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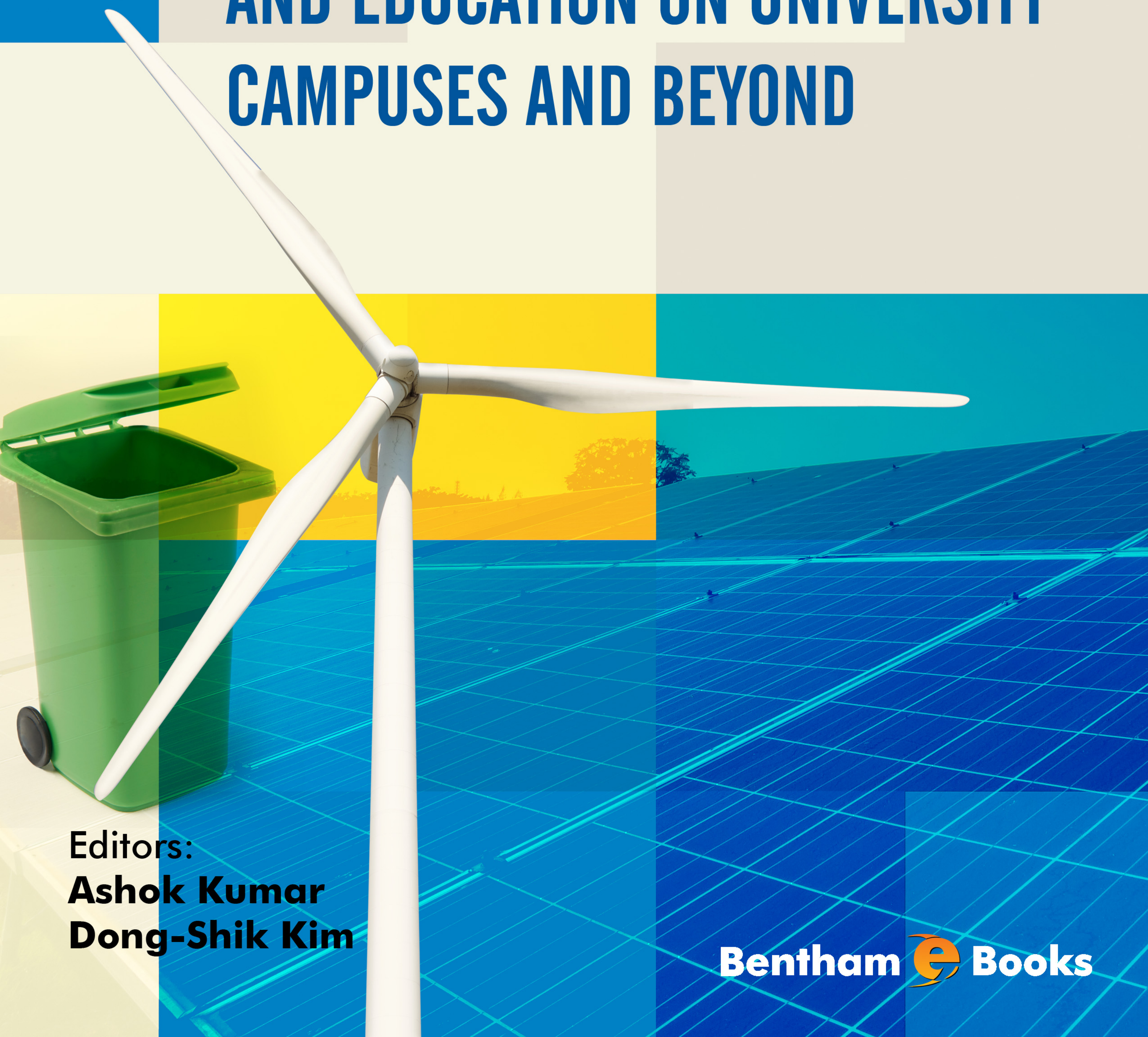
SUSTAINABILITY PRACTICE AND EDUCATION ON UNIVERSITY CAMPUSES AND BEYOND



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Sustainability Practice and Education on University Campuses and Beyond

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FOREWORD

Sustainable development became a major driver of technological and social innovation in 1983, shortly after the release of the report from the World Commission on Environment and Development; what later became known as the Brundtland Commission. Following recognition of the societal imperative to preserve resources and the environment, and the challenges associated with poverty and other social injustice, researchers began to embrace these concerns and seek solutions. Technological solutions were developed to address many of the environmental issues associated with clean air, drinking water, and the production of energy from non-fossil resources. Economic analyses were developed to internalize the true costs of environmental harm. But solutions for social challenges continued to lag.

Even with the identification of the triple bottom line as a corporate imperative, business continued to develop new technologies that consumed non-renewable resources at an alarming rate, fossil resources were consumed producing CO_2 and other global warming gases, and the use of critical materials (*i.e.* minerals that are in low supply but essential for modern electronics and other essential services), remained the norm.

What remained missing throughout the equation of sustainable development were new and holistic techniques for the education of the next generation of business and technology leaders. Individual faculty in isolated locations made heroic efforts to engage students in these important topics, but such efforts frequently would only reach those individuals who were already inclined to create a more sustainable world. As a whole, colleges and universities, especially those outside of Europe, largely carried on with their curriculum, without the pointed attention that this growing challenge deserved.

Fortunately, many of today's educators have recognized the challenges of sustainable development, and the holistic approach that is needed for students to properly address these challenges. Universities throughout the world are developing new curricular elements that integrate sustainability challenges throughout their coursework. And perhaps more importantly, university leaders are adopting sustainability principles and embedding them into the operating procedures that make up the fabric of the modern university.

This new work looks at several initiatives underway at universities to provide a view of some of the ways in which issues of sustainable development are now being considered on college campuses. It brings together various efforts across a range of opportunities; from under-graduate and graduate courses to the development of a university sustainability office; that provides the reader an opportunity to consider what has worked elsewhere and how it can possibly be adapted for application on one's own campus.

One of our great challenges as educators is to do more than simply instruct our students on how they should behave. Rather, it is to adjust our attitudes to behave in the manner that we would like our students to emulate. To teach by example, and thus to show with our deeds the important lessons that our students must internalize. In this way, we can impact the future and make our world a better place for the generations that will come after us. Fundamentally, that is the point of sustainability; to ensure that our children, and their children, have the opportunity for a life well-lived on a healthy planet. Through the lessons included within this book, we move closer to that ideal.

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PREFACE

The idea of this book originated from a Sustainability conference at The University of Toledo on Nov. 1, 2012 organized by Dr. Kumar. The conference has been a focal point of students-initiated activities and colleges' efforts to promote sustainability on campuses in Northwest Ohio. Students, faculty, staff, and administrators gathered together to share their experiences and discuss the lessons learnt and future directions to achieve sustainable campuses and communities. Since the release of its definition by the World Commission on Environment and Development (Burndtland Commission), "Sustainability" has been a buzz word in every aspect of our lives. The "Sustainable Development" concept is regarded as one of the most successful approaches to support strong economic and social development. However, despite its popularity, it is not clearly understood by many ordinary citizens due to its broad and rather vaguely defined concept. Many people regard that practicing sustainability should be government-driven and industry-oriented business, something that they don't know (or don't care) except for putting an empty aluminum can in a recycle bin.

Environmental pollution has emerged as a serious problem in the past few decades. The increasing population has further burdened our environmental resources and intensified the already existing problems. Industrial processes, power generation and transformation, and various other demands of a modern lifestyle have resulted in production of many chemicals and their byproducts that deteriorate the quality of air, water, and soil. With the growing concern about the environment, sustainability issues are being prioritized for comprehensive development.

Development and maintenance of a sustainable environment is one of the major challenges that mankind is facing today. One should always consider a sustainable alternative under all circumstances, so that the limited amounts of natural resources can meet the requirements of the ever-increasing population. Sustainable Development stands for meeting the needs of present generations without jeopardizing the ability of future generations to meet their own needs. In other words, it stands for a better quality of life for everyone, now and for generations to come. It offers a vision of progress that integrates immediate and longer-term objectives, local and global action. It also regards social, economic and environmental issues as inseparable and interdependent components of human progress.

Although taken as a critical issue, sustainable development has been actually practiced in limited areas. Conceptual understanding on sustainable development is either too specific to certain fields, too broad in others, or even incorrect in still many other fields. Most research on sustainable development has been focused on technical approaches to alternative energy development and its impacts. This book contains practical and hands-on examples of sustainable practice, and sustainability education happening on college campuses. This book is a showcase for many ideas and endeavors pursued on college campuses. Through the case studies presented in this book, the concept of sustainable development can be more clearly understood. From a textbook approach to a "crazy" idea, campus activities for sustainable development are an effective way of learning and implementing sustainability in surrounding communities and industry. A college campus would be the best place to practice and test new ideas and to learn valuable lessons from the results and mistakes. The case studies include past, current and projected activities to green college campuses. In addition, the pedagogical challenges in sustainability education are included to address the key issues of the multi-disciplinary nature of sustainability, useful tools, and lessons learnt.

Most of the book chapters have been selected based on the concept and depth of presentations given at the conference. We also invited outside authors who are working in the similar areas to elaborate the topics. *The additional chapters are believed to help the readers see similarities and differences between campus and off-campus practices, which reinforce readers' insights on sustainability practice. It also helps the readers understand how the campus practices be extended to communities, industries, and governments.* For example, case studies by professionals who apply and practice sustainability for military bases and governments provided deeper insights and comparisons with the campus practice and broadened possible applications. All the selected authors prepared their book chapters according to editors' guidelines. They described the contents in detail, included the literature review and added any new material and future direction on their case studies. *The topics in each chapter have been extended to global perspectives in order to help readers apply the campus practices to various levels and areas.* Each book chapter was reviewed by one of the editors and/or an invited reviewer who is an expert in the related field.

