REPORT

Quorn Footprint Comparison Report

December 2023

V3.61

About the report

This report summarises the Carbon Trust's research into carbon, water, and land use footprints for the comparison of alternative protein sources and the comparison of competing products based upon these proteins.

Two comparisons have been conducted in this report: a comparison using the average footprint figures for the competing products and a comparison using the lower limit footprints for the competing products. The lower limit footprints were used in order to conduct a "lower than" comparison analysis. To have confidence that one product can be said to have a lower environmental impact than another, the variability and uncertainty of footprinting must be taken into account.

Who we are

Our mission is to accelerate the move to a decarbonised future. We are your expert guide to turn your climate ambition into impact.

We have been climate pioneers for more than 20 years, partnering with leading businesses, governments and financial institutions to drive positive climate action. To date, our 400 experts globally have helped set 200+ science-based targets and guided 3,000+ organisations and cities across five continents on their route to Net Zero.

CARBON TRUST

The Carbon Trust's mission is to accelerate the move to a decarbonised future.

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Updates:

V3.61 has been updated to include 2022 representative values for Mycoprotein and Quorn Yorkshire Ham, based on 2022 recertifications.

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1. Introduction

This report summarises the Carbon Trust's research into carbon, water, and land use footprints for the comparison of alternative protein sources and the comparison of competing products based upon these proteins.

Two comparisons have been conducted in this report: a comparison using the average footprint figures for the competing products and a comparison using the lower limit footprints for the competing products. The lower limit footprints were used in order to conduct a "lower than" comparison analysis. To have confidence that one product can be said to have a lower environmental impact than another, the variability and uncertainty of footprinting must be taken into account. For example, to state that a specific product has a lower impact it must:

1. Be compared against the market dominant products that fulfil the same defined function
2. Be compared against substitutable products in a specifically defined geographical region
3. Account for uncertainty and variability in the comparison: Specifically, the upper end of this product's uncertainty range, lies below the lower end of all major market standard products' uncertainty range. In both cases accounting for reasonable but not extreme uncertainty.

Based upon this, the research took the following two stage approach:

- Stage 1, the lower end of footprints for **common comparator protein sources** were calculated and compared against the relevant upper end of the uncertainty range for **Quorn proteins** (i.e. the base protein used in Quorn products) (Table 1)
- Stage 2, the footprints found in stage 1 were used to perform a lifecycle assessment of products to compare them with the lifecycle impact of the **relevant Quorn product**, again comparing upper uncertainty range of Quorn products, with lower end of footprints for **meat-based comparator products** (Table 2).

The analysis in this report compares the footprints on a per kilogram of product basis rather than on a per equalised kilogram of protein basis. A per kilogram of protein approach is generally taken to compare the footprints of different food items within the context of a balanced diet and will yield different comparison numbers based on the protein content of each product. Since the aim of this analysis was to directly compare the footprints of the final products, the per kilogram of product approach was deemed to be the most relevant. For example, Quorn Nuggets are sold in UK supermarkets in 300g and 476g bags. This is comparable to the meat chicken nuggets which are also available in portion sizes in the range of 300g to 500g.

We acknowledge there are differences in the production methods and resource requirements within each source of protein. As such, there can be uncertainties when evaluating and reporting the impacts of agriculture and food production. To account for this, and to ensure that any comparisons include and reflect the uncertainties and variability as far as possible, this research has prioritised studies that evaluate the lowest reasonable impact of these sources of protein and compared them with the upper uncertainty limit of the Quorn products. Where information was available, country specific research has been used however where not available, average figures for the UK and continental Europe have been used as proxy.

Table 1 – Stage 1: Comparison of footprints for competing protein inputs.

Quorn Protein	Comparator Protein	Target Countries
Quorn Mycoprotein	Soybeans, tofu, soy protein isolate (SPI), textured vegetable protein (TVP)	UK
Quorn Mince	Beef Mince	UK, Sweden, Netherlands, Belgium
Quorn Pieces	Chicken Breast	UK, Sweden, Netherlands, Belgium
Quorn Fillets	Chicken Breast	UK, Sweden
Quorn Sausages	Pork Primal Cuts	UK

Table 2 – Stage 2: Comparison of lifecycle impacts of competing products.

Quorn Product	Product comparator	Target Countries
Quorn Fishless Fingers	Fish Fingers	UK
Quorn Nuggets	Chicken Nuggets	UK
Quorn Cocktail Sausages	Pork Sausage	UK
Quorn Yorkshire Ham	Pork Ham	UK
Quorn Vegan Ham	Pork Ham	Sweden, Netherlands

2. Footprinting introduction

We have researched the carbon, water, and land use footprints for each product in this report in order to provide a full view of their environmental impact.

2.1. Carbon footprint

The carbon footprint assesses all the greenhouse gases (GHGs) released from the various processes required to produce the finished product from the ‘cradle to the processing gate’ boundary. For the comparison of Quorn products and meat-based comparator products, emissions associated with upstream transport and distribution, and packaging have been included. However, for the comparison of Quorn proteins to comparator proteins, packaging has been excluded as these are considered the input proteins that will be further used in the finished and packaged products. The downstream impacts of the Quorn products were assumed to be the same as the comparator products since there is little to no systematic difference in the way that meat and meat-alternative products are used after the production stage (Dettling, 2016). While the term carbon footprint is used throughout this report, the measurement units are carbon dioxide equivalent (CO_2e). CO_2e is a reference unit to assess the global warming potential of a range of different GHGs. For example, methane has a global warming potential 28 times greater than carbon dioxide (Greenhouse Gas Protocol).

Using chicken as an example, the lifecycle analysis has evaluated all the GHGs released in the rearing and processing stages of a chicken’s life. This includes all the emissions associated with the cultivation of feeds, use and manufacturing of synthetic fertiliser, upstream transportation, heating and lighting requirements, and processing energy required to produce a chicken carcass.

2.2. Land footprint

The land footprint focuses on the physical area required to produce the finished product. For meat products, this mainly involves the land that livestock is raised on (such as the area livestock require to live on), and the land used to grow the feed that the livestock consume. For crops and plant-based products, this involves the land required to grow the crops or produce the raw ingredients that are involved in the production of the product. The land footprint is expressed in terms of hectares per kg of finished product (ha/kg) and includes the land use associated with the packaging of each product.

2.3. Water footprint

Water footprints[1] assess the total amount of water used during the processes required to produce the finished product. This includes water consumed by the animals (such as water that livestock have

[1] The Water Footprint Network defines a water footprint as a volumetric “... The water footprint is an indicator of freshwater use that looks not only at direct water use of a consumer or producer, but also at the indirect water use.” This is distinct from LCA which requires an additional impact assessment step – for example volumetric data is modified by an appropriate local scarcity modifier.

drunk), water used to produce the feed, rain and dirty water that returns to rivers and water consumed during processing.

