May 2013

Livestock Production on Molokai Island, Hawaii

A Life-Cycle Assessment of Three Commercial Scenarios

This report details the findings from a Yale School of Forestry and Environmental Studies investigation of scaling up commercial livestock production on Molokai Island, Hawaii. Using scenario analysis, we compare the feasibility and impact of three livestock production scenarios. The three scenarios are: (1) local beef production, using Molokai forage for a grass-fed product; (2) local pork production, using local food waste and imported pig feed; and (3) local venison production, commercializing the invasive deer population. The scenario analysis takes into consideration the environmental and economic desirability of each option based the objectives of the Molokai community and resources available on the island. To assess the environmental impact of each scenario, we employed life-cycle assessment (LCA). Our findings identify grass-fed beef production as the best production model for Molokai. Venison production was found to be very resource-efficient, but it is currently infeasible because of regulatory and social barriers. Increasing pork production to a commercial level would require importing feed because local food waste flows for pig ration have already been captured. Grass-fed beef production represents an optimal use of the forage on Molokai and is favored by the community; however, there are significant barriers to establishing this industry. Traditional cow-calf management practices must be transformed in order to run a successful grass-fed operation; careful land stewardship and grass cultivation is vital. Local branding and investment in haying equipment to ensure consistent supply through droughts are also important in creating a consistent, resilient grass-fed beef product on Molokai.

Yale School of Forestry & Environmental Studies

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Yale University's School of Forestry and Environmental Studies is a graduate school for environmental professionals founded in 1901. It is located in New Haven, Connecticut. The Center for Industrial Ecology was established in 1998 at Yale to provide an organizational focus for research in Industrial Ecology.

Industrial Ecology uses ecological principles to analyze material and energy flows in industrial processes. An industrial process is defined widely enough to include such activities as gold mining, automobile manufacture, biofuel refining, agriculture, and many other economic activities. By looking at the materials used in each step of an industrial process, we can identify opportunities for local sourcing of materials, waste reduction, recycling, and other optimization. In doing so, we aim to turn material flows that move one-way from remote extraction to local disposal into local, sustainable material cycles. An Industrial Ecology team from Yale visited Molokai last year, and this report follows on the work that team accomplished.

Researcher Biographies

Rebecca de Sa is a second-year Master of Environmental Management student focused on agricultural land management and supply chains. Previously, she researched land use change on soy/corn farms and cattle ranches in Mato Grosso, Brazil. She currently works for American Farmland Trust on conservation initiatives in New England, with particular emphasis on maintaining the economic viability of agriculture in a densely populated, expensive operating environment. Rebecca aims to use her environmental engineering training and experience with diverse conservation mechanisms to construct sustainable agricultural systems wherever possible.

David Emmerman is a first-year Master of Environmental Management and MBA joint-degree student focusing on energy and materials management. David wrote his undergraduate thesis on agricultural diversification around cattle and livestock in Ecuador. His research dealt with adapting the traditional pasture model to local environmental, climatic, and cultural realities. Some of the problems the project addressed included cattle health and productivity, local sources of feed, erosion and flooding, drought, soil quality, loss of biodiversity, economic viability, and land stewardship education. David has previously worked at the U.S. Environmental Protection Agency and as a Fulbright Research Fellow in Portugal.

Drew Veysey is a first-year Master of Environmental Management student focusing on energy systems analysis. He is originally from Ames, Iowa. While there he had first-hand exposure to livestock agriculture and its ramifications on the local environment. Later on he worked for community groups concerned with the air and water quality issues associated with Concentrated Animal Feeding Operations (CAFOs) for swine and cattle. More recently Drew has worked for a grass-fed organic dairy farmer in Fairfield, Iowa on efforts to bring more sustainable energy to the state of Iowa.

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I. INTRODUCTION

Molokai, a rural island in the State of Hawaii, has a modern history of extensive cow-calf livestock operations. The tuberculosis-driven cattle eradication on Molokai in 1986 diminished livestock production significantly,[1] and economic trends—particularly fuel and feed prices—have reduced current cattle production to a shadow of its former scale. However, agriculture remains the dominant industry on Molokai, and many of its residents would like to see a thriving livestock industry on the island again. This report investigates the potential to expand livestock production on Molokai, using local inputs and innovative management practices to spawn local industry and lessen the environmental impact of the food supply. The goal of this study is to use industrial ecology tools and concepts such as life-cycle analysis and hidden resource flows to evaluate the feasibility of scaling up a commercial cattle, hog, or deer operation on Molokai.

A team from the Yale School of Forestry and Environmental Studies visited Molokai to conduct fieldwork from March 9-16, 2013. The 2013 team benefited from research conducted in March 2012 by another team from Yale. The 2012 study constructed an all-island material flow analysis. The 2013 group performed interviews with ranchers, business owners, USDA extension agents, waste disposal experts, food processors, and long-time residents in an effort to gain quantitative and qualitative information on Molokai's livestock agriculture. The group also made site visits to the landfill, shipyard, and local businesses to evaluate possible hidden sources of alternative livestock feed.

II. BACKGROUND

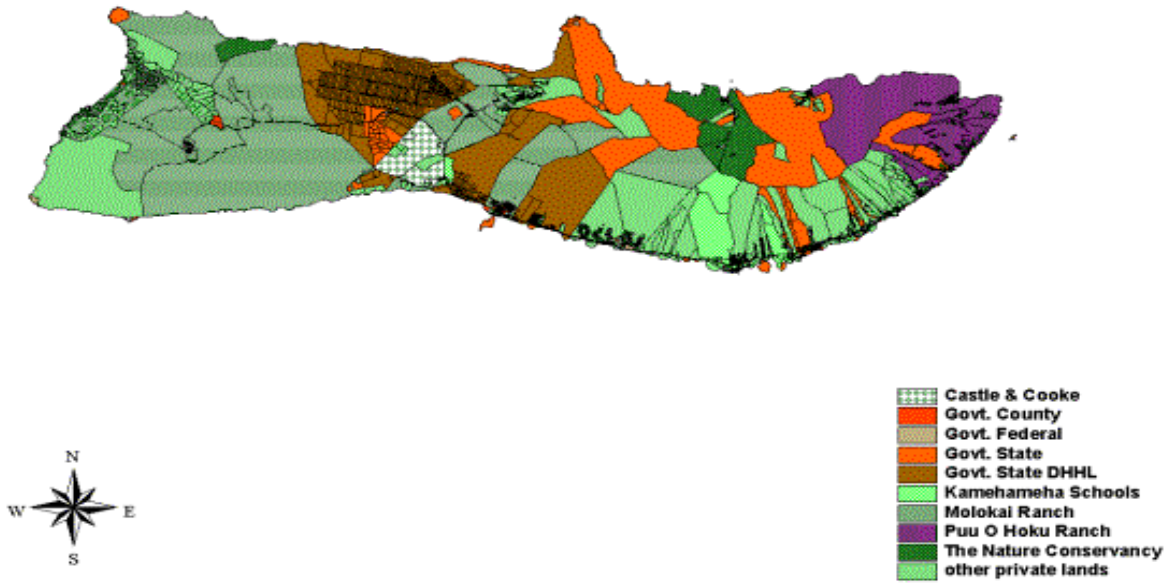
History of Molokai

The Hawaiian Islands were first colonized by Polynesian seafarers around 500 CE.[2] These Native Hawaiians brought domesticated hogs and the starchy plant taro (*Colocasia esculenta*), which eventually formed a staple of the Hawaiian diet. Europeans first came to the islands in the late 1700s, bringing cattle and other breeds of domesticated hogs. Hawaiian King Kamehameha I united the entire Hawaiian archipelago under his dynasty in 1810. His successor, King Kamehameha III enacted significant land reform known as the Great Mahele of 1848, which allowed for private ownership of land within the Kingdom of Hawaii.[3] This differed from the traditional bioregionalist system of land division known as ahupua'a in the Hawaiian language.[4] Large estates were thus created, leaving many other Hawaiians landless. Many parcels of land

[1] "Molokai Ranchers might get County Aid" 3/2/1988
[2] The Hawaiian Islands. "Hawaiian History." http://www.gohawaii.com/statewide/travel-tips/history
[3] "The Great Mahele." http://colorwaveimaging.com/mahele/
[4] Molokai: Future of a Hawaiian Island. Page 24. http://sustainablemolokai.org/wp-content/uploads/2012/06/Molokai-Future-of-A-Hawaiian-Island.pdf

passed into European/American ownership. In the 1890s, residents of American and European descent overthrew the Native Hawaiian monarchy and Hawaii became a U.S. territory in 1898.

