Food to Energy: A K12/University Partnership to Develop a Resource Recovery Program

Dr. Jan DeWaters P.E., Clarkson University

Jan DeWaters is an Associate Professor in the Wallace H. Coulter School of Engineering at Clarkson University, in Potsdam, New York. She teaches introductory courses on energy issues and energy systems, and is part of the development team for Clarkson's First Year Engineering/Interdisciplinary course. Her current research interests include the implementation and evaluation of evidence-based effective learning practices in STEM education, environmental education, and energy education.

Prof. Stefan J. Grimberg, Clarkson University

Stefan J. Grimberg completed his PhD in 1995 from the University of North Carolina at Chapel Hill. Since that time he has been a faculty member of the Department of Civil and Environmental Engineering at Clarkson University. He received his Diplom in Chemical Engineering from the Technical University of Munich, Germany (1987) and his Masters in Environmental Engineering from the University of North Carolina at Chapel Hill (1989). Dr. Grimberg's research focuses on delineating the role of microorganisms on contaminant transport in atmospheric and aqueous systems. Most recently he and his students are investigating the most efficient process to convert farm waste into biogas using anaerobic digestion.

Food-to-Energy: A K12/University Partnership to Develop a Resource Recovery Program

Abstract

An on-going, multi-faceted university/K-12 partnership, now in its third year, integrates a school-wide food waste recovery program with classroom and extracurricular education in resource recovery. Pre- and post-consumer food waste from the high school and middle school cafeterias at a nearby K-12 school district is treated at an anaerobic digester system as part of an on-going University research project investigating the benefits of supplementing dairy farm digester feed with food waste to increase energy production. Our underlying hypothesis is that teaching students the benefits of waste source separation and resource recovery with a project-based, place-based education program will help them develop and retain good waste disposal habits, and will encourage them to share these habits with their families at home. Results from a relatively simple, anonymous pre-post survey indicate significant improvement in students' self-assessed knowledge about energy and resource recovery, a demonstrated increase in their understanding of anaerobic digestion and its capacity for producing energy from organic waste. Students are also more willing to talk to their families about proper waste disposal practices and encourage them to reduce FW.

Introduction and Background

Every year approximately 40% of the food produced in the United States [1] (approximately one third, globally [2]) is wasted rather than eaten. Food is wasted or discarded throughout the food supply chain, creating significant economic, societal, and environmental impacts. The U.S. Environmental Protection Agency (EPA) estimates that 63.1 million tons of food waste (FW) were generated from commercial, institutional, and residential sectors in the United States in 2018, with an additional 40 million tons generated from industries [3], [4]. Along with that wasted food is the wasted farm land, water, labor and energy resources required to grow, process, package and transport it. According to the NRDC, food waste accounts for approximately 19% of all U.S. croplands, 18% of all farming fertilizers, 21% of the U.S. agricultural water usage, and costs $218 billion per year [1]. Food waste is also a significant contributor to climate change; approximately 2.6% of all U.S. greenhouse gas emissions are produced by food that is wasted [1], and on a global scale, if food waste were a country it would rank third in greenhouse gas emissions, behind China and the U.S. [5].

Although K-12 schools produce only about 2% of the total U.S. food waste, the amounts are still staggering -- 530,000 tons per year, or 39.2 pounds of food waste per student, which is 9% higher than the estimated amount the average American wastes at home [6]. Food waste costs U.S. schools about $1.2 billion per year in food purchases and waste management costs, or roughly 26% of the total food budget for a school participating in the National School Lunch Program (NSLP) [7], [8].

EPA's Food Recovery Hierarchy (Figure 1) suggests various actions that can be taken to reduce food waste and the negative impacts from food waste disposal. Each tier of the pyramid focuses on a different management strategy, beginning with strategies that create the greatest benefit for environment, society, and the economy (prevention or recovery strategies such as source

reduction, feeding humans or animals), followed by recycling strategies such as reprocessing or composting, and ending with disposal, landfill/incineration, as a last resort.
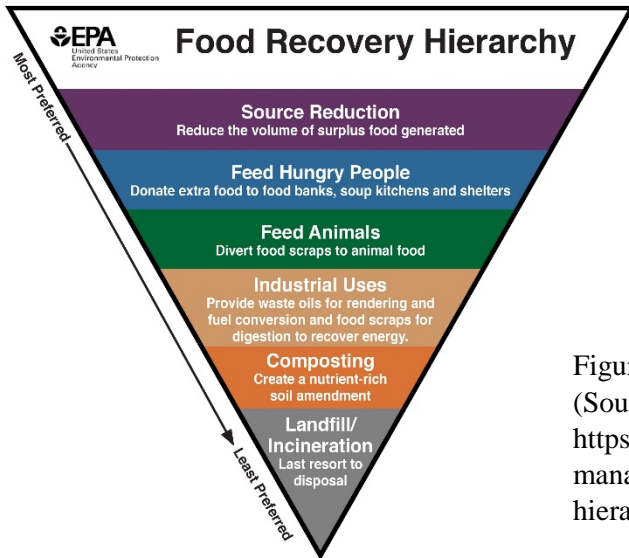