Water footprints have been divided (Water Footprint Network, 2011) between ‘green water’, ‘blue water’, and ‘grey water’:

- Green water is related to water from precipitation in vegetation and soil, which is typically the greatest category of water use
- Blue water is surface and ground water consumed by food production, which relates to the growing of feed for the livestock and the growing of crops
- Grey water is the amount of water needed to dilute pollution and is a product of activities such as polluted water from manure, fertiliser, or pesticides, which would be applicable to the growth of livestock and feed

The water footprint is expressed in litres per kg of finished product (L/kg) and includes the water footprint associated with the packaging of each product.

Regarding the analysis, blue water is the most important footprint for direct comparisons, as it is most easily measured and controlled by businesses. Green water, although often a large value, represents water that although temporarily affected by agriculture, is not removed from the natural system. Grey water is difficult to estimate, and in Europe is already regulated by water quality laws. It is important to keep these water footprints separate when performing a comparison as they have different impacts and so that the most controllable water footprint, blue water, can be easily compared between products.

3. Assumptions

We made several assumptions in the process of gathering and calculating the environmental footprints for the food products. For carbon, all Quorn and meat products were compared with the 'cradle to grave' boundary. It is worth noting two distinctions in analysis: 'cradle to processor's gate' and 'processor's gate to grave'. Due to the likeness of the Quorn products with the comparative products, it is assumed that the transport, packaging, waste, cooking, and refrigeration requirements for both products will be very similar This is due to the little systematic difference in how both products are packaged, transported, cooked, and stored. As such, the difference in downstream impacts while comparing the products are assumed to be negligible therefore it was deemed unnecessary to calculate these differences. As for the 'cradle to processor gate' analysis, the upstream impact of each product and its comparator may be significantly different so individual analysis was carried out for all Quorn and comparator products.

With regards to the calculation of the land and water footprints, the scope has been limited to direct land and water used and **does not consider the impact of land-use change** associated with production. For example, if the land was converted from forest to grow soy, then there would likely be an impact on the local water cycle and indirectly effect the water footprint of the soy. Including this type of analysis would likely increase the emissions of the comparator products more than that of the Quorn products. Therefore, since a conservative approach was taken in this comparison analysis, indirect land-use change was not included.

For stage 1 of the research, the raw data used for comparison did not always have similar boundaries. Therefore, for consistency across products, the meat proteins were reported in **kg CO_2e per kg carcass weight** and the **soy products were reported in kg $CO2_e$ per kg soy produc**t (i.e. soybean was reported in kgCO_2e per kg soy bean, tofu in kgCO_2e per kg tofu etc.). The emission boundaries were calculated using industry factors for conversion rates.

For stage 2, **all products were reported in kg CO_2e per kg product** so that they could be fairly compared to the Quorn products. A range of footprints were also provided rather than just the lowest footprint so that greater detail is provided in the distribution of footprints and what the difference that can occur. These ranges exist due to variation in study results, what factors are included (such as with or without land use change (LUC)), sub-regions, and categories of species. Therefore, the average and high figures are a result of differentiating figures from the references used. The low figures are the lowest reasonable emission factors found in the literature for each specific country. For countries that import meat from elsewhere, the emission factor for the imported meat is only used if the imports from that country account for more than 10% of the meat products sold in the destination country. It is the lowest emission factors that were used to compare to the upper footprints of the Quorn Products to ensure a conservative approach.

4. Footprint results of proteins

In this section, we summarise the results for each protein source according to the footprints studied. The key assumptions and carbon, land, and water footprints for each protein source (soy, beef, chicken, pork, and fish) are also discussed. Depending on the country the protein is produced in, there can be a large difference in the range of footprints for that given product. Where known, the reasons for these variations have been explained in the relevant sections. Section 5 provides a detailed analysis of how these footprints compare to the chosen Quorn proteins and products: Mince, Pieces, Fillets, Sausages, Cocktail Sausages, Nuggets, Yorkshire Ham, Vegan Ham, Vegan Fishless Fingers, and mycoprotein.

4.1. Soy

The soy carbon, land, and water footprints were all gathered from online agricultural sources and research papers. Soy, compared to the other sources cannot be calculated based on the resources that are used in growing the product (for example, this refers to the feed provided to the animals for the meat sources). Therefore, all three footprints for soy are based on the researched data from papers, articles, and agricultural organisations.

A limitation of soy compared to the other products is that the majority (90%) is produced outside of the UK and Europe boundary, in the US, Brazil, and Argentina (Nadathur, Wanasundara, & Scanlin, 2017), (WWF, 2018). However, as the UK and Europe source soy from the regions it is mostly produced in, it can be said that the global figures are the same for the UK and Europe. Results for soy were also found to be in a range of products of the bean, for example, 13% is used directly for soymilk, tofu, miso, and tempeh, and 87% is used for soymeal and oil (Nadathur, Wanasundara, & Scanlin, 2017). This is because soybeans are processed into several co-products, which means that additional carbon emissions and water consumption occur. Multiple soy products also requires allocation of emissions to the different products. For example, what proportion of the bean is used for different products varies according to the products made. A product, which uses a small amount of the bean, may have a smaller footprint per kg. In addition, there are different ways to process soybeans which have different energy requirements. This analysis included footprints for some of the soy products available (tofu, soy protein isolate (SPI), textured vegetable protein (TVP)). Highly processed soy products such as SPI and TVP are commonly used to make meat alternative products and hence are a good comparator protein source.

A wider variability in emissions exists compared to the other protein sources, and can be associated with geographic location, management practices, and soil type (Cerri, et al., 2017). Geographic location can influence the range due to the varying management practices and soil types in different regions – for example, Southeast Asia peat soils will release more carbon than oxisols in Brazil. For example, soy is often grown in Brazil, which will have different cultivation and land management operations compared to soy that's grown in Southeast Asia. The geographic locations will therefore have an influence on all three footprint aspects – carbon from the climate, land use, and soil classification differences, water from the climate and local practices, and land from the regional practices of different regions.

4.1.1. Carbon

Several issues are involved in determining the footprint of soy, and the results can vary greatly. The carbon emissions of the soy product only take into account the proportion of the entire emissions associated with the part of the original soybean and husk/shell that is used. Direct LUC also plays a significant role in the footprint of soy, as soy is one of the main vegetation species that is grown in deforested areas (see below for a comment on 'indirect' LUC). When an area of existing land-use (typically native grassland, forests or rainforests depending on the region) is cleared to make room for agriculture, all the embodied carbon in the existing vegetation is removed. Proportions of soil carbon is also released into the atmosphere when the top layer is disrupted during the clearing of the pre-existing vegetation. If included in the carbon footprint calculation, this can dramatically increase the results. For example, when excluding LUC, the footprint of soy can range between 0.3-0.8 kg CO_2e/kg, but when LUC is included, it can range between 0.1-17.8 kg CO_2e/kg depending on the scenario (conversion of tropical forest, forest plantations, perennial crop plantations, savannah, and grasslands), cultivation (tillage, reduced tillage, and no tillage), and soybean transportation systems (Castanheira & Freire, 2013). The difference in the minimum figures (with LUC being 0.1 kg CO_2e/kg and without being 0.3 kg CO_2e/kg) is due to tillage systems having higher GHG emissions than no tillage or reduced tillage. When LUC is considered, the carbon footprint can sometimes be lower than the no LUC figure. This is due to the carbon sequestration afforded by planting soy crops on degraded land, hence the low LUC figure of 0.1 kgCO_2e/kg. As such, the original conversion of land and the original land choice has a large influence on the wide range in the footprint. For example, soybean cultivation on degraded grassland results in the lowest emissions, and cultivation in wet tropical regions has the highest GHG emissions (Castanheira & Freire, 2013).

