all materials, activities and processes that contribute to the chosen product's life cycle.

Natural Capital held an initial brainstorming session with DCS to build a high-level process map that was then refined through desktop research and discussions with deer managers and venison processors. Figure 3-1 shows the process mapping for wild venison.

The following stages have been identified in the life cycle of wild venison:

1) Deer Management
This includes, for example, activities such as deer counting, culling, fencing, and habitat management. Deer management involves the use of fuel for vehicles and machinery, the use of some raw materials, energy usage in any administration buildings, and the generation of waste materials.

2) Stalking and Extraction
This stage involves the shooting of deer and then extracting the carcass from the land. Inputs to this stage are vehicle fuel use for transporting the stalker(s) to site and transportation of carcass to the larder.

3) Storage at the Larder
The carcass is dressed and stored in the larder. Most larders have cold storage facilities and this will consume energy. Other processes at this stage include water usage for washing and cleaning and the generation of waste materials.

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[11] Carbon Trust http://www.carbon-label.com

4) Processing

The venison dealer collects the carcasses from various estates around Scotland and transports them to the processing plant. At the processing plant the carcasses are processed to produce the venison product. This stage involves the storage of carcasses in refrigeration units, energy use in lighting and heating buildings, water consumption, and the generation and disposal of waste materials.

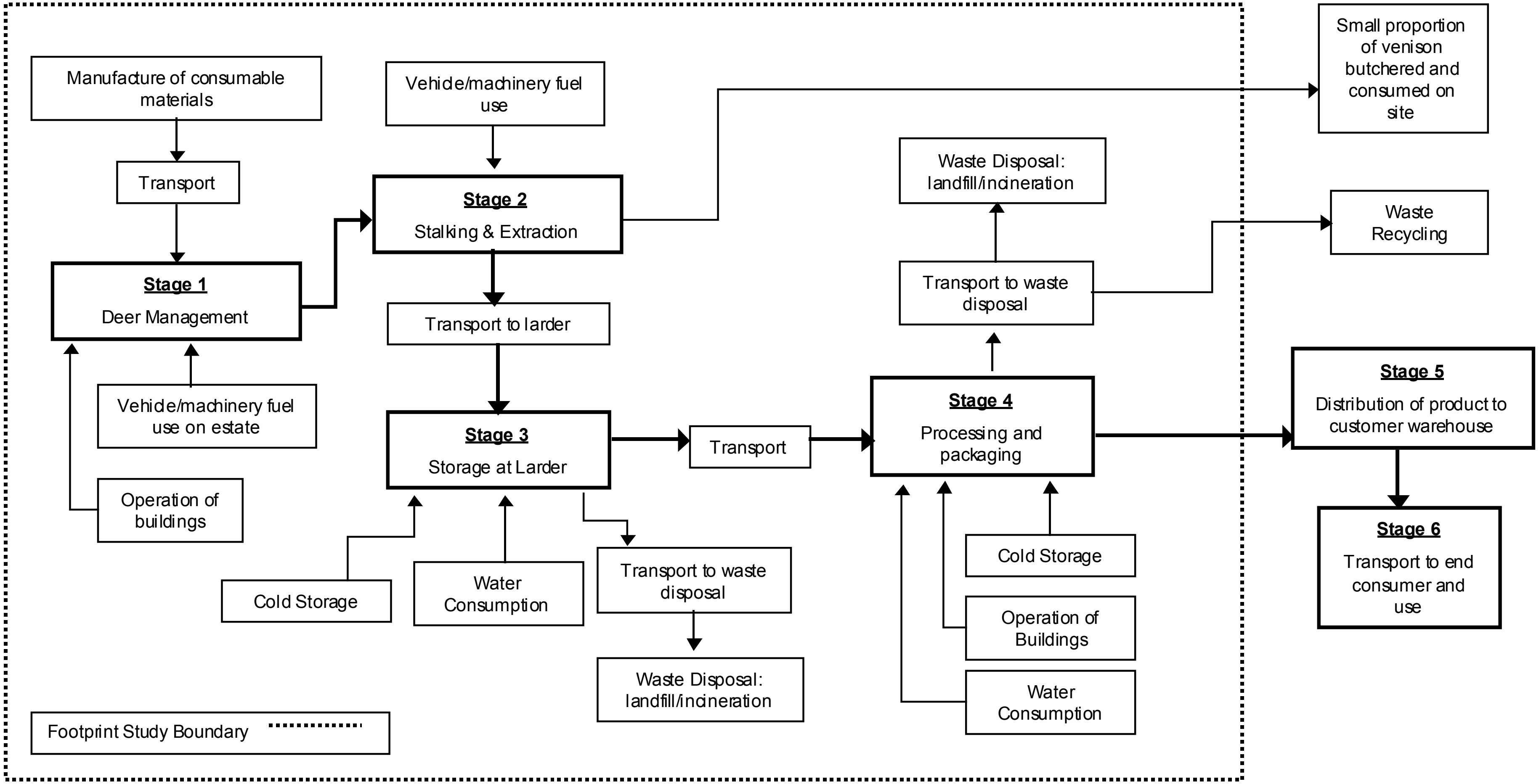
5) Distribution of Product to Customer Warehouse

The product is distributed from the processing plant to various wholesalers and retailers.

6) Transport to End Consumer and Use

This stage involves transportation of the product from retailer or wholesaler to end consumer as well as final use and disposal of the product.

Figure 3-1 Process Mapping for Scottish Wild Venison



3.4 BOUNDARY AND SCOPE OF THE STUDY

The system boundary defines the scope for the product carbon footprint, i.e. which life cycle stages, inputs and outputs are included in the assessment. It is important to set boundaries for a study of this kind in order to:

- describe clearly what is included and what is not;
- enable a clear understanding of the scope of the research; and
- allow better comparability between similar studies.

The following sections describe the boundaries of the study and the rationale as to its overall scope.

3.4.1 Emissions at the Estate Level

This part of the study considered emissions arising from deer management activities at the estate level. This relates to stages 1-3 in the life cycle of wild venison as outlined above in the process map.

Emissions are normally grouped into two broad categories: direct emissions and indirect emissions. This classification reflects the level of control the producer has over those emissions.

Direct Emissions

Most commonly, direct emissions will result from combustion of fuels that produce CO_2 emissions. This includes the most obvious forms of energy used in deer management - diesel, petrol, and burning oil (kerosene). Natural Capital obtained the annual usage of these inputs from estate manager records. Private use of these inputs (i.e. for domestic buildings) was deducted.

Many estates employ contractors to carry out activities such as track maintenance, deer counting, and fencing. Fuel use by contractors is significant on many estates and varies with the type of operations performed. This input may vary considerably from year to year depending on requirements and budgetary considerations. For some operations the contractor uses the estate's fuel and so this is covered by the estate's fuel records. In most cases, however, the contractor provides the fuel. Details of the contracting operations were noted by Natural Capital so that an estimate of fuel use could be obtained based on industry standards.

Indirect Emissions

These emissions arise as a consequence of activities associated with the product but occur from sources not directly controlled by the estate. Purchased electricity is one of the main sources of indirect emissions. Electricity generation comes from a range of sources, including nuclear and renewables. In the UK around 75% of electricity is produced from the combustion of fossil fuels[12]. In Scotland approximately 20% of electricity is generated from renewable sources[13]. Although the organisation is not directly in control of the emissions, by purchasing the electricity it is indirectly responsible for the release of greenhouse gases.

Other key indirect sources of emissions at the estate level include: water supply, the purchase and transport of consumable materials, and the transport and disposal of waste materials.

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[12] www.carbontrust.co.uk
[13] http://www.scotland.gov.uk/About/scotPerforms/indicators/electricity

Methane Emissions

Methane is produced by herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by microorganisms. Methane is also produced from the decomposition of manure under anaerobic conditions.

For the purposes of this study, emission factors are taken from the National Atmospheric Emissions Inventory[14], which is based on IPCC guidelines. Table 3-1 below presents methane emission factors for livestock emissions, including: dairy breeding herd; beef herd; pigs; sheep; goats; horses; deer (stags and hinds); deer (calves); and poultry. It is noted that methane emissions from deer are low relative to cattle and are comparable to sheep.

Table 3-1 Methane Emission Factors for Livestock Emissions (adapted from Table A 3.6.2 NAEI)

	Enteric Methane ($kgCH_4$/head/year)	Methane from Waste ($kgCH_4$/head/year)
Dairy Breeding Herd	115	13.0
Beef Herd	48	2.74
Pigs	1.5	3
Breeding Sheep	8	0.19
Goats	5	0.12
Horses	18	1.4
Deer (stags & hinds)	10.4	0.26
Deer (calves)	5.2	0.13
Poultry	0	0.078

The above figures are for farmed animals in the UK. Methane emission factors for wild deer were not found during this research, and for the purposes of this study figures for farmed deer were used as the most reliable estimate available. A number of points should be noted here:

- methane emissions are lower in younger animals; the figure given above for calves is 50% of that for stags and hinds;
- diet (i.e. type of forage and quantity of food eaten) is likely to be one of the main influences on methane emissions. It is possible that wild deer could produce more methane than farmed deer because of the differences in diet and because the diet of wild deer might be of a lower quality with possibly a higher fibre content. In addition, deer on poor quality diets would need to consume greater amounts of food to reach a given live weight. For these reasons it is possible that wild deer could produce more methane than farmed deer, however this is clearly highly complex and would need further detailed research to provide the answers;
- it is also likely that larger animals will consume more food and would therefore be likely to produce more methane. This would therefore need to be taken into consideration when comparing woodland and upland estates, since the larger red deer are mostly found on upland open hill whereas the smaller roe deer are mainly found on woodland estates; and

[14]NAEI, UK Greenhouse Gas Inventory 1990 to 2007: Annexes, National Atmospheric Emissions Inventory. http://www.naei.org.uk/reports.php?list=GHG (accessed 8.10.09)

- in comparing methane emission factors contained in the UK inventory on emissions (NAEI) with the New Zealand Inventory[15], it was found that the value given for farmed deer in the UK is approximately 50% of that given for farmed deer in New Zealand (found to be on average approximately 22 kg CH4/head/year[16]). In fact more recently it has been suggested that the value for farmed deer in New Zealand may go up to 24.2 kg CH4/head/year[17]. It has not been possible to clearly determine the reasons for these differences but it is anticipated that they are likely to relate to several possible factors such as for example the size of deer, their diet and the amount of feed given to them.