First four chapters address past, current and projected activities to promote sustainability and to green our campuses. Success stories, pitfalls, and opportunities are shared. These four chapters cover the development of a sustainability office, recycling program, waste reduction program, and LEED certification for universities and colleges. Next four chapters include the information derived from students' projects and homework assignments involving university education, teaching life cycle assessment, design of a solar power system, and role of a field station. Furthermore as the multi-disciplinary nature of sustainability presents pedagogical challenges, the key issues that should be discussed in class to overcome these challenges are presented in these chapters.

The last four chapters focus on miscellaneous topics related to sustainability. The areas covered include a shrinking city, use of biodiesel in transit buses, military installations, and technologies for nitrogen removal. Sustainable Military Installations presents a unique approach to achieving sustainability spearheaded by US Air force. This chapter talks about application of sustainability within the military (triple bottom line), DoD programs/guideline, and case studies from U.S. DoD, assessment of success and projections for future/conclusions

The primary audience of this book are college students, faculty and sustainability-related researchers. It will be a good source for high school students and teachers as well to get a better understanding on the concept of sustainability and what can be done on campus and community. Decision makers in governments and industries may use this book as a resource to get possible ideas for promoting sustainable development. This book may be of interest to environmental administrators and facility managers in charge of environment who want to install new plans and investigate potential impacts and pitfalls.

Keywords: Sustainable Education, Green Engineering, Sustainable Practice, Sustainable Research, Sustainable Manufacturing

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CHAPTER 1

Approach to Developing a Sustainability Office at the University Level

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Abstract: The process of effectively advancing sustainability on a university campus takes a coordinated effort achieved through an institutional commitment. Wayne State University (WSU) embarked upon a campus-wide initiative to develop a report that would guide the institution toward achieving the triple-bottom line of environmental, economic, and social sustainability. A multi-disciplinary group made a series of recommendations that would usher WSU forward in sustainable best practices within the campus environment. Of singular importance among these recommendations was the call for a dedicated office that would have oversight of University sustainability initiatives. Nearly four years following the initial report, WSU established an Office of Campus Sustainability (OCS) charged with coordinating the University's efforts to move toward an environmentally-friendly institution. The pathway leading to opening the OCS was long and arduous with various results yielding successes and challenges. The office structure played an important role in the scope of activities that the sustainability office could become engaged. Importantly, initial administrative support became tepid through leadership changes slowing attempts to gain traction on campus-wide initiatives. Through continuous attempts at campus engagement OCS has been able to build a foundation that would help solidify its standing as a campus resource while proving to be a valuable means of developing worthwhile sustainability programming.

Keywords: Administration, Alternative-transportation, Campus, Community, Detroit, Education, Energy, Environment, Facility, Fund, Outreach, Recycling, Research, Stormwater, Students, Sustainability, University, Urban-garden, Waste, Watershed.

INTRODUCTION

In the United States, the National Environmental Policy Act of 1970 (NEPA) was

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the beginning of a movement that helped solidify stewardship of the environment as an increasing focal point around the global community [1]. It is significant because it called for processes that implement goals for the protection, maintenance and enhancement of the environment within all federal agencies. Importantly, NEPA is a directive that over time has had a significant impact on the broad, systemic acceptance of environmental protections [1].

Globally, the sustainability movement (SM) was born in 1972 through the Stockholm Declaration which helped begin its movement into higher education [2]. The Stockholm Declaration outcomes included 24 principles that helped guide environmental sustainability in multiple ways [2]. Several years later, the Tbilisi Declaration continued to move the SM forward during the Intergovernmental Conference on Environmental Education in Tbilisi city [3]. Notably, this was the first intergovernmental conference on environmental education and recommended development of criteria to help guide the discipline. Another significant sustainability outcome occurred with the Kyoto Declaration of 1993, which convened 90 international university leaders for the Ninth International Association of Universities Round Table [4]. The main focus of the Kyoto Declaration was to develop clear outlines for sustainable environmental roles in universities. The Kyoto Declaration also emphasized the need for environmental education at universities to not stand by itself, but should be combined with physical operations [5].

In 1996, Ball State University held the first conference called Greening of the Campus, which involved 200 participants from 29 states and five different countries [6]. International collaboration at the conference increased the discussion toward ideas on environmental science on campuses worldwide. In 1997, the conference involved 50 educators, consultants, and researchers in workshops to resolve environmental challenges surrounding paper waste, energy waste, and physical plant operations. The conference has been held every year since and has led to the development of environmental science curricula on university campuses [6].

The Earth Charter initiative, established in 2000, challenged traditional educational methods to increase instruction of environmental education through life-long learning at the university level [7]. It also sought to inspire all humans to take action and responsibility toward protecting the earth for the benefit of families, communities, and future generations [7]. Also, in 2000, the Global Higher Education for Sustainability Partnership (GHESP) convened a meeting of the Association of University Leaders for a Sustainable Future. The main goal of the GHESP meeting was to discuss and improve the plans that help impact the role of sustainability in higher education [8].

Given these precursors, the Office of Campus Sustainability (OCS), as an integral part of Wayne State University's sustainability effort, works to reduce the environmental impacts created by the University's operation. The main role of a sustainability office is to enhance the educational level of the campus community by discussing social and global challenges to the environment that could happen from the present on into the future [9]. Nonetheless, a sustainability office's role is important in linking itself to curriculum taught to students in various disciplines [10 - 14]. However, other sustainability educational programs include application with knowledge to make sure students understand the environmental issues [10 - 14]. The Wayne State OCS seeks to engage the campus community in sustainability through exposure to opportunities that allow experiential learning throughout the campus and community. An example of an OCS-sponsored activity is its sustainability lecture series. Figs. (**1** and **2**) show a presentation by the Detroit River International Wildlife Refuge Manager, Dr. John Hartig, discussing implications of historical industrial pollution and the subsequent cleanup of several regional waterways.

PRESIDENT'S TASK FORCE ON ENVIRONMENTAL INITIATIVES

In response to excitement surrounding student-run grassroots programs and a variety of voices pushing for environmentally friendly practices at Wayne State, leadership at the university chose to join the sustainability movement in the late 2000's. This crusade boomed in institutions of higher education across America at the turn of the third millennium. At the time, the term *sustainable development* fused together two conflicting ideas of, first, preserving items that are endangered of exhaustion and, second, the idea of accommodating desires to continue development [15].

While these concepts have proven difficult to maneuver on a global scale, higher education institutions like Wayne State University (WSU) were exploring ways to achieve sustainable development. New guidelines and higher environmental standards were being applied to myriad organizations across the country. As an influential Detroit institution and source of world-class education to many Michigan residents, it made sense that Wayne State should strive to also be a leader in conservation and sustainability efforts through research, promotion, and practice.

In 2006, President Reid assembled a diverse group of Wayne State faculty, staff and students to form the President's Task Force on Environmental Initiatives. The group was charged with reviewing and analyzing existing programs related to the University's environmental impacts and stewardship, and then followed up with a comprehensive plan for improving the university's resource use. The group was

CHAPTER 2

A Comprehensive Overview of University and College Recycling Programs

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Abstract: Recycling was one of the first steps many colleges and universities took to make their campuses greener. Schools began to realize the benefits of recycling including reduced costs for landfilling, saving raw materials, pollution prevention, and many others. Not all campus recycling programs operate under the same parameters and can differ significantly depending on the labor structure and collection system used. Despite the system a campus selects, additional factors must be considered to develop a successful program including campus support and education, program branding, bin selection and placement, operational efficiencies, as well as planning and tracking. Today, many school recycling programs go beyond providing only basic recycling services. Programs have branched out to also focus on additional initiatives including recycling competitions, event recycling, composting programs, electronics recycling programs, reuse programs, and student education and behavior changing initiatives. The latest trends to push their campuses towards a sustainable future include broader zero waste goals, removing trash cans from offices and classrooms, plastic bag and bottle bans, and paperless campuses.

Keywords: Branding, Campus support, Competition, Compost, Educated Population, Electronics, Financial support, Marketing, Recycling programs, Reuse, Single-stream recycling, Surplus, Sustainability, Waste audit.

INTRODUCTION

The 1990 Tallories Declaration, a consensus document on sustainability created by university leaders from around the globe, encouraged campuses to set examples for their communities [1]. Sustainability is defined by the Brundtlant Report as meeting "the needs of the present without compromising the ability of future generations to meet their own needs [2]." Before this declaration, recycling was one of the first green programs colleges and universities implemented. Recycling

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is defined as sending materials to a place where they will be turned into something new [3]. The U.S. recycling movement began on college campuses in the 1970s. Schools began to realize the benefits of recycling including reducing costs for landfilling, saving raw materials and energy resources, preventing pollution, benefiting the local economy with job creation, and many others [4]. By the 1990s a large number of colleges and universities had well established programs resulting in financial savings and potential revenue [5].

A 2006 survey found that sustainability was taking hold on campuses. Of the 472 staff at North American universities surveyed, 66% stated that their universities and colleges place more importance on green initiatives than in the past and 33% had or would soon have offices of sustainability [6].

Today, the attention of many schools' recycling and sustainability programs has shifted from recycling to the greater need for waste minimization through initiatives like green procurement, reuse programs, and inventory control. This paradigm shift limits the amount of materials needing to be landfilled or recycled, taking the benefits received from recycling to the next level by dramatically decreasing the need for energy and raw material consumed [7].

TYPES OF RECYCLING PROGRAMS

Not all campus recycling programs operate under the same parameters. There are major differences between programs, which dictate how they operate. All programs fall into one of two organizational structures: in-house or outsourced.

An in-house program uses internal labor to collect the material. The amount of internal processing depends on the program. On one extreme, a program can have intensive internal operations which handle collection, processing, and selling the material. On the other extreme, they can have very limited internal operations which include simply collecting the material and placing it in a centralized location for an outside company to service.

