The Carbon Footprint of Scottish Wild Venison

Prepared for the Scottish Venison Association

By

SAC Consulting

February 2024

Authors:

John Farquhar

Matt Herbst

Executive Summary

This report summarises the results of a study commissioned by the Scottish Venison Association, to estimate the current carbon emissions of Scottish wild venison, look at options to reduce the emissions where possible to the minimum level, and explore the potential for insetting using woodland creation and peatland restoration. This work looks to revisit a similar Life Cycle Assessment (LCA) study conducted in 2009[1] for what was then the *Deer Commission for Scotland* and update it with current carbon assessments methods and the latest research.

This report is focused on the direct primary emissions of deer, the emissions created through the collection, processing, and distribution of deer carcasses and meat, and the indirect emissions that arise across the supply chain involved with wild deer meat production. Wider carbon opportunities caused by deer population control, such as improved tree establishment, and reduced peatland degradation are covered in a qualitative context.

This report does not aim to compare the emissions figures of wild venison with other published emissions claims of other meat products. The potential variation between apparently similar methods makes this difficult without carrying out the analysis ourselves with exactly the same methods, assumptions, and calculations.

The scope of this carbon footprint is a *cradle-to-gate* assessment covering from the point the deer are born, up to the point the product leaves the processors as a product ready to cook, covering;

- The deer in the hills and woodlands, this includes direct emissions from the animals themselves, the majority of which is methane produced from their digestive system. It does not include any potential indirect emissions from tree browsing damage, or peatland erosion.
- The estates and business managing those deer (electricity and heating for the business buildings, fencing, driving, hauling carcasses, refrigeration of the larder, disposal of waste etc.).
- Transport to the processor.
- Processing of the gralloched carcass into retail products.

We have also run some basic scenarios using assumptions beyond the processor point to allow a comparison between different routes to market i.e. large scale production using processors, distributors and large retailers; small scale production with estates butchering

[1] https://media.nature.scot/record/~7a8334b23c#

the deer and selling direct to customers via farmers market or an inhouse butchers; a hobbyist taking their own culls, butchering them and either selling or giving the meat to friends and family.

To achieve the objectives of this study, we reviewed the methods used in previous and similar studies and have broadly followed them in this study with updated emissions factors. However, one area that we have significantly revised is methane emissions. We decided that recent research and data allowed us to produce a model of methane emissions which would far better represent the Scottish deer population. When applied correctly most earlier methods tend to overestimate the carbon emissions from Scottish wild venison, as they use average emission factors which appear to be based on quite large deer, whereas Scotland has a significant proportion of smaller deer species such as roe deer. We have developed a model which can model emissions for animals of different sizes.

The analysis produced the results summarised in the table below:

		$kgCO_2e/t$ CW	**Proportion of footprint (%)**
Estate	Utilities	148	0.7%
	Vehicle fuel use	1,567	7.0%
	Waste	156	0.7%
	Methane emissions	19,771	88.6%
Processor	Utilities	238	1.1%
	Vehicle fuel use	383	1.7%
	Refrigerants	14	0.1%
	Waste	35	0.2%
	Total	**22,312**	

Approximately 97% of the footprint is generated on the hills and the estates, with processing only contributing about 3% of the emissions.

Methane emissions, which are out of the control of the supply chain, account for 89% of the emissions. On the face of it when we use percentages, it could appear it's not worth addressing the remaining 11% of emissions that are to some extent within the control of the supply chain. However, if we consider it in terms of the absolute amount of carbon, then we can see that 11% is about 2.5 tonnes of carbon for every tonne of carcass, and therefore clearly worth addressing.

Transport and vehicle use is a very significant portion of the emissions at about 8.5%, with electricity use for refrigeration also high at about 1.5%.

Reduction interventions centre around adoptions non-mechanised haulage of carcasses, such as the adoption of low emission vehicles such as electric ATVs and biofuel vehicles or the use of ponies.

With current prices of electricity, adoption of renewable power generation is economic even without any grant incentives. Therefore, wider adoption of renewables in those businesses and processors which have not already adopted, could lead to a significant reduction in carbon.

We have also considered carbon sequestration and storage potentials on land associated with wild venison. Principally these are peatland restoration and woodland or scrub creation. We have not included these as directly connected to wild venison production, as the relationship between peatlands, woodland and deer is complex, and does not easily fit the rules in the carbon footprinting standards around direct removals. For this reason, we would see this form of sequestration and storage as “insetting”, which is an unofficial term often used to describe offsetting that is carried out on land under the control of the businesses involved in the product supply chain. Insetting via peatland restoration and suitable woodland or scrub creation offers a huge potential for short-term and medium-term sequestration. 80% of Scottish peatland is degraded with the potential for restoration to reduce carbon emissions, and we would estimate a significant portion of this degraded peatland is on land used by wild deer and under the control of businesses involved in wild venison production. High deer numbers often lead to an increase in peat degradation through increased trampling and rubbing of bare peat, which causes erosion. Also, on restored peatlands larger populations can damage peat dams and other interventions resulting in both carbon and financial losses. An IUCN report[2] estimates that significant restoration efforts could reduce emissions by 2.7MtCO2e per year. This demonstrates the potential that peatland restoration has for insetting the emissions from wild venison. Based on Peatland Code data, the estimated 3,500 tonnes of Scottish wild venison a year could be net zero with the restoration of 7,000 – 42,000 ha of degraded peatland (depending on the level of degradation). Crucially continued deer management is an essential part of peatland restoration and for increasing carbon storage in local ecosystems. However, peatland restoration is difficult and to-date the rate of restoration even with government funding, has

[2] https://www.iucn-uk-peatlandprogramme.org/sites/www.iucn-uk-peatlandprogramme.org/files/100218Briefing_Peatlands_andGreenhouseGasEmissions.pdf

been hampered by lack of trained and skilled labour and contractors to carry out the restoration.

Woodland areas also provide large amounts of carbon storage potential if implemented correctly. Currently Scotland has only about 17% of its land area covered by forests, higher than the rest of the UK but well below the European average of 38%.[3] Over the past 100 years Scottish forestry has changed from large scale single species timber forestry that was prevalent in the 1960s-1980s and has now transitioned to more sustainable forestry practices. Widescale forestry growth will lead to higher levels of carbon stored, in 2016 around 12 million tonnes of CO2 were removed and that will only have increased as more forests have been planted/established.[4] New planting will need to consider pressures from deer browsing and land constraints, but when implemented new forests can create potential offsetting options. The IUCN advocates for forest landscape restoration, a restoration plan that examines the whole landscape and builds in ways of strengthening resilience in the system.[5] Based on Woodland Code data, Scottish wild venison could be net zero with 10,500 – 21,000 ha of broadleaf woodland creation.

1 Introduction

Wild deer are an important resource for Scotland. They offer a wild caught meat option that also give a cultural and historical connection to the land. Deer provide provisioning services through their meat, supporting services from their manure deposits in soils, cultural services from their cultural importance and potential for tourism, and when in healthy numbers can be a regulating service keeping certain trees and vegetation under control.

However, with a lack of wild predators of deer in the Scottish landscape, uncontrolled numbers are a problem, principally through excessive browsing damage. In a study investigating potential deer impacts on Scottish woodland sequestration, it was theorised that currently 15-20% of young woodlands have been damaged by deer browsing. This effect also limits the natural regeneration of forest, and the creation of new tree stands. This will hurt above ground carbon storage overall as no younger trees will have established an understorey, leading to the dominance of smaller brush species within current woodland

[3] www.gov.scot. (2019). *Scotland's Forestry Strategy 2019–2029 - gov.scot*. [online] Available at: https://www.gov.scot/publications/scotlands-forestry-strategy-20192029/pages/4/.
[4] www.gov.scot. (n.d.). *Scottish greenhouse gas emissions 2016*. [online] Available at: https://www.gov.scot/publications/scottish-greenhouse-gas-emissions-2016/.
[5] www.iucn.org. (n.d.). *Forest Landscape Restoration | IUCN*. [online] Available at: https://www.iucn.org/our-work/topic/forests/forest-landscape-restoration.

habitats[6]. Other concerns around below ground carbon as leaf litter composition changes will affect the overall carbon cycling within soils, limiting the ability of microorganisms to best decompose litter into usable soil nutrients. This study does not intend to quantify this indirect carbon benefit, but it is noted that any measures to control the population numbers with activities such as stalking, can only improve the carbon credentials of Scottish wild venison.