Figure 1. Food Recovery Hierarchy. (Source: U.S. EPA, https://www.epa.gov/sustainable-management-food/food-recovery-hierarchy)

Unfortunately, as shown in Figure 2, most food waste produced in the U.S. is sent to the landfill (56% [3]), making it the single largest fraction of material (over 24%) disposed in U.S. landfills [9]. Sending FW to the landfill contributes to multiple pressing issues including greenhouse gas emissions, contaminated leachate generation, and diminishing landfill capacity. Many states in the U.S. are in the process of revising waste disposal regulations to more closely control the disposal of organic wastes. For example New York State has mandated that as of 2022, facilities
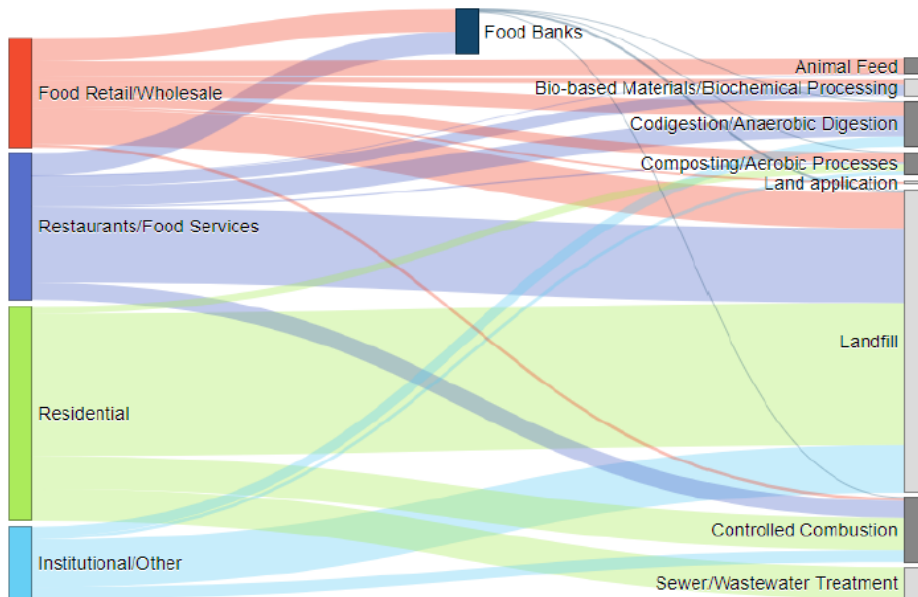

Figure 2. Summary of Wasted Food Generation and Management Flows (2018, excluding the industrial sector [3])

producing an annual average of at least two tons of FW per week will no longer be allowed to landfill their organic wastes [10]. Certainly, the time is ripe for educating students about best practices for waste disposal and issues related to food waste.

Efforts to educate students about food systems and reduce food waste from K-12 school cafeterias are not new. Strategies for food waste reduction more commonly target prevention – changing the quantities and choices of food provided, and switching to the Offer versus Serve (OVS) method of food service, in an effort to encourage students to eat more of what they take. The USDA, EPA, and US Food and Drug Administration provide regulatory guidance and grants; NRDC provides policy guidance; and the WWF, Johns Hopkins Center for a Livable Future, and the Environmental Research and Education Foundation (EREF) provide a research framework and curricula to engage students in learning about the importance of curtailing food waste [11]. For example the WWF has created guidance for conducting a food waste audit, recognizing that awareness is the first step toward solving the problem. Their studies show that participating schools cut their average trash output by 3% during the four- to six-week audit period, with the top three participating schools producing 53% less trash than before the program launched [6].

No matter how much food waste is prevented at the source, there will always be waste that requires proper management. Resource recovery (RR) processes view food waste as an untapped resource – recovering energy and nutrients from food and other organic wastes provides economic opportunities while simultaneously alleviating environmental problems associated with their disposal. School food waste management programs most commonly focus on compost systems. For example, a school district in Lincoln, Nebraska has instituted a successful composting program funded by the town's solid waste program, with one elementary school reportedly composting about 90% of their food waste [12]. There are multitude other examples, both large and small, throughout the U.S. The website "Healthy Food Choices in Schools" recommends using food waste for composting or farm animal feed, and sending waste fats and oils to a facility for making biodiesel [13].

