



› Living well on leftovers: the potential of nutrient recycling to contribute to a reduced livestock sector, within planetary boundaries

KEY MESSAGES

- Globally, people living in industrialised countries in ‘protein surplus regions’ need to eat much less meat to avert the climate and biodiversity crises. Current levels of food system emissions mean the world cannot meet the Paris Agreement target of limiting warming to 2°C above pre-industrial levels, let alone 1.5°C: however, halving food waste, eating a healthy level of calories and switching to sustainable diets could deliver 88%^a of the total mitigation needed within the food system to limit warming to 1.5°C.
- Reducing meat and dairy consumption is necessary but not sufficient to keep global temperatures below 1.5°C and to alleviate the nature and biodiversity crises; it is also vital to change how the meat and dairy that continues to be eaten is produced.
- The safe ‘recycling’ of surplus nutrients into non-ruminant animal feed presents an underexplored scenario that would allow the production of a smaller quantity of meat within planetary boundaries. In this paper, Feedback sets out the role a limited number of farm animals must play in a future food system, applying a global food-feed competition avoidance principle.
- Halving existing levels of both UK food waste and meat and dairy consumption is an essential pre-requisite to implementing nutrient recycling within planetary boundaries.
- What we can eat within planet boundaries is a different question to what we should eat, and there are different perspectives and cultural and ethical considerations to take into account. Scientific evidence is one part of the puzzle in the discussion on dietary change; all actions must be rooted in food justice and account for the many functions that food fulfils.

INTRODUCTION

Eating less meat, particularly in countries in ‘protein surplus regions’, is an essential prerequisite to safeguarding nature and climate (Clark et al., 2020; Springmann et al., 2018; Willett et al., 2019). Taking this position as its starting point, this paper explores one scenario for ‘better meat’ production, in which a greatly reduced number of non-ruminant farm animals recycle unavoidable leftovers and by-products back into the food system, within a wider agroecological and circular approach to food production.

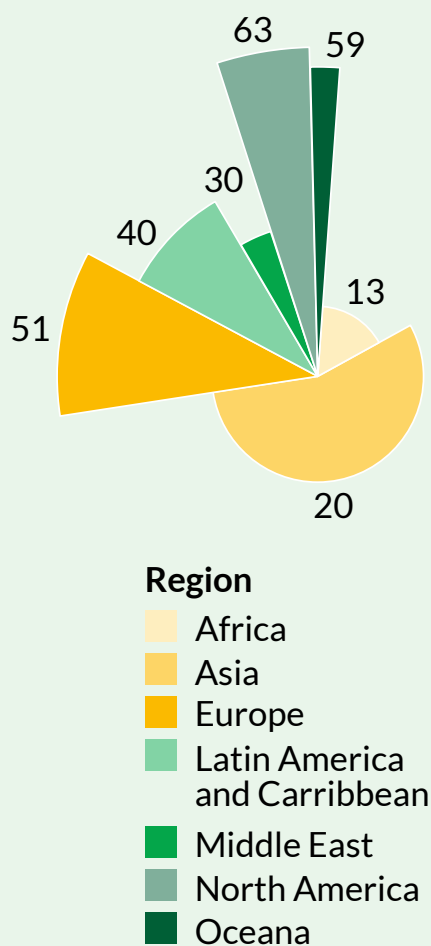
Current food system emissions mean we cannot meet the Paris target of keeping warming below 2°C above pre-industrial levels (Bajželj et al., 2014; Springmann et al., 2018, 2016), and changes to production methods will be insufficient to reduce farming’s emissions and meet global biodiversity targets (Bailey et al., 2014; Benton et al., 2021; Leip et al., 2019; Wollenberg et al., 2016). This means without reducing meat consumption, we will be unable to limit global warming to less than 2°C (Clark et al., 2020; van de Kamp et al., 2018; Wellesley et al., 2015). However, halving food waste, eating a healthy level of calories and switching to sustainable diets, including much less animal source foods, deliver 88% of the total mitigation needed within the food system to bring us within a 67% chance of meeting 1.5°C.^a The UK’s Committee on Climate Change recommends “low-cost, low-regret” actions to reduce meat consumption on the ‘balanced pathway’ to net zero emissions in the UK (Committee on Climate Change, 2020).

Although some may choose to eat no animal products at all, meat is culturally important to many people, and farm animals have a role to play in resilient food systems (Poux and Schiavo, 2021). While the case for reduction in consumption of animal source foods is unequivocal, there is an important debate to be had about how livestock production systems can support environmental and health outcomes. Broadly characterised as ‘better meat and dairy’ (Eating Better, 2021), this has been variously presented as livestock systems that are higher welfare, contribute to local ecosystems and biodiversity, reduce damaging inputs such as nitrate fertilisers or purpose-grown feed, or change feeding methods to reduce livestock emissions and land use demands. Much of the conversation surrounding ‘better meat’ in the UK has focused on pasture-reared ruminant livestock. Garnett et al. (2017) found that “rising animal production and consumption, whatever the farming system and animal type, is causing damaging greenhouse gas release and contributing to changes in land use”, while the ‘Ten Years for Agroecology’ study found that livestock play an important role in building natural soil fertility (Poux and Aubert, 2018).

BOX 1: THE PROTEIN SURPLUS

A number of regions worldwide are characterised by excessive production and excessive per capita consumption of animal source foods, including meat and dairy. These regions principally encompass countries which industrialised earlier or are characterised by high incomes compared to the global average, including the UK, EU countries and North America. Figure 1 demonstrates current animal source protein consumption in the world’s regions (Van Zanten et al., 2018). Climate justice principles dictate that countries which bear outsized responsibility for emissions burdens should be the first to reduce emissions and to do so radically. Therefore, the recommendations in this report are particularly aimed at the UK and other early industrialisers.

