Measuring and Mitigating GHGs: Chicken

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There are millions of farms globally, each using a unique set of practices to cultivate their products in the local climate and soils. Thus, for any commodity, there are many thousands of different production systems and many thousands of different sources of greenhouse gases. The relative GHG emissions of producing the same product may differ drastically depending on how and where it is grown. To fully understand how to mitigate emissions and on which farms to focus mitigation efforts, we need a better grasp of the variations and gaps in data.

The authors do not think all the information to quantify GHG emissions from the chicken value chain exists. At the very least, not in one place; this document is our attempt to collate currently available information. This is a working draft; debate, discussion, and comments are welcomed to advance the understanding of this topic. WWF will be producing similar pieces on other key food commodities to stimulate similar discussions. All comments should be justified with evidence and data and sent to Emily Moberg at GHGCommodities@wwfus.org.

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ABOUT CHICKEN

Chickens are produced worldwide, with high meat production in Latin America and the Caribbean, North America, and East and Southeast Asia. Consumption of chicken has increased dramatically in nearly every country in the world over the past 50 years, and production has similar increased. Chicken is one of the most widely consumed meats in the world, accounting for about 30% of meat production worldwide, after pork at 38%. The consumption of chicken is increasing in almost every country globally and consumption tends to increase with per capita GDP.

Chickens are reared both for meat and egg production at both commercial and subsistence scales, although the vast majority of product comes from commercial production.

CHICKEN SUPPLY CHAINS

Asia is the largest producer of chicken meat followed by North & South America. Together they produce over 3/4 of total chicken meat. In 2020, there were over 33 billion chickens worldwide.[1]

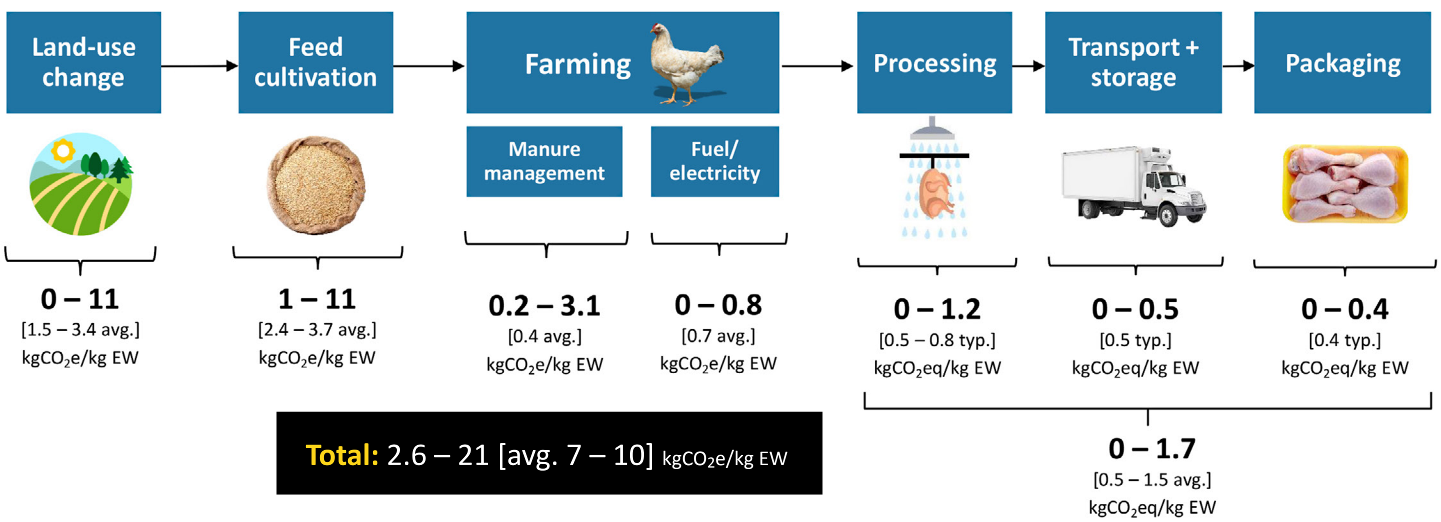
While egg production systems also produce some meat, most chicken meat is produced through commercial broiler systems. Much of this production is conducted through vertically integrated or contract farming, where farmers are provided chicks that they rear to sell back to the slaughtering company. This integrator company often provides technical assistance, feed, and veterinary service.