This resource is very different from farmed meat sources. Livestock and the controlled nature of their lives allow for much more regulation of their food and how their emissions are produced, and sometimes captured. Methane emissions are always a part of the carbon cycle of deer, meaning that any controls for their food intake or feed additives will have an overwhelming effect on deer emissions. The lack of ability to influence or change wild deer diets mean that on methane emissions alone we are unlikely to ever manage to directly reduce emissions from the hill stage of production. This does not mean that the product should be removed, instead the relationship between deer and climate change will need to be adapted to continue to ensure that these animals are allowed to thrive in their natural habitats.

Wild animals offer different benefits to their ecosystem vs farmed livestock. There are no artificial inputs such as fertilisers and pesticides being used in the soils where these deer reside. The benefits of no artificial fertilisers are lower emissions of nitrous oxide, a potent greenhouse gas, ammonia to the atmosphere – associated with eutrophication and human health issues, and less pollutants entering water sources. More focused management of deer numbers ensures that healthy, diverse wild landscapes will continue to flourish while also limiting the negative effects on peatlands, forests and woodlands. The hunting of this animal also provides a natural meat source allowing for people to feel more connected to the food and their lands. As a meat source wild venison also has the advantage of having no artificial inputs such as medicines or feeds.

The management of these animals will help to ensure that they continue to play a role in the future of Scottish meat consumption and the ecological future of Scotland. Whilst it is not the focus of this study, which is looking at a meat product, to consider the wider impacts of the whole herd, very basic calculations of the impact of the methane emissions from the Scottish wild dear population show it is significant, and therefore clearly the control of the population can only help. Taking population estimates from the publications of between 600,000 and 800,000[7] and a 60:40 split of Red to Roe (it is acknowledged that these are very broad

---

[6] Hirst, C., 2021. *Deer in a changing climate–how do wild deer affect carbon sequestration in Scottish woodlands?* University of Edinburgh.
[7] https://www.gov.scot/publications/management-wild-deer-scotland/pages/5/

estimates, but it at least gives an idea) and using our methane emissions estimates (not the current ones used for national inventories), gives an annual impact of 110,000 – 130,000 tonnes of CO_2e a year from the Scottish herd.

However, whilst the headline figure of ~23 tCO_2e/tCW produced in this study include methane, there is an argument that could be made that as this is a wild animal, these methane emissions would happen anyway, and as the primary activity of stalking is to control deer numbers, not meat production. Only the additional activities involved in processing the carcass into meat should be included. Whilst we haven't done the full work to calculate this accurately, we can estimate it by simply removing the methane emission from our calculations. This results in a red meat product with a carbon footprint of about 2.5tCO_2e/tCW, an order of magnitude lower than any of the various figures quoted for farmed red meat.

Unlike the 2009 study, this report does not aim to compare the carbon footprint of wild venison with other wild or farmed meats. The reason for this is that even today, with over 15 years of development and standardisation of LCAs and carbon footprints[11,8,9], comparison of carbon footprints between different studies is challenging. There are number existing national and international standards that describe methods for conducting LCAs and carbon footprints, the UK developed one of the first, known as PAS 2050, which was then adapted to form the international standards from the *International Standards Organisation* (ISO) such as ISO14044, ISO14067. Whilst it is the intention of these standards to allow comparison across products in a similar sector, and they do achieve this at a high level, in reality the very necessary flexibility required for them to be applied across a wide range of businesses and supply chains, allows for users to choose slightly different assumptions and calculations. Within the standards, legitimate variations in calculations and assumptions are permitted for very good reasons, but these *may* result in significant variation in the results when carried out by different entities. Often, published emissions figures include insufficient details of the methods to allow other parties to either copy, or adjust their results to make a comparison, but currently there are a number of emissions claims for different meat products with insufficient information to allow reliable comparison. For a robust comparison, SAC Consulting would recommend that the same entity carry out the LCA for all products in the comparison to ensure all the same methods, assumptions and calculations are used. However, this would be beyond the scope, focus and resources of this study.

[8] https://www.iso.org/standard/71206.html
[9] https://www.iso.org/standard/37456.html

2 Scope of the Footprint

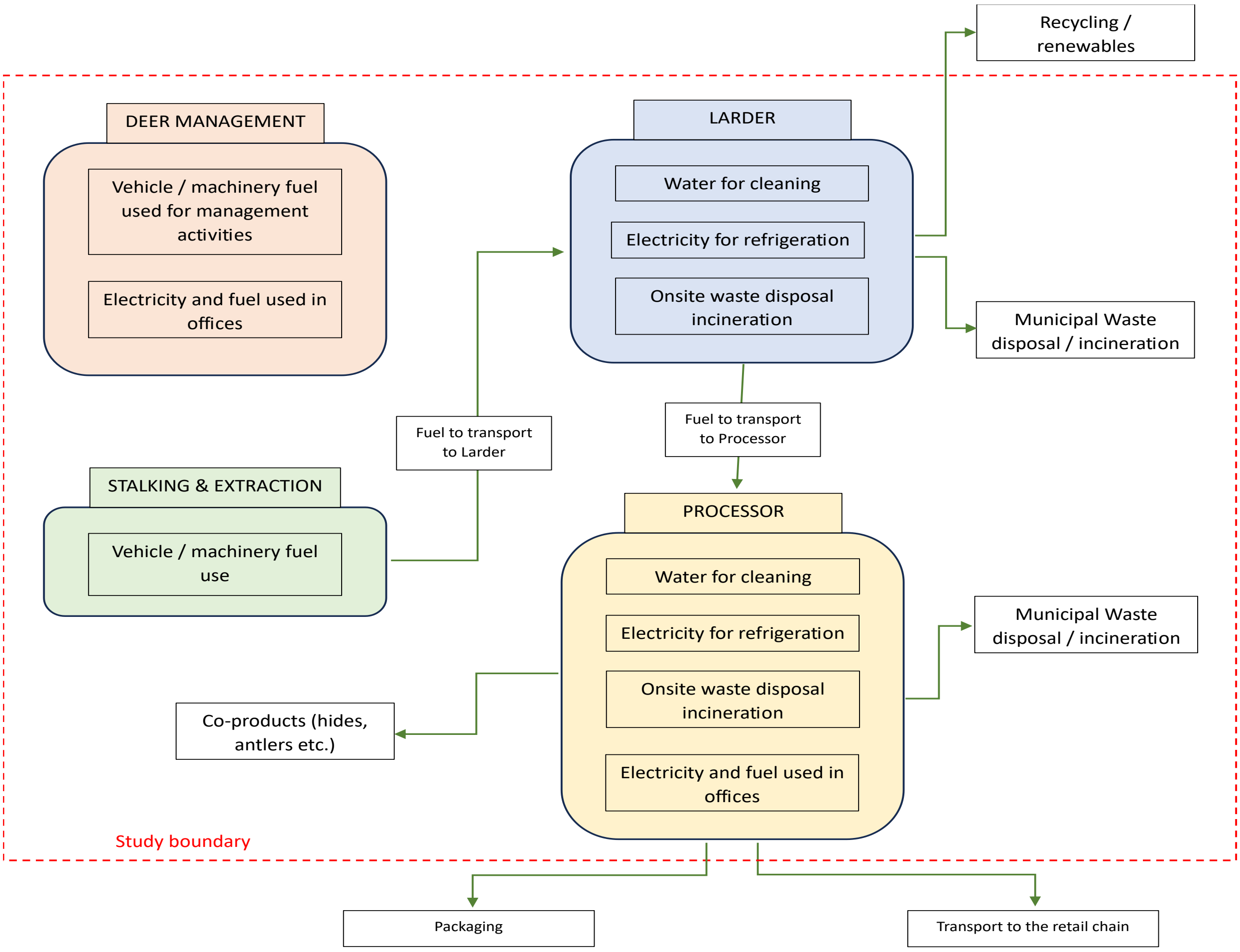

Figure 1 - Boundary of the study showing inclusions

This footprint is focused on the greenhouse gas emissions associated with wild venison in Scotland, the study covers both direct and indirect emissions from the supply chain. Direct emissions are those that occur within the physical boundaries of the businesses involved in wild venison production e.g. CO_2 from the exhaust of vehicles used on an estate, indirect emissions are those that occur as a result of activities or use of resources by the businesses, but the actual emissions occur elsewhere, e.g. on-site electricity use resulting in CO_2 emissions from the power station.

