World Sustainability Series

Walter Leal Filho
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Golda Edwin
Mihaela Sima *Editors*

Implementing Campus Greening Initiatives

Approaches, Methods and Perspectives

Springer

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Preface

This book introduces a set of papers presented at the “Green Campus Summit” (GCS-2013), organised by the Association for Promoting Sustainability in Campuses and Communities, under the auspices of the Research and Transfer Centre “Applications of Life Sciences” of the Hamburg University of Applied Sciences (Germany), Pondicherry University (India), Manchester Metropolitan University (UK), and Pondicherry Pollution Control Committee, Government of Puducherry. It took place in Puducherry, India, on 4–5 April 2013.

The aims of GCS-2013 were: to provide Universities and Higher Education Institutions all round the world with an opportunity to display and present their works on campus greening initiatives; to foster the exchange of information, and dissemination of knowledge, ideas and experiences; to promote adopting/implementing strategies for campus sustainability; to discuss methodological approaches for campus greening projects and provide opportunities to showcase thought leadership; to network the participants and provide a platform so they can explore possibilities for cooperation and collaboration. GCS-2013 was attended by over 200 delegates from 12 countries—representing both industrialised and developing geographical regions—and was a great success. The delegates included several leading experts/practitioners on green campuses and sustainability from around the world.

Apart from the plenary lectures on the state-of-the-art of knowledge and practices on the subject, the technical sessions covered important topics such as: Action Research and Models of Campus Greening Initiatives, Environment Education and Curriculum Development, Green Building/Architecture/Land Use, Energy Management/Energy Conservation/Green Chemistry, Waste Management/Water Management/Water Treatment/Transportation and Campus Ecology/Biodiversity/Food Services and Food Security. All these elements are reflected in this book.

It is unanimously agreed that integrating the principles and the concepts of green campuses and sustainability into the core of students' academic experiences from the high school to College/University levels is important, since it ensures that the current and future student communities acquire the required knowledge, skills, attitudes and values necessary to create a more sustainable economy and social environment in the future. It is also widely accepted that commitments at institutional level are more likely to make a positive difference and help progress towards a sustainable future. This book fills a gap and helps to address these issues.

The present book "Implementing Campus Greening Initiatives: Approaches, Methods and Perspectives" is a ground-breaking publication on the theory and practice of sustainable development, and offer a comprehensive overview of campus greening, focusing on both industrialised and developing nations. We hope readers find it both informative and useful in their day-to-day work and that it supports long-term efforts in fostering campus greening.

Spring 2015

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Evolving and Implementing Energy Recovering Strategy from Food Wastes at Jawahar Navodaya Vidhyalaya (JNV) Fostering Campus Sustainability

M. Nandhivarman, G. Poyyamoli, Golda A. Edwin, Ramaswamy Arun Prasath and Dwipen Boruah

Abstract

A huge quantity of organic food wastes generated in educational campuses goes unutilized and gets disposed of in landfills, despite the tremendous potential to turn the on-campus waste mis-management into a profitable and sustainable venture. The vision of green campus initiative at Jawahar Navodhaya Vidhyalaya (JNV) is to transform itself into a model for a self-sufficient campus. To foster this initiative, we envisaged a system of highly evolved, self-sufficient strategies not only to sustain the needs of the campus but also to reduce costs and generate income through integrated sustainable projects. The project is carried out through a cooperative effort among Pondicherry University researchers and APSCC's

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strategic green action plan team for campus sustainability, focused on the campus's commitment towards sustainability encompassing social equity, environmental management, and economic prosperity in tune with the Principles of Agenda 21 and Millennium Development Goals. The Campus biogas generation project is one such unique attempt which has prompted the JNV campus community to ponder over the causes of significant socio-environmental problems, and subsequently make an attempt to solve them through collaborative effort using scientific processes. This study involved rigorous field visits with observational study, building prototypes to try out various possible alternatives, hoping to arrive at an optimum solution by comparing different experimental models, field work, research and innovative ideas. The goal of the study is to foster student's experience and learning along with research and planning for reducing fuel consumption through biogas production from organic waste generated within the campus. It is found that by adopting a 7 m^3 Antirotatory-anaerobic Baffled Co-coupled Double-digester (ABCD-hybrid) model of an anaerobic digester, enough biogas is produced to replace approximately 6.2 LPG cylinders/month with the potential reduction in petroleum gas of 10.34 % and saving of around INR 7,864 per month.

Keywords
Green campus · Solid waste management · Anaerobic digestion · Biogas

1 Introduction

Each and every campus is endowed with a measurable stock of environmental assets such as flora and fauna, fertile and non-cultivable land, ground and surface water, clean air, landscapes, etc. Unless the resources are managed sustainably, the result is the loss of ecological carrying capacity and ecosystem services of the campus. It is the responsibility of every individual of the campus community to embrace the Principle of Intergenerational Equity, which states that "as members of the present generation, we hold the Earth in full trust for future generations". Ecologically, sustainable campus development is the environmental component of sustainable development. Comprehensive organic kitchen waste management is one of the greatest challenges to achieving campus environmental sustainability (Danielle et al. 2010; Nandhivarman et al. 2012). The aim of this project is to estimate the amount of organic waste generated in the central kitchen, its composition and the current management practices within the key operational areas of the campus and to evolve an action frame work for organic waste management, with higher rates of energy and nutrient recovery, thereby improving the overall sustainability of the campus's waste management program. This project was evolved based on the research studies done globally in various educational campuses. It was hypothesized that the anaerobic digester for the production of methane from kitchen waste is capable of reducing the organic pollutant load and also provide recovered energy for the kitchen and recovered nutrient for the olericulture, horticultural, xeriscape and other landscaping purposes meeting the standards prescribed in the Municipal Solid Wastes Management and Handling Rules of Government of India (MSW 2000).

The major agenda of this project for campus sustainability is “to implement the effective and immediate measures to prevent environmental degradation”, which is based purely on Precautionary Principle 15 of the Rio Declaration—“where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as reason for postponing cost effective measures to prevent environmental degradation”. This is also supported by the Principle of Intergenerational Equity—“the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of the future generations; the conservation of biological diversity with ecological integrity; and improved valuation, pricing and incentive mechanisms, for the up-gradation of environmental factors should be included in the valuation of assets, liabilities and services”. Since 2002, the international gathering of The Earth Summit on Sustainable Development which was held at Johannesburg, affirmed and confirmed the commitment to the ‘full implementation’ of Agenda 21, along with the other MDGs to be achieved through educational institutions. To facilitate this in the Indian scenario, the Green Campus Initiative for Jawahar Navodhaya Vidhyalaya (JNV) was evolved and adopted from the conceptual framework developed for Pondicherry University’s Action Plan towards Environmental Sustainability (Nandhivarman et al. 2011).

2 Project Site

JNV is a Central School in Puducherry, situated on the Coromandal coast, 160 km south of Chennai, (11° 56′ N; 79° 53′E). It was founded in the year 1985 by the Government of India. Since then it has emerged as India’s fastest growing residential central school of the region, principally focused on the development of rural children who cannot afford to pay exorbitant fees for such private schools. Figure 1 shows the aerial view of JNV on the Northern border of the state.

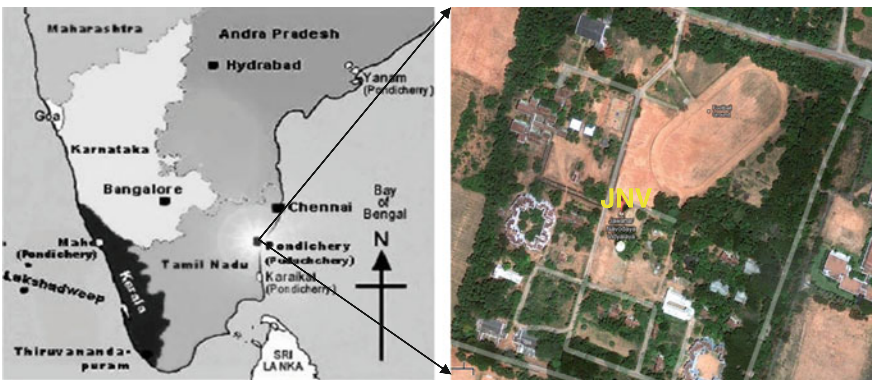

Fig. 1 Location map showing Jawahar Navodhaya Vidhyalaya (JNV)

JNV is the only central residential school in the Union Territory of Puducherry; it has heavy responsibilities to educate the young and vibrant minds especially from the rural poor, catering for the needs of the present and future generation in a sustainable and holistic manner.

3 Current Management Practices

The waste, especially organic waste, is dumped in open places, causing heavy environmental pollution to soil, groundwater and ecosystems in many campuses (Nandhivarman et al. 2011). To address this, an integrated framework was evolved to recover energy in the form of methane through a biodigester, to recover nutrient through proper utilization of spent slurry and carbon sequestration through organic farming mitigating climate change.

4 Waste Audit

Conducting an organic kitchen waste audit is the first critical and crucial step in the successful implementation of a waste management program, while planning and progressing for the overall campus environmental sustainability. Sustainable Solid Waste Management (SSWM) requires a complete understanding of the composition of the waste stream as well as the activities that determine its origin and generation in the first place. The generated food residues such as vegetable peelings, leafy vegetables, etc. in the kitchen are collected in gunny bags (primary collection) and, along with the uncooked food residues and uneaten food waste from the dining hall, are transported to the Anaerobic Digester (AD) plant for processing. Examining the waste source is very important, as the characteristics and composition of solid waste vary according to its source (Tchobanoglous et al. 1996). SWM programs based on origin and generation of the source are far more successful than mimicked programs which have been implemented elsewhere (Armijo de Vega et al. 2008). Hence, conducting a waste characterization and quantification study is a critical first step in successful waste management planning and advancement for the overall sustainability of the educational institution.

Based on the kitchen waste audit conducted for a period of 28 days, with 20 full working days and 8 days of weekends, it was estimated that the JNV kitchen generated on an average 25 [±7] kg of organic waste per day, and without proper waste management strategies it is either dumped or buried. To manage these scenarios, a detailed action plan was evolved for segregating inorganic waste for recycling and safe disposal, followed by recycling of organic waste for the generation of biogas for the kitchen in the first phase. Following the audit, a hybrid model of an anaerobic digester for waste management developed by BD&TC of APSCC is implemented adjacent to the campus's central kitchen.

5 Background and Features of the "ABCD-Hybrid Plant"

By the year 1962, the First Biogas Plant, KVIC Floating Dome Model, popularly known as the Indian Model, was commissioned in India. Biological treatment has already been demonstrated as one of the most advantageous methods for maximizing recycling, with energy and nutrient recovery. Anaerobic digestion (AD) of sorted organic solid wastes, especially food wastes, is the utmost attractive alternative to conventional ones and the most cost-effective technology (Jantsch and Mattiason 2004; Rao and Singh 2004; Bolzonella et al. 2005; Bouallagui et al. 2005; US EPA 2010). Among the cost-effective treatment methods, anaerobic digestion of biodegradable organic wastes is the most popular, because of the high energy recovery and low environmental impact (Mata-Alvarez et al. 2000). In recent years, AD technology has been well established and is showing satisfactory performance in organic kitchen waste stabilization. Because of the coupling of pollution reduction and energy production, various types of anaerobic digester have been installed and operated (Frankin 2001). The biogas program has developed quickly in some developing countries only because of substantial support from governments and aid agencies (Martinot et al. 2002). However, in the case of organic kitchen waste stabilizing biogas plants, the long run efficiency influencing the long-term profitability is sometimes not satisfactory, mainly because of low consistency of biogas production. Moreover, methane has more than 20 times the global warming potential than carbon dioxide. Biogas is therefore a highly recommended option for new and renewable energy resources (Taleghani and Kia 2005). Apart from this, bio fertilizer production from the biogas slurry makes it distinct. It is established that it is difficult to maintain consistency of gas production through single waste used as biogas feedstock in the same place (Raven and Gregersen 2007). However, gas production can be increased by adding other sources of organic wastes to the system such as food waste, dairy waste, etc. (Callaghan et al. 1999; Amon et al. 2006).

