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Life cycle assessment of trayless dining

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LIFE CYCLE ASSESSMENT OF TRAYLESS DINING

By

Nawaf Isam Blaisi

A THESIS

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

(Environmental Engineering)

MICHIGAN TECHNOLOGICAL UNIVERSITY

2011

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This thesis "Life Cycle Assessment of Trayless Dining," is hereby approved in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN ENVIRONMENTAL ENGINEERING.

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Table of Contents

List of Figures	vi
List of Tables	vii
Acknowledgements	ix
Abstract	x
1 Introduction.....	1
1.1 Background	1
1.2 Previous Studies conducted on trayless dining	2
1.2.1 Studies on Resource Consumption.....	2
1.3 History of Trayless Dining at Michigan Tech University.....	3
1.4 Goals of this Thesis.....	4
1.5 Description of Study site.....	4
1.6 Life Cycle Assessment.....	5
2 Methods	9
2.1 Introduction and Experiment Design	9
2.1.1 Tableware and Trays	11
2.1.2 Electricity	11
2.1.3 Water	11
2.1.4 Food Consumption and Waste	11
2.1.5 Steam Measurements	12
2.2 Experimental Procedures	13
2.2.1 Pilot Test	13
2.2.2 Determine Optimum Length for Full Scale Experiment.....	14
2.2.3 Full-Scale Experiment.....	15

2.2.4	Life Cycle Assessment and Cost.....	16
2.2.4.1	Identifying the Inventory Data	16
2.2.4.2	Determine the life cycle impact/cost assessment of life cycle inventory data.....	17
2.2.4.3	Interpreting the results of life cycle impacts assessment.....	18
2.3	Limitations and Assumptions.....	18
3	Data Analysis and Discussion	19
3.1	Pilot Test	19
3.1.1	Tableware Use.....	19
3.1.2	Food Consumed and Wasted.....	20
3.1.3	Water, Electricity, and Steam Consumption	22
3.2	Determining Optimum Length for the Full-Scale Experiment	24
3.3	Full-Scale Experiment.....	26
3.3.1	Dinner Plates and Dishwashing Glass Rack	27
3.3.2	Food Waste from Pre-rinse and Pan Washing Area.....	28
3.3.3	Food Prepared, Unserved, and Consumed	31
3.3.4	Dishwashing Machine Water Consumption.....	33
3.3.5	Steam.....	34
3.3.6	Electrical Data.....	35
3.4	Life Cycle Cost Analysis	36
3.5	Environmental Impact Analysis.....	37
4	Conclusion	41
5	References.....	43
	Appendix A Sample Calculation	45

Appendix B Pilot and Full Scale Experiment Raw Data	47
Appendix C SimaPro Software Parameters Description	50
Appendix D Survey of Students Attitudes for Trayless Dining	51

List of Figures

Figure 1.1 Life cycle assessment	6
Figure 1.2 General system boundary for the study	7

List of Tables

Table 2.1 Changed parameters.....	10
Table 3.1 Count of tableware and number of diners during the first pilot test	19
Table 3.2 Data for food prepared, served, consumed, and waste from the first pilot test	21
Table 3.3 Water, electricity, and steam consumption for the second pilot test	22
Table 3.4 Sample size determination for the full-scale experiment.....	25
Table 3.5 Number of diners during the full-scale experiment	27
Table 3.6 Dinner plates used during the full-scale experiment	27
Table 3.7 Dishwashing glass rack used during the full-scale experiment	28
Table 3.8 Food waste from the pre-rinse area for the full-scale experiment	29
Table 3.9 Food waste from the pan washing area for the full-scale experiment	30
Table 3.10 Prepared food for the full-scale experiment	31
Table 3.11 Unserved food for the full-scale experiment	32
Table 3.12 Food consumed results for full-scale experiment	32
Table 3.13 Dishwasher machine water consumption for the full-scale experiment	34
Table 3.14 Steam consumption in the full-scale experiment.....	35
Table 3.15 Dishwasher electrical consumption data for the full-scale experiment	36
Table 3.16 Life cycle cost analysis	37
Table 3.17 Environmental impact analysis by using the IPCC 2007 GWP 100a method	38
Table 3.18 Environmental impact analysis by using the cumulative energy demand method.....	39
Table B. 1 Second pilot test water consumption raw data.....	47
Table B.2 Second pilot test electrical consumption raw data	48

Table B. 3 Full-scale experiment dishwashing machine electrical consumption raw data	
.....	48
Table B. 4 Full-scale experiment water consumption raw data.....	49
Table D. 1 Survey results.....	51

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Abstract

Universities in the United States are applying more sustainable approaches to their dining service operations. "The increase in social consciousness and environmental stewardship on college campuses has spurred an array of new and innovative sustainability programs"(ARAMARK Higher Education 2008). University residence dining is typically cafeteria style, with students using trays to carry food. Studies report that food served without trays substantially reduces food waste and water and electrical consumption associated with washing trays. Commonly, these reported results are estimates and not measurements taken under actual operating conditions.

This study utilizes measurements recorded under actual dining service conditions in student residence halls at Michigan Technological University to develop the following: 1) operational-specific data on the issues and potential savings associated with a conversion to trayless dining and 2) life cycle assessment (LCA) cost and environmental impact analyses comparing dining with and without trays. For the LCA, the entire life cycle of the system is considered, from the manufacturing to the usage and disposal phases.

The study shows that trayless dining reduces food waste because diners carry less food. The total savings for the diner shifts when not using trays for the standard academic year (205 days), with an average number of 700 diners, is 7,032 pounds of food waste from the pre-rinse area (33% reduction) and 3,157 pounds of food waste from the pan washing area (39% reduction). In addition, for each day of the study, the diners consumed more food during the trayless portion of the experiment. One possible explanation for the increased food consumption during this short duration study could be that the diners found it more convenient to eat the extra food on their plate rather than carrying it back for disposal. The trayless dining experiment shows a reduction in dishwasher water, steam, and electrical consumption for each day of the study. The average reduction of dishwasher water, steam, and electrical consumption over the duration of the study were 10.7%, 9.5%, and 6.4% respectively. Trayless dining implementation would result in a decrease of 4,305 gallons of consumption and wastewater discharge, 2.87 mm BTU of steam consumption, and 158 kWh of electrical

consumption for the dinner shift over the academic year. Results of the LCA indicate a total savings of \$190.4 when trays are not used during the dinner shift. Trayless dining requires zero CO₂ eq and cumulative energy demand in the manufacturing stage, reductions of 1005 kg CO₂ eq and 861 MJ eq in the usage phase, and reductions of 6458 kg CO₂ eq and 1821 MJ eq in the end of the life cycle.

1 Introduction

1.1 Background

Universities in the United States are applying more sustainable approaches to their dining service operations. "The increase in social consciousness and environmental stewardship on college campuses has spurred an array of new and innovative sustainability programs" (ARAMARK Higher Education 2008). The environmental performance of dining services is also increasing worldwide due to the administrators and students' positive attitudes toward the environment. A high percentage of students reside on campus and eat in campus dining halls (Upcraft and Schuh 1996), so increasing the sustainability of these operations could result in significant savings.

Dining service providers at universities are implementing green initiatives, such as biofuel generation from used cooking oil, food composting, trayless dining, recycled napkins, green chemicals, among others. University residence dining is typically cafeteria style with students using trays to carry food. Studies have shown that serving food without trays substantially reduces food waste and consumption and water and electrical consumption associated with washing trays; based on published data, a number of universities are implementing trayless dining.

The most commonly referenced study by ARAMARK provides substantive data on food waste reduction, but their estimates for other types of savings, e.g., water and electricity are questionable. For example, "ARAMARK determined that on average, a tray conservatively requires one-third to one-half gallon of water to wash" (ARAMARK Higher Education 2008). There may be little or no correlation between how much water it takes to wash a tray and the savings realized in dining operations. In addition, the director of Dining Services at Michigan Technological University, Robert Hiltunen, has attended many food service conventions. According to him, many attendees quoted the same results and figures for water savings, which came from the ARAMARK study (Hiltunen 2009). The only way to obtain accurate values for water savings is to physically measure water consumption under actual cafeteria conditions. In addition, none of the studies utilized life cycle analysis (LCA) to determine the overall costs of dining with trays and without trays. The other studies provide general details on dining operations, but fewer

details on the type of machine, number of diners, type of food served, and other factors. This study utilizes measurements recorded under actual dining service conditions. For the LCA, the entire life cycle of the system will be considered, including the manufacturing, usage, and disposal phases.

This study will provide a valuable comparison of the environmental impacts of dining with and without trays, but the results cannot be generalized to all cafeteria dining operations. The dishwasher in this study was the conveyer type with autosense rinse and an autostop conveyer. (With autosense rinse, water only sprays when dishes are passing through the dishwashing machine, and with autostop, the conveyer stops if no dishes are loaded for a five-minute period). If the dishwasher is a batch or conveyer type of dishwasher without autosense rinse and autostop features, the actual change in water and electricity use could vary widely. Nevertheless, because conveyer type dishwashers with autosense and autostop are common in large university dining service operations, the results will be broadly applicable. Even operational differences, such as the number of diners at the institution or the type of food served, could affect realized water and electricity use per diner, but these variations would generally not be significant. Michigan Tech Dining Services supported this study to provide definitive data for the University's dining operations.

1.2 Previous Studies Conducted on Trayless Dining

1.2.1 Studies on Resource Consumption

Trayless dining studies have been reported by several dining service companies, such as ARAMARK, Bon Appétit, and by universities, such as American University and Purdue University. However, these studies were not comprehensive in accurately measuring all changes. Most studies concentrated on electricity, water, or waste savings. For example, Bon Appétit, a dining management company provider for many universities in the U.S., conducted an experiment to determine the feasibility of trayless implementation at St. Joseph's College in Maine. The study showed a 20% reduction in total waste, which would result in significant reductions of methane generation for the land-filled waste (Bon Appétit 2009). American University conducted a trayless dining study in one of its dining halls (Terrace Dining Room), which showed a reduction in

waste and dish use during trayless dining. This study recommended implementation of trayless dining at American University (Sobecki 2009).

1.3 History of Trayless Dining at Michigan Tech University

In the fall semester of 2009, dining services at Michigan Technological University introduced and implemented trayless dining every Tuesday in its three residence halls: Wadsworth, McNair, and Douglass Houghton. However, because of adverse student reactions, such as diners throwing food on the floor, and harassment of the dining hall workers, the experiment was quickly discontinued.

ARAMARK Higher Education, a dining service provider, released a study on the social aspects and barriers to implementing trayless dining (ARAMARK Higher Education 2008). Information in this study is useful in understanding the students' reactions. Some common recommendations for implementing trayless dining are to start at the beginning of school year and provide students with information on the advantages of going trayless.