There is on-going debate regarding the best, most useful or most accurate way to calculate LUC emissions (Euractiv, 2017). One aspect is the difference between direct and indirect changes. The former is when land is cleared and used directly for soy. The latter occurs when soy is grown on cropland previously used for something else and the displaced crop then moves, causing indirect LUC. For the purposes of finding the lowest carbon footprint of soybeans, LUC has been considered. Therefore, the lowest carbon footprint we use for fresh soybeans is 0.10 kg CO_2e/kg (Castanheira & Freire, 2013) (Carbon Trust Internal Document, 2022).

Table 3 – The ranges and average of soy carbon footprints per kg soybean (Global)

	Low (kg CO2e)	Average (kg CO2e)	High (kg CO2e)
Soy (Global)	0.10	1.02	17.80

4.1.2. Land

The land footprint for soy relates to the area required to grow the crop rather than any indirect land use such as that required to grow the feed for livestock. LUC also does not affect the land footprint (unlike the carbon footprint), as this aspect of soy production starts after an area of land has been cleared. However, for soy grown in the Americas, the lowest land footprint found in the literature was 0.00029 ha/kg for the US (Taherzadeh & Caro, 2019). The high and average footprints in Table 4 are based on global averages (Dalgaard, et al., 2008) (Taherzadeh & Caro, 2019) (Carbon Trust Internal Document, 2022).

Table 4 – The ranges and average of soy land footprints per kg soybean (Global)

	Low (ha)	Average (ha)	High (ha)
Soy (Global)	0.00029	0.0014	0.0025

4.1.3. Water

Green water is the water category with the greatest value, with a low value of 1260 L/kg soybean. Blue and grey water are much lower at 50 L/kg and 10 L/kg respectively (Table 5) (Ercin, Aldaya, & Hoekstra, 2012) (Water Footprint Network, 2011). See section 2.3 for an overview of the different types of water footprint category.

Table 5 – The ranges and average of soy water footprints per kg soybean (Global)

Water category	Low (L)	Average (L)	High (L)
Green	1260	1855	2070
Blue	50	240	520
Grey	10	573	1100

4.2. Beef

4.2.1. Carbon

The boundary for beef includes all feed production, manure storage and spreading, and enteric methane for the UK and Europe. In terms of herd structure, the supporting suckler herd and replacements are allocated to the resulting beef produced and sold regardless of whether they are maintained on the final (finishing) farm or not. As the boundary of these footprints are cradle to processing gate, the carbon footprint for beef also includes the conversion ratio for live weight to carcass weight (EBLEX, 2012).

A crucial point of continuing debate is how to manage the interaction between dairy and beef herds, where surplus dairy calves are transferred to beef production. Economic allocation is used to estimate the environmental (carbon, water, and land) impact associated with dairy calves fattened for beef, which we assumed here to be a 95:5 split between milk/cull cows and calves to beef (E-CO_2 personal communication). Other methods (feed energy requirements etc.) may result in slightly different ratios, but the overall result in this context is not significantly different.

Other key data includes the type of feed and efficiency of the suckler herd. Emissions are high when large numbers of animals are maintained for longer in order to produce finished animals. The main causes we consider are health, husbandry, feed quality, and deforestation. Health and husbandry determine the size of the suckler herd and number of required replacements, whilst feed quality determines the rate of finisher maturity. The more animals and the longer they are on farm, the higher emissions per kg of meat tend to be; poorer health and feed also tend to lead to higher emissions.

The variation in carbon footprints between the different countries can be attributable to several factors; For example, Swedish beef has a higher carbon footprint compared to the other countries. This is likely due to the data used for calculating the Swedish carbon footprint considering a high proportion of imported ingredients being used in the feedlot feeds (González, Frostell, & Carlsson-Kanyama, 2011). Whereas the UK emission factor for beef was calculated considering a mix of both imported and grass-fed feeding practices (EBLEX, 2012). Another reason could be countries having different slaughter weights for the animals; If the average slaughter weight is older for some countries, then the emission factor would be higher due to the additional food and resources the animal would consume while living for the extra time. Other variables are the efficiencies within the production system. The quicker an animal can get to the ideal slaughter weight the lower the carbon footprint of that animal would be (assuming types of inputs stay the same). For the context of this analysis, we analysed the systems that would produce the lowest emissions for the meat products. For this reason, we sought different emission factors between countries and where possible we used **the lowest, country-specific emission factor found in the research.** The average and high figures are a combination of country specific research and average EU emission factors for the beef sector. Where necessary, the emission factors have been converted to kgCO_2e/kg carcass weight (Carbon Trust Internal Document, 2022).

Where available, **the low footprint was based on data from dairy herd beef** (Carbon Trust Internal Document, 2022) as this is generally the least carbon intensive rearing method. The average and upper figures use data from general beef (where results were for beef generally and not specific like mixed or grazed) (Audsley, et al., 2009) (EBLEX, 2013), and grazed (a single species that graze). Grazed beef systems generally have the highest associated emission factors.

Table 6 – The ranges and average of beef carbon footprints in the UK, Sweden, Netherlands, and Belgium per kg carcass weight

Country of Production	Low (kg CO2e)	Average (kg CO2e)	High (kg CO2e)
UK	16	18.44	65.33
Sweden	20	24.69	65.33
Netherlands	15.93	22.92	65.33
Belgium	15.93	18.96	65.33

4.2.2. Land

The land use requirements for beef can vary greatly depending on the production system. Beef production in Europe is different than in other areas as there is a high reliance on stock coming from the dairy sector with most of the EU cattle population being dairy cows (Desjardins, et al., 2012). Dairy systems in Europe are relatively more efficient than other beef production systems as they commonly require low amounts of meadow grazing, consist of housing in confined space, and have high ratios of concentrates in feed (Nijdam, Rood, & Westhoek, 2012). Beef cattle that come from dairy systems also produce two valuable outputs in their lifetime, dairy and beef, meaning the footprints and impacts can be allocated between the two products instead of just beef.

For this reason, when considering the lowest figure land footprint for beef, beef from dairy herds was selected since a large proportion of the footprint associated with them are attributed to the dairy sector (International Dairy Federation, 2009). There was limited information on the country specific land use footprint of beef from dairy herds, so the EU average has been selected for the lowest figure for all of the countries. Table 7 from Nijdam, Rood, & Westhoek, (2012) shows the variation in land footprints associated with different beef production systems within Europe.