In addition, the report goes into detail for each business type (estates and processors) on their scope 1, 2, and 3 emissions as defined in the Greenhouse Gas Protocol (GHG Protocol)[10]. It should be noted that for a ***product*** such as wild venison, we don't use the

10 https://ghgprotocol.org/sites/default/files/ghgp/standards_supporting/Diagram%20of%20scopes%20and%20emissions%20across%20the%20value%20chain.pdf

terms scope 1,2, and 3, as they only apply to an organisation or business's footprint. Therefore, scope 1,2, and 3 emissions breakdown is included for information purposes for those business involved in the supply chain. A basic description of the different emission scopes is below.

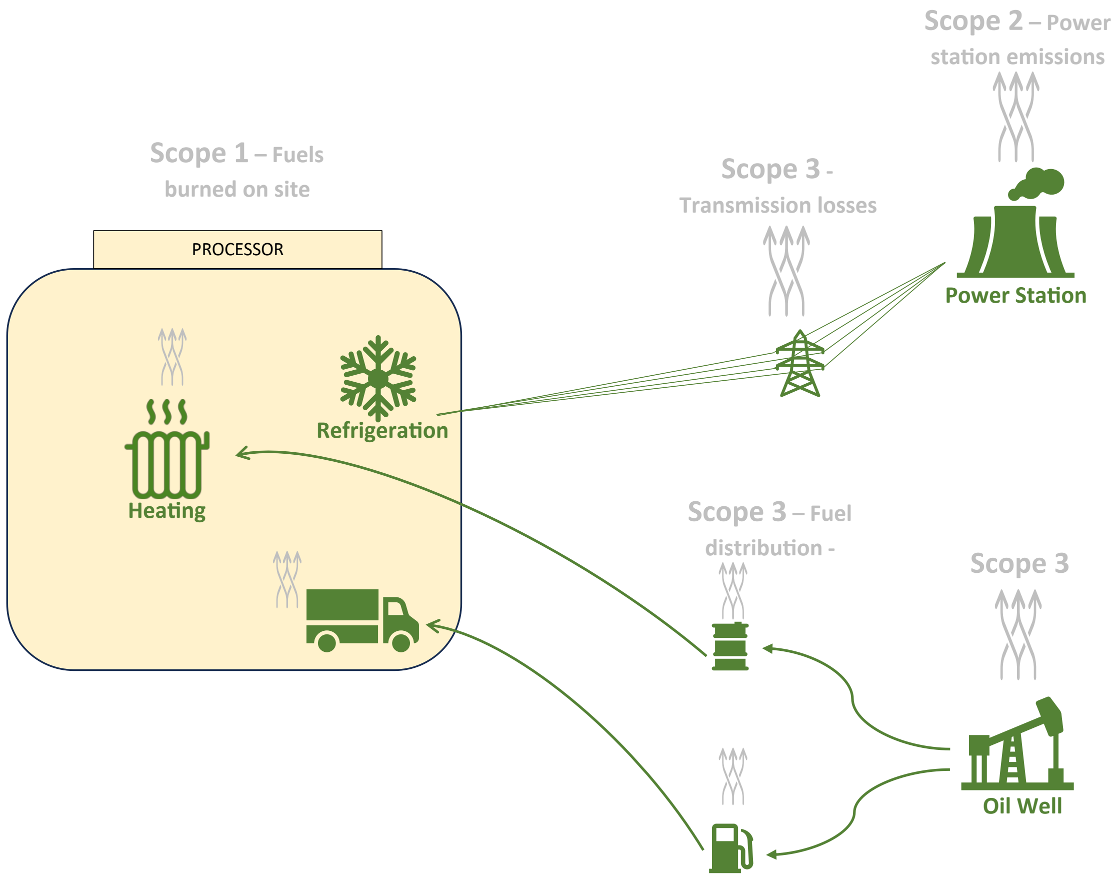

Figure 2 - Basic description of GHG emissions scopes

The carbon footprint is focused on the direct primary emissions of deer, the emissions created through the collection, processing, and distribution of deer carcasses and meat, and the indirect emissions that arise across the supply chain involved with wild deer meat production.

Emissions from four estates are examined to determine the approximate amount of the greenhouse gas emissions from the wild deer supply chain. The measurements are all made in CO_2 equivalent (CO_2e) measures which equates other forms of greenhouse gas emissions, notably methane in this footprint, to the standard CO_2 measurements.

Out-of-scope for this study are the following:

- Indirect Scope 3 emissions from the manufacturing and disposal of machinery and vehicles used in the supply chain. They are excluded due to both the complexity involved in estimating them, and that they would be expected to be a fraction of a percent of the total emissions.
- Indirect Scope 3 emissions from the manufacturing and disposal of packaging used for the venison products. They are excluded due to the complexity of LCA for packaging would have added to this study, and again would likely not be a very significant part of the total emissions.

The scope of this carbon footprint is a *cradle-to-gate* assessment covering from the point the deer are born, through the estates and businesses carrying out deer management in the woodlands and uplands, up to the point the product leaves the processors as a retail product (steaks, mince, sausages etc.). However, the *functional unit* (the functional unit is the LCA term for the quantity of a product that is used to calculate the emissions for) in this study is not the retail meat products after final processing, but instead is the dressed carcass that comes out of initial processing (skinned, head and legs removed, and final internals removed) before being further processed into the retail products. This mix between the functional unit and the end point of the assessment is not ideal, as we include emissions after the dressed carcass has been produced, which therefore means we are overestimating the carbon footprint of the dressed carcass. However, it does allow comparison with the previous study and others which have used this same mixed approach, which we feel is more important.

Whilst it is a very important aspect of deer management, the potential indirect carbon benefits from avoided tree damage, improved woodland establishment, and reduced peatland degradation, are not a focus of this study.

For the purposes of this footprint only the emissions from wild deer are examined. The data is not compared with other similar emission sources such as farmed animals for meat. The data is focused on identifying areas for future improvement within the wild venison supply chain. Parts of the recommendations will examine changes to land uses and other ecological processes involved with wild venison consumption.

3 Methods

We have used the raw estate data collected as part of the 2009 study carried out for what was then the Deer Commission for Scotland, no new resource use and cull data has been collected.

The functional unit in this study is a tonne of dressed carcass (t CW) before it gets further processed into retail cuts at the processor. This is the whole carcass with internals removed, head and legs removed, and skin removed.

3- Courtesy of Highland Game

Carbon baseline

Broadly we have used the methods in the public standard developed by BSI – PAS 2050[11], this is the method used in previous studies and is the method that has been minorly adapted to form the methods in major carbon accounting systems such as the GHG Protocol and Science Based Targets initiative (SBTi). There are other more recent standards such as ISO-14067, however the underlying emission calculation methods are the same, but with the addition of carbon storage, more clarifications, sector specific guidance and defined reporting methods, none of which particularly apply in this study.

