NAICS Code: 311611 - Animal (except Poultry) Slaughtering

SUMMARY INFO: The animal slaughtering industry includes facilities that slaughter, prepare, and package meat, carcasses, and other animal products from cattle, sheep, and hogs. A foundation of the agricultural economy, these facilities provide critical markets for American livestock, with cattle the largest agricultural product in the American economy. These facilities can include large-scale meatpacking plants, as well as smaller facilities producing cured and canned meat products. Over 71,000 workers were employed in slaughtering and meat packing in 2023, with employment concentrated heavily in midwestern states.[1]

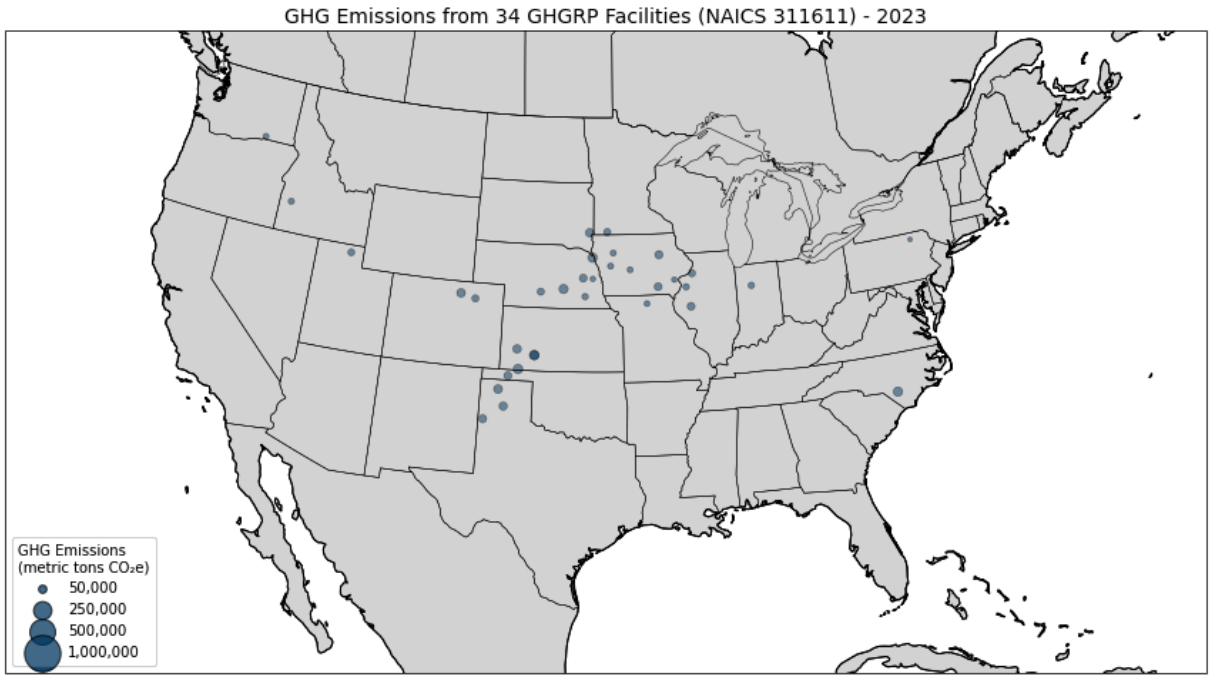
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Link to archetype code:
https://github.com/ISALGroup/archetypes/blob/main/archetypes_list/archetype_animal_slaughtering.py

Archetype Name: Animal slaughtering

Emissions and facility overview: According to the United States Census Bureau, there are 1,274 establishments associated with the NAICS code 311611 in the United States in 2023, 34 of which report annual GHG emissions in the GHGRP.[2] Reported emissions from GHGRP amounted to 1.4 Mt CO_2e in 2023 for all plants with the 311611 NAICS code. The majority of these plants are concentrated in the midwest U.S., as summarized in the map below.



[1] https://www.bls.gov/oes/2023/may/oes513023.htm
[2] U.S. Census Bureau. 2023: ECNSVY Business Patterns County Business Patterns CB2300CBP. 2023; U.S. Environmental Protection Agency. Greenhouse Gas Reporting Program (GHGRP). 2025.

Sector outputs: Animal slaughtering plants produce a wide variety of non-poultry animal products such as fresh, boxed, frozen or smoked meats; cuts such as bacon; side products like lard, fat or tallow; processed meats like hot dogs; or carcasses.