Subsequent to the fall 2009 experiment, the director of dining facilities at Michigan Tech, Mr. Robert Hiltunen, asked the Green Campus Enterprise to study the feasibility of implementing trayless dining in the residence halls during the spring 2009 semester. At Michigan Tech, students can enroll in "enterprise" classes that function as a consulting company to work on a project for a client. The Green Campus Enterprise works to reduce the University's carbon footprint, and it was well positioned to take on this project. The Green Campus students began work on the project by studying trayless implementation at other universities and surveying students in each of the Michigan Tech's dining halls regarding their opinions on trayless dining. (See Appendix D for further information on the survey.) One of the universities contacted for information on their previous trayless implementation was Grand Valley State University. Using information provided by Grand Valley and the data obtained from the surveys, the Green Campus students made the following recommendations to Mr. Hiltunen regarding trayless dining implementation:

- 1.) Widely publicize the change to trayless and provide students with data on why trayless dining makes sense.

- 2.) Conduct an actual experiment at Michigan Tech comparing dining with trays and without trays.
- 3.) Initiate the trayless dining program at the start of a new academic year.
- 4.) As indicated in the survey, student reactions to trayless dining are favorable, with the overall survey results indicating that 31% of respondents were in favor of a complete switch to trayless, 23% of the respondents were in favor of trayless sometimes, and 46% responded they did not want to go trayless.
- 5.) There is no need to change the standard tableware currently used at Michigan Tech when switching to trayless dining.

Mr. Robert Hiltunen accepted the recommendations, including the suggestion to conduct the experiment at Michigan Tech. The decision was made to conduct the project as part of a master's thesis. Mr. Robert Hiltunen will use the results of this experiment in deciding whether to implement trayless dining at the University.

1.4 Goals of this Thesis

A variety of goals of this thesis relate to environmental issues, but two primary goals exist. One can be generalized to a wide variety of educational and non-educational institutions and the other is specific to Michigan Tech as follows:

1. Conduct a life cycle assessment (LCA) and cost analysis of trayless and tray dining. The results of this study can be utilized by a broad range of educational and non-educational institutions to facilitate decisions related to green dining.
2. Provide Michigan Tech dining services with data specific to their operations, which can be used to make a determination regarding trayless dining implementation.

1.5 Description of Study Site

There are three main residence halls at Michigan Tech, Wadsworth, McNair, and Douglas Houghton, each with an integral dining facility. Based on recommendations by dining service director Mr. Robert Hiltunen, Wadsworth Hall was chosen as the optimum study site. Wadsworth Hall is the largest dining hall on campus and receives the largest

number of diners. During the trayless dining experiment, all dining halls at Michigan Tech were trayless, but the measurements were taken only at Wadsworth Hall during the dinner shift. The hours of operation of the Wadsworth Hall dinner service shift typically started Monday through Friday at 4:00 p.m. and ended at 6:30 p.m., and Saturday and Sunday the hours were from 4:00 p.m. to 7:30 p.m.

Food prepared in the Wadsworth Hall kitchen is served cafeteria style with students returning dishes to a centralized wash location. Once the dirty dishes enter the wash area, they are manually pre-rinsed and then loaded in the dishwashing machine. The dishwashing machine is a Hobart model PTM-824BD-7-8-9. The machine is a conveyer style machine with autosense rinse and autostop features. The autosense only sprays water when dishes are loaded into the dishwashing machine. When the dishwasher is idle (no dishes are loaded), the conveyer and pumps automatically shut off.

1.6 Life Cycle Assessment

According to Allen and Shonnard, “products, services, and processes all have a life cycle. For products, the life cycle begins when raw materials are extracted or harvested. Raw materials then go through a number of manufacturing steps until the product is delivered to a customer. The product is used, then disposed of or recycled” (Allen and Shonnard 2002). Figure 1-1 shows the life cycle stages in which emissions and wastes are generated and raw materials and energy are consumed.

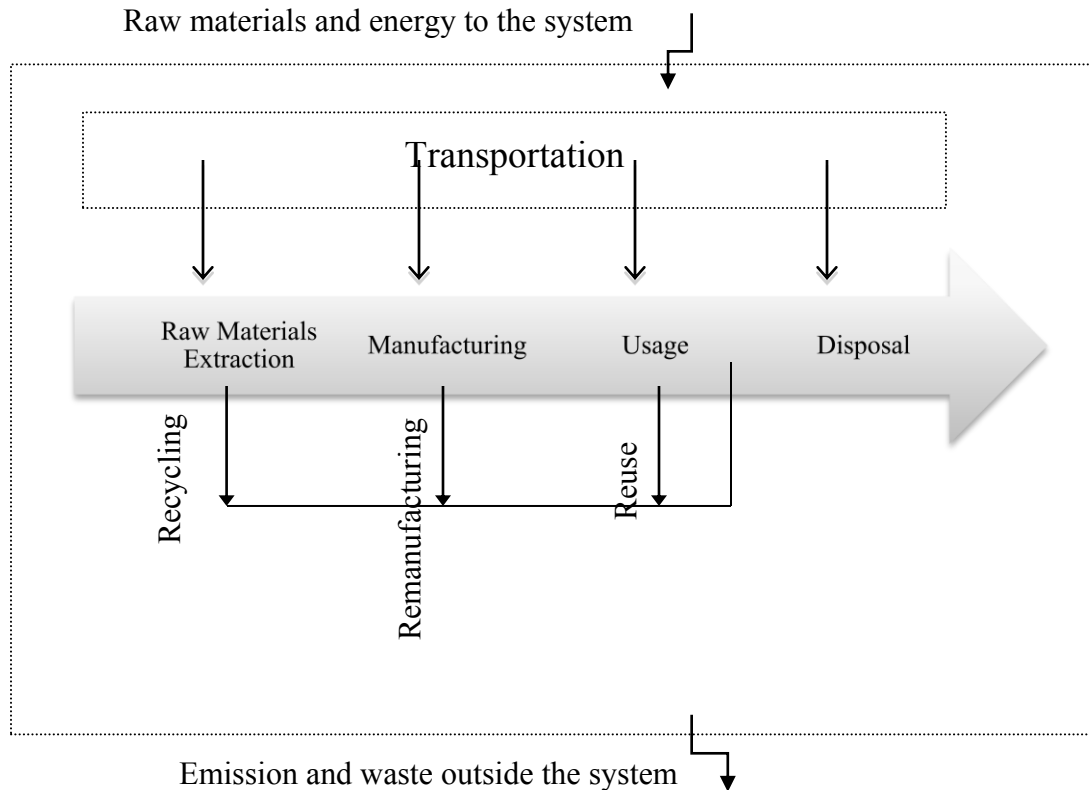


Figure 1.1: Life cycle assessment

With LCA studies there are four main steps to the process (Allen and Shonnard 2002):

1. Defining the goals and boundaries of the experiment and identifying the functional unit;
2. Identifying the inventory data;
3. Assessing life cycle impacts; and
4. Interpreting the results of life cycle impacts assessment.

Step 1 is defining the goal, boundary condition, and functional unit. The goal of this study is to compare the life cycle costs of dining with and without trays and to provide decision makers with a planning tool related to trayless dining. The boundary condition is defined as —simply the limits placed on data collection for the study”(Allen and Shonnard 2002). The system boundary for this study encompassed the dishwashing area at Wadsworth Hall dining operation. Data used in the LCA was a limited set of the

inputs and outputs from this system. This study conducted a limited life cycle assessment and did not account for all the inputs and outputs from the dining hall. This study will account for the most important parameters that had significant changes in values. For example, the electricity needed to light the entire dining hall is the same when dining with trays or without trays, so the LCA was accounted for it. Figure 1-2 illustrates the general system boundary for this study. The green dotted line is the system boundary for this study. Inputs and outputs to the system are indicated by arrows entering or exiting the system respectively.

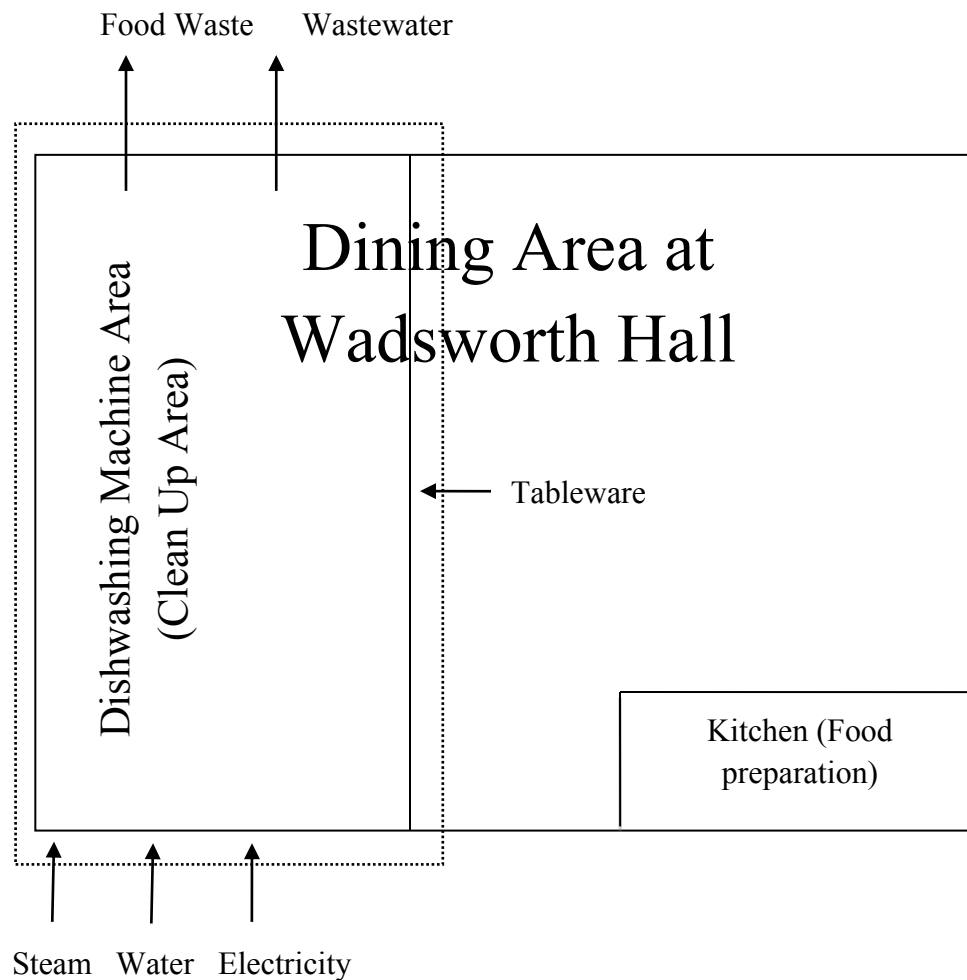


Figure 1.2: General system boundary for the study

Further, it is important to define the functional unit of this experiment. The functional unit can be defined as the service delivered by the product system, which in this case is one dinner meal.