Figure 1: Land Ownership on Molokai[5]



The largest continuously intact land parcel on the island of Molokai, referred to by residents as Molokai Ranch, was made possible by the Great Mahele. It was created in the late 1800s when the Bishop family gained the property through intermarriage with Hawaiian royalty. [6] Cattle and sheep have been raised on parts of the land since the 1800s, with sections of the land being periodically leased to large companies to raise various agricultural products. Molokai Ranch has since changed ownership several times. First owned by the Bishop family as part of their estate, the Ranch was sold to the Cooke family in the early 20th century, and has since been owned by Japanese, New Zealand, and Singaporean conglomerates.[7] The Ranch started to fail financially in the mid-1980s after a bovine tuberculosis outbreak and a government-ordered cattle herd eradication.[8] Molokai Ranch and local activists have disagreed recently over tourism development, with the Ranch ceasing livestock operations in 2008. As of 2012, Molokai Ranch's stated business pillars are animal husbandry, sustainable agriculture, renewable energy and improving infrastructure through "green" improvements.[9] Expanded livestock and hog production is intended to fit into the Ranch's sustainable agriculture goals.

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[5] Safe Harbor Agreements in Hawaii, State Department of Land and Natural Resources. http://www.state.hi.us/dlnr/dofaw/safeharbors/MolokaiBlanketMay05-2002_files/image004.gif
[6] Molokai Ranch. "Our History." http://molokairanch.com/about-molokai-ranch/our-history/
[7] Bly, L. (1997). Home on the range, Hawaiian style Rustic paradise on a Molokai cattle ranch. USA Today.
[8] Interview with Nancy Schmicker, Molokai Ranch
[9] Molokai Ranch. "The Four Pillars" http://molokairanch.com/our-vision/four-pillars/

Most of the roughly 8,000 Molokai residents are of majority Native Hawaiian descent; Molokai has the largest proportion of Native Hawaiians of the major Hawaiian islands.[10] Molokai residents have deliberately resisted an intensive tourism industry of the type found on Oahu or Maui. Most prefer the rural lifestyle that maintains connections to traditional Hawaiian culture. Molokai's relative seclusion and dependence on imports of most manufactured goods keep consumer prices very high. An illustrative example is the sole centralized power plant on Molokai: a 6-megawatt diesel generator that provides electricity for approximately 45 cents per kilowatt hour, one of the highest prices in the United States.[11] These very high electricity costs make energy-intensive industries uncompetitive on Molokai, influencing possible future development patterns.

Molokai's Current Agricultural Status

Agriculture has always been a large component of Molokai's economy. Initially, Polynesian settlers cultivated taro, breadfruit, sweet potato, yams, and aqua-cultured fish in subsistence systems.[12]

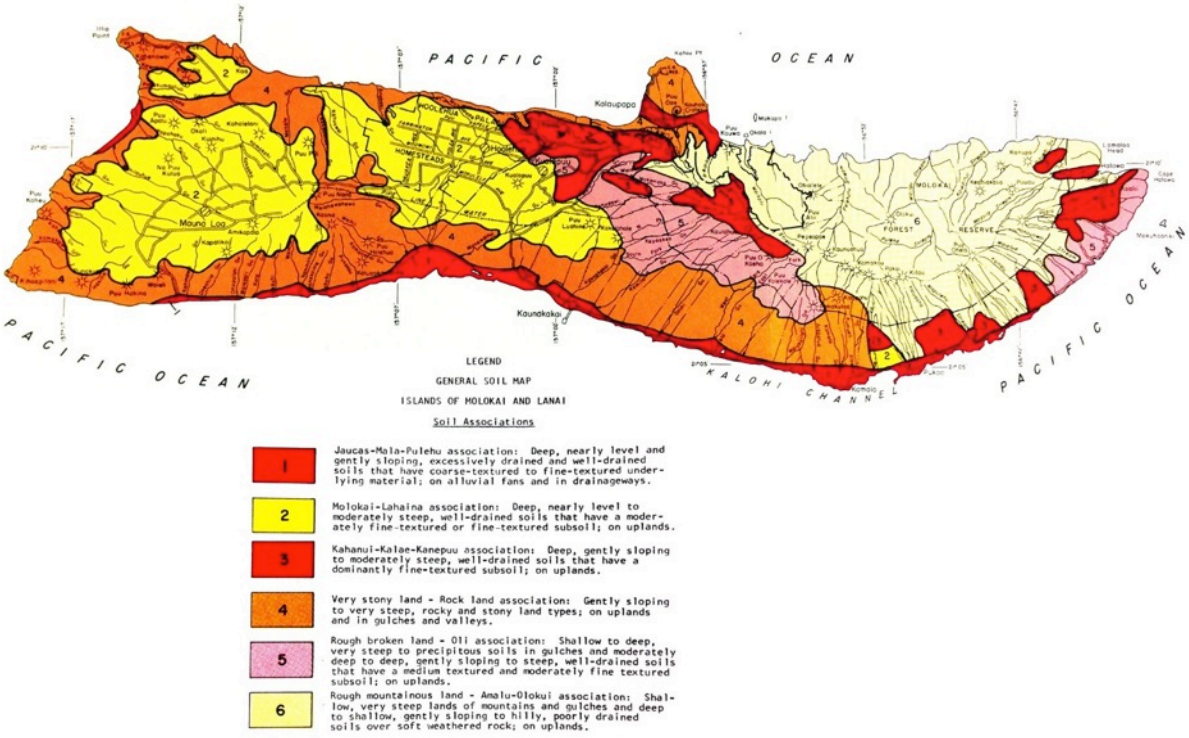
Figure 2: Taro Field on Molokai

In the late 19th and early 20th century, sugar and pineapple plantations opened on land leased from Molokai Ranch.[13] The large pineapple plantations began to close in the late 1970s.[14]

[10] Molokai Visitor Center. Frequently Asked Questions. http://visitmolokai.com/faq.php
[11] Maui Electric Company. "Average Rates." http://www.mauielectric.com/portal/site/meco/menuitem.853d25dd64dca44973b5c410c510b1ca/?vgnextoid=8352b4afc9472110VgnVCM1000005c011bacRCRD&vgnextfmt=default
[12] Canoe Plants of Ancient Hawaii. "Kalo." http://www.canoeplants.com/kalo.html

Diversified crops such as papaya, sweet potatoes, watermelons, and bananas were then cultivated on the same land. Seed corn companies began operating on Molokai in the late 1960s.[15] Monsanto and Dow Agro-Science still operate fields of seed crops on Molokai, which is a subject of local controversy.[16] [17] Monsanto is the largest single employer on the island, employing 123 people.[18]

Figure 3: Molokai Soil Types[19]