Waste organics can also be treated with anaerobic digestion (AD). Bacteria in anaerobic digesters convert organic wastes into biogas (60%-70% methane, 30%-40% carbon dioxide, and traces of other gases such as hydrogen and hydrogen sulfide), which can displace fossil fuel in a variety of energy systems. The residue – or digestate – that remains is rich in nutrients and can be used as crop fertilizer. The anaerobic digestion process can be implemented in individual food waste digesters or as part of food waste co-digestion at wastewater treatment plants or dairy manure digesters. Food waste is an energy-rich feedstock that, when added to municipal wastewater or dairy manure anaerobic digestion systems, increases energy production and improves process economics. Food waste produces three and up to 15 times as much energy per unit mass compared to digesting biosolids or dairy manure, respectively, and has a much higher volatile solids destruction rate (86%-90%), resulting in minimal increase in residual byproducts [14].

Results from systems-based analyses of various options for food waste management show that in general, source-separating food waste and treating it by anaerobic digestion offers the greatest benefits in terms of reducing overall environmental impacts and producing an economically viable energy resource [5], [15]. These benefits can be realized only if the costs for providing

'clean' waste, free of inorganic contaminants, are low. Thus the feedstock must be void of contamination that would require pretreatment to separate non-biodegradable substances (e.g. plastics, metals, glass) prior to being added to the AD system. This may be one of the reasons why AD systems for treating food wastes are not more common. It is estimated that less than 2% of food waste is anaerobically digested, much less than the amount that is composted or landfilled [16].

Although we were unable to find K-12 school food waste programs that incorporate anaerobic digestion, there are in fact a few college or university-scale resource recovery programs that use AD systems to treat campus food waste. A program in the City of West Lafayette, Indiana takes food waste from Purdue University and feeds it to the anaerobic digesters at the wastewater treatment plant, producing electricity for the plant [17]. At the University of Wisconsin in Oshkosh, organic materials and food wastes are treated at the camp U.S. digester to produce energy and compost [18]. Finally, while the East Bay Municipal Utility District (East Bay MUD, in Oakland, California) has been producing electricity by treating 20 to 40 tons of restaurant and community food waste per day in their anaerobic digesters for the past seven years [19], a research project at UC Davis is investigating the feasibility of using small-scale anaerobic digesters treating campus food waste, as an alternative to the larger, centralized AD facilities. They are using community-scale AD systems to produce electricity, heat, and fertilizer from food waste collected within a 50-mile radius of the campus [20].

This paper describes an ongoing university/K-12 partnership whose primary focus is to operate a successful food waste separation program in the school cafeteria, and treat the food waste in a nearby anaerobic digester to recover energy and fertilizer. Diverting FW from the waste stream on a large scale will require a *cultural shift* so that organic waste streams of high enough quality can be generated. Like the majority of the general population, most students lack awareness of what happens to items they throw away. Most don't know, and don't think about, where 'away' is. Our experience with educating college students on best practices for waste management and the merits of separating food waste for composting or anaerobic digestion indicates that it is difficult to obtain a contaminant-free waste stream. Despite extensive outreach efforts it is still difficult to "undo bad habits". It is well known that long term behavioral change originates in early experience [21]. The patterns of behavior adopted by children are often set for life. Thus, exposing K-12 students to source separation will engage them in good practices before those bad habits develop. The underlying hypothesis of our project is that that the earlier we expose students to FW separation and resource recovery the more likely they will retain proper waste disposal habits, generating a feedstock suitable for anaerobic digestion. A successful K-12 source separation program could facilitate long-term waste reduction and resource recovery.

Our program integrates a school-wide food waste recovery program with classroom and extracurricular education in resource recovery. The activities include: (1) foster a successful food waste recovery program in the school cafeteria; (2) leverage educational activities as a way of engaging students in the program; and (3) conduct a simple pre/post assessment to evaluate the impact of the project on students' knowledge, attitude, and behaviors related to food waste disposal and resource recovery. These activities are guided by the following objectives:

1. Increase students' AWARENESS of the PROBLEM:
   - What happens to the solid waste they dispose of at school/home?

- How much food waste is present in our waste stream?
- What happens to that food waste when it is in the waste stream?

2. Increase students' UNDERSTANDING of the SOLUTION:
   - What other sustainable options exist for disposing organic waste (food waste)?
   - What is anaerobic digestion? How does it work, and how does it transform food waste into a valuable energy resource?
   - What is the overall impact and potential value of different waste disposal options such as recycling, composting, or sending organic materials to a food digester?

3. Increase students' PARTICIPATION in the SOLUTION:
   - Engage university students in classroom and mentoring interactions with K-12 students in order to promote environmental consciousness.
   - Develop all students' understanding of what can and cannot be placed into the feed stream of the anaerobic digester.
   - Increase student participation in recycling food waste at school.

