Food Waste Diversion: A Comparative Carbon Footprint Study using Life Cycle Analysis

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Introduction:

The term “food waste” often implies negative connotations of being burdensome or undesirable. However, the inherent properties of food waste and even organic waste in general can create opportunities for sustainable practices, whereby it is transformed from a “waste” into a useful resource. Furthermore, diverting food waste from the landfill will not only help Fort Collins become a zero waste city, but can also aid in decreasing greenhouse gas emissions. The purpose of this report is to examine the advantages and disadvantages of several different options for food waste management in Fort Collins based on greenhouse gas emissions. In addition to reducing greenhouse gas emissions, food waste diversion from the landfill will help Fort Collins achieve its goal of zero waste by 2030.

Driver 1: Fort Collins as a Zero Waste City

The City of Fort Collins, Colorado is dedicated to becoming a “zero waste” city. A goal of 50% waste diversion from the landfill was set in 1999, and in 2014 Fort Collins achieved a 68.4 diversion rate. The current goal set by the Fort Collins City Council is to achieve zero waste by 2030. In 2016 the consulting firm Sloan Vazquez McAfee conducted a study to categorize the composition and characteristics of Fort Collins’ solid waste that is sent to the Larimer County Landfill. The analysis was conducted for residential, commercial, and construction and demolition waste for both Fall and Spring of 2016. The results of the two season study found that on average food waste accounts for 34.3% of residential organic waste, and 43.4% of commercial organic waste. Due to these large percentages, food waste diversion will be instrumental in helping Fort Collins achieve its zero waste goals.

Driver 2: Decreasing GHG Emissions

Fort Collins is also determined to decrease greenhouse gas (GHG) emissions. Ambitious goals have been set for reducing GHG emissions including a 20% reduction below 2005 levels by 2020, 80% below 2005 levels by 2030, and carbon neutral by 2050. When food waste is sent to a landfill, it decomposes to produce a mixture of various gases of about 50% carbon dioxide (CO_2) and 50% methane (CH_4). The CO_2 emissions are classified as biogenic, or in other words, emissions that are considered to be part of the natural carbon cycle. However, the CH_4 produced is not part of this natural cycle and is 25 times more potent than CO_2 on a 100 year timescale (recent reports from the GPC suggest it may be even higher).

Thus, CH_4 emissions from food waste can have large implications on overall city GHG emissions. Diverting food waste from the landfill will help the City achieve their GHG reduction goals.

Food Waste Material Flow Analysis

Food waste in the United States is a complicated issue to understand, and harder still to mitigate. According to the United States Environmental Protection Agency (EPA) “food waste is the second largest category of municipal solid waste (MSW) sent to landfills in the United States” and makes up about 14.6% of the total waste stream. There are obvious restraints and difficulties to reducing food waste due the nature of food itself, i.e. spoilage, supply and demand, shipping, etc. but there still exist opportunities for waste reduction and waste to energy technologies. In order to identify some of the “low hanging fruit” a Material Flow Analysis (MFA) was conducted in order to better understand the food waste streams in Fort Collins. A MFA is an analytical way to quantify flows and stocks of materials through a defined geographical area and over a set period of time. In this case the geographical area was Fort Collins, CO and the time frame was one year. By reducing complexity, this type of analysis assists in establishing priorities regarding environmental protection, resource conservation, and especially waste management. When used in conjunction with a Life Cycle Analysis (LCA) the results will not only yield waste streams but will also highlight the potential environmental impacts associated with their management.

Utilizing a City of Fort Collins business database, food waste generation was calculated with formulas from a California Department of Resources Recycling and Recovery study. Figure 1 displays the results of the MFA. For additional details see the report “Understanding Food Waste in Fort Collins, CO”.