Table 7 – Land use of different beef systems per kilogram of product (Nijdam, Rood, & Westhoek, 2012)

Product	Land use (m^2 y kg^{-1})	Of which grassland (m^2 y kg^{-1})
Beef (15 studies, *n* = 26)	7–420	2–420
Industrial systems (*n* = 11)	15–29	2–26
Meadows, suckler herds (*n* = 8)	33–158	25–140
Extensive pastoral systems (*n* = 4)	286–420	250–420
Culled dairy cows (*n* = 3)	7	ca 5

4.2.3. Water

Similar to the land footprint of beef, the water footprint can vary depending on production system with different ratios of green, blue and grey water being used for different production systems. For example, industrial systems on average have a lower overall water footprint per kg beef however they require a larger proportion of blue and grey water compared to grazing systems (Mekonnen & Hoekstra, 2010).

For the reasons discussed in section 2.3 of this report, the blue water footprint is considered the most relevant to be used for the comparison. Therefor the production system with the lowest blue water footprint was selected and the green and grey water footprints from this system were also used. The figures used in this report are from (Mekonnen & Hoekstra, 2010). The study is a comprehensive account of each country's green, blue and grey water footprints and considers the different production systems and the conditions associated with production in each country. Table 8 shows the ranges of blue water use for the different production systems for each of the countries. Footprints for grey and green water use can be found in the (Carbon Trust Internal Document, 2022). The lowest footprint for each country was selected and converted to a functional unit of L/kg carcass weight using industry factors (Table 9) (Carbon Trust Internal Document, 2022). The Netherlands has a comparatively high water footprint compared to the other countries. This is likely due to the Netherlands importing a large amount of its cattle feed from abroad and the additional water use associated with that (Mekonnen & Hoekstra, 2010).

Table 8 - The ranges of blue water footprint for different production systems for beef in the UK, Sweden, Netherlands, and Belgium per kg live weight (Mekonnen & Hoekstra, 2010)

Country of Production	Blue Water footprint (L)			
	Grazing	Mixed	Industrial	Weighted average
UK	62	67	106	84
Sweden	60	55	57	51
Netherlands	0*	374	183	216
Belgium	0*	59	93	76

**There are no grazing production systems in the Netherlands or Belgium*

Table 9 - Lower range water footprints of beef for UK, Sweden, Netherlands, and Belgium per kg carcass weight

Country of Production	Blue Water footprint (L)	Green Water footprint (L)	Grey Water footprint (L)
UK	115	4837	722
Sweden	94	5304	533
Netherlands	400	3691	211
Belgium	109	6421	256

4.3. Chicken

The following footprints relate to the rearing practices for broilers and layers in the UK, Sweden, Netherlands and Belgium, where broilers are loose housed on litter with automatic feed and water, and layers are housed in a variety of cage, barn, and free-range systems with automatic feed and water. However, most references did not specify the rearing practices and can therefore be assumed to be an average.

4.3.1. Carbon

The carbon footprint for all countries have been calculated by reviewing publications such as (Cederberg, Sonesson, Henriksson, Sund, & Davis, 2009) (Blonk, Kool, Luske, & de Waart, 2008) (Riera, Antier, & Baret, 2019) (Audsley, et al., 2009) (Clune, Crossin, & Verghese, 2017) (MacLeod, et al., 2013) and (Co-op, n.d.).

For the lowest figures for each country, a country specific footprint was found to reflect the lowest expected footprint in that country (Carbon Trust Internal Document, 2022) (UK: (Co-op, n.d.); Sweden: (Cederberg, Sonesson, Henriksson, Sund, & Davis, 2009); Belgium: (Riera, Antier, & Baret, 2019); Netherlands: (Blonk, Kool, Luske, & de Waart, 2008)). The average and high figures are calculated using a mix of country specific data and data based on EU averages (Audsley, et al., 2009) (Clune, Crossin, & Verghese, 2017). The footprints have been converted to a consistent functional unit (kgCO2e/ kg carcass weight) using conversion factors included in the resources or from the Carbon Trust database.

Industry data from the UK and Ireland was certified by the Carbon Trust against PAS 2050 (confidential results) and uses a method fully consistent with the FAO (MacLeod, et al., 2013), which provides equivalent footprints.

LUC from imported soy is a big factor and the carbon footprint of chicken is largely dependent on the feed source (MacLeod, et al., 2013). The higher end figures in Table 5 are averages of both emissions for LUC and emissions without LUC as not all resources specified the feed type. The range of emission factors are wide with a low figure of 1.90 kgCO2e per kg of carcass weight for Swedish chicken and a high of 5.81 kg of carcass weight in UK. This may be due to different feed types used in different countries and different rearing systems. Farm and animal efficiency will also contribute to the variation in emission factors based on how long it will take for a chicken to meet the ideal slaughter weight. Table 10 is a summary of the low, average, and high carbon footprints for each of the countries.

Table 10 – Summary of the ranges and average carbon footprints for chicken in the UK, Sweden, Netherlands, and Belgium per kg carcass weight

Country of Production	Low (kg CO2e)	Average (kg CO2e)	High (kg CO2e)
UK	2.83	3.81	5.81
Sweden	1.9	3.52	5.81
Netherlands	3	3.52	5.81
Belgium	2.9	3.52	5.81

4.3.2. Land

The majority of the land footprint for chicken is based on the area required to grow the feed of the chicken, and the composition and amount of feed. The footprints used in this study are from a range of literature sources (Rias Inc., 2016) (Williams, Audsley, & Sandars, 2006) (Hallstrom, Roos, & Borjesson, 2014) and where available, the lowest reasonable land footprint for each country has been used (Carbon Trust Internal Document, 2022). Limited information was available for chicken production in Belgium and hence the footprint for Netherlands has been used as a proxy due to similar production methods (Table 11).

Table 11 - Lower range land footprints for chicken production in the UK, Sweden, Netherlands, and Belgium per kg carcass weight

Country of Production	Land Footprint (ha)
UK	0.00064
Sweden	0.000532
Netherlands	0.000334
Belgium	0.000334

4.3.3. Water

The water footprint for chicken was obtained from Mekonnen & Hoekstra (2010), however there is less variation in footprints in production systems compared to beef. However, the system with the lowest blue water footprint was selected and converted to a functional unit of L per kg of carcass weight using industry figures (Carbon Trust Internal Document, 2022). Table 12 shows the figures used in this analysis for the water footprint of chicken in each country.