FIGURE 1: CURRENT AVERAGE ANIMAL SOURCE PROTEIN SUPPLY IN THE WORLD’S REGIONS (GRAMS PER PERSON PER DAY)



Source: Van Zanten et al. (2018)

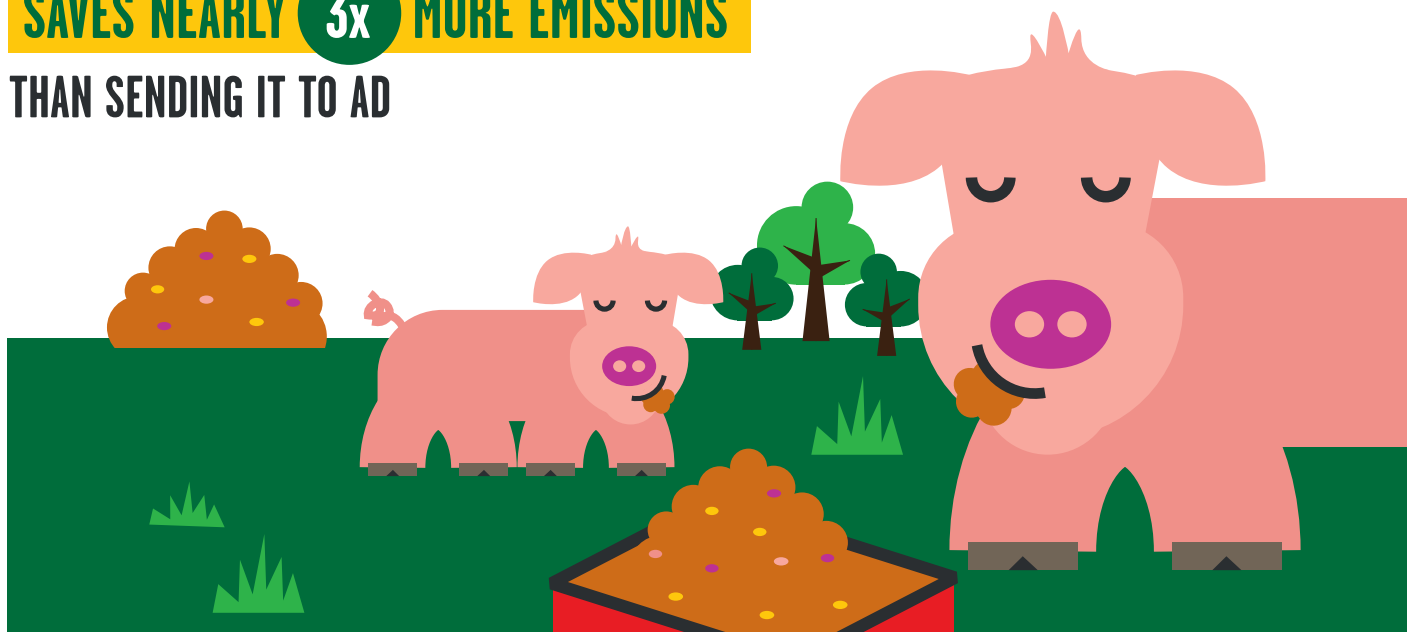
^a Alongside halving food wastes and eating a healthy level of calories, switching to sustainable diets by 2050 delivers a reduction of 1077 Gt CO₂-we compared to cumulative Business as Usual food system emissions of 1356 Gt CO₂-we by 2100. See Supplementary materials from Clark, M. A., Domingo, N. G., Colgan, K., Thakrar, S. K., Tilman, D., Lynch, J., ... & Hill, J. D. (2020). Global food system emissions could preclude achieving the 1.5° and 2° C climate change targets. *Science*, 370(6517), 705-708.

FIGURE 2: USING FOOD WASTE AS ANIMAL FEED SAVES NEARLY THREE TIMES MORE EMISSIONS THAN SENDING IT TO ANAEROBIC DIGESTION (AD)

USING FOOD WASTE AS ANIMAL FEED

SAVES NEARLY 3x MORE EMISSIONS

THAN SENDING IT TO AD



Source: Feedback (2020b)

This paper focuses on non-ruminant livestock (pigs and chickens) as well as ‘fed aquaculture’ (farmed fish that relies on external feed inputs, as opposed to unfed forms of aquaculture such as mussel farming). By transitioning non-ruminant farm animals to feeds made from leftovers and food by-products, they can play an important role in ‘recycling’ otherwise-wasted nutrients back into the food system. In this scenario, non-ruminant meat and eggs could be produced solely from feed that does not directly compete with human-edible crops for arable land. Recycling ‘low opportunity cost’ feeds, such as inedible food surplus or by-products, into animal feed for omnivorous non-ruminants (pigs or chickens, as well as carnivorous farmed fish, such as salmon) reduces reliance on terrestrial and marine resources for feed including land, soya imports and fishmeal and fish oil from wild-caught fish used in feed (Bowman and Luyckx, 2019; Feedback, 2020a). Furthermore, feeding waste to animals saves nearly three times more greenhouse gas emissions than sending it to anaerobic digestion (Feedback, 2020b).

It is important to note some necessary preconditions attached to this scenario in order to truly reduce the impact of the food system on nature. Without first, as much as possible, reducing or preventing food waste or by-products from arising, or using them for direct human consumption, nutrient recycling cannot deliver positive environmental outcomes and may deliver negative ones by creating a market driver that prevents waste reduction. This has been the case with the anaerobic digestion industry, policies for which have disincentivised food waste reduction by creating economic incentives to

send food waste to anaerobic digestion (Bowman and Woroniecka, 2020). However, in the right circumstances, using low-opportunity cost feeds to produce enough animal source foods to maximise livestock’s contribution to human nutrition provides a highly effective dietary change mitigation scenario (Van Zanten et al., 2018). By providing an overview of the ecological case for leftovers as non-ruminant feed and then using two case studies – ‘eco-feed’ for pigs and limiting salmon farming to rely on fisheries by-products only – this paper will highlight the role that safe nutrient recycling into non-ruminant animal feed can play in sustainable diets. Both cases are based on the extensive Feedback research and body of academic evidence detailed in the REFRESH policy brief (Bowman and Luyckx, 2019) and Feedback’s ‘Off The Menu’ report (Feedback, 2020a).

This position sits alongside social justice and cultural considerations around access to healthy, delicious and culturally appropriate food, as well as amongst a much wider debate on other aspects of ‘better meat’ (well documented elsewhere by the Eating Better coalition (Eating Better, 2018)), for example, animal welfare. As such, this paper does not seek to provide a single answer to the question of how animals and meat consumption can best be rationalised with climate and environmental concerns, but instead seeks to contribute a proposal on a specific and underexplored aspect of this question: the role of feed and nutrient recycling. This paper discusses how we could best implement nutrient recycling into animal feed in a way that supports independent and agroecological farming, employment and animal welfare outcomes.

THE ENVIRONMENTAL CASE FOR DIETS WITH LIMITED ANIMAL SOURCE FOOD FROM ANIMALS FED ON “ECOLOGICAL LEFTOVERS”

This section sets out the case for a major societal shift in the UK and other protein surplus countries towards diets that are low in meat and dairy yet have small amounts of animal source foods from animals fed on by-products and unavoidable leftovers that are inedible for people. It shows that it is necessary to prevent food waste from occurring in the first place and then discusses the non-ruminant and salmon case studies.