An outsourced program involves hiring an outside company, like Waste Management as shown in Fig. (**1**), to handle the campus's material. Most often with this type of structure, the outside company services centralized containers. While many schools prefer this option because of reduced labor costs, it is often the more expensive option. It can add tens or hundreds of thousands of dollars to campus disposal costs annually depending on the size of the campus and scope of the program [5].

Under these two structures, programs can use one of four methods for material collection: single-stream, commingled, source separated, or all-in-one. The right collection method depends on the program's goal, composition of the waste stream, previous techniques used, amount of support, and available labor [8].

Fig. (1). Waste Management, Inc. services a client's recycling needs (Image courtesy of Waste Management, Inc.).

On one end of the spectrum is single-stream, which is becoming very common in both municipal and campus recycling programs. A single-stream program collects all recyclables in one bin, like the Big Belly compactors at Saint Louis University as shown in Fig. (**2**).

Fig. (2). Saint Louis University uses Big Belly compactors for their single-stream recycling program. Above is a picture of their side-by-side trash and recycling bins (Image courtesy of Saint Louis University).

The material is then sent to a material recovery facility (MRF) where a combination of machinery including sensors, magnets, and gravity are used in concert with human labor to sort out the different types of recyclables [9]. On the

CHAPTER 3

University Waste Reduction and Pollution Prevention Assistance Programs: Collaborations with Industry, Government and Academia

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Abstract: Since the mid-1990's collaboration between the local government, industry, and academia was established to offer zero cost energy and waste assessments to businesses and organizations that operate in Lucas County, Ohio, USA. The research project, named the Business Waste Reduction Assistance Program (BWRAP) has performed over 85 solid waste assessments and identified over 125,000 short tons of waste for reduction. In addition to the waste reduction, the BWRAP program has also identified over $3.5 million in cost savings through the implementation of the recommendations. This chapter provides an overview of the BWRAP program including its framework and a comparison to similar collaborations in the US. A case study is also provided.

Keywords: Academia, Economic analysis, Energy reduction, Government, Greenhouse gas reduction, Partnerships, Pollution prevention, Recycling, Solid waste assessments, Waste reduction.

INTRODUCTION

The United States generated over 250 million tons of municipal solid waste (MSW) in 2013, up from over 200 million tons in the year 1996 [1]. In terms of recycling, the US increased recycling levels to over 85 million tons, an increase from 29 tons in the mid-1990's [1]. This represents a recycling rate of 34.3% in the US or more than double of the 1996 rates. Although this represents a positive trend; innovative work is still needed to address the 65.7% that is not being recycled, reduced, or reused. Waste reduction is a critical concern from both a US and worldwide perspective. For example, a recent study in China indicated that close to 90% of solid waste was being disposed at landfills in this country [2].

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This is where programs such as the Business Waste Reduction Assistance Program (BWRAP) come into play. In 1996, a joint partnership between The University of Toledo, Industrial Engineering Department and the Lucas County Solid Waste Management District (the District) was created to assist companies in the region in reducing solid waste amounts sent to the landfills and to reduce operating costs. The intent of this chapter is to provide universities and local governments with a framework to implement similar programs. This includes a discussion of relevant background, the BWRAP framework, and a detailed case study. Finally a discussion regarding opportunities and potential barriers is provided.

BWRAP BACKGROUND AND OVERVIEW

In 1989, the Ohio Solid Waste Disposal Act established a statewide system to plan to reduce the reliance on landfills for solid waste disposal. The Act created 54 new Solid Waste Disposal Districts in the state of Ohio to achieve these reductions. The Solid Waste Districts were concerned with increasing recycling, reducing waste, and diverting wastes from Ohio landfills. The established goals of the Lucas County Solid Waste Management District (District) included [2]: 1. Increasing recycling, reduction, and reuse of materials in Northwest Ohio. 2. Increase recycling residential rates to 25% or greater and industry recycling rates to 50% or greater. To accomplish these goals the District collaborated with the College of Engineering at University of Toledo, Ohio, specifically the Industrial Engineering Department, to create the Business Waste Reduction Assistance Program. The District awarded at $1.4 million grant to create the BWRAP program. The funding provided allow the BWRAP program to hire a full time engineer/director, three engineering graduate students and two undergraduate engineering students. The mission statement of the BWRAP program is stated “to assist various organizations in Lucas County to improve ‘green and sustainable; efforts through *via* cost effective process changes in conjunction with the education of engineering students in waste reduction, pollution control, and environmental management”. The primary purpose of the BWRAP program was to provide zero cost environmental assessments to business and organizations that reside in Lucas County, Ohio. In addition, the BWRAP program offered the numerous no cost services ranging from scrap reduction, to zero landfilling, to waste-to-energy, to six sigma. The group also assisted in areas such as the application of alternative/green energy, high efficiency lighting, and LCA analyses.

WASTE AUDIT PROCESS OVERVIEW

A waste assessment conducted by the BWRAP program consists of nine steps.

The BWRAP process was adapted from an US EPA waste audit assessment manual [3].

In a recent study, a researcher used this US EPA manual to reduce waste water emissions by over 20% in Slovenia at a textile facility [4]. The first step of the BWRAP waste assessment process is to provide the client with a Pre-Assessment Questionnaire. The Pre-Assessment Questionnaire provided the student research team with a baseline understanding of the client's processes, waste streams, and operating procedures. Table **1** provides and overview of the nine step waste assessment process [11].

Table 1. Waste assessment process overview.

	Process step	**Description**
1.	Pre-Assessment Questionnaire	Gather basics company operating information *via* an email survey.
2.	Pre-Assessment Meeting	Meet with the organization's management team to discuss the pre-assessment questionnaire and determine project goals.
3.	In Plant Data Collection	Collect data onsite at the facility; this includes a detailed facility tour, observing waste amounts/compositions for every waste container in the facility, and creating process flow charts/diagrams.
4.	Data Analysis	Analyze the data collected for trends and areas of concern.
5.	Additional Data Collection	Conduct a second facility visit to collect any necessary data not collected during the first visit such as equipment specifications, layouts, and employee feedback.
6.	Research Progress Meeting	Determine improvement opportunities based on the data collected.
7.	Waste Assessment Research Report Writing	Provide the facility management team with information regarding amounts and compositions of waste streams and cost effective recommendations to reduce waste.
8.	Presentation	Prepare a formal presentation for the facility management team regarding the assessment findings.
9.	System Feedback	Gather feedback regarding the assessment process and recommendations that have been implemented.

The purpose of steps one and two are to gain a baseline understanding of the client's operations in terms of waste generation amounts, waste disposal costs, and operating constraints. During this step, the team also assigns tasks and 'lead roles' to each student team member.

The purposes of step three are to verify the information collected from the Pre-Assessment Questionnaire and to gather additional raw data. The 'facility walk through' provides a firsthand opportunity for the team to observe waste streams

CHAPTER 4

University Waste Reduction and Pollution Prevention Assistance Greening College Campuses through LEED Certification

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Abstract: Greening efforts on campus are often reported to enhance students' performance in class and help higher education systems better equipped with a strong sense of sustainability. LEED certification program promotes the greening efforts on campus that can also affect surrounding communities. This chapter looks into these efforts and their consequences on and around campus. Two exemplary schools are selected based on their success in implementing LEED program into building construction and renovation and applying it to the pedagogy of education for sustainability and eco-friendly practices. Georgia Tech has successfully transformed its campus more walkable, bikeable using LEED as a tool for on-going operations and maintenance of the campus. LEED program is aligned with its more than 100 courses with a sustainability focus. The University of North Carolina at Greensboro (UNCG) successfully completed building renovation through LEED. The project is notable because of the reuse of existing structural elements rather tearing down and using new materials.

Keywords: Building renovation, Building reuse, Carbon neutral buildings, CO_2 sensors, Green buildings, Green metric, HVAC, Irrigation, LEED certificate, Rain garden, Runoff water, Stormwater, Sustainability, VOCs.

INTRODUCTION

Green school /grEn skül / n. a school building or facility that creates a healthy environment that is conducive to learning while saving energy, resources and money – US Green Building Council.

According to the 2014 survey result published in the Princeton Review's Guide to

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332 Green Colleges [1], there is a rising interest among students in attending colleges that practice, teach, and support environmentally responsible choices.

Among the more than 9,900 college applicants the Princeton Review surveyed for its "2013 College Hopes & Worries Survey," 62 percent of respondents said they would value having information about a college's commitment to the environment. As it turns out, the school's commitment and active practices to promote environmental sustainability is regarded as an important deciding factor by students. There is no doubt that making a green commitment helps enhance a school's image and reputation to students and also strengthens students' attachment to the school.

There are many reports that greening of campuses help students learn better in a quiet, comfortable, and properly lit environment [2]. Not only reducing energy consumption by buildings and reducing waste production, greening efforts also provide learning environments conducive to student and faculty health. Green buildings are reported to improve student test scores, promote better attendance, and provide healthier learning environments [3]. Furthermore, a green campus movement can create opportunities for faculty to incorporate project-based learning into coursework, and provide students valuable hands-on project experience.

One green building program adopted by US colleges that stands out among many others is the US Green Building Council's (USGBC) Leadership in Energy & Environmental Design (LEED) certification program. LEED is a green building certification program that recognizes best-in-class building strategies and practices. To receive LEED certification, building projects satisfy prerequisites and earn points to achieve different levels of certification. Prerequisites and credits differ for each rating system, and teams choose the best fit for their project. LEED certification activities at colleges and universities have impacted student education and even job placement.