Step 2 is identifying the inventory data. The inventoried data are the inputs (e.g., dishes and water consumption) and the outputs (e.g., food waste) for the system.

Step 3 "in a life cycle assessment is to assess the environmental impacts of the inputs and outputs compiled in the inventory" (Allen and Shonnard 2002). A computer program was used to assess the environmental impact analysis, which will be discussed further in the method section below.

Step 4 is to interpret the results of life cycle impacts assessment. "It comprises of three main elements:

- Identification of the significant issues based on the results of the LCI and LCIA phases of a LCA.
- Evaluation of results, which considers completeness, sensitivity, and consistency checks.
- Conclusions and recommendations.

The aim of the interpretation phase is to reach conclusions and recommendations in accordance with the defined goal and scope of the study. Results from the LCI and LCIA are combined together and reported in order to give a complete and unbiased account of the study. The interpretation is to be made iteratively with the other phases" (Tosca 2011).

2 Methods

2.1 Introduction and Experiment Design

During the initial planning and execution phases, meetings were held with Robert Hiltunen, the Michigan Tech director of dining services, and William Hall, the associate director of residential dining. The meetings were conducted to identify the dining facility's expectations for the project, to analyze relevant aspects of the dining operations, to obtain input on the timing and design of the project, and to discuss funding for instrumentation required to run the tests.

The data required to address the dining facilities' expectations for the project, as identified in these meetings, closely paralleled the data needed to develop the LCA. Developing the LCA of dining with and without trays and developing data specific to Michigan Tech to assess trayless dining implementation were previously identified in the Introduction section as primary goals 1 and 2. Data required to achieve goals 1 and 2 are similar and consist of dining operations parameters expected to change when switching to trayless dining. For example, water consumption for the dishwashing machine would be expected to change, but the power required to light the dining area would not change. Both of these cross the LCA system boundary, but because the power to run the lights will not change, it is not measured or considered in the LCA. Values for the parameter that change (hereafter "changed parameters") will be measured during dining service operations with and without trays for use with the LCA, goal 1, and to develop the Michigan Tech specific data, goal 2. In collaboration with dining services personnel, a comprehensive listing of changed parameters was identified. Along with identifying these parameters, a technique for measuring each parameter was developed. Table 2.1 identifies the changed parameters, the method for measuring each parameter, and the timing of these measurements.

Table 2.1
Changed parameters

Changed Parameters	Measurement Procedures	Timing
Number of Diners	At the end of each dinner shift, one of the dining hall supervisors supplied the data.	Number of diners was recorded based on the number of swipe cards.
Tableware and Trays	All counting was by hand tally counters. Counts were taken at 30-minute intervals until the end of the shift. For more details refer to the next section.	Start: beginning of dinner service End: when workers finished cleaning dishes.
Food waste	Food waste was measured by weighing the waste receptacle bags. For more details refer to the next section.	When workers finished cleaning dishes
Amount of food consumed	The following equation was used to determine the consumed food in pounds Consumed food = prepared food - unserved food - waste food. For more details refer to the next section.	When dining services stopped serving students
Table cleaning and amount of water in wash buckets(buckets are filled with water to clean the dining hall tables)	Buckets were assigned to the worker with a known volume. Each time the worker fills the bucket, he/she recorded the filling time with the assigned volume.	When dining services stopped serving students
Floor cleaning	The crew supervisor recorded time for each worker and provided data.	When dining services stopped serving students
Electricity	Electrical meters installed in dining and dishwashing area. Details are provided in subsequent section	Start: beginning of dinner service End: when workers finished cleaning dishes.
Water	Water meters were installed in dishwashing area. Details provided in the subsequent section.	Start: beginning of dinner service End: when workers finished cleaning dishes.
Steam to heat the water	Details on procedures are provided in the subsequent section.	Start: when serving students in the dinner shift End: when workers finished cleaning dishes.

2.1.1 Tableware and Trays

The tableware and trays were counted using hand tally counters as the items were loaded into the dishwashing machine. Subtotals were recorded at 30-minute intervals. Two people were involved in the counting procedure; one counting the tableware items and the other recording the time. The types of tableware, which were accounted for in this study are provided in sections 2.2.1 and 2.2.3.

2.1.2 Electricity

Two electricity meters were installed at Wadsworth Hall for continuous reading of electricity consumption. One meter (Veris Industries model 8036) measured the electricity for the entire dining area, and the other meter (Veris Industries model 8035) measured the electrical consumption of the dishwasher. The meters stored the kWh readings at 15-minute intervals in digital files that were later accessed later to determine the electrical consumption during the dinner shift.

2.1.3 Water

Three water meters were installed at Wadsworth Hall to measure the dishwasher's cold water consumption (Badger Meter Model RCDL 70), hot water consumption (Badger Meter Model RCDL 70), and pre-rinse area consumption (Badger Meter Model RCDL 25). A single meter was used in the pre-rinse area to measure the mixed (hot and cold) water. The meters readings were recorded manually at 30 minutes intervals.

The dishwashing machine tanks were drained at the end of each meal and filled prior to the next meal. Fill volume for the tanks was 120 gallons; therefore, a total of 360 gallons were used to fill the tanks each day. The fill volume was not considered in this study because the same procedure was followed with and without trays.

2.1.4 Food Consumption and Waste

Wadsworth Hall uses self-serve cafeteria style dining. This study measures only the quantities of main dish items. Main dish items for each day are identified as a footnote in the results section. Side dish food items from the salad bar, dessert area,

beverage area, the self-cooking area, and french fries and hamburgers were excluded from the food measurement because they represent only a small portion of the food consumption and waste by diners (Hiltunen 2009). Main dishes in Wadsworth Hall are served in pans. The workers weighed the food in two sample serving pans for each main dish item, and the average of these values was used in calculating the total amount served for each main dish item. Unused pans of main dish food items were refrigerated for later use. At the end of the dinner shift, food from partially full pans was discarded. In addition, the shift manager prepared a production sheet after each dinner that provided data on the weight of each main dish prepared and the amount refrigerated for later use.

The two sources of food waste are uneaten food that the students return to the dishwashing area, and unserved food remains from empty and partially empty serving pans. The two sources of food waste were measured using a scale. The weight of the main dish consumed food was calculated using the following equation:

$$\text{Consumed Food (lbs)} = \text{Prepared Food (lbs)} - \text{Unserved Food (lbs)} - \text{Waste Food (lbs)}$$

Eq. 1

Discards of the side dishes (e.g., hamburgers and french fries) were included in the total weight of the waste food, but they were not included in the weight of the prepared or the unserved food. Because the measured waste food included some contribution from side dishes, the previous equation underestimated the actual quantity of main dish consumed food.

2.1.5 Steam Measurements

Steam, generated at the natural gas fired central heating plant, is used for heating domestic water at Wadsworth Hall. Energy losses associated with water heating arise from the generation of steam from natural gas, heat loss through steam piping from the central heating plant, and heating the water with steam. This study does not account for these losses. Steam consumption to heat water for the pre-rinse and washing machine can be determined using Equation 2:

$$\text{Steam Consumption} = \text{Gallons of Water Consumed} * \frac{8.43 \text{ lbs}}{\text{gallon}} * \frac{(\text{Temperature}_{\text{final}} - \text{Temperature}_{\text{initial}})}{1,000,000}$$

Eq.2

where the steam consumption is in units of mmBTU (one million BTUs). The water consumption was determined from the dishwasher water meter readings in gallons. The initial temperature was taken in degrees Fahrenheit directly from the tap water using a thermometer. The final temperature was taken in degrees Fahrenheit directly from the dishwashing machine's water temperature display.

2.2 Experimental Procedures

The procedures for this experiment can be broken down into four main phases as follows:

1. Pilot test.
2. Determine optimum length for full-scale experiment.
3. Full-scale experiments.
4. Life Cycle Assessment and cost analysis.

2.2.1 Pilot Test

A pilot test was conducted first to assess the selected measurement protocols, such as the counting methods for tableware and trays and metering of water and electrical consumption, and to obtain data used to determine the optimal length for the full-scale experiment. The pilot test was conducted at the diner shift for five days (Tuesday, October 26, through Saturday, October 30, 2010) under normal operating conditions, i.e., trays were used. These five days were selected because they were typical dining days with no breaks or vacation days. The students were not aware of the pilot test because it occurred during normal operating conditions and the individuals performing the counting were in the enclosed dishwashing area. Changed parameters measured during the pilot were those listed previously in Table 2.1. For tableware, the following were counted: trays, dinner plates, 10-oz. bowls, 12-oz. bowls, salad bowls, dessert plates, dishwasher glass racks (each rack holds 25 glasses), ketchup plates, and cereal bowls.

Two of the changed parameters identified previously in Table 2.1—time and amount of water for table cleaning and time for floor cleaning—were not measured during the pilot test. These two parameters were omitted because the floor and tables must be cleaned whether the floor is clean or not, and the time taken to clean floor and table were the same as the regular dining days.

During the pilot test, a malfunctioning valve in the dishwasher resulted in erroneous water consumption readings. This necessitated a second pilot test during the dinner shift for seven days (Tuesday, December 7, through Monday, December 13, 2010) to obtain dishwasher consumption data. This second test measured only water, steam, and electrical consumption.

2.2.2 Determine Optimum Length for Full-Scale Experiment

A statistical approach was used to determine the minimum number of days the full-scale experiment (with and without trays) could be run to provide accurate results. The method selected for this analysis involved the use of an online statistics calculator (Dimension Research 2005) to determine the confidence interval around the mean. Data input to the calculator were as follows: 1) the sample size, 2) the mean of the sample, 3) the standard deviation of the sample, and 4) the selected confidence level (90%). The mean and standard deviation, calculated using Microsoft Excel, associated with data measured during the pilot tests for each of the changed parameters listed in Table 2.1 were input to the calculator and the sample size (number of days to run the full-scale experiment) was adjusted until an appropriate confidence interval around the mean was obtained. The confidence interval was considered appropriate when the upper and lower range for the true population mean (i.e., mean + confidence interval value and mean) were within the range $0.9 * \text{mean}$ and $1.10 * \text{mean}$. For example, if the calculated upper range for the true population mean of a particular parameter was more than $1.10 * \text{the mean}$, then the sample size (number of days to run the full-scale experiment) would be increased.