As monogastrics, chickens need to eat non-grass feed in order to meet their nutritional needs. The provisioning of feed for chickens is a major cost for chicken production and a major source of their environmental impacts.

Chickens are then slaughtered and processed and packaged for retail. This processing may be significant, as chicken is a popular convenience food (e.g., frozen nuggets).

GHG EMISSIONS FROM CHICKEN SUPPLY CHAINS

Figure 1: Range of GHG emissions from chicken supply chains

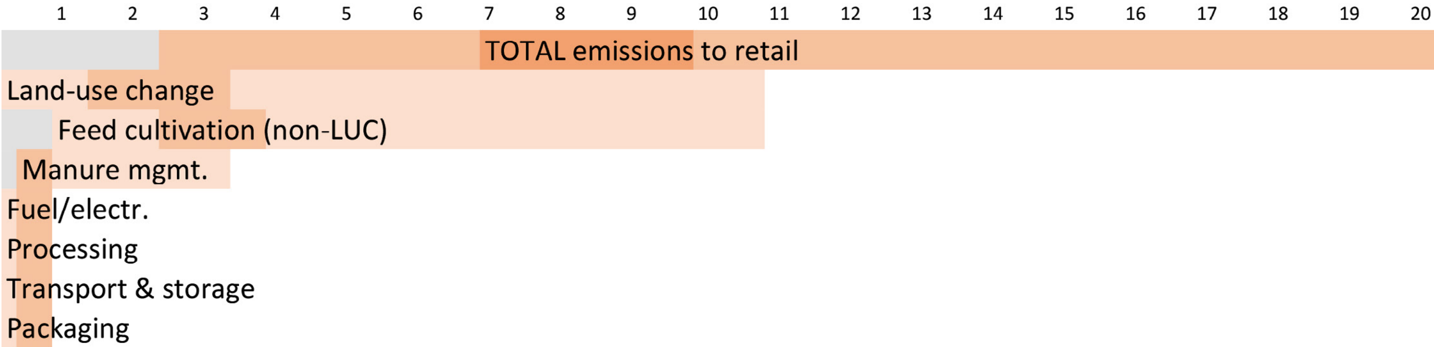


Greenhouse gas emissions from chicken arise largely from the feed they eat, although significant emissions also occur during the rearing phase.

The GHG emissions from cradle-to-retail chicken meat average about 7–10 kgCO_2e/kg edible weight (EW) but can range from 2.6 up to 20 kgCO_2e/kg EW.[2]

Of this, most of the footprint is from cradle-to-farm gate: an avg. 6.4 kgCO_2e/kg EW.

This variability arises from variable emissions across each stage of production. The full range of impacts (in kgCO_2e/kg edible meat) is shown in the following chart, with the typical range highlighted in darker orange.

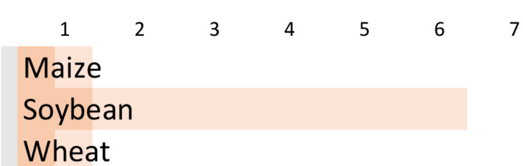


Feed

Most emissions from chicken meat come from the feed they eat. Each ingredient in chicken feed has some emissions footprint; this is then multiplied by the amount the chicken eats. The feed-conversion ratio captures how much feed is needed to produce a kg of live-weight. Both the feed-conversion ratio and GHG intensity of feed can vary widely.

- Backyard chickens tend to have a lower feed conversion ratio, but also eat more scavenged materials and second grade crops, with minimal embedded emissions; the feed-conversion ratio for back-yard chickens is about 10 per kg of liveweight.[3]
- Commercial broiler production has a FCR closer to 2. However, almost all chicken meat is produced in broiler systems.