Preferred ranch grasses for Molokai include Green Panic (Megathyrsus maximus), Giant Guinea (Panicum maximum), and Buffelgrass (Cenchrus ciliaris). These are not native grasses, and most of Molokai's native grasses have been outcompeted by other species planted for ranching.[20]

[13] Molokai: Future of a Hawaiian Island. Page 14. http://sustainablemolokai.org/wp-content/uploads/2012/06/Molokai-Future-of-A-Hawaiian-Island.pdf
[14] Interview with Tina Tamanaha, Hikiola Cooperative
[15] Interview with Glenn Teves and Alton Arakaka, CTAHR
[16] A'ole GMO – Molokai, http://www.youtube.com/watch?v=LLEzdjR1IUY
[17] Interview with Dathan Bicoy, Molokai Ranch
[18] Interview with Ray Foster, Monsanto
[19] Tri-Isle Resource Conservation and Development Project. Program of Action. February 1971, USDA Soil Conservation Service, Hawaii
[20] Carlson, Norman. "Grazing Land Problems, Molokai Island, Territory of Hawaii." *Journal of Range Management*

Water allocation follows complex regulations on Molokai.[21] The western side of the island is dry and receives far less rainfall than the eastern side. A recent drought has been hard on farmers and ranchers. Pasture grass has not grown well, and ranchers have imported additional feed for livestock as a temporary relief measure.[22] In 2012, the most recent drought year, farmers purchased 662,000 pounds of cattle and horse feed through the farm supply cooperative. Under better circumstances, grazing could have met the same nutritional needs.[23] The drought has also driven invasive Axis deer onto farmland, destroying crops in the process.

Cattle Production History

Cattle production has occurred on Molokai in some capacity since the late-1700s, characterized by Paniolo management techniques.[24] In these systems, herds graze on 5000 acre paddocks, three months at a time, among other measures. At its peak, Molokai supported cattle herd sizes between 6,000 and 7,000 head, as opposed to hog operations, which never grew above 5 to 10 sows per operation.[25] After the tuberculosis outbreak, the cattle herd size on Molokai peaked at 3,000 head about ten years before this study was conducted.[26] Estimates differ, but there are likely between 1,000 and 2,000 animal units of cattle on the island at any one time, depending upon the season.[27] [28] [29]

Molokai Ranch now has plans to raise a herd size of 1,200 cows. Those cows would form the basis for having 3,000-4,000 animals on the 56,000-acre property split into 5 or 6 slaughter herds.[30] Molokai Ranch's goal is to scale up to the point where it can annually produce 800 head of grass-finished beef. Alongside the renewed cattle operation, Molokai Ranch is also exploring opening up a small hog operation. The herd would most likely have 60 sows, 5 boars, and aim to deliver 20 animals per week to the slaughterhouse.[31]

All cattle operations on Molokai were either corn-finished beef or cow-calf operations. Corn feed was shipped to the island for finishing. Cow-calf operations work differently than either grass-finished or corn-finished operations. Cow-calf operations maintain a herd of females and a few bulls for breeding purposes. The calves are weaned and then grazed on grass until they reach

[21] Interview with Glenn Teves and Alton Arakaki, CTAHR
[22] Interview with Tina Tamanaha, Hikiola Cooperative
[23] Interview with Tina Tamanaha, Hikiola Cooperative
[24] Interview with Jimmy Duvauchelle, independent rancher
[25] Interview with Dathan Bicoy, Molokai Ranch
[26] Interview with Glenn Teves and Alton Arakaka, CTAHR
[27] Interview with Jimmy Duvauchelle, independent rancher
[28] Interview with Glenn Teves and Alton Arakaka, CTAHR
[29] Interview with Wally Jennings, David Duvauchelle, and Glenn Sakamoto
[30] Interview with Dathan Bicoy, Molokai Ranch
[31] Interview with Nancy Schmicker, Molokai Ranch

approximately 400 pounds, or around six months of age.[32] They are then sold to feedlots on the mainland to be finished.

Agricultural Infrastructure

The Hikiola Cooperative supplies seeds and farm equipment to farmer-members on Molokai. It is the only farm supply store on Molokai. It began in 1976 as the pineapple-centric agricultural system was being phased out.[33] They now do $3 million of business annually. They sold 206,000 pounds of pig feed to home growers in 2012. When feed prices went up four years prior to this study, some of the larger home hog growers ceased operation. Conventional feed must be shipped from the mainland and ordered four weeks in advance, forcing the small extant hog operations to forecast their needs.

The Molokai Livestock Cooperative operates a small USDA-licensed slaughterhouse capable of slaughtering 18 animal units per week.[34] It opened nearly ten years ago.[35] A challenge for ranchers and the slaughterhouse itself is that "the drop" – the blood, bones, skin and other non-meat parts of the cow – do not have value on Molokai. On the mainland, these parts can be sold to leather tanners, pharmaceutical companies, and other businesses, whereas on Molokai there is no demand for these products and these flows are currently composted. The slaughterhouse processed 500 animals in 2012, 30 to 40 percent of which were raised on Molokai. Due to the current underutilization of the slaughterhouse, some animals are shipped in from other islands to be processed and the business is open four days per week.

Young Brothers operates the sole freight shipping facility on Molokai.[36] Calves from the extant cow-calf operations are barged to Oahu in "cowtainers" by Young Brothers, the local transportation company.[37] Palletized cargo is $40 per pallet, which is the method used to export some agricultural products off of Molokai. Meat processed at the slaughterhouse is shipped off-island in one of the five refrigerated containers owned by Young Brothers.[38]

[32] Interview with Jimmy Duvauchelle, independent rancher
[33] Interview with Tina Tamanaha, Hikiola Cooperative
[34] Interview with Jack Spruance, Molokai Livestock Cooperative
[35] "New slaughterhouse on Molokai means more fresh meat locally." The Associated Press State & Local Wire. 6/3/2003
[36] Interview with Al Ranis, Young Brothers Shipping
[37] Interview with Dathan Bicoy, Molokai Ranch
[38] Interview with Al Ranis, Young Brothers Shipping

III. METHODOLOGY

Primary Data Collection

Interviews

While on Molokai, the group conducted in-person and telephone interviews with agricultural, waste management, business planning, government and community stakeholders on Molokai and other islands.

Interviews provided qualitative information about the historical structure of the cattle industry on Molokai, the current status of household pig operations, and the problems and opportunities associated with the wild population of Axis deer. They also provided insight into political issues on the island, as well as economic, cultural, and regulatory constraints that would affect any commercial livestock operation.

Wherever possible, the group gathered raw data from interview subjects including animal feed imports,[39] animal processing quantities at the slaughterhouse,[40] and animal grazing stocking rates and nutritional needs.[41]

Discovery of Hidden Flows

The group attempted to uncover hidden organic waste flows that could be used as hog feed, searching for unused school cafeteria waste, landfill green waste, farm organic waste, home organic waste, and sources from other islands.

Small-scale hog production is common in many homes, usually one or two animals at a time for a special event.[42] Because Molokai is a small, interconnected community, these home producers have already engaged school cafeterias and are taking up all school food waste for home pig production.

At the Molokai Landfill, the group examined incoming green waste. This green waste was typically coarse yard waste, and was not suitable for feed. The landfill mulches this waste and it is available to local residents at no charge.[43] Rudy Cabanting, the landfill manager, stated that

[39] Interview with Tina Tamanaha, Hikiola Cooperative
[40] Interview with Jack Spruance, Molokai Livestock Cooperative
[41] Interview with Jimmy Duvauchelle, Independent Rancher
[42] Interview with Glenn Teves and Alton Arakaki, CTAHR
[43] Interview with Rudy Cabanting, Molokai Landfill

residents typically use this green waste for gardening. This green waste could potentially be used for hog bedding under the Inoculated Deep Litter System (IDLS)[44] that Molokai Ranch is currently proposing to utilize.