Process pathways: Most slaughtering plants rely on the same general process units: stunning the live animal, exsanguinating it, processing viscera, and cutting off the carcass and further processing. Depending on the type of animal being processed, such as cattle or swines, some units will be different from one process to the other, for example cattle will require hide processing, while swines will require scalding and dehairing. In addition to cut pieces of meat that are considered the main product of the process, other parts of the animal need to be processed and will yield valuable byproducts: blood from exsanguinated animals that needs to be processed into blood meal; hides removed from cattle; tripe and edible organs removed from the carcass; trimmed fat from the carcass; and finally inedible parts of the animal. In this work, a generic process for cattle is modeled.

Process Overview: The slaughtering process can be broadly separated in 4 distinct phases: processing of the live animal, blood processing, cutting and finishing/packaging. It is represented in Figure 1 below.

Live Animal Processing Production Line: The first step of the processing involves moving and stunning the animal. Stunning here refers to inducing a state of unconsciousness to the animal, to prepare it for bleeding. That stunning can take different forms depending on the plant's requirements and the type of livestock being processed. For example, electric stunning is typically applied to pigs and sheep, contusion can be applied to most livestock, albeit in different conditions depending on the animal; and CO_2 exposure at high concentrations (greater than 65% in air volume) can be applied to pigs and sometimes sheep.[3] While being a process with little to no material or energy demand compared to the rest of the process,[4] this step is crucial to ensure meat quality and safety of operation.

Blood Processing Production Line: Once stunned, the animal is sent to be killed by being bled out. It is done by hanging the animal head down and sectioning major sanguine vessels within a short time of stunning the animal. As blood is a vehicle for microbial contamination, exsanguination is required for sanitary reasons. Blood typically makes up around 4% of the live weight of the animal,[5] and that blood is assumed to be sent to be processed in order to recover valuable byproducts by drying it to obtain bloodmeal. To that end, blood is sent to a dryer, typically in a spray dryer configuration. Dried blood is around 0.6% live meat in weight.[6] The amount of steam required is calculated according to the amount of water evaporated from the blood.

[3] Guerrero-Legarreta, I.; de Lourdes Perez-Chabela, M. (2012). Chapter 21: Slaughtering Operations and Equipment. In Handbook of Meat and Meat Processing, CRC Press.
[4] Genne, I.; VITO (2008). Handbook of water and energy management in food processing: Water and energy management in the slaughterhouse.
[5] Rahman, U.; Sahar, A.; Khan, M., A. (2014). Recovery and utilization of effluents from meat processing industries. Food Research International 66, 322-328.
[6] United States Department of Agriculture (2015). BY-PRODUCT DROP VALUE (STEER)−An Overview.

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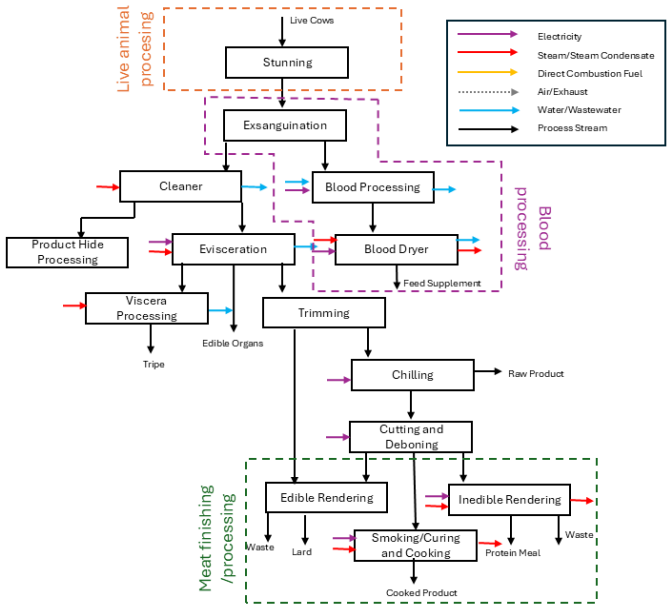


Figure 1: Animal Slaughtering Archetype Process Flow Diagram

After exsanguination, the carcass is sent for cleaning, which is operated with hot water at around 80°C for sanitary reasons.[7]

Carcass Cutting Production Line: The cleaned carcass is then sent to be eviscerated, where the carcass is hung, gut is removed through a vacuum and other organs are mechanically removed. Hot water is used throughout the process in the same temperature range as the cleaning step. Removed organs are put into 2 categories: edible parts (which contains organs like heart or liver) and inedible viscera which needs to be processed further.

Viscera processing consists in heavily washing intestines and other viscera to obtain by products that can be used either as food, for rendering, or for feed.[8] Washing water is assumed to be used in similar conditions as previous units.

Part of the carcass is then trimmed out to remove excess fat. That excess fat is sent to be rendered to be transformed into valuable products.

The trimmed carcass is then sent to a cold room in order to store the meat and inhibit bacterial growth. This step is fairly electricity intensive due to the compressors used.