Table 12 – Lower range water footprints for chicken in the UK, Sweden, Netherlands, and Belgium per kg carcass weight

Country of Production	Blue Water footprint (L)	Green Water footprint (L)	Grey Water footprint (L)
UK	24	1565	307
Sweden	13	1694	371
Netherlands	63	1487	159
Belgium	66	1969	273

4.4. Pork

4.4.1. Carbon

The carbon footprint of pork was calculated based entirely from figures researched from articles, papers, and online agricultural sources (Table 13) (Cederberg, Sonesson, Henriksson, Sund, & Davis, 2009) (Co-op, n.d.) (Kool, Blonk, Pnsioen, & Sukkel, 2009) (Audsley, et al., 2009) (BPEX, 2011) (Clune, Crossin, & Verghese, 2017) (MacLeod, et al., 2013) (Smith, 2013) (Blonk Consulting, 2022). These figures relate to typical housed rearing practices. The carbon footprints have been converted to a consistent functional unit of kgCO_2e/ kg carcass weight. The variation in emission factors between countries could be due to variation in rearing practices within the country. One example of this would be different countries having different slaughter weights for pigs; If the slaughter weight is older for some countries, then the emission factor would be higher due to the additional food and resources a pig would consume while living for the extra time. Other variables are the efficiencies within the production system. The quicker a pig can get to the ideal slaughter weight the lower the carbon footprint of that animal would be (assuming types of inputs stay the same). This could explain the variations in emission factors between countries and **where possible the lowest, country-specific emission factor found in the research has been used for comparison** (Carbon Trust Internal Document, 2022).

Table 13 – The ranges and average of pork carbon footprints in the UK, Sweden, and Netherlands per kg carcass weight

Country of Production	Low (kg CO2e)	Average (kg CO2e)	High (kg CO2e)
UK	4.83	7.7	12.24
Sweden	3.4	7.04	9.94
Netherlands	4.68	6.91	11.60

As is the case for poultry, feed and manure management can have large influences on the carbon footprint for pork. The emissions arising from feed production can account for 60% and those from manure management can account for 27%. These two processes also vary between rearing practices. Storage of manure generates emissions within the production system. These vary according to style (anaerobic liquid storage creates methane and dry storage with bedding, nitrous oxide) and time. Removing manure regularly (e.g. to spread on fields or process in anaerobic digesters) is a good way to reduce livestock emissions.

4.4.2. Land

Similar to chicken, the majority of the land footprint associated with pork is from the land used to grow the pig feed. The living area of the pigs is very minor compared to land-use from feed. The figures in Table 14 are the land footprints for pork in the UK, Sweden and Netherlands (Hallstrom, Roos, & Borjesson, 2014) (zu Ermgassen, Phalan, Green, & Balmford, 2014) (Williams, Audsley, & Sandars, 2006) (Blonk Consulting, 2022).

Table 14 – Lower range of pork land footprint for the UK, Sweden, and Netherlands per kg carcass weight

Country of Production	Land footprint (ha)
UK	0.00074
Sweden	0.00062
Netherlands	0.00052

4.4.3. Water

As with beef and chicken, the water footprint for pork was based on the study by Mekonnen & Hoesktra (2010). There was less variation in water use associated with different rearing practices, however the system with the lowest blue water footprint was selected for analysis (Table 15).

Table 15 – Lower range pork water footprint for the UK, Sweden, and Netherlands per kg carcass weight

Country of Production	Blue water footprint (L)	Green Water footprint (L)	Grey Water footprint (L)
UK	217	2875	513
Sweden	156	2549	531
Netherlands	173	3055	357

4.5. Fish

The boundary for fish is **wild caught**, as that is the criteria that would be most similar to what Quorn's product (vegan fishless fingers) is compared against. **Therefore, land and water footprints do not apply** (as no land or feed are required) and these are excluded from this study. A variety of common fished species were used in the following carbon footprint calculations, such as cod, haddock, and tuna.

4.5.1. Carbon

The UK is a net importer of cod, with the majority coming from China and Iceland (Marine Management Organisation, 2019). As the aim of this piece of work is to compare Quorn products against the 'low carbon' meat equivalent, the Icelandic cod was chosen to be the focus of this analysis due to Iceland's close proximity to the UK, therefore, reducing processing and transportation emissions resulting in lower kgCO2e/kg cod.

Cod is commonly caught by either longline or trawler systems, Guttormsdóttir (2009) finds long line caught cod to have a GWP 3 times less than trawled cod, therefore longliner systems would produce the lower carbon cod for use in this comparative report. Icelandic cod is either transported by sea or air freight, generally fresh cod would be transported by air and frozen cod by sea, therefore with sea freight having lower emissions this transportation method will be considered for the analysis. Finally, economic allocation was applied to reflect the higher value/kg of cod fillet in comparison to the cod as a whole. European Market Observatory for Fisheries and Aquaculture Products (EUMOFA, 2017) reports cod fillets 2.7 times higher cost per kg (net weight) than whole cod per kg (net weight). Therefor the carbon footprint would uplift by 2.7x to reflect the value nature of this cut.

Foulton (2010) performs LCA for line caught Icelandic cod, both sea and air freighted to Grimsby UK. Following a mass allocation approach, the cradle-to-gate footprint of sea transported cod at the point of entry to the UK resulted at 0.7kg CO2e per kg cod. This was used to calculate the emission factor of cod fillet following an economic approach; Using figures for the economic allocation of cod fillet to whole cod (whole cod: 3.33 EUR/kg; fillet: 9.32 EUR/kg) and a yield factor of 45% from EUMOFA, (2017) a carbon footprint of 1.08kgCO_2e per kg cod fillet was calculated.

Carbon footprints of fish were gathered from a range of online food/fish specific sources and research papers (Audsley, et al., 2009) (Buchspies, Tolle, & Jungbluth, 2011) (Ziegler, 2012) (Cermaq, 2012) (Carbon Trust Internal Document, 2022). The majority of emissions from sea caught fish comes from the fishing process, therefore, no emissions are associated with the growth of fish compared to farmed fish, as it all occurs naturally.

Table 16 – The ranges and average of fish fillet carbon footprints in the UK per kg fillet

	Low (kg CO2e)	Average (kg CO2e)	High (kg CO2e)
Fish Fillet	1.08	4.57	8.31

The average carbon footprint for wild caught fish is roughly 67% of the footprint of farmed fish (33% less) (Clune, Crossin, & Verghese, 2017) (Environmental Working Group, 2011) (Rias Inc., 2016). This difference is due to lack of energy and resources (such as feed) required for farming fish, as described above. The most common fish species farmed in the UK however, is salmon, but the species that are wild caught are mainly cod, haddock, and tuna. This presents an issue with comparing wild caught to farmed fish, as the species are not consistent.

5. Footprint comparisons

The following sections presents the results of the footprinting and comparison analysis. Section 5.1 is a summary of the lower limit footprints for all the products used in the lower than analysis. Section 5.2 is a summary of the average footprints for the comparator protein products used in the average comparison analysis. Section 5.3 and 5.4 are the results of the comparison analysis carried out it stage 1 (Table 17) and stage 2 (Table 18) respectively.

Table 17 – Stage 1: Comparison of footprints for competing protein inputs.

Quorn Protein	Comparator Protein	Target Countries
Quorn Mycoprotein	Soybeans, tofu, soy protein isolate (SPI), textured vegetable protein (TVP)	UK
Quorn Mince	Beef Mince	UK, Sweden, Netherlands, Belgium
Quorn Pieces	Chicken Breast	UK, Sweden, Netherlands, Belgium
Quorn Fillets	Chicken Breast	UK, Sweden
Quorn Sausages	Pork Primal Cuts	UK

Table 18 – Stage 2: Comparison of lifecycle impacts of competing products.