Because data recorded during the pilot test was unique to each changed parameter, these statistical analyses yielded a range of values for the minimum days to run the full-scale experiment. Values for the number of days to run the experiment,

tabulated in the results section, ranged from three days to more than 150 days. A meeting was scheduled with representatives of Michigan Tech Dining Services to discuss the duration of and to select dates for the full-scale experiment. Because of practical limitations on the length of the trayless portion of the full-scale experiment, the Dining Services representatives were asked to identify the changed parameters that they deemed significant for the experiment. Those selected were water and electricity consumption, food consumed, and the number of trays and dinner plates used. For the changed parameters of interest to Dining Services, the minimum length of time to run the experiment was six days, and this met the time limitations for the trayless portion imposed by Dining Services.

2.2.3 Full-Scale Experiment

The full-scale experiment was conducted at Wadsworth Hall dining area during the dinner shift for two six-day periods. Tuesday, February 15, through Sunday, February 20, 2011, were the dates of the first portion of the experiment, with trays, and Tuesday, March 29, through Sunday, April 3, 2011, were the dates of the trayless portion of the experiment. The selected dates represent typical dining days, i.e., no special student events or breaks were scheduled. Further, the same main dishes were served on the corresponding days for the tray and trayless portions of the experiment. Based on the results of the pilot tests, measurements were recorded for only a subset of the changed parameters identified in Table 2.1.

Measurements were recorded for electricity, steam, and water consumption for dishwashing, food preparation, food waste, and cleaning of trays, dinner plates, and glassware. Measurement procedures for these parameters followed the protocols used during the pilot tests.

Meetings were held with Dining Services personnel to plan other aspects of the full-scale experiment. During the first portion of the full-scale experiment, i.e., with trays, standard dining practices were followed, so no special planning was needed. For the trayless portion of the experiment, plans were developed for informing the students in advance, minimizing negative reaction from the students, and conducting operations at the two other University residence hall dining facilities. Prior research (see the social

analysis section in Appendix D) indicated that the best approach in changing to trayless operations was to inform the students in advance regarding why the change was being made and to do so in a conspicuous manner. Dining Services followed this advice and advertised the trayless portion of the full-scale experiment with large posters and flyers identifying the need for the experiment and explaining its limited duration

Some adverse reactions from students regarding tray removal were anticipated, so in an effort to minimize those reactions, an ice cream social was held at the conclusion of the experiment to thank students for their cooperation. The site for this experiment was Wadsworth Hall dining area, but during the trayless portion of the experiment, trays were also removed from the dining facilities at the two other University residence halls. The same posters and flyers were displayed at all three dining halls, but the students were not informed that measurements were being taken only at Wadsworth Hall.

2.2.4 Life Cycle Assessment and Cost

The typical phases for an LCA were discussed in the previous Introduction Section. The goals, functional unit, and boundary of the experiment were identified and discussed in Section 1.6. For the reader's convenience, the system boundary and functional unit identified previously are redefined here. The system boundary for this study will encompass the dishwashing area at Wadsworth Hall dining operation. The functional unit is defined as one dinner meal served. Therefore, for the LCA, the values measured in the experiments for changed parameters were normalized by the number of diners.

2.2.4.1 Identifying the Inventory Data

For this step, the inputs and outputs to the system are identified and quantified. As this is a limited LCA, only a subset of the inputs and outputs to the system are considered. The inputs to the system measured in the full-scale experiment consist of electricity, steam, and water consumption for dishwashing, and trays, dinner plates and glassware used. Prepared and consumed food was measured during the full-scale experiment, but these data were analyzed to inform Dining Services. Prepared and

consumed food does not cross the system boundary, so it will not be included in the LCA. The outputs from the system are food waste and wastewater.

Related information for these data inputs and outputs include the primary constituents in the fuel mix to generate the electricity are coal 69.4%, and nuclear 23.9% (UPPCO 2011); tap water is the dishwashing water source; the tray material is fiberglass (Cambro Manufacturing Company 2011); and the plate material is fiberglass (Carlisle FoodService Products 2011). The weight of the trays and plates were determined using a laboratory balance.

2.2.4.2 Determine the Life Cycle Impact/Cost Assessment of Life Cycle Inventory Data

All of the inventory results data were grouped into different environmental impact categories, such as global warming and the cumulative energy demand, using SimaPro software (Product Ecology Consultants 2010). SimaPro software was utilized to run the environmental impact analyses. The environmental impacts of each inventory element were quantified using the impact assessment tools, including the IPCC 2007 GWP 100a and Cumulative Energy Demand (CED), which are available in SimaPro. IPCC 2007 GWP 100a was used to determine the total green house emissions with a unit of kg CO₂ eq. The life cycle impacts assessment consists of manufacturing, usage, and end life cycle phases. The manufacturing phase of this study includes raw materials, electricity, air emissions, and water emissions associated with the manufacturing of the trays and plates. The usage phase of this study includes the water and electrical consumption, and steam consumption for the dishwashing machine. The end of the life cycle impact analysis includes the wastewater and food waste.

In addition to the LCA, dining services requested a cost analysis. This analysis considered the purchase cost of the trays and the usage cost for water, electricity, and steam consumed. The purchasing cost of the trays was provided by the Associate Director of Dining Services (Hall 2011). The electricity, water, and steam billing rates for Michigan Tech were provided by the University Energy Manager (Taivalkoski 2010).

2.2.4.3 Interpreting the Results of Life Cycle Impacts Assessment

Recommendations and suggestions will be provided to the decision makers through combining the results of the inventory analysis and the life cycle impact/cost assessment.

2.3 Limitations and Assumptions

1. This study considers only the electrical consumption for the dishwashing machine. Electricity to run the kitchen was not included because electricity consumed by other devices, e.g. lighting, within the system boundary is independent of tray use.
2. Forks, spoons, and knives were not counted because their use was considered independent of tray use and because of the difficulty in obtaining an accurate count.
3. Only a small fraction of students use coffee cups, so they were not included.
4. A small quantity of dirty dishes from the previous shift (prior to dinner) was held over to the dinner shift. These dishes and the related water and electricity consumption were not measured for this experiment.
5. The quantity of prepared food reported in this study was for main dishes only. Side dishes were ignored because they represent only a small portion of the food consumption and waste by diners. Food not considered included the salad bar, dessert food, beverages, french fries, hamburgers, and food prepared in the self-cooking area. The same main dish items were served for corresponding days of the tray and trayless experiments to provide a consistent basis for comparison.

3 Data Analysis and Discussion

3.1 Pilot Test

Pilot tests were conducted to assess the selected measurement protocols and to determine the optimal length for the full-scale experiment. The first pilot test was conducted in Wadsworth Hall dining area during the diner shift for five days (Tuesday, October 26, through Saturday, October 30, 2010). Due to a malfunctioning valve on the dishwashing machine, a second pilot test was required to measure water and electricity consumption. This test was conducted during the dinner shift for seven days (Tuesday, December 7, through Monday, December 13, 2010). This section will address the results from the pilot tests, including the count of the tableware used, the number of diners, food consumption and waste, and water and electrical consumption.

3.1.1 Tableware Use

Table 3.1 shows the tableware count and the number of diners for each day of the first pilot test.

Table 3.1
Count of tableware and number of diners during the first pilot test

	Tuesday	Wednesday	Thursday	Friday	Saturday
Trays	733	850	821	694	593
Dinner plates	789	913	1116	795	720
10 oz bowls	154	52	112	35	106
12 oz bowls	93	80	116	122	56
Salad bowls	398	487	440	413	283
Dessert plates	303	265	109	216	170
¹ Dishwashing glass rack	40	52	37	41	31
Catsup plates	33	133	15	89	172
Cereal bowls	33	35	30	35	20
# of diners	720	715	828	773	570
Notes: ¹ Each dishwashing glass rack contained 25 glasses.					

It is clear from Table 3.1 that, for most days, the number of trays and dinner plates used closely parallels the number of diners. Several possible explanations exist for

variation in the number of trays and the number of diners shown for some days. At times, students only come to eat dessert or drink coffee, and they do not use a tray. In addition, Dining Services workers can eat in the cafeteria for free and are not counted in the number of diners. Finally, some students, who go back for a second serving, pick up a new tray.

For all days, the number of dinner plates used exceeds the number of diners, as well as the number of trays. It is not uncommon, depending on the main dish served that day, for a student to take more than one plate. During the full-scale experiment, it will be interesting to see if the ratio of dinner plates to diners changes.

For the other types of tableware, the number of plates and bowls used was much lower than the number of diners. Also for most of these items, a high degree of variability is shown in the number used across the five days of the test and a poor correlation exists between the number of these items used and the number of diners.

3.1.2 Food Consumed and Wasted

Table 3.2 provides data from the first pilot test on food preparation, consumption for the main dish items, and the amount of food waste. Also identified are the main dish items for each day of the test.

Dining Services provided data on the amount of prepared and unserved food, and using these values, the amount served was calculated. The food waste from pans is the food scraped out of the empty or partially empty pans by the food service workers. Food waste from the pre-rinse area is the uneaten food that students return to the dishwashing area.

Table 3.2
Data for food prepared, served, consumed, and waste from the first pilot test

	¹ Tuesday	Wednesday	² Thursday	Friday	Saturday
Prepared food (lbs)	485	500	1165	831	775
Unserviced food (lbs)	40	48	276	16	126
³ Actual food served (lbs)	445	452	889	815	649
Food waste from pre-rinse area (lbs)	145.5	217	343	145	129
Food waste from pans washing area (lbs)	46.5	60	42	45	50
⁴ Consumed food (lbs)	253	175	504	625	470
# of diners	720	715	828	773	570
<p>Notes:</p> <p>¹Main dish items for each day were:</p> <ul style="list-style-type: none"> • Tuesday: Milwaukee cod, mixed sausage grill, waffle fries, corn • Wednesday: Chicken parmesan with meatballs, marinara sauce, garlic bread, sugar snap peas • Thursday: Chicken hot wings, chili nachos, maggot casserole, spilled guts, and fresh corn ears • Friday: Fish, BBQ pork chops, veggie dumplings, steak fries, mixed vegetable • Saturday: Burger bar, wildfire wings, onion rings, and corn <p>²Thursday was a Halloween special dinner. The food names reflect the Halloween customs, such as maggot casserole and spilled guts.</p> <p>³Actual served = prepared food – unserved food.</p> <p>⁴Consumed food = prepared food – unserved food – food waste from pre-rinse area – food waste from pan washing area.</p>					

The amount (weight) of food prepared depends on the popularity of the main dish and the inedible components. For example, on Thursday, the amount of main dish prepared was much greater than other days, but the chicken bones and corncobs, which are inedible, would add weight. Dining services uses data from previous consumption to determine the amount to prepare. Because of these differences in the amount of main dish prepared and served, it is important that the same main dishes be served on corresponding days of the tray and trayless full-scale experiment.

The weight of food waste from the pre-rinse area, show in Table 3.2, is the major constituent of total food waste. Because the students control how much is returned uneaten, analyzing whether the amount changes when switching from trays to trayless will prove interesting.