Methane emissions were calculated based on the number of deer culled per annum on each estate and sent to market. This approach was adopted over a 'whole-herd' approach (whereby emissions would be calculated based on the total population of deer on the estate). This is because venison is considered to be a by-product of culling activity, carried out primarily to control deer numbers (particularly in the case of woodland estates where deer have a negative impact on forestry) and for sporting interests. In addition the whole-herd approach would not be practicable since accurate population estimates are not available.

In terms of converting methane emissions to carbon dioxide equivalent, a factor of 21 is applied (DEFRA 2009[18]). This effectively means that per kg emitted, methane is twenty-one times more potent a greenhouse gas than carbon dioxide.

3.4.2 Emissions at the Processing Stage

This part of the study focussed on the climate change impacts from the transportation of carcases to the processing plant and subsequent processing of the carcass (including associated waste disposal) into products. This relates to stage 4 in the life cycle of wild venison as outlined above in the process map.

Direct Emissions

Direct emissions arise from the transportation of deer carcasses from various estates around Scotland to the processing plant. The vehicles used to transport carcasses have cold storage facilities and so associated fuel use is relatively high.

Other sources of direct emissions at the processing stage include the combustion of fuels to provide heating and hot water for buildings.

Indirect Emissions

Indirect emissions at the processing stage include: the use of electricity to power offices and also to run refrigeration units used for cold storage; water consumption for washing and other uses; and the disposal of waste materials.

Where waste material is produced in the course of the processing operations it has to be disposed of, usually either via landfill, recycling or other conventional form of treatment. Where a waste is landfilled or incinerated the emissions from this are included in the footprint of the product. Where a waste is recycled, however, the emissions from the recycling process are not included: they are

[15] New Zealand Greenhouse Gas Inventory 1990-2004. http://www.mfe.govt.nz/publications/climate/nir-apr06/html/index.html (accessed 8.10.09)
[16] New Zealand Greenhouse Gas Inventory 1990-2004. Annex 3. Detailed methodology information for other sectors. Table A3.1.2 http://www.mfe.govt.nz/publications/climate/nir-apr06/html/page16.html (accessed 9.10.09)
[17] Chapter 4, Table 4.3 in: http://www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/climate/abatement-of-agricultural-greenhouse-gas-emissions/abatement-of-agricultural-greenhouse-gas-emissions-15.htm#P1048-87050
[18] 2009 Guidelines to DEFRA/DECC's GHG Conversion Factors for Company Reporting. Available online: http://www.DEFRA.gov.uk/environment/business/reporting/conversion-factors.htm (accessed 9.10.09)

outside of the study's boundaries. This is because the energy required to recycle the material (e.g. cardboard) and the associated GHG emissions will be associated with the new product that the material will be turned into. This approach is in line with the PAS 2050 methodology.

3.4.3 What is not Included in this Study

Prioritisation

Based on the process mapping exercise, as well as generic industry data, an initial assessment was made as to where data collection efforts should be focused. Activities or materials that form a part of the process flow but that are unlikely to produce substantial GHG emissions were given a lower priority in terms of collecting data (e.g. office paper and stationery). This allowed greater attention to be focused on the most significant sources of emissions (e.g. fuel use).

Items not assessed as part of this study included:

- embodied carbon associated with packaging materials used at the processing stage to package the final product. While an approximate measure of the quantity of packaging material purchased per annum by the processor was obtained, no suitable emissions factor was found which could be applied to calculate the resulting greenhouse gas emissions. Further research would be required to accurately determine carbon emissions associated with packaging. However, it is unlikely packaging would make a substantial contribution to the overall carbon footprint. The HIE study of Highlands and Islands agricultural produce (Bevan 2008) found that, for the beef chain, packaging accounted for less than 1% of the overall footprint;
- emissions associated with the transport of waste to the treatment site. This is because in some cases the distance travelled to the treatment site was not known. It is considered that this would not make a substantial contribution to the overall carbon footprint.

Boundary

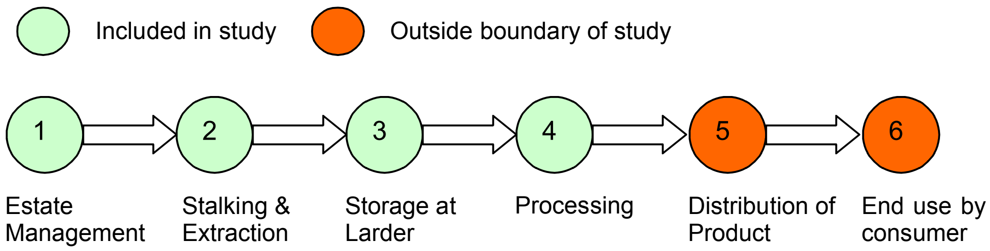
This study does not extend to an assessment of the GHG emissions after the processing stage. The study does not therefore include emissions associated with the distribution of the product to wholesalers or retailers or emissions associated with transport to end consumer and use.

While it is recognised that the distribution of venison products to retailers is likely to generate a significant amount of emissions, this stage of the process has not been included for the following reasons:

- the level of complexity such an assessment would entail. For example, several different logistics companies may be involved in the transport of venison to the retailer and several different products may be carried alongside the venison product. It was therefore considered more appropriate to focus attention on those processes that are unique to venison production. Once the product leaves the processing plant it is, in effect, dealt with in a similar manner to other meat products such as beef or lamb;
- the distribution and end use stage of the process is not directly controlled by the venison industry and the level of influence that can be exercised is therefore limited.

Figure 3.2 summarises the study boundary.

Figure 3-2 Summary of Study Boundary



3.5 DATA GATHERING

3.5.1 Activity Data

Activity data refers to all the material and energy amounts involved in the product's life cycle (material inputs and outputs, energy used, transport, etc.) Within the scope of the study, activity data was gathered from each of the case study deer management estates as well as from the venison processor. A standard data collection template was used such that participants could input their data for each stage of the process. Natural Capital provided guidance on what was required, and the suitable units to describe the data.

Where possible, data were collected from metered or measured sources (such as electricity use in units of kWh) as this provides greatest accuracy. Where such data were not available, financial records were used, which then required conversion into more relevant units.

3.5.2 Emissions Data

Emission factors provide the link that converts activity data into the resulting GHG emissions: the amount of greenhouse gases emitted per 'unit' of activity data (e.g. kg CO_2e per kg input or per kWh energy used).

Emission factors were obtained from publicly available databases and carbon calculator tools (See Table 3.2). Emissions factors for energy and fuel use, water, treatment of waste materials, manufacture of materials and transport emissions were gathered from a variety of sources including DEFRA, Water UK, the National Atmospheric Emissions Inventory (NAEI), the Carbon Trust, and Envirowise. These factors were then applied to the relevant stages of the process.

3.6 CASE STUDIES

Natural Capital surveyed four deer management estates; two upland estates and two woodland estates. Red deer, the larger of Scotland's two native species of deer, is typically found on the open hill and uplands and was expected to be the dominant species in the upland estates. Roe deer is smaller, and is typically a species of the woodland edge and fields, and was expected to be dominant in the woodland estates (see Section 3.7.3). The estates used as case studies were identified by DCS with the aim of providing a representative range of stalking methods (e.g. use of ponies or argocats to support open hill stalking, use of land rovers to support forest stalking) and to include a range of premises in terms of scale of production, location, distance from markets, etc.

A suitable case study processor was selected by DCS for this study. Natural Capital then contacted the processing company in order to gather the necessary primary data about their activities. This company is based in Dundee and processes around 350 tonnes of venison per annum. The final product is distributed within the UK and across Europe.

Table 3-2 Data Sources and Quality

Component of Carbon Footprint		Activity Data Source	Emissions Conversion Factor	Emissions Factor Database	Reliability of Data
Electricity consumption		Energy Bills	0.54418 $kgCO_2e/kWh$	DEFRA (2009)[19]	High
Natural gas			0.20417 $kgCO_2e/kWh$		
Heating oil			0.2.5442 $kgCO_2e/kWh$		
Vehicle fuel use	Gas oil	Fuel receipts	3.0289 $kgCO_2e$/litre		
	Diesel		2.6694 $kgCO_2e$/litre		
	Petrol		2.3307 $kgCO_2e$/litre		
	Aviation fuel		2.5540 $kgCO_2e$/litre		
Water consumption		Metered supply or estimated based on typical usage	0.276 $kgCO_2/m^3$	Water UK – Sustainability Indicators 2007/08	Medium – The emissions conversion figure from Water UK is an average figure for the UK as a whole. Actual emissions will vary from site to site, however the average figure provided is considered to be reasonably representative

[19] 2009 Guidelines to DEFRA/DECC's GHG Conversion Factors for Company Reporting. Available online: http://www.DEFRA.gov.uk/environment/business/reporting/conversion-factors.htm (accessed 9.10.09)

Component of Carbon Footprint		Activity Data Source	Emissions Conversion Factor	Emissions Factor Database	Reliability of Data
Waste materials	Municipal Solid Waste (MSW) to landfill	For estates quantities of waste were estimated based on number and size of bins and frequency of collections. For the processor measured quantities of waste materials were available from waste records.	0.548 $kgCO_2e/kg$ MSW	Carbon Trust – based on data from Smith et al 2001and the National Atmospheric Emissions Inventory	Medium – Clearly calculating carbon emissions from treatment of waste will be a complex process and research in this area is ongoing. The emission factors used are considered to be the most robust available
	Municipal Solid Waste (MSW) to incinerator		0.839 $kgCO_2e/kg$ MSW	Carbon Trust - based on data from the National Atmospheric Emissions Inventory	Medium - See above comments
Methane	Enteric Fermentation	Number of deer stalked per annum	10.4 kg CH_4/head/year (stags and hinds) 5.2 kg CH_4/head/year (calves)	National Atmospheric Emissions Inventory	Medium – Emission factors are given for farmed venison only. Figures for wild venison are not available. Please refer to discussion in Section 3.4.2
	Methane from wastes		0.26 kg CH_4/head/year (stags and hinds) 0.13 kg CH_4/head/year (calves) (To express methane as CO_2e, methane emissions are multiplied by 21 (DEFRA 2009))		

3.7 CALCULATING THE FOOTPRINT

The equation for product carbon footprinting is the sum of all materials, energy and waste across all activities in the product's life cycle multiplied by their emission factors.