Quorn Product	Product comparator	Target Countries
Quorn Fishless Fingers	Fish Fingers	UK
Quorn Nuggets	Chicken Nuggets	UK
Quorn Cocktail Sausages	Pork Cocktail Sausage	UK
Quorn Yorkshire Ham	Pork Ham	UK
Quorn Vegan Ham	Pork Ham	Sweden, Netherlands

5.1. Summary of lower limit footprints

This section summarises the lowest footprint figures that were obtained for each widely sold comparator product and subsequently the footprint figures that were used in the lower than comparison analysis in Section 5.3 and Section 5.4. The figures come from a range of industry and academic literature with the lowest footprint being selected for each country where possible (Carbon Trust Internal Document, 2022). The footprints in Table 19, Table 20 and Table 21 are the carbon, land and water footprints for the protein sources described in Section 4, the comparator products, and the Quorn products. The highest footprints for the Quorn proteins and Quorn products have been used for analysis. The footprints for the comparator products were calculated by researching the recipes for each product. The recipe with the lowest meat content was selected for comparison as meat was the most impactful ingredient. An emission factor, land footprint, and water footprint was then obtained for each ingredient in the recipe and the total footprints for each product was calculated. The Quorn product footprints were calculated in a similar way however the information for the recipes and the products were supplied directly from Quorn.

For the comparator proteins, beef mince has the highest carbon footprint (27.88 – 34.85 kg CO_2e/kg), and soybeans the lowest (0.10 kg CO_2e/kg) of all the analysed sources of protein. Chicken breast and fish fingers are around the same at the lower end of 2.47 – 3.90 and 3.05 kg CO_2e/kg respectively, and pork has a range of 4.90 – 6.96 kg CO_2e/kg . The Quorn products had relatively low carbon footprints ranging from mycoprotein at 0.53 kg CO_2e/kg to Quorn Yorkshire Ham at 2.6 kg CO_2e (Table 19).

The results were more varied for the land and water footprints with pork primal cuts having the largest land footprint at 0.001066 ha/kg for UK pork (Table 20) and soy protein isolate and textured vegetable protein the largest water footprint at 38940 L/kg (this is due to the large amounts of water used during processing and the relatively low yield per soybean) (Table 21). Quorn Nuggets had the lowest land footprint (0.000147 ha/kg) (Table 20) and Swedish chicken breast had the lowest water footprint (16 L/kg) (Table 21).

Table 19 – Summary of the carbon footprints for the comparator proteins (lower limit footprints), Quorn proteins, comparator products (lower limit footprints) and Quorn products

		(kgCO2e/kg)			
Product		UK	Sweden	Netherlands	Belgium
Comparator Proteins*	Soybean	0.1			
	Tofu	0.32			
	Soy Protein Isolate	20.2			
	Textured Vegetable Protein	20.28			
	Beef Mince	27.88	34.85	27.75	27.75
	Chicken Breast	3.68	2.47	3.9	3.77
	Pork Primal Cut	6.96	4.90	6.73	
Quorn Proteins**	Mycoprotein	0.53			
	Quorn Mince	1.29	1.39	1.58	1.5
	Quorn Pieces	1.23	1.35	1.63	1.41
	Quorn Fillets	1.26	1.46		
	Quorn Sausages	1.34			
Comparator Products*	Fish Fingers	1.36			
	Chicken Nuggets	2.08			
	Pork Cocktail Sausage	4.44			
	Pork Ham	6.08	4.46	5.97	
Quorn Products**	Quorn Yorkshire Ham	2.6			
	Quorn Vegan Ham		2.79	2.64	
	Quorn Cocktail Sausages	1.64			
	Quorn Nuggets	1.48			
	Quorn Fishless Fingers	1.92			

*Lower limit footprint
**Upper limit footprint

Table 20 – Summary of the land footprints for the comparator proteins (lower limit footprints), Quorn proteins, comparator products (lower limit footprints) and Quorn products

		(ha/kg)			
Product		UK	Sweden	Netherlands	Belgium
Comparator Proteins*	Soybean	0.00029			
	Tofu	0.000181			
	Soy Protein Isolate	0.00087			
	Textured Vegetable Protein	0.00087			
	Beef Mince	0.000915	0.000915	0.000915	0.000915
	Chicken Breast	0.000833	0.000692	0.000435	0.000435
	Pork Primal Cut	0.001066	0.000893	0.000749	
Quorn Protein**	Mycoprotein	0.000167			
	Quorn Mince	0.000427	0.00043	0.000494	0.000493
	Quorn Pieces	0.000283	0.000299	0.000325	0.000325
	Quorn Fillets	0.000262	0.000262		
	Quorn Sausages	0.00037			
Comparator Product*	Fish Fingers	N/A			
	Chicken Nuggets	0.000551			
	Pork Cocktail Sausage	0.000716			
	Pork Ham	0.000896	0.000761	0.000639	
Quorn Products**	Quorn Yorkshire Ham	0.000139			
	Quorn Vegan Ham		0.000197	0.000196	
	Quorn Cocktail Sausages	0.000306			
	Quorn Nuggets	0.000147			
	Quorn Fishless Fingers	N/A			

*Lower limit footprint
**Upper limit footprint

Table 21 – Summary of the blue water footprints for the comparator proteins (lower limit footprints), Quorn proteins, comparator products (lower limit footprints) and Quorn products

		Blue water use (L/kg)			
Product		UK	Sweden	Netherlands	Belgium
Comparator Proteins*	Soybean	50			
	Tofu	83			
	Soy Protein Isolate	38940			
	Textured Vegetable Protein	38940			
	Beef Mince	200	165	697	190
	Chicken Breast	31	16	82	85
	Pork Primal Cut	312			
Quorn Protein**	Mycoprotein	31			
	Quorn Mince	59	59	79	79
	Quorn Pieces	75	79	98	98
	Quorn Fillets	50	50		
	Quorn Sausages	126			
Comparator Product*	Fish Fingers	N/A			
	Chicken Nuggets	154			
	Pork Cocktail Sausage	284			
	Pork Ham	264	191	212	
Quorn Products**	Quorn Yorkshire Ham	65			
	Quorn Vegan Ham		55	55	
	Quorn Cocktail Sausages	519			
	Quorn Nuggets	69			
	Quorn Fishless Fingers	N/A			

*Lower limit footprint
**Upper limit footprint

Table 22 – Summary of the carbon footprints for the comparator proteins (average footprints) and Quorn proteins

		(kg CO2e/kg)			
Product		UK	Sweden	Netherlands	Belgium
Comparator Proteins*	Soybean	0.78			
	Tofu	0.57			
	Soy Protein Isolate	20.2			
	Textured Vegetable Protein	20.28			
	Beef Mince	32.13	43.02	39.93	33.03
	Chicken Breast	4.96	4.58	4.58	4.58
	Pork Primal Cut	11.09	10.14	9.95	
Quorn Protein**	Mycoprotein	0.53			
	Quorn Mince	1.29	1.39	1.58	1.5
	Quorn Pieces	1.23	1.35	1.63	1.41
	Quorn Fillets	1.26	1.46		
	Quorn Sausages	1.34			

*Average footprint
**Upper limit footprint

5.2. Summary of average footprints

This section summarises the average footprint figures for the comparator protein products and subsequently the footprint figures that were used in the average comparison analysis in Section 5.3 and Section 5.4. The figures come from a range of industry and academic literature with the average footprint being calculated for each country where possible (Carbon Trust Internal Document, 2022). The footprints in Table 22, Table 23 and Table 24 are the carbon, land and water footprints for the protein sources described in Section 4 and the Quorn proteins. The highest footprints for the Quorn proteins and Quorn products have been used for analysis.