Grains have a GHG footprint of 0.3–1.0 kgCO_2e/kg typically without land-use change; when natural habitats have been converted to cropland, this value can be many times higher. The chart below shows the range of footprint from GFLI for three common chicken feed ingredients. The upper end of each range is typically from countries with high conversion.



The footprint of the composite feed is then a mass-weighted average of the footprint of each ingredient. This footprint is then multiplied by the amount eaten. So, a feed with a footprint of 1kgCO_2e/kg would mean a chicken with a FCR of 2 would be 2 kgCO_2e/kg live weight or 3.5 kgCO_2e/kg edible weight.

Excluding land-use change from producing the feed, emissions from feed are an average 2.6[4] – 3.4 kgCO_2e/kg EW for broiler systems, with a low of 2.2 kgCO_2e/kg EW in Russia and 5.8 in East & Southeast Asia.[5]

However, because of the presence of soy and oil palm products in feed, emissions from land-use change essentially double emissions.

- GLEAM (which only includes emissions from soy and oil palm) estimates the contribution from LUC averages at 1.5 kgCO_2e/kg EW. This ranges from a 0 contribution for North America and 3 kgCO_2e/kg EW in sub-Saharan Africa.[6]
- In a global analysis of life-cycle analyses, Poore & Nemecek found the feed footprint was double that, at 3.4 kgCO_2e/kg EW of which 2.5 kgCO_2e/kg EW was from LUC, which is likely due to the fact that LUC across other feeds is also considered.

To meet Paris climate targets, the footprint from deforestation must go to zero by 2050, meaning that deforestation needs to reach 0 by 2030.

Emissions from feed range from about 2.2 to over 6 kgCO_2e/kg edible weight. Estimates near the low-end are without land-use change; land-use change footprints are typically 1.5 to nearly 3.5 kgCO_2e/kg EW.

Enteric fermentation

Chickens have short digestion systems, so food remains only about 6 hours in the digestive system. Most studies associated with chicken meat production take CH_4 emission from enteric fermentation to be negligible; those that include it have found it to be less than 1% of total emissions.[7]

Manure management

Chicken production is often concentrated, and produces large amounts of manure. Manure handling, storage, processing, and application can produce CH_4 released from organic material and N_2O emissions.

Methane and nitrous oxide are produced through different biochemical reactions, so the amount of each gas produced depends on the manure composition and the temperature and oxygenation conditions of storage. Chicken manure is, in some cases, used as fertilizer which some studies have used (with system expansion) to offset emissions from fertilizer production.[8]

Manure management contributed 0.4 kgCO_2e/kg EW (range: 0.3 – 3.3 kgCO_2e/kg EW); higher emissions are from back-yard systems.[9] Eggs have higher manure emissions intensity because layers have a greater proportion of their manure managed in anaerobic conditions, which lead to higher CH_4 emissions.[10]

Energy use

The main on-farm energy uses for broiler production are heating, lighting, ventilation, feeding, and manure removal. In broiler chicken production, most of this (80–90%) is for heating. The heat and ventilation requirement vary considerably during the growing period. Improving the efficiency of energy consumption on the farm can be achieved through decreasing total energy consumption and increasing the proportion of renewable energy. Energy use ranges from near 0 to over 4 kWh/kg EW;[11] the GHG emissions arising from on-farm energy use vary regionally depending on the electricity generation and transmission.

The contribution from energy consumption was 0.7 kgCO_2e/kg EW meat (range: 0.4 – 0.8 kg CO_2e/kg EW).[12]

Post-farm emissions

Post-farm emissions arise from transportation, slaughter, and processing, as well as packaging. Most of these emissions are from the fossil fuel emissions in producing electricity or directly burned as fuel.