A focus on nutritional value – creating maximum nutritional value directly consumed by people for the least environmental impact – guides the proposals in this position paper. Eating plants, particularly fruit and vegetables as well as pulses, delivers well on this equation, providing high-quality and varied nutrition, largely within planetary boundaries. This is because animal products commonly generate substantially higher emissions per unit of nutrition produced than plant-based foods (Springmann et al., 2016). In the case of non-ruminants, which produce much lower levels of methane than ruminant animals, this emissions burden is largely linked to the crops and other resources used to feed them. Large-scale, industrialised livestock systems are particularly damaging, as they are heavily reliant on external, commodified feed crops, such as soya, to intensify production, deliver economies of scale and extract value for the corporations controlling these systems (Feedback, 2020c).

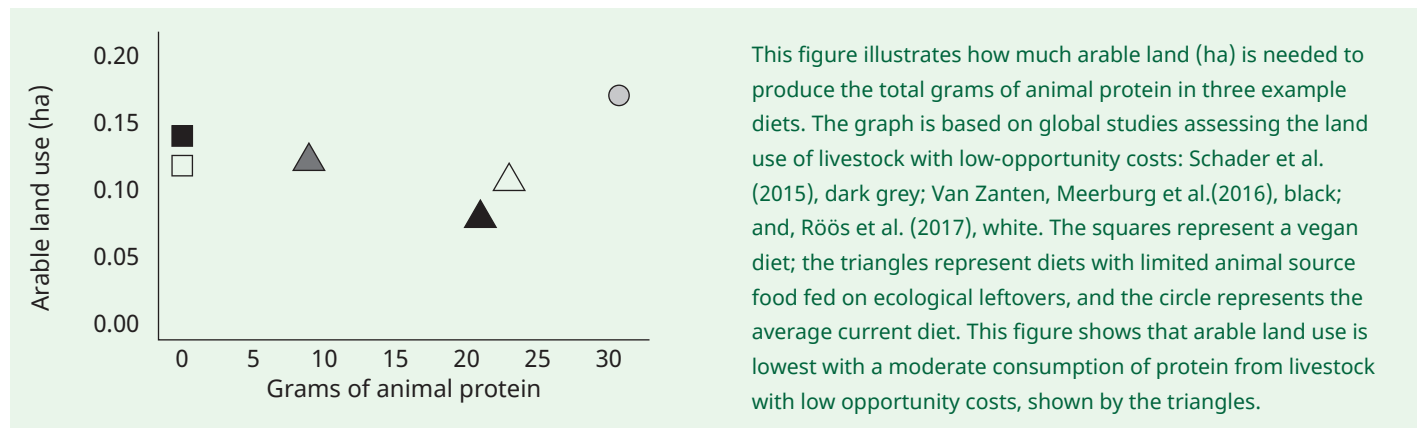
Mottet et al. (2017) estimate that 400 million ha of cropland produces feed for livestock in a way that competes with food crop production (including production of edible feed crops, oil seed and oil seed cakes, and inedible fodder crops). They additionally class another 700 million ha of grassland as competing with food crops for land, because this area is suitable for cropping despite being currently grazed; this makes the total land area 1.1 billion ha (or 17% of estimated agricultural land area) that produces livestock when it could produce crops to be eaten by people (Breewood and Garnett, 2020).

Other feed ingredients, such as fishmeal or fish oil manufactured from whole, wild-caught fish, which is used in salmon farming as well as in some pig and chicken feeds and petfood, also impose outsized ecological burdens, depleting wild fish stocks and failing to make good use of wild nutrients in human diets (Feedback, 2020a). Thus, the

food-feed challenge explored in the introduction requires not only a major societal shift in the UK and other protein surplus countries towards diets that are low in meat and dairy, but also requires limiting the production of ‘fed aquaculture’ to that reared on by-products and leftovers. Indeed, this is a prerequisite to halting the destruction of nature and global heating (Feedback, 2019a).

While a vegan diet is often proposed as offering the greatest potential to reduce land use and greenhouse gas emissions, a food system free of any farmed animals limits opportunities to recycle unavoidable leftovers and by-products back into the food system. This creates higher demand for land to cultivate additional crops to meet the nutritional requirements of a vegan population. In this context, using non-ruminant livestock, and aquaculture, to recycle some of these ‘surplus’ nutrients back into the food system makes ecological sense. Some agricultural by-products, such as rapeseed meal, wheat middlings, spent brewers’ grains and molasses, are already important ingredients in pig feed. However, there are still many sources of surplus nutrients left untapped. 12.7 million tonnes of surplus food is wasted in the UK each year (Gillick and Quested, 2018; Quinn, 2017), of which an estimated 2.5 million tonnes - 20% of the UK’s total estimated food waste - could be processed into non-ruminant feed if we were to change legislation to ensure the safe treatment of this surplus (Feedback, 2018). Furthermore, other by-products, such as poultry processed animal proteins (PAPS), could be valuable contributions to pig feed if rigorous processes would replace currently prohibitive legislation (Searby, 2014). It is crucial that only true by-products of the food industry are used to produce animals reared on genuinely ecological leftovers. ‘Recycling’ nutrients through safely feeding food surplus to non-ruminants would also help put the UK on track to meet Sustainable Development Goal 12.3 (to halve food waste by 2030) and help the UK make a major contribution to meeting its emissions targets under the Climate Change Act. Figure 3 below shows the potential of diets with limited animal source food fed on ‘ecological leftovers’ to reduce the amount of land used for food production. While vegan diets use less land than our average current diet, a diet incorporating a small amount of animal source foods from animals reared on ecological leftovers uses even less land (Van Zanten et al., 2018).

FIGURE 3: A COMPARISON OF THE LAND USE OF AN ECOLOGICAL LEFTOVERS DIET WITH THE LAND USE OF A VEGAN DIET OR THE CURRENT AVERAGE DIET