Methodology

Partnerships. The structure of our project relies on a number of partnerships that bring together knowledge, skills and experience from a range of specialties. At the base is a University/Extension Service partnership between faculty at Clarkson University (CU) and the Cornell Cooperative Extension Service of St. Lawrence County (CCE). Over the past 10 years with the help of USDA and USEPA funding we have studied the technical/social/economic viability of AD for smaller dairy farms. As part of the program we have integrated a model AD system at CCE. The modular AD system uses food waste from CCE's commercial Harvest Kitchen and dairy manure as inputs; and digester products include heat, which is used to heat a greenhouse; recovered solids used as animal bedding; and AD effluent used to fertilize farm fields (Figure 3). The system integration demonstrates to farmers economic and environmental benefits of AD.
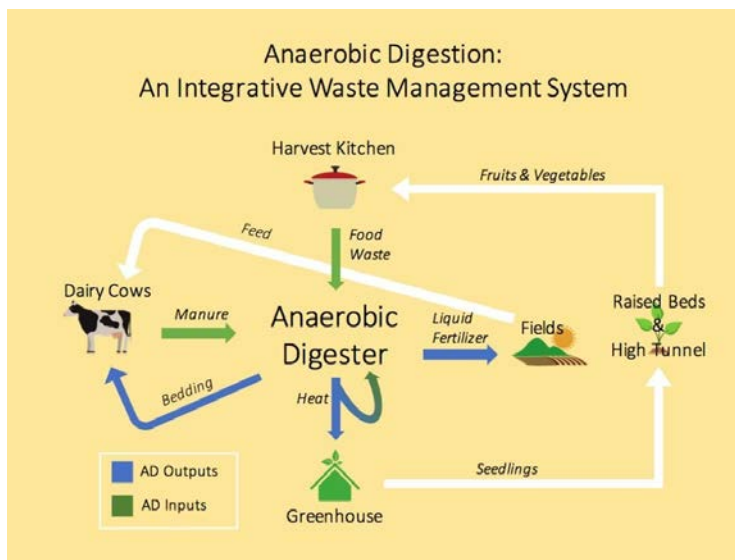

Figure 3. Process Schematic of the Clarkson/CCE AD System

The other key partnership is with a local school district, where a core group of teachers are engaged with the project. Canton Central School (CCS) is located in rural St. Lawrence County, NY, the 7th most impoverished county in NY State, with 19.1% of residents, and 29% of all children and youth and youth living below the poverty line [22]. In Canton the poverty level (19.6%) is higher than the county rate, and 47% of the students at CCS qualify for free/subsidized school lunches. Given its geographical location close to the Canadian border, ethnic minorities represent a small fraction

of the school population; our partners in this school district are economically deprived, majority white. This program, therefore, addresses some of the biggest discriminators against educational opportunity: economic disadvantage, and small, rural schools lacking enriched academic programs.

In spring 2018 the high school (HS) environmental club reached out to initiate a pilot program to collect post-consumer food waste from the HS cafeteria and deliver it to the CCE Farm digester to supplement the manure feed. The successful program garnered enthusiasm and support beyond the high school. The middle school Green Team (MS GT), an active group of 5th and 6th graders, quickly became interested in food issues and sought after activities related to food systems and food wastes. Additional teachers have become engaged in the partnership as it has grown, most prominently the science teachers in the HS and MS, as well as the upper level elementary school teachers, who have engaged mainly through the curricular components of the program, described below.

A team of university students who are enrolled in a credit-bearing project course round out the partnership. These students mentor middle and high school students to organize the cafeteria food waste collection system, and facilitate the transport of food waste between the school and the digester. Simultaneously, under faculty guidance, they develop and teach interactive, hands-on educational modules related to waste disposal and resource recovery.

Food Waste Program. For the past two years, students in the middle and high school cafeterias have been scrapping their food waste into clear 20 Liter bins at the cafeteria waste stations. Cafeteria staff supplement the bins with pre-consumer food waste from the school kitchens. School maintenance personnel, with assistance from student members of the HS Environmental Club and MS Green Team, deliver the bins to the loading dock on a daily basis as part of the lunch time clean up. A team of Clarkson students is responsible for delivering the food to the extension farm, where it is added to the anaerobic digester feed.

Students are educated about food waste, resource recovery, and the food waste program with educational posters and announcements prepared by the HS Environmental Club and MS Green Team. Additionally, Clarkson students and CCE educational staff periodically visit the cafeterias to coach students on proper food waste management procedures.

Curriculum development and instruction. The cafeteria food waste program offers an excellent opportunity for students to engage in place-based learning experiences that use the school as a living laboratory [23]. Project-based educational experiences have been developed to complement the cafeteria food waste program, so that students can learn the science behind resource recovery and anaerobic digestion. Evidence has shown that project-based and place-based learning experiences enhance student motivation, engagement, and learning [24]. Open-ended projects challenge students to operate at the higher levels of Bloom's taxonomy, and students tend to be more engaged in the learning process because they see the relevance of what they are learning to their lives outside of school. The method deepens students' understanding of principles that link concepts together, and enhances students' ability to retain and apply knowledge [25].