As part of this study, the common AD digester has been designed incorporating such items as anti-rotatory, baffling and coupling features (subject to IPR). Thus the hybrid digester is called the "Antirotatory-anaerobic Baffled Co-coupled Digester" (ABCD-Hybrid). In this hybrid system, hydrolysis and acidogenesis is initiated prior to entering the main digesting reactor, resulting in the improvement of the bioconversion efficiency and the stabilization of the microbial community structure. Anaerobic co-digestion is an attempt not only to enhance the overall biogas production but also to improve the economic efficiency of large scale plant operations (Kullavanijaya and Thongduang 2012). The various components involved in the hybrid system are:

- Manual Rotatory Homogenizer
- Front End Hydrolysis Reactor
- Phase Separated Anaerobic Double Digester
  - Mesophilic
  - Thermophilic

- Inbuilt Mechanical Reciprocating Device
- Antirotatory Floating Gas Holding Reactor
- Coupled Spent Slurry Inoculator
- Rear End Spent Slurry Reactor

The 7 m^3 "ABCD-Hybrid Plant" has produced biogas substituting approximately 6.2 cylinders/month with the potential reduction in petroleum gas by 10.34 % with a saving of around INR 7,864 per month.

6 Benefits

AD is a waste stabilization process in the absence of oxygen and thermophilic conditions. This differentiates it from aerobic decomposition, which occurs naturally in most cases with the ability to achieve only partial stabilization. Waste stabilization is governed by microbially mediated biochemical reduction of the carbon in complex organic compounds and finally to CH_4 and CO_2. Since the waste stabilization process occurs under controlled anaerobic conditions, it provides an opportunity for the capture and combustion of methane to supplement fossil petroleum gas or the generating of electricity (US EPA 2010).

As a controlled unit process for the sustainable management of organic kitchen waste, this AD can provide the following benefits:

- *Reduced landfill gas emissions to the atmosphere*: The campus environment improves by reduced gas emissions from the landfill, usually located within the campus premises in many campuses of the developing countries. Organic food wastes which are diverted to landfill produce methane through decomposition along with other adverse gases. Landfill gas is approximately 40–60 % methane, mostly CO_2 with varying amounts of nitrogen, oxygen, water vapour, hydrogen sulphide, and other contaminants. The other contaminants make up for less than 1 % of landfill gas and are commonly known as non-methane organic compounds (NMOC), which includes toxic chemicals such as chloroform, benzene, toluene, vinyl chloride, and carbon tetrachloride. NMOCs usually make up less than 1 % of landfill gas. The lifetime of CH_4 in the atmosphere is much shorter than CO_2, but CH_4 is more efficient at trapping radiation than CO_2. The comparative impact of CH_4 on climate change is over 20 times greater than CO_2 over a 100-year period (www.epa.gov, http://epa.gov/climatechange/ghgemissions/gases/ch4.html).
- *Reduced noxious odors*: Either prolonged or incomplete anaerobic digestion or aerobic decomposition in the landfill site results in noxious odors. This is especially a common problem for campuses adopting only composting techniques for waste management. They are eliminated in the ABCD-Hybrid System because of anaerobic digestion process in the multiple stages with phase separation, where the organic waste is digested and stabilized within the system itself, before it exits as biogas and spent slurry.

- *Reduce ground water pollution potential*: Avoiding dumping the wastes to landfill sites eliminates the infiltration of toxic substances into ground water. Food wastes are usually rich in oxygen-demanding organic compounds which is eliminated or reduced when digested in AD. However, when the food wastes directly enter surface water bodies, then the microbial population in the water body tends to increase in proportion to the amount of food available. This leads to depletion of oxygen in the water bodies resulting in the death of fishes and other aquatic organisms.
- *Enteric pathogenic microorganisms*: Pathogens associated with diseases, previously common because of landfill, are either killed or reduced to a negligible amount if the organic materials are fully digested in the thermophilic conditions. High temperatures and long retention times in the digester are more efficient in killing the pathogens. The following are the principal organisms eliminated in biogas plants:
  - Typhoid, paratyphoid, cholera and dysentery causing bacteria in 1 or 2 weeks (Sasse 1988)
  - Schistosome ova were completely eliminated after 40 days (McGarry and Stainforth 1978)
  - *Salmonella* sp. found in the kitchen waste are eliminated by the ninth day of digestion
  - Tapeworm and roundworm die completely only when the fermented slurry is dried in the sun (Sasse 1988)
  - Thermophilic digestion reduced 5.07 log for *E. coli*, and 4.0 log for Enterococci (www.southampton.ac.uk)
- *Generation of renewable energy*: During the digestion process, the generated biogas is captured and used as a fuel for cooking or for generating electricity. Biogas replaces firewood and conventional energy sources in rural areas. When the biogas is compressed and bottled, with removal of CO_2 and other impurities, it can become a substitute for transportation fuel or as renewable natural gas (RNG), which also is known as bio-methane. In rural areas, biogas and diesel-based dual fuel engines are also used for irrigation purposes. Biogas is also used in industrial sectors for refrigerators, incubators and water boilers. Table 1 shows the quantities of various fuels equivalent to 1 m^3 of biogas.
- *Investment costs offset through revenue generation*: The potential for biogas to generate revenue and offset the investment costs are well established. Revenue is generated by producing electricity or replacing fossil fuels. Selling it as carbon emission reduction credits can also be a source of income for the anaerobic digestion system.
- *Biogas spent slurry management*: The NPK content of biogas spent slurry is more than four times richer than farmyard manure which is about 0.5, 0.2 and 0.5 %, respectively. The efficiency and benefits of the bio-fertilizer depends primarily on the applicator knowledge of how to use it. Compared to fresh manure, the immediate and proper application of the digested slurry can yield 0.5 kg extra nitrogen (Sasse 1988). If the slurry is first left to dry and/or

Table 1 Quantities of various fuels equivalent to 1 m^3 of biogas

Name of the fuel	Kerosene	Fire-wood	Cow-dung cakes	Char-coal	Soft coke	Butane	Furnace oil	Coal gas	Electricity
Quantities equivalent to 1 m^3 of biogas	0.620 L	3.474 kg	12.296 kg	1.458 kg	1.605 kg	0.433 kg	0.417 L	1.177 m^3	4.698 kWh

Source NABARD biogas program

improperly applied, the nitrogen yield is considerably reduced (www.greenpowerindia.org). The application of processed bio-gas spent slurry can replace the chemical fertilizers to a larger extent, even as countries such as India spend a lot to import synthetic fertilizers. Besides, fossil fuel-based chemical fertilizers are the major sources of off-site greenhouse gas emissions, application of digested biogas slurry enhances ecosystem services by improving the soil porosity, texture and beneficial microbial populations. The biogas spent slurry from the digester can also be composted using indigenous earthworms to produce vermicompost/bio-fertilizer, which can be used for horticultural activities and in kitchen gardens, minimizing the application of synthetic fertilizers (Nandhivarman et al. 2012).

7 Conclusion

With each advancing year, the depletion of fossil oil reserves are deepening the 'Energy Crisis', including comfortably placed energy sufficient countries (Roberts 2005). We are in an era of exploring suitable alternatives to replace fossil fuels. Methane is one such resource which is renewable and can reduce the dependence on fossil oil. Biogas will replace conventional energy sources in areas such as domestic cooking, lighting, etc. without further delay so that precious fossil oil could be saved for longer and critical uses. The by-product of the anaerobic biodigestion process is spent slurry manure, which is very rich in NPK and can improve top soil up gradation, soil fertility, soil porosity, water holding capacity, and soil microbiology, resulting in greater food production and reducing the import of chemical fertilizer. Campuses can adopt anaerobic digestion as an attractive, cost effective, eco-friendly route to minimize kitchen waste, landfill dumps, and, in turn, generate a high-quality renewable fuel and reduce GHG emissions. Co-digestion strategies are widely applied in order to enhance the methane production in biogas plants based on food waste. It is established based on the principles of environment, economy, and systematic engineering, fostering campus environment sustainability, and addressing the pressing issues of energy and ecosystems security with multidimensional advantages such as:

- Transforming the campus into a living laboratory
- Improvement of the local environmental conditions
- Empowerment of students and faculties
- Increased renewable energy generation
- Top soil rejuvenation through spent slurry management
- Protection and conservation of ground water aquifers and other water bodies
- Habitat restoration and biodiversity conservation
- Organic farming mitigating climate change.

Operational research with integrated strategies can provide recommendations to the campus administration and to the government on waste minimization, recycling and composting effectiveness, and overall sustainability of the campus/institutional waste management program. This project as a whole not only fosters organic waste management but also environmental education and outreach, and is of significant contribution to the United Nations Decade of Education for Sustainable Development, 2005–2014.

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Authors Biography

Nandhivarman Muthu received his Masters degree in zoology and has over 10 years experience as an environmentalist, researcher and an activist for sustainable development. He is currently pursuing his doctorate from Pondicherry University, India. His research interests include an extensive study to evolve policies and implement Green Campus Initiative in Pondicherry University and other educational campuses. The main objective of this research is to assess and provide factual solutions to the educational institutions such as schools and colleges to make them sustainable with special reference to water, energy and waste management.

Dr. G. Poyya Moli Associate Professor, Department of Ecology and Environmental Sciences Pondicherry University, Puducherry, India Ph.D. (Ecology—Madurai Kamaraj University, Madurai). Areas of specialization: social ecology and sustainability—climate change mitigation and adaptation, agro-ecology and ecosystem services, environmental education for sustainable development, green campus, industrial ecology, sustainable tourism, sustainable solid waste management and integrated coastal zone management. Member of the State Expert Appraisal Committee; member of the Commission on Ecosystem Management, IUCN, Switzerland; member of the Global Experts Directory on Ecosystem Services (IUCN, WRI, WBCSD and Earth Watch Institute); a network member of the National Ecosystem Services Research Partnership, US EPA; Published 31 international journal articles and contributed 14 invited articles to SAGE Series on Green Society, SAGE Publications, USA; written eight book chapters; Guided 10 Ph.D. candidates; guiding 8 Ph. D. students.

Golda A. Edwin is a researcher at Pondicherry University. She has been involved in a number of green campus projects in her region and had implemented meaningful sustainability projects. She decided to pursue her research and career in water science because of her passion for addressing the challenges of sustainable water management in developing countries. Her core area of research is abatement of water pollution using eco-technologies. She authored several articles and presented her findings in several national/international conferences and workshops. She was awarded a gold medal from Pondicherry University for her outstanding academic excellence. She is also one of the Founders and Executive Director of Association for Promoting Sustainability in Campuses and Communities (APSCC).

Dr. R. Arun Prasath Ph.D (Chemical Science/Materials, Anna University, Chennai). He was a recipient of prestigious DAAD fellowship (1999–2001) for his doctoral research work at Max-Planck Institute for Polymer Research, Mainz, Germany. After his doctoral degree he worked as material researcher in several prestigious institutes; as research associate in Indian Institute of Science, Bangalore, India (2002–2004), as postdoctoral researcher in University of Strathclyde, Glasgow, United Kingdom (2004–2006) and in the University of New South Wales, Sydney, Australia (2006–2008), and as senior researcher in Ghent University (2008–2010) with a special fellowship called BOF. He has published more than 20 peer-reviewed journal articles, more than 10 published articles in proceedings and book chapters, and is co-inventor in 3 International patents as well as in 2 European patent applications. For his professional development, he has visited Germany, United Kingdom, Australia, Belgium, Brazil, Italy, and Bangladesh. He has made more than 40 oral presentations in various conferences/seminars/courses/invited talks. He is actively involved in teaching and research on renewable energy from 2010 onwards.

Dwipen Boruah graduated in 1990 as a Mechanical Engineer and completed his Postgraduate Programme on Renewable Energy (PPRE) from Oldenburg University, Germany. He has more than 22 years of experience in renewable energy engineering design, planning, research, project management and training. He has the experience of working with a number of local, regional and national organisations in several countries and has proven knowledge of renewable energy technologies, barriers for deployment, methods and approaches applied in the field of technology road-maps. Dwipen has also authored or co-authored books and training manuals on solar PV (photovoltaic) system design installation, maintenance and inspection; he has to his credit training manuals on improved cook stoves, more than 60 technical and professional reports and several articles in the technical magazines and journals.