The impacts of pursuing and achieving LEED certification at a school appear to be broad. One of the major impacts is reinforcement of students' learning experience by incorporating LEED into coursework. Schools can include students in projects seeking LEED certification for a new or existing building. Through class assignments, internships and volunteer programs, students can assist with many of the tasks associated with LEED and help significantly reduce project costs. The activities may include early planning or assessment tasks to help schools determine which campus facilities are best suited for LEED certification. At Purdue University students taking their multi-semester LEED Lab course identify how credits can be obtained for campus buildings in the LEED for

Existing **B**uildings: **O**perations & **M**aintenance (EBOM) rating system, and then document those credits [4]. Students and faculty members may be involved in evaluation of current operations and maintenance procedures and policies, conducting light, water and waste audits to benchmark a building's performance, creating and administering occupant and transportation surveys, researching sustainable strategies and technologies, and planning educational programs to inform students and staff on new sustainability policies and programs.

By incorporating project-based learning into their coursework, faculty can demonstrate how to apply lessons learned in the classroom to real-world projects. Students are also exposed to a process that embraces collaboration and fosters creativity, and the participating faculty can use field experience to inform their research and keep curriculum current.

Excerpts from Gregor [4] state as follows: After hearing about Universities engaging students in LEED projects as volunteers or interns, the U.S. Green Building Council's (USGBC) Center for Green Schools collaborated with Catholic University of America to develop a for-credit academic course based on LEED EBOM. Instead of only getting volunteer experience, they sought to give students course credit and an academic experience that would equip them with "a professional skill set gleaned through actual building certification," according to Jaime Van Mourik, the director of higher education at the USGBC. "One of our goals was to help universities and colleges build capacity in-house to begin to better integrate sustainability into their daily operations and maintenance practices," said Van Mourik. The LEED Lab program is a hands-on course, initially launched at Catholic University and currently replicated at about seven colleges and universities, in which students join forces with the campus facilities department or consultants to improve campus sustainability by working toward obtaining LEED certification of existing campus buildings. As a result of student coursework since 2011, the Crough Center for Architectural Studies, a former gymnasium built in the early 1900s, was certified in September of 2014. At Colorado State University-Pueblo, their LEED Lab course is structured around learning modules adapted from chapters of the LEED Reference Guide for Green Building Operations and Maintenance, supplemented by other reading and tutorials. Students work in groups, each assigned a few credits toward certification of the Library Academic Resources Center, a building on Colorado State's campus that also serves as their classroom.

This learning experience may easily expand to surrounding community members who seek to create green sports complexes, gyms, and libraries. At the University of Dayton students who take the course "LEED Building Design," offered in the School of Engineering, review drawings and do LEED related calculations on real

CHAPTER 5

Graduate Education for Sustainability of Sugarcane Biorefineries in Mexico

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Abstract: *Sugarcane Biorefineries* provide an important issue to several applied fields of technologies because they integrate sustainable sugarcane byproducts utilization with basic sciences and core technologies. However, for competiveness, they require highly multidisciplinary skilled human resources in engineering, agronomy, biology, economics and others. In Mexico, sugar agro-industry produces a single undifferentiated final product (sucrose) with the implementation of highly polluting conventional transformation processes, and with demands of fossil energy. It also creates low level of integration of universities for the implementation of technological innovations in the sugar industry and a number of socioeconomic constraints and low environmental sustainability. Therefore, the University of Veracruz, with professionals from all areas of knowledge, located in the Mexican region with the highest sugar production, has carried out a sugarcane master's program with the commitment to enhance sustainability, training, development of educational capabilities and technology transfer and professionalization for sugar industry stakeholders since 1996. The Master's Program allows to develop skills of agronomic and sustainable conversion technologies, and strategic management for graduates. It promotes regional development to build biorefineries according to sustainable development and competiveness with a wider international perspective and also the participation of sugar and ethanol technicians sharing practical experiences. This approach discusses in detail the structure of graduate academic program as well as the necessary technology and research actions and the fundamental participation of technical graduates for the transition from traditional sugar industry to sugarcane biorefinaries.

Keywords: Competiveness, Ecological constraints, Master´s program, Productive diversification, Socioeconomic constraints, Sugar industry, Sugarcane biorefinery, Sustainability, Veracruz Mexico.

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INTRODUCTION

The worldwide need for alternative sources of biomass and agro-industrial byproducts such as sugar cane, oilseeds, cereals and forest products is increasing for the intensive and extensive productions of renewable energy, biofuels, food and livestock feed. Thus, biomass refineries (known as “biorefineries”) are poised to contribute significantly to the growth and sustainability of the wide world economy in coming years [1 - 4].

The main objective of sustainability of biorefineries is to minimize the use of inputs, chemicals and energy derived from nonrenewable resources extracted from the earth to reduce environmental impacts. Sustainability is a very different approach to the conventional productivity concept from chemical and agronomic process [5].

The goal of sustainable development is to achieve progress on economy, environment, and society[2]. The sugarcane industry[3], like other agribusiness, requires drastic changes due to globalization, environmental pressure, natural resource depletion, *etc*. The agroindustry recognizes the need to contribute to sustainable development through biorefineries and green chemistry and to add values to the conventional production chain [6].

Biorefineries

The biorefinery concept is similar to fossil refinery, which produces multiple fuels and chemical products, as a technology strategy to enhance regional energy security, mitigating climate change and global warming [7, 8]. A biorefinery integrates a variety of conversion processes by producing multiple products, and maximizing the added values from biomass feedstocks. Therefore, biorefining is regarded as sustainable treatment of green biomass into marketable products and energy through chemical, thermochemical, mechanical, biotechnological and physical processes. The input materials range from specialized plants to waste materials from agribusiness. The output covers different energy sources such as heat, electricity, biogas, syngas, ethanol, methanol, biodiesel, and other resources as food, animal feed, fertilizers, and chemical building blocks for further refinery [10 - 14].

Accordingly, sugarcane is the most promising raw material to creation of a sustainable bio-based economy and environment, mainly in developing countries, because converting 100 tons of whole feedstock sugarcane is possible to obtain at least 10 tons of sugar (sucrose), 30 tons of trash (tops and leaves), 30 tons of bagasse (fiber and pith), 4 tons of molasses, 0.3 tons of ashes and 3 tons of filter mud, and a variety of potential products reducing greenhouse gas (GHG) emissions (Fig. **1**) [15].

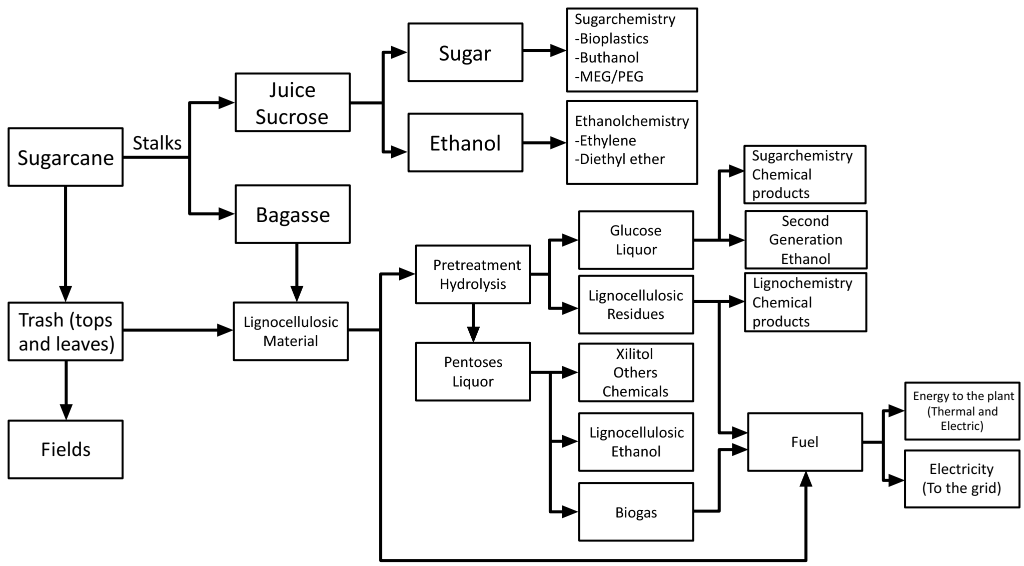

Fig. (1). Sugarcane biorefinery [16].

The sugarcane biorefinery is complex; sugar mill production depends on the supply of sugarcane as raw material, and other inputs. The main products (ethanol, sugar and energy) are sold as principal products. The byproducts are used for several industries, such as pulp and paper, compost and animal feed. Nowadays, sugar mills use the residues, such as vinasse and cake filter, as bio-fertilizers. At these chained values in sugarcane agriculture, training, research and knowledge provide capacities that can increase efficiencies, business integration, responsiveness, sustainability and regional competitiveness [17 - 21]. In sugar industry, research has expanded rapidly over the past two decades. It has been mostly motivated by low world sugar prices, rising costs of production and competition with high fructose corn syrup (HFCS) and other artificial sweeteners. In relation to biorefineries, there are potentials to double the biomass production in most parts of the world and smart use will make it possible to provide the needed energy, food, feed, and chemical building blocks for alternative usages [19].

But, the increased production and intelligent use of sugarcane biomass requires extensive research, innovation and education for students, producers and stakeholders [22]. Although it exists at the intersection of multiple sciences, including agronomy, economics, chemistry, organic chemistry, biochemistry, bioprocessing, microbiology, enzymology, biology, plant science, and

CHAPTER 6

Teaching Life Cycle Assessment (LCA) to Graduate Students at The University of Toledo

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Abstract: Life cycle assessment (LCA) is a tool for assessing the environmental impacts of a product or service throughout its life cycle. LCA is considered an important modeling tool for sustainability assessment and many universities are currently offering LCA courses. However, due to unavailability of established text books or approaches, it is difficult for an instructor to develop and teach an LCA course. The goal of this chapter was to share the experience from the University of Toledo in developing and teaching of an LCA course. A systematic approach based upon Fink's taxonomy of learning was used in designing the course. The course was organized in ten learning modules: introduction to LCA, LCA steps, EIOLCA, process based LCA, computational structure of LCA, carbon footprint analysis, personal footprints, life cycle costing, LCA peer reviewed literature, and semester long project. Active learning methods were used throughout the semester with at least one assignment per module. The process based LCA module was taught *via* slides, manual matrix calculations, and use of the commercial GaBi LCA software. The LCA peer reviewed literature module included written and oral presentation assignments requiring students to evaluate the LCA aspects of the paper as well as technical writing and technical quality of the paper. The semester long project was taught using multiple steps and encompassed most of the course objectives identified earlier in the course design.