The consumed food shown in the table was calculated as served food minus the sum of the food waste from pans and pre-rinse. Because discards from the side dishes

were included in the weight of the waste food, but not included in the weights of the prepared or the unserved food, the actual weight of consumed food would be greater than indicated in the table.

3.1.3 Water, Electricity, and Steam Consumption

Five meters were installed in the Wadsworth dining area to measure water and electricity consumption. Three water meters were installed on the dishwashing machine and the pre-rinse area. One electric meter measured consumption of the overall dining area and the second meter measured consumption of the dishwashing machine only. Because of the boundary condition selected for this study, only data for the dishwasher electrical consumption was used for this analysis. Steam generated on campus is used to heat the water. Steam consumption was calculated using measured water temperatures and the equation provided previously in the Method section above.

Table 3.3 shows the water, electricity, and steam consumption for the pre-rinse and dishwashing machine. The water and electricity consumption is the water and electricity meter reading at the end of the shift, minus the water and electricity meter reading at the start of the shift.

Table 3.3
Water, electricity, and steam consumption for the second pilot test

	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday	² Monday
³ Pre-rinse water (gal)	12.6	7.9	18	8	13.1	24.2	36.5
³ Dishwashing machine water (gal)	272	289	216	241	251	357	296.6
³ Electricity (kWh)	12.4	11.7	10.3	15	17.7	17.8	13.6
¹ Steam (mmBTU)	0.20	0.21	0.16	0.18	0.19	0.27	0.22
# of diners	858	893	818	740	740	888	1154
Notes: ¹ mmBTU stands for one million BTUs. ² A special dinner was served on this day, which accounted for the large number of diners. ³ Raw data is provided in Appendix B.							

No direct correlation exists between the pre-rinse water consumption and the number of diners. For example, on Wednesday, the number of diners was 893 and pre-

rinse area water consumption was 7.9 gallons, while on Thursday, more than twice the water was consumed but there were only 818 diners. The data for Sunday shows an even greater variation. Workers manually spray the dishes for the pre-rinse and the workers rotate shifts throughout the week. Observation of the pre-rinse process over the duration of the experiment indicated the large variation in consumption was due to differences in rinse styles. Some workers completely rinse the dishes, whereas others only partially rinse.

The dishwashing machine water and steam consumption shows a much better correlation to the number of diners. The only day with a significant variation is Sunday. In addition to dishes, cooking pans were also washed in the dishwasher and account for some of the water usage.

A noteworthy event regarding the operation of the dishwasher machine occurred on Thursday of the pilot test. On this day, the worker made a conscientious effort to load the dishwasher in a manner that would minimize water and electricity consumption. The worker loaded the machine fully and turned off the conveyer when no dishes were loaded. This practice yielded reduced consumption of water and electricity, but the consumption was not dramatically different from other days, e.g., Tuesday. The lack of variation can be attributed to the automatic features of the dishwashing machine, which shuts off the water and conveyer when no dishes are present in the machine. At no time during the full-scale experiment did a worker conspicuously try to minimize water and electricity use.

The dishwasher water consumption indicated in Table 3.3 only accounts for water used in the dishwashing process. The dishwashing machine tanks are drained at the end of each meal, and they are filled prior to the next meal. Fill volume for the tanks is 120 gallons, so a total of 360 gallons were used for tank filling each day. The fill volume was not considered in this study because the same procedure was followed with and without trays.

3.2 Determining Optimum Length for the Full-Scale Experiment

A statistical calculator for the confidence interval around the mean was used to evaluate the minimum number of days required for the full-scale experiment. Data developed during the pilot experiments for food, tableware, electricity, and water were used in this analysis. A 90% confidence level and a range of $\pm 10\%$ around the mean were used in the calculations. Details for the calculation method were provided previously in the Method section above. Table 3.4 provides the results of calculations for the minimum number of days to run the full-scale experiment for each of the parameters measured during the pilot tests. Values for the mean and standard deviation presented in the table were calculated by first normalizing the raw data for each day of the pilot test by the number of diners and then calculating the mean and standard deviation. For example, to calculate the mean and standard deviation for the trays in Table 3.4, the number of trays measured during each day of the first pilot test was divided by the corresponding number of diners (See Table 3.1). These normalized values for each day of the test were then averaged to develop the mean, and then the standard deviation was calculated. The raw data was normalized for two reasons: to provide better data consistency (lower values for standard deviation) and the functional unit defined previously in the methods section for the LCA is one dinner meal.

Table 3.4
Sample size determination for the full-scale experiment

	² Standard deviation normalized data	Mean normalized data	Number of days required for full-scale experiment (days)
Trays	0.11	1.03	3
Dinner plates	0.13	1.20	3
10 oz bowls	0.07	0.13	65
12 oz bowls	0.02	0.13	7
Salad bowls	0.07	0.56	12
Dessert plates	0.11	0.30	30
Dishwashing glass rack	0.01	0.06	5
Catsup plates	0.11	0.13	150
Cereal bowls	0.01	0.04	More than 150 days
Pre-rinse area water consumption (gal)	0.01	0.02	More than 150 days
Dishwasher water consumption, (gal)	0.05	0.32	6
Dishwasher electricity (kWh)	0.55	4.77	3
¹ Steam (mmBTU)	N/A	N/A	N/A
Food waste from pre-rinse area (lbs)	0.09	0.27	40
Food waste from pan washing area (lbs)	0.02	0.07	More than 150 days
³ Consumed food (lbs)	N/A	N/A	N/A
Notes: ¹ mmBTU stands for one million BTUs. ² The mean and standard deviation are based on the functional unit by dividing the value of each parameter in each day by the number of diners. ³ Steam and consumed food are omitted because they are calculated values and not measured values.			

The number of days required for the full-scale experiment to obtain accurate data for the various parameters ranged from three days to more than 150 days. After developing these data, a meeting was held with representatives of Michigan Tech Dining Services to select the duration of the experiment. Due to practical limitations, Dining Services requested that the full-scale experiment be run for no more than one week.

The parameters meeting this criterion were trays, dinner plates, 12-oz. bowls, dishwashing glass racks, and dishwashing machine electrical and water consumption. In

further discussions, Dining Services representatives indicated the following parameters were of significant interest for them in the full-scale experiment: water, steam and electricity consumption, food consumed and wasted, and the number of trays and dinner plates used. Based on the results of the statistical analysis and the input from Dining Services, the following parameters were selected for inclusion in the full-scale experiment: trays (during the portion of the experiment with trays), dinner plates, dishwashing glass racks, and dishwashing machine electrical, water and steam consumption, all of which met the one-week criteria, and food consumed and wasted, which were of interest to dining services.

3.3 Full Scale Experiment

The full-scale experiment was conducted at Wadsworth Hall dining area during the dinner shift for two six-day periods. Tuesday, February 15, through Sunday, February 20, 2011, were the dates of the first portion of the experiment, with trays, and Tuesday, March 29, through Sunday, April 3, 2011, were the dates of the trayless portion of the experiment. The dates selected were typical dining days, i.e., no special student events or breaks were scheduled. Further, the same main dishes were served on the corresponding days for the tray and trayless portions of the experiment.

An ice cream social was held at the end of the trayless portion of the experiment to thank the students for cooperation during the experiment. The head of Dining Services scheduled the social after the completion of the Sunday dinner service, but the ice cream was actually served during the meal. The extra dishes used with the ice cream could result in changes in values for some of the parameters measured, e.g., dishwasher water and electricity use, so the data for Sunday was not included in any of the overall calculations.

Table 3.5 shows the number of diners for the tray and trayless dining. Note the consistency in the number of diners for corresponding days of the tray and trayless experiment.

Table 3.5
Number of diners during the full-scale experiment

	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Trays dining (# diners)	714	788	700	645	671	840
Trayless dining (# diners)	708	756	725	574	663	825

3.3.1 Dinner Plates and Dishwashing Glass Rack

Table 3.6 and Table 3.7 show the dinner plates and dishwashing glass racks counted during the full-scale experiment. Both the total count and the ratio by diner are shown. Also included is the percentage change from tray to trayless with the calculations based on the ratio by diner.

Table 3.6
Dinner plates used during the full-scale experiment

	Dinner plates				
	Trays dining		Trayless dining		
Days	Count	Ratio by diner	Count	Ratio by diner	¹ Percentage change based on the ratio by diner (%)
Tuesday	927	1.30	746	1.05	-19.2
Wednesday	951	1.21	832	1.10	-9.1
Thursday	928	1.33	1019	1.41	6.0
Friday	814	1.26	694	1.21	-4.0
Saturday	826	1.23	793	1.20	-2.4
² Sunday	1058	1.26	886	1.07	-15.1
³ Average value		1.26		1.17	-7.1
Notes: ¹ Percentage change is calculated by (Ratio by diner trays dining – Ratio by diner trayless dining)/(Ratio by diner trays dining) *100 ² Sunday is excluded from the overall percentage change analysis because of the ice cream social. The ice cream social was held at the conclusion of the experiment to thank the students for their cooperation. ³ The averaged value is based on the ratio by diner because of the functional unit of this study.					

Table 3.7
Dishwashing glass rack used during the full-scale experiment

Days	¹ Trays dining	Trayless dining	² Percentage change based on the ratio by diner (%)
Tuesday	33	35	6.1
Wednesday	42	32	-23.8
Thursday	33	35	6.1
Friday	31	26	-16.1
Saturday	37	31	-16.2
³ Sunday	36	32	-11.1
Average value	35.33	31.8	-10.0
Notes: ¹ Overall number of glass racks. ² Percentage change is calculated by (Ratio by diner trays dining – Ratio by diner trayless dining)/(Ratio by diner trays dining) *100 ³ Sunday is excluded from the overall percentage change analysis because of the ice cream social. The ice cream social was held at the conclusion of the experiment to thank the students for their cooperation.			

Data in Table 3.6 and Table 3.7 indicate that the number of plates and glasses used by diners typically decreases when switching from dining with trays to dining without trays. During dining with trays, it was common for a student to have more than one dinner plate with food or glasses on their tray. With trayless dining, the students are still on average using more than one dinner plate per diner, but overall, there is a significant decrease in the number of plates and glasses used. The main reason for this decrease is that, without trays, diners were only taking one plate with food.

3.3.2 Food Waste from Pre-rinse and Pan Washing Area

Table 3.8 and Table 3.9 show the food waste from the pre-rinse and pan washing area for the full-scale experiment. The food waste from pans is the food scraped out of the empty or partially empty pans by the food service workers. Food waste from the pre-rinse area is the uneaten food that students returned to the dishwashing area. The total value and the ratio by diner are tabulated. Also included is the percent change in consumption based on the ratio by diner when converting from tray to trayless dining.