The Charter of Todi and the Strategy of Education for a Sustainable Management and Promotion of Territory

Adriano Ciani

Abstract

The issue of territorial governance and the promotion of integrated and sustainable land use are currently at the center of international debate. This focuses on strategies for the protection, conservation and enhancement of the different areas around the world, the relationship between urban and rural areas, the challenge of renewable energy, green economy and the eradication of poverty. These objectives and issues therefore need to be put into practice by local, national and international professionals who, from the perspective *of* "*think globally, act locally*", have distinctly modernized "*know-how*" and the "*ability to act*". With these targets, an International Summer School entitled Sustainable Management and Promotion and Territory-SIS SMPT was set up, which has already seen and realized Editions I and II in 2011 and 2012 in Todi(Italy). The participants at the International Summer School—SIS-SMPT have decided to draw up a final document that, in honor of the City of Todi, location of the SIS-SMPT, recognized as the City more Sustainable in the World, was named the Todi Charter. The Charter indicates in the keyword "TRADI-OVATION" intended as an acronym for "Territory, Rural Areas, through Development, Innovation, Organization, Valorization, user friendly Technology, ICT sharing, Online Networking" the main theme around which this innovative process can be structured to give effective credibility. The Charter of TODI could be an attractive example of modality to capture the curiosity of the student to be involved in study, research and training with reference to the implementation of the Sustainable Development Strategy all around the world.

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1 Introduction

The theory of welfare economy, since its very beginning, has always promoted reflection on the growth and development models. The quantitative importance of development has been predominant until the second half of the last century, which brought minor considerations of issues such as environmental equilibrium and equity, and intra- and inter-generational and sustainability strategy. The principles of sustainable development have been remarked upon through several stages and, thanks to that, it is currently a widespread heritage among the most important international institutions. It is worth mentioning some of them: Hirschman in 1958, Rachel Carson in 1962 (Carson 1962), the Club of Rome in 1971, United Nations in 1972, the WCED in 1987, the First World Summit on Sustainable Development in 1992 with the Agenda 21 proposal (United Nation 1992), the Millennium Goals in 2000, the WSSD of Johannesburg in 2002 (UN 2003), the promotion of the Decade of Sustainable Development by UNESCO (2005–2014) (UNESCO 2005), UNESCO World Conference on Sustainable Development in Bonn (UNESCO 2009), G8 University Summit in Turin (May 2009), UNGASS Resolution for Rio+20 (UNGASS 2009), and Zero Draft Rio+20 (UNCSD 2012). Beside these general stages, together with the Bonn Declaration, other deliberations such as University Conferences have also occurred. The most important are: Talloires Declaration (1990), Halifax Declaration (1991), Earth Summit Agreements (UNCED 1992), Swansea Declaration (1993), Kyoto Declaration (1993), Copernicus Charter (1993), and Student Declaration for a Sustainable Future (United Nation 1995). Numerous scientists, researchers and universities from all over the world have contributed to the evolution of the principles, issues, and methods for the evaluation of Sustainable Development. Perugia University is located in Umbria, a region in central Italy. Its historical traditions concerning natural resources management are retrievable in several famous ancient historical and literary works such as "*Bucoliche*" by Virgilio, "*RerumNatura*" by Plinio il Vecchio, and "*Canticodelle Creature*" by S. Francesco. The socio-economical context has always been strongly related to the territorial development processes and to the valorization of natural resources. Umbria was also a leading region during World War II's most important industrialization period, with its conservation of land peculiarities and rural agricultural reality. In 1955 this context was analyzed in a noteworthy study by Henry Desplanques, "*Campagne Umbre*" (Desplanques 2006, Reprint); it is a significant piece of research, with a penetrating interpretative capacity, concerning the *sui generis* value of the regional area, whose sustainable management is deeply rooted in the awareness of economical subjects and policy makers. It is not a case that this region is known worldwide as "*the Green Heart of Italy and Europe*". Perugia University joined with a gradual and magisterial activity the context described above: its main concern is in fact the affirmation of the principles of Sustainable Development Strategy by means of research, didactics and extension. The Perugia University Department of Agricultural Economics, Farm Appraisal and Food Sciences—DSEEA—since the end of 1960 showed its long tradition of directing crucial research and teaching methods to reach an innovative model of development. After the publication at the Club of Rome in 1972 of *The Limits of Development* (Meadows et al. 1972), there has been an extensive analysis of the central role of proper land management, leading to *Earth conquest or re-conquest*. The publication of the famous Brundtland Commission Report "*Our Common Future*" in 1987 was followed by an intensive sequence of conferences and seminars on the contents and targets of the already organized Sustainable Development Strategy; its success derived from the positive activities gradually introduced by the Department in order to acquire a new role within the issues of integrated rural development and sustainable initiatives, in both domestic and international levels. Since 1987, an intense network of relationships was established with fellow researchers and teachers from more than 30 countries—Latin America, Central and Eastern Europe, Asia and the Mediterranean Basin. In 1994 the Department obtained the funds to run one of the earliest ALFA-Latin America Academic training projects, financed by the EU, named *GEASUD-Gestion des Entreprise Agricole et Soutenabilitè du Development* in which eight universities were involved (five Latin American and three European), co-ordinated from Perugia. At the same time, because of development of the training demand, the sustainable development led to the opening of the Bologna Processes, which were activated in both degrees: the first on Agricultural and Environmental Sciences, the second focused on Sustainable Rural Development. One of them is a first level degree (3 years), while the other is a second level degree (3 + 2 years). In 1996, 2 years later, Perugia University promoted a *Ph.D. on Sustainable Rural Development, Environment and Territory* attended by Italian and foreign students. This activity increased the visibility and the organizational skills of DSEEA, which, in September 2000, also organized in Perugia the 1st World Forum of Agro-Tourism and Rural Tourism, with the participation of experts and entrepreneurs of more than 65 nationalities. On that occasion, *the International Association of Experts in Rural Tourism and Agro-tourism* (*IAERT*) was also founded and was considered to be an international reference point on those specific topics for several years. Especially after the *Johannesburg WSSD* in 2002, research was dedicated to both young researchers and older academic staff, as long as they focused on the same subjects of the present work during the 1990s. Close attention was paid to the issues related to the sustainable development indicators, the Environmental Impact Assessment, the Strategic Environmental Assessment and Support Tools, strictly analysed using multi-criteria. In 2010 the spin-off *Centro Ambiente Rafforzamento Economico-Strengthening Economic Environment Centre* (*CARE*) was created, which operated positively, especially in extension services. Recently, in September 2011, the DSEEA promoted an International Summer School—SIS entitled "*Sustainable Management and Promotion of the Territory*"—*SMPT* (www.gpst-smpt.com) in collaboration with Todi's Agricultural Technical Institute "A. Ciuffelli", the Alumni Association, and the Local Municipality. The scope of the choice of the Degree, Masters Degree and Ph.D. courses is to form young technicians and researchers, and provide them with the knowledge background necessary to develop a future perspective regarding the regional niche markets of food farming production, handcraft, fashion, and renewable energy, even in a period of international crisis, thanks to the input given by the internal critical set of skills belonging to the experts in local sustainable development. The International Summer School was born with the aim of stimulating the mechanisms of benchmarking the University's activities, with the objectives of both keeping the didactics profile high, and proposing a repeatable and transferable model to help foreign students realize projects and processes of sustainable development in their own areas. On the other hand, one of the aims is to provide local youth (operators, researches, technicians, teachers, policy makers) with continuing attention and operative emulation in transferring their own skills for the consolidation of sustainable development (Leal Filho 2011).

2 The Vision of Perugia University to Promote Sustainable Development Strategy

The future of the world, as they say, is the basic theme of the forthcoming Rio+20 Summit, based on the *affirmation of a program firmly focusing on integrated and sustainable development.* The aim of the above-mentioned program is to publicise the need for an integrated amount of support for new synergies, beyond the monothematic approach (often required in developmental processes and actions) because this innovative yielding approach gives more effective and efficient results. With integration, we intend to achieve a model which could help improve the real sectors of economic growth of each sensitive area of the world, by emphasizing the maximum opportunity for increasing the value of these realities. Thanks to their typical specificity, they may—if properly guided—*turn their elements of weakness* into *points of strength*, for use in their social-economic modernization process. A more endogenous rather than exogenous development, a bottom-up rather than top-down approach, should characterize this course of action in the scientific and technological innovation fields which it has to support too. Sustainable development means are not to be considered as only linked to utopian matters, but rather, by preserving the environment, they can lead to a *perspective of fairness intra-and inter-generationally developed through* at least the following five key factors: *economic* (*income adjustment*), *social* (*adaptation of the quality of life*), *environment* (*productive conservation and sustainable use of natural resources*), *cultural* (*management of cultural diversity*), and *management* (*sustainability management*).

The *formation of the human capital, research development and technological innovation* are essential, and they are the two options to be considered. This must be done while avoiding the risk of introducing those mechanisms which lead to a breaking point with past and present structures, and also with social values hierarchy, still prevalent in harsh transitions occurring in many countries around the world. We must aim for a smooth introduction of innovations which does not produce any negative impact on the values of hierarchy and social and economic organization in all the areas in which we operate. In the present work we believe the improved professional formation of human capital should facilitate the acquisition of the required social factors, particularly within the weakest areas, using a special flexible ability which is suitable for the creation of increasingly self-rooted new value shifts, which can be—introduced when a company engages in the process of modernization with fairness and sustainability.

3 Sustainable Development: Output of Political Strategy Toward the *Culture* of All People and Nations

Activity is stimulated within society's catalyst areas where it has been particularly identified that young people require the provision of projects aimed at making them reach out for higher education (as far as possible) and helping them join the working world. The result would be acceleration in the educational process, so as to overcome crises, such as the current phase of the development model involving a billion people who live below the minimum level of nutrition; this 20 % of the world's population has just 1.4 % of the global wealth.

In this context, all projects of international cooperation, including mutual consultation, become operative in a coherent, comprehensive, frequent, clear and penetrating atmosphere, with an appropriate relationship with the media. The factors mentioned above serve to enable the gradual establishment and positioning of the elements which science links together in peace and solidarity through the use of technological innovations, increasing *friendly use* and general *accessibility.* All initiatives should follow the guidelines of an ambitious program, aimed at reaching the establishment of a "common house" supplying scientific global-scale research, involving in its wide planning all the potential which each socio-economic state can bring: the areas of education, science and technology, together with the "spearhead" of the action needed to support a sustainable development culture.

The action is characterized by progressive work to build a successful scientific framework, based on the above-mentioned values and aiming at a more concrete awareness and knowledge of new generations—a scientific society within which the University may be the starting point of a *New Renaissance*, a process related to each country and the whole of World Society.

What the multitude of young people living today needs are concrete *signs of hope and freedom, which lead to a more sustainable life and livelihood*, and can overcome the current systematic way of working, *which dominates our modern* "*easy times*" as a prison in order to obtain a *happier and sweeter society.*

In this sense, science must facilitate the removal of barriers which often imprison and overshadow the ancestral values of ancient societies, *not to be approached as if they belong to a museum, but rather with a spirit of revival and rediscovery*: a kind of science that *awards property but also humanity.*

The growth of university research centers acts *as windows of consciousness*, exploiting their spirit of analysis and the skills brought by all the autonomous self-decision-making people of world society.

4 The A.M.A.R. Project

The partnerships, in particular the town of Todi, the *Veralli-Cortesi Institute,* and the *ETAB-La Consolazione Charity Organization*, are still supplying different kinds of assistance. They work, as usual, with intense interest and wide availability.

The Summer School is part of a more extended project called **Associazione Mondialedi Amiciziadelle Aree Rurali (A.M.A.R.)** (***World Friendship Association of Rural Areas***) which we want to set up in Todi during 2014, when **the State Technical Agricultural College "A. Ciuffelli" 150th Anniversary Since its Foundation** is celebrated. The first step of the AMAR Project was the drawing up of the Todi's Charter, which then became a Final Document of the Summer School activities. The project intends to build up the AMAR association as a possible international entity, with the will and duty of looking after Rural Areas' Sustainable Development all over the world (see Fig. 1). Many of the most remarkable current "voices" (such as that of Bill Gates)—each within his own field of activity—already declared a few years ago their agreement with the AMAR aims. The same project, if well guided in the development of sustainable management and promotion, can represent the main base to support the *eradication of poverty to achieve a fairer and happier life throughout the world.*

The **establishment** and activation of the International Summer School **on** Sustainable Management and Promotion of Territory—**SMPT**

An International Summer School was create in 2011 within the framework of the A.M.A.R. Project as an item with the objective of solving the different management requirements of the Perugia University area and the Umbria Region, which could be *repeatable in* and *transferable to* many areas of the World (Ciani 2012).