Allocation

Under the PAS 2050 and other standards, there are a couple of ways we can allocate resources to a target product (in our case wild venison) when a site uses resources to

[11] https://knowledge.bsigroup.com/products/specification-for-the-assessment-of-the-life-cycle-greenhouse-gas-emissions-of-goods-and-services?version=standard

produce more than one product. One method is to split the resources based on the relative monetary values of the different products – this is known as “Economic Allocation”. The other method is based on the relative quantities of each product, e.g. weight, volume, energy content etc. this is known as “Physical Allocation”.

PAS 2050 defaults to economic allocation as the preferred method, but SAC typically recommends the use of physical allocation when wanting to compare changes in emission over time. The unit quantity is fixed, whereas the unit market value can change resulting in a change in the carbon footprint over time without any physical change in the production process. Most more recent carbon methods (GHG Protocol, SBTi, ISO14067) also recommend physical allocation as the preferred option. However, when the relative quantities of the products are vastly different, as is the case on an estate which produces wild venison (a few tonnes) and timber (hundreds of tonnes), then there is a need to use the economic allocation to reasonably allocate the total estate resource use. However, it is important if you wish to compare one year’s emissions with another, that the same economic values used in year one are used from then on, they should not be updated to current market values.

Unfortunately, the study carried out in 2009 did not include the full details of the allocation method used at the estate level to split resources between deer management and other estate products and services, but it does tell us it used economic allocation, but not the specific monetary values used just relative values. Therefore, we have had to take the data published in the that report and assume the allocation is correct (See Appendix 3 – Raw data and comments from 2009 Study).

Whole herd versus food animals

For farmed animals, a common method of carbon calculation is to use an annualised “whole-herd” approach which can be used from farm level right up to national herds. In the whole-herd method, you take all the emissions produced in one year from all animals in the, for example beef herd, including the calves, youngsters, finishing animals, mothers, and bulls. Those emissions are then averaged across the amount of meat produced in the processors in that same year. This is a valid method as all those animals in the herd are required for farmed meat production and would not otherwise be there. Whereas wild venison comes from a cull to control numbers of a wild animal which no longer has predators, the wild herd is not there simply to provide meat, they would exist anyway. Therefore, for our quantitative review, we do not take a whole herd approach, we only take emissions from the animal destined for the dinner table. However, to get the true emissions from that animal we need to include all the emissions since it was born. This is in effect a “single-animal, whole-life” approach.

Methane emissions

Methane is the biggest source of emissions from wild venison, therefore differences in calculation methods and assumptions will have a critical impact on the overall result. We reviewed the methods and data used in previous studies and updated them to reflect the latest research and methods and make them more applicable to Scottish deer populations.

Most methods for emissions from deer rely on a method designed in 2006 by the IPCC to estimate national and global emissions, and changes in them, from wild animal populations. The method was never really designed to be used to estimate emission from a specific supply chain, more to be used at the national level for emissions inventories. Over time the single methane emissions estimate for all “deer” in these inventory approaches have ranged from 10.4kgCH_4/head/y in 2007[12], up to the current figure of 20kgCH_4/head/y based on the 2021 national inventory[13].

These figures are simply “per animal” regardless of their size, and methane emissions in all ruminants are strongly correlated to size[14] as this in turn correlates to the amount of food intake. The main issue with the IPCC based methods, is that they generally rely on the least robust type of emission factor, known as a Tier 1 factor, these are estimates based on averages either across the whole world or sub-regions, such as tropical, temperate etc. Yet deer species range in size from a few kilos up to hundreds of kilos, therefore the averaged emission factor for temperate zones, with such a wide range of sizes, is unlikely to be applicable to a more limited range of species in a smaller geographical area such as Scotland. Due to the significant number of roe deer in Scotland, which is a relatively small species, ranging from 10-25kg, it is likely that using the national inventory approach would lead to overestimates of methane emissions.

There are other better (Tier 2) methane emission factor calculation methods based on an alternative IPCC method using a formula to calculate methane emissions based on measured dry matter feed intake, and estimated feed energy. However, there are no specific formula for deer, therefore sheep is generally used as a proxy, reducing the accuracy.

---

[12] https://naei.beis.gov.uk/reports/reports?report_id=556
[13] https://naei.beis.gov.uk/reports/reports?report_id=1108
[14] Smith, F. A., Lyons, S. K., Wagner, P. J., & Elliott, S. M. (2015). The importance of considering animal body mass in IPCC greenhouse inventories and the underappreciated role of wild herbivores. *Global Change Biology*, *21*(10), 3880-3888.

The most relevant piece of work relating to methane emissions, was a wild ruminant meta-study of available literature, plus some new methane measurements from deer (red deer)[15], and more specifically red deer fed on a heather and grass mix, which should more closely approximate the type of natural food a significant proportion of wild deer in Scotland consume.

We therefore decided to estimate methane emissions based on the size of the deer typically found in Scotland. We took the raw measured methane dataset found in the Pérez-Barbería 2017[15] study and filtered for all the red deer methane emissions test result which included the animal weight. From this dataset we were able to produce an average enteric emission figure per kilo of animal liveweight per year of 0.137kgCH_4/kg/y. The Smith *et al* 2015[14] study showed that emissions are very strongly correlated to weight, therefore we were confident to apply this emission factor per unit body weight, to weight data for the Scottish venison population.

Methane emissions from manures are conventionally estimated using specific emission factors per animal per year from the IPCC Tier 1 (least accurate) method in the national inventories[12] of 0.26kgCH_4/head/y. However, this again does not factor in the size of the animal and would therefore lead to gross errors when applied to smaller deer such as roe deer. Unfortunately, we were unable to find specific tested manure emissions data for deer to get some accurate raw data. Therefore, we extrapolated the IPCC Tier 1 manure methane per animal per year figure to a per kilo liveweight per year, by using the same ratio of emission found when converting the enteric emissions from per animal to per kilo liveweight i.e. approximately 56:1. This is definitely not the most robust method, however we feel it is far more accurate that using Tier 1 averages for all temperate regions of the world. When we apply the conversion ratio it produces a manure methane emissions factor of 0.0046kgCH_4/kg/y.

With access to some of the large datasets collected for stags over the last decade, and also collated cull returns with data from over 30,000 animals. With an allowance for the gralloch, we have been able to get a more accurate picture of the actual weight of the animals entering the wild venison supply chain, along with the very limited published weight data for red deer[14] and roe deer[16] and information sheets from various mammal and deer interest groups, we are reasonably confident in the weight data in the model. However, the age data

[15] Pérez-Barbería FJ. Scaling methane emissions in ruminants and global estimates in wild populations. The Science of the Total Environment. 2017 Feb;579:1572-1580. DOI: 10.1016/j.scitotenv.2016.11.175. PMID: 27923575.
[16] Pėtelis, Kęstutis & Brazaitis, Gediminas. (2003). Morphometric Data on the Field Ecotype Roe Deer in Southwest Lithuania. Acta Zoologica Lituanica. 13. 61-64. 10.1080/13921657.2003.10512544.

is based on a relatively small monitored and modelled population from the Isle of Rum and is probably the least robust in the model.

The weight profiles below were those used for modelling methane emissions.

Age (yrs)	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Red deer weight (kg)													
Red deer stag	7	26	44	63	82	100	119	119	119	119	119	119	119
Red deer hind	6	19	32	46	59	72	85	85	85	85	85	85	85
Roe deer weight (kg)													
Roe deer buck	1	4	7	11	14	17	20	20	20	20	20	20	20
Roe deer doe	1	4	7	10	12	15	18	18	18	18	18	18	18

The importance of age

When modelling emissions from animals, especially any ruminant which produces methane, the age of the animal at slaughter or cull has by far the greatest effect on emissions. The longer the animal has been alive the more emission have come from that animal. Therefore, accuracy of age estimation is key to an accurate carbon footprint. However, wild deer are difficult to age by all but the most experienced, unless relatively lengthy procedures analysing teeth or jaw bones are used [17].

Due to the difficulty in getting accurate age estimates of the specific animals culled at this stage, we have used a different approach based on the average age of the whole Scottish deer population[18]. As this is part of a cull it is not important which specific animal is culled, it is more important that the required number are culled. Otherwise from the point of view of purely carbon, then culling only young animals would reduce the carbon footprint of the meat on paper, in reality there would be no net difference in emissions from the herd compared to only culling older animals. Overall, each year there are the same number of animals left in the herd, so the herd emits the same amount of methane.