The CU team developed and taught a variety of activities for students at the middle and high school levels, with some adaptation for the upper level elementary grades. Our most popular is a science class experiment whereby students build small anaerobic bioreactors using small-mouthed glass bottles and balloons or Tedlar gas sampling bags (Figure 4). Various organic food wastes are added together with nutrient seed from the anaerobic digester, and students measure the volume of gas production and methane concentration as a function of organic substrate composition over time. Other activities include a trash sorting exercise with a decision matrix for proper waste disposal practices, which has an accompanying bingo game for students and adults of all ages as well as a coloring sheet for the younger grades.

Figure 4. Anaerobic digestion bottle reactors using balloons (l) and Tedlar bags (r) to collect biogas

Results and Discussion

Our data collection and analysis process strives to measure the degree to which we have been able to achieve the project objectives, indicated by three measures of success: the extent to which we are able to foster a successful food waste recovery program in the school cafeteria; student and teacher engagement in the program's educational activities; and our impact on student knowledge/affective/behavior outcomes as measured by our pre/post survey. The results presented below are based on the program's first two years.

Food Waste Program. Food waste has been collected daily from the MS and HS cafeterias. The MS Green Team developed plans to start a food waste collection program in the Elementary School cafeteria, which would entail student representatives staffing the tray tables during the morning breakfast period to get the program going, although with the Covid-19 pandemic and ensuring school closures those plans did not materialize. On average 300 kg of FW was collected each week and delivered to the CCE digester over the spring semester in year 1. Due to COVID restrictions food collection in year 2 was more limited; cafeteria programs ended in March 2020, and the bulk of food waste since then has consisted of pre-consumer waste generated by the kitchen staff as they prepare meals for in-school and home deliveries.

Over the course of the project (years 1 and 2) approximately 14 metric tons of FW was treated resulting in approximately 3,000 m^3 biogas produced. Given the lower heating value of biogas, at 60% methane, the generated biogas represents an energy content of 18,000 kWh. That is approximately equivalent to the average annual heat energy consumed by one residential home

in the U.S. [26]. In addition to the production of renewable energy, diverting 14 metric tons of FW from the solid waste stream represents a $3500 savings to the school district in waste hauling fees in Saint Lawrence County. Assuming FW diversion would occur over the entire school year (approximately 40 weeks per year) we estimate that 12 metric tons of FW per year would be diverted from the middle and high school cafeterias alone.

Student and Teacher Engagement. Through our educational programming and field trips, we have engaged about 1/3 of the middle school (grades 5-6) and high school (grades 9-12) students in structured learning opportunities related to resource recovery and anaerobic digestion. Fewer students were engaged in year 2 of the program because activities were curtailed due to the Covid-19 pandemic. CU students worked alongside four different classroom teachers to facilitate hands-on lessons that lasted anywhere from one to five days. So far we have worked with HS and MS students in Living Environment, Chemistry, Earth Science and Environmental Science classes, as well the MS Green Team, which is comprised of approximately half of all 5th and 6th grade students. Our educational activities, described above with more details available on our project website [27], include general lessons and science experiments about waste management and anaerobic digestion. Our CU team created the basic content while classroom teachers in various classes adapted the lessons to meet class-specific learning objectives. For example, chemistry students worked out the stoichiometry of the anaerobic digestion reaction; environmental science students predicted potential biogas produced from a typical dairy farm and the resulting impact on electricity-related CO_2 emissions. Lessons have been adapted for elementary age students, but due to Covid-19 related constraints in spring 2020 they have not yet been implemented on a wide scale. In general the response from teachers and administrators at the middle and high school level has been enthusiastic, with renewed interest to find new ways for moving forward with expanded programming in the future. Teachers at the elementary school level are also enthusiastic, and look forward to the opportunity to engage in programming as the project moves forward.

Student outcomes. A brief pre/post questionnaire, developed for this project, was used to measure the program's impact on students' awareness and understanding of resource recovery and anaerobic digestion, as well as their attitudes and willingness to engage in solutions. The questionnaire was anonymous and was administered online. Knowledge questions used a combination of multiple choice and open-ended formats. Attitude and behavior items used a 5-option Likert-type response scale, with options ranging from strongly agree to strongly disagree. Questionnaires were modified to create age-appropriate forms for students at different grade levels. The resulting questionnaire contained 7 (pre) and 9 (post) attitude/behavior items, all students; 11 (HS), eight (MS) knowledge questions, both pre and post; and 2 questions that asked students to self-assess their knowledge about energy and resource recovery (all students, pre and post). Survey items are included in Table 1.