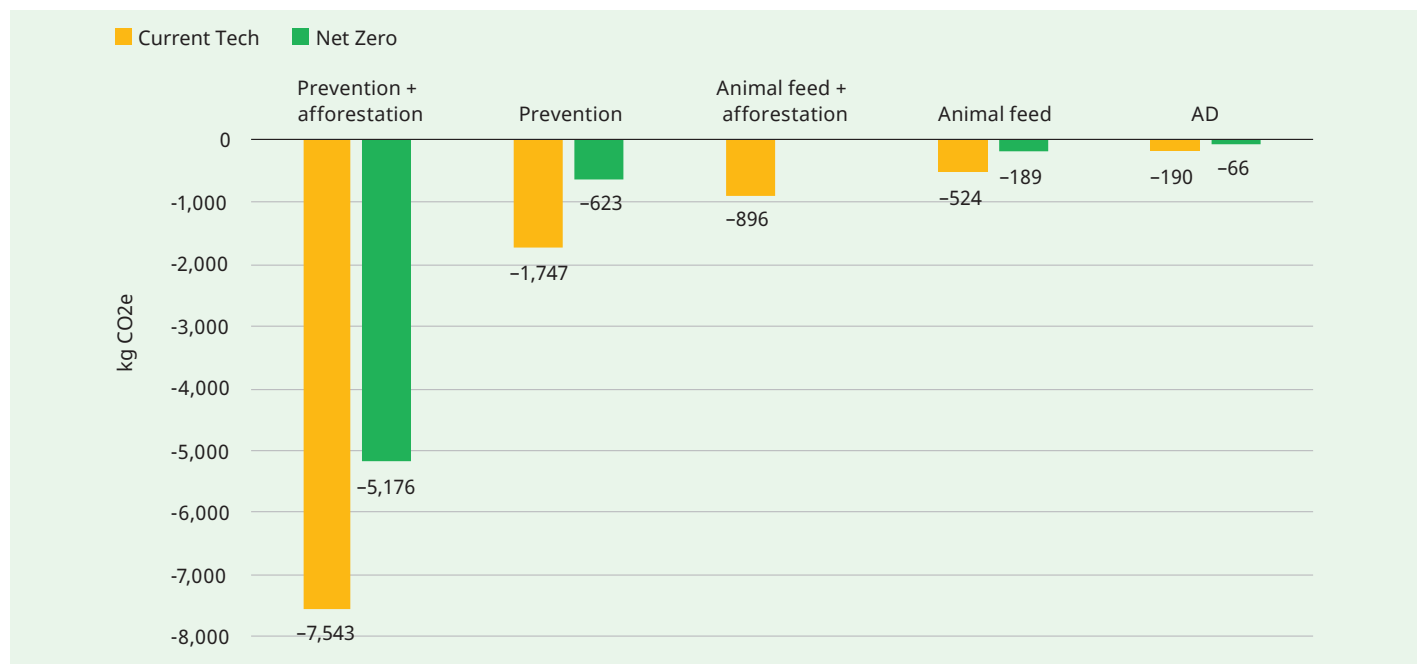
Source: Van Zanten et al. (2018)

THE IMPORTANCE OF PREVENTING OVERPRODUCTION OF FOOD

It is vital that the approach described above sits alongside a much broader drive towards a low-waste, more circular food system, in which waste prevention is paramount. The UK – and global – food system is defined by overproduction, with considerable ecological damage generated in producing food that is never eaten: for example, it is estimated that between 3.5 and 5 million tonnes of food is wasted before it even leaves the farm (WRAP, 2020). There are many measures that could be implemented to address and minimise this waste: more accurate measurement of food waste across all

levels of the supply chain, including farms, to provide an accurate baseline for reductions; a regulatory approach to business-level food waste reduction; and a shift to a food culture in which food’s inherent value is recognised and celebrated. All these measures would not only start to reduce the wastefulness of the food system, they would also contribute to meeting climate goals^b. Figure 4 below shows the greenhouse gas emissions savings of preventing food waste from occurring (1,747 kg CO₂e) versus the savings from sending food waste to animal feed (524 kg CO₂e).

FIGURE 4: EMISSIONS SAVINGS BY FOOD WASTE DESTINATION IN CURRENT TECHNOLOGY AND NET ZERO CONTEXTS (PER TONNE OF FOOD WASTE. CREDIT FEEDBACK (2020B)

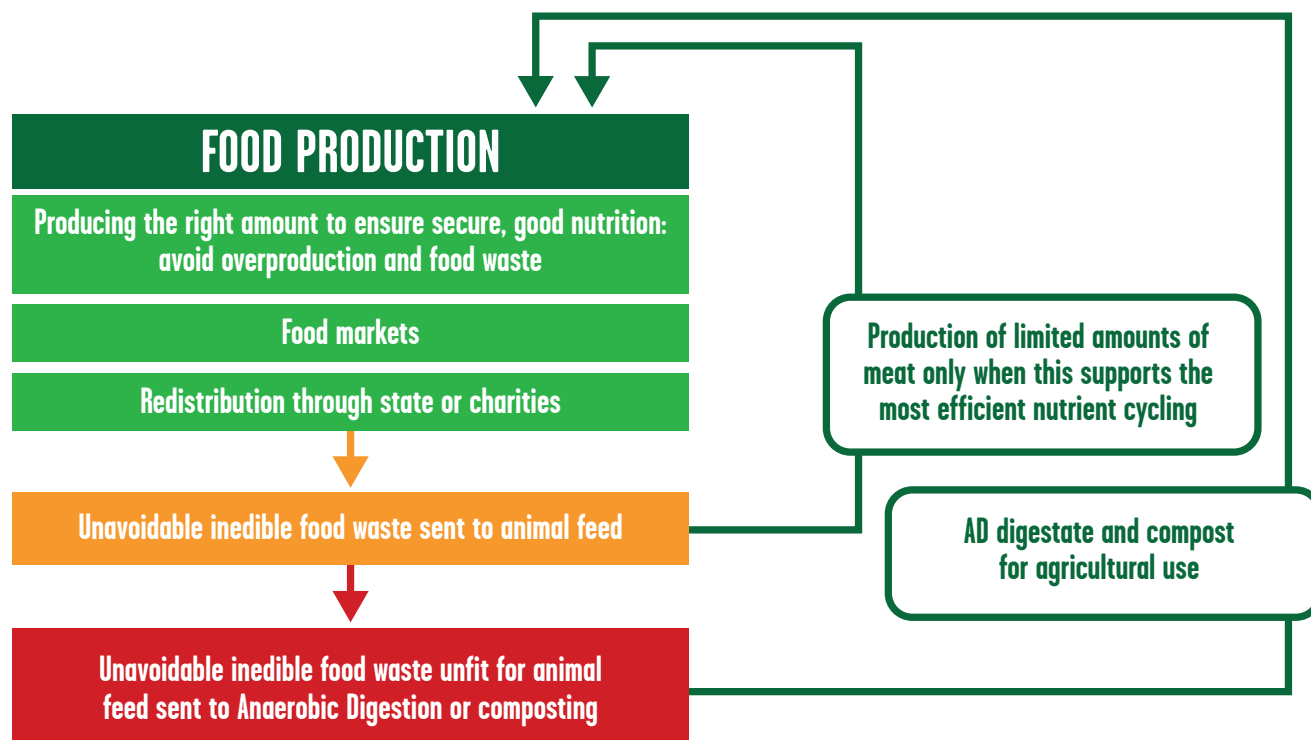


^b A more detailed exploration of food waste prevention measures can be found in Feedback’s policy brief, ‘Where there’s no waste there’s a way (to net zero): a call for policy for food waste prevention’ (Feedback, 2020d).