3.7.1 Exclusions

In accordance with PAS 2050, "capital goods" are excluded from the life cycle emissions assessment. Capital goods include items such as buildings, machinery and equipment (e.g. a tractor). These emissions are excluded based on:

- lack of carbon footprint data currently available to identify sectors where capital goods emissions are material; and
- cost/complexity of analysis.

3.7.2 Allocation of Emissions between Enterprises

Many deer management estates have a mixture of enterprises (e.g. salmon fishing, woodland management, etc). Allocation of emissions is required where a process contributing to the production of venison also results in more than one useful product, i.e. a co-product that has economic value. For example many estates have an administration building (with associated emissions from electricity consumption, etc), which is used for a variety of purposes other than deer management. In such cases it is necessary to allocate emissions between enterprises and PAS 2050 recommends allocating emissions in proportion to the economic value of the co-products.

4 RESULTS

4.1 ESTATE LEVEL

4.1.1 Woodland Estates

Table 4-1 Comparison of Venison Outputs from Woodland Estate Case Studies

Estate	Number of Deer Stalked per Annum			Total Weight of Carcasses to Dealer per Annum (kg)
	Stags and Hinds	Calves	Total	
Estate A	203	60	263	2,890 (100% roe deer)
Estate B	457	78	535	19,274 (mix of red (60%) and roe (40%) deer)

Table 4-2 Emissions at Estate Level for Estate A

Estate A				
Component of Carbon Footprint		Carbon Emissions ($kgCO_2e$/year)	Carbon Emissions ($kgCO_2e$/t CW)	Proportion of Footprint (%)
Electricity		1,695	586	3%
Heating oil		33	11	<1%
Water consumption		3	1	<1%
Total Utilities		**1,731**	**599**	3%
Vehicle fuel use	Diesel	6,620	2,291	11%
	Petrol	699	242	1%
Total Fuel		**7,319**	**2,533**	**12%**
Waste Materials	Waste to landfill	6.6	2.3	<1%
Total Waste		**6.6**	**2.3**	**<1%**
Methane Emissions (converted to carbon dioxide equivalent)[20]	Enteric fermentation: stags & hinds	44,335	15,341	72%
	Enteric fermentation: calves	6,552	2,267	11%
	Methane from waste: stags & hinds	1,108	384	2%
	Methane from waste: calves	164	57	<1%
Total Enteric Fermentation and Manure		**52,159**	**18,048**	**85%**
Total Footprint		**61,216**	**21,182**	**100%**

[20] As an example calculation, the figure for 'Enteric: stags & hinds is calculated as follows - the number stalked per annum= 203 which should be multiplied by 10.4 (which is the kg CH_4/head/year) and then multiplied by 21 (the conversion of methane to CO_2e) therefore: 203 x 10.4 x 21 = 44,335

Table 4-3 Emissions at Estate Level for Estate B

Estate B				
Component of Carbon Footprint		**Carbon Emissions ($kgCO_2e$/year)**	**Carbon Emissions ($kgCO_2e$/t CW)**	**Proportion of Footprint (%)**
Electricity		1,820	94	1%
Total Utilities		**1,820**	**94**	**1%**
Vehicle fuel use	Diesel	10,715	556	8%
	Petrol	862	45	1%
Total Fuel		**11,577**	**601**	**9%**
Waste Materials	Waste to landfill	19	1	<1%
	Waste incinerated	5,336	277	4%
Total Waste		**5,355**	**278**	**4%**
Methane Emissions (converted to carbon dioxide equivalent)	Enteric fermentation: stags & hinds	99,809	5,178	77%
	Enteric fermentation: calves	8,518	442	7%
	Methane from waste: stags & hinds	2,495	129	2%
	Methane from waste: calves	213	11	<%
Total Enteric Fermentation and Manure		**111,035**	**5,761**	**86%**
Total Footprint		**129,787**	**6,734**	**100%**

4.1.2 Upland Estates

Table 4-4 Comparison of Venison Outputs from Upland Estate Case Studies

Estate	Number of Deer Stalked per Annum			Total Weight of Carcasses to Dealer per Annum (kg)
	Stags and Hinds	Calves	Total	
Estate C	232	27	259	10,650
Estate D	299	35	334	8,006

Table 4-5 Emissions at Estate Level for Estate C

Estate C				
Component of Carbon Footprint		**Carbon Emissions ($kgCO_2e$/year)**	**Carbon Emissions ($kgCO_2e$/t CW)**	**Proportion of Footprint (%)**
Electricity		3,432	322	4%
Heating oil		349	33	<1%
Total Utilities		**3,780**	**355**	**5%**
Vehicle fuel use	Gas Oil	357	34	<1%
	Diesel	13,950	1,310	18%
	Petrol	1,645	155	2%
	Aviation Fuel	2,452	230	3%
Total Fuel		**18,405**	**1,728**	**24%**
Waste Materials	Waste to landfill	731	69	1%
Total Waste		**731**	**69**	**1%**
Methane Emissions (converted to carbon dioxide equivalent)	Enteric fermentation: stags & hinds	50,669	4,758	65%
	Enteric fermentation: calves	2,948	277	4%
	Methane from waste: stags & hinds	1,267	119	2%
	Methane from waste: calves	74	7	<1%
Total Enteric Fermentation and Manure		**54,958**	**5,160**	**71%**
Total Footprint		**77,874**	**7,312**	**100%**

Table 4-6 Emissions at Estate Level for Estate D

Estate D				
Component of Carbon Footprint		**Carbon Emissions ($kgCO_2e/year$)**	**Carbon Emissions ($kgCO_2e/t$ CW)**	**Proportion of Footprint (%)**
Electricity		4,807	600	5%
Total Utilities		**4,807**	**600**	**5%**
Vehicle fuel use	Diesel	15,013	1,875	16%
	Petrol	2,154	269	2%
Total Fuel		**17,166**	**2,144**	**18%**
Waste Materials	Waste to landfill	321	40	<1%
Total Waste		**321**	**40**	**<1%**
Methane Emissions (converted to carbon dioxide equivalent)	Enteric fermentation: stags & hinds	65,302	8,157	70%
	Enteric fermentation: calves	3,822	477	4%
	Methane from waste: stags & hinds	1,633	204	2%
	Methane from waste: calves	96	12	<1%
Total Enteric Fermentation and Manure		**70,852**	**8,850**	**76%**
Total Footprint		**93,145**	**11,634**	**100%**

Table 4-7 Comparison of Emission Sources at the Estate Level

Average Emissions at the Estate Level		
Component of Carbon Footprint	**Carbon Emissions ($kgCO_2e/t$ CW)**	**Proportion of Footprint (%)**
Utilities	412	4%
Vehicle Fuel	1,752	15%
Waste Materials	97	1%
Enteric Fermentation & Manure	9,455	81%
Average Footprint for Estates	11,716	100%

Table 4-8 Comparison of the Carbon Footprint at the Estate Level for Different Case Studies

	Estate	**Carbon Emissions ($kgCO_2e$/year)**	**Carbon Emissions ($kgCO_2e/t$ CW)**
Woodland	Estate A	61,216	21,182
	Estate B	129,787	6,734
	Average Woodland		**13,958**
Upland	Estate C	77,874	7,312
	Estate D	93,145	11,634
	Average Upland		**9,473**
Overall Average Footprint for Estates			**11,716**

4.2 TRANSPORT TO PROCESSOR

Table 4-9 Weights of Carcasses Transported to Processor per Annum

Total Weight of Carcasses per Annum (kg)	Total Weight of Carcasses per Annum (tonnes)
555,000	555

Table 4-10 Emissions Associated with Transportation of Carcasses from Estate to the Processing Plant

Component of Carbon Footprint		Carbon Emissions ($kgCO_2e$/year)	Carbon Emissions ($kgCO_2e$/t CW)	Proportion of Footprint (%)
Transport	Diesel	181,519	327	100

4.3 PROCESSING

Table 4-11 Emissions Associated with Processing of Product

Processor				
Component of Carbon Footprint		**Carbon Emissions ($kgCO_2e$/year)**	**Carbon Emissions ($kgCO_2e$/t CW)**	**Proportion of Footprint (%)**
Electricity		219,849	396	83%
Natural Gas		25,113	45	9%
Water consumption		1,573	3	1%
Total Utilities		**246,535**	**444**	**93%**
Waste Materials	Waste to incinerator	16,780	30	6%
	Waste to landfill	2,959	5	1%
Total Waste		**19,739**	**36**	**7%**
Total Footprint		**266,274**	**480**	**100%**

4.4 LIFE CYCLE ASSESSMENT

Table 4-12 Summary of Emissions at Each Stage of the Life Cycle

Life Cycle Stage	Carbon Emissions ($kgCO_2e$/t CW)	Proportion of Footprint
Estate level	11,716	94%
Transport to Processor	327	3%
Processing	480	4%
Total Footprint	**12,523**	**100%**