The survey was administered to HS and MS students who participated in the educational components of the program. Students completed the pre-survey early in the school year, and the post-survey toward the end of the school year after the CU team had finished working with their teachers or club advisors. Not all students completed both the pre- and post-surveys because of logistical issues; in year 1, grade 6 (GR6) students not involved in the Green Team (GT) took the post survey only, following a field trip to visit the CCE farm and anaerobic digester. In year 2 we were only able to collect data from HS students because the MS students did not complete post-

surveys. Data were analyzed with descriptive statistics, using unmatched t-tests to calculate the significance of pre-post changes in student responses, and for the two post-only questions, to compare responses in year 1 vs. year 2.

Results are provided in Table 1 with details about sample sizes provided in the table notes. In terms of self-perceived learning, all students felt that by the end of the program they knew more about resource recovery, and HS students felt they knew more about energy as well. By the end of the program, more students knew the destination of their household trash than at the start.

All students showed a significant increase in their knowledge of AD – 92% (HS), 48% (GT), 64% (GR6) responded that they 'know' or 'think they know' what AD is, and 69% to 89% of HS students correctly defined the process and identified it among a list of other FW options as a method of energy production.

Although there were no significant changes in student attitudes, there were measureable improvements in their waste-related behaviors, and some interesting differences between the MS and HS students. Participation rates in the cafeteria program were higher for MS than for HS students during both years of the program. By the end of year 1, 92% of the MS and 54% of the HS students said they separated their FW 'always' or 'quite frequently'; in year 2, the HS response was 68%, significantly higher than in year 1 but still less than the MS response (in January) of 85% (data not shown). Compared to HS students, MS students exhibited greater feelings of self-efficacy about their ability to contribute toward solving issues related to energy and the environment, although the HS response went up between years 1 and 2 (data not shown). These findings are consistent with our earlier studies looking at energy-related attitudes and behaviors, where MS students had more positive energy-related behaviors and greater feelings of energy-related self-efficacy than HS students [28]. The link between self-efficacy and behavior is consistent with the work of Bandura et al. [29] who provided empirical evidence that people's behavior is strongly influenced by the confidence they have in their ability to perform the behavior. More MS than HS students reported that they talked to their families at home about proper waste disposal practices, although the pre/post increase among HS students was significant in both years of the program, and higher in year 2 than year 1. By the program's end, 62% (MS, year 1) and 47% (HS) students were 'quite frequently' or 'almost always/always' willing to encourage their families to reduce their FW, and 57% (MS), 48% (HS) students were willing to encourage their families to separate their FW either for a compost system or for RR. Compared to the rest of the 6th graders, GT members report higher rates of participation in the FW program, are more willing to talk to their families about FW disposal, and have a greater sense of self-efficacy with respect to contributing to positive environmental/energy-related change.

Table 1. Pre and Post Results, Food-to-Energy Questionnaire, 2019 and 2020

Survey Item	HS Pre	HS Post	MS GT Pre	MS GT Post	GR 6 Post
Self-assessed knowledge [mean of 1 ("nothing – not in the running") to 5 ("a lot – expert")]					
How much do you know about **energy**?	2.93	3.28*	3.59	3.72	3.57
How much do you know about **resource recovery**?	2.40	2.91*	2.38	3.76*	2.75

How often do you …. [mean of 1 ("hardly ever" or "never") to 5 ("almost always" or "always")]					
I put my food waste into the trash at home (reverse scored)	3.66	3.57	3.07	3.64	3.22
I talk to my family about reducing food waste, or not throwing food into the trash at home.	1.90	2.18*	2.79	2.80	2.57
At school I put my leftover cafeteria food into the bin for the food digester.	3.39	3.61	3.03	4.88*	4.55
POST ONLY: I am willing to encourage my family to reduce the amount of food that we throw away.		3.29**		3.68	3.62
POST ONLY: I am willing to encourage my family to separate our food waste from the trash so we can compost it or send it off for resource recovery.		3.25**		3.28	3.65
How do you feel …. [mean of 1 (strongly disagree) to 5 (strongly agree)]					
I don't need to worry about putting my food waste into the trash, because it will be gone in a short amount of time.	2.52	2.29	2.41	3.00	2.63
Keeping food waste out of the trash will help reduce global climate change.	3.72	3.77	3.72	3.76	3.99
I believe that I can contribute to solving energy and environmental problems by making appropriate choices and actions.	4.01	3.92	3.83	4.28	4.09
I believe that I can contribute to solving energy and environmental problems by working with others.	4.02	3.93	4.03	4.20	4.08
Knowledge, Understanding, Awareness [numbers represent % students responding correctly]					
% of students who know their trash goes to a landfill.	34.4	50.7*	24.1	40.0*	42.9
During an average day, do you notice how much food you throw into the trash? (% yes)	17.6	23.2*	31.0	28.0	37.7
Besides the trash, do you know any other options for your food waste? (% yes)	75.3	85.9*	51.7	68.0	67.5
Do you know what anaerobic digestion is? (% 'yes' or 'I think so')	53.8	92.2*	24.1	48.0*	63.7
Do you know what recycling is? (% 'yes' or 'I think so')	97.8	98.6	89.7	88.0	96.1
(HS only) % students who correctly defined anaerobic digestion	39.0	69.0*			
(HS only) % students who identified anaerobic digestion (from a list of options) as a way to produce energy from food waste	67.0	88.7*			
Do you recycle at home? (% 'yes' or 'I think so')	92.2	91.5	72.4	76.0	87.0