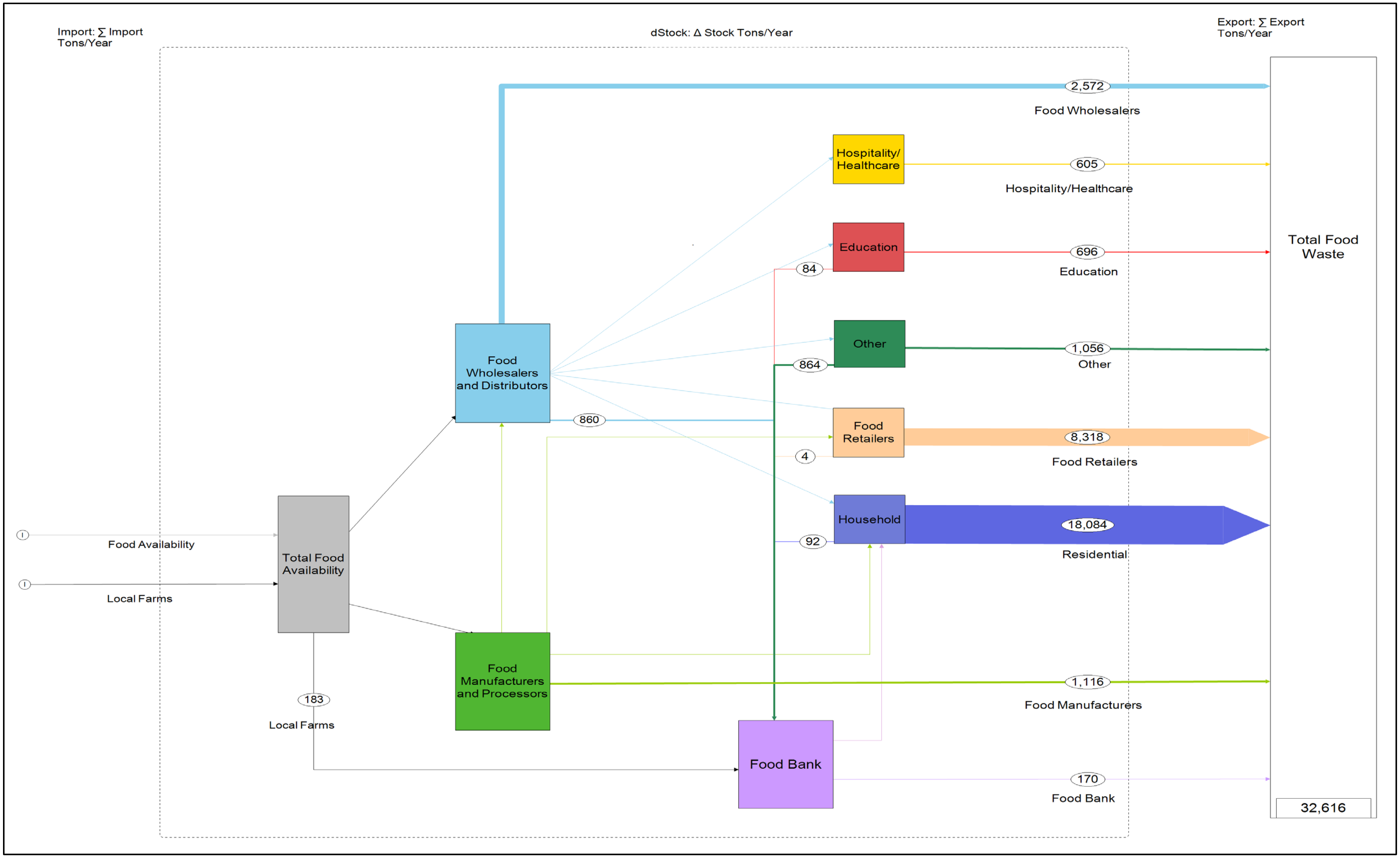

Figure 1: Detailed MFA of Food Waste in Fort Collins. It is estimated that about 32, 600 tons of food waste is generated per year in Fort Collins.

Utilizing Food Waste at Drake Wastewater Reclamation Facility

The two season waste composition study found that food waste accounts for 34.3% of residential organic waste, and 43.4% of commercial organic waste. One particularly option that Fort Collins was interested in investigating is sending food waste to the anaerobic digesters at the Drake Wastewater Reclamation Facility (DWRF). Anaerobic digesters are utilized in wastewater treatment plants to reduce the amount of organic matter that will ultimately need to be transported to landfills or other disposal facilities. The bacteria responsible for breaking down organic waste produce CO_2, CH_4, and heat, collectively referred to as biogas, which can be used as a fuel source for generators, boilers, internal combustion engines, or other mechanisms for energy production. If no energy recovery equipment is in place, biogas is typically flared. Currently, the facility combusts the portion of the biogas required to heat its digesters and flares the surplus biogas. Opportunities have been identified by the City to add co-generation engines to recover additional gas to power their on-site operations. The addition of food waste to the facility's anaerobic digesters will increase the amount of biogas produced, which will in turn increase the potential for energy production in a co-generation scenario.

Food Waste Diversion Scenarios

Delivery of food waste to DWRF consisted of two different scenarios. The first, referred to as the residential scenario, involved sending residential food to DWRF via the sewer system. The food waste would then go through the same treatment plant processes as regular wastewater (see Figure 2). The second scenario, referred to as the commercial scenario, assumed a truck transported commercial food waste to DWRF. The food waste would then be sorted to remove contaminants and then added directly to the anaerobic digesters (see Figure 3). Of particular interest to the City was, given limited digester capacity, which method of food waste delivery had lower GHG emissions.