Keywords: Carbon footprint, GaBi, Graduate class, Learning modules, Life cycle assessment, Life cycle costing, Semester long project, Sustainability assessment.

INTRODUCTION

There is a rapidly growing body of sustainability engineering education literature which shows that sustainability education is transforming the content and format of engineering education [1 - 10]. Life cycle assessment (LCA) is one of the most commonly taught sustainability engineering education concepts [11, 12]. LCA is a

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tool for assessing the environmental impacts of a product or service throughout its life cycle. Many universities are already teaching LCA, typically at the graduate level. However, there are no established textbooks or best practice approaches for teaching LCA. This makes it difficult for an instructor to develop and teach an LCA course.

At the University of Toledo, an LCA course has been offered once a year in fall semesters since 2011. The enrollment in this course has varied from 5 to 13 people, populated primarily by civil engineering graduate students and to a lesser extent by graduate students from chemical engineering and environmental science departments. A systematic approach was used to design the LCA course and feedback from students has been improving the course since its inception. The goal of this paper was to share the experience from the University of Toledo so as to help other LCA instructors improve their own courses. Towards this goal first, the design and philosophy of the course are discussed. Then, the learning modules created for the course are discussed along with the activities used in teaching these learning modules.

COURSE DESIGN AND PHILOSOPHY

The LCA course was designed using Fink's taxonomy of learning which includes six realms of learning (Table **1**) [13]. The most common taxonomy used in college teaching is the one developed by Bloom which includes knowledge, comprehension, application, analysis, synthesis, and evaluation [14]. Fink's approach expands on the concepts of Bloom's taxonomy and incorporates other dimensions that enrich the learning experience (Table **1**). One of these additional dimensions is 'learning how to learn' which is critical for today's students where online and paper based learning opportunities are endless, but require students to have the capacity and the discipline to teach themselves the knowledge and skill sets. Another consideration in Fink's taxonomy is 'learning about oneself and others'. This consideration is important because it puts the learning process in the context of a community where the learner is making neural connections about the topic in the context of how this knowledge relates to the learner and others. The last dimension in Fink's taxonomy is 'caring' which a prerequisite to learning is. There can be little to no effective learning if the learner does not care about the topic. This dimension also nurtures the students in their ability to help themselves and the society and is therefore a good pedagogical approach for developing human beings that will benefit our society and all living things.

With Fink's taxonomy serving as the foundation for course development, a list of course objectives were developed. Separate course objectives were identified for each of the six realms of Fink's taxonomy (Table **2**). This process created a long list of course objectives. However, this list was helpful in ensuring that Fink's approach was adequately implemented in class. Many of the course objectives can be achieved primarily by having students work on projects; simpler activities may not be sufficient to cover all realms of Fink's taxonomy. Therefore, project based learning has been an important aspect of the LCA course at UT since its inception.

Table 1. Comparison of Bloom's and Fink's taxonomy (Apul and Philpott [19]).

Bloom's taxonomy:		Fink's taxonomy:
1. Knowledge 2. Comprehension 3. Application 4. Analysis 5. Synthesis 6. Evaluation	Similar	1. Foundation 2. Application 3.Integration
	Additional	4. Learning how to learn (becoming a better student, inquiring about a subject, self-directed learners) 5. Human dimension (learning about oneself and others) 6. Caring (learning new feelings, interests, values)

The expectations from a graduate level engineering class can be manifold but can be summarized as covering content and developing students' skills. In the LCA class the content was organized in separate learning modules. The core skills that students were expected to develop included: I) ability to read and analyze research papers; II) quantitative problem solving, III) software use, IV) oral and written communication, and V) team work. These expectations were intentionally incorporated into the learning objectives listed in Table **2**.

LEARNING MODULES AND ACTIVITIES OF THE LCA COURSE

The content was organized in 10 separate learning modules (Table **3**). The online environment for the course clearly distinguished the different learning modules and stored relevant resources within each learning module. Modules 9 and 10 spanned the entire semester while the other modules were covered within one or more weeks. Three of the learning modules are explained in greater depth in section "Description of selected modules".

Various in- and out of class activities were incorporated into course design to achieve the objectives shown in Table **2** while covering the 10 learning modules shown in Table **3**. A list of the class activities is shown in Table **4**. The types of activities were intentionally made diverse so as to enrich the learning experience.

CHAPTER 7

Enhancing Environmental Sustainability Through A University Field Station

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Abstract: University field stations are located off site from the main campuses and frequently in a natural setting, providing opportunity for students, faculty, and the public to engage with – and appreciate – local ecosystems. Their missions usually encompass the three cornerstones of environmental research, education, and outreach/community engagement, which go hand-in-hand with understanding and furthering sustainability. University field stations enhance environmental sustainability by helping to preserve a natural setting for coming generations, fostering research and monitoring of local ecosystems and their component biodiversity, and training the next generation and citizen scientists for field and laboratory work. Here we provide an example of how we are addressing sustainability through growth of the Lake Erie Center, a mid-sized university center with modest funding and staff that is located at the heart of land-water issues of runoff, sedimentation, algal blooms, legacy contaminants, and habitat loss facing the world's largest freshwater ecosystem of the Laurentian Great Lakes. We have networked our mission by building an Environmental Science Learning Community, which brings together faculty, students, educators, agencies, stakeholders, and the public to work towards the common goal of improving land-lake ecosystem services. This background has allowed us to rapidly respond to the August 2014 "Toledo Water Crisis" in which the Lake Erie water supply to 500,000

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local citizens was contaminated by the algal toxin microcystin, resulting in a "do not drink" health advisory. The Lake Erie Center's strategic location, both geographically and scientifically, has enhanced our effective education, research, and community engagement programs.

Keywords: Biodiversity, Climate change, *Dreissena polymorpha*, Dreissenid mussel, Eddy covariance, Field station, Graduate student education, Harmful algal bloom, Invasive species, Lake Erie, *Microcystis*, Quagga mussel, *Sander vitreus*, Sensor network, Sustainability, Tiered mentoring, Toledo, Undergraduate education, Unionid mussel, Walleye, Water quality, Zebra mussel.

INTRODUCTION

As universities throughout the nation embrace their outreach and engagement missions, it is not surprising that university field stations comprise excellent assets for combining research, education, and community outreach, thereby serving as hubs of environmental sustainability. Notably, marine ecologist Dr. Jane Lubchenko [1] wrote on behalf of the board of the American Association for the Advancement of Science that, "The new and unmet needs of society include more comprehensive understanding and technologies for society to move toward a more sustainable biosphere – one which is ecologically sound, economically feasible and socially just." As such, university field stations and their sustainability programs, such as provided by the University of Toledo's Lake Erie Center, offer avenues to work towards addressing the complex ecological and economic problems of a sustainable future.

The Lake Erie Center (Fig. **1**) is an example of a small field station that serves as a hub of environmental sustainability. The mission of the Lake Erie Center is "to improve the environmental condition, ecosystem services, natural resources, and sustainability of Lake Erie and its watersheds, and to enhance undergraduate, graduate, and public education". According to a report by the National Council for Science and the Environment [2], such "interdisciplinary environmental and sustainability academic and research programs play an important and unique role in higher education" and further serve a common education goal to "prepare sustainability-oriented problem solvers through interdisciplinary scholarship, research, practice, and informed citizenship".

In 2005, the Carnegie Foundation for the Advancement of Teaching created the new "Community Engagement Classification", in which community engagement is used to describe the broadest conceptions on how universities interact in a partnership with their larger communities (local, regional, national, global) in the context of partnership and reciprocity [3, 4]. The University of Toledo is one of 361 campuses that have earned this Community Engagement Classification. The contributions of the Lake Erie Center faculty and staff were highlighted as a specific example of how the university is engaged with our local midwestern community.

Fig. (1). The Lake Erie Center of the University of Toledo is located on the shores of Maumee Bay in western Lake Erie, which is about a 25 minute drive from the main campus. The Center opened in 1998. Photo by Donald Kemp.

The goal of this chapter is to outline how the Lake Erie Center embraces the idea of sustainability through its ideal location on the shores of Lake Erie, leads regional efforts in interdisciplinary research on issues such as harmful algal blooms and habitat loss, mentors students and teachers to be leaders on issues at the land-lake interface, and engages the public through our activities to promote a sustainable future for Northwest Ohio and beyond. The specific vision of the Lake Erie Center reflects this environmental and educational commitment to local sustainability, by seeking "to improve the environmental condition, ecosystems services, natural resources, and sustainability of Lake Erie and its watersheds, and to enhance undergraduate, graduate, and public education towards achieving this vision" [5].