The Umbria Region, a naturalistically rich area, is subject to frequent phenomena of hydrogeological instability, and also to fire hazards in summertime because of the large number of woods.

In order to limit these risks, the trend is to promote prevention through learning of GPS and GIS use. The aim is to improve a management method able to safeguard—through constant monitoring—the development, the good quality of life, and the protection of environmental resources, especially landscape and biodiversity.

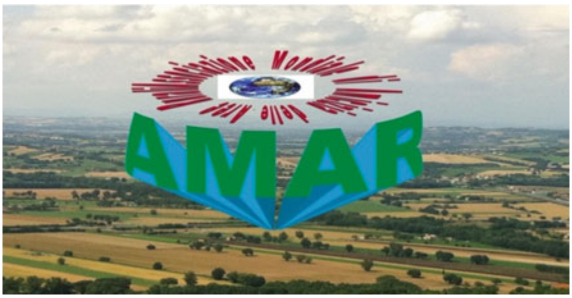

Fig. 1 A possible logo of A.M.A.R.—(World Friendship Association of Rural Areas Project)

There is the will to start and consolidate a mechanism which can make “the country talk” by use of the new ICT. For example, the contextual use of websites, webcams, e-commerce, etc. can turn the local firm (handcraft, agricultural, and services) into a globalized entity which is detectable and reachable by any potential client from any place in the world. This procedure leads to a loyalty effect with a high surplus value, since it is linked to the “face” of every operator, and to the image of specificity of the country. This is the direction of the processes of growth and innovation, aimed at safeguarding an internal sustainable development which is repeatable and transferable. From these two attributes it is possible to originate additional opportunities. On the one hand, the opportunity of strengthening the sustainable development culture for the needs of the regional reality where Perugia University and SIS operate; on the other, through the involvement of foreign students, the opportunity to promote SIS with a cognitive system of training and learning.

The experience and demand from local and foreign people increase the level of the formative activity’s value. The various experiences are compared, they act as a fertilizer and an accelerator, and they enrich the cognitive system. The SIS, linked to the State Agricultural Technical Institute and to Perugia University, plays the role of *advanced factory*, which the operators, educators, and single citizens emulate for the concretization of the sustainability strategy beyond any boundary.

In light of the already mentioned “tradi-ovation activity” and the Territory’s Sustainable Management and Promotion, it is conceived as a professional training and demand component, supplying the best skills for the technicians who work in the area: agronomists, architects, engineers, surveyors, and land surveyors. During the workshop week, full immersion activity’ projects are carried out, involving enhancement and intervention on some subjects, within Todi’s district: the Castles of Monte Nero and the village of Petroro, the Widespread Hotel in Massa Martana’s territory, and the Arboreal Archaeology Company. All this was achieved in a 2-day visiting tour. Within this framework, the Summer School was attended by young people from 16 countries (see Fig. 2) attending very high-level academic lessons and training, with the participation of University teachers from Bern, Budapest CMBS, Iasi (Romania), Chiba (Tokyo) Siena, Tuscia in Viterbo, and Perugia.

Fig. 2 Group of participants at the educational excursion in Assisi surroundings

5 The Charter of TODI

Following the careful preparation of the SIS on its educational contents and the training within the territory, an extensive discussion during the final session of Edition I of SIS, GPST-SMPT was held, the majority of the group sharing the same basic ideas.

5.1 An Operational Implementation of the Strategy of Sustainable Development and Fight Against Poverty in the World

The participants of the International Summer School—SIS—SMPT agreed that it is necessary to face the global crisis which involves manufacturing, financial, social and moral aspects. It is a continuous process which goes on beyond the options of sustainable development, the green economy, and the third industrial revolution, in order to give tangibility to the two guidelines of the next World Summit on Sustainable Development (United Nation and WSSD—Rio+20 2012) about operational implementation of the Sustainable Development Strategy to fight against World poverty and to create conditions for a future of prosperity which are the main guidelines for the final document of the same Rio+20 "The Future We Want" (United Nation and WSSD—Rio+20 2012).

5.2 Essential "NEW RENAISSANCE"

We must take into account that the territory in its widest and most holistic form, together with Man with his capacity to analyse, choose and operate together with the "humanity" which distinguishes him from all other living creatures, should be brought back to the centre of strategies used by any development model, by using a concrete, operational parameter to create the basic conditions for a strong "NEW RENAISSANCE".

5.3 Emphasize and Reach the TRADI-OVATION

It has been assumed that the nature of Todi's town was declared as the most sustainable in the world by the Kentucky University Professor Richard S. Levine. This could be the possible national and international benchmark to strengthen and improve the effective action of guardianship, enhancing and promoting any rural area in the world. The members of the core group decided to draw up this charter, and agreed to promote this initiative in their home countries and those of foreign partners. They also undertook to establish a Local Action Group—LAC, which helps to spread this mission all over the world.

The Charter indicated with the keyword "**TRADI-OVATION**" (for short) the acronym of "**T**erritory, **R**ural **A**reas, through **D**evelopment, **I**nnovation, **O**rganization, **V**alorization, friendly user, **T**echnology, **I**CT sharing, **O**nline **N**etworking"; this is the main component with which this innovative process can be structured to give effective credibility, and to erase the increasing disillusion that usually follows major international meetings: it is necessary to turn the words to practical action, towards the foundation of the new model of territories management and promotion. The TRADI-OVATION acronym and the words it represents are a pervasive and concrete way to give the younger generation a learning motivation and interest in the Sustainable Management of Territory.

5.4 A Society Able to Think but Particularly to Act

The initiative aims to create not a narrow, local concept, but rather a wide-ranging, international vision which can be used not only to do business "selling knowledge", but also simultaneously to bring the local system in Umbria to the centre of worldwide attention as an example of excellence in modern, territorial, local government. The issue of territorial governance and the promotion of integrated and sustainable land use is currently at the centre of international debate, particularly in view of the World Summit in Rio de Janeiro from 4th to 6th June 2012, better known as Rio+20 on the Strategy for Sustainable Development. The initiative focuses on strategies for the protection, conservation and enhancement of the different areas around the world, the relationship between urban and rural areas, the challenge of renewable energy, green economy, and the eradication of poverty. Therefore, these objectives and issues need to be put into practice in local, national and international contexts with professionals who, from the perspective of "think globally, act locally", have the distinctly modernized know-how and the "ability to act" which match up to the ongoing revolution, known as the third industrial revolution. Above all, they are aware of the strategic prospects of saving the planet through good practice in the processes of the Strategy of Sustainable Development, at the Centre of which lies the serious global problem of famine and the current phenomena of serious regional food shortages (950 million people live with a daily food calorie level well below minimum standards, 2 billion live on less than a dollar per day).

5.5 The Friendly Use of Innovation Communication Technology

The SIS intends to corroborate firmly their conviction that actions of territorial programming and planning must be strongly supported by an appropriate and widespread use of advanced instrumentation of Information and Communication Technology—ICT, of which GIS, GPS, DSS, (decision support systems, geomatics,

Table 1 The meaning of the TODI “quadrangle of words”

Territory	h**O**listic	**D**ematerialization	**I**nvent
Tradition	**O**bservation	**D**igitalization	**I**nnovation
Training	**O**rientation	**D**emonstration	**I**CT
Tutoring	**O**rganization	**D**evelopment	**I**nternationalization

geographic information systems, remote sensing and monitoring) and broadband Internet should be key elements of the “user friendly” store of knowledge of the modern agronomists and agricultural experts registered in their respective professional associations, all for the sake of the innovative continuity of the guiding principles of the Declaration of Cork and the G8 in Treviso–Cison di Valmarino 2009.

5.6 The Quadrangle of Words of the TODI Charter

The Charter invites everyone to take into account the fact that the *Charter of TODI* and the town’s initials: **T.O.D.I.** are emblematic and of great significance in capturing attention, according to the logic shown by the *words quadrangle* in Table 1.

The last part of the document concerns the aspiration that the national and international Summer School training activities on “The Sustainable Management and Promotion of the Territory” become the basic tools for the implementation of Todi’s Charter principle itself. The Charter of Todi, through the original representation of the *quadrangle of words*, (shown below), is an intriguing frame of references for the Operational Sustainable Development Strategy. This aspect could be analyzed in the future World Friendship Association of Rural Areas—AMAR to obtain innovative and integrated sustainable territory development everywhere.

6 Conclusions

The Green Campus—2013 of Pondicherry University was intended, as one of its main target, to make learning easier for young people and to implement concrete measure to diffuse the culture and the modern governance of Sustainable Development. I would like to stress that the case of the DSI-GPST-SMPT in TODI and the Todi Charter is a possible positive study case to achieve this aim.

The planning of the AMAR Project, the activation of the International Summer School on Sustainable Management and Promotion of Territory, and the drafting of the Charter of TODI all showed that international and local levels of response were significant.

This is a way to support the assertion of the Strategy of Sustainable Development, even though probably weak in terms of Cartesian analysis and predictive power, but with a strong will to promote the culture of territory sustainability. In times of deep global crisis and lack of economic governance models, we can suppose that is sufficient to go out and start working, using proper management and promotion of the territory as a great vital resource. A series of mechanisms could enhance wealth and healthy production, so as to start defeating the impairing strength of the globalized international speculator lobbies.

DSEEA promoted its initiative for the diffusion of the principles of the sustainable development culture. After a publication about the role of the Earth during the 1970s, DSEEA studied the research, didactics, and extension of the development of the issues, and the gradual but inexorable affirmation of the new model of industrial development earlier and in recent years. The promotion of specific Masters Courses and a Ph.D. in Sustainable Rural Development, Environment and Territory from 1996 allowed DSEEA and Perugia University to play a leading role in the professional formation of graduate students and technicians of Public Administrations who deal with the management of environmental and territorial problems of the Umbria region. This region is of great interest from the environmental, productive, historical, and cultural points of view, and it needs a preventative approach towards geological instabilities and fire hazards, but also an innovative effort to valorize and promote the natural resources which represent the basis of the production and wealth for the whole region.

The promotion of sustainable development culture during the last few years undertaken by CARE (Environment Center and Economical Improvement) is intended to activate a consistent and concrete action of extension, in step with the country’s needs, especially for the Evaluation of Environmental Impact and Environmental Strategic Evaluation.

The foundation of the AMAR Project (World Friendship Association of Rural Areas) represents the choice of deep internationalization, solidarity, and international cooperation for the creation of a future world society which is more sustainable, fairer, and happier.

The main idea is to create the conditions to give sustainable continuity to formative action related to the region’s future, and to export the formative model of development throughout the entire world.

One of the future perspectives is to improve the formative issues, specifically with local and international cases of study.

The elaboration and analysis (first of all, the Charter of TODI, which has the logo of “tradi-ovation”) by SIS are gradually transferred through seminars and conferences in the formative local institutes. The Charter of TODI has been shared by famous national experts, and is gradually brought into the schools and Public Administrations. It is already present in the formative obligatory issues of the Agricultural Technical Institute, which is a partner of the project. The following step forms a competition in the Technical Institute of the town, with a scholarship for the best essays on the Charter. An additional project is its integration in all the schools of the region. Two municipalities have already approved it as an operative strategy for their government's program. The second edition produced in 2012 and its conclusion were presented at an International Conference of *Territory, Sustainable Development, and Renewable Energy*. The executive staff of SIS accepted from the town of Todi the proposal to prepare the Project of Park T.U.De.R. [acronym and also old name of Todi City (Urban Territory and Rural Area Park)]. At present, the preparation phase for an appropriate operative General Agreement between the University and Todi's Municipality is proceeding.