Residential Scenario

The overall system of the residential scenario is presented in Figure 2. Food waste is processed within each home using an in-sink grinder (garbage disposal) and is sent to DWRF through the sewer system. It is then treated at the wastewater plant, and sent to the anaerobic digesters, i.e. the biomethane production picture in the figure. The outputs of the biomethane production process are heat and electricity production, water that is re-treated at the wastewater treatment plant, and organic solids that are applied to grasslands, i.e. Meadow Spring Ranch.

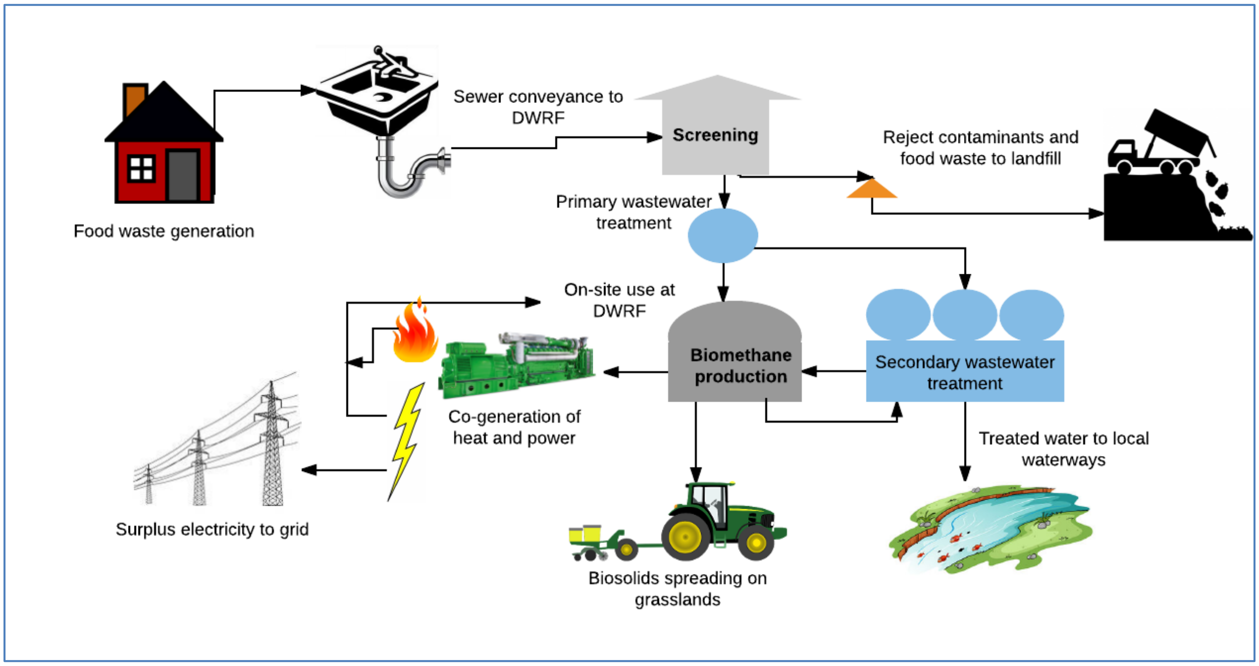

Figure 2: Overall process of the residential scenario. Food waste is initially generated in households, and is sent to the wastewater treatment plant via the sewer system.

Commercial Scenario

The commercial scenario is somewhat simpler due to the fact that the food waste does not go through the wastewater treatment process before entering the anaerobic digesters. As can be seen from Figure 3 food waste is hauled to DWRF and is sorted and processed to remove contaminants before being added to the anaerobic digesters, i.e. the biomethane production process. Similar to the residential scenario, the outputs of the biomethane production process are heat and electricity production, water that is re-treated at DWRF, and organic solids that are applied to grasslands, again referring to Meadow Springs Ranch.