FIELD STATIONS AS PLACE-BASED VENUES TO EMBRACE SUSTAINABILITY

Ecosystems across the world are experiencing rapid and extensive ecological challenges of unprecedented magnitude, which are especially acute at the

CHAPTER 8

Life Cycle Assessment of a Solar Power System Designed to Meet University Energy Demand

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Abstract: This book chapter evaluated the life cycle assessment (LCA) of a solar power system designed to meet university energy demand. A three-step approach was adopted and implemented in this study to determine the scope of using a solar power system as a sustainable renewable energy source. The three-step approach included: (a) design of a solar power system based on university energy demand, (b) review of published solar energy LCA studies to identify appropriate material-based solar cell for consideration in design, and (c) performing economic input-output LCA (EIO-LCA) of the designed the solar power system to understand the environmental impacts. The design of solar power system in this book chapter was based on the actual peak monthly energy demand of 397,911 kilo watt-hours from select facilities within Prairie View A&M University, Prairie View, Texas. This study adopted the use of crystalline-silicon (c-Si) solar panels on the basis of optimal energy efficiency with respect to pricing. The designed solar power system comprised of 27,089 ZBR-280P mc-Si solar panels, 1,957 Rolls 1,284 ampere-hour battery banks, 1,529 PST-240 1000 watt inverters, 10,283 Sunforce-60022 30 ampere solar charge controllers, and 27,089 solar panel universal mounts with folding tilt legs. EIO-LCA results of the designed solar power system indicated a total release of 14,241 metric tons of CO_2 equivalent GHG emissions and 170 tons of conventional air pollutants. This book chapter provides detailed insights on the design and LCA considerations for use by educational institutions when consi-dering the adoption of solar power systems to go green.

Keywords: Design of solar power systems, EIO-LCA, Graduate class, Life cycle assessment, Renewable energy, Solar energy, Sustainability assessment.

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INTRODUCTION

The International Energy Outlook report projects an increase in world energy consumption between 2010 and 2040 to be 56% (2010: 524 quadrillion British thermal units (Btu); 2040: 820 quadrillion Btu). Approximately 80% of the total world energy demand is supplied from the use of non-renewable fossil fuels [1]. This report indicates an ample scope for expanding the use of renewable energy sources in meeting energy demands across the world. During the same period, the United States (U.S.) energy consumption was anticipated to increase from 98 quadrillion Btu in 2010 to 107 quadrillion Btu in 2040, thereby, indicating an increase in energy consumption by 9%. In the U.S., 'renewable energy (conventional hydroelectric power, geothermal, solar/photovoltaic, wind, and biomass) accounts for only 9% of the total energy consumption by source and primarily serves four different sectors (transportation: 13%, industrial: 25%, residential/commercial: 8%, and electric power: 54%)' [2]. Of the available renewable energy sources, 'hydroelectric power (52%) and wind (32%) contribute predominately to electricity generation in the U.S., and are subsequently followed by biomass (11%), geothermal (3%), and solar (2%)' [3]. All the energy in the earth's reserves of coal, oil, and natural gas equals just 20 days of energy produced by the sun, but only 1-2% of that solar energy is used to generate power [4]. Despite the vast potential that solar energy presents as a renewable and sustainable energy source in meeting the world's energy demand, the use of solar energy to date has been very limited.

Solar energy may be referred to as the energy harnessed from solar radiation that the earth receives to be utilized for energy needs. The primary mechanism that facilitates the harnessing of solar energy to generate electricity involves the movement of electrons from the atoms when sunlight hits the semi-conductor based solar panels (photovoltaics). At a macroscopic level, solar thermal power plants accumulate the sun's energy to serve as a heat source that may be used subsequently in boiling water that drives a steam turbine to generate electricity. Solar energy has the advantages of providing with easy installation, low maintenance costs, and environmentally clean energy (with minimal greenhouse gas (GHG) emissions). The only limitation is that solar energy at a given location is dependent on the incoming solar radiation that is influenced by time of the day, season of the year, and local weather conditions.

Several studies [5 - 39] performed the life cycle assessment (LCA) of solar power systems to understand the environmental impacts and energy payback time (EPBT) periods. The level of solar radiation, position of modules, modules manufacturing energy intensity and corresponding fuel mix, and solar radiation conversion efficiency were noted to be the major factors influencing the life cycle performance of solar panels [5]. The electricity production efficiency (electricity output/total primary energy input excluding insolation) using building integrated photovoltaics were computed to range between 3.6 and 5.9 [6]. In general, the EPBT are shorter than the panel operation life even in the worst geographic conditions, thereby, indicating that solar panels are beneficial to the environment [9]. The use of solar panels with electric passenger vehicles proved to be environmentally beneficial in comparison with conventional passenger vehicles [11]. The majority of the solar panel LCA studies [5, 8, 10, 12, 16, 18, 20, 23, 27 - 38] quantified the life cycle GHG emissions and EPBT periods. These studies differed mainly in context with use of varying material composition in the solar panels. Additional details on the quantified GHG emissions and EPBT periods of these studies are documented in the '***Review of Solar Panel LCA studies***' section of this book chapter.

None of the published solar panel LCA studies used the Economic Input-Output LCA (EIO-LCA) method to evaluate the environmental impacts of a solar power system designed to meet university energy needs. This study aims at filling that knowledge gap by following a three-step methodology that includes:

a. Designing a solar power system based on Prairie View A&M University (PVAMU) energy demand,
b. Identifying appropriate material-based solar cell (from the review of solar panel LCA studies) for use in this study, and
c. Performing an EIO-LCA that provides insights into the environmental costs for the designed solar power system meeting university energy needs.

This study will add to existing literature on solar power system based LCA studies. It aims at providing educational institutions across the world with a case scenario that may prove beneficial in decision-making when considering the possibility of adapting the use of solar power systems for electricity generation that eventually decreases our overall dependence on fossil-fuel generated electricity and helps reduce GHG emissions.

METHODOLOGY

This section summarizes in detail the three fundamental components of the study, *i.e.*, design of a solar power system (based on university energy demand), review of solar LCA studies to identify appropriate material-based solar cells (optimal cost and efficiency considerations), and EIO-LCA method.

Design of a Solar Power System

A solar power system may be designed by evaluating the actual peak energy

CHAPTER 9

Approaches to Sustainability in a Shrinking City: A Collaborative Urban Design Studio in Toledo's Civic Center Mall

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Abstract: Once a flourishing manufacturing center closely linked to the auto industry, Toledo and its region are struggling with a number of challenges, among them the long-term decline in the manufacturing sector and the recent economic downturn. Over the past four decades, the city has lost about a quarter of its residents. This is reflected in the physical fabric of the city in the increasing numbers of vacant and abandoned homes and buildings, as well as vacant land. By many definitions, Toledo is a shrinking city.

Although they are found all over the world, shrinking cities are concentrated in old industrial regions and are challenging conventional approaches to architecture, urban design and urban planning. These disciplines have historically been framed by narratives of growth and a reluctance to speak about shrinkage or decline. This is true of urban policy as well, where even when focusing on the sustainability of cities, the underlying presumption has always been of growth.

We use this chapter to explore what sustainability means in a shrinking city and how we can prepare students of architecture and urban planning to work in this context. We begin by examining policies used in shrinking cities in the old industrial belt, then focus on Toledo's history of dealing with this challenge. We discuss four urban design ideas proposed by students of architecture and urban planning working collaboratively. These proposals deal explicitly with the challenges of vacant land in a shrinking city and based on these, offer some lessons for a sustainable future.

Keywords: Architecture, Collaborative studio, Community engagement, Cross-disciplinary research, Cross-disciplinary teaching, Ohio, Old industrial cities, Population decline, Public realm, Rustbelt cities, Shrinking cities, Social inc-

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lusion, Studio pedagogy, Sustainability, Toledo, Urban design, Urban planning, Urban Sprawl.

INTRODUCTION

After many decades when rapid population growth was the biggest challenge facing cities, there are now cities on every continent that are experiencing sustained population loss. Together, they are often categorized as the "shrinking city phenomenon" [1]. Many of these cities, especially the ones most widely studied, are concentrated in industrial "rustbelts," regions that have been facing a steep drop in manufacturing employment [2]. In the U.S., the mortgage finance crisis has had an additional, severe impact on the housing sectors of these shrinking cities [3].

In our case study of Toledo, Ohio, a city emblematic of shrinking cities in the U.S. Midwest, we make two main points: first, we make the case for a role for urban design in shrinking cities to develop options for a more sustainable future. We argue that any future investment in the downtown should be designed both to complete the intent of a long-abandoned historic plan for the area, and to link the various vacant and abandoned lots of downtown into a coherent whole. A proposed new federal courthouse provides an opportunity to do so. Second, we make a case for educating architects, urban planners and urban designers in a way that prepares them to work towards sustainability in the context of population and economic decline. Particularly in the current context of decline, it is incumbent upon universities to reflect on and implement approaches to pedagogy in which the sustainability of our cities and neighborhoods is the central focus. In this chapter, we critically analyze a joint project between an architecture studio at Bowling Green State University and an urban design seminar at the University of Toledo that explored these two ideas.

We begin by outlining spatial strategies that have been proposed or implemented in shrinking cities in the U.S. Midwest. We then briefly sketch Toledo's demographics, which clearly depict a shrinking city. Next, we draw on Toledo's history to demonstrate that the city has used an 'investing' approach without a vision or even a unified plan, which has resulted in individual buildings located in close proximity having little relationship with each other or with their surroundings. We then document a history of competing political, administrative and business interests leading to an uneven legacy of urban planning and design in the central city. Finally, we introduce the four urban design approaches that the city might use in conjunction with the proposed new federal courthouse, and we conclude by discussing some of the case study's implications for design and planning for sustainability.

DESIGN AND PLANNING STRATEGIES FOR SHRINKING SUSTAINABLY

Our definition of shrinking cities as those that have lost 25% or more of their population over the past 40 years follows Vey [4]. Shrinking cities have used several strategies to address the problem of population loss, and the attendant vacant and abandoned buildings and lots, particularly at their centers [5]. Shrinking cities in the American Midwest have used four sets of strategies: investing in the downtowns of their central cities, cleaning and greening, re-sizing, or a combination of these strategies. We briefly review them below.