The pillar of the proposal for a learning circuit associated with sustainable development is based on an adaptive and visionary testing method. It is not possible to achieve happiness (which is considered lawfully indispensible in most countries' constitutions, and one of the most important targets of the next RIO+20) *without big dreams to imagine and to reach.*

For all these reasons, we have suggested to the colleagues of Pondicherry University that we establish a Regional SIS-GPS-SMPT. We can do, we must do!

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Overview of Natural Stones as an Energy Efficient and Climate Responsive Material Choice for Green Buildings

P.P. Anil Kumar

Abstract

In building construction, natural stones are the most pristine materials one can choose for a varied number of reasons from thermal efficiency to their natural looks. Natural stones are heterogeneous mixture of minerals formed over millions of years under the joint effect of pressure and presence of suitable binders. There are around 4,500–500 varieties of natural stones present across the world today. For thousands of years, natural stones were in use, as one can see in Egyptian, ancient Greece and Roman architecture. All these civilizations were aware of the multifarious advantages offered by this natural material. Fortunately in today's world, where we frantically formulate rules for sustainable modes of architecture, development and construction, we are able to draw liberally on the experience that was acquired by the ancient and traditional builders over the past millennia and before in construction using natural stones. Their merits are many from the extraction, energy consumption, processing, recyclability and waste production and combustibility viewpoints especially for Green buildings. Certified green buildings are identified as the best vehicle to deliver sustainable architecture in an organized way. They are also projected as the flagships of sustainable development due to its underlying responsibility for balancing long term economic, social and environmental impacts on nature. The paper attempts to overview the virtues and benefits of using natural stones for the Green building certification regime as followed by leadership in energy and environmental design (LEED). Through judicious use of natural stones, one can majorly influence/enhance the extent of compliance of a building for green building certification. The paper discusses the suitability and

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varied applications of natural stones in buildings as applied to Indian context. The paper draws liberally from the background study on 'sustainability dimensions of natural stones from the green building certification perspective' which is part of a broader study being done at NIT Calicut to evolve an Indian certification norm for green buildings, modifying LEED and green rating for integrated habitat assessment (GRIHA) systems of certification.

Keywords
Green buildings · Natural stones · Climate responsiveness · Energy efficiency · Sustainable architecture

1 Introduction

In building construction, natural stones are the most pristine materials one can choose for a varied number of reasons from thermal efficiency to their aesthetic appeal. Natural stones are heterogeneous mixtures of minerals which have formed over millions of years and under the effect of pressure and specific natural binders such as lime. There are about 4,500–5000 varieties of natural stones available in the world adding colour, strength and comfort to our exteriors, structures and interiors alike. As one can see in various examples of great architectural monuments across the globe, stones of multiple varieties were preferred building materials all along the history. Inca buildings were made out of fieldstones or semi-worked stone blocks set in mortar usually laid over stone foundations (Protzen 1983), Egyptians used it for building their pyramids, Romans and Greeks for their great stately buildings and streetscape. Choice of natural stones for most of these great monuments, were informed ones, where the designers and builders of the period were aware of the properties and versatility of stone as a building material to a great extent.

The most common natural stones are granite, marble, limestone, slate, sandstone and quartzite in the Indian context. One of the distinct qualities of natural stones is that each piece has a distinct texture and pattern. Because stones are made in nature and out of natural processes, its colours and textures vary, making it an aesthetically appealing choice almost always. The paper is attempting an overview of the properties of stones from the architectural perspective, their energy efficiency aspects and the reasons why choosing stones takes a designer closer to more climate responsive, natural and sustainable ways of building and how stones can earn you more credits in qualifying to be green buildings.

2 Important Properties of Natural Stones

When considering using natural stones in a project, one would want to consider their properties to determine which natural stone is best for the job. Natural stones have the potential to be an ideal flooring, cladding, roofing or paving material, and their properties decide the applications they are best suited for. In particular, stone can support reduced energy consumption, decreased utility costs, and an improved environmental footprint (Lindberg et al. 2004). When it comes to green buildings, stones have the potential to earn considerable amount of credits as well. Their core properties as relevant to green buildings are briefly reviewed next.

2.1 Thermal Properties

Most important thermal property of natural stones used in buildings is their low co-efficient of thermal expansion. When a natural stone is exposed to temperature variation, it causes the stone to expand or contract at a specific rate and co-efficient of thermal expansion indicates this and for different variety of natural stones it varies in a wide range. Based on the application in mind, one can make a suitable choice of stone. The metric associated with the heat island concept is known as solar reflectance index (SRI) (University of Tennessee 2007). SRI is calculated as "the ratio of the reflected flux to the incident flux." Basically, it is the ability of a material to reject solar energy. As such, a material's contribution to a heat island decreases with increasing SRI. Relatively high SRI products are referred to as cool materials, such as cool roofs and cool pavements. Specific heat capacity is another thermal property that tends to be important for natural stones. And the higher it is the less it behaves like a heat sink.

2.2 Mechanical Properties

One of the important properties of natural stone is its place on the Mohs hardness scale which rates it as a hard material in most contexts. A hard stone is, tough to be scratched and it makes it most suitable for facing/cladding applications and in preventing weathering this property helps considerably. Young's modulus is another important critical property of natural stone that gives critical benefits when stones are used for structural applications.

2.3 Chemical Properties

Many varieties of natural stones have innate acid resistance and this remains an important property in building related applications. It measures what portion of the weight of the natural stone will be lost when the stone is subjected to an acidic environment for a specific amount of time at certain temperatures. Granite as such is hard, brittle and can easily withstand acids. On the other hand, marble can be easily be corroded by acids. Natural stones absorb liquids like water to varying extents and each stone has different chemical water absorption properties. The typical water absorption of granite is 3 %, and for marble is 1–2 %. From construction perspective, these are acceptable values and contribute greatly to their omnipotent application in buildings.

2.4 Energy Efficiency Dimension of Natural Stones

Generically speaking, energy consumption depends on the petrographic characteristics (composition, porosity, and cementation) of stone variety considered. However, energy efficiency evaluation of natural stone needs to be conceived from a holistic perspective, where all stages of production from extraction to disposal is duly considered (Lopez-Buendía et al. 2010). Important stages of life of stones from extraction onwards are grouped as follows:

- *Quarrying*: Energy consumption during extraction which includes internal transport, drilling, cutting, water pump usage, maintenance and general assistance, is generally normalized by production ratio. The recycling, as aggregate, for example, can be used to reduce the extractive energy consumption.
- *Transport*: It considers the distance and transport media from the quarry to the factory of treatment, as well as from factory to the building in construction. By going for locally available natural variety of stones, this aspect of energy consumption remains mostly under check.
- *Processing*: Based on dimensioning using cutting tools and polishing, for most natural stones it is low as there is no energy intensive manufacturing process involved as in the case of other artificial building materials.
- *Application*: Application areas depends on functionality in building, architectural design and energy contribution in habitat conditioning (climate responsiveness) and under all these natural stones score better than their artificial substitutes.
- *Maintenance*: Energy cost derived from treatments, replacing and durability and natural stones are safe bet under this category as well.
- *Waste management*: As the waste material form natural stones have multiple applications, as aggregate and otherwise (except when combined with a binder like in concrete) energy consumed in its waste management is significantly less and when reused it saves energy.

To consolidate, natural stone application has been considered traditionally a choice of low energy demand even from the quarrying and processing perspective. In some varieties of stones where artificial substitutes are minimal, it is increasingly so (Ozkahraman and Bolatturk 2006; Anani and Jibril 1988).

3 The Question of Sustainability; How Natural Stones Can Answer Your Queries?

Sustainable development is development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987) Sustainable architecture is the design or creation of enduring space which caters to the demands that generates its existence, and has the capacity to endure over time. It should be viewed as a process of change in design approach in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations (Hotten and Diprose 1994). The typical urban lifestyle, with its linear metabolism, risks us to be in the danger zone in terms of extensive wasteful and unsustainable resource consumption. To overcome this, we must devise circular metabolisms using green principles maintaining natural ecological cycles and allowing for reuse and regeneration of materials (Shashank 2007) and use of natural stones is a designer's long proven short cut to achieve this.

Sustainability in architecture is to be considered through a multi-disciplinary approach that embraces aspects like functional utility, user satisfaction, appropriate materials and technology and economic value. Hence as a part of the design process, we need to assess the life cycle of a project—whether and to what degree this project is crisis proof i.e. whether it will survive the future energy crisis or not. This may be over and above the prescriptions of the green buildings' regime. An ideal building in such a case would be self-reliant with respect to energy utilization and would mostly service itself through environmental energy and resources taken from its immediate surroundings. The contribution of stone to a sustainable construction is very relevant due to its low energy consumption during processing and the generally low conductivity of the rocks, mainly in porous rocks. Stone also means plenty of flexibility in architectural solutions, especially for cladding, paving, and flooring and ventilated façades. Natural stone used as a building or landscaping material can decrease the urban heat island effect and as roofing tiles, large decorative pieces etc.

There are not many in depth analyses of life cycle analysis of natural stone and the energy consumption in their life period. The efficiency and consumption of the cutting process was studied by Ersoy and Atici (2004) and Atici and Ersoy (2009). Some totally industrial approaches have also been analyzed (Patricia 2008) considering different factors to estimate the total energy consumption per unit of volume of stone.

3.1 Use of Natural Stones in Green Buildings

At present, the certification of a built environment as sustainable is largely identified through the "Green" rating systems in place that determine various parameters that make up sustainable architecture. At the purely architectural end, the scope of green architecture includes: the size and shape of buildings, their usefulness, their material stability, their embodied and recurring energy loads, their embodied and recurring outputs of pollution, their longevity and vulnerability of disrepair, their recyclability and reusability and their contribution or disruption to microclimate and biodiversity (Reference guide, IGBC 2009). In regard to the mentioned items of green certification criteria, natural stones score considerably and thus become invaluable resources in creating truly green buildings.

Leadership in energy and environmental design (LEED) for new construction (NC) projects is the most widely used green building rating system in most part of the world including in India. LEED-NC emphasizes certification under six categories for environmental improvement:

1. Sustainable sites (SS)
2. Water efficiency (WE)
3. Energy and atmosphere (EA)
4. Materials and resources (MR)
5. Indoor environmental quality (IEQ)
6. Innovation and design (ID)

Natural stone products, such as those made from granite, marble, and limestone, among others, can contribute to points in several of these categories (University of Tennesse 2007). Under the sustainable siting head use of stones can get points for heat Island effect, non-roof: It states that using light-colored natural stone with suitable solar-reflective index can reduce heat-island effects, which of late is a major menace in urban contexts. Use of light colored stone as caps on such features as landscaping walls, stair treads, and pavement can earn these credits. Under EA Credit, through optimizing energy performance, natural stone having good thermal mass (the ability of a material to store heat and slowly release it), can earn points. Depending on the climatic context, use of stones can positively influence indoor ambient air temperature and thus can add to energy efficiency. The number of points earned depends on the thermal mass of the specific type of stone used.

Under the head of MR, due to the durable nature of most variety of stones, substantial points may be scored. Credits 1.1 and 1.2 namely, Building Reuse, Maintain at least 75–95 % of existing walls, floors, and roof can help you score these points. Such credits can be earned only if the life-cycle of existing building stock is continued in the new project. In the Indian context, as most traditional techniques advocate use of natural stone, their reuse after the building's normal life is common, and here is an instance where vernacular systems help in scoring higher for green buildings. Also credits 2.1 and 2.2 under this head can be earned through the wise use of stones. Under construction waste management, divert 50–75 % of the waste from disposal for use in construction. Such credits can be earned only if 'waste stone' used in construction is diverted to a beneficial use. Also through credits 3.1 and 3.2 points can be earned. Through, reuse of at least 5–10 % of the materials, these points can be earned. These credits apply only if salvaged stone products can be reused for another purpose in a building design. By using natural stones, through credits 5.1 and 5.2 also point can be earned. The norm prescribes it as regional materials, 20–50 % extracted, processed and manufactured within a reasonable distance (500 miles), if used points can be earned. A minimum of 20 % (based on cost) of the total materials value should also be materials so collected. (if only a fraction of a product or material is extracted/harvested/recovered and manufactured locally, then only that percentage, by weight, contributes to the regional value). Under the head of, ID, points can be scored by using stones to reflect innovative concepts in design and ideas, and with the variety of stones at the designer's disposal it is possible to score under this head as well with reasonable effort. Such ideas may emphasize exceptional performance in areas such as life-cycle cost and durability and improved air quality. With a variety of natural stones at the designer's disposal, there can be many innovative ways of uses possible to enhance the green dimensions of the building.