- **Slaughter/processing:** Emissions from slaughter and processing to carcass or breasts range from 0.5 – 1 kgCO_2e/kg EW.[13] How byproducts are used and the electricity mix of the slaughter facility will influence these emissions.
- **Transport:** Emissions for transportation depend on both the distance traveled and the mode of transit; per kg-kilometer, boats and trains have much lower emissions than trucks which are then lower than airplanes. To our knowledge, chicken products are not frequently air-freighted. Estimated emissions from transport range from 0 for backyard farms to 0.1– 0.5 kgCO_2e/kg EW for commercial products.
- **Packaging:** Emissions from packaging depend on the type of packaging, and largely arise from energy use in production. Plastic packaging emits about 0.14 kgCO_2e/kg EW,[14] while aluminum packaging (tray) tends to be higher (~0.4 kgCO_2e/kg EW).[15]

Overall, the post-farm emissions contribute an average 0.5[16] to 0.9[17] kgCO_2e/kg edible weight. The distance and mode of transport is likely the most critical determinant of this value.

PRODUCTION SYSTEMS

The aforementioned processes often differ systematically across different types of 'production systems.' Chickens are reared at both commercial and subsistence scales, for either meat or eggs. Most meat and eggs come from industrial production. This brief focuses on meat production, but we have provided some information on emissions from eggs, which broadly follow a similar pattern in terms of emissions sources. Note that per kg product or protein, eggs have lower GHG intensity than meat.

- **Broiler:** Broiler chickens are raised for their meat. About 90% of chicken meat globally comes from broilers. The average GHG emission intensity for broiler meat is about **6.4[18] – 9.7[19] kgCO_2e/kg EW** (range: 4 – 21 kgCO_2e/kg EW for individual farms,[20] and 3.8 – 9.1 across regions[21]). Stocking density within broiler systems has a minimal effect on GHG intensity.[22]
- **Layers:** Layer systems primarily produce eggs; about 92% of eggs are produced by layers. The egg production system produces two co-products, eggs and spent hen meat. However, spent hen meat represents a minimal part of the co-production, both in terms of quantity and economic value.[23,24,25,26] Only about 6% of global chicken meat is from layer systems. For meat, the GHG emission intensity was higher than for broiler systems at 11.2 kgCO_2e/kg EW (range: 3.4 – 13.0 kgCO_2e/kg EW), while for eggs the imapct was 3.8[27] – 4.7[28] kgCO_2e/kg egg (range: 2.6 – 8.4 for individual farms[29] and 1.5 – 4.7 across regions[30]).
- **Backyard:** Backyard chicken systems produce both eggs (8% of global total) and meat (2% of global total). The GHG emissions for eggs from the backyard system was 3.4 kgCO_2e/kg egg, ranged from 1.3 – 5.9). For meat, the GHG emissions was **7kg CO_2e/kg EW** (range: 2.6 – 8.6 kgCO_2e/kg EW).