Investing in Downtown Projects

Facilitated by a number of factors such as the creation of the highway system, increasing rates of home ownership, the post-World War II population boom, quicker and relatively affordable methods of home construction, government policies such as the G.I. Bill and mortgage loan guarantees, American cities, in the first half of the 20th century, expanded rapidly through suburban and ex-urban development [6].

Parallel to this phenomenon has been an interest in the dominant central city of a metropolitan area, particularly its downtown. In his study of the history of downtown policy, Abbott [7], suggests that early investments in downtowns, between 1945-55, assumed the strong link between the metropolitan growth and the size and role of the downtown. As metropolitan regions grew, the importance of the downtown core to the region was never in question.

With time, regions grew ever outward leaving hollow cores, a pattern clearly visible in shrinking mid-western shrinking cities [8]. As these cities lost population, they were competing with their suburban neighbors. "Downtown areas were increasingly seen as environments to be consciously designed in the interest of enjoyment and tourism. This conception of downtown as a theme park accepted its loss of primacy within the metropolitan community. It was to be reconstructed to serve tourists, conventioneers, and occasional visitors on safari from the suburbs. It also accepted that suburban "outer cities" were emerging as co, equals to down, town and then borrowed some of the ideas of the consciously designed suburban environment. If direct retail competition with suburban malls was a failure, planners asked, why not emphasize specialized entertainment and shopping. The results were downtowns conceived as museums, cultural centers, amenity districts, and amusement parks" [9]. In addition to just competing with the suburbs, scholars have suggested other reasons for the importance of the core, making the case that downtowns, unlike suburbs, offer spaces that create the opportunities for greater and more diverse interactions between people, for more

CHAPTER 10

Development of a Methodology to Evaluate the Impacts of Public Transport Bus Emissions Using Biodiesel as a Sustainable Alternative to Conventional Fuels

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Abstract: This book chapter provides insights into the development of a methodology to evaluate the role of geographic information systems (GIS) and AERMOD software in understanding the impacts of biodiesel as a sustainable alternative fuel for use in public transportation buses at a microscopic level in the City of Toledo and Sylvania Township areas in the State of Ohio, USA. The methodology discussed in this book chapter is comprised of a multi-pronged step-by-step approach that included: (i) implementation of a real-world exhaust emission field monitoring study, (ii) use of ArcGIS software in examining study area features that included identification of the salient features (*e.g.*, schools, churches, hospitals) within a certain vicinity radius of the exhaust emission field monitoring study, (iii) use of AERMOD dispersion air quality model in ranking the most affected salient features (identified with ArcGIS) based on the regulatory dispersion modeling of exhaust emissions from public transportation systems operating on biodiesel, and (iv) estimation of a quantified reduction in exhaust emissions with use of biodiesel as a sustainable alternative fuel to conventional fuel in public transportation buses on the basis of existing literature. This book chapter presents a comprehensive assessment of the adopted methodology and discusses in detail on how GIS and AERMOD software may be used by environmental students, engineers, and scientists in understanding the impacts of biodiesel as a sustainable alternative fuel for use in public transportation buses with emphasis on the exhaust emissions of CO, NO_x, and SO_2.

Keywords: AERMET, AERMOD, Alternative fuels, ArcGIS, Biodiesel, Exhaust emissions, Geographic information systems, Mobile source dispersion modeling, Public transportation buses, Sustainability.

INTRODUCTION

The average annual increase in population and road vehicle miles traveled bet-

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ween 2008 and 2035 in the United States (U.S.) were estimated to be 0.9% and 3.4% respectively [1]. The increase in vehicle miles traveled were mainly a result of the U.S. population's expected shift into suburban and exurban areas [2]. Over the years, vehicular usage also increased along with an increase in the population growth [3]. A combination of increasing population, vehicle miles traveled, and vehicular usage would increase vehicular pollution manifold, thereby, contributing to a significant increase in regional air pollution. The major air contaminants emitted from vehicle exhaust are carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter (PM), and volatile organic compounds (VOCs) – mainly hydrocarbons (HC). The International Transport Forum identified road transportation as a major area of concern due to its high global growth rate and increased contribution of 45% global CO_2 emissions between 1990 and 2007. Transportation sector (road transport predominance) accounts for 23% of the global CO_2 emissions [4].

In the U.S., transportation sector is the second fastest growing energy consuming sector and accounts for one-third of all CO_2 emissions [1]. Highway vehicles in the U.S. contribute to about 50% of the total CO emissions, 32% of the total NO_x emissions, 2% of the total particulate matter less than 2.5 micrometers ($PM_{2.5}$) emissions, 1% of the total particulate matter less than 10.0 micrometers ($PM_{10.0}$) emissions, 21% of the total VOC emissions, and 1% of the total sulfur dioxide (SO_2) emissions [5]. Considering the impacts of vehicular pollution on human occupied environments, the U.S. Environmental Protection Agency (EPA) aims at reducing the emissions through technological advances in vehicle and engine design, together with cleaner and high quality fuels. Despite the increasing vehicular usage and miles traveled, the U.S. EPA succeeded in reducing the vehicular emissions to some extent by encouraging the use of alternative/clean fuels such as biodiesel, electricity, ethanol, methanol, compressed natural gas, liquefied natural gas, and hydrogen (used specifically in fuel cell vehicles). One of the most visible applications of alternative fuels in the transportation sector is in public transit systems. There are nearly 75,000 transit buses operating across the nation that make up about 58% of the transit vehicle miles traveled [6, 7]. In context of the aforementioned statistical information, it is imperative that one carefully examines the environmental impacts of biodiesel (BD) fuel as a sustainable alternative for use in the public transportation buses.

In 2006, Toledo Area Regional Transit Authority (TARTA) had undertaken the initiative to gradually convert its bus fleet to run on 20% grade BD (BD20), with a long-term view of decreasing the annual vehicular emissions from public transportation buses and contributing towards the development of sustainable public transportation systems and cities. The Air Pollution Research Group (APRG) in the Civil Engineering Department at The University of Toledo (UT) worked extensively on evaluating the environmental impacts of using alternative fuels in public transportation buses and since has published several articles in relation to both in-vehicle air quality [8 - 26] and outdoor air quality [27 - 29]. This book chapter will serve as an addition to the existing knowledgebase in relation to environmental impact assessment of using BD20 alternative fuel in public transportation systems. Additionally, this book chapter serves as a pilot study for universities and colleges that have transit buses operating within their respective campuses to determine the pollution caused by existing conventional fuel operated vehicles and assess the scope for improving air quality on-campus by adopting BD20 operated vehicles using software such as ArcGIS and AERMOD; primary focus being on the microscopic detailed area rather than a spatially larger area that is normally the case. The multi-pronged four-step methodology proposed and implemented in this book chapter to evaluate the role of BD20 as a sustainable alternative fuel for use in public transportation buses included:

1. Implementation of a real-world exhaust emissions field monitoring study,
2. Use of ArcGIS software in examining the study area features that includes identifying the salient features (*e.g.*, schools, churches, hospitals) within a certain vicinity radius of the real-world experimental monitoring study,
3. Use of the AERMOD air quality model in ranking the most affected salient features (identified by using ArcGIS) due to exhaust emissions from public transportation systems operating on BD20,
4. Estimation of the quantified reduction in exhaust emissions by the use of BD20 as sustainable alternative fuel to conventional fuels in public transportation buses by referring to current literature on conventional fuel operating public transport emissions.

METHODOLOGY

This section provides complete details on the four-step methodology developed and adopted for use in this study.

Real-World Exhaust Emission Monitoring

The design and implementation of the real-world exhaust emission monitoring from public transportation buses running on BD20 fuel was performed on the basis of outline provided by Kumar and Nerella [27].

Route and Bus Selection

The route selected for the study was 20T that covered both the City of Toledo and Sylvania Township areas. Fig. (**1**) shows the route selected for this study, *i.e.*,

CHAPTER 11

Sustainable Military Installations

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Abstract: Military installations and university campuses are, perhaps surprisingly, quite similar. The U.S. Department of Defense (DoD) has a number of programs focused on sustainable operations at its installations. In this chapter, we describe these programs and present some case studies that demonstrate implementation of sustainable practices within the DoD. Many of these programs and practices are universally applicable, with relevance to academic institutions.

Keywords: Environmental management systems, Environmentally preferable purchasing, Greenhouse gas reduction, Hazardous waste minimization, LEED, Low impact development, Military installations, Military operations, Net-zero, Pollution prevention, Recycling, Sustainability, Waste-to-energy.

INTRODUCTION

Perhaps surprisingly to some, military installations and university campuses have much in common. Both are essentially small cities, with living facilities (dormitories), dining facilities, recreational venues (gymnasiums and sports fields), laboratories, laundries, offices, industrial and warehouse buildings, *etc.* along with all the supporting infrastructure required to sustain them – roads, utility distribution networks, communication networks, emergency and security services, and the like. With regard to sustainable practices, there's another similarity. Both military installations and universities are non-profit institutions, whose motivation to be sustainable is presumably not primarily driven by market or profit motives. The motivation for the military to operate sustainably is in one sense the same as the motivation at a university campus, and in another sense it is quite different. It's the same in the sense that sustainable operations are often the most economically viable approach to accomplishing the mission regardless of whether it's an academic mission or a military mission. As Jeffrey Immelt, Chair-

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man and CEO of General Electric, stated: "green is green" [1]. That is, being “green” (*i.e.* being environmentally aware, acting sustainably) is also good for the bottom line. An example showing how sustainable practices make economic sense may be found in the practice of hotels now requesting that their guests leave towels on the rack, or a card on the bed, if they do not want their towels or linens washed. Water is conserved, while the hotel saves money by doing less washing. And on top of that, the hotel generates good will among guests who are happy to see that the hotel is environmentally friendly. The Department of Defense is perhaps our country’s largest institutional owner of buildings. Institutional owners plan, build, own, operate and dispose of their own real estate holdings over their entire life-cycle, and therefore are motivated by practices which are life-cycle cost effective over a building functional life – often in excess of 50 years. The Department of Defense owns and operates roughly two billion square feet [2] of built space, and the average building age is 67 years old. Therefore the military is motivated to invest in sustainability practices which may require up-front investment, such as energy and water efficiency and renewable energy, but which will pay themselves back over time in reduced operating cost. Many universities are also institutional owners and share this long-term perspective towards asset management.