Figure 4-1 Comparison of Emissions for Different Stages of the Life Cycle

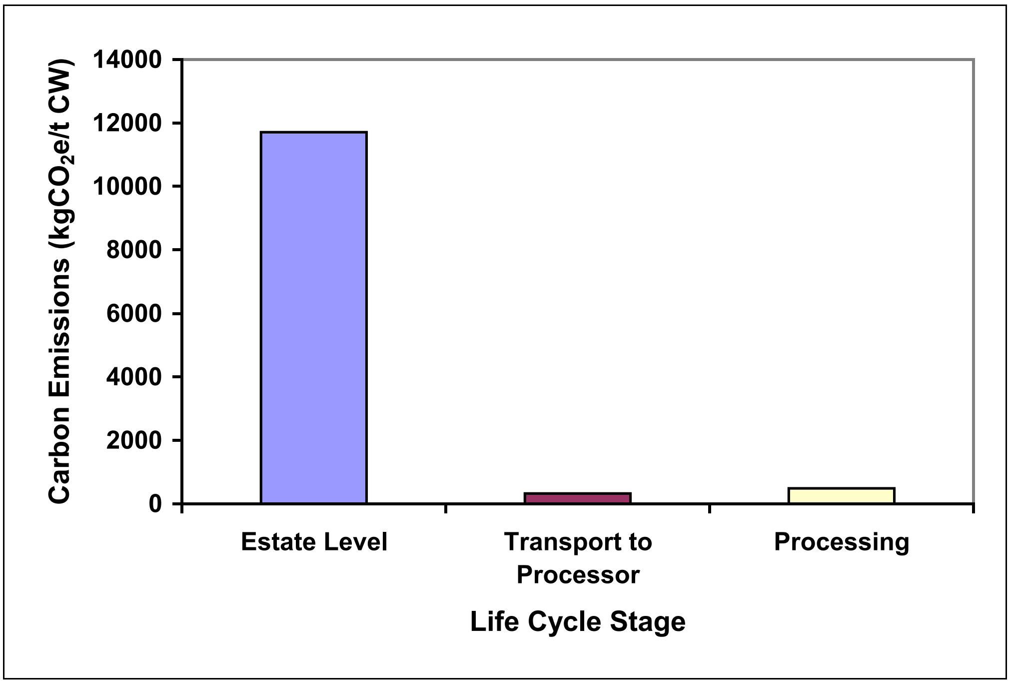
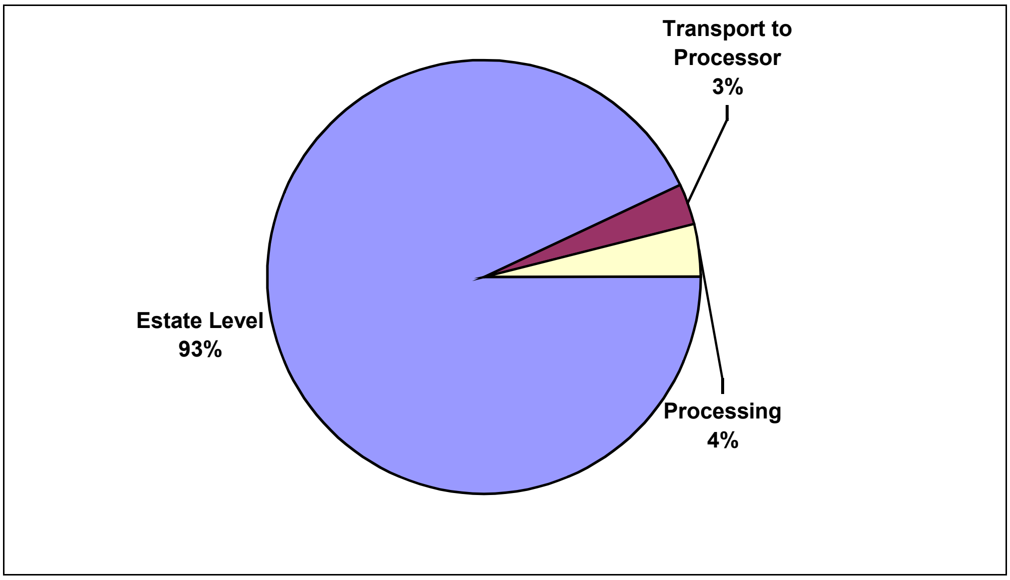


Figure 4-2 Proportion of Carbon Footprint from Different Stages of the Life Cycle



4.5 Comparison with Beef and Lamb

Table 4-13 provides a comparison of the carbon footprint of Scottish wild venison and Highlands and Islands agricultural produce. The figures presented below for beef and lamb are adapted from a study by Highland and Island Enterprise[21] assessed the carbon footprint of key regional agricultural produce.

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[21] Bevan, K. (2008) *Comparing the carbon footprint of Highlands and Islands agricultural produce and its domestic and international competition*. Highlands and Islands Enterprise

The results indicate that wild venison compares very favourably with agricultural meat produce. The carbon footprint of wild venison is estimated to be approximately 38% lower than beef and 49% lower than lamb. The results also indicate that the majority of emissions occur at the farm/estate level (over 90%). This is primarily because ruminant animals produce large quantities of methane, a potent greenhouse gas.

Deer produce less methane emissions per head compared to a beef herd (see Table 3-1) and this is one of the main reasons its carbon footprint is lower. The HIE report concludes that the high emissions figure associated with lamb is primarily due to the inherent low productivity of extensive lamb production in the Highland and Island region.

It is recommended, however, that caution be exercised in drawing conclusions from this comparison for a number of reasons:

- the sample sizes used in both studies were relatively small. A more extensive survey would be required in order to generate a greater degree of confidence in the results;
- there are differences in terms of the way in which wild venison is produced compared to agricultural produce. For example, beef and lamb require the input of fertilisers and agrichemicals, and there are emissions of nitrous oxide associated with manure management systems on farms. Also, as discussed in Section 3.4.1, methane emissions from deer are calculated based on the number of deer stalked per annum rather than for the whole herd.

Table 4-13 Comparing the Carbon Footprint of Scottish Wild Venison and Highland and Islands Agricultural Produce

Stage	**(kgCO_2e/t Carcass Weight)**		
	Venison	**Beef**	**Lamb**
Farm/Estate level	11,716	20,171	23,583
Transport to processor	327	7	6
Processing (incl. waste)	480	204	1,093
TOTAL	**12,523**	**20,382**	**24,682**

4.6 Discussion of Results

Estate Level

- the average footprint at the estate level is estimated to be 11,716 $kgCO_2e/tCW$;
- methane emissions, produced as a by-product of digestion (enteric fermentation) and also from the decomposition of manure, account for the majority of emissions at this stage. Methane emissions typically appear to make up around 80% of the footprint at the estate level;
- direct fuel use for vehicles and machinery typically accounts for approximately 15% of carbon emissions at the estate level;
- emissions associated with utilities (i.e. electricity consumption, heating oil, water use, etc) account for approximately 4% of the footprint at this stage, while waste is estimated to account for 1%;
- there is a significant difference in the overall footprint of the two woodland estates surveyed. One of the main reasons the footprint of Estate A is higher than that of Estate B is because the average carcass weight of deer from Estate B is significantly higher and this leads to greater output per unit input. The reason for the difference in average carcass weight between the two estates is because in Estate A the venison comprises of 100% roe deer whereas for Estate B the composition is nearer to 60% red deer and 40% roe deer. An additional factor is that the land use pattern at Estate A is mixed with dispersed areas of woodland, increasing the ranger's travel time between sites, resulting in higher fuel consumption. In contrast, Estate B consists of less fragmented woodland requiring less travel to various sites;
- on average, upland deer management estates have a lower carbon footprint per tonne of carcass weight produced compared to woodland estates (9,473 $kgCO_2e$ versus 13,958 $kgCO_2e$, or 32% lower). One reason for this difference may be because average carcass weights on upland estates are higher than for woodland estates. In general, there are more red deer stalked on upland estates, whereas on woodland estates it is mostly the smaller roe deer with a lower body weight. However, it must be remembered that the sample size for this study is very small and as mentioned above there are significant differences between the two woodland estates surveyed.
- another limitation in the calculation of the final figures is the assumption that all the deer killed goes to the processor. This is not necessarily the case and on most estates a significant number of carcasses are made available for local people.

Transport to Processor

- the collection and transportation of deer carcasses to the processing plant involves consumption
- of fuel and emissions of greenhouse gases. From this study, it is estimated that 327 $kgCO_2e$ were emitted for each tonne of carcass weight transported to the processor.

Processing Stage

- at the processing plant, the consumption of electricity accounts for the majority of greenhouse gas emissions (approximately 83%). Natural gas, used for heating, is also a significant contributor, making up around 9% of the footprint at this stage;
- waste materials, including both municipal solid waste to landfill and animal waste to incineration, forms around 7% of the footprint at this stage.

Whole Life Cycle

- the total average footprint of wild venison is estimated to be 12,523 kgCO_2e/tCW. Approximately 93% of the total footprint can be attributed to the estate stage, 3% to the transportation stage, and 4% to the processing stage;
- overall, it is emissions of methane (associated with digestion and the decomposition of manure) that make up the greatest proportion of the overall footprint, accounting for approximately 76% of emissions.

5 OPTIONS FOR REDUCING THE CARBON FOOTPRINT OF SCOTTISH WILD VENISON

This section considers the options available for reducing the impacts of greenhouse gas emissions associated with the production of Scottish wild venison.

The options are considered at:

- the estate level;
- the post-estate level; and
- the whole chain level.

5.1 ESTATE LEVEL

Options to improve the carbon footprint at the estate level must also be balanced against other objectives, including:

- other environmental benefits (e.g. biodiversity, landscape management);
- economics (e.g. the price of fuel); and
- socio-economic goals (e.g. providing local employment).

5.1.1 Energy Management

There are a number of options available to estate managers for improving energy management. These include:

Energy Efficiency

As well as the environmental benefits, there are clear cost savings to be gained from cutting fuel and power usage. Most businesses could use a lot less energy, experience shows that even low cost actions can usually reduce energy costs by at least 10% during the first year and produce quick returns.