Farm organic waste is typically reused on-site. Community members may take off-grade food, but this is too small of a feed source for a commercial operation. Residential organic or food waste is already used in home pig production, and the remaining waste is landfilled.

Food or organic waste from the Hawaiian visitor industry could represent a significant opportunity for hog producers on Molokai. This would have to come from hotels or similar facilities on other islands, because the visitor and hotel infrastructure on Molokai is small. Oahu is an ideal source for this type of food waste; however, transporting wet waste is not economically viable.[45] Dehydrated, pelletized waste is not currently available. Further work needs to be done to make importing food waste from Oahu viable.

Scenario Analysis

To determine the ideal livestock production scheme for Molokai, the group used scenario analysis to compare beef, pork and venison. Scenario analysis is used in industrial ecology to enable comparison of possible future scenarios. Scenario analysis can also aid the discovery of potential synergies and can highlight activities within a process that are particularly resource intensive. Considering livestock production as a way to feed the local community and stimulate the local economy, the group examined a Molokai grass-fed beef scenario, a mainland grain-finished beef scenario, a Molokai food waste/feed pork scenario, and a Molokai commercialized venison scenario. The group combined quantitative data with qualitative information obtained through interviews to characterize each scenario. Together, this data informed the group's ranking and recommendation for the ideal livestock production scheme.

Life-Cycle Assessment

The group conducted life-cycle analyses (LCA) to gauge the environmental impact of each scenario. LCA is well suited for assessing quantitative impacts; it gives us baseline environmental impact scores by which we can compare very different livestock scenarios.

In conducting our LCAs, we used secondary data provided in the LCA Food DK library of the SimaPro 7 software. This data was compiled by agricultural science researchers in Denmark using agricultural and food product data from Denmark. In using this data, we assume that

[44] The Natural Farming Concept: A New Economical Waste Management System for Small Family Swine Farms in Hawai'i
[45] Interview with Nancy Schmicker, Molokai Ranch

environmental impact data from Europe for basic elements of the livestock raising process—e.g. methane emissions from cattle—is applicable in Hawaii.

To build LCA models for each scenario, we made many assumptions. Generally, for beef, we assumed no irrigation and no fertilizer or pesticide use. For pork, we assumed use of the Korean Inoculated Deep Litter System, which eliminates water use for cleaning. We assumed a pig feed mixture of 50 percent mill run waste from Oahu (see analysis section) and 50 percent imported feed. For venison, we assumed no land use or other resource use associated with raising the animals, as they already exist in a wild population on the island. We assumed all electricity use came from the single diesel power station on Molokai. For all stages involving shipment to the mainland, we assumed an interoceanic barging distance of 3,841 kilometers—roughly the nautical distance between Honolulu and San Francisco—and a local barging distance from Honolulu to Kaunakakai, Molokai, of 88 kilometers. Sensitivity analysis was conducted to assess driving factors behind results in each scenario.

To gauge the environmental desirability of each scenario, we used three different assessment methods: Ecopoints 94, IPCC Global Warming Potential 500a, and EDIP LCA Food. We used the first method to assess the energy impact of each scenario in mega joules lower heating value (MJ LHV). The second method evaluates the climate change 500-year impact of each scenario in kilograms of CO_2 equivalent (kg CO_2 eq.). The third assessment method creates a point score (pt) based on an aggregation of environmental impact factors. While LCA can be used to specifically assess impacts like ozone depletion, smog, acidification, eutrophication, ecotoxicity, and respiratory effects, our research suggests that the impacts of the livestock regimes described in this paper would not be isolated in these areas.

IV. ANALYSIS AND DISCUSSION

The group considered multiple objectives when evaluating each potential livestock production model. These objectives were based on the goals of the field of industrial ecology as well as the goals outlined by the Molokai community in the report prepared by Sust'ainable Molokai.[46] The objectives detailed below address increasing food independence and security, increasing local economic independence, reducing waste, and minimizing environmental impact. Additionally, the group assessed the feasibility of each scenario by considering political implications and social values of the community.

- *Food independence*: Per the Sust'ainable Molokai report, the Molokai community has a goal of greater food independence. Because the island is not a major stop for barges traveling from Honolulu to Maui, the cost of transporting food to Molokai is very high. Food imported in this manner is vulnerable to supply interruptions; that is, if a barge is delivery is interrupted or the supply runs short elsewhere, Molokai could be left without food. Food produced locally with local inputs could potentially be cheaper, and the entire economic value chain would remain on-island while reducing food supply vulnerability.[47]

- *Economic independence:* A local meat industry could generate significant value on Molokai, and if the industry relies on local inputs it would keep this value on the island. If, on the other hand, Molokai relies on imported meat or imported feed to raise meat, it will continue to send money off island and out of the local economy.

- *Waste reduction:* Waste disposal is expensive on Molokai, which has limited land space available for landfills. Material flows classified as "waste" can often have value when used as an input for agriculture or other industries. For example, waste food can be used as slop for pigs. On Molokai, the group learned that all recycled metal is shipped off island. Residential waste is mostly landfilled, and organic waste is mulched. One local landfill has already been filled and sealed. Several innovative initiatives are already in place, such as organized recycling bins at the landfill where community members can drop off or pick up items for re-use (e.g. jars for canning, boxes for packing, etc.). Building a livestock industry that uses unpackaged, local inputs would help to reduce waste while building the economy.

[46] Molokai: Future of a Hawaiian Island. http://sustainablemolokai.org/wp-content/uploads/2012/06/Molokai-Future-of-A-Hawaiian-Island.pdf

[47] It is important to note that a meat industry is not the only way to increase food independence or even protein independence on Molokai; there are nonmeat alternatives such as legumes that are often environmentally and economically preferable to meat. However, the scope of this project is to compare alternatives for a meat industry on Molokai.

- *Malama 'aina*: As outlined in the Sust'ainable Molokai report, *Malama 'aina,* or taking care of the Earth, is a core value to the Molokai community. Building resilient, sustainable livestock production systems is one way of embodying and living this ideal.

Scenario 1: Grass-fed Beef Production

Two types of beef are currently available in Molokai supermarkets; local, grass-fed beef, and corn-finished beef from the Mainland. Comparing the two, the group observed that grass-fed beef from Molokai has a much smaller energy intensity, carbon footprint and overall environmental impact.

As shown in Figure 4, our Ecopoints LCA assessment showed that imported beef had an energy intensity of 138 MJ LHV/kg of beef, while locally raised, grass-finished beef had an energy intensity of 7.68 MJ LHV/kg of beef, almost 20 times smaller. Our EDIP LCA assessment showed an overall environmental impact of .236 points for imported beef and .182 for local, grass-finished beef. Finally, our IPCC LCA assessment showed that Molokai grass-fed beef had a carbon footprint of 30 kg CO_2-eq/ kg beef, whereas Mainland beef is nearly 41 kg CO_2-eq/ kg beef (see Appendix I for EDIP and IPCC LCAs).

All of these assessments show that local, grass-fed beef is the clear winner over imported beef in terms of energy use and environmental impact. We see a high value under the IPCC global warming assessment for both imported and local beef due to the fact that methane emitted by cattle carries a very high global warming potential.