There are several estimates of the age structure of the Scottish deer population[18] and based on some of these we have estimated the average age initially at 4 years old for males and 5 years old for females for both red deer and roe deer.

[17] Pérez-Barbería, Francisco & Duff, Elisabeth & Brewer, Mark & Guinness, Fiona. (2015). Estimating the age of Scottish red deer.
[18] Buckland, S. T., Ahmadi, S., Staines, B. W., Gordon, I. J., & Youngson, R. W. (1996). Estimating the Minimum Population Size That Allows a Given Annual Number of Mature Red Deer Stags to be Culled Sustainably. Journal of Applied Ecology, 33(1), 118–130. https://doi.org/10.2307/2405021

Based on the weight profiles and average age, we have produced the following lifetime methane emission for each class of deer (species, male, female, juvenile).

	Lifetime enteric methane $kgCH_4$/head	Lifetime manure methane $kgCH_4$/head
Red deer stag	30.3	1.03
Red deer hind	31.9	1.08
Red deer calf	4.5	0.15
Roe deer buck	5.0	0.17
Roe deer doe	6.6	0.23
Roe deer calf	0.7	0.02

These were then applied to deer numbers returned by each estate, to give the overall methane emissions which were then converted to CO_2 equivalents.

Reduction interventions

To evaluate potential discrepancies within deer emissions a systematic review of previous research was conducted. This review examined various factors that may affect the overall deer emissions on Scottish estates and what potential options that estates and landowners might have to better mitigate the emissions.

This review was conducted through an online search of relevant academic articles that examined deer methane emissions, and carbon mitigation measures. The focus was on studies involving Scottish deer or in habitats most similar to Scotland. The results of this review found six different carbon mitigation methods that all had varying potential for carbon reduction within the wild deer supply chain. These six mitigations were evaluated to find their potential carbon reductions in CO_2e and what changes they would have on overall emissions.

4 Results

The full details and breakdown of the emissions by scope are detailed in *Appendix 1 – emissions breakdown*. Below are the summaries of emission across the supply chain.

The results of this study show that Scottish venison emissions have been underestimated in the past, but that there are options to reduce carbon emissions. Equally there is an opportunity, with cooperation across the supply chain, to improve the accuracy of the LCA to better target interventions with the greatest reduction potential.

Estates

At the estate level we have split the emissions by category of activity, broadly grouped as Resource use and methane emissions. The data for each estate is listed in tables 1-4 below.

To make comparison between estates we have summarised all the emissions across the estate level below based on a tonne of dressed carcass weight.

Table 1: Emissions from the 4 sampled estates, split by resource uses and methane emissions.

	Estate A	Estate B	Estate C	Estate D	
Carcass weight sent to dealer	2,890	19,274	10,650	8,006	kg
Utilities	292	45	192	287	$kgCO_2e/t$ CW
Vehicle fuel use	2,958	702	2,024	2,538	$kgCO_2e/t$ CW
Waste	2	278	65	38	$kgCO_2e/t$ CW
Methane emissions	14,531	14,853	19,642	33,677	$kgCO_2e/t$ CW
Total emissions	**17,783**	**15,877**	**21,923**	**36,540**	$kgCO_2e/t$ CW

We can see that there is considerable variation between estates, however this is mostly due to variation in methane emissions, specifically Estate D appears to have significantly higher methane emissions. Looking at the detailed data returned from the estate (see Appendix 1 – emissions breakdown and Appendix 3 – Raw data and comments from 2009 Study) it appears to have a very low average carcass weight (24kg) compared to the other red deer estate (41kg). Our method based on an estimated age of 4-5 years would skew the results for those estates with younger smaller deer.

Combining the data to produce a weighted average, gives the following emissions.

Table 2: Weighted average emissions at the estate level

	ALL Estates	
Carcass weight sent to dealer	40,820	kg
Utilities	148	kgCO2e/t CW
Vehicle fuel use	1,567	kgCO2e/t CW
Waste	156	kgCO2e/t CW
Methane emissions	19,771	kgCO2e/t CW
Total emissions	**21,642**	kgCO2e/t CW

As the tables above show, there are considerable emissions from the estate level. One of the main sources of emissions that is within the control of the estates is vehicle and machinery usage which does provide some potential avenues for carbon reduction throughout the supply chain.

Processors

In the case of large-scale wild venison production there are a handful of game processors and dealers which process venison at scale and supply at a national level, most of these operate a vehicle fleet to collect the partially processed carcasses from the larders on the estates, we have shown the transport emissions separately. Data from a sample of these processors collected in the 2009 study, is shown below. It should be noted that at this time we are not aware if any of the processors had any renewable energy generation on site such as Solar PV or biomass boilers, it wasn't mentioned in the 2009 study, so we assume not.

Transport to Processor	
	Total kgCO2e/t CW
Diesel	383
Total Transport	**383**

Total emissions	21,642	kgCO2e/t CW

Processor

Utilities		
	Total $kgCO_2e/t$ CW	**Proportion of footprint (%)**
Electricity	187	65%
Natural gas	47	16%
Water consumption	4	1%
Total Utilities	**238**	**83%**
Refrigerants		
Refrigerants *	14	5%
Total Refrigerant	**14**	**5%**
Waste		
MSW to landfill	5	2%
Animal waste to incinerator	30	11%
Total Waste	**35**	**12%**

*Estimated based on SAC data gathered from other meat processors for refrigerant losses

As expected, the greatest sources of emissions are from electricity usage in the refrigeration system and gas usage for heating water.

Wild venison emissions

When we combine all the separate emissions from the estate, transport and processing we get the combined data as shown below.

		$kgCO_2e/t$ CW	**Proportion of footprint (%)**
Estate	Utilities	148	0.7%
	Vehicle fuel use	1,567	7.0%
	Waste	156	0.7%
	Methane emissions	19,771	88.6%
Processor	Utilities	238	1.1%
	Vehicle fuel use	383	1.7%
	Refrigerants	14	0.1%
	Waste	35	0.2%
	Total	**22,312**	

Different routes to market

As part of the study, we have been asked to model some alternative routes to market for wild venison. But it should be noted that this is not a proper carbon footprint or LCA, it is a modelled scenario using broad unqualified assumptions to assess potential difference in emission between those routes. The routes to market we considered are:

- Large scale production using large processors and game dealers, distributors, and large retailers. This is the system studied in detail as part of the main study.
- Small scale production with estates butchering the deer and selling direct to customers via farmers market or an inhouse butchers.
- A hobbyist taking their own culls, butchering them and either selling or giving the meat to friends and family.

All routes involve the same methane emissions, and the same stalking vehicle use. It is after this point that they diverge from the large-scale production system we have considered in the main study.

- Large scale production has the same emissions as those in the study up to the point it leaves the processor, then HGV refrigerated transport is used to transport to UK wide distribution points and retailers to we add on emission for this transport and storage (estimated from the fuel usage and refrigeration data provided by the processors for collecting the carcasses)
- Small scale production has the same estate resource usage emission as large scale production but has a slightly higher processing emissions than large scale, as we would reasonably expect efficiencies of scale to come into play to reduce energy use per tonne of carcass. But after this the transport to local markets or butchers would involve far lower transport distances than large scale national distribution, and hence reduced emissions in comparison.
- Hobbyist production does not have any of the estate resource usage, as the carcass will leave the hill in the stalkers vehicle and use their domestic fridges and freezers in their home. As it is likely they would have these fridges and freezers running anyway, we have not included any emissions from storage or processing. As the meat is likely to be supplied to neighbours and friends they would see anyway, we also assume to additional transport emissions to get it to the consumers.