Reducing meat waste must also be considered in overall food waste reduction efforts: importantly, the return to a 'nose to tail' eating of animal products has the potential to significantly reduce food waste from meat production and (alongside considerable reductions in the UK's meat and dairy consumption) maximises the nutritional value of

animals reared for human consumption (Xue et al., 2019). Feedback's Circular Food Use Hierarchy (figure 5) shows the role of unavoidable inedible food waste for animal feed, while prevention of food waste and redistribution (shown in green) is higher up the hierarchy.

FIGURE 5: THE CIRCULAR FOOD USE HIERARCHY (CREDIT FEEDBACK 2020)



BOX 2: CONTEXTUALISING ECOLOGICAL LEFTOVERS IN THE DEBATE ON LESS AND BETTER MEAT: DEFINING 'INDUSTRIAL' MEAT AND DAIRY

In general, at 'its most industrial', industrial meat and dairy has the following characteristics:

- Large, embedded land use for growing feed, often overseas
- High level of nutrient loss through pollution (e.g. by waste run-off)
- A low ratio of nutritional value to external resource input (i.e. significant inputs – such as energy, fertilisers, water – are needed to produce the meat and dairy products)
- High level of product specialisation (i.e. only one specific or a small number of meat and dairy products)
- Both inputs and outputs embedded in global, financialised commodity markets
- Innovation solely profit-driven (i.e. driven by a need for higher shareholder returns)
- Productivity understood as the financial value generated.

Together, these features create a system of meat and dairy production which cannot co-exist with high animal welfare standards, good human health and continued availability of vital antibiotics, and the preservation of our global biodiversity and a liveable climate (Feedback, 2020c).

In contrast, in a 'non-industrial' approach to livestock rearing, which, at its 'most non-industrial', is an agroecological one:

- Less embedded land use linked to imported feed (even if local land footprint may be larger due to less intensive practices)
- High levels of nutrient recycling, with soils replenished and enriched (e.g. through careful manure management)
- A high ratio of nutritional value to external resource input (i.e. few inputs, such as fertilisers or energy, are required to generate nutritional value)
- Farms produce diverse outputs as well as meat or dairy
- Both inputs and outputs embedded in a regional food economy, with short supply chains
- Innovation-driven by increasing nutritional output and environmental enhancement
- Productivity understood as the seeking of maximum nutritional value for minimal environmental damage, or maximum environmental enhancement.
- Smaller scale (humane-scale) herd numbers

PREREQUISITES TO FEEDING LEFTOVERS TO LIVESTOCK AND FARMED FISH

There are three essential prerequisites without which any consideration of the role of non-ruminant farm animals becomes futile at best, or dangerous greenwash at worst. To truly contribute to a healthy climate and food security, the proposals set out in this paper **must be preceded** by a comprehensive UK legislation and policy strategy package as follows:

1. **Halve all food waste through prevention at source**, including a return to nose-to-tail eating.

2. **Halve consumption and production of meat, dairy and farmed fish**, promoting small-scale agroecological livestock and mixed farming and eliminating all direct and indirect support for disease-prone intensive animal farming operations. Initial estimates suggest that about one third of our recommended protein requirement could be supplied by meat and dairy products from farm animals fed on ecological leftovers, i.e. feed that did not compete over arable land with human-edible crops (Van Zanten et al., 2018).

3. Ensure that relevant national and local authorities have the policies and resources for **adequate monitoring and control in relation to food and feed safety and animal welfare**, as described in our full reports on safe nutrient recycling into non-ruminant animal feed (Bowman and Luyckx, 2019; Luyckx et al., 2019).

Without firm political, regulatory and private sector commitment on the above systemic issues, the significant environmental benefits of the proposals set out below will be at risk. There is a risk that repurposing ecological leftovers as feed incentivises the intensification of livestock and aquaculture operations by reducing feed costs in a manner that benefits very large farms. This could continue to drive cultural acceptance of excessive meat consumption and create a market for food waste which could otherwise be prevented.

FIGURE 6: PREREQUISITES TO FEEDING LEFTOVERS TO LIVESTOCK AND FARMED FISH



CASE STUDY 1: SENDING ECOLOGICAL LEFTOVERS TO AQUACULTURE

The Scottish salmon farming industry currently uses 460,000 tonnes of wild-caught fish every year, which is roughly equivalent to the amount of seafood (both wild and farmed) purchased by the entire UK population in the same period (Feedback, 2019b; Seafish, 2018).

Salmon farming can provide a mechanism to prevent micronutrients from leaving the food system, but only if it restricts itself to using truly unavoidable by-products from capture fisheries (wild-caught fisheries) rather than fish caught specifically for feed. Ensuring the integrity of by-products supply chains, and avoiding the demand for by-products driving increased catches, requires regulation and governance. Feeding salmon on by-products alone allows us to significantly reduce the amount of crops and wild-caught fish that are currently used in salmon feed. To fulfil this scenario, based on current available data, the Scottish farmed salmon industry would need to reduce in size by two thirds. A smaller, more sustainable industry could play a vital role in retaining omega 3s from fish by-products that would otherwise be wasted (Feedback, 2020a).

Rendering is the process that converts by-products from the meat and livestock industry into usable and safe materials, called 'processed animal proteins' (PAPs). In Europe, there are 18 million tonnes of animal material processed each year. In 2013, the European Commission re-authorised PAPs derived from non-ruminant animals (such as pigs and poultry) for use in aquaculture feed. Poultry meal is considered a nutritious ingredient for carnivorous fish and is commonly used in salmon farming

in Canada and elsewhere. However, while the Scottish salmon industry has yet to include poultry meal in its feed formulations because of a perceived resistance from retailers and consumers, outside of Scottish production, the UK imports seafood that is fed on poultry proteins for domestic consumption, such as warmwater prawns from countries including Indonesia, Thailand, Vietnam, China and Bangladesh (Tacon, 2012). If we want to achieve a genuinely circular food system, we will need to overcome legislative and market barriers to ensure the optimal use of high-quality proteins currently leaving the food system.

BOX 3: HOW DO THESE BENEFITS COMPARE TO FEEDING ECOLOGICAL LEFTOVERS TO INSECTS?

Insects are often touted as a future food for humans and feed for animals, but the most important question when considering their benefits is, 'What do the insects eat?' Feeding unavoidable household food waste to insects may produce protein-rich insect-based food, as well as poultry and aquafeed ingredients, but only where this waste could not be fed directly to animals or people. Black Soldier Fly (BSF) larvae reared on unavoidable waste streams offer potential to replace conventional feed protein sources and, thereby, to lower the environmental impact of food production, but BSF larvae reared on feed products that directly compete with human food or livestock feed generally have relatively high environmental impacts (Bosch et al., 2019). Insects come at the bottom of the hierarchy of the food-feed competition avoidance principle, though they certainly have a role to play.