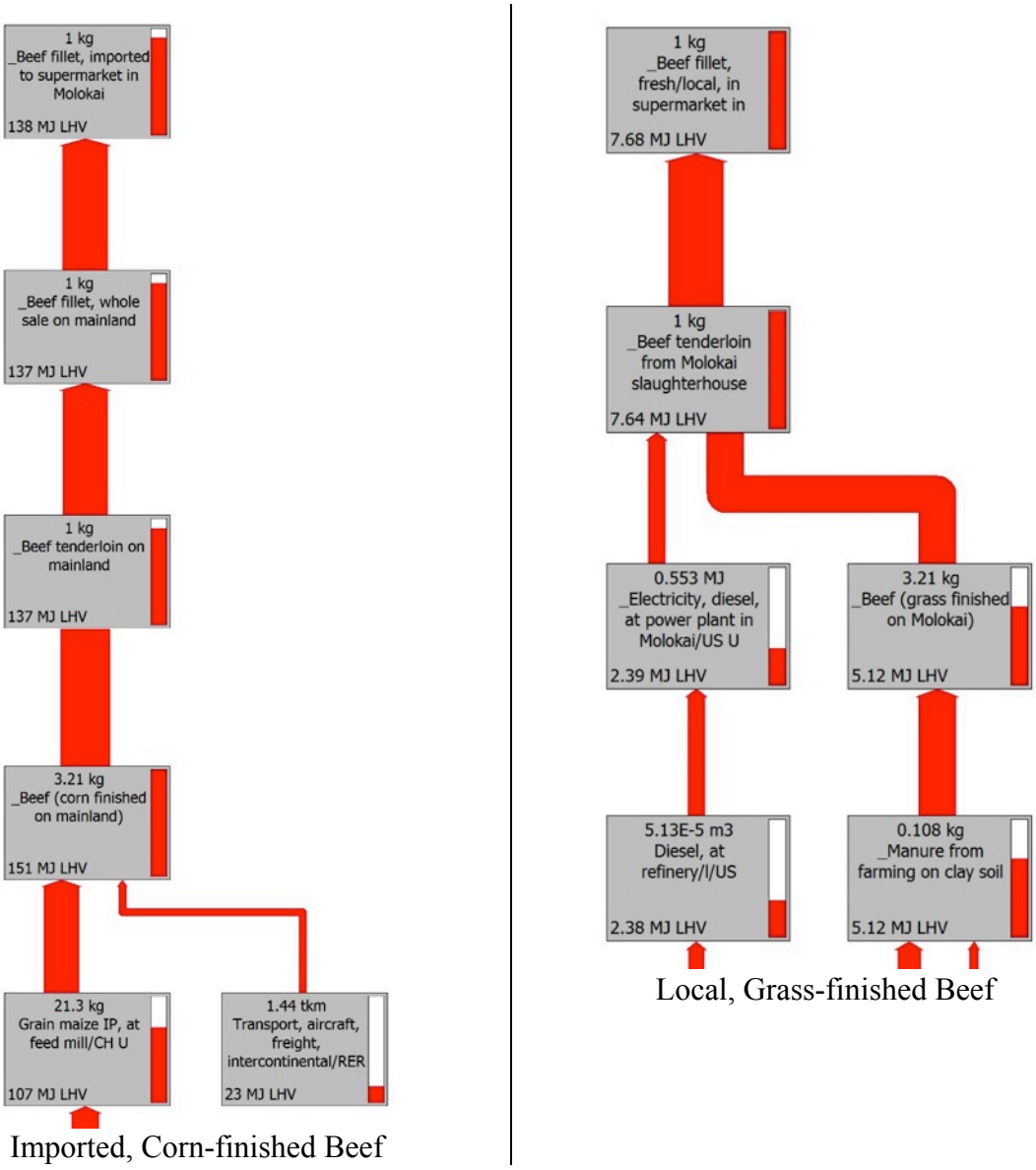
The relatively low environmental impact of Molokai grass-fed beef is a strong argument in its favor. However, production must be scaled up to supply local and export markets. Molokai already has a slaughterhouse with the appropriate capacity for increased livestock production and processing. The slaughterhouse currently composts part of the carcasses and landfills the bones. If livestock production were to scale up on Molokai, the group would recommend exploring alternative uses and industries for these materials.

Increased livestock production will require producer training and education. Grass-fed beef operations require very different expertise from cow-calf operations.[48] [49] Cow-calf operations were prevalent on Molokai historically, and ranchers would need to become acquainted with different management techniques in order to successfully make the transition. Grass-fed beef is only as good as the grass consumed, and growing high quality in a resource-constrained environment requires skill and careful management of the ecosystem. In sum, raising grass-fed beef entails becoming a grass farmer.

[48] Interview with Dutch Kuyper, Parker Ranch
[49] Interview with Jimmy Duvauchelle, Independent Rancher

To manage for extended drought conditions on Molokai, producers would have to significantly alter their grass management, stocking rates and grazing techniques. Currently, there is no hay production or storage facilities on Molokai, and this might help producers to harvest grass at its nutritional peak and weather drought periods.[50] The group encountered mixed sentiments regarding hay production, but the overall consensus suggested that current grazing practices were not optimal.

Figure 4: LCA, Beef, Imported vs. Local Grass-Fed, Ecopoints Energy Use



[50] Interview with Jennifer Hawkins, Kuha'o Business Center

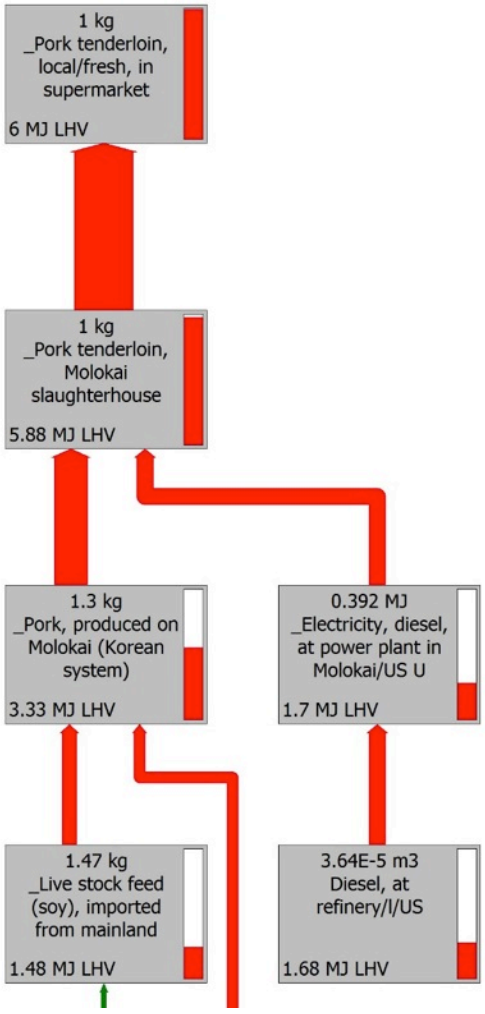
There are also capital constraints for smaller Molokai producers who may want to cooperatively enter the grass-fed beef business. Grass-fed beef are bred for different characteristics, and these producers will have to build new herds.

Because of the historical prominence of cattle on Molokai and the widespread discontent surrounding the decline of the industry, a grass-fed beef industry would be popular among the community.

Scenario 2: Local Pork Production

If pork were commercially produced on Molokai, the pigs would be fed a ration of 50% flour mill-run or other food waste and 50% imported feed. As explored in the *Discovery of Hidden Flows* section of this report, the food waste or flour mill-run supply might be unreliable.

Figure 5: LCA, Local Pork, Ecopoints Energy Use



Examining Molokai pork production through life-cycle analysis, the group observed that hog production had a low energy intensity of 6 MJ LHV/kg pork and a very low environmental impact score of .00792 points. Under the 50/50 ration scenario described above, pork production would yield 0.959 kg CO_2-eq/ kg pork (see Appendix II for all LCA diagrams). This is significantly less than the 30-40 kg CO_2-eq/ kg beef scenarios. We see this more favorable carbon footprint (and environmental impact point score) due to lowered methane emissions. However, since local feed sources are still unavailable, Molokai pork production would remain dependent on imported feed.