The current definition of green buildings lacks depth in terms of ecological impact. Many recent regulations and energy codes focus almost exclusively on energy efficiency during the operational life of a building. In our struggle to adapt to these changes and still appear 'modern', architects and designers are increasingly looking to energy-intensive materials and high-tech solutions, often ignoring many of the wider impacts of their projects (Rao 2009). The importance of assessing the embodied energy of materials is a much debated topic and use of natural stones is your best option for the least of embodied energy.

3.2 Vernacular Architecture and Natural Stones

The 'vernacular architecture', as practiced in most parts of India, denotes the architecture that is low cost, prevalent in traditional village and small town settlements, where construction is carried out without the help of architects and professionals, where building activity is regulated by tradition that stretches back for many centuries, in many cases (Nangia 2009). The basic logic in the design process of a dwelling aims at keeping the occupants comfortable, effectively utilizing the locally available materials to possible maximum, being sensitive to climate, lifestyle and the activity patterns of the occupants. Use of natural stones directly translates into the listed attributes, and thereby it becomes a stunning revelation for us that vernacular and green systems are complimentary, and can mutually enrich each other. Unfortunately in the present context, with the technology induced twists in lifestyles, building typologies get dictated by technology rather than user lifestyle, and it is the user who adapts to the building rather than the other way around. The envelope is created, then its problems are assessed and technology is sought to ameliorate the situation, the cost to the environment being seldom looked into. The rapid rate at which this kind of architecture is mutating itself is alarming even in semi urban areas of India. This technology assisted planning philosophy is highly unsustainable from the energy, climate and social perspectives. Insistence of use of natural stones that is locally available as matter of policy can be the most direct shortcut to have green and sustainable buildings.

4 Conclusion

Natural stones with their variety and range of unique properties and applications are truly god's gift to mankind for realizing sustainable architecture. As covered in the chapter, an overview of their core properties and their energy efficient life cycle provides us sufficient rationale to advocate their use at an increasing scale for sustainable architecture and a pollution free world at large. A thorough overview of vernacular architecture as practiced in various parts of the world also opens vistas on the age-old knowhow on the goodness of using stones, and how one can continue to promote the use of natural stones as an eco-friendly and sustainable material. Recent manifestations of promoting sustainable architecture through the advent of green buildings also emphasize the use of natural stones for appropriate certification and better quality of built environment. The study results referred also show the category wise scoring potentials when natural stones are used in a green building and the chapter conclude that wherever locally available natural stones of minimum processing are available, that should be treated as the first and best choice of material for a true green building, wherever possible. Taking our inherited knowledge into consideration, in a country like India, we can even come up with a new grammar for sustainability based on vernacular principles that predominantly uses natural materials, majorly stones and thereby rewrite the prescriptions for green buildings as adapted for India. The chapter may be viewed as a consolidated background study for research in this direction.

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The Role of Higher Educational Institutions and Other Training Organizations to Promote Renewable Energy in India

R. Arun Prasath, G. Poyyamoli, Dwipen Boruah, M. Nandhivarman and Golda A. Edwin

Abstract

India's demand for energy is growing with the energy gap between demand and supply of about 12–15 %. As a developing country, India has to play an important role in the development and utilization of renewable energy resources (solar, wind, bio-energy, hydro, etc.) for sustainable development. The country has high potential to harvest the renewable energy because of strategic geographic location. Considering the renewable energy potential, India can play a responsible role to take positive steps towards carbon emission and ensuring for its sustainable future by increase its energy share through renewable energy.

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Currently, the renewable energy accounts 26 GW (12 %) of the total power generation capacity of 212 GW as in 2013. The renewable energy industry has shown a promising growth over the last couple of years compared to non-renewable energy and it is expected to grow at an even higher rate in the Twelfth Five Year Plan period (2012–2017). The country's vision in renewable energy development aims to achieve 55 GW by 2022, and by 2050 about 50 % of its total energy through renewable sources. An extensive pool of knowledgeable and skilled manpower competent to design, install and maintain renewable energy systems will be required. The MNRE report published in 2012 on "Human Resource Development Strategies for Indian Renewable Energy Sector", at a moderate growth of 10 % the wind sector would employ about 75,000 people by the year 2020. Similarly, the report estimated that Solar PV on-grid and off grid sector would employ 1,52,000 and 2,25,000 respectively by the year 2022. The estimated numbers are equally large for the other renewable energy technologies like solar thermal, small hydro, biomass, biogas etc. Shortage of skilled and quality trained manpower is considered to be a major challenge in the growth of renewable energy sector. Higher educational institutions (HEIs) and renewable energy organizations have to play a crucial role in human resource development and capacity building to overcome the challenges, and achieve projected renewable energy target in sustainable manner to reduce India's energy dependency.

Keywords
Higher educational institutions · Renewable energy · Renewable energy organizations · Human resource development · Sustainable

1 Introduction

Energy is vital for humans, without which human life on earth is unimaginable. Civilization began once human being recognized how to use the energy in the form of fire for their survival. Gradually, they mastered the use of wood to generate energy with sufficient high temperature for extracting pure metals, minerals, chemicals from earth. Burning the wood in atmospheric oxygen (O_2) generates heat energy and releases the carbon dioxide (CO_2). By photosynthesis process, the CO_2 is absorbed by plants along with water to convert back to wood and O_2. In such a way, the amount of CO_2 in the atmosphere was maintained steadily until the industrial revolution started by the use of fossil fuels, e.g. oil, coal and gas. Through rapid industrialization for materials and implementation of modern economic systems in heating, cooling, transporting, lighting, communication, large food production and processing to feed the ever increasing population comes at the cost of accelerated energy use. The amount of fossil fuels (non-renewable fuels) used in the last few decades by the developed nations and recently by the developing nations for the above said reasons are of great concern. The main concern is global warming caused by the release of harmful emission of greenhouse gas (GHG). The other important concern predicted by the World Energy Forum is that the fossil-based oil, coal and gas reserves could exhaust with in another $\sim$200 years. All over the world, the demand for energy has increased in an alarming way due to the population growth coupled with the development in human race. In spite of increasing popularity of renewable energy sources/technologies, we still depend mostly on fossil fuels for our development. Currently, the China and US are the world's largest consumer of energy followed by Russia, and India. The use of fossil fuel for energy and its related application around the world is above 80 %, which severely damaging the environment by release of greenhouse gases (GHGs) (e.g. CO_2, NO_x, SO_x, CH_4, CFCs, halons, aerosols, etc.) into the atmosphere. In 2013, the concentration of CO_2 was above 400 ppmv in the atmosphere compared to 280 ppmv in the mid-1800s and increases year by year. Also, significant increase has also occurred in the levels of methane (CH_4) and nitrous oxide (N_2O) into the atmosphere. In its Fourth Assessment Report (IPCC 2007), the IPCC concluded: 'Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse-gas concentrations'. Nearly 80 % anthropogenic GHGs is due to the use of fossil fuel for energy production and utilization. Among the GHG emitted into the atmosphere, CO_2 alone contributes 94 %. Industrialized nations showed higher emission levels of GHGs compared to the developing nations. In near future, the energy service to households and productive activities in developing countries will expand in a very rapid manner to improve the living standard of millions. It is predicted that the fast developing countries such as China, India and South American countries could consume larger energy share by the use of fossil fuels and emits more than 50 % of GHGs by 2030. IEO (2012) reports states the energy related carbon-dioxide (CO_2) emissions would peak before 2020, with a decline thereafter consistent with a long-term temperature increase of 3 °C. The IPCC report predicts an average global temperature of around 5–6 °C in the next hundred years (IPCC 2007). If this will be true, catastrophic damages such as sea level rise, drought, floods, cyclones, hurricanes, storms, typhoons, etc., could occur frequently in most part of the world. The developed nations, developing nations and under developing nations are doing their bids to reduce the emission levels of GHGs by opting for renewable energy systems. As energy starving nation, India seriously and sincerely looking for greener renewable energy to sustain its economic growth for a sustainable future. Renewable energy resources can help the country to provide secure energy, increase its economic growth, reduce the adverse environmental impacts, reduce carbon foot print, balance regional development, promote sustainable development, and become a leader in renewable energy technologies. India encourages and promotes the development of renewable energy sources to accelerate the shift towards sustainable consumption and production for its sustainable future. Renewable energy sources and technologies offer a chance to protect the atmosphere by reducing GHGs emission. In addition, switching over to renewable energy will reduce the rate of depletion of natural resources and in turn supports for sustainable development across the country.

India's demand for energy is also growing at the same pace of economic growth. Currently, the gap between demand and supply of energy resource is about ~ 15 %. About 40 % of the population, particularly the rural population has little or no commercial energy access. Also, the others who have access to energy often have to cope with poor and erratic energy supply. The per capita consumption of electricity in India during 2012 is 778 kWh (CEA), which is much lower than the world average which stands at 2,782 kWh. India Visions 2020 targets to have per capita consumption of electricity at 2,460 kWh, still well below world average (Gupta 2002). If this target has to be achieved, power generation capacity has to be increased to 2,000 GW compared to ~ 212 GW as on 31st January 2013 (Ministry of Power, Govt. of India). To sustain its economic growth and provide decent energy supply, India has to increase its energy production to reduce the energy gap (~ 15 %) between its demand and supply. This can be achieved by harnessing its abundant naturally available renewable energy such as biomass, solar, wind, hydro, waste-to-energy, ocean, geothermal, etc. India can play an important role in the development and utilization of renewable energy for sustainable development, the strategic geographical location and the world's largest young (0.672 billion out of 1.2 billion, age group 15–64) trained/trainable manpower gifted the country to harness its abundant renewable energy resources. India is blessed with solar radiation of 4–7 kWh/m^2/day; its potential to harvest the solar energy is very high, its tropical location blessed for biomass generation at higher rate to harness bioenergy, hilly areas for hydro energy, seasonal for wind energy, long coastline for ocean energy, etc. However, there are several constrains for the development of renewable energy in the country; lack of awareness/skilled personal/research and development/proper linkage between public and private sectors/access to appropriate technology/appropriate policies, higher cost, inadequate financing capabilities, tariff disparity in renewable energy projects, issues in uploading renewable power to grids, subsidies given to conventional energy sources, etc. Though considerable work has already been done on the application of renewable energy in rural and urban India, its sustainability and growth is in questionable and crossroad. This is mainly because of lacked skilled manpower to promote and sustain the renewable energy resources. We strongly believe that both the public and private sectors of higher educational institutions (HEIs), foreign educational universities/institutions, various funding agencies around the world, energy and renewable organizations including small medium enterprises (SMEs) and Non-Government organizations (NGOs) has to play an important role to promote and sustain the renewable energy in India, such that they will be instrumental in facilitating awareness, action in ground level, action research to promote R&D; co-curricular activities and community out-reach on renewable energy technologies.

To promote and to sustain in the utilization of renewable energy resources, India has to target its HEIs for development and implementation of various renewable energy technologies to fully exploit its real renewable energy potential. The country has one of the largest higher education systems in the world next to china and US. English as primary language for teaching and research in the country has played a significant role in building a large, high quality higher education system (HES) in the 21st century knowledge race. According to the annual report (2011–2012) from the Ministry of Human Resource Development (MHRD 2012) on higher educational institutes, there are 523 universities and university level institutions, 33,023 colleges, 118011 AICTE technical Institutions, and 200 distance education universities/institutions to provide higher education in India. At the beginning of the academic year 2011, the total number of students enrolled in the formal system in the universities and colleges has been reported at 16.9 million. The present gross enrollment ratio (GER) in higher education in India is around 15 % (world average 23.2 %) and the Government of India wants to increase the GER to 21 % by 2017, and set 30 % GER by 2020. Considering the second largest population with 0.69 billion out of 1.2 billion in the age of working group, the country has the potential to become a hub of trained manpower provided the young population is given the right knowledge and training, particularly in the focused areas such as in field of green/renewable energy sector. In order to do so, the HEIs should be in a position to provide all the educating students with knowledge in renewable energy technologies, environment and sustainable development.