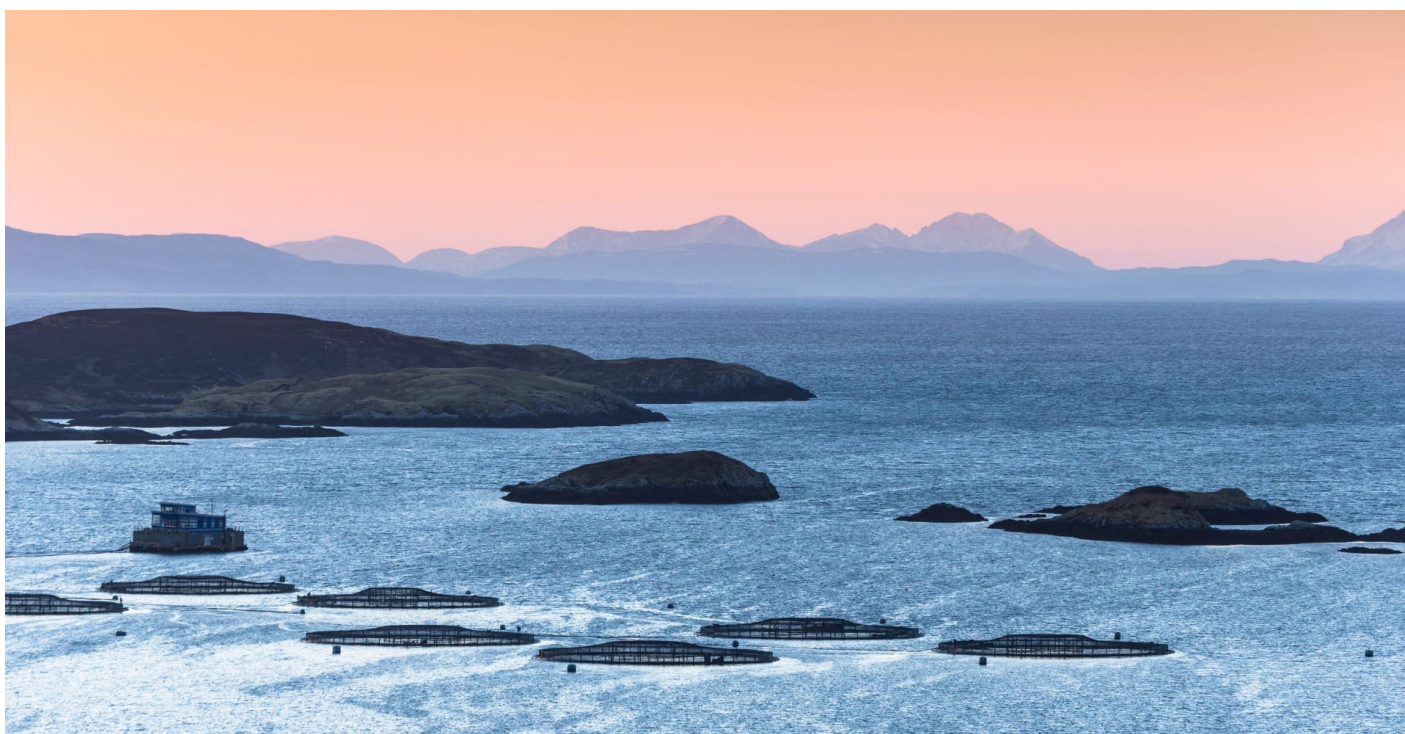


Image source: Shutterstock

CASE STUDY 2: SENDING ECOLOGICAL LEFTOVERS TO PIGS AND POULTRY

Pigs have an unrivalled ability to take up a wide variety of lower quality mixed food waste streams, and this makes them a key potential animal source food for global westernised populations. Compared to current EU livestock numbers, an optimal conversion of surplus and by-products would limit pig production to 22% of current production (van Hal et al., 2019), assuming 35% of current food waste would be available and suitable for conversion into animal feed.

Egg production from hens whose feed is solely comprised of by-products and vitamin supplements already happens on the Kipster farm in the Netherlands (Kipster, 2020). Kipster has 24,000 laying hens producing 7.3 million eggs per year on a pilot farm in collaboration with Compassion in World Farming, amongst others (Kipster, 2020). By comparison, an egg-producing facility qualifies as a mega-farm (or concentrated animal feed operation – CAFO) when it has at least 82,000 layers (Davies and Wasley, 2017).

There are also several co-benefits that small numbers of farm animals play in addition to upcycling surplus food. Poultry can help control pests, while hardy pig breeds are effective at keeping bracken or brambles under control, tilling fields, and grazing forests, where their rooting behaviours (if regulated) can perform useful ecological functions like helping forests regenerate by clearing weeds (Robinson, 2013). When fed on acorns and beechmast, pigs can generate income for native wood conservation efforts. Small amounts of nitrogen-rich poultry or pig manure can add a lot of value to farm composting and mulching systems, reducing reliance on external inputs. In sum, if kept in small numbers proportionate to the average unavoidable surplus in climate-resilient production systems, non-ruminant farm animals further add resilience and circularity to agro-ecological farming systems.

FIGURE 7: HENS ON THE KIPSTER FARM



Image source: Kipster (2019)

THREE STEPS TO ENSURE PIGS CAN SAFELY UPCYCLE UNAVOIDABLE LEFTOVERS

STEP 1. ELIMINATE INTENSIVE AND INDUSTRIAL FARMING SYSTEMS

Large numbers of animals found in large-scale intensive and highly concentrated farms are more susceptible to infection and increase the risk of emergence of more virulent disease strains, including influenza (Casey et al., 2013; Garner et al., 2006; Jones et al., 2013; Lunney et al., 2010; McOrist et al., 2011; Mennerat et al., 2010; Saenz et al., 2006). The high density and almost clonal nature of pig genetics can provide a ‘monoculture’ environment detrimental to natural resistance to pathogens and which may lead to explosive outbreaks of novel disease (Drew, 2011). In contrast to high-density pig production, village pig production may result in virus fitness loss and manifest as lower virulence viruses (Drew, 2011).

As a result of this increased disease risk in intensive industrial livestock farming, these farming systems heavily rely on antimicrobials for prophylactic purposes. The pursuit of profit above all else also drives the use of antimicrobials to accelerate growth. The repeated exposure to low doses of antimicrobial agents for growth-promotion and prophylactic purposes creates ideal conditions for the emergence and spread of antibiotic-resistant bacteria in animals, posing a significant threat to human and animal health (Van Boeckel et al., 2015). Nearly three quarters of all antimicrobials sold worldwide are used in livestock and fish, and antimicrobial use for livestock farming is projected to increase a further 67% (Van Boeckel et al., 2015). Intensive farming practices have not only been associated with antimicrobial resistance

in animals, humans, and meat but also with numerous other livestock diseases, such as highly pathogenic avian influenza H5N1 and porcine reproductive and respiratory syndrome (Van Boeckel et al., 2015).