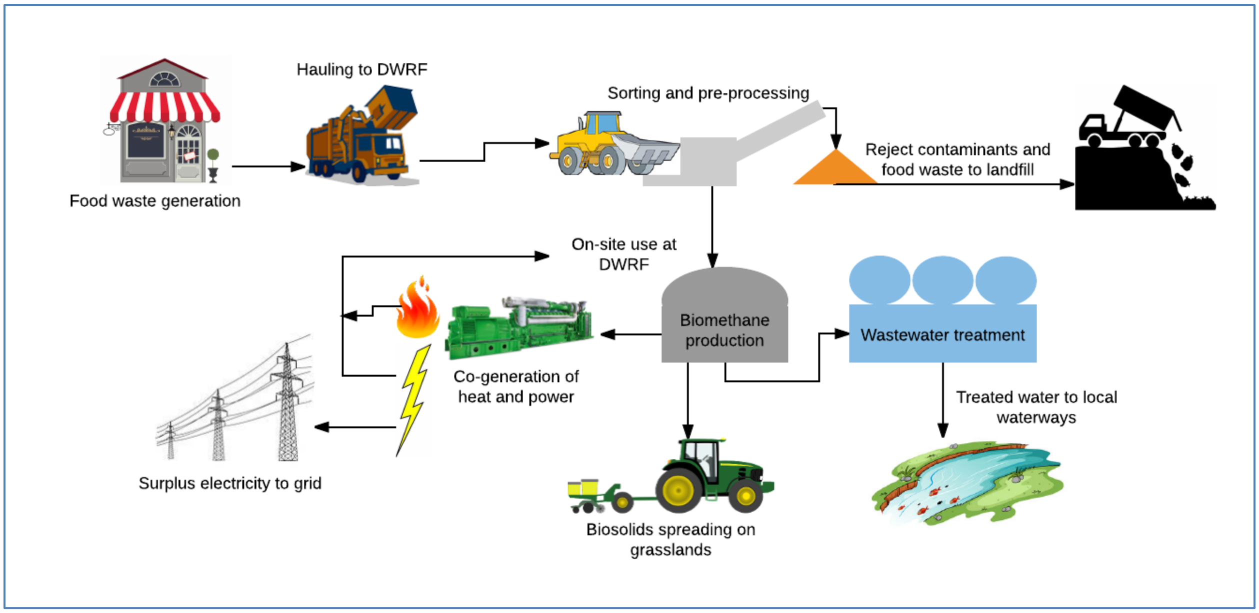

Figure 3: Overall process of the commerical scenario. Food waste is initially generated in households, and is sent to the wastewater treatment plant via the sewer system.

Life Cycle Analysis

In order to compare the two scenario's GHG emissions, the life cycle analysis (LCA) method was applied. A full LCA is essentially a cradle to grave system analysis that compares the environmental impacts of two or more processes/products. Environmental impacts often include global warming, acidification, eutrophication, human and eco-toxicity, and resource depletion. Due to data and budgetary constraints this report only analyzes global warming (GHG emissions) impacts, and net water demand. LCA is a useful resource for decision makers to compare the advantages and disadvantages of the two food waste management options.

To insure scenarios are compared on an equal basis, LCA utilizes a functional unit. A functional unit is a way to measure the service or function that the analyzed process provides. In the case of this study, the functional unit is one metric ton of food waste diverted from the landfill.

Results

GHG Emissions

Ultimately, the commercial scenario proved favorable to the residential scenario. The commercial scenario resulted in lower overall GHG emissions and lower water consumption. The net GHG emissions were $1.3*10^{-1}$ tons CO_2 eq/Metric ton of food waste for the residential scenario and $-8.98*10^{-2}$ tons CO_2 eq/Metric ton of food waste for the commercial scenario. It is significant to note that the commercial scenario produced net negative GHG emissions. Figure 4 displays an aggregated view of the various processes emissions and credits for each scenario.

Water Consumption

Water usage was calculated to be 10 times higher for the residential scenario. The authors utilized literature values from previous studies to arrive at this number. The residential scenario requires more water to dilute the food waste to a mixture where it can be ground down in a household garbage disposal. The commercial scenario does not require additional water due to the intrinsic moisture of food waste. In other words, adding food waste directly to the anaerobic digesters will not require any additional water potable.

Conclusion

The results of this analysis provided several interesting conclusions.

1. The production of a residential food waste processor, i.e. garbage disposal, creates surprisingly large emissions from the manufacturing, packaging, and distribution of the unit. The commercial scenario also grinds and processes food waste, but it is likely that industrial food processors are more efficient than individual, smaller processors and see higher volumes of food waste, lowering the resource to processed output ratio over their lifespan.
2. Adding food waste directly to the anaerobic digesters in the commercial scenario produces significantly more biogas than the residential scenario as no losses occur in the sewer or during superfluous wastewater processing. Increased biogas per food waste input results in more electricity and heat production, leading to a much larger energy credit for the commercial scenario. Truck transportation did not offset the benefits of the larger energy credit.