The development of renewable energy depends upon the availability of adequate trained manpower and appropriate resources. The skill requirements for renewable energy technologies are unique in nature and vary widely across different renewable energy sectors. Indian renewable energy sector suffers mainly due to non-availability of trained manpower across various renewable energy sectors. The AICTE database shows that only about 50 colleges offer courses on Energy Management in PG level, in which renewable energy is one of the major electives. India slowly addressing the problem by providing renewable energy degree courses at PG levels in the universities/colleges. As of now, the renewable energy education level is not adequate compared to the focused demand level. There are very few colleges/universities/institutions promote and educate renewable energy technologies. Most of the promoted/implemented renewable energy demonstration projects in some of the HEIs such as solar street lighting, solar hot water for hostels, solar thermal cooking system, electrical mobility; mobile chargers, etc. are not in a sustainable manner. In order to develop and promote renewable energy in large way the HEIs in India should adopt for strong policies. Though, the India's education policy embedded with several principles of sustainable development, the implementation of the same faced with challenges due to lack of inter-disciplinary competence among staff and students, and traditional methods of assessment in higher education (Kiran 2010). This is because the Indian HEIs lag behind in the adoption of environment management system (EMS) in contrast the developed world. In spite, there are some institutions, such as IITs (Kanpur, Madras, and Delhi), IIMs (Calcutta, and Ahmedabad), IISc, and universities (Madras, Jabavpur, Hyderabad, Pune and Jammu) which have established sustainable education programmes/courses to promote sustainable development in India. TERI University in Delhi is a model green campus in terms of building, energy conservation including promoting renewable energy in the campus, water conservation and waste-water recycling etc., embeds the sustainability concepts in most of its courses offered in the campus (Kiran 2010). It is pertinent to recall that the Rashtrapati Bhawan (office cum residence of the President of India) has asked to adopt its 'Roshni' model for sustainable management of large campuses of Raj Bhawans and institutes of higher education, especially Central Universities, IITs and IIMs. Indian Government's commitment to the promotion of energy efficiency in buildings through green rating for integrated habitat assessment (GRIHA) has attracted several HEIs in India to adopt for energy efficiency appliances, and promote the renewable energy through green buildings (GB) concept. Some of the currently registered projects with GRIHA are from Centre for Environmental Science and Engineering in the Indian Institute of Technology (IIT) Kanpur, IIT-Bhubaneswar, five Indian Institute of Science Education and Research campuses (IISERs), the National Institute of Fashion Technology in New Delhi and others.

Universities and colleges across developed nations have done notable development in sustainable education in their HEIs campuses, Brown (2009) in his review article on higher education sustainability explored on campus sustainability programs that have been the subject of recent case studies of several workers (reduction of energy, water, and waste, awareness in energy efficiencies and renewable energy, etc.). The main target by the higher education sustainability focused on GHG reduction goals by reducing their energy use and specifically targeting their renewable electricity purchase goals. The procurement of renewable energy credits (RECs) and building retrofits are two main popular methods in reduction of GHGs at colleges and universities (ACUPCC 2010). Several US universities and colleges are members and participating in the green power partnership (GPP), a voluntary environmental program initiated to promote use of renewable energy power among US organizations by the US Environmental Protection Agency in 2001. Among the US universities, University of Pennsylvania ranks first with the capacity of annual renewable energy power usage of 201,841,600 KW, which is about 48 % of its total power use and prides itself on the Green Power Leadership Award 2002, Partner of the Year 2003 and 2008 awards (Soma 2011). Though, India has large number of engineering and technology institutions both in government and private sectors, they concentrate on basic research rather than the application of science and technology in sustainable development. Only very few initiative are in progress in scattered location of India where renewable energy technologies are widely adopted in such a large scale to have significant impact on the environmental and economic sustainability of campus. In spite of the wider adoption of renewable energy technologies in rural and urban India, its development and sustainability is uncertain. The HEIs, which need to produce good number of skills renewable energy technologist for the market need is not happening, and thus creating an increasing disparity between market needs and academic deliverables in the area of renewable energy technologies, producing intellectual capital, and knowledge workers (Arun Prasath 2012). Thus, it is to critically analyze the strength, weakness, and opportunities for private and public HEIs and other organizations which care for promotion and development of renewable energy technologies across the country for sustainable development. The potentials, challenges and the key to success for implementation will be discussed.

2 Renewable Energy Scenario in India

The strategic geographical location of India gifted with abundant renewable energy resources to harness energy from solar, wind, biomass, waste-to-energy, and small hydro power. India can overcome its energy deficit by harnessing these resources; particularly it will help to meet the energy requirement in over 90,000 villages ($\sim$400 million). India recognized the importance of renewable energy in the early 1970s. The first country in the world to establish separate department to promote renewable energy, the Department of Non-Conventional Energy Sources in 1982, which was upgraded in 1992 as ministry of non-conventional energy sources (MNES) and subsequently renamed as ministry of new and renewable energy (MNRE). The report (Akshay Urjoa 2011) from MNRE showed the potential of renewable energy from wind, small hydro and bio-energy as 87 GW excluding solar energy, the report estimates about 20–30 MW per km^2 for solar power. The accurate potential of solar energy of India remains largely elusive because of non-availability of credential solar radiation data base. It has been estimated that if India's 10 % of waste-land been used of solar PV installation (using current technologies), it could generate about 8,000 GW of solar energy. Interestingly, the world bank of South Asia Energy Unit report estimated the renewable energy potential for India as 150 GW. There are independent reports, which claims that the reassessment is needed to estimate the renewable energy potential of India by keeping pace with improving technologies in the field, the new research indicates that India can have higher than 1,000 GW, which is fives time more power than current production cum consumption. Currently 26 GW power is produced through renewable energy, which accounts for nearly 12 % of the total power (212 GW) generated in India (CEA 2013). Figure 1 shows the share of renewable energy from the total installed capacity connected through grid as on January 2013.

The renewable energy sector has shown highest growth rate registering an annual growth rate at 18 % in the Eleventh Plan Period (2007–2012) compared to just 5 % witnessed in the non-renewable sector. By knowing the potential of renewable energy, the thermal major companies like the National Thermal Power Corporation Limited, Tata Power Company, and Reliance Power have begun investing in a big way in renewable energy business. This clearly indicates that

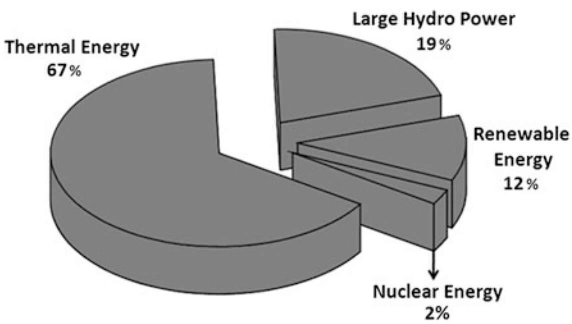
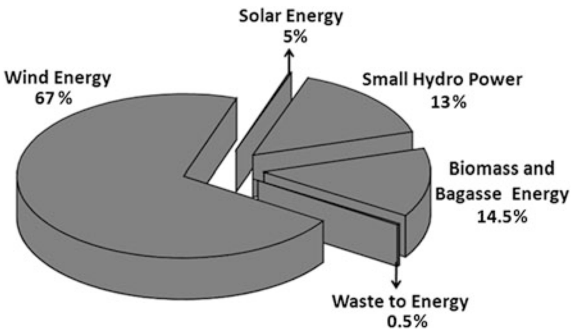


Fig. 1 Total electricity installed capacity: 212 GW (data *source* CEA 2013)

Fig. 2 Grid-interactive renewable power in India (data *source* MNRE 2013)



India is determined to become one of the world's leading renewable energy producers. Figure 2 shows the percent of installed power capacity by various renewable energy sectors in India with grid-interactive as on February 2013 according to MNRE (2013).

2.1 Renewable Energy Potentials

India has one of the world's largest programs in solar energy, which include Research & Development, demonstration and utilization, testing and standardization, industrial and promotional activities. India possesses abundant solar energy resource as it receives an average incident solar radiation of 4–7 kWh/m^2/day with 250–300 clear sunny days in a year. The country receives solar energy equivalent to 5,000 trillion kWh/year. Solar thermal and photovoltaics technologies are used since 1960s to harness solar energy. Though the solar energy potential is huge, only 1,447 MW is produced via grid-connected and about 107 MW produced by off-grid achieved as on February 2013 (MNRE 2013). National Action Plan on Climate Change which was announced in June 2008 with eight missions for protection of climate which includes its first mission statement as solar mission, a major step for the utilization of solar energy for power generation and other purposes. The solar mission, Jawaharlal Nehru National Solar Mission (JNNSM) was launched to boost the solar energy in India, with a target of 20 GW grid connected solar power (based on both solar photovoltaic (SPV) technologies and solar thermal power generating systems), 2 GW of off-grid capacity including 20 million solar lighting systems and 20 million m^2, solar thermal collector area by 2022 (MNRE 2011a). The mission will be implemented in three phases. The first phase for three years (ends by March, 2013), the second phase till March 2017 and the third phase will continue till March, 2022. The first phase project allocation was done to set up 1.1 GW grid connected solar plants, 100 MW of rooftop, 200 MW capacity equivalent off-grid solar applications and 7 million m^2 solar thermal collector area. The state, Rajasthan, Gujarat, Andhra Pradesh, Tamil Nadu and Karnataka are major players for developing and implementing solar energy projects through national solar mission and their own state policy. In 2010, the employment in solar PV on-grid is estimated to be around 4,000. Considering the JNNSM targets, it is estimated that the solar PV on-grid sector would employ 39,000 people by the year 2017 and 152,000 by the year 2022. The estimated employment for solar PV off-grid is about 72,000 in 2010 and the sector would employ about 140,000 people by the year 2017 and 225,000 by the year 2022 at the growth rate of 10 % (CII-MNRE 2010).

India ranks fifth largest installed wind power capacity in the world and the industry is much matured than other renewable energy technologies. The wind power in the country began to develop from 1990s, and has progressed steadily in the last few years. The total installed capacity is 18,635 MW as on February 2013, which accounts for 67 % of the country's total installed renewable energy (refer Fig. 2). The major wind power capacity is in the states of Tamil Nadu, Gujarat, Maharashtra, Karnataka and Rajasthan. The nation's wind energy resources have been mapped by Centre for Wind Energy Technology in Chennai, Tamil Nadu. Centre for Wind Energy Technology provides technical support to the MNRE in the implementation of its wind energy programmes across India. The estimated potential of wind energy by MNRE is around 50,000 MW (Akshay 2011). However, the actual potential will be much higher due to technology development and offshore potential is not taken into consideration. The World Institute for Sustainable Energy (WISE) estimates the potential could be as high as 100 GW. The long coastline (about 7,500 km) of India could promote to develop and this offshore wind energy which is not explored until now. It is estimated that there are more than 40,000 people employed in the wind sector in 2010 and expected to have about 75,000 jobs by 2020 at the medium growth rate of 10 % (CII-MNRE 2010).

Biomass energy is another very important renewable energy mix of India and predominantly used in rural households. Biomass resources are abundant in India, it has been estimated that about ~51,000 MW potential is there, ~17,000 MW from agro-residue (straw, stalk and husk can be the main contributors) and ~34,000 MW from energy plantation in waste land (MNRE 2011b). The MNRE expects the launch of National Bioenergy Mission (NBEM) which will target a cumulative bio-mass based power generation of 10,000 MW by end of 2022. India with nearly 70 % of its population lives in villages and their main source of their living is through agriculture. The biomass as agricultural residues produced in these villages has been estimated as 600–700 million tons per year. The biomass can be harnessed for production of commercial energy including fuel, power and heat. However, it has been found that above 50 % of the biomass residue is not harvested due to various reasons. At the level of less than 50 % harvesting efficiency, it is possible to generate 7,000 MW power based on using various conversion technologies (combustion, gasification, pyrolysis, bio-methanation, etc.). The technology choices exist for development of KW ranges gasification based system to both small (1–2 MW) and large scale (10–30 MW) combustion based systems. By increased efficiency in these technologies, the potential would further increase. According to the Planning Commission 14, "India has approximately 50 million hectares of degraded wasteland that lie outside the areas demarcated as national forests, and another 34 million hectares of protected forest area, of which tree cover is severely degraded. A massive program of energy plantation consisting of fast-growing tree crops such as bamboo, casuarinas, and eucalyptus etc. can serve as the raw material for a national network of small, decentralized biomass power plants (Gupta 2002). In spite of all above, only 3,600 MW is produced via grid-connected and about 550 MW produced by off-grid achieved as on February 2013 (MNRE 2013).