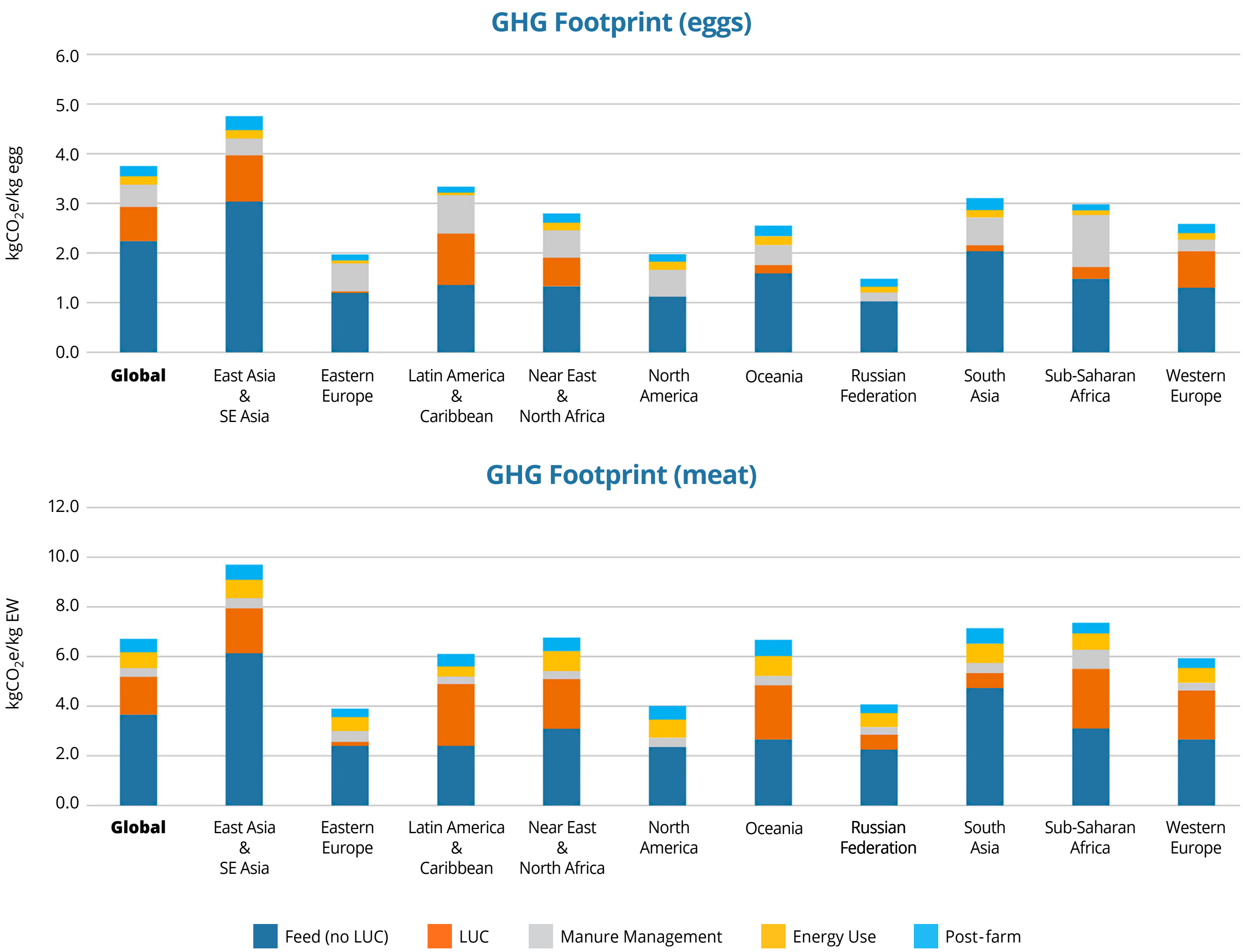
Within the industrial farms, conventional farming has lowest emissions (4.6 kgCO_2e/kg EW) relative to 6.7 for organic, and 5.5 for non-organic, free-range chicken. The reasons for higher impact in organic system were: lower bird performance (due to higher death rates and lower fertility rates) and low efficiency of feed conversion in organic production systems. In addition, organic production systems had higher slaughter weight and thus a longer growing period, which results in higher GHG emissions because the animals eat and defecate over a longer period for the same amount of meat.

REGIONAL VARIATION

Emissions also vary regionally. This is a function both of which practices tend to be used in a region (which are not inherently geographic) and local climatic factors. Our analysis suggests that the variation in GHG emissions across geographies comes from feed sourcing (land-use change) and animal efficiency.

Other than heating and ventilation needs and manure decomposition that differ based on local climate, most emissions intensity are determined by the production practices.

Figure 2: Regional variations in the GHG emissions for 1 kilogram eggs and 1 kilogram EW (meat) production across the world from GLEAM 2010 data[31]



The United States, Brazil, and China each produces over 10% of the global chicken meat. Table 1 shows some key statistics about these countries and a few others with high production that represent different geographies.