Based on the assumptions above we have the modelled emissions below. Please note, to avoid having to allow for additional wastage from final processing into products such as steaks and joints, we have kept the functional unit as a tonne of dressed carcass. Therefore, the overall emissions in the scenarios below are NOT the net emission for a tonne of meat product. This is not important for the purposes of this scenario modelling as we are only interested in the relative differences between the routes to market.

		Large scale	Small scale	Hobbyist
		kgCO_2e/t CW	kgCO_2e/t CW	kgCO_2e/t CW
Estate	Utilities	148	148	
	Vehicle fuel use	1,567	1,567	1,567
	Waste	156	156	156
	Methane emissions	19,771	19,771	19,771
Processing	Utilities	238	286	
	Vehicle fuel use	383		
	Refrigerants	14	17	
	Waste	35	42	
To market	Utilities for storage	167		
	Vehicle fuel use	765	115	
	Total	**23,244**	**22,102**	**21,494**

We can see from the above that small scale and hobbyist have lower emissions, mostly due to the reduced transport requirements. But it should be considered that it may be difficult or impossible to get all the wild venison produced in Scotland, to consumers via small scale or hobbyist routes.

Reduction potential

During the qualitative review six mitigation measures were examined to find their relevant carbon removal potential. These measures were: deer culling, carcass transport improvements, ericaceous diet changes, tree planting, and peatland restoration.

When reviewing literature on GHG emissions from deer, it is generally considering it at a national scale, generally in the context of national GHG inventories. Reduction options suggested in the literature at the national level include deer culls as the clearest and quickest way to a reduction in greenhouse gas emissions. However, in the context of this study, which is calculating the carbon footprint of a *product*, rather than a country, the specific calculation method that has been used (single-animal, whole-life) means that reducing the whole herd does not alter the carbon emissions of the meat that comes from that single animal. Therefore, this study does not consider wider culling policy.

By improving the way carcasses are transported, wild deer hunters and processors can directly lower their own carbon footprints. Currently, the most common form of transport involves the use of all-terrain vehicles to transport carcasses shot back to the larder, to be processed. These carcasses are then transported to the processing facility, again with vehicle using fossil fuels. Options like the creation of local transport hubs and increased collaboration between estates can help reduce overall milage. Minimising the amount of fuel use throughout this process would significantly lower scope 1 emissions on estates. In a study in northern Italy, it was estimated that around 50% of the direct emissions of red deer hunts resulted from hunter transportation choices, with another 30% of emissions coming from secondary production emissions of the transport in question[19]. Other options would be the use of lower emitting transport options like electric drivetrain vehicles or ponies to use for carcass transport. Finally better planning and routing of transport vehicles for collection of carcasses from estates would limit the total distance required and lower the direct emissions from processors collecting meat from estates.

Tree planting and peat restoration are both often mentioned in studies around carbon mitigation for rural estates. The creation of new tree stands, and healthy peat would lead to mitigation as more carbon is captured within those environments. Woodland creation would need to be carefully sited as concerns around tree location and species choice will be incredibly important to ensure the highest amount of carbon can be sequestered. Costs of separating woodland creation through fencing are high and maintenance would also need to

[19] Fiala, M., Marveggio, D., Viganò, R., Demartini, E., Nonini, L. and Gaviglio, A., 2020. LCA and wild animals: Results from wild deer culled in a northern Italy hunting district. *Journal of Cleaner Production*, *244*, p.118667.

be factored into any fencing creation. Broadleaved species will usually provide wider benefits to the local ecosystem and long-term carbon storage, through both above ground and below ground capture, but conifer plantings may lead to more short-term carbon storage from their faster growth rates. For any environmental restoration work to be successful a healthy deer density of <4km2 would need to be achieved. This would allow for natural regeneration and expansion of woodlands and lower the overall negative impact of wild deer herds.

5 Reduction Recommendations

5.1 Estate Level

5.1.1 Energy Management

As outlined in earlier reports energy management improvements offer a path forward for reducing carbon emissions.

Energy Efficiency

Lowering energy used for heating (offices etc) and chilling (larder) through increased efficiency is an ideal method of reducing Scope 2 emissions from estates. Efficiency measures such as increased insulation, regular maintenance and enhanced temperature control in both the heating system and the chiller, would lower energy requirements and lower energy costs for the estate. These changes should be implemented after an energy audit is conducted to best identify which areas will offer the highest level of improvement.

Renewable Energy

Each of the estates listed in the tables above displayed noticeable Scope 2 electricity emissions as part of the footprint. Switching to greener more renewable sources will help to reduce reliance on national grid power which will still include fossil fuel usage. This could be done through on-estate adoption of solar, hydro, or small wind power, but the removal of renewable incentives from the government means that the financial viability of renewable energy projects needs to be carefully considered. In addition, battery systems could be installed to help ensure a stable supply of green local electricity on days where solar or wind sources are not as abundant.

Based on the data collected from the estates in 2009, if all estates were to install renewable energy generation, and assuming it could contribute to 50% of the annual power requirement, it would reduce the overall carbon footprint of wild venison by 75 – 110 kgCO_2e/tCW.

5.1.2 Reducing Fuel Usage

Lowering on-estate fuel consumption will be an important step in addressing scope 1 emissions. Fuel usage on site makes up the large majority of non-methane scope 1 emissions at all of the estates in the study as well as a large component of the processor's emissions. One potential switch would be to invest in new electric off-road vehicles to carry carcasses, especially if the power used to charge them is coming from renewable sources, this would result in a decrease in scope 1 emissions.

Changes in driving practices to improve fuel savings, ensuring that vehicles are well maintained, and using the most fuel-efficient vehicles could also play a role in lowering fuel consumption throughout the entire venison system. The creation of local transport hubs, or cooperative transport can also be utilised to lower overall mileage travelled.

Based on the data collected from the estates in 2009, if all estates were to switch to electric vehicles, or use more fuel efficient vehicles and carried out other measures which could reduce the overall fuel use by 50%, it would reduce the overall carbon footprint of wild venison by 700 – 800 kgCO_2e/tCW.

5.1.3 Management of Land for Carbon Sequestration

The creation of carbon rich environments and long-term support of their sustainability can help to counteract emissions during venison processing. The storage of carbon within plant organic material is a possible avenue to help reduce the overall carbon footprint of estates. Investing in the rehabilitation of carbon rich environments, such as peatlands, biodiverse forests, riparian areas, and other landscapes can play a major role in preserving and improving the carbon storage of the land within the estate's boundaries.

Where possible deer density on estates should be managed to lower the overall pressure created by high stocking densities. Larger populations of deer can lead to ecological degradation and lowering the overall deer density in the area can help reverse some of the most destructive processes created by deer. These include peatland degradation, inability of forests to naturally regenerate, damage to existing forests and trees, loss of soil cover and more.

The capture and storage of carbon in the landscape needs to be carefully done as improper methods can lead to carbon loss. Transitions such as the creation of single species timber forests can lead to short term carbon gains from tree growth but can on the wrong soil types, lose carbon storage from soil respiration loss and the destruction of healthy ground level, and where already present, certain understorey habitats. Commercial forestry projects are important to UK timber resources overall, but they can present biodiversity loss when planted on biodiverse habitats such as those found in upland moorland habitats associated with some wild deer populations. Single species forests tend to have little understorey present, limiting the potential for further biodiversity growth within the forest. Therefore, where possible in upland settings more biodiverse native woodlands should be prioritised over single species timber forests. These biodiverse areas are more likely to survive as the climate changes and provide secondary benefits that will support healthy ecosystems. Continued deer management is an essential part of high diversity woodland creation, to prevent both tree and understorey habitat damage.