3. In contrast to the commercial scenario, the residential scenario saw lower resource and energy efficiency from equipment (mentioned in conclusion 1) and higher losses due to degradation during sewer transportation and wastewater treatment processes. While still much lower in terms of emissions than the landfill, given the limited digester capacity at DWRF, the commercial scenario provides more energy for the same initial amount of food waste.
4. Water consumption is 10 times higher for the residential scenario, due to the dilution of food waste required for a household garbage disposal.

Bottom Line Summary

The material flow analysis conducted provided an estimate of how much and where food waste is being generated in Fort Collins. To compare GHG emissions for two different food waste diversion strategies, LCA methodology was utilized. This carbon footprint study found that the commercial scenario was not only superior to the residential scenario, but also resulted in net *negative* GHG emissions. In addition, the commercial scenario resulted in 10 times less water consumption than the residential scenario.

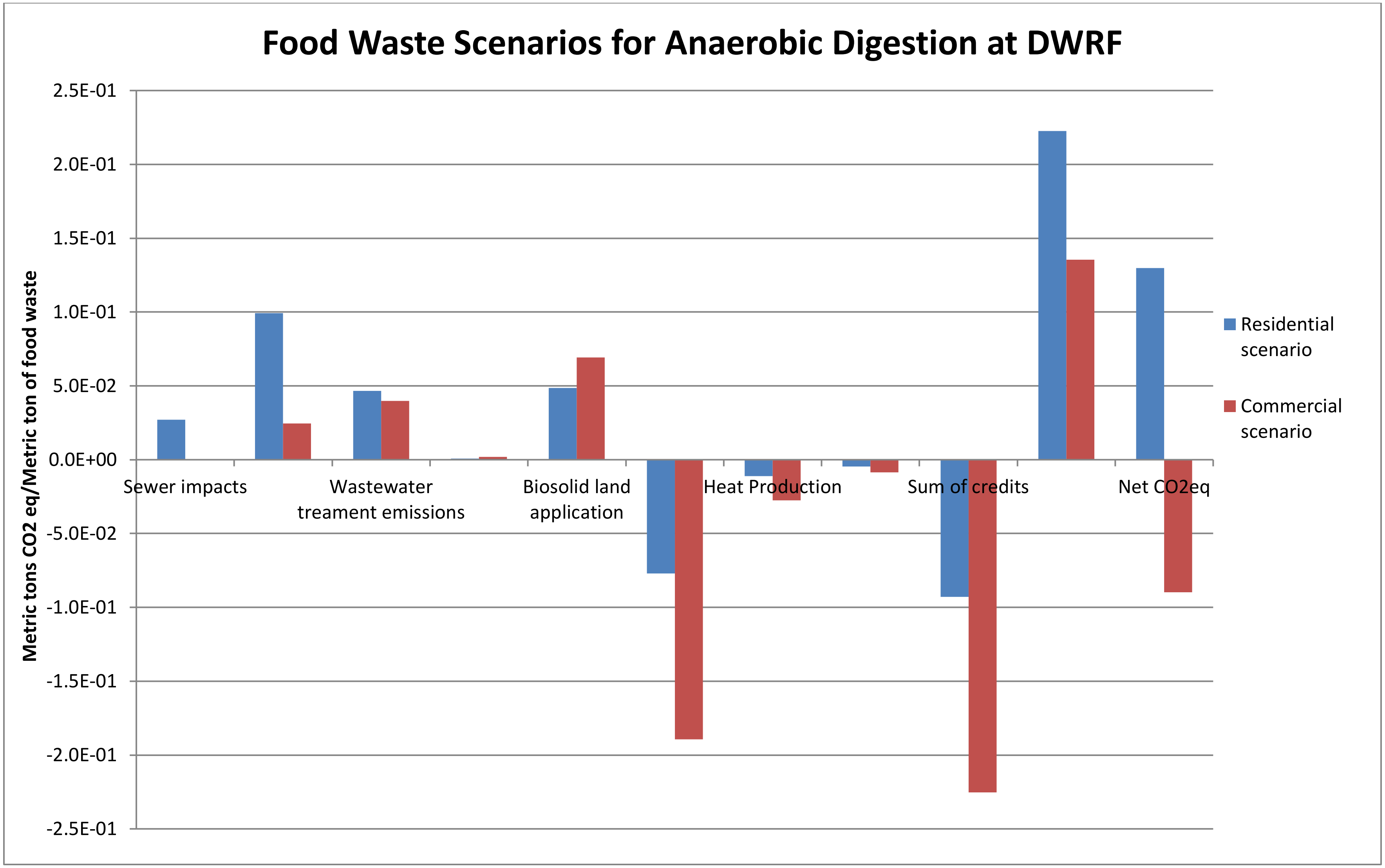

Figure 4: Aggregated GHG emissions per process for both residential and commercial scenarios.