Table 3.8
Food waste from the pre-rinse area for the full-scale experiment

Food waste from pre- rinse area					
	Trays dining		Trayless dining		
Days	Total amount (lbs)	Ratio by diner (lbs/diner)	Total amount (lbs)	Ratio by diner (lbs/diner)	¹ Percent change based on the ratio by diner (%)
Tuesday	120	0.168	115	0.162	-3.6
Wednesday	150	0.190	142	0.188	-1.1
Thursday	115	0.164	79	0.109	-33.5
Friday	156	0.242	93	0.162	-33.1
Saturday	152	0.227	82	0.124	-45.4
² Sunday	165	0.196	155	0.188	-4.1
Total value	693	0.991	511	0.745	-24.8
³ Average value		0.198		0.149	-24.7
Notes: ¹ Percentage change is calculated by (Ratio by diner trays dining – Ratio by diner trayless dining)/(Ratio by diner trays dining) *100 ² Sunday is excluded from the overall percentage change analysis because of the ice cream social. The ice cream social was held at the conclusion of the experiment to thank the students for their cooperation. ³ The average value is based on the ratio by diner because of the functional unit of this study.					

Table 3.9
Food waste from the pan washing area for the full-scale experiment

Food waste from pan washing area					
	Trays dining		Trayless dining		
Days	Total amount (lbs)	Ratio by diner (lbs/diner)	Total amount (lbs)	Ratio by diner (lbs/diner)	¹ Percent change based on the ratio by diner (%)
Tuesday	34	0.048	29	0.041	-14.6
Wednesday	57	0.072	20	0.026	-63.9
Thursday	28	0.040	24	0.033	-17.5
Friday	35	0.054	28	0.049	-9.3
Saturday	47	0.070	16	0.024	-65.7
² Sunday	37	0.044	30	0.036	-18.2
Total value	201	0.284	117	0.173	-39.1
³ Average value		0.057		0.035	-38.6
Notes: ¹ Percentage change is calculated by (Ratio by diner trays dining – Ratio by diner trayless dining)/(Ratio by diner trays dining) *100 ² Sunday is excluded from the overall percentage change analysis because of the ice cream social. The ice cream social was held at the conclusion of the experiment to thank the students for their cooperation. ³ The average value is based on the ratio by diner because of the functional unit of this study.					

The study shows that trayless dining reduces food waste because diners are carrying less food. When dining with trays, students frequently take more food than they consume. Without trays, diners will take smaller amounts of food and consume most of what they do take. Another note to mention is the decreases in food waste from pan washing area because the average unserved food (See Table 3.11) decreased in the trayless dining experiment; diners consumed more food in the trayless dining experiment.

For each day of the test, there is a reduction of food waste when not using trays. Saturday yielded the greatest difference, with a savings of 0.103 pounds per diner from the pre-rinse area, which is a 45.4 % reduction in food waste, and 0.046 pounds per diner from the pan washing area, which is a 65.7 % reduction in food waste. The total savings for the dinner shifts only when not using trays for the standard academic year (205 days) with an average number of 700 diners would be 7,032 pounds of food waste from the pre-rinse area and 3,157 pounds of food waste from the pan washing area.

3.3.3 Food Prepared, Unserved, and Consumed

Dining Services provided data on the amount of prepared and unserved (prepared but unserved) food, and using these values, the amount served was calculated. Table 3.10, Table 3.11, and

Table 3.12 shows the prepared, unserved, and consumed food for the full-scale experiment. The total value and the ratio by diner are tabulated. Also included is the percent in change of consumption based on the ratio by diner when converting from tray to trayless dining.

Table 3.10
Prepared food for the full-scale experiment

Prepared food				
	Trays dining		Trayless dining	
Days	Total amount (lbs)	Ratio by diner (lbs/diner)	Total amount (lbs)	Ratio by diner (lbs/diner)
¹ Tuesday	345	0.48	350	0.49
Wednesday	715	0.91	700	0.93
Thursday	600	0.86	605	0.83
Friday	330	0.51	330	0.57
Saturday	507	0.76	473	0.71
² Sunday	584	0.70	623.8	0.76
³ Average value		0.70		0.71
Notes: ¹ Main dishes are: <ul style="list-style-type: none"> • Tuesday: Swedish meatballs, panko chicken, cut green beans, egg noodles, pesto sauce • Wednesday: Chicken strips, lasagna, seasoned redskins, corn, garlic bread • Thursday: Teriyaki chicken dippers, tacos, curly fries, broccoli • Friday: Buffalo chicken wings, fish, egg-roles, peas, tater tots • Saturday: Chicken fries, shrimp basket, mush Swiss burger, vegetable baked beans, pasta, chicken dippers ² Sunday is excluded from the overall percentage change analysis because of the ice cream social. The ice cream social was held at the conclusion of the experiment to thank the students for their cooperation. ³ The average value is based on the ratio by diner because of the functional unit of this study.				

Table 3.11
Unserved food for the full-scale experiment

Unserved food				
	Trays dining		Trayless dining	
Days	Total amount (lbs)	Ratio by diner (lbs/diner)	Total amount (lbs)	Ratio by diner (lbs/diner)
Tuesday	10.5	0.015	25	0.035
Wednesday	28.8	0.037	42.57	0.056
Thursday	93.6	0.134	38.10	0.053
Friday	3.3	0.005	7.7	0.013
Saturday	7	0.01	13.5	0.020
¹ Sunday	128	0.152	17.7	0.021
² Average value		0.042		0.035
Notes: ¹ Sunday is excluded from the overall percentage change analysis because of the ice cream social. The ice cream social was held at the conclusion of the experiment to thank the students for their cooperation. ² The averaged value is based on the ratio by diner because of the functional unit of this study.				

Table 3.12
Food consumed results for full-scale experiment

⁴ Consumed food					
	Trays dining		Trayless dining		
Days	Total amount (lbs)	Ratio by diner (lbs/diner)	Total amount (lbs)	Ratio by diner (lbs/diner)	¹ Percent change based on the ratio by diner (%)
Tuesday	180.5	0.253	181	0.256	1.2
Wednesday	479.2	0.608	495.4	0.655	7.7
Thursday	363.4	0.519	463.9	0.640	23.3
Friday	135.7	0.210	201.3	0.351	67.1
Saturday	301	0.449	361.5	0.545	21.4
² Sunday	254	0.302	421.1	0.510	68.9
Total value	1459.8	2.04	1703.1	2.45	20.1
³ Average value		0.407		0.489	20.2
Notes: ¹ Percentage change is calculated by (Ratio by diner trays dining – Ratio by diner trayless dining)/(Ratio by diner trays dining) *100 ² Sunday is excluded from the overall percentage change analysis because of the ice cream social. The ice cream social was held at the conclusion of the experiment to thank the students for their cooperation. ³ The average value is based on the ratio by diner because of the functional unit of this study. ⁴ Consumed food = prepared food - unserved food - food waste from pre-rinse area - food waste from pan washing area.					

Data from Table 3.13 indicates that for each day of the study the diners consumed more food during the trayless portion of the experiment. Further study would be required to identify the reason for the increased consumption, but it could be that the diners found it more convenient to eat the extra food on their plate instead of carrying it back for disposal. It would be interesting to determine if the increased consumption would continue after the students became acclimated to trayless dining.

The significant variations in the weight of consumed food for some of the days of the study are due, in part, to the popularity of the main dish and to the inedible components of the food—for example, chicken bones. As previously stated in the methods section, this study only accounted for main dish items. On days when the main dish served was less popular, students would eat more of the side dishes, such as the salad bar, french fries, hamburgers, and the self-cooking area.

3.3.4 Dishwashing Machine Water Consumption

Table 3.13 shows the dishwashing machine water consumption for the full-scale experiment. The total value and the ratio by diner were tabulated. Also included is the percent change in water consumption based on the ratio by diner when converting from tray to trayless dining.

Table 3.13
Dishwasher machine water consumption for the full-scale experiment

⁴ Dishwasher machine water consumption					
	Trays dining		Trayless dining		
Days	Total amount (gal)	Ratio by diner (gal/diner)	Total amount (gal)	Ratio by diner (gal/diner)	¹ Percent change in based on the ratio by diner (%)
Tuesday	147	0.21	130	0.18	-14.3
Wednesday	202.5	0.26	166	0.22	-15.4
Thursday	225	0.32	169	0.23	-28.1
Friday	205	0.29	175	0.32	10.3
Saturday	223	0.33	215	0.32	-3.0
² Sunday	296	0.35	310	0.37	-5.7
Total value	1002.5	1.41	855	1.27	-9.9
³ Average value		0.28		0.25	-9.9
Notes:					
¹ Percentage change is calculated by (Ratio by diner trays dining – Ratio by diner trayless dining)/(Ratio by diner trays dining) *100					
² Sunday is excluded from the overall percentage change analysis because of the ice cream social. The ice cream social was held at the conclusion of the experiment to thank the students for their cooperation					
³ The average value is based on the ratio by diner because of the functional unit of this study.					
⁴ Raw data is provided in Appendix B.					

Table 3.13 shows a decrease in dishwasher water consumption when converting to trayless dining for each day of the study. This decrease parallels the reduction in dishwasher electrical consumption. The average reduction of dishwasher consumption over the duration of the study was 9.9%. If trayless dining were implemented, this would result in a decrease of 4,305 gallons of consumption and wastewater discharge for the dinner shift over the academic year, based on 205 days of operation per year with an average of 700 diners.

3.3.5 Steam

Table 3.14 shows the steam consumption for the full-scale experiment. The total value and the ratio by diner are tabulated. Also included is the percent change in steam consumption based on the ratio by diner when converting from tray to trayless dining.

Table 3.14
Steam consumption in the full-scale experiment

Steam consumption					
	Trays dining		Trayless dining		
Days	¹ Total amount (mmBTU)	Ratio by diner (mmBTU)	Total amount (mmBTU)	Ratio by diner (mmBTU)	² Percent change based on the ratio by diner (%)
Tuesday	0.11	0.00016	0.01	0.00013	-15.2
Wednesday	0.15	0.00019	0.12	0.00016	-16.3
Thursday	0.17	0.00024	0.13	0.00017	-28.9
Friday	0.15	0.00022	0.13	0.00023	9.2
Saturday	0.17	0.00024	0.16	0.00023	-4.1
³ Sunday	0.22	0.00026	0.23	0.00027	4.6
Total value	0.75	0.00105	0.55	0.00092	-10.9
⁴ Average value		0.00021		0.00018	-10.9
Notes: ¹ mmBTU stands for one million BTUs. ² Percentage change is calculated by (Ratio by diner trays dining – Ratio by diner trayless dining)/(Ratio by diner trays dining) *100 ³ Sunday is excluded from the because of the ice cream social. The ice cream social was held at the conclusion of the experiment to thank the students for their cooperation. ⁴ The average value is based on the ratio by diner because of the functional unit of this study.					