Having considered the evidence on disease risk and the scale and nature of livestock farming, it is clear that the greatest threat to food safety and the safety and well-being of farm animals is the increasing intensity and industrial nature of livestock farming. **There is no place for intensive and industrial livestock farming in a future food system.**

STEP 2. PROMOTE GENETIC DIVERSITY AND BREED FOR RESILIENCE AND DISEASE RESISTANCE

Because animal genetic diversity is critical for food security and rural development, there are growing concerns about the erosion of genetic resources in livestock (Ajmone-Marsan, 2010). Through the maintenance of rare breeds, smallholders play a crucial role in protecting food security because maintaining genetic diversity allows farmers to select stock or develop new breeds in response to changing conditions, including climate change and new or resurgent disease threats (Hoffmann, 2010). Furthermore, rare-breed smallholders also make important contributions to the rural economy, education and national heritage (RBST, 2018). Intensification goes hand in hand with the almost clonal genetics of pig breeding, driven by improving feed conversion ratios at the expense of pig disease resilience.

Breeding, therefore, needs to return its focus to disease resilience and to enhance pigs' and chickens' natural ability to upcycle an incredibly wide variety of leftovers.

Pigs and chickens bred for top feed conversion ratios are very fast growing and, therefore, rely on extremely precise feed formulations, usually eating the same dry pelleted feed day-in and day-out. More traditional breeds may grow slower but have retained the ability to forage and to thrive on a more diverse diet as long as overall nutritional requirements are met. This is a key example of the input-output issue discussed in the industrial farming definition in Box 2 and in greater detail in Feedback's Big Livestock report (Feedback, 2020e): the output will be smaller because the pigs will grow slower, but such lower outputs need to be considered alongside the huge decrease in feed inputs, which can account for up to 67% of total pig production costs (AHDB, 2018).

STEP 3. CREATE AND LEGISLATE FOR A ROBUST RISK MANAGEMENT AND FEED TREATMENT SYSTEM

The UK and the EU urgently need to legislate for the safe use of suitable surplus food in non-ruminant feed. A discussion of the technical aspects of such legislation, including the heat treatment parameters to render feed safe, can be found in the REFRESH Technical Guidelines on Animal Feed (Luyckx et al., 2019). Within this legislation, risk management needs to be proportionate to the scale of risk. A definable, small farm size with minimal numbers of animals" carries less risk in terms of infectious disease and antimicrobial resistance (Gilchrist et al., 2007)

Box 4 discusses Feedback's theoretical proposal for the small-scale commercial farming needed to ensure unavoidable surplus from the primary, processing, retail and catering sectors can be kept in the food supply chain as feed.

BOX 4: ECOLOGICAL LEFTOVERS IN THE UK: HUMANE-SCALE COMMERCIAL PIG AND CHICKEN FARMING WITH SEPARATE FEED TREATMENT FACILITIES

To ensure that feed made from food leftovers is safe for humane-scale non-ruminant livestock farming, food leftovers must be heat-treated in specialist facilities located off-farm. This can also help ensure animals' nutritional requirements are met by carefully blending different by-product and leftover streams (Luyckx et al., 2019).

As well as looking to the Japanese experience in these systems, the UK can build on a current Dutch government-funded multi-stakeholder project with the University of Wageningen. The focus of this project is primarily technical, and key partners involved are the Dutch pig and feed associations (Nevedi) and companies such as ForFarmers, Trouw Nutrition and Darling Ingredients, which also operate in the UK. This project is also actively supported by the Dutch Chief Veterinary Officer.

To explore the viability of such off-farm treatment plants for pigfeed specifically, an economic evaluation was conducted, extrapolating treatment plant set-up and operational costs from existing facilities in Japan. These costs were then considered

alongside current liquid pigfeed prices in the UK and the Netherlands (Broeze, 2019). The evaluation compared the use of food leftovers from the greater London area to feed pigs in East Anglia against different configurations of population and pig farming density in the Netherlands. The evaluation found that transport distances both from the surplus food source to the treatment plant, and from there to the farms, was by far the most important factor in terms of both determining financial viability and maximizing the environmental benefit of the system (given transport emissions and costs).

More precisely, 30 treatment plants processing around 80–100 thousand tonnes of leftovers per year would be located in areas with medium population density, allowing for leftovers to be collected within a radius of around 35–40km, and feed to be distributed to high welfare farms at a distance of about 30km (Broeze, 2019). Importantly, these treatment plants would have to be cooperatively owned by the farms to ensure cost savings are passed on to farmers and pigs in the form of high welfare conditions. Safety controls would apply to 30 or so

treatment facilities, while farms using ecological leftovers would apply for a permit. Existing safety controls would remain for farms outside of this model.

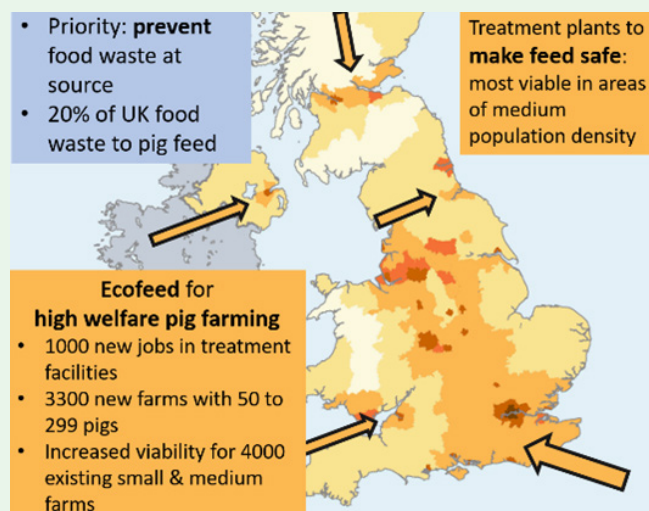
The most intensive pig farming areas (East Anglia and East Yorkshire) are not close enough to areas of medium population density, and thus food leftovers. Furthermore this type of intensive pig farming would not exist in the food system under consideration here.

Taking the average yields of dry feed from three key Japanese feed treatment plants, Feedback calculated that 2.5 million tonnes of leftovers can deliver an estimated 500 thousand tonnes of feed on a dry matter basis^c, an estimated 28% of total UK pig feed production (breeders, growers and finisher pigs) (Defra, 2018). A cross-check between the numbers of pigs fed by the feed from the JFEC plant in Japan^d, compared to the total UK pig herd (AHDB, 2021) then leads to an estimated 1 million pigs – between 20-25% of the current UK pig herd – that could be kept on eco-feed. If small and medium sized farms just used eco-feed (no soya, wheat, barley, or fishmeal), we could produce around a quarter of current UK pig production, increasing the viability of 4,000 small and medium farms that already exist, plus 3,300 new small farms with pigs, creating an estimated 1,000 new jobs.