It is assumed that part of the carcasses are sent straight to market, while others are processed onsite. Chilled carcasses are then sent to be deboned and cut. This step is mostly mechanical. Some of the cuts consist mostly of edible fat, which are sent to be rendered. Others are unfit for human consumption but can be processed to obtain meal. Finally, some of the cuts can be smoked or cured to prepare a market-ready product.

Meat Finishing/Packaging Production Line: For edible materials, rendering consists in bringing the

[7] Meat & Livestock Australia (2012) . Hot Water Rinse. Available at https://www.mla.com.au/globalassets/mla-corporate/research-and-development/program-areas/food-safety/documents/food-safety-intervention/hot-water-rinse.pdf?utm

[8] Ninios, T.; Lunden, J.; Korkeala, H.; Fredriksson-Ahomaa, M. (2014). Meat Inspection and Control in the Slaughterhouse. John Wiley & Sons. DOI:10.1002/9781118525821

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byproducts at high temperature to produce lard/tallow and separate it from other waste that can be used as feed.
Inedible materials are applied a similar process but the only products obtained are meal for non human uses.
Finally, the cuts of meat are assumed to go through a smoking process that requires the meat to be brought to a higher temperature.

Archetype Unit Process Assumptions:

In this work, it is assumed that meat has a heat capacity of 3.54 $\frac{kJ}{kg℃}$. The model used is depicted in Figure 1, and Table 1 contains the assumptions made in each process unit of the model.

Limitations and future work: The type of animal processed is typically unknown, so a generalized process based on cattle has been assumed. The split of byproducts is also not known from the datasets used. In the future, models based on individual animals will be developed with their specialized units.

Table 1: Animal Slaughtering Archetype Unit Process Assumptions

Unit Process Name	Assumptions	Parameter Basis	Source
Exsanguination	Blood Content: 4%	Literature-derived	United States Department of Agriculture. BY-PRODUCT DROP VALUE (STEER)−An Overview. 2015.
Blood processor	Water ratio : 0.75	Engineering judgement	
	Electricity : 0.15 kWh/kg	Engineering judgement	
Blood dryer	Electricity: 0.25 kWh/kg	Engineering judgement	
	Moisture Content out: 0.1	Literature-derived	United States Department of Agriculture. BY-PRODUCT DROP VALUE (STEER)−An Overview. 2015.
	Steam Temperature: 110 ℃	Literature-derived	UC Davis Animal Science, "By-Products from Beef and Pork."
	Heat losses: 10%	Engineering judgement	
Cleaner	Cleaning temperature: 80 ℃	Literature-derived	Meat & Livestock Australia. Hot Water Rinse. 2012.
	Heat Losses: 5%	Engineering judgment	
Evisceration	Organs split: 12.5%	Literature-derived	North American Meat Institute. Humane Handling Guidelines. UC Davis Animal Science,
	Viscera amount : 50%	Literature-derived	

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	Unit Temperature: 75℃	Literature-derived	"By-Products from Beef and Pork." FAO. "Water and Energy Use in Meat Processing."
	Electricity: 0.021 kWh/kg	Literature-derived	
	Heat Losses: 10%	Engineering judgment	
Viscera processing	Waste amount: 20%	Engineering judgment	
	Heat Losses: 10%	Engineering judgment	
Trimming	Electricity: 0.15 kWh/kg		
	Trimming ratio: 17.5%	Literature-derived	UC Davis Animal Science, "By-Products from Beef and Pork." UC Davis. "Sustainability Energy Audit in Beef Plants."
Chiller	Electricity: 0.225 kWh/kg	Literature-derived	UC Davis. "Sustainability Energy Audit in Beef Plants." USDA. “Pathogen Reduction Performance Standards.” Iowa State University. “Carcass Cooling and Shrinkage.”
	Product Split: 0.25/0.75	Literature-derived	
Cutter	Electricity: 0.15 kWh/kg		
	Inedible proportion: 0.15	Literature-derived	Penn State. Understanding Beef Carcass Yields and Losses During Processing
	Edible proportion: 0.65	Literature-derived	
Inedible Renderer	Electricity: 0.15 kWh/kg	Literature-derived	FPRF. "Rendering Industry Sustainability Report." UC Davis Animal Science, "By-Products from Beef and Pork."
	Steam demand: 1000 kJ/kg	Literature-derived	
	Protein meal per input: 40/150	Literature-derived	
	Steam temperature: 120 ℃		
Smoking	Electricity: 0.275 kWh/kg	Literature-derived	USDA FSIS. “Processing Bacon and Smoked Meats.”
	Steam demand: 1000 kJ/kg	Literature-derived	
	Steam temperature: 115 ℃	Literature-derived	

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