Do you know what composting is? (% 'yes' or 'I think so')	96.1	98.6	93.1	88.0	90.9
Do you compost at home? (% 'yes' or 'I think so')	41.8	46.5	62.0	48.0	59.8
(HS only) % students who correctly defined 'renewable energy resource'	68.1	63.4			

Table Notes:
HS results are from 7 classes in year 1 (n=132 pre; 99 post) and 3 classes in year 2 (n=50 pre; 43 post);
MS GT = Middle School Green Team, grades 5 and 6 (n=29 pre; 25 post)
GR 6 students only took post survey (n=77)
*pre-post changes are significant, $p<0.05$
**post-only responses in year 2 were significantly greater than in year 1 ($p<0.05$)

Conclusions and Future Work

This partnership program has shown that by leveraging the combined efforts of university faculty and students with public school teachers, personnel, and K-12 students, a successful resource recovery program has been instituted. Educational programming has added to the success of the program by engaging students in a variety of activities designed to deepen their knowledge and understanding of waste issues, resource recovery, and anaerobic digestion. This program provides a model for other schools in the area who wish to institute a similar program. Our findings demonstrate the project's success in terms of total food waste recovered, energy produced, and student learning outcomes. Nevertheless, as this is an ongoing project, these findings represent interim results, and our numbers show that there is room for growth and improvement.

Specific goals as we move forward are to continue developing educational programming for a wider range of grade levels, with specific focus on students in the lower elementary grades. With educational activities in place we hope to expand the food waste separation program to the elementary school cafeteria, under the guidance of student ambassadors from the Middle School Green Team. We hope to accomplish this expansion with our current grant funding. Part of our programming for high school students will explore ways to make the program more sustainable so it can outlive grant funding. We will develop an educational module that incorporates a cost/benefit analysis of food waste management practices at the school, with the goal of determining the economic impacts of institutionalizing a resource recovery program.

Acknowledgements

References

[1] NRDC (2017). WASTED: How America is losing up to 40 percent of its food from farm to fork to landfill. Natural Resources Defense Council. Retrieved 12/10/2020 from https://www.nrdc.org/sites/default/files/wasted-2017-report.pdf.

[2] Van den Boss Verma, M., de Vreede, L., Achterbosch, T., Rutten, M. (2020). Consumers discard a lot more food than widely believed: Estimates of global food waste using an energy gap approach and affluence elasticity of food waste. Plos One, February 12, 2020. Published online at https://doi.org/10.1371/journal.pone.0228369. Retrieved 12/16/2020 from https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0228369.

[3] U.S. EPA. (2018). Wasted Food Report, Estimates of generation and management of wasted food in the United States in 2018. EPA 530-R-20-004 November 2020, retrieved 12/10/2020 from https://www.epa.gov/sites/production/files/2020-11/documents/2018_wasted_food_report.pdf

[4] U.S. EPA (2019). Advancing Sustainable Materials Management: Facts and Figures Report. Retrieved 12/10/2020 from https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/advancing-sustainable-materials-management.

[5] Heller, M. (2019). Waste Not, Want Not: Reducing Food Loss and Waste in North America through Life Cycle-Based Approaches. United Nations Environment Programme, North America Office. Washington, DC, U.S.A. Recovered 12/16/2020 from https://www.unenvironment.org/resources/report/waste-not-want-not-reducing-food-loss-and-waste-north-america-through-life-cycle.

[6] World Wildlife Federation (WWF) (2019). Food Waste Warriors: A deep dive into food waste in U.S. schools. World Wildlife Fund, available at https://www.worldwildlife.org/publications/food-waste-warrior-report-2019.

[7] Cohen, J., Richardson, S., Austin, S., Economos, C., Rimm, E. (2013). School lunch waste among middle school students: nutrients consumed and costs. American Journal of Preventative Medicine, 44(2): 114-121. doi: 10.1016/j.amepre.2012.09.060

[8] World Wildlife Federation (WWF) (2019). Food Waste Warriors: A deep dive into food waste in U.S. schools. World Wildlife Fund, available at https://www.worldwildlife.org/publications/food-waste-warrior-report-2019.