The first step is to conduct an energy audit (walk round) to assess where energy is being used, to identify wasteful practices and any maintenance issues, and then to explore opportunities for savings. As the pattern of energy use will differ throughout the day, it is useful to conduct a series of walk round audits and to vary the times that they are carried out. This will provide a better picture of when and where energy might be being wasted. The areas to look at on a walk round are heating, lighting, refrigeration units, and any other electrical equipment.

The Carbon Trust[22] provides useful guidance on how businesses can identify measures where energy and cost savings can be easily made with little cost.

Renewable Energy

Renewable energy refers to energy that occurs naturally and repeatedly in the environment. The options include the use of biomass, local wind generation, solar panels, ground source heat pumps, and anaerobic digestion.

Renewable energy can offer a wide range of benefits to businesses including:

- reduced reliance on fossil fuels, potentially lowering energy bills;
- providing possible backup if fossil fuel supply fails;
- improving businesses' 'green' credentials, leading to brand strengthening through the demonstration of corporate social responsibility; and

[22] Carbon Trust – *Better business guide to energy saving: Introducing measures to help organisations save carbon.* CTV034

- providing the opportunity to sell renewable electricity to an electricity distributor or nearby business at a premium.

Further information on renewable energy technology is available from the Carbon Trust[23].

Green Electricity
About two thirds of the electricity in the UK is generated by burning coal and gas in power stations releasing millions of tonnes of carbon dioxide each year. Green electricity is electricity produced from sources that don't impact on the environment in such a negative way. All types of electricity generation will have some effect on the environment but there are some sources that are much greener and cleaner than others. Green electricity is from renewable energy sources such as wind and solar.

There are several providers of green electricity for businesses. The National Energy Foundation[24] (NEF) recommends the following energy supply companies to business seeking green tariffs: Good Energy; Ecotricity; and green energy UK.

5.1.2 Reducing Emissions from Fuel Usage

Reducing the use of Vehicles and Machinery
Many estates traditionally used ponies to retrieve deer from the hill. Ponies are often more adept than vehicles when crossing particular terrain and tend to have less of an impact on the environment. Promoting a return to the use of ponies may be one way of cutting the need for fuel and thereby reducing carbon emissions. It is recognised however, that in some cases it may be more appropriate to use all-terrain vehicles, depending on the ground and weather conditions.

Helicopters are sometimes used when carrying out deer counting as this enables large geographical areas to be covered and digital cameras can be used to monitor deer numbers. This is an accurate and time-efficient way to assess and monitor deer populations over large areas, however it also consumes a significant amount of fuel and contributes to carbon emissions. Counting deer by foot, rather than using helicopter, would help to reduce fuel consumption and carbon emissions.

Fuel-efficient Vehicles
More efficient vehicles use less fuel and attract a lower rate of road tax, thereby saving money. They also produce fewer emissions.

Fuel-efficient Driving Practices
The Energy Saving Trust[25] provides useful tips and guidance on improving driving practices to reduce fuel use and these are summarised below. It is estimated that by following these tips, it is possible to save one month's worth of fuel over a year:

- driving smoothly and at a slower speed to reduce fuel consumption;
- anticipating road conditions and driving smoothly, avoiding sharp acceleration and heavy braking;
- the most efficient speed depends upon the car in question but is typically around 45 - 50mph. Faster speed will greatly increase fuel consumption;

[23] Carbon Trust – *Renewable energy sources technology overview.* CTV010
[24] http://www.nef.org.uk/ (accessed 23/04/09)
[25] http://www.energysavingtrust.org.uk/Travel (accessed 23/04/09)

- moving up a gear at 2,500 revs per minute (rpm) for petrol cars and 2,000 rpm for diesel cars;
- using air conditioning sparingly as it significantly increases fuel consumption.

Using Greener Fuels
Biofuels, for example biodiesel and bioethanol, are made from plant materials like vegetable oils or wheat. Biofuels can reduce climate change impacts because the plants they're made from take in carbon dioxide (CO_2) when they grow. This helps balance out the CO_2 emissions when the fuel is burned.

Biofuels can be mixed with ordinary diesel or petrol and used in normal cars. Much of the diesel available in the UK, and some petrol, now contains 5 per cent biofuel. This is suitable for use in all vehicles without modification.

It's possible to convert vehicles to run on fuel made with a higher proportion of biofuels. A small number of UK filling stations supply these higher biofuel blends.

Hybrid cars use a petrol engine combined with a battery and are very fuel-efficient without any compromise on performance.

Vehicle Maintenance
Well-maintained cars tend to run more efficiently and recommendations include:
- checking tyre pressures regularly, since under-inflated tyres can increase fuel consumption by up to three per cent;
- removing unnecessary weight and roof racks - these increase the weight and air resistance, and therefore the amount of fuel you use;
- using air conditioning and other on-board electrical devices (like mobile phone chargers) sparingly and only when necessary since they increase fuel consumption.

5.1.3 Management of Land for Carbon Sequestration

Carbon is the main building block of all vegetation and plant material, which accumulates in soils as partially or fully decomposed organic matter, making all soils that contain organic matter natural stores of carbon.

In many areas of Scotland, cold and wet climatic conditions have led to the accumulation of soil organic matter. Scottish soils are therefore particularly rich in organic matter, making them an important carbon store. Scottish soils are estimated to contain approximately 3,000 MtC, which is the majority of the soil carbon stock of the whole of the UK. Scottish peat soils are also significant both at European and global scales.

Soil can act as a source and sink for carbon, depending on land use and climatic conditions. Land use change can trigger organic matter decomposition, primarily via land drainage and cultivation. Restoration and re-creation of peatlands can result in increased methane emissions initially as soils become anaerobic, whereas in the longer term they become a sink for carbon as organic matter accumulates.

The Scottish Soil Framework[26] published by the Scottish Government in May 2009 sets out the Government's policy with regard to protecting soil quality and has a chapter that deals with the role of soil in the context of climate change, the uptake and release of greenhouse gases and the storage of carbon. The Macaulay

[26] http://www.scotland.gov.uk/Publications/2009/05/20145602/13

Institute[27] and the Scottish Agricultural College[28] are carrying out research into land management for carbon sequestration and may be able to provide further sources of information.

5.1.4 Reducing Emissions of Methane

Emissions of methane are responsible for an estimated 76% of the overall carbon footprint of venison. Unfortunately, it is outwith the scope of this study to make a full investigation into the opportunities for mitigating methane emissions. However some suggested avenues for further research include:

- reduction in herd numbers. While this would not reduce the carbon footprint of venison (as measured by this study, see Section 3.4.1 on the 'whole-herd' approach) it would result in less greenhouse gas emissions at the national scale;
- where wild deer are fed then manipulation of dietary composition could be considered, to increase digestibility. It is acknowledged that this may not be practicable in the case of wild deer and is likely to be more applicable to farmed animals;
- a wide range of feed additives has been proposed to reduce methane. Again it is recognised that this suggestion is more applicable to farmed animals;
- experiments involving the immunisation of animals against methanogens are being conducted in Australia; and
- the literature suggests that there may be large difference between individual animals in methane emission. If this is proven to be the case then genetic markers could be sought to underpin a selection programme.

More information on methane abatement technologies and recommended research is available for the New Zealand Ministry of Agriculture and Forestry[29].

5.2 POST-ESTATE LEVEL

This section considers measures for reducing the carbon footprint through reducing resource consumption and improving efficiency. It is often possible to make significant reductions in water and energy use and the amount of waste produced by implementing low-cost measures. If appropriate, businesses can then make more long-term capital investments in more efficient plant and equipment in order to further improve their environmental performance.

5.2.1 Energy Efficiency Measures

Assessing Energy Use

Monitoring energy use allows businesses to:

- understand where and how energy is being used;
- identify areas where energy consumption can be reduced and savings made;
- confirm whether energy-saving measures are working.

A walk round the site to carry out an energy assessment can help to identify bad practice, inefficient equipment, maintenance needs and opportunities for savings.

[27] http://www.macaulay.ac.uk/
[28] http://www.sac.ac.uk/
[29] http://www.maf.govt.nz/mafnet/rural-nz/sustainable-resource-use/climate/abatement-of-agricultural-greenhouse-gas-emissions/abatement-of-agricultural-greenhouse-gas-emissions-06.htm (accessed 9.10.09)

Efficient Operation of Heat Distribution Systems
Heat losses associated with heat distribution systems can often represent a significant proportion of an organisation's energy consumption and costs. Regular and effective maintenance is crucial for energy efficient operation of heat distribution systems. The Carbon Trust provides useful advice on reducing the losses from heat distribution systems, delivering energy, carbon and cost savings[30].

Refrigeration
Refrigeration is another significant energy consumer. Poorly maintained systems can use significantly more energy, for example a blocked condenser can increase consumption by over 20% while faulty door seals can increase consumption by as much as 11%[31]. Waste heat from refrigeration systems can be used elsewhere in the building where there is a requirement for space heating, for example offices. Furthermore changing refrigerants to those with a lower or no global warming potential can reduce climate change impacts incurred from fugitive emissions of refrigerants.

"Green" Electricity
Switching to electricity providers who can guarantee that a percentage of their supplied electricity is from renewable sources should be investigated. There is often a premium for selecting renewable energy, however, this is offset by the fact that Climate Change Levy is not paid on that proportion of the electricity, if applicable to that business. Fully renewable electricity is considered to be carbon neutral so will not contribute to the carbon footprint.

5.2.2 Fleet Management

The transport of venison from the various estates to the processor contributes significantly to the overall carbon footprint. The fuel-efficiency tips listed above in Section 5.1.2 can help to reduce fuel consumption and carbon emissions. In addition the use of satellite navigation and telematics can be useful in helping drivers avoid congestion and use the most efficient route to reach their destination.

The Energy Saving Trust (EST) provide Green Fleet Reviews, offering fleet management advice and best practice examples to help lower running costs, reduce environmental impact and enhance corporate social responsibility.

5.2.3 Waste Management

Reducing waste offers a significant opportunity to reduce the carbon footprint of wild venison. Not only are there emissions associated with the treatment of wastes, but there are also savings to be made in terms of packaging and disposal costs.