Table 1: Potential Pig Ration Components

Feasibility (0-10)	Possible Feed Source	Justification
10	Waste water-grown bananas	Feasible, but small part of diet
10	Grazing grass	Feasible, but small part of diet
8	Oahu flour mill run	Feasible, but needs to be tested and shipped
8	Alfalfa	Must be planted on island
7	Maui Brewing distillers grain	Must be shipped and small part of diet
3	Oahu military base food waste	No dehydrator available, must be shipped
3	Kiave beans	Grows invasively, difficult to collect
3	Off-grade sweet potatoes	Insufficient quantities
2	Big Island Spirulena	Needs further research
2	Black Fly Larvae	Needs further research
1	Household food waste	Already utilized elsewhere
1	School/restaurant food waste	Already utilized elsewhere
1	Molokai aquaculture byproduct	Native aquaculture is defunct, possible revitalization
1	Coffees of Hawaii cherries	Already commercialized as a niche tea
0	Seed corn byproducts	Monsanto composts all byproducts to protect intellectual property
0	Molokai Dump green waste	Found to be inedible

The group observed that home pig production for special events had important cultural significance. The export potential for Molokai-raised pork or pigs is large though, especially for events in places where pigs cannot be raised so easily. There seemed to be ample available bedding for the Inoculated Deep Litter System, which uses enzymes to break down pig waste products and bedding. The enzymes and new bedding are simply added on top of the existing

bedding, and odor is also neutralized. For pig production, a constant food waste supply is essential, and has not yet been discovered.

Molokai Ranch discussed growing bananas in wastewater and using them as a ration component.[51] The ration must be nutritionally balanced, however, which is harder to achieve when relying on unpredictable quantities and compositions of food waste. To supplement this organic waste ration component, the group discussed several alternative feed sources with interview subjects. These food sources are ranked in terms of feasibility. A grade of 10 denotes "most feasible" based on logistical, cultural, environmental and economic factors.

Based on these factors, pork production is not scalable on Molokai, at least in the short term. Though the processing and transportation capacity exists on-island, the ration composition is uncertain, and would lead to unsustainable reliance on imported inputs. Additionally, some of the alternative feed sources examined here can negatively impact the meat taste if not balanced with conventional, imported feed.[52]

Scenario 3: Commercialize Venison

Axis deer are invasive and overpopulated on Molokai. Alongside feral pigs, they are a favorite of local hunters, and with reason; they are abundant, and the quality of their meat is among the best of any deer species. However, they are also a pest to local farmers and gardeners, especially during drought when they encroach on farms in search of water. Because deer have small incisors, they are able to graze close to the root, leaving no forage for other livestock.

Deer emit roughly half as much methane as cattle. With the exception of consumption in farms and gardens, Molokai deer rely exclusively on local vegetation for their diet so there are no fertilizer, pesticide, or feed inputs. As a result, deer on Molokai enjoy a low carbon footprint. Given the preexisting population of animals, the only fossil-derived carbon dioxide in the venison lifecycle would be from electricity used by the slaughterhouse.

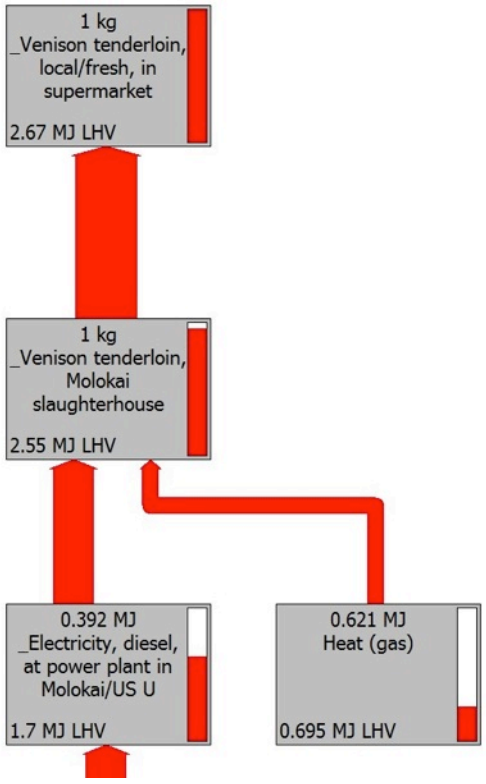
Accordingly, we see a very low energy use value of 2.67 MJ LHV/kg venison, a very low environmental impact score of .00258 points, and a very low global warming impact of .188 kg CO2 eq./kg venison (see Appendix III for additional LCAs).

As stated elsewhere in this report, most Molokai residents supplement their diets by hunting. While deer meat was not a traditional staple of the Hawaiian diet, it has gained a prominent place in local cuisine and tradition since its introduction in the 1800s and is now a highly valued

[51] Interview with Dathan Bicoy, Molokai Ranch
[52] Interview with Jennifer Hawkins, Kuha'o Business Center

source of protein. The island's carrying capacity for deer is roughly 60,000 animals, but hunting has helped to limit the population, which is currently at a more manageable level of approximately 18,000. Even at this level, however, deer caused millions of dollars of property damage during the recent drought and caused many farmers to cease their agricultural operations.[53]

Figure 6: LCA, Venison, Ecopoints Energy Use



In terms of commercialization, venison is highly valued with some restaurants in Oahu paying $300 per carcass.[54] However, hunting at a commercial scale is infeasible due to slaughtering regulations. To sell game meat commercially, an inspector must travel with the hunter to supervise the slaughter of the animals. With the inspector present, the hunter must locate the deer, kill each animal with a single shot through the head, and bring them to the slaughterhouse within three hours, which is very challenging when hunting on foot. The hunter would have to pay the inspector for his or her time during the entire process. If the hunting is done at night as is most practical for deer, the slaughterhouse must open outside of normal operating hours and pay overtime to employees. The risk associated with these requirements makes commercial

[53] Interview with Glenn Teves and Alton Arakaka, CTAHR
[54] Interview with Al Ranis, Young Brothers Shipping

scalability impossible; though there have been one-time hunting ventures in the past, their infrequency and risk of failure do not allow for a steady source of product around which to build a brand and sustain the slaughterhouse.

A potential solution is to create a domesticated herd. Axis deer have been domesticated elsewhere, and it is possible to create a sustainable domesticated herd by capturing only 10 percent of the Molokai deer population. This would interfere minimally with hunting, and would further help to manage the invasive population. However, because deer are so highly valued socially, many oppose domestication because they see it as diminishing the resource.

In the future, it is possible that a community-driven deer domestication initiative with appropriate limitations could overcome some opposition. Public-interest deer management has been successful elsewhere; in managing its invasive deer population, the government of New Zealand created a domesticated herd that now serves a $200 million industry.[55] However, it is clear that it is not feasible to scale up commercialized venison operations on Molokai in the short term.

[55] "Introduction and impact of deer." Te Ara Encyclopedia of New Zealand. http://www.teara.govt.nz/en/deer-and-deer-farming/page-1 (accessed September 10, 2013).