Table 3.14 shows a decrease in steam consumption when converting to trayless dining for each day of the study, except for Sunday, which was not included in the analysis because of the unplanned ice cream social. Steam use decreases because of the reduced water consumption for the dishwashing machine. The average reduction of steam consumption over the duration of the study was 10.9%.

Based on the average results, the total savings when not using trays for the standard 205-day academic year with an average of 700 diners would be 2.87 mmBTU for the dinner shift.

3.3.6 Electrical Data

Table 3.15 shows the electrical consumption for the dishwasher during the full-scale experiment. Both the total value and the ratio by diner are shown. Also included is the percentage change in electrical consumption based on the ratio by diner when converting from tray to trayless dining.

Table 3.15
Dishwasher electrical consumption data for the full scale experiment

	⁴ Electrical consumption				
	Trays dining		Trayless dining		
Days	Total value (kWh)	Ratio by diner (kWh/diner)	Total value (kWh)	Ratio by diner (kWh/diner)	¹ Percentage change based on the ratio by diner (%)
Tuesday	10.9	0.0153	10	0.0141	-7.8
Wednesday	12	0.0152	11.2	0.0148	-2.6
Thursday	11.8	0.0169	10.6	0.0146	-13.6
Friday	12	0.0186	9.9	0.0172	-7.5
Saturday	13.2	0.0197	12.8	0.0193	-2.0
² Sunday	13.8	0.0164	9.9	0.0120	-26.8
Total Value	59.9	0.0857	54.5	0.0800	-6.7
³ Average value		0.0171		0.0160	-6.4
Notes: ¹ Percentage change is calculated by (Ratio by diner trays dining – Ratio by diner trayless dining)/(Ratio by diner trays dining) *100 ² Sunday is excluded from the overall percentage change analysis because of the ice cream social. The ice cream social was held at the conclusion of the experiment to thank the students for their cooperation. ³ The average value is based on the ratio by diner because of the functional unit of this study. ⁴ Raw data is provided in Appendix B.					

Table 3.15 shows a reduction in dishwasher electrical consumption for each day of the study when converting to trayless dining. The primary reason for the change is the reduction in tableware to be washed: trays, plates, glassware, etc. The overall percentage reduction for the study was 6.4%. If trayless dining were implemented, this would result in a decrease of 158 kWh for the dinner shift over the academic year based on 205 days of operation per year with an average of 700 diners.

3.4 Life Cycle Cost Analysis

This study accounted for purchasing cost along with usage cost. Mr. Hiltunen, the director of Michigan Tech Dining Services, provided the purchasing cost of the trays used in Wadsworth Hall. The electricity, water, and steam costs are based on current local bills at Michigan Technological University, which were obtained from Mr. David

Taivalkoski, Energy Manager at Michigan Tech. Table 3.16 shows the life cycle cost of the full-scale experiment.

Table 3.16
Life cycle cost analysis

	Price/ unit	Cost (\$/unit)	¹ Trayless dining (\$/205 days)	² Trays dining (\$/205 days)
Purchasing cost				
Purchasing trays	\$/tray	1.37	X	93.51
Usage cost				
³ Water	\$/gallon	0.01109	397.85	445.59
Electricity	\$/kWh	0.08	183.68	196.30
Steam	\$/mmBTU	12.75	347.62	384.22
Overall cost	dollars		929.15	1119.62
⁴ Total saving	\$190.4			
Notes: ¹ The cost is based on a standard academic year (205 days) for the dinner shift only with average number of diners of 700. ² The unit cost for trays is based on the per unit price of trays purchased in quantities of 1000, which is the number of trays currently in use at Wadsworth Hall. The purchasing cost was calculated in this manner: (\$1.37/tray*1000 trays)/(trays life span* dinner factor). The dinner factor was calculated as (average # diners breakfast+ average # diners lunch+ average # diners dinner)/(average # diners dinner). The main reason to include the dinner factor is because all the usage cost values are for the dinner meal only. The dinner factor will only account for the purchase cost of trays in the dinner meal. The average # of dinners during breakfast, lunch, and dinner are 450, 900, and 700 respectively, and trays life span is 5 years. ³ Water cost includes only the purchasing cost of water. It does not include the disposal cost of water ⁴ Total saving value is based on the saving when not using trays, and does not include the purchase or the production cost of food.				

Table 3.16 indicates that trayless dining reduces costs for all items measured. There is a total savings of \$190.4 when not using trays during the dinner shift for the standard academic year, 205 days, assuming an average number of diners of 700. There will be a similar savings for any facility that has features (e.g., using a similar dishwasher machine, similar number of diners) similar to Michigan Technological University dining, if the facility transitions to trayless dining.

3.5 Environmental Impact Analysis

Table 3.17 and Table 3.18 address the total greenhouse gas emissions a unit of kg CO₂ equivalent (eq) by using the IPCC 2007 GWP 100a method and the Cumulative Energy Demand (CED) for the manufacturing of the trays, usage phase of the full-scale experiment, and end of life cycle. The usage phase includes dishwashing machine water,

steam, and electrical consumption from Table 3.13, Table 3.14, and Table 3.15. The end of life cycle includes wastewater and food waste from pre-rinse and pan washing area. The data are based on the functional unit of one dinner meal.

Table 3.17
Environmental impact analysis by using the IPCC 2007 GWP 100a method

	Trays dining (kg CO ₂ eq)			Trayless dining (kg CO ₂ eq)		
	³ Manufacturing	¹ Usage	² End life cycle	Manufacturing	Usage phase	End life cycle
Tuesday	5.32	0.048	0.14	0	0.043	0.13
Wednesday	5.79	0.055	0.17	0	0.049	0.14
Thursday	5.51	0.066	0.13	0	0.051	0.09
Friday	5.47	0.068	0.19	0	0.064	0.14
Saturday	5.54	0.071	0.19	0	0.069	0.10
Average	5.53	0.062	0.16	0	0.055	0.12
700 Average diners	3871	43.4	115.5	0	38.5	84.0
Standard academic year (205 days)	363.1	8897	23677.5	0	7892.5	17220
Difference (kg CO ₂ eq)	7825					
Notes: ¹ The usage values are based on the ratio by diner because of the functional unit of this study and includes dishwashing machine water, steam, and electrical consumption from tables 3.13, 3.14, and 3.15. ² The end of life cycle values are based on the ratio by diner because of the functional unit of this study. ³ The average value under the manufacturing phase multiplied by the average number of diners. The manufacturing impact of trays in column (Standard academic year 205 days) was calculated by this manner: (Environmental impact to produce one tray* existing number of trays at Wadsworth Hall)/(life span of trays*dinner factor). Environmental impact to produce one tray is 5.32 kg CO ₂ eq Existing number of trays is 1000 Life span of trays is 5 years The dinner factor was calculated as (average # diners breakfast+ average # diners lunch+ average # diners dinner)/(average # diners dinner). The main reason to include the dinner factor is because all the usage cost values are for the dinner meal only. The dinner factor will only account for the purchase cost of trays in the dinner meal. The average # of dinners during breakfast, lunch, and dinner are 450, 900, and 700 respectively.						

Table 3.18
Environmental impact analysis by using the cumulative energy demand method

	Trays dining (MJ eq)			Trayless Dining (MJ eq)		
	³ Manufacturing	¹ Usage	² End life cycle	Manufacturing	Usage phase	End life cycle
Tuesday	5.32	0.048	0.042	0	0.044	0.039
Wednesday	5.79	0.055	0.051	0	0.050	0.042
Thursday	5.51	0.066	0.042	0	0.051	0.029
Friday	5.47	0.068	0.058	0	0.064	0.043
Saturday	5.54	0.071	0.059	0	0.070	0.032
Average	5.53	0.062	0.050	0	0.056	0.037
700 Average diners	3871	43.4	35.0	0	39.2	26.1
Standard academic year (205 days)	363.1	8897	7175.0	0	8036	5354.5
Difference (MJ eq)	3045					
Notes: ¹ The usage values are based on the ratio by diner because of the functional unit of this study and include dishwashing machine water, steam, and electrical consumption from tables 3.13, 3.14, and 3.15. ² The end of life cycle values are based on the ratio by diner because of the functional unit of this study. ³ The average value under the manufacturing phase multiplied by the average number of diners. The manufacturing impact of trays in column (Standard academic year 205 days) was calculated by this manner: (Environmental impact to produce one tray* existing number of trays at Wadsworth Hall)/(life span of trays*dinner factor). Environmental impact to produce one tray is 5.32 MJ eq Existing number of trays is 1000 Life span of trays is 5 years The dinner factor was calculated as (average # diners breakfast+ average # diners lunch+ average # diners dinner)/(average # diners dinner). The main reason to include the dinner factor is because all the usage cost values are for the dinner meal only. The dinner factor will only account for the purchase cost of trays in the dinner meal. The average # of dinners during breakfast, lunch, and dinner are 450, 900, and 700 respectively.						

According to Table 3.17 and Table 3.18, there are more greenhouse emissions when dining with trays. Purchasing trays for one residential hall will result in extra purchasing costs and environmental impacts. Besides the extra green house emissions and cumulative energy demand in the tray dining usage phase, there is a manufacturing impact associated; creating one tray produces 5.32 kg of CO₂ eq and 89.9 MJ eq. The added environmental impact values can be removed when shifting to trayless dining. Trayless dining produces a zero amount of CO₂ eq and cumulative energy demand in the

manufacturing stage, reductions of 1005 kg CO₂ eq and 861 MJ eq in the usage phase, reductions of 6458 kg CO₂ eq and 1821 MJ eq in the end of the life cycle, and overall reductions of 8830 CO₂ eq and 3906 MJ eq. Green dining facilities should consider these applications because they carry fewer environmental impacts.

4 Conclusion

The results of this study indicate that trayless dining can reduce water, electricity, and steam consumption, can generate potential cost savings, and can reduce environmental impacts. The study shows that trayless dining reduces food expenditures because diners are wasting less food. The total savings when not using trays for the dinner shift for the standard academic year (205 days) with an average number of 700 diners is 7,031.5 pounds of food waste from the pre-rinse area and 3,157 pounds of food waste from the pan washing area. Moreover, for each day of the study, the diners consumed more food during the trayless portion of the experiment. Further study would be required to identify the reason for the increased food consumption, but it could be that the diners found it more convenient to eat the extra food on their plate instead of carrying it back for disposal. It would be interesting to determine if the increased consumption would continue after the students became acclimated to the trayless dining system.