[9] U.S. Environmental Protection Agency. (2020). Advancing Sustainable Materials Management: 2018 Fact Sheet. https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/advancing-sustainablematerials-management

[10] New York aims to curb food waste. https://www.timesunion.com/news/article/New-York-aims-to-curb-food-waste-13769177.php. Accessed 1/11/21.

[11] Nargi, L. (2019). "Millions of dollars' worth of food ends up in school trash cans every day. What can we do?" ensia, retrieved 12/17/2020 from https://ensia.com/features/school-food-waste-solutions/.

[12] Waste 360 (nd). Nebraska School Succeeds in Composting Most of its Food Waste. Retrieved 12/17/2020 from https://www.waste360.com/organics/nebraska-school-succeeds-composting-most-its-food-waste.

[13] Healthy Food Choices in Schools. https://healthy-food-choices-in-schools.extension.org/decreasing-waste-in-schools-food-recycling-options/. Accessed 1/11/21.

[14] U.S. EPA (nd) The Benefits of Anaerobic Digestion of Food Waste at Wastewater Treatment Facilities. Retrieved 12/16/2020 from https://www.epa.gov/sites/production/files/documents/Why-Anaerobic-Digestion.pdf.

[15] Edwards, J., Othman, M., Crossin, E., Burn, S. (2018). Life cycle assessment to compare the environmental impact of seven contemporary food waste management systems. Bioresource Technology 248(Q): 156-173. www.sciencedirect.com/science/article/pii/S0960852417309744.

[16] Food Waste Reduction Alliance (2016). Analysis of U.S. Food Waste Among Manufacturers, Retailers, and Restaurants. Retrieved 12/16/2020 from http://www.foodwastealliance.org/wp-content/uploads/2013/05/FWRA-Food-Waste-Survey-2016-Report_Final.pdf.

[17] Food Waste Project, City of West Lafayette. https://www.westlafayette.in.gov/topic/index.php?topicid=12&structureid=188. Accessed 1/11/21.

[18] Titan Gold, University of Wisconsin Oshkosh. https://uwosh.edu/titangold/. Accessed 1/11/21.

[19] U.S. EPA (nd). Turning Food Waste into Energy at the East Bay Municipal Utility District: Investigating the Anaerobic Digestion Process to Recycle Post-Consumer Food Waste. U.S.EPA Archived document, Retrieved 12/17/2020 from https://archive.epa.gov/region9/organics/web/pdf/ebmudfactsheet.pdf.

[20] UC Davis Food Loss and Waste Collaborative. https://foodwastecollaborative.ucdavis.edu/project/demonstrating-potential-site-electricity-generation-food-waste-using-containerized. Accessed 1/11/21.

[21] Evans, G. W., Otto, S., & Kaiser, F. G. (2018). Childhood Origins of Young Adult Environmental Behavior. Psychological science, 29(5), 679-687.

[22] Lawton, J., (2019). Poverty a problem in St. Lawrence County; 29% of kids live below poverty line. North Country This week, Monday, April 22, 2019. Accessed 9/20,2020 at https://www.northcountrynow.com/b U.S.iness/poverty-problem-st-lawrence-county-29-kids-live-below-povert-line-0257011#:~:text=A%20family%20of%20three%20earning%20%2421%2C330%20or%20less%20is%20considered%20impoverished.&text=According%20to%20a%20report%20from%20the%20St.,County%20residents%20live%20in%20poverty.

[23] SERC (Science Education Resource Center; nd). Why use the Campus as a Living Laboratory? Pedagogy in Action, the SERC portal for Educators. Retrieved 12/17/2020 from https://serc.carleton.edu/sp/library/campusbased/why.html.

[24] N. Capon and D. Kuhn (2004). What's so good about problem-based learning? Cognition and Instruction, 22(1): 61-79.

[25] D. Gijbels, F. Dochy, P. Van den Bossche and M. Segers, (2005). Effects of problem-based learning: A meta-analysis from the angle of assessment. Review of Educational Research, 75(1): 27-61.

[26] Energy consumption per household, U.S. Average and by census region in selected years. U.S. Energy Information Administration. https://www.eia.gov/energyexplained/ U.S.e-of-energy/homes.php (Accessed 1/7/2021).

[27] Clarkson food-to-Energy: Cross-Fertilizing a K-12/University Partnership to develop a Resource Recovery Program. https://sites.clarkson.edu/foodwaste/

[28] DeWaters, J.E., and S.E. Powers, (2011). Energy Literacy of Secondary Students in New York State (USA): A Measure of Knowledge, Affect, and Behavior. Energy Policy, 39(3): pp.1699-1710.

[29] Bandura, A., N.E. Adams, A.B. Hardy, G.N. Howells, (1980). Tests of the generality of self-efficacy theory. Cognitive Therapy and Research, 4: 39–66.