Table 23 – Summary of the land footprints for the comparator proteins (average footprints) and Quorn proteins

		(ha/kg)			
Product		UK	Sweden	Netherlands	Belgium
Comparator Proteins*	Soybean	0.001400			
	Tofu	0.000181			
	Soy Protein Isolate	0.004200			
	Textured Vegetable Protein	0.004200			
	Beef Mince	0.006830	0.006403	0.006403	0.006403
	Chicken Breast	0.001201	0.001282	0.001282	0.001282
	Pork Primal Cut	0.001728	0.004457	0.004457	
Quorn Protein**	Mycoprotein	0.000167			
	Quorn Mince	0.000427	0.000430	0.000494	0.000493
	Quorn Pieces	0.000283	0.000299	0.000325	0.000325
	Quorn Fillets	0.000262	0.000262		
	Quorn Sausages	0.000370			

*Average footprint
**Upper limit footprint

Table 24 – Summary of the blue water footprints for the comparator proteins (average footprints) and Quorn proteins

		Blue water use (L/kg)			
Product		UK	Sweden	Netherlands	Belgium
Comparator Proteins*	Soybean	106			
	Tofu	83			
	Soy Protein Isolate	38940			
	Textured Vegetable Protein	38940			
	Beef Mince	1048	194	1207	300
	Chicken Breast	73	18	82	87
	Pork Primal Cut	320	230	288	
Quorn Protein**	Mycoprotein	31			
	Quorn Mince	59	59	79	79
	Quorn Pieces	75	79	98	98
	Quorn Fillets	50	50		
	Quorn Sausages	126			

*Average footprint
**Upper limit footprint

5.3. Stage 1: Footprint comparison of proteins

5.3.1. Quorn Mycoprotein comparison

Quorn mycoprotein is compared against the footprints of soy and various soy products. The percentages below show the ratio of Quorn's Mycoprotein footprint compared to the soy products. For the processed soy products (tofu, soy protein isolate, textured vegetable protein) there was limited LCA data available and a range could not be found for the land and water footprints of some of these products. Where this is the case the lower and average footprints are the same. **Table 25** contains the comparison results of comparing Quorn Mycoprotein with the **lower limit footprint data** of each soy product and **Table 26** contains the comparison results of comparing Quorn Mycoprotein with the **average footprint data** of the soy products.

Table 25 – Ratio of Quorn mycoprotein footprints to soy products using the lower limit footprint data for the comparator protein

Soy product (lower)	Carbon	Land	Blue Water	Green Water	Grey Water	Total Water
Soybean	530%	57%	62%	40%	1913%	55%
Tofu	165%	92%	37%	21%	435%	29%
Soy Protein Isolate (SPI)	3%	19%	0.1%	7%	145%	2%
Textured Vegetable Protein (TVP)	3%	19%	0.1%	7%	145%	2%

Upper limit footprint of the Quorn product is compared against the lower limit footprint of the comparator product.

Table 26 – Ratio of Quorn mycoprotein footprints to soy products using average footprint data for the comparator protein

Soy product (average)	Carbon	Land	Blue Water	Green Water	Grey Water	Total Water
Soybean	68%	12%	29%	26%	89%	32%
Tofu	94%	92%	37%	21%	435%	29%
Soy Protein Isolate (SPI)	3%	4%	0.1%	7%	145%	2%
Textured Vegetable Protein (TVP)	3%	4%	0.1%	7%	145%	2%

5.3.2. Quorn Mince comparison

Quorn Mince is compared against the footprints of primal cuts of beef used in mince, as this is the most appropriate comparator against Quorn Mince. The footprint for beef mince was calculated using the different economic values of different parts of beef carcass, and the percentage of carcass weight each comprises (based on FAO data (FAO, 2021)). Beef mince is assumed to contain 100% beef with primal cuts being used as standard for mince production (Business Companion, 2021). **Table 27** contains the comparison results of comparing Quorn Mince with the **lower limit footprint data** for beef mince and **Table 28** contains the comparison results of comparing Quorn Mince with the **average footprint data** for beef mince.

Table 27 – Ratio of Quorn Mince footprints to beef mince for UK, Sweden, Netherlands, and Belgium using the lower limit footprint data for beef mince

		Carbon	Land	Blue Water	Green Water	Grey Water	Total Water
Quorn Mince Vs Beef Mince (lower)	UK	5%	47%	29%	8%	77%	18%
	Sweden	4%	47%	36%	8%	106%	17%
	Netherlands	6%	54%	11%	12%	306%	27%
	Belgium	5%	54%	41%	7%	252%	17%

Upper limit footprint of the Quorn product is compared against the lower limit footprint of the comparator product.

Table 28 – Ratio of Quorn Mince footprints to beef mince for UK, Sweden, Netherlands, and Belgium using average footprint data for beef mince

		Carbon	Land	Blue Water	Green Water	Grey Water	Total Water
Quorn Mince Vs Beef Mince (average)	UK	4%	6%	6%	4%	69%	8%
	Sweden	3%	7%	31%	7%	71%	15%
	Netherlands	4%	8%	7%	9%	215%	19%
	Belgium	4%	8%	26%	6%	229%	14%

5.3.3. Quorn Pieces and Quorn Fillets comparison

Quorn Pieces and Fillets are compared against the footprints of chicken breast as that is the closest product to the Quorn products. The footprints have been compared using the upper limit footprints of the Quorn Pieces and Fillets and the lower limit footprints for chicken breast. The footprint for chicken breast was calculated using the different economic values of different parts of chicken, and the percentage of carcass weight each comprises. **Table 29** contains the comparison results of comparing Quorn Pieces and Quorn Fillets with the **lower limit footprint data** for chicken breast, and **Table 30** contains the comparison results of comparing Quorn Pieces and Quorn Fillets with the **average footprint data** for chicken breast.

Table 29 – Ratio of Quorn Pieces and Fillets footprints to chicken breast for UK, Sweden, Netherlands and Belgium using the lower limit footprint data for chicken breast

		Carbon	Land	Blue Water	Green Water	Grey Water	Total Water
Quorn Pieces vs Chicken Breast (lower)	UK	33%	34%	241%	32%	200%	62%
	Sweden	55%	43%	481%	31%	175%	60%
	Netherlands	42%	75%	119%	38%	445%	79%
	Belgium	37%	75%	114%	29%	259%	59%
Quorn Fillet vs Chicken Breast (lower)	UK	34%	31%	160%	29%	197%	58%
	Sweden	59%	38%	305%	27%	163%	53%

Upper limit footprint of the Quorn product is compared against the lower limit footprint of the comparator product.