We would see this form of sequestration and storage as “insetting”, which is an unofficial term often used to describe offsetting that is carried out on land under the control of the businesses involved in the product supply chain. Insetting via peatland restoration and suitable woodland or scrub creation offers a huge potential for short-term and medium-term sequestration. 80% of Scottish peatland is degraded with the potential for restoration to reduce carbon emissions, and we would estimate a significant portion of this degraded peatland is on land used by wild deer and under the control of businesses involved in wild venison production. High deer numbers often lead to an increase in peat degradation through increased trampling and rubbing of bare peat, which causes erosion. Also, on restored peatlands larger populations can damage peat dams and other interventions resulting in both carbon and financial losses. An IUCN report[20] estimates that significant restoration efforts could reduce emissions by 2.7MtCO2e per year. This demonstrates the potential that peatland restoration has for insetting the emissions from wild venison. Based on estimated offsetting rates from the Woodland Carbon Code[21] and Peatland Code[22], the accredited carbon offsetting schemes in the UK, we could assume average offsetting rates of about 4-8 tCO_2/ha/y for suitable diverse woodland creation projects, and anything from 2-12 tCO_2/ha/y for peatland restoration depending on the state of the peatland. Whilst there is no formal accurate data collected on wild venison quantities, based on discussions with SVA we have assumed Scottish wild venison production of 3,500t/y. The net annual emissions of

[20] https://www.iucn-uk-peatlandprogramme.org/sites/www.iucn-uk-peatlandprogramme.org/files/100218Briefing_Peatlands_andGreenhouseGasEmissions.pdf
[21] https://woodlandcarboncode.org.uk/standard-and-guidance/3-carbon-sequestration/3-3-project-carbon-sequestration
[22] https://www.iucn-uk-peatlandprogramme.org/peatland-code/how-it-works/projects

the total Scottish wild venison production could be inset with either 10,500 – 21,000 ha of broadleaf woodland creation, or 7,000 – 42,000 ha of peatland restoration.

5.1.4 Reducing Emissions of Methane

Most carbon emissions from venison come from direct methane emissions from the deer. Methane has an effect that is over 27 times the global warming potential of CO_2. Due to the short-term nature of methane in the atmosphere any reduction in methane emissions could lead to significant short term gains in greenhouse gas emissions.

Deer create methane through enteric fermentation in their guts and the anaerobic breakdown of their manure. Of these two the enteric fermentation accounts for most methane emissions. To counteract methane emissions the clearest way forward is to lower overall herd numbers. This would not necessarily lower the carbon footprint of venison, as the deer harvested will still retain the same carbon footprint, but it will lead to a reduction in national level emissions as well as potentially wider effects around ecological restoration and increased carbon capture.

5.2 Post-Estate Level

5.2.1 Energy Use assessments

An energy audit should be the first step to evaluate where efforts should be focused post-estate. Processors run very energy intensive systems that will require high energy inputs, finding and removing inefficiencies and substituting green energy for high carbon power will all lead to emissions reductions. A baseline energy audit will also provide a good measure of how effective changes have been as future energy costs can be accurately measured.

5.2.2 Refrigeration

Lowering costs around refrigeration offers considerable carbon savings for processors. Ensuring that all refrigerated units are properly insulated and running as efficiently as possible will minimise carbon emissions while also lowering financial costs around keeping carcasses properly preserved. Changing to lower global warming potential refrigerants, is an essential step in reducing refrigeration emissions. This should be carefully researched to ensure that there are no safety concerns around increased levels of toxicity or flammability within the refrigeration system.

Heating from the condenser can also then be transferred to local heating which will further lower natural gas usage across the building.

5.2.3 Renewable electricity

Wherever possible, processors should be accessing and utilising renewable sources of electricity for their operations. This can be through on-site renewable energy, such as rooftop solar or small wind turbines, (generally the location of the larger processors are not close enough to be suitable for hydro) or through renewable energy sourced via the national grid “green electricity tariffs”. It should be pointed out carbon savings from green electricity tariffs generally have to be accounted for separately in most carbon accounting and reporting systems, so often does not confer the same carbon reduction as renewable onsite generation. Renewable sources on site can be utilised to charge battery storage systems when there are higher generation rates to usage which can then be used in lieu of more polluting sources from the grid. Due to changes in UK renewables funding, sending power back to the grid may not be economical but with a well thought out system, electrical prices could be significantly lowered as well as overall emissions from power generation.

For most processors it could be a challenge to install enough renewables to meet their relatively high demand. However, if they could meet 50% of their usage from renewables, it would reduce the venison emissions by about 100-130 kgCO_2e/tCW.

5.2.4 Fleet management

Minimising distance travelled by optimising collection times and routes for carcass transport will have a noticeable impact on overall emissions. Where possible processors should communicate with estates to best plan their collection times around efficiency of travel. If multiple estates can have their carcasses collected on one trip instead of individual transport from each one, total mileage travelled should be lower. For picking up venison transport hubs should be created where minimal mileage can be applied and lower the overall need for emissions from transport.

5.2.5 Waste Management

Currently there is noticeable room for improvement around waste management in venison processing. The processor assessed in Table 5 above shows that only 64% utilisation of the deer carcass. By increasing the amount of usage per carcass will lower overall kgCO_2e of each deer processed.

Reduced Packaging

Whilst this study did not include the emissions from packaging due to the complexity associated with packaging calculations, we will discuss the general benefits of streamlining packaging.

Simplifying and reducing packaging has two potential benefits. Firstly, the direct reduction in high carbon packaging materials, and secondly the potential to increase the amount of product in each delivery. Simpler or smaller packaging can fit more to a lorry and reduce deliveries. Also transitioning to renewable sources like paper-based packages would lower the required petroleum inputs that are required for plastic packaging. There are the additional benefits of reduced pollution from biodegradable or compostable packaging that will be easier to break down instead of traditional plastic (preferably compostable material, as some biodegradable plastics cause pollution via micro-plastics).

5.3 Whole Chain Management

Effective changes across the entirety of the venison supply chain will help to lead overall reductions. Sharing resources such as larders will lower the overall footprint of the industry as a whole, or costs can be shared between estates or processors to help fund renewable energy projects such as wind farms. More actively cooperating between different stages of venison production, to minimise travel costs and maximise road mile efficiency for carcass transport would also lower carbon costs.

6 Discussion

Wild venison as a meat brings many benefits that other domesticated meat sources cannot. Venison has a minimal impact on landscape change. The production of wild venison also involves no artificial additives or fertilisers at any point, this minimises the potential emissions of greenhouse gasses like N_2O from soil respiration while also having no potential for ammonia or other emissions.

Greater deer management of the land where they currently exist could also lead to improved ecosystems throughout Scotland. Peatland restoration and woodland creation both offer paths where certain carbon emissions from deer may be inset, with proper validation, by allowing for carbon sequestration from these environments. With peatlands and woodlands, a lower deer density could lead to significant carbon improvements through reduced browsing damage of trees and re-wetting peat that has been damaged from high levels of browsing and trampling.

By sustainably hunting and processing deer for consumption, this industry helps lower overall impacts as the product can be used in lieu of other livestock animals that are not subject to a cull. This would lower the overall impact of meat production in Scotland if venison is able to replace some of the domesticated meat sold around the country.

Overall venison offers a different option to domesticated meats with less downsides and lower impact on its surroundings. By facilitating a transition towards more sustainable venison production there is potential for significant environmental gain.

7 Future Research and data gaps

This carbon footprint has taken information and sources from many different areas but there are still gaps in research when it comes to the wild venison supply chain. Questions still remain to fully understand the overall carbon footprint of venison and how those emissions can be further reduced.

Whilst there has been a very small number of studies carried out in this field, one area for future research is to examine the enteric methane emissions or N_2O emissions from deer manure. Any study would need to focus on using foods that wild deer would most likely be browsing to create an accurate picture for what any manure-based emissions would be.

Further study into the methane production in a range of deer species that reflect the Scottish herd would be useful for a more accurate carbon accounting in the future. This will hopefully allow for increased knowledge of when in the lifecycle of deer do methane emissions reach their highest point and if there are any changes that could be made to lower their overall emissions.

More detailed data from the hill and woodlands on estimated age and weight of all Scottish species, would help increase the accuracy of the methane emissions calculations, as these are the two metrics which most affect the calculations.

In addition, a survey of major wild venison processors and game dealers would help produce a reasonably accurate estimate of the annual production, which in turn would help calculations for what level of insetting would be required if it was desired to achieve a net zero product.