Table 1: Characteristics of top chicken producing countries

	Production (million tons)[32]	Export (%)[33]	Chicken GHG ($kgCO_2e/kg$ EW)	LUC in feed ($kgCO_2e/kg$ EW)[34]
USA	19.2	17	~4[35]	0
Brazil	13.4	28	6.1 – 11.0[36]	2.5 – 5.0
China	13.3	3	9.7[37]	1.7
Russia	4.4	4	4.1; 10.3[38]	0.6
India	3.7	<1	7.1[39]	0.6

OUTLIER EMISSIONS SOURCES

The variability in emissions per kilogram of edible chicken highlights the large mitigation potential that exists across current practices. Here we highlight the "low hanging fruit," or practices that drive unusually high emissions intensity. These practices may be good targets for initial screening for improvement.

- **LUC in feed:** Emissions from LUC for chicken feed are a major global source of emissions, totaling about 0.2[40] – 0.5[41] $GtCO_2e$/yr. Much of this comes from soy; about 40% of soy goes to poultry.[42] Ensuring that purchased feed was not produced on converted forest or habitat is critical not only to both reducing the footprint of chicken but also for reaching global climate targets.
- **Optimized diet and feed use:** Improvements in FCRs and the footprint of feed formulations can dramatically lower the overall footprint for chicken.

MITIGATION

There are many mitigation options for chicken production. Many mitigation strategies have been explored in the literature, including the poultry housing conditions and rearing, diet formulation and feeding strategies, reduced age at slaughter, and best management of manure.[43] Animal performance linked to the feed, especially feed intake, daily weight gain, and, consequently, the FCR have been identified as critical levers for modulating GHG emissions from chicken supply chains. Growing period mortality and animal health are particularly critical indicators.

Deforestation and conversion-free feed: Feed ingredients for chicken are often associated with deforestation and habitat conversion. Heavy usage of soybean meal (30% – 40% in the feed formula) is used in high-performance monogastric diets.[44]

In general, the overall GHG emissions of soybean (from cradle to farm gate) emit between 0.2 and 15+ $kgCO_2e/kg$ soybean, with an average of about 2.5 $kgCO_2e/kg$ soybean; all but about 0.5 $kgCO_2e/kg$ soybean are from LUC.[45]

Feed: High-quality diets that maximize growth per unit of feed reduce GHG emissions due to lower embedded emissions in feed and lower emissions from manure. For many crops, the difference between low- and high-GHG intensity products is 2 – 3x even without LUC; improved sourcing of the same ingredient can lower the embedded footprint. In some cases, novel dietary ingredients may help lower emissions. For instance, broiler chickens were reported with about 32% – 167% higher GHG emissions from conventional feed relative to mealworms.[46]

Manure management: There are many strategies for mitigation of emissions from manure in poultry.

- CH_4 production increases with the storage temperature of the manure; a reduction of storage temperature can drop CH_4 emissions by 30% – 50%, but this is possible at the expense of energy used for the adopted cooling system.[47]
- Advanced layer housing using belt scrapers can be efficiently used to remove litter/manure continuously and decrease GHGs emissions.[48] Likewise, adoption of solid-liquid separation technology helps partially separate the solids from liquid manure and can have mitigation potential of 30% of CH_4 compared to the untreated manure.[49]
- Integration of anaerobic digestion facilities to trap CH_4 can help mitigate GHG emissions. The digestate can be used as fertilizer, and the biogas is a source of renewable energy.[50] Although these facilities are not widely used, small-scale studies indicate that emissions reductions can exceed 75%.[51]

Others: Energy consumption contributes around 0.9 kgCO_2e/kg EW meat.[52] However, the intensity of emissions due to energy use depends on the types of fuels used and the efficiency of energy conversion and distribution system, and of energy use, both on-farm (in housing and field operations) and off-farm (manufacture of agricultural inputs, and transportation and processing of farm products). In poultry housing, energy consumption can be managed through improving housing conditions, ventilation, stocking density, etc.[53]

Table 2: Mitigation summary

Intervention	Target	Cost	Mitigation Potential	Barriers
Prevent deforestation for feed ingredients	Grain traders, governments	\$10–\$100/tCO_2e/yr[54]	0.04 – 0.1 GtCO_2e/yr (based on current deforestation rates for soy and that ~40% of soy goes to poultry[55])	Traceability
Manure management	Chicken farmers	?	~0.008 GtCO_2e/yr (30% reduction of 25 million tCO_2e from manure in 2010 – GLEAM)	
Renewable energy on farm	Chicken farmers	?	0.08 GtCO_2e/yr (all electricity use for chickens switched to renewable)	Cost, availability