Reducing Packaging
Packaging of food products can account for a significant proportion of business costs. With current legislation and expectations from customers for environmentally friendly products, packaging is becoming an increasingly important issue.

The benefits of reducing the amount of packaging used and switching to more sustainable types of packaging include cost savings, improved "green" image, reduced environmental impact.

[30] Carbon Trust GPG382 *Energy efficient operation of heat distribution systems*
[31] Carbon Trust CTV002

Envirowise[32] provides very useful information and guidance on the eco-design of packaging and the responsible sourcing of materials. The following is a brief guide to good practice in managing packaging wastes.

Packaging Wastes

As discussed above, good packaging design can help to reduce the amount of materials used and ensure that packaging can be reused or recycled.

In terms of legislation, the packaging waste regulations require businesses to minimise packaging weight and volume (subject to safety, hygiene and consumer acceptance) and make sure packaging can either be recycled, have energy recovered from it, or be composted or reused. Businesses should also make sure packaging is manufactured to contain minimum levels of hazardous substances.

Ways of reducing packaging waste include:

- using a compactor or baler, which crushes packaging into blocks. This will allow larger volumes of packaging waste to be transported which in turn will reduce recycling or disposal costs;
- buying goods in bulk;
- reusing packaging such as wooden pallets and cardboard boxes.

5.2.4 Water Efficiency Measures

It is estimated that by adopting a systematic approach to reducing water use and implementing simple measures most businesses could cut water consumption by up to 30%[33]. The following is a list of top tips to reduce water use:

- measuring and monitoring the amount of water being used, comparing water use each year so that any unusual patterns of consumption can be identified;
- making sure staff are fully aware of the importance of water minimisation;
- appointing a water monitor within the organisation to undertake periodic site walk-overs to identify water minimisation opportunities;
- ensuring pipes are well insulated to protect against frost damage;
- using spray taps where possible since they can reduce water use by 60 - 70% compared with conventional taps;
- making use of tap aerators and flow restrictors which can save money;
- considering alternative water sources, e.g. rainwater use and greywater re-use;
- taking water efficiency into account when purchasing new equipment. It may be more expensive to buy water efficient equipment, but it may have a short payback period due to the water savings achieved;
- training staff to implement good practice (e.g. brushing waste away rather than washing). This should be integrated with health and safety training and be given the same level of importance;

5.2.5 Support in Implementing these Measures

There are a number of organisations and schemes that are set up to provide support for businesses seeking to improve their sustainability:

[32] http://www.envirowise.gov.uk/uk/Topics-and-Issues/Packaging.html
(see envirowise Packguide: A guide to packaging eco-design)
[33] http://www.envirowise.gov.uk/

Organisation	Description	Contact
Carbon Trust	Offers a wide range of support for businesses in the UK seeking to become more energy efficient and reduce their carbon footprint. There are also opportunities to apply for grant funding for specific energy saving projects.	http://www.carbontrust.co.uk/
Envirowise	Offers advice and support to businesses seeking to become more resource efficient. Focus primarily on waste management and water consumption.	http://www.envirowise.gov.uk/
Energy Saving Trust	Focus on energy efficiency and reducing greenhouse gas emissions. Provide advice on transportation and fleet management	http://www.energysavingtrust.org.uk/
National Industrial Symbiosis Programme	Brings together companies to improve cross-industry resource efficiency	http://www.nisp.org.uk/
NetRegs	Service provided by the Environment Agency offering free environmental guidance for small business in the UK on what is required to be compliant with UK environmental legislation	http://www.netregs.gov.uk/
Waste and Resources Action Plan (WRAP)	Provides advice on how businesses can reduce waste and recycle more	http://www.wrap.org.uk/

5.3 Whole Chain Level

Good supply chain management is a critical to the success of most industries. Through working together producers, processors and retailers are more likely to identify areas where reductions in greenhouse gas emissions could be achieved. This could also lead to financial cost savings and added value. Good communication between the dealer and estates would help to ensure collections of carcasses are well coordinated and efficient. For instance, estates could monitor quantities of venison at their larders and relay this information to the dealer. The dealer would then be able to plan more effectively collections and ensure that transportation wagons were fully laden and therefore travelling efficiently. This would help to reduce the overall number of trips made by the dealer and thereby cut fuel consumption.

In some cases there may be opportunities for estates to share larders. This would help to reduce the overall number of larders in operation. It would also improve efficiency, as the larders would be more full. This would, however, need to be assessed on a case-by-case basis as it may involve greater transportation costs.

The way in which the deer are stalked can have an effect on the amount of carcass that is usable. If the carcass is badly damaged from the impact of the shot then the amount of wastage is increased. Promoting good shooting practice may help to increase the percentage of carcass that can be used for meat thereby increasing overall system efficiency.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 INTRODUCTION

This study was commissioned as a first attempt at calculating the carbon footprint of Scottish wild venison. It involved two stages:

- firstly, scoping out the boundaries for calculating the carbon footprint; and
- secondly, gathering data and carrying out the first calculations.

The study was based on a relatively small sample size and so the results should be treated with caution. Nevertheless, it is considered that the results generated do provide a reasonable first estimation of the current emissions associated with the scope of the footprint established for this particular study.

The results from the study permit some initial conclusions to be drawn (see 6.2) and some recommendations for a number of areas that could be followed up with further research (see 6.3).

6.2 CONCLUSIONS

The key findings are:

- From the data collected in the present study the total average footprint of wild venison was calculated to be 12,523 kgCO_2e/tCW. Approximately 93% of the total footprint can be attributed to the estate stage, 3% to the transportation stage, and 4% to the processing stage.

- Overall, it is emissions of methane (associated with digestion and the decomposition of manure) that appear to make up the greatest proportion of the overall footprint, accounting for approximately 76% of emissions. It is important to recognise the limitations in the data used to calculate this result (see Section 3.4.1), particularly as the emission factors used are for farmed deer. There are also significant difference between methane emission factors given in the UK Inventory on emissions (NAEI) and the New Zealand Inventory. It has not been possible to determine the reasons for this difference within the scope of the present study.

- At the estate level, direct fuel use for vehicles and machinery accounts for a significant proportion of the footprint. A number of suggestions have been put forward for reducing fuel use, including:
    - encouraging a return to the traditional use of ponies to extract deer from the hillside;
    - reducing the use of helicopters for deer counting and counting on foot instead;
    - using more fuel-efficient vehicles;
    - using biodiesel;
    - adopting fuel-efficient driving practices.

- On average, upland deer management estates appear to have a lower carbon footprint per tonne of carcass weight produced compared to woodland estates (9,473 kgCO_2e versus 13,958 kgCO_2e, a difference of 32%). One reason for this difference may be because average carcass weights on upland estates are higher than for woodland estates, leading to a greater output per unit input. In general, there are more red deer stalked on upland estates, whereas on woodland estates it is mostly roe deer, which are smaller animals and have a lower body weight. However, it must be remembered that the sample size for this study is very small and as discussed below there are significant differences between the two woodland estates surveyed as part of this study.

- In comparing the two woodland estates, one of the main reasons the footprint of Estate A is much higher than that of Estate B is because average carcass weights of deer from Estate B are significantly higher, resulting in a greater output per unit input. This is almost certainly related to the fact that on Estate A the venison was 100% roe deer whereas for Estate B there was a mix of 60% red deer to 40% roe deer. Clearly there is not a like for like comparison here. In addition, the land use pattern at Estate A is mixed with dispersed areas of woodland. This increases the Ranger's travel time between sites, resulting in higher fuel consumption. In contrast, Estate B consists of less fragmented woodland requiring less travel to various sites.

- The collection and transportation of deer carcasses from estates across Scotland to the processing plant involves consumption of fuel (this includes fuel used for cold storage in vehicle) and results in emissions of greenhouse gases. From this study, it is estimated that 327 kgCO_2e are emitted for each tonne of carcass weight transported to the processor, equating to approximately 3% of the total footprint.

- At the processing stage, it is the consumption of electricity that accounts for the majority of greenhouse gas emissions (approximately 83%). Natural gas, used for heating, is also a significant contributor, making up around 9% of the footprint during processing, while the generation and disposal of waste is estimated to account for 7% of emissions at this stage.

- Wild venison compares favourably with agricultural meat produce. It is estimated that the carbon footprint of wild venison is approximately 38% lower than beef and 49% lower than lamb. It is noted that caution should be exercised in making these comparisons, due to the small sample sizes used in the present study.

- Finally it should also be remembered that there will be carbon emissions associated with the journeys that those partaking in deer stalking make, to get to the site. Deer stalking as a sporting activity in its own right will therefore have a carbon footprint. Detailed consideration of this aspect has not been included in the present research.

6.3 RECOMMENDATIONS

A number of recommendations are suggested as a result of the conclusions drawn above. These are:

- Because the sample size included in the present study is relatively small it is recommended that further research be carried out based on a wider sample size including more comparative woodland estates and a greater number of upland estates. This would generate a greater degree of confidence in the results and would give a more representative figure for the carbon footprint of wild venison. As carbon footprinting becomes more commonplace within the food industry, it will also be possible to draw more reliable comparisons with similar products.

- There are a number of options available for reducing the carbon footprint of venison and it is recommended that these are supported and promoted to estates and businesses involved in the industry, in particular:

    - promoting energy efficiency;
    - encouraging estates to install renewable energy systems;
    - reducing the fuel usage for vehicles and machinery and promoting the use of efficient vehicles;
    - reducing the amount of packaging materials;
    - implementing waste management systems, and encouraging recycling;
    - adopting water efficiency practices to conserve water resources;
    - supply chain management and good communication between dealers and estates.

- Although it is beyond the scope of this study to cover in detail activities at the estate level that relate more to the wider issues of stalking and deer management (rather than food production) a number of suggestions have been put forward for reducing fuel use, including:

    - encouraging a return to the traditional use of ponies to extract deer from the hillside;
    - reducing the use of helicopters for deer counting and counting on foot instead; and
    - generally using more fuel-efficient vehicles.