V. FINAL RECOMMENDATIONS

Table 2: Livestock Scenarios

Objective	Scenario 1: Local Grass-Fed Beef	Scenario 2: Local Pork	Scenario 3: Commercialized Venison
Food Independence	Good Local • Protein supplied on-island vs. Imported • Vulnerable to supply interruption	Good Local • Protein supplied on-island vs. Imported • Vulnerable to supply interruption	Good Commercialized • Protein supplied on-island vs. Status Quo • Protein supplied on-island • Deer destroy food crops
Economic Independence	Good • Economic value stays on Molokai	Poor • Money exported for feed imports	Good • Economic value stays on Molokai
Waste Reduction and Local Resource Use	Good • Utilize abundant forage	Poor • Imported feed • Waste flows already utilized	Good • Utilize abundant forage • Utilize invasive species
Environmental Impact (Malama ‘aina)	Fair Local • 30 kg CO2e • .182 Pt vs. Imported • 40.9 kg CO2e • .236 Pt	Good • .959 kg CO2e • .00792 Pt	Very Good • .188 kg CO2e • .00258 Pt • Controls invasive species
Energy Use (Malama ‘aina)	Good Local • 7.68 MJ LHV vs. Imported • 138 MJ LHV	Good • 6 MJ LHV	Very Good • 2.67 MJ LHV
Feasibility	Very Good • Favored by community	Good • Community receptive	Poor • Regulatory and social barriers

Based on the objectives of food independence, economic independence, waste reduction, and malama ʻaina, commercialized venison production is the optimal choice for a commercial meat industry on Molokai when compared against a beef or pork industry (Table 2). However, regulatory and social obstacles make venison commercialization infeasible, and therefore we cannot recommend it. It is important to note that Molokai's heavily hunted deer population already helps meet the objective of food independence without commercialization; deer represent a significant local protein source for residents, although their damage to agricultural crops robs local residents of other food resources.

There are insufficient food waste flows on Molokai to sustain a commercial hog operation. While pork itself offers good environmental performance, a hog operation on Molokai would require feed from off-island. This is because on-island edible flows of "slop" have already been identified and fully utilized to feed homegrown pigs, fulfilling the objective of waste reduction without intervention. Importing feed does not achieve the objectives of economic independence and waste reduction, and would preclude having closed-loop livestock operations that build the on-island economy.

Local grass-fed beef is the best option when all objectives are considered alongside feasibility. A grass-fed cattle operation would make the best use of local resources and would be most favored by the community. Though this analysis is primarily concerned with local sustainability, we must be aware of the contribution of any cattle operation to global climate change; grass-fed beef represents a substantial improvement in carbon footprint over a baseline of imported beef, and the contribution of cattle on Molokai would be small compared with emissions in the mainland U.S.

We identify three opportunities for further exploration to optimize grass-fed cattle production and make commercialization more tractable:

1. Become adept at farming grass. Grass-fed beef is only as good as the grass used as feed, and therefore it requires skilled ecosystem management. Begin haying excess grass production to ensure consistent feed supply and protect against droughts. Hay production is uncommon, and increasing production will require investments in machinery and storage capacity. This is crucial to drought resilience and increasing the carrying capacity for cattle on the island without damaging the land or importing feed from the mainland.

2. Commoditize livestock slaughterhouse byproducts as much as possible. Identify opportunities for higher value uses of the blood and hides on-island. There is an opportunity for industrial symbiosis if an entrepreneur on island starts a leather tannery. Leather products would offer a new source of employment and income to Molokai.

Commercialize the compost produced by byproducts that cannot be sold. This deserves further research.

3. Build expertise in direct marketing. Use local certification labeling to promote the local aspect of the Molokai grass-finished product. Launch a concerted campaign throughout Hawaii to create brand awareness around this label and increase demand.

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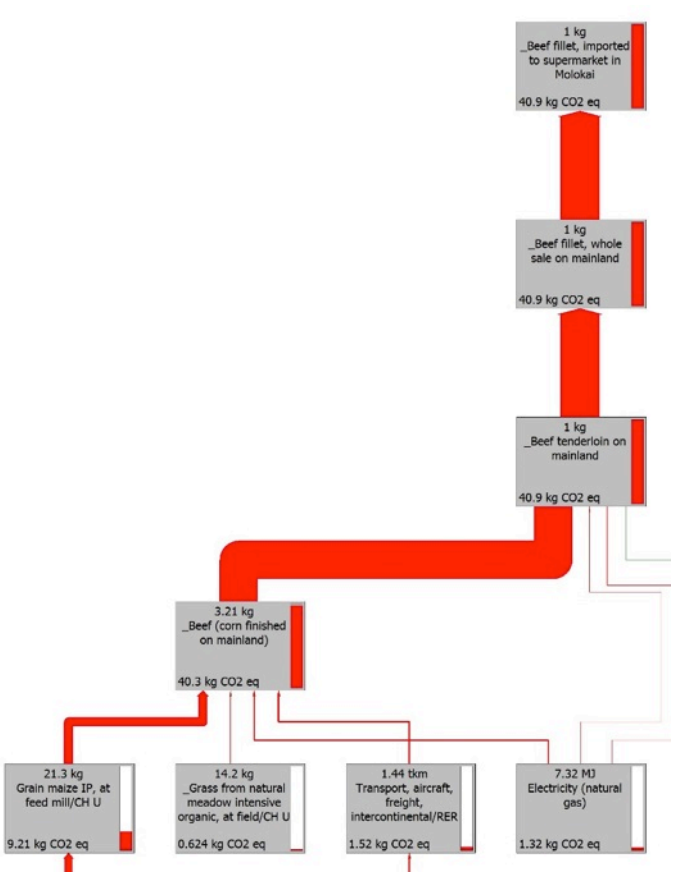
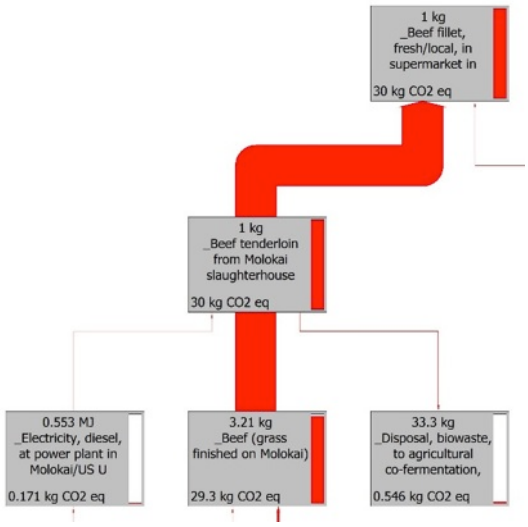
APPENDIX I: BEEF LCAS