8 Conclusion

Wild venison as a resource still has space to improve a modest amount on overall carbon emissions. There are still many areas at both the estate and post-estate levels where more emission reduction is possible. Most of these changes focus on a large switch from combustion sources of power to renewable energy wherever possible. For estates this would mainly take the form of a switch from internal combustion engines for transport and on-estate use to less polluting options like electric vehicles. Other options include a switch to greener electricity sources wherever possible, more efficient direct transit routes for carcass transfers and finally improved use of lands for more carbon sequestration.

Limiting the total scope 1, 2, and 3 emissions will require many different adjustments to the overall wild venison supply chain, but a significant reduction is possible and will help reset overall emissions that come from this product. By applying the recommended changes along with certain environmental rehabilitation measures, wild venison could help to maintain a healthy rural space while also providing low carbon natural meat option in the future.

Appendix 1 – emissions breakdown

Table 3: Scope 1,2 and 3 emissions from Estate A

Estate		Deer stalked	CW per annum (kg)	Average carcass weight (kg)
A (100% roe deer)		263	2,890	11

	Scope 1 $kgCO_2e/y$	Scope 2 $kgCO_2e/y$	Scope 3 $kgCO_2e/y$	Total $kgCO_2e/y$	Scope 1 $kgCO_2e/t$ CW	Scope 2 $kgCO_2e/t$ CW	Scope 3 $kgCO_2e/t$ CW	Total $kgCO_2e/t$ CW	Proportion of resource use (%)
Electricity		645	155	**800**		223	54	**277**	9%
Heating oil	33		7	**40**	11		2	**14**	<1%
Water consumption			4	**4**			1	**1**	<1%
Total Utilities	33	645	166	**844**	11	223	58	**292**	**9%**
Vehicle & Machinery Fuel use									
Diesel	6,230		1,515	**7,745**	2,156		524	**2,680**	82%
Petrol	629		174	**804**	218		60	**278**	9%
Total Fuel	6,859		1,690	**8,549**	2,373		585	**2,958**	**91%**
Waste									
MSW to landfill			6	**6**			2	**2**	<1%
Total Waste			6	**6**			2	**2**	**<1%**
Total emissions from use of resources	6,892	645	1,862	**9,399**	2,385	223	644	**3,252**	

Table 4: Scope 1,2 and 3 emissions from Estate B

Estate		Deer stalked	CW per annum (kg)	Average carcass weight (kg)
B (60% red, 40% roe deer)		535	19,274	36

	Scope 1 $kgCO_2e/y$	Scope 2 $kgCO_2e/y$	Scope 3 $kgCO_2e/y$	Total $kgCO_2e/y$	Scope 1 $kgCO_2e/t$ CW	Scope 2 $kgCO_2e/t$ CW	Scope 3 $kgCO_2e/t$ CW	Total $kgCO_2e/t$ CW	Proportion of resource use (%)
Electricity		693	167	**859**		36	9	**45**	4%
Total Utilities		693	167	**859**		36	9	**45**	**4%**
Vehicle & Machinery Fuel use									
Diesel	10,083		2,453	**12,536**	523		127	**650**	64%
Petrol	776		215	**991**	40		11	**51**	5%
Total Fuel	10,859		2,668	**13,527**	563		138	**702**	69%
Waste									
MSW to landfill			18	**18**			1	**1**	<1%
Animal waste incinerated			5,336	**5,336**			277	**277**	27%
Total Waste			5,354	**5,354**			278	**278**	**27%**
Total emissions from use of resources	10,859	693	8,170	**19,723**	563	36	424	**1,023**	

Table 5: Scope 1,2 and 3 emissions from Estate C

Estate		Deer stalked	CW per annum (kg)	Average carcass weight (kg)
C (100% red deer)		259	10,650	41

	Scope 1 $kgCO_2e/y$	Scope 2 $kgCO_2e/y$	Scope 3 $kgCO_2e/y$	Total $kgCO_2e/y$	Scope 1 $kgCO_2e/t$ CW	Scope 2 $kgCO_2e/t$ CW	Scope 3 $kgCO_2e/t$ CW	Total $kgCO_2e/t$ CW	Proportion of resource use (%)
Electricity		1,306	314	**1,620**		123	30	**152**	7%
Heating oil	348		73	**421**	33		7	**40**	2%
Total Utilities	348	1,306	387	**2,041**	33	123	36	**192**	**8%**
Vehicle & Machinery Fuel use									
Gas Oil	325		74	**399**	31		7	**37**	2%
Diesel	13,128		3,193	**16,321**	1,233		300	**1,533**	67%
Petrol	1,481		410	**1,891**	139		39	**178**	8%
Aviation Fuel	2,441		507	**2,948**	229		48	**277**	12%
Total Fuel	17,375		4,184	**21,559**	1,631		393	**2,024**	**89%**
Waste									
MSW to landfill			694	**694**			65	**65**	3%
Total Waste			694	**694**			65	**65**	**3%**
Total emissions from use of resources	17,723	1,306	5,266	**24,294**	1,664	123	494	**2,281**	

Table 6: Scope 1,2 and 3 emissions from Estate D

Estate		Deer stalked	CW per annum (kg)	Average carcass weight (kg)
D (100% red deer)		334	8,006	24

	Scope 1 $kgCO_2e/y$	Scope 2 $kgCO_2e/y$	Scope 3 $kgCO_2e/y$	Total $kgCO_2e/y$	Scope 1 $kgCO_2e/t$ CW	Scope 2 $kgCO_2e/t$ CW	Scope 3 $kgCO_2e/t$ CW	Total $kgCO_2e/t$ CW	Proportion of resource use (%)
Electricity		1,854	446	**2,300**		232	56	**287**	10%
Water consumption									<1%
Total Utilities		1,854	446	**2,300**		232	56	**287**	**10%**
Vehicle & Machinery Fuel use									
Diesel	14,339		3,488	**17,827**	1,791		436	**2,227**	78%
Petrol	1,951		540	**2,491**	244		67	**311**	11%
Total Fuel	16,290		4,028	**20,317**	2,035		503	**2,538**	**89%**
Waste Materials									
MSW to landfill			305	**305**			38	**38**	1%
Total Waste			305	**305**			38	**38**	**1%**
Total emissions from use of resources	16,290	1,854	4,779	**22,922**	2,035	232	597	**2,863**	

We have separated out methane emissions as this is a source which the wild venison supply chain cannot reduce, unlike resource use.

	Estate A Total kgCO2e/y	Estate B Total kgCO2e/y	Estate C Total kgCO2e/y	Estate D Total kgCO2e/y	Estate A Total kgCO2e/t CW	Estate B Total kgCO2e/t CW	Estate C Total kgCO2e/t CW	Estate D Total kgCO2e/t CW
Methane								
Enteric	35,035	270,807	201,377	259,558	12,123	14,050	18,909	32,420
Manure	6,960	15,466	7,807	10,062	2,408	802	733	1,257
Total Methane	**41,995**	**286,273**	**209,184**	**269,620**	**14,531**	**14,853**	**19,642**	**33,677**

Appendix 2 – Emission factors

	Unit	Scope 1 Conversion Factor (kgCO_2e/unit)	Scope 2 Conversion Factor (kgCO_2e/unit)	Scope 3 Conversion Factor (kgCO_2e/unit)
Electricity	kWh		0.21	0.05
Heating oil	Litres	2.54		0.53
Natural gas	kWh	0.18		0.03
Water consumption	m3			0.38
Diesel	Litres	2.51		0.61
Petrol	Litres	2.10		0.58
Gas Oil	Litres	2.76		0.63
Aviation Fuel	Litres	2.54		0.53
MSW to landfill	kg			0.52

Appendix 3 – Raw data and comments from 2009 Study

Currently having difficulty extracting the tables from the original PDF, we will need to do this manually, but it will be ready for the final report. however they are all available in the appendix of the report which can be found at https://media.nature.scot/record/~7a8334b23c#