- In the wider research context because of the apparent differences between the emission factors for methane from farmed deer in New Zealand versus methane from farmed deer in the UK (see Section 3.4.1) it is recommended that further research be undertaken to investigate this apparent discrepancy. There could clearly be a number of reasons that explain the difference ranging from the possibility that the races of red deer in Scotland and New Zealand are different sizes (and body mass) to differences in feeds and diet.

- It is also recommended that further research be carried out into the following areas:
    - mitigation of methane emissions from deer through, for example, manipulation of dietary composition or the use of feed additives;
    - management of land for carbon sequestration since soils can be an important sink for carbon.

Appendix A: Carbon Footprint Calculations

Table A.1 Estate A

Estate	Number of Deer Stalked per Annum	Total Weight of Carcasses per Annum (kg)	Total Weight of Carcasses per Annum (tonnes)
Estate A	263	2,890	2.89

Utilities						
Item	**Quantity per Annum**	**Unit**	**Conversion Factor ($kgCO_2e$/unit)**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Electricity	3,114	kWh	0.54418	1,695	586	3%
Heating oil	13	Litres	2.5442	33	11	0%
Water consumption	11	m^3	0.276	3	1	0%
Total Utilities				**1,731**	**599**	3%

Vehicle and Machinery Fuel Use						
Item	**Quantity per Annum**	**Unit**	**Conversion Factor ($kgCO_2e$/unit)**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Diesel	2,480	Litres	2.6694	6,620	2,291	11%
Petrol	300	Litres	2.3307	699	242	1%
Total Fuel				**7,319**	**2,533**	12%

Materials						
Item	Quantity per Annum	Unit	Coversion Factor ($kgCO_2e$/unit)	$kgCO_2e$/year	$kgCO_2e$/t CW	Proportion of Footprint (%)
Bullets	350	no.				
Total Materials						

Waste Materials						
Item	**Quantity per Annum**	**Unit**	**Conversion Factor ($kgCO_2e$/unit)**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Waste to landfill	12	kg	0.548	6.6	2.3	0.01%
Total Waste				**6.6**	**2.3**	0.01%

Methane Emissions						
Item	**No. of Deer**	**kg CH_4/head/year**	**CO_2 equivalent**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Enteric fermentation: stags and hinds	203	10.4	21	44,335	15,341	72.42%
Enteric fermentation: calves	60	5.2	21	6,552	2,267	10.70%
Methane from wastes: stags and hinds	203	0.26	21	1,108	384	1.81%
Methane from wastes: calves	60	0.13	21	164	57	0.27%
Total				**52,159**	**18,048**	**85.21%**

Estate A	$kgCO_2e$/year	$kgCO_2e$/t CW
Total Footprint	61,216	21,182

Estate A	
Component	**Comment**
Allocation of emissions between co-products	Income from venison accounts for approximately 0.2% of overall income for the estate. The chief purpose of culling deer on the estate is to protect young trees from being eaten, rather than as a source of income from venison sales
Utilities	
Electricity	Total electricity consumption for the administration office and yard is 57,000 kWh per annum. Allocating emissions based on economic value this gives 114 kWh per annum. Electricity consumption at the larder is 3,000 kWh per annum. This is all attributable to venison
Heating oil	Total heating oil consumption for the office is 6,450 litres per annum Allocating emissions based on economic value this gives 13 litres per annum
Water	Total water consumption for the larder is estimated at 11 m^3 per annum. This figure is based on the Ranger's own estimate of daily usage
Vehicle and Machinery Fuel Use	
Diesel	2,480 litres – Ranger's 4 x 4 pick-up
Petrol	300 litres – ATV Quad
Waste Materials	
Municipal solid waste to landfill	Estimated 9 black bags of municipal waste per week. This equates to 468 bags per annum. 1 black bag typically weighs 12.5kg[34]. Therefore total weight of waste is 468 x 12.5 = 5,850 kg per annum. Allocating emissions based on economic value – 5,850 x 0.002 = 12 kg per annum
Animal waste	Animal remains reused on site as carrion to feed birds of prey
Methane Emissions	
Total number of deer stalked per annum	263
Stags and Hinds	203
Calves	60
Venison Outputs	
Weight of carcasses to dealer per annum	2,890 kg

[34] http://www.quakergreenaction.org.uk/

Table A.2 Estate B

Estate	Number of Deer Stalked per Annum	Total Weight of Carcasses per Annum (kg)	Total Weight of Carcasses per Annum (tonnes)
Estate B	535	19,274	19.27

Utilities						
Item	**Quantity per Annum**	**Unit**	**Conversion Factor ($kgCO_2e$/unit)**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Electricity	3345	kWh	0.54418	1,820	94	1.4%
Water consumption	Not available	m^3	0.276	-	-	-
Total Utilities				**1,820**	**94**	**1.4%**

Vehicle and Machinery Fuel Use						
Item	**Quantity per Annum**	**Unit**	**Conversion Factor ($kgCO_2e$/unit)**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Diesel	4,014	Litres	2.6694	10,715	556	8.3%
Petrol	370	Litres	2.3307	862	45	0.7%
Total Fuel				**11,577**	**601**	**8.9%**

Materials						
Item	**Quantity per Annum**	**Unit**	**Coversion Factor ($kgCO_2e$/unit)**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Bullets	750	no.				
Total Materials						

Waste Materials						
Item	**Quantity per Annum**	**Unit**	**Conversion Factor ($kgCO_2e$/unit)**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Waste to landfill	35	kg	0.548	19	1	0.0%
Waste incinerated	6360	kg	0.839	5,336	277	4.1%
Total Waste				**5,355**	**278**	**4.1%**

Methane Emissions						
Item	**No. of Deer**	**kg CH_4/head/year**	**CO_2 Equivalent**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Enteric fermentation: stags and hinds	457	10.4	21	99,809	5,178	76.90%
Enteric fermentation: calves	78	5.2	21	8,518	442	6.56%
Methane from wastes: stags and hinds	457	0.26	21	2,495	129	1.92%
Methane from wastes: calves	78	0.13	21	213	11	0.16%
Total				**111,035**	**5,761**	**85.6%**

Estate B	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**
Total Footprint	129,787	6,734

Estate B	
Component	**Comment**
Allocation of emissions between co-products	Income from venison versus overall income for Estate B is approximately 1.25%
Utilities	
Electricity	Total electricity consumption for administration building is 27,600 kWh per annum. Allocating emissions based on economic value this equates to 345 kWh per annum There are three larders in total; one of which is shared with another estate (in this case electricity usage has been allocated based on the number of carcasses) Electricity consumption for the larders is calculated at 3,000 kWh per annum. This is all attributable to venison.
Water	Data for water consumption not available. This is considered to be immaterial to overall footprint
Vehicle and Machinery Fuel Use	
Diesel	4,014 litres. This is all attributable to venison (although a small proportion of this could be attributed to other activities, such as squirrel management, it is considered prudent to attribute it all to venison)
Petrol	370 litres per annum. This is all attributable to venison (as per diesel, see comment above)
Waste Materials	
Municipal solid waste to landfill	1 x 360 litre bin per week. MSW is assumed to weigh 150kg/m^3[35]. Therefore mass of MSW per annum is 52 x 0.360 x 150 = 2,808 kg. It is assumed that this waste goes to landfill. Allocating emissions based on economic value – 2,808 x 0.0125 = 35 kg per annum attributable to venison
Animal waste	In calculating animal waste from the larders it is assumed that for 1kg of carcass weight approximately 0.33kg of waste is produced[36]. Therefore total animal waste from the larders is 19,274 x 0.33 = 6,360 kg. This waste is incinerated.
Methane Emissions	
Number of deer stalked per annum	535
Stags and Hinds	457
Calves	78
Venison Outputs	
Weight of carcasses to dealer per annum	19,274 kg

[35] http://www.hardall.co.uk/
[36] http://www.butcher-packer.com/

Table A.3 Estate C

Estate	Number of Deer Stalked per Annum	Total weight of Carcasses per Annum (kg)	Total weight of Carcasses per Annum (tonnes)
Estate C	259	10,650	10.65

Utilities						
Item	Quantity per Annum	Unit	Conversion Factor ($kgCO_2e$/unit)	$kgCO_2e$/year	$kgCO_2e$/t CW	Proportion of Footprint (%)
Electricity	6306	kWh	0.54418	3,432	322	4%
Heating oil	137	Litres	2.5442	349	33	0%
Water consumption	Private source	m^3	-	-	-	-
Total Utilities				**3,780**	**355**	**5%**

Vehicle and Machinery Fuel Use						
Item	Quantity per Annum	Unit	Conversion Factor ($kgCO_2e$/unit)	$kgCO_2e$/year	$kgCO_2e$/t CW	Proportion of Footprint (%)
Gas Oil	118	Litres	3.0289	357	34	0%
Diesel	5,226	Litres	2.6694	13,950	1,310	18%
Petrol	706	Litres	2.3307	1,645	155	2%
Aviation Fuel	960	Litres	2.554	2,452	230	3%
Total Fuel				**18,405**	**1,728**	**24%**

Materials						
Item	**Quantity per Annum**	**Unit**	**Coversion Factor ($kgCO_2e$/unit)**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Bullets		no.				
Total Materials						

Waste Materials						
Item	**Quantity per Annum**	**Unit**	**Conversion Factor ($kgCO_2e$/unit)**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Waste to landfill	1,334	kg	0.548	731	69	1%
Total Waste				**731**	**69**	**1%**

Methane Emissions						
Item	**No. of Deer**	**kg CH_4/head/year**	**CO_2 Equivalent**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Enteric fermentation: stags and hinds	232	10.4	21	50,669	4,758	65%
Enteric fermentation: calves	27	5.2	21	2,948	277	4%
Methane from wastes: stags and hinds	232	0.26	21	1,267	119	2%
Methane from wastes: calves	27	0.13	21	74	7	0%
Total				**54,958**	**5,160**	**71%**