Table 30 – Ratio of Quorn Pieces and Fillets footprints to chicken breast for UK, Sweden, Netherlands and Belgium using average footprint data for chicken breast

		Carbon	Land	Blue Water	Green Water	Grey Water	Total Water
Quorn Pieces vs Chicken Breast (average)	UK	23%	24%	103%	18%	192%	37%
	Sweden	29%	23%	437%	29%	160%	55%
	Netherlands	33%	25%	119%	38%	434%	78%
	Belgium	29%	25%	112%	28%	253%	57%
Quorn Fillet vs Chicken Breast (average)	UK	24%	22%	69%	16%	189%	34%
	Sweden	30%	20%	277%	24%	150%	48%

5.3.4. Quorn Sausage comparison

Quorn's Sausage is compared against the footprints of pork primal cut. Research suggests that primal pork cuts are used in pork sausages, so the emission factors associated with these were used for comparison. An economic approach was used for the allocation of emissions to the pork cuts. **Table 31** contains the comparison results of comparing Quorn Sausage with the **lower limit footprint data** for pork primal cuts, and **Table 32** contains the comparison results of comparing Quorn Sausage with the **average footprint data** for pork primal cuts.

Table 31 – Ratio of Quorn Sausage footprints to pork primal cut for the UK using the lower limit footprint data for pork primal cuts

	Carbon	Land	Blue Water	Green Water	Grey Water	Total Water
Quorn Sausage vs Pork primal cuts (lower)	30%	52%	44%	30%	223%	57%

Upper limit footprint of the Quorn product is compared against the lower limit footprint of the comparator product.

Table 32 – Ratio of Quorn Sausage footprints to pork primal cut for the UK using average footprint data for pork primal cuts

	Carbon	Land	Blue Water	Green Water	Grey Water	Total Water
Quorn Sausage vs Pork primal cuts (average)	11%	21%	39%	20%	141%	39%

5.4. Stage 2: Footprint comparison of competing products

5.4.1. Quorn Nuggets comparison

Quorn's Nuggets were compared against the footprints of chicken nuggets as that is the closest product to Nuggets. The footprint for chicken nuggets were calculated by analysing the ingredients of chicken nugget products from various UK supermarkets. To obtain the lowest footprints, the chicken nuggets with the lowest chicken content were selected (chicken being the most intensive ingredient). The footprint for chicken breast was calculated using an economic allocation method and was used as the primary meat source in the chicken nuggets. The UK recipe for chicken nuggets has been used for all the countries as there did not appear to be significant variation in the ingredients used or the amounts of these ingredients in the other countries. The percentages below show the ratio of Quorn Nuggets footprints compared to chicken nuggets for the UK.

Table 33 – Ratio of Quorn Nuggets footprints to chicken nuggets for the UK

	Carbon	Land	Blue Water	Green Water	Grey Water	Total Water
Quorn Nuggets vs Chicken Nuggets (lower)	71%	27%	45%	79%	135%	83%

Upper limit footprint of the Quorn product is compared against the lower limit footprint of the comparator product.

5.4.2. Quorn Cocktail Sausages comparison

Quorn's Cocktail Sausages were compared against the footprints for pork cocktail sausages as this was the closest product. The footprint for pork cocktail sausages were calculated by analysing the ingredients of products from various UK supermarkets. To obtain the lowest footprint figures, the pork sausages with the lowest pork content were selected as this had the lowest overall carbon footprint (because pork was the most intensive ingredient). The percentages below show the ratio of Quorn Cocktail Sausages footprints compared to pork cocktail sausages for the UK.

Table 34 – Ratio of Quorn Cocktail Sausage footprints to pork cocktail sausage for the UK

	Carbon	Land	Blue Water	Green Water	Grey Water	Total Water
Quorn Cocktail Sausages vs Pork cocktail sausages (lower)	35%	42%	180%	46%	146%	70%

Upper limit footprint of the Quorn product is compared against the lower limit footprint of the comparator product.

5.4.3. Quorn Yorkshire Ham comparison

Quorn's Yorkshire Ham was compared against the footprints of pork ham, as that is the closest product to Yorkshire Ham. The footprints for pork ham were calculated by analysing the ingredients of products from various UK supermarkets. To obtain the lowest footprint figures, the ham products with the lowest pork content were selected as this had the lowest overall carbon footprint (because pork was the most intensive ingredient). The percentages below show the ratio of Quorn Yorkshire Ham footprints compared to pork ham for the UK.

Table 35 – Ratio of Quorn Yorkshire Ham footprints to pork ham for UK

	Carbon	Land	Blue Water	Green Water	Grey Water	Total Water
Quorn Yorkshire Ham vs Pork ham (lower)	43%	16%	25%	16%	28%	18%

Upper limit footprint of the Quorn product is compared against the lower limit footprint of the comparator product.

5.4.4. Quorn Vegan Ham comparison

Quorn's Vegan Ham was compared against the footprints of pork ham, as that is the closest product to Vegan Ham. The footprints for pork ham were calculated by analysing the ingredients of products from various UK supermarkets. To obtain the lowest footprint figures, the ham products with the lowest pork content were selected as this had the lowest overall carbon footprint (because pork was the most intensive ingredient). The ingredient allocation for the UK has been used for all of the countries as there did not appear to be significant variation in the ingredients used or the allocation of these ingredients in pork ham in other countries. The percentages below show the ratio of Quorn Vegan Ham footprints compared to pork ham for the different countries.

Table 36 – Ratio of Quorn Vegan Ham footprints to pork ham for Sweden and Netherlands

		Carbon	Land	Blue Water	Green Water	Grey Water	Total Water
Quorn Vegan Ham vs Pork ham (lower)	Sweden	63%	26%	29%	20%	39%	24%
	Netherlands	44%	31%	26%	17%	56%	22%

Upper limit footprint of the Quorn product is compared against the lower limit footprint of the comparator product.

5.4.5. Quorn Vegan Fishless Fingers comparison

Quorn vegan fishless fingers is compared against the footprints of fish fingers, as that is the closest product to the fishless fingers. The footprints for fish fingers were calculated by analysing the ingredients of products from various UK supermarkets. To obtain the lowest footprint figures, the fish fingers with the lowest fish content were selected as this had the lowest overall carbon footprint (because fish was the most intensive ingredient). The percentages below show the ratio of Quorn Vegan Fishless Fingers footprints compared to fish fingers for the different countries.

Table 37 – Ratio of Quorn Fishless Fingers footprints to fish fingers for the UK

	Carbon
Quorn Fishless Fingers vs Fish fingers (lower)	141%

Upper limit footprint of the Quorn product is compared against the lower limit footprint of the comparator product.

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The Carbon Trust is a company limited by guarantee and registered in England and Wales under Company number 04190230 with its Registered Office at: Level 5, Arbor, 255 Blackfriars Road, London SE1 9AX, UK.

Published in the UK: 2023