Part of the economic viability of the modern surplus-food-to-feed pioneer industry in Japan is the prohibitive penalties associated with disposing of by-products and food surplus lower down the food use hierarchy. A tiered penalty system for food waste disposal might be one way to keep the use of surplus in animal feed within its 'sustainable niche'; for more information on this, see Feedback's report on food waste (Feedback, 2020b).

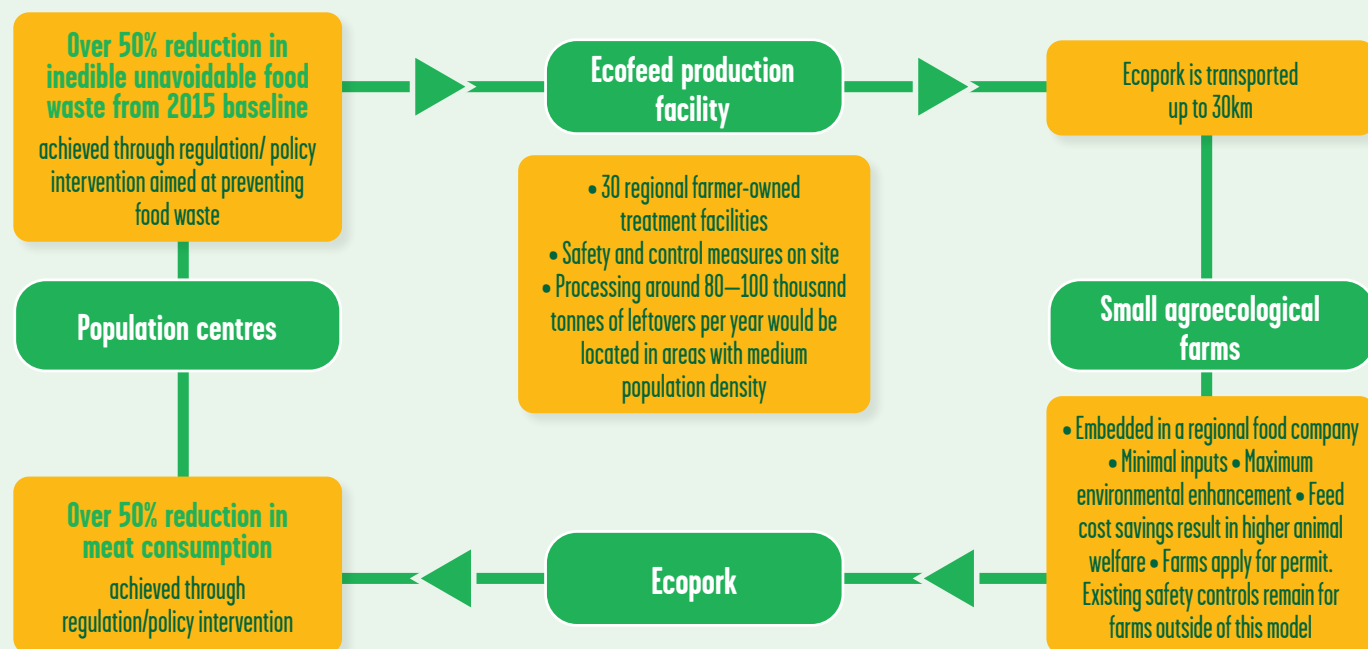
FIGURE 8: UK BY POPULATION DENSITY (PEOPLE BY KM²)

Areas of medium population density are shown in south and central England.



Map source: (BBC)

FIGURE 9: HOW ECOFEED (FEED MADE FROM ECOLOGICAL LEFTOVERS) COULD BE FED TO PIGS TO PRODUCE “ECOPORK” IN THE UK CONTEXT



c Feedback calculate an average of 0.2 tonnes of dry feed produced per tonne of food waste, based on figures on eco-feed production for different Japanese plants (Kawashima, 2018).

d JFEC provides feed for 15 pig farms, with 300 – 2,000 pigs, so assuming an estimated 7,500 pigs fed by FFEC. UK plants at optimum capacity of 80kt food waste processed per year, would be about 5.6 times bigger. So, 7,500 * 5.6 * 30 plants gives us about 1.2 million pigs, which is a quarter of pig herd. This cross-checks with dry feed yield also being around a quarter of UK feed production.

BOX 5: EATING MEAT – SOCIAL AND ETHICAL CONSIDERATIONS

The evidence in this paper presents a highly effective dietary change climate mitigation scenario based on peer-reviewed scientific evidence (Van Zanten et al., 2018). However, scientific evidence is one part of the puzzle in the discussion on dietary change; all actions must be rooted in food justice and account for the many functions that food fulfils. Food is not merely nutrition but a source of comfort, culture and community for most people, and it is vital to be conscious of not further disenfranchising those who already experience the most injustice in our food system and wider society.

Additionally, this paper does not address animal ethics – just because we can does not mean we should eat animals, for example. There are trade-offs to consider and there may be further ethical questions of the quantities of meat to eat, both for good personal nutrition and climate mitigation.

These considerations, and others, are among the many reasons why the UK is in urgent need of a comprehensive and effective food policy, one which integrates nature, climate and human goals, and which takes account of communities' needs and preferences.

CONCLUSION

The evidence on the need to reduce meat consumption and production for both health and environmental reasons is well established, but there is less clarity on truly impactful changes in the production systems of a reduced non-ruminant livestock sector. The deployment of innovative technology and robust legislation for the safe production of feed made from UK-sourced unavoidable surplus could provide the basis for much smaller, deforestation-free non-ruminant livestock production. The UK could establish itself as a global leader promoting an economically viable, modern and bio-secure eco-feed industry, reducing our reliance on imported feed, which is a driver of climate change through indirect land use change in the Amazon, the Cerrado, the Chaco and other biomes.

The new political context in the UK offers the opportunity for swift legislative change to allow this, even though it will take some time before the findings of this work are

translated into robust legislation supporting an industry delivering safe feed from unavoidable mixed food waste in the EU. At a minimum, British legislation on non-ruminant feed safety can be brought in line with countries such as New Zealand, the United States, Japan and Australia, all of which allow the feeding of treated animal protein to omnivorous non-ruminant livestock.

It is vital that at the forefront of policy-makers' minds is a vision of a just, sustainable and equitable food system that meets people's needs within planetary boundaries and shoulders a fair proportion of the UK's historic and ongoing responsibility for climate change. This means that addressing demand – by creating the policy frameworks to halve food waste from farm to fork and halve meat consumption by 2030 – must be the first priority.

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