Estate C	kgCO_2e/year	kgCO_2e/t CW
Total Footprint	77,874	7,312

Estate C	
Component	Comment
Area covered	Note this survey does not cover the entire estate. The estate is divided into seven beats, three of which were selected for this study.
Allocation of emissions between co-products	Income from venison for the three beats covered by this study versus overall income is approximately 7.6%
Utilities	
Electricity	Total cost of electricity for the administration building is £600 per annum. The unit cost of electricity is estimated at 10p/kWh. Total electricity consumption for administration building is therefore calculated to be 6,000 kWh per annum. Allocating emissions based on economic value, this gives 456 kWh per annum attributable to venison. Electricity usage in the larder is estimated based on: 35 kWh per day when running at maximum (from July to Sept); 17.5 kWh per day when running at half capacity (from Oct to Feb); and not in use for the rest of the year. Electricity usage in the larder is therefore estimated at 5,850 kWh (Note: This is considered to be an overestimate. As the larder is newly installed, actual meter readings are not yet available) Total electricity use for the area covered by the study is estimated at 456 + 5850 = 6,306 kWh/annum
Heating oil	1,800 litres of heating oil used per annum to heat administration buildings and workshops. Allocating emissions based on economic value gives 137 litres per annum
Water	The estate uses its own private supply of water from a borehole. The electricity used to power the pump is covered above under total electricity usage.
Vehicle and Machinery Fuel Use	
Gas oil	Total gas oil for the whole estate is 200 litres per annum. Assume this is all attributable to venison. Venison from the three beats covered by this study accounts for 59% of the total venison income for the estate. Allocating emissions based on economic value gives 118 litres per annum

Diesel	Total diesel for the three beats covered by this study is 5,226 litres per annum. Assume this is all attributable to venison (a small proportion of the total amount of diesel may be attributable to other activities such as salmon fishing, however it is considered prudent to attribute all to venison)
Petrol	Total petrol – 706 litres per annum. Assume this is all attributable to venison (see comment above for diesel)
Aviation fuel	Helicopters are used every second year to carry out deer counting surveys on the estate. The head ranger estimated approximately 12 hours flying time to cover the three beats. It is assumed a helicopter consumes 160 litres of fuel per hour of flying time[37]. This gives a total of 960 litres aviation fuel per annum
Waste Materials	
Municipal solid waste to landfill	There are 3 x 750 litre bins collected weekly by the local authority. MSW is assumed to weigh $150kg/m^{3}$[38]. Therefore mass of MSW per annum is equals 17,550 kg. It is assumed that this waste goes to landfill. Allocating emissions based on economic value gives 1,334 kg per annum attributable to venison.
Animal waste	Animal waste from the larder is dealt with on site
Methane Emissions	
Total number of deer stalked per annum	259
Stags and hinds	232 (estimated to be 90% of total)
Calves	27 (estimated to be 10% of total)
Venison Outputs	
Weight of carcasses to dealer per annum	10,650 kg

[37] http://www.uhnl.nf.ca/fleet.htm
[38] http://www.hardall.co.uk/

Table A.4 Estate D

Estate	Number of Deer Stalked per Annum	Total weight of Carcasses per Annum (kg)	Total weight of Carcasses per Annum (tonnes)
Estate D	334	8,006	8.01

Utilities						
Item	Quantity per Annum	Unit	Conversion Factor ($kgCO_2e$/unit)	$kgCO_2e$/year	$kgCO_2e$/t CW	Proportion of Footprint (%)
Electricity	8833	kWh	0.54418	4,807	600	5%
Water consumption	0	m^3	0.276	0	0	0%
Total Utilities				**4,807**	**600**	5%

Vehicle and Machinery Fuel Use						
Item	Quantity per Annum	Unit	Conversion Factor ($kgCO_2e$/unit)	$kgCO_2e$/year	$kgCO_2e$/t CW	Proportion of Footprint (%)
Diesel	5,624	Litres	2.6694	15,013	1,875	16%
Petrol	924	Litres	2.3307	2,154	269	2%
Total Fuel				**17,166**	**2,144**	18%

Materials						
Item	Quantity per Annum	Unit	Coversion Factor ($kgCO_2e$/unit)	$kgCO_2e$/year	$kgCO_2e$/t CW	Proportion of Footprint (%)
Bullets		no.				
Total Materials						

Waste Materials						
Item	**Quantity per Annum**	**Unit**	**Conversion Factor ($kgCO_2e$/unit)**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Waste to landfill	585	kg	0.548	321	40	0%
Total Waste				**321**	**40**	**0%**
Methane Emissions						
Item	**No. of Deer**	**kg CH_4/head/year**	**CO_2 Equivalent**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Enteric fermentation: stags and hinds	299	10.4	21	65,302	8,157	70.11%
Enteric fermentation: calves	35	5.2	21	3,822	477	4.10%
Methane from wastes: stags and hinds	299	0.26	21	1,633	204	1.75%
Methane from wastes: calves	35	0.13	21	96	12	0.10%
Total				**70,852**	**8,850**	**76%**

Estate D	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**
Total Footprint	93,145	11,634

Estate D	
Component	Comment
Allocation of emissions between co-products	Income from venison versus overall income for Estate D is approximately 10%
Utilities	
Electricity	Electricity bill for the administration building is £1,681. At a unit rate of £0.12 per kWh this equates to 14,008 kWh p.a. Approximately 1/5 of electricity usage is attributed to the post office (based on an estimate of floor area). Of the remainder, 10% is attributed to venison based on economic value. Therefore electricity from administration building that is attributable to venison 1,121 kWh p.a. Electricity usage in the larder is estimated based on wattages of appliances: Fan @ 0.34 kW - running 24/7 for 14 weeks a year – equals 800 kWh per annum Fly trap @ 0.05 kW – running 24/7 for 14 weeks a year – equals 118 kWh per annum 2No. Bulbs @ 0.20 kW – running 1 hour per day for 14 weeks – equals 40 kWh per annum Total electricity usage for the larder equals 958 kWh p.a. There is a Bothy for students training to become stalkers. The electricity bill for this building is £1,621. 50% of this is attributed to the production of venison. This equates to 6,754 kWh p.a. Total electricity use attributable to venison equals 8,833 kWh p.a.
Heating oil	Heating oil bill equals £3,000. Approximately 50% of this can be attributed to venison. At a unit rate of £0.45 per litre this equates to approximately 3,500 litres of kerosene heating oil.
Water	The estate uses its own private supply of water from a borehole. The electricity used to power the pump is covered above under total electricity usage.
Vehicle and Machinery Fuel Use	
Diesel	Diesel consumption from August to February equals 3,585 litres. This is all attributable to venison Agricultural diesel (June, July, & August) equals 1,689 litres – Digger and tractor for track maintenance. This is all attributable to venison Estate manager's vehicle use – 350 litres (10% of total, allocation based on economic value of venison)
Petrol	Petrol for August to February equals 924 litres – used for quad, argo and snowtrack. This is all

	attributable to venison
Waste Materials	
Municipal solid waste to landfill	General waste from administration building – 1 x 750 litre collected once per week. Based on economic value, 10% of this can be attributed to venison. MSW is assumed to weigh 150kg/m^3[39]. Waste attributable to venison is 585 kg p.a.
Animal waste	Animal waste from the larder is dealt with on site
Methane Emissions	
Total number of deer stalked per annum	334
Stags and hinds	299
Calves	35
Venison Outputs	
Weight of carcasses to dealer per annum	8,006 kg

[39] http://www.hardall.co.uk/

Table A.5 Transport and Processing

Processor	Total Weight of Carcasses per Annum (kg)	Total Weight of Carcasses per Annum (tonnes)	Percentage usable (%)	Total Weight of Venison Produced per Annum (kg)	Total Weight of Venison Produced per Annum (tonnes)
Processor	555,000	555	64	355,200	355.20

Transport to Processor						
Item	**Quantity per Annum**	**Unit**	**Conversion Factor ($kgCO_2e$/unit)**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Diesel	68,000	Litres	2.6694	181,519	327	100%
Total Fuel				**181,519**	**327**	**100%**

Utilities						
Item	**Quantity per Annum**	**Unit**	**Conversion Factor ($kgCO_2e$/unit)**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Electricity	404000	kWh	0.54418	219,849	396	83%
Natural gas	123000	kWh	0.20417	25,113	45	9%
Water consumption	5700	m^3	0.276	1,573	3	1%
Total Utilities				**246,535**	**444**	**93%**

Waste Materials						
Item	**Quantity per Annum**	**Unit**	**Conversion Factor ($kgCO_2e$/unit)**	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**	**Proportion of Footprint (%)**
Waste to incinerator	20000	kg	0.839	16,780	30	6%
Waste to landfill	5400	kg	0.548	2,959	5	1%
Total Waste				**19,739**	**36**	**7%**

Processor	**$kgCO_2e$/year**	**$kgCO_2e$/t CW**
Total Footprint	266,274	480

Processor	
Component	**Comment**
Utilities	
Electricity	Electricity use includes administration building and chillers. Total electricity use at processing plant is 404,000 kWh per annum
Natural Gas	Total natural gas consumption is 123,000 kWh per annum
Water	Total water consumption is 5,700 litres per annum
Vehicle and Machinery Fuel Use	
Diesel	Total diesel use is 68,000 litres per annum. This covers collection of carcasses and transport to processing plant
Waste Materials	
Municipal solid waste to landfill	Municipal Solid Waste (MSW) – 6m^3 skip collected once per month by waste contractor – assume goes to landfill – 50% attributable to Scottish wild venison. MSW is assumed to weigh 150kg/m^3[40]. Therefore total MSW is 5,400kg per annum
Packaging waste	Collected by contractor and recycled
Animal waste	Carcass skins – 20,000 kg per annum – collected by contractor and go to incinerator Bones and other waste – 184,000 – collected by contractor and used for dog food
Outputs	
Total weight of carcasses processed per annum	550,000 kg
Average percentage usable	64%
Total weight of venison produced per annum	352,000 kg

[40] http://www.hardall.co.uk/

www.snh.gov.uk

ISBN: 978-1-78391-132-5

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