TOOLS AND DATA AVAILABILITY

The GHG footprint of chicken is well characterized in the literature, as are the common feed ingredients used. Given that the majority of emissions for chicken are on-farm, a selection of farm-focused GHG calculators is highlighted here:

- **Cool Farm Tool:** An online tool produced by the Cool Farm Alliance that allows farmers to specify animal feed intake, composition, growth, and manure management to calculate a GHG footprint. The footprints are not regionally tailored, but the tool works globally. The results are particularly sensitive to the feed intake.
- **GLEAM-i:** An online tool produced by the Food and Agriculture Organization of the United Nations based on the Global Livestock Emissions Assessment Model. This tool can capture backyard and commercial production with default values for each country. The tool input asks for vital rates (rather than feed intake and animal numbers), which may make usage difficult.
- **Feedprint:** A stand-alone tool focused on emissions embedded in animal feed; there are a huge number of feed compositions and sourcing locations available. These feed ingredients can be tailored. The tool is geared toward Europe but has sourcing from many locations globally. On-farm emissions can also be calculated in the tool.
- **National tools:** Many countries have nationally specific calculators that include poultry and feeds – for example, COMET-Farm for the U.S. and the Farm Carbon Toolkit for the U.K.

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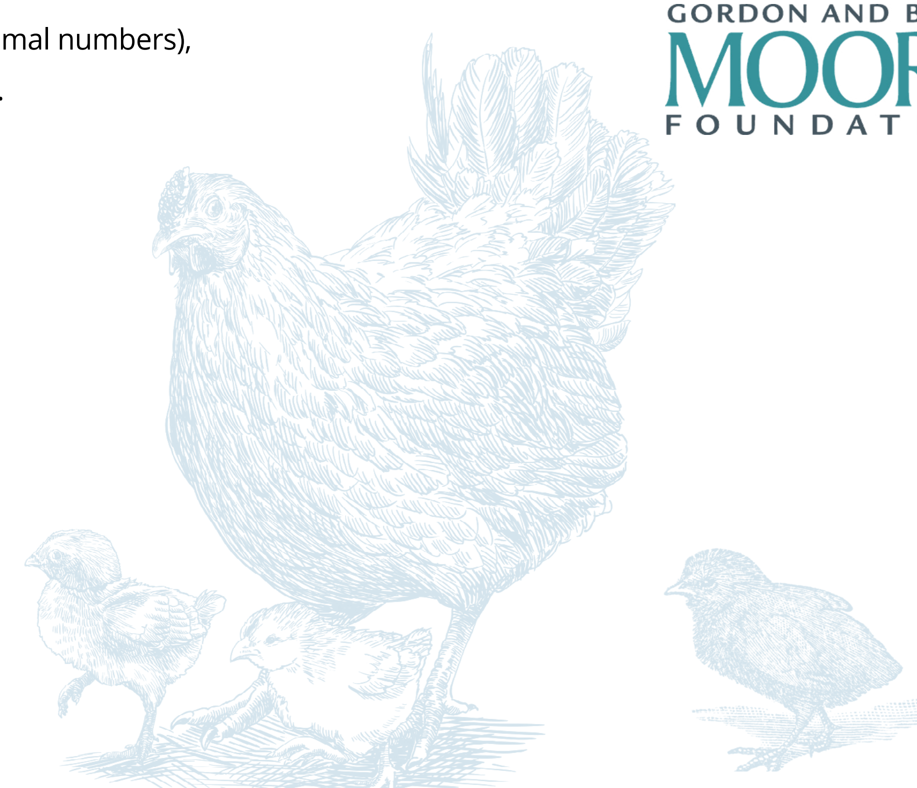

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All photos/art: © iStock / Getty

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