The motivation for the military to conduct sustainable operations is in a second sense, somewhat unique. All militaries require access to land, water, and air resources, as well as funds and human resources, to accomplish their missions. Gaining access to these resources hinges upon the decisions of political leaders. These leaders, and their constituents, must constantly balance the benefits of having a strong, well-prepared defense establishment with the costs (including the environmental costs) of maintaining military readiness. There are a number of examples within the U.S. Department of Defense where access to natural resources that were required for mission accomplishment was denied because of the perceived impact of military operations on those resources. For example, in 2006 the Army was sued by Native Hawaiian groups and lost for having stationed 25-ton Stryker fighting vehicles in Hawaii without properly analyzing alternative locations. The Native groups asserted that “the impacts of Stryker training and related activities on Hawai'i's unique cultural sites and fragile native ecosystems…” was not accounted for and the Ninth Circuit court agreed saying the Army failed to investigate alternate locations where training could occur, “at potentially less detriment to the environment [3].” In response to this and other cases, the military departments initiated the concept of “sustainable operations,” which may be defined as “ ... operations that are conducted in a manner that preserves the resources (*e.g.*, human resources, natural resources, man-made resources-facilities, equipment, financial, and community support) that are necessary to conduct successful mission operations indefinitely into the future”

[4]. Ultimately, at least in a democratic society, community support is the foundation upon which access to all other resources (financial, human, *etc.*) depends. Thus, a military organization that is perceived to be a poor environmental steward by the community may jeopardize the access it needs to all resources, and this loss of access will result in degradation of its ability to accomplish the mission.

In addition to saving money, building good will and demonstrating environmental stewardship, the military sees sustainability as vital to defense of the nation. Resource scarcity and climate change are key trends identified in the National Defense Strategy, and the Department of Defense has shown leadership in sustainability in order to counter what it sees as potential underlying causes of future conflict. Developing enterprise-wide climate change and energy strategies were key reforms identified in the 2010 Quadrennial Defense Review[1].

Finally, during contingency operations where military personnel operate in harm's way, sustainability takes on greater urgency. Military personnel must be able to literally "sustain" themselves in the field or in remote locations for both short and long term operations. Development and deployment of solar panels and rechargeable batteries is underway to reduce the 20 - 35 pounds of batteries soldiers and marines must carry in order to operate their electronic equipment (radios, sensors, night vision goggles, *etc.*) in a contingency environment [5]. During the war in Iraq, the US military reported one out of eight US Army casualties was the result of protecting a fuel convoy [6]; therefore any efficiency measures literally saved both convoys and lives lost to road-side improvised explosive devices (IEDs). Therefore, in times and places of war, sustainability takes on a life-or-death importance to military operations, making the battlefield often an important, if unlikely, incubator for sustainability practices.

Clearly the military has myriad motivations to create sustainable installations, both at home and abroad, making them perhaps surprising leaders in sustainability. In 2011 the US Army launched its "Net Zero Pilot Installation" program, announcing its intention to make 14 entire installations "net-zero," in terms of the installations energy, water, material use, or all three, by 2020 [7], and for these installations to act as pilots for the rest of the Army's inventory. In this chapter, we will look at how the U.S. military is implementing sustainable operations. We will examine Department of Defense programs that are being implemented, and then present case studies of specific projects that have been accomplished. We will conclude with a look at the future of sustainable operations in the U.S. military.

CHAPTER 12

Biological Nitrogen Removal Technologies for Wastewater Treatment - A Review

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Abstract: Conventional wastewater treatment does not normally remove nutrients to a remarkable extent. Pollution of water bodies due to discharge of nitrogen and its compounds are among one of the major problems. Nitrogen is present in the effluent of various industries, landfill leachates, and sludge digester effluent. Excess nitrogen discharge in water streams leads uncontrolled eutrophication, considerable loss of oxygen and unwanted changes in aquatic population. Biological nutrient removal technologies have been developed and more emphasis has been placed on limiting the nutrient discharge in water streams. New nitrogen removal technologies like single reactor system for high ammonia removal over nitrite (SHARON) process, completely autotrophic nitrogen removal over nitrite (CANON), anaerobic ammonium oxidation (ANAMMOX) process and granular sludge technology are easy in operation and cost effective. This paper presents a review on biological nitrogen removal technologies suitable for wastewater treatment.

Keywords: Aerobic granules, Ammonium, ANAMMOX, Anoxic, Autotrophic, BOD, CANON, COD, Denitrification, Dinitrogen, Granular Sludge, Heterotrophic, HRT, Nitrate, Nitrification, Nitrite, Nitrogen SBR, SHARON, SRT.

INTRODUCTION

Environmental legislations have become more restricted for the discharge of nutrient containing wastewater especially in the sensitive areas and vulnerable zones. Many studies have been performed on the understanding and improvement of biological nutrient removal processes.

In recent years, more emphasis has been given on limiting the quantities of nutrient discharge (nitrogen and phosphorus) because it stimulates the growth of

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algae and various photosynthetic species which results in excess eutrophication, considerable loss of oxygen, and unwanted changes in aquatic population.

Nitrogen is present in the effluents of various industries as well as in the landfill leachates. Landfill leachate consist of very high amount of ammonia, organic matter is also high with low biodegradable fraction and high alkalinity and salinity [1]. The other sources of accounts for highly concentrated ammonium streams results from digestion and centrifugation of sludge. During such processes the breakdown of protein takes place and about 50% of sludge containing nitrogen is released to wastewater streams as ammonium. If recycled to the head of wastewater treatment plant such streams on contributes 15-20% average increase in total nitrogen load.

Conventional biological nitrogen removal is accomplished in two steps, first step is the complete oxidation of ammonia to nitrate and second step is the reduction of nitrate to nitrogen gas under anoxic conditions with the addition of external carbon source such as methanol.

For denitrification process addition of external carbon source is required if the wastewater have low BOD/N ratio. This increases the cost of the treatment process. The anaerobic ammonia oxidation process commonly known as ANAMMOX process gained popularity these days in the field of biological nitrogen removal from wastewater, in this process ammonia is oxidizes to nitrogen gas with nitrite as an electron acceptor under strictly anoxic condition. This eliminates the requirement of external carbon source and requires less energy for aeration as compared to conventional nitrification denitrification process [2]. Another new technique for removal of biological nitrogen is CANON process *i.e.* completely autotrophic nitrogen removal over nitrite in which ammonium removal from wastewater takes place in single oxygen limited treatment step. The CANON process depends on the stable interaction between the two bacterial populations like aerobic Nitrosomonas and anaerobic ammonia oxidizing bacteria like Planctomycete [3].

In CANON system oxygen and oxygen-free zones within the biofilm depth are available so aerobes and anaerobes can co-exist in one reactor [4, 5]. Under oxygen limiting conditions ammonia is partially oxidized to nitrite and then nitrite together with remaining ammonia is converted to dinitrogen gas by the ANAMMOX bacteria.

A number of reactor configurations have been used as biological treatment systems. In the last decade sequencing batch reactor (SBR) has gained importance in the field of wastewater treatment over other reactors. Sequencing batch reactors are especially preferred when nutrient removal is important because enrichment in nitrifiers and denitrifiers and phosphorus removal bacteria may take place in the same reactor by simply changing the mixing and aerations conditions and time schedule.

With increasing population and industrialization the water demand is also increasing, which places more and more concerns on water resources. The conventional wastewater treatment facilities are not been designed for nitrogen removal, so many plants do not meet the current discharge norms [6].

The industries should reduce the emission of nitrogen compounds like ammonia, nitrate, *etc.* to surface and ground waters, because final effluents from sludge digester and other industries containing high amount of nitrogen compounds can adversely affects and pollute aquatic life causing depletion of dissolve oxygen, excessive eutrophication and methemoglobinemia in receiving water [7]. For this reason, greater efforts have been placed on improving and developing new techniques and strategies to reduce the amount of nitrogen in wastewater.

For wastewater treatment dealing with high concentrations of ammonia nitrogen, various chemical, physiochemical and biological methods are employed taking into account different criteria like cost-benefit analysis, energy requirement and chemical doses, familiarity with operational procedures, and environmental sustainability, and based on these criteria a particular treatment for a specific pollutant is usually selected [8]. Nitrogen in wastewater is mostly present in the form of ammonium and is removed by physicochemical and biological processes. Biological treatment for nitrogen removal from wastewater is cheap and more feasible than physicochemical treatment so it is used more often to achieve nitrogen removal from domestic and industrial wastewaters [9].

CONVENTIONAL NITROGEN REMOVAL PROCESS

Conventional biological nitrogen removal from municipal and industrial wastewater comprises of two biological steps *i.e.* the nitrification (oxidation of ammonium to nitrite or nitrate), and the denitrification (reduction of nitrite or nitrate to nitrogen gas). But, in many cases wastewater contains the low level of organic matter which is not sufficient for a complete denitrification step, and addition of an external carbon source, such as methanol, is often required to attain complete denitrification [10, 11]. The cost of chemical addition and the treatment of the additional sludge that is generated from the chemical reaction increases the overall operating costs in wastewater treatment plants. Conventional biological nitrogen removal comprises of autotrophic nitrification and heterotrophic denitrification. The process involves aerobic nitrification (*i.e.*, the conversion of NH_4^+ to NO_2^- and further to NO_3^-) with oxygen as the electron acceptor. The relevant reactions are as follows:

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