Figure 7: LCA, Beef, Imported vs. Local, IPCC Global Warming Impact

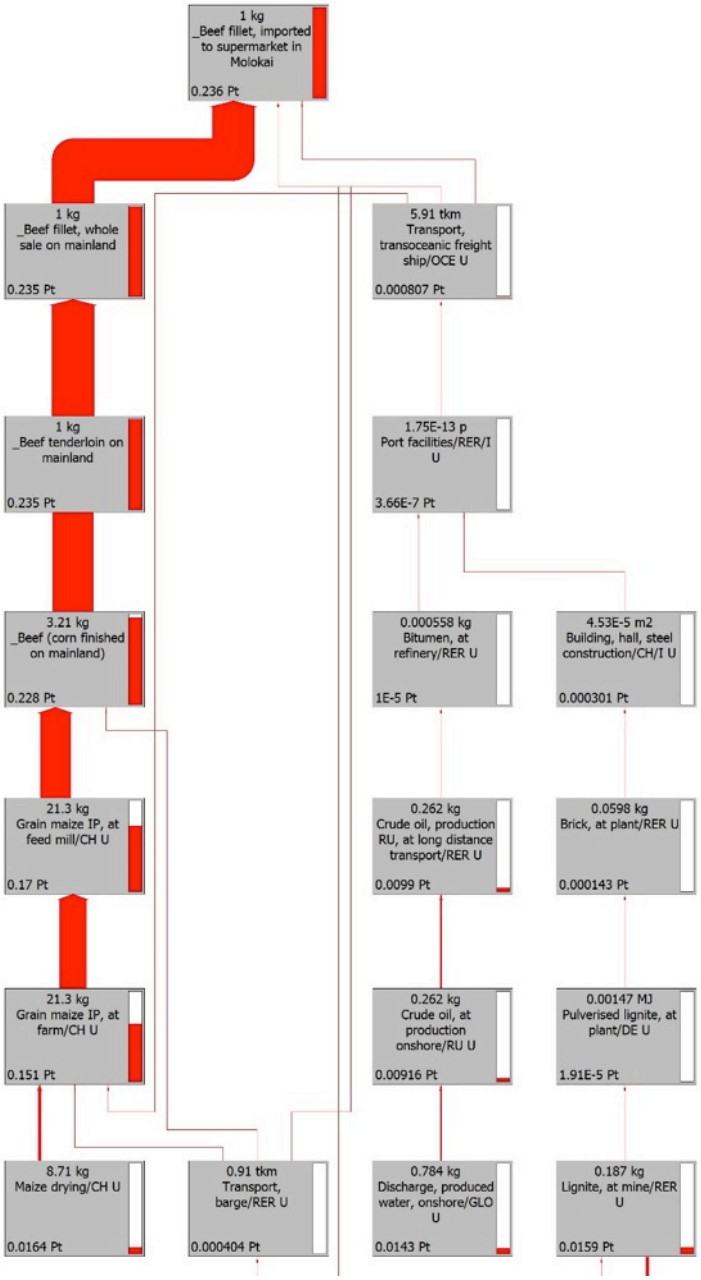


Imported, Corn-Finished Beef

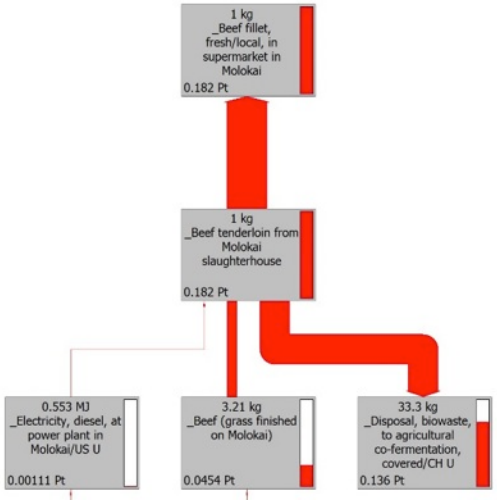


Local, Grass-Finished Beef

Figure 8: LCA, Beef, Imported vs. Local, EDIP Environmental Impact



Imported, Corn-Finished Beef



Local, Grass-Finished Beef

APPENDIX II: PORK LCAS

Figure 9: LCA, Pork, IPCC Global Warming Impact

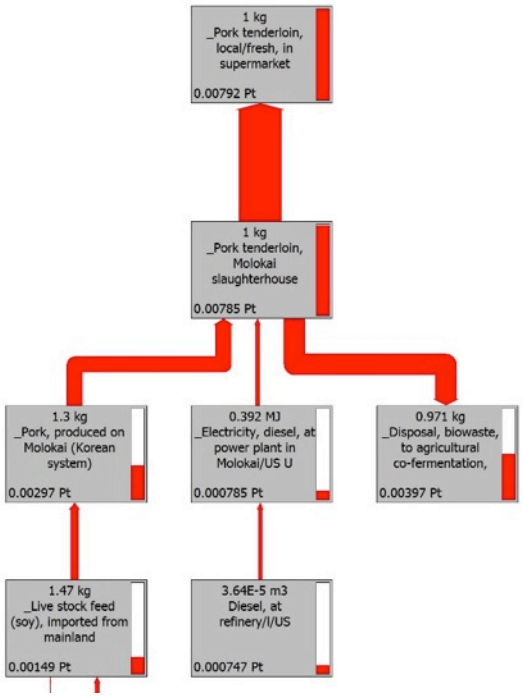
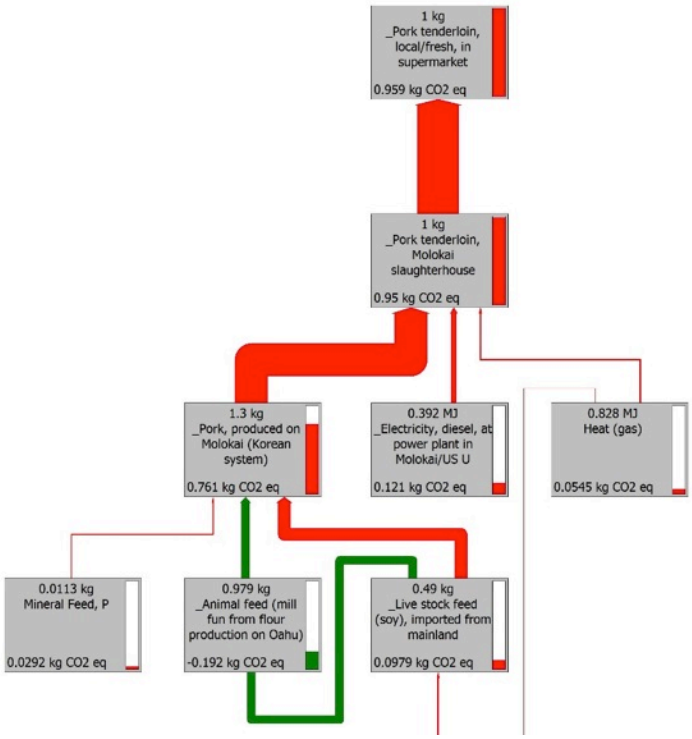


Figure 10: LCA, Pork, EDIP Environmental Impact



APPENDIX III: VENISON LCAS

Figure 11: LCA, Venison, IPCC Global Warming Impact

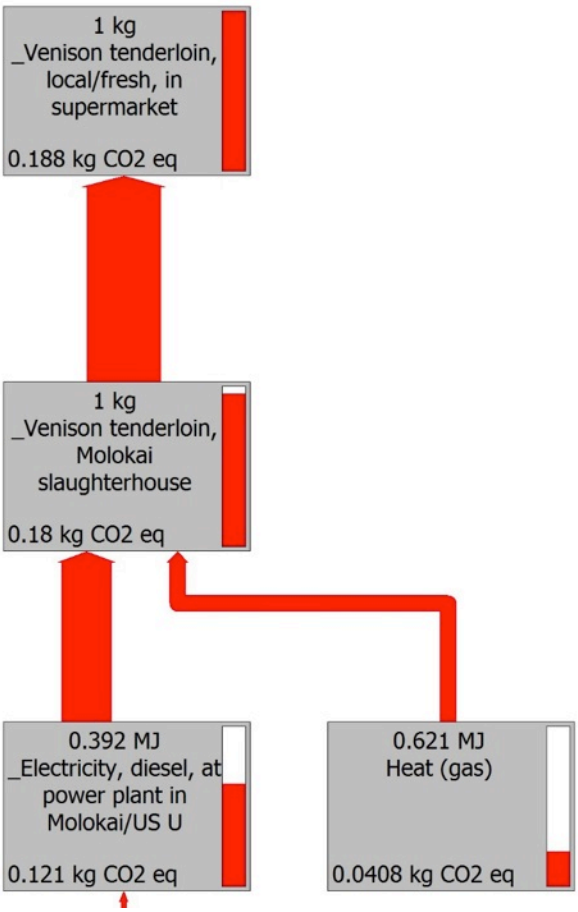


Figure 12: LCA, Venison, EDIP Environmental Impact