The trayless dining experiment shows a reduction in dishwasher water, steam, and electrical consumption for each day of the study. The average reductions in dishwasher water, steam, and electrical consumption over the duration of the study were 9.9%, 10.9%, and 6.4 %, respectively. If trayless dining were implemented, this would result in a decrease of 4,305 gallons of water consumption and wastewater discharge, 2.87 mmBTU of steam consumption, and 158 kWh of electrical consumption for the dinner shift over the academic year, based on 205 days of operation with an average of 700 diners.

Based on the LCA, there is a total savings of \$190.4 when not using trays during the dinner shift for the 205-day standard academic year. There will be an extra savings for any new facility that has features (e.g., using a similar dishwasher machine, similar number of diners) similar to Michigan Technological University dining if the facility is not purchasing trays.

Trayless dining produces zero amount of CO₂ eq and cumulative energy demand in the manufacturing stage for the trays, reductions of 1005 kg CO₂ eq and 861 MJ eq in the usage phase, reductions of 6458 kg CO₂ eq and 1821 MJ eq in the end of the life cycle, and overall reductions of 8830 CO₂ eq and 3906 MJ eq.

This study suggests implementation of trayless dining at the beginning of the academic year so that incoming freshmen are more accustomed to dining without trays. Furthermore, providing students with data on the advantages of going trayless will be helpful in the implementation process.

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Appendix A: Sample Calculation

First pilot test consumed food weight on Tuesday:

Consumed food weight= prepared food - unserved food – (food waste from pre-rinse area + food waste from pan washing area)

- Prepared food= 485 lbs
- Unserved food= 40 lbs
- Food waste from pre-rinse area= 145.5 lbs
- Food waste from pan washing area= 46.5 lbs

Consumed food weight= 485 lbs - 40 lbs - (145.5 + 46.5) lbs

Consumed food weight = 253 lbs

Second pilot test steam consumption on Tuesday:

$$\text{Steam Consumption} = \text{Gallons of Water Consumed} * \frac{8.43 \text{ lbs}}{\text{gallon}} * \frac{(\text{Temperature}_{\text{final}} - \text{Temperature}_{\text{Initial}})}{1,000,000}$$

- Dishwashing machine water consumption= 272 gal
- Initial temperature dishwashing machine water = 68 °F
- Final temperature dishwashing machine water =156 °F

Steam consumption= 272 (gal)* 8.43 lbs/gal * (156 – 68)/1000000

Steam consumption=0.201 mmBTU

Full-scale experiment consumed food weight on Tuesday February 15 2011 (Trays dining):

Consumed food weight= prepared food-unserved food – (food waste from pre-rinse area+ food waste from pan washing area)

- Number of diners= 714
- Prepared food= 345 lbs
- Unserved food= 10.5 lbs
- Food waste from pre-rinse area= 120 lbs
- Food waste from pan washing area= 34 lbs

Consumed food weight= 345 lbs-10.5 lbs-(120+34) lbs

Consumed food weight=180.5 lbs

Consumed food weight/diner= 180.5/714

Consumed food= 0.253 lbs/diner

Full scale experiment steam consumption on Tuesday February 15 2011 (Trays dining):

$$\text{Steam Consumption} = \text{Gallons of Water Consumed} * \frac{8.43 \text{ lbs}}{\text{gallon}} * \frac{(\text{Temperature}_{\text{final}} - \text{Temperature}_{\text{Initial}})}{1,000,000}$$

- Dishwashing machine water consumption=147 gal
- Initial temperature= 68 °F
- Final temperature= 156 °F
- Number of diners=714

Steam consumption= $147 \text{ (gal)} \times 8.43 \text{ lbs/gal} \times (156-68) / 1000000$

Steam consumption=0.109 mmBTU

Steam consumption= $0.109 / 714$

Steam consumption= 0.000153 mmBTU

Appendix B: Pilot and Full-Scale Experiment Raw Data

Table B. 1
Second pilot test water consumption raw data

	Pre rinse meter reading at the start of the shift (gal)	Pre rinse meter reading at the end of the shift (gal)	Pre rinse water consumption (gal)	Dishwasher meter reading at the start of the shift (gal)	Dishwasher meter reading at the end of the shift (gal)	Dishwashing machine water consumption (gal)
Tue,07 Dec 2010	5554.9	5567.5	12.6	131973	132245	272
Wed,08 Dec	5596.2	5604.1	7.9	133185	133474	289
Thu,09 Dec	5687.8	5705.8	18.0	134739	134955	216
Fri, 10 Dec	5735.3	5743.3	8.0	135804	136045	241
Sat, 11 Dec	5841.5	5828.4	13.1	136500	136751	251
Sun, 12 Dec	5830.22	5854.4	24.18	137346	137703	357
Mon, 13 Dec	5942.8	5979.3	36.5	139051.4	139348	296.6

Table B.2
Second pilot test electrical consumption raw data

Days	Dishwasher electricity meter reading at the start of the shift (kWh)	Dishwasher electricity meter reading at the end of the shift (kWh)	Electricity consumption for the dishwasher (kWh)	Diners
Tue,07 Dec 2010	3595.5	3607.9	12.4	858
Wed,08	3632.5	3644.2	11.7	893
Thu,09	3666.2	3676.5	10.3	818
Fri, 10	3699.5	3714.5	15	740
Sat, 11	3729.4	3747.1	17.7	740
Sun, 12	3763.4	3781.2	17.8	888
Mon, 13	3806.6	3820.2	13.6	1154

Table B. 3
Full-scale experiment dishwashing machine electrical consumption raw data

		Raw electricity meter reading at the start of the shift (kWh)	Raw electricity meter reading at the end of the shift (kWh)	Electricity consumption (kWh)
Trays Dining	Tuesday	94.2	105.1	10.9
	Wednesday	135.8	147.8	12
	Thursday	171.4	183.2	11.8
	Friday	135.8	147.8	12
	Saturday	229.8	243	13.2
Trayless Dining	Tuesday	140.9	150.9	10
	Wednesday	155.1	166.3	11.2
	Thursday	207.9	218.5	10.6
	Friday	243.1	253	9.9
	Saturday	201.6	214.4	12.8

Table B. 4
Full-scale experiment water consumption raw data

		Raw dishwashing machine water meter reading at the start of the shift (gal)	Raw dishwashing machine water meter reading at the end of the shift (gal)	Water consumption (gal)
Trays Dining	Tuesday	184838	184985	147
	Wednesday	185782.5	185985	202.5
	Thursday	186838	187063	225
	Friday	188001	188206	205
	Saturday	188840	189063	223
Trayless Dining	Tuesday	225185	225315	130
	Wednesday	226358	226524	166
	Thursday	227436	227605	169
	Friday	228665	228840	175
	Saturday	229510	229725	215

Appendix C: SimaPro Software Parameters Description

Notes: The following descriptions were adopted from SimaPro Software 2011

Electricity

"SimaPro Software Name: Electricity, hard coal, at power plant/DE S" (SimaPro Software 2010).

Water

"SimaPro Software Name: Tap water, at user/RER S" (SimaPro Software 2010).

Steam

"SimaPro Software Name: Steam, for chemical processes, at plant/RER S" (SimaPro Software 2010).

Trays and dinner plates

"SimaPro Software Name: Glass fibre reinforced plastic, polyamide, injection moulding, at plant/RER S" (SimaPro Software 2010).

Wastewater

"SimaPro Software Name: Treatment, sewage, to wastewater treatment, class 4/CH U" (SimaPro Software 2010).

Food Waste

"Disposal, refinery sludge, 89.5% water, to sanitary landfill/kg/CH" (SimaPro Software 2010).

Appendix D: Survey of Students Attitudes for Trayless Dining

To ascertain student opinions regarding trayless dining in Michigan Tech residence hall dining areas, a team of students from the Green Campus Enterprise conducted a survey (approval number M0498 from the Office of Research Integrity and Compliance) at Michigan Tech in the three residential halls at Michigan Tech: Wadsworth Hall (October 21, 2009), McNair Hall (November 11, 2009), and Douglass Houghton Hall (November 18, 2009) during the 2009 fall term dinner shift. To ensure that students were adequately notified of the survey before its occurrence, flyers specifying the time (normal dinner hours) and location (the dining hall) were circulated two days prior to the survey date. To generate further interest in the survey, a prize drawing was incorporated into the survey submission process by including detachable "tickets" on the top portion of the survey form; Michigan Tech Dining Services donated the prizes. To ensure the anonymity of those taking the survey, submissions were tabulated separately from the contact information. Both the design of the flyers and the design of the survey document were submitted to the Institutional Review Board at Michigan Technological University to obtain human subjects approval for the team's processes before the survey procedure began.

The students were asked, "Would you be supportive of instituting a trayless dining policy in the dining halls at Michigan Tech?" The students could respond by selecting from three options: 1) One day per week, 2) Seven days per week, or 3) Never. The results are shown in Table D.1. The first survey was conducted at Wadsworth Hall cafeteria, followed by McNair Hall, and then Douglas Houghton Hall (DHH).

Table D. 1
Survey results

	¹ Wads Responders	Percent	² McNair Responders	Percent	³ DHH Responders	Percent
One day/week	106	29.5%	24	16%	21	24.1%
Seven days a week	88	24.5%	44	29.3%	33	37.9%
Never	165	46.0%	88	54.7%	33	37.9%
Notes: ¹ Actual number of diners was 725. Percentage of diners responding to the survey was 49.5 % ² Actual number of diners was 550. Percentage of diners responding to the survey was 28.4 % ³ Actual number of diners was 620. Percentage of diners responding to the survey was 14.0 %						

Although a significant number of students opposed implementing trayless dining, the majority of respondents in Wadsworth and DHH approved trayless dining at least one day per week. DHH is the smallest of the dining halls with food served a short distance from the dining tables so the higher percentage of students in favor of the conversion was understandable. During the survey, the students were asked for feedback and suggestions if trayless dining was implemented at Michigan Tech. The following list identifies the common comments elicited during the survey.

- Inform students before implementation
- Introduce trayless dining at the beginning of the academic year
- Make change as a gradual process from one day to seven days a week
- Make trays available upon request
- Pass on any savings to students by lowering housing costs
- Use compartmentalized trays

A large portion of students surveyed also suggested the possibility of switching to compartmentalized trays as a means of cutting down on dishes by eliminating the need for plates, while not reducing dining convenience. Mr. Hiltunen, Director of Dining Services, was not in favor of this suggestion stating that compartmentalized trays would create an overly institutionalized feel to the students' dining experiences. To explore this option further, Green Campus students suggested displaying a sample compartmentalized tray in the dining halls and polling the students on their opinion.

The Green Campus Enterprise students also contacted Amrys Mikinel of Grand Valley State University, which had recently made the switch to trayless dining.

Suggestions for the conversion included the following:

- Inform the students of the reason for the change, including data on savings.
- Advertise the change rather than trying to make the change quietly.
- Make the shift at the start of the academic year before incoming freshmen have grown accustomed to dining with trays.