The country has launched National policy on Bio-fuels in 2009 to promote bio-fuels in India. Bio-fuels is another important resource for India to supply its energy need particularly for vast rural population without grid connectivity and the transport sector. Biofuels are derived from renewable bio-mass resources and, therefore, provide a strategic advantage to promote sustainable development. The biofuel sector has been driven by the MNRE's national policy on biofuels (NPBF 2009). The goal of the policy is to ensure that a minimum level of biofuels become readily available in the market to meet the demand at any given time. An indicative target of 20 % blending of biofuels, both for bio-diesel and bio-ethanol, by 2017 is proposed (NPBF 2009) MNRE along with other departments such as Ministry of Environment and Forests, Ministry of Petroleum and Natural Gas, Ministry of Rural Development and Ministry of Science and Technology to deal with different aspects of biofuel development and promotion in the country. These departments promotes bio-fuel development from non-edible oilseed bearing plants second generation biofuels including conversion of ligno-cellulosic materials to ethanol such as crop residues, forest wastes and algae, biomass-to-liquid (BTL) fuels, bio-refineries, etc. India's waste generation capacity increasing enormously due to its population growth, urbanization and industrialization coupled with rising standards of living. As the industrial, urban and biomass wastes contains organic matter, these waste can be used to generate power and solve the problem of huge waste management. Ministry of Urban Development estimates about 64 million tons of solid waste and about 40,000 million liters of liquid municipal waste is generated per day in urban areas. MNRE targets to produce 1,500 MW of power from current municipal solid waste in the country and focused to achieve 5,000 MW of power from waste in future with economic developments (Arijit 2011) using various waste-to-conversion technologies. However, due to environment concerns from some waste-to-conversion technologies, the production of power via waste is on cross road, the main problem is that the waste is not segregated from the source and because of that most of the waste have large non-combustible and toxic waste materials in the waste. In 2010, the employment in bio-energy (bio-mass on-grid and off-grid, biogas) is estimated to be around 142,000, predicted to grow at 10 % in coming years and it is estimated that the bioenergy sector would employ 561,000 by the year 2020 (CII-MNRE 2010).

India is blessed with immense amount of hydro-electric potential and currently 20.5 % of total electricity power of India via large hydro power plants. The total hydroelectric power potential of the country is estimated to about 150,000 MW, equivalent to 84,000 MW at 60 % load factor. The potential of small hydro power projects (SHP) is estimated at about 15,000 MW. In India, the large hydro power projects are under Ministry of Power, while the small hydro power development under the MNRE. As on August 2011, 3,154 MW is produced through small hydro power, which estimates 15 % of country's renewable energy (MNRE 2011c). The large potential of SHP is largely untapped because of the location of potential sites in remote and mostly underdeveloped hilly regions of northern states. The employment status in SHP stood at 12,500 in 2010 and it is estimated to have 30,000 by 2020 at 10 % growth scenario (CII-MNRE 2010).

3 Challenges and Drivers of Renewable Energy Sector for India

In India, renewable energy can contribute a significant portion of the nation's energy and could provide the energy security in future. Though the country has a greater potential in harnessing renewable energy resources, there are several challenges that need to overcome: (1) high capital costs, (2) lack of primary solar radiation/wind speed/biomass data, (3) lack of clarity on technologies- as technologies are still evolving, (4) inadequate infrastructure, (5) lack of technical support after sale service network, (6) lack of technological advancement, (7) incentive challenges, (8) difficulty in raising finance, (9) optimal pricing of power generated from the renewable energy sources-affordability issues, (10) technical feasibility to generate biogas from human excreta versus social acceptability, (11) quality and consistency issue of renewable power arising from the intermittent nature of electricity from wind and small hydropower, (12) costs of technology development and production need to be reduced significantly from current levels, (13) lack of coherent long term policies/policy instruments, (14) inadequate R&D sector, etc.

One of the important measures identified in NAPCC involves increasing the share of renewable energy in total electricity consumption in the country. There are several opportunities for users of renewable energy technologies/devices in India, the following renewable energy drivers will encourage to adopt renewable energy technologies/devices: (1) decline in the cost/kWh for renewable based power generation and increase in the cost of conventional fuel, (2) recent advances in material science and renewable energy technologies, (3) Government (both Central as well as State) is encouraging investments in solar energy by providing various incentives and duty concessions, (4) capital subsidy in case of semi-conductor based units, (5) low import duty for several raw materials and components required for solar projects, bringing down the cost, (6) 100 % Export Oriented Units is permissible and also permitted to import raw materials and component duty free bringing down the cost, (7) soft loans to users, intermediaries and manufacturers, (8) renewable energy certificate (REC) Mechanism, (9) clean development mechanism (CDM) projects, etc. In addition, the government's renewable energy targets, initiatives under way across India that include the development and implementation of energy-efficiency improvements for appliances, buildings, power generation, and industry; a revised national policy to upgrade and "smarten" much of India's power grid; and emerging leadership in states like Gujarat, Rajasthan, Maharashtra, and Tamil Nadu to adopt and implement progressive renewable energy policies. Civil society and the private sector are increasingly active in implementing renewable and smart energy projects across many parts of the country.

4 Role of HEIs and Other Organizations to Promote and Develop Renewable Energy in India

India's renewable energy installation is expected to grow about $\sim$4 folds in the next 10 years, which in turn will create number of job opportunities in this sector. Implementation of various renewable energy technologies requires human expertise and skilled professionals at all levels, from local communities up to the national policymakers. Capacity development and training activities are essential to empower stakeholders for planning, installations, and maintenance of renewable energy devices. Indian renewable energy industry/promotion is faced with severe problem of getting renewable energy experts, i.e., underprovided renewable energy experts in spite India has world's largest young educatable/trainable population. To remedy this major bottleneck problem of trained manpower, selected educational institution can organize training and capacity building programmes in the form of technical training courses and workshops besides offering professional diploma courses. The technical training and capacity building programmes should aim to provide a better understanding of the principles and operations of renewable energy technologies. The similar facility will also play an important resource for teaching, applied research to develop the technology, and outreach to educate community through community colleges/sources on renewable energy. To generate large pool of skilled manpower in renewable energy, it is been recommended that AICTE and MNRE should encourage more number of engineering colleges to offer renewable energy courses. In order to extend renewable energy education across several HEIs in India, mandatory undergraduate/postgraduate renewable energy courses should be in place to sensitize the urgent need of renewable energy technologies for sustainable development. In addition, the government should make renewable energy jobs as attractive compared to other sectors. Because the real concern is that the actual number of students opting for renewable energy jobs is very less compared to the needs of the sector, this is due to (1) unattractive salary, (2) wide difference in salary package within various renewable energy sectors, (3) off take of renewable energy students into industry through campus selection is minimal due to reputed renewable energy companies are non-existent or minimal or only play mediator to promote foreign companies, (4) the career prospects in renewable energy sector is not attractive compared to other sectors, (5) awareness of renewable energy prospects among the students are low, (8) lack of skilled and knowledgeable trainers, (6) lack of proper course syllabus and laboratories to address the requirement, (7) non availability of adequate scholarships, (8) inadequate R&D laboratories, (8) inadequate coordination between different disciplines in this multidisciplinary sector, (9) subsidy given to renewable energy industry really kills its development and jobs, and (10) one way to promote renewable energy should be that to remove subsidy for non-conventional energy resources. In order to attract students, there is an urgent need to address the above concerns to increase the number of students for renewable energy courses in various universities/colleges/institutions. In addition, the due-recognition and encouragement should be provided by the administration of the concerned institutions to promote renewable energy courses.

The CII-MNRE report (2010) recommends various strategies such as MNRE scholarships to PG students opting for renewable energy courses, funding reputed central universities/institutions to develop/procure necessary infrastructural facilities such as lab equipment, training prototype models etc., for imparting renewable energy education, increase campus recruitment in HEIs, promotion of industry—HEI linkages, interaction and collaboration with world class international universities, setting up a cell to organize renewable energy awareness programs by experts from industry and institutions, facilitating the creation of green jobs in sector-specific skill gaps in various renewable energy technologies. There are exciting possibilities for integrating the concepts of renewable energy technologies into various disciplines such as science (physics, chemistry, biology, and ecology,) engineering and technology, as well as in social sciences. However, very little is done towards this direction, to overcome this drawback, major revision of the curricula and syllabi by including leading experts from the academia and industry in the field of renewable energy technology. Particularly, acceleration is very much need of the hour through public-private partnership programmes (PPPP) in renewable energy related technologies in the areas of fostering awareness progammes, training workshops at the national, regional and local levels, education and capacity-building strategies in close collaboration with a wide range of partners, development of educational material/training modules for renewable energy systems and in energy supply/managements sectors, demonstrating decentralized renewable energy electrification systems;-installation of small to medium sized renewable energy system through decentralised energy production (focused towards rural) via hybrid renewable energy system (e.g., solar-wind-bio-power, solar-fuel cell, solar PV-thermal, biofuel-electric mobility, etc.), energy assessment studies to evaluate the renewable energy application potentials and market opportunities, and developing means for removing barriers facing renewable energy applications. All the above said areas can be achieved effectively with the already existing private-public partners, NGOs, international agencies such as UNDP, UN-energy members, UN-HABITAT, UNIDO, UNFCCC, UNCTAD, UNEP, UNECA, UNESCO, UNESCAP, ESCWA, IUCN, WWF, WBC, GEF, WMO, ESCWA, USAID, national, local, regional organizations, and others. Thus the country's public-private organisations (HEIs/companies/partners, etc.), NGOs and international organisations should integrate effectively to take bold steps in providing teaching, training and services in renewable energy technologies for its promotion and sustainable development.

5 Conclusion

The government has to provide strong support/direction to HEIs, public-private organizations, NGOs, international agencies and others to promote renewable energy technologies for large scale diffusion of renewable energy across the country. These organizations in return have to play a very important role in generating highly skilled renewable energy technologists through training and services to meet the market need. We believe that India's abundant natural renewable energy potential could be explored well for the country's sustainable development; only if the above said organisations really focused for the development of renewable energy.

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Authors Biography

Dr. R. Arun Prasath obtained his doctoral degree in Chemical Science/Materials from Anna University, India. He was a recipient of prestigious DAAD fellowship, (1999–2001) for his doctoral research work at Max-Planck Institute for Polymer Research, Mainz, Germany. After his doctoral degree he worked as material researcher in several prestigious institutes; as research associate in Indian Institute of Science, Bangalore, India (2002–2004), as postdoctoral researcher in University of Strathclyde, Glasgow, United Kingdom (2004–2006) and in University of New South Wales, Sydney, Australia (2006–2008), and as senior researcher in Ghent University (2008–2010) with special fellowship called BOF. He has published more than 20 peer-reviewed journal articles, more than 10 published articles in proceedings and book chapters, co-inventor in 3 International patents as well as in 2 European patent applications. For his profession development, he has visited Germany, United Kingdom, Australia, Belgium, Brazil, Italy, and Bangladesh. He has presented more than 45 oral presentations in various conferences/seminars/courses/invited talks. He actively involved in teaching and research on renewable energy from 2010 onwards.

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Dwipen Boruah graduated in 1990 as a Mechanical Engineer and completed his Post Graduate Programme on Renewable Energy (PPRE) from Oldenburg University, Germany. He has earned more than 22 years of experience in Renewable Energy Engineering design, Planning, Research, Project Management and Training. He has the experience of working with a number of local, regional and national organisations in several countries and has proven knowledge of renewable energy technologies, barriers for deployment, methods and approaches applied in the field of technology road-maps. Dwipen also authored or co-authored books and training manuals on solar PV system design Installation, maintenance and inspection; he has to his credit training manuals on improved cook stoves, more than 60 technical and professional reports and several articles in the technical magazines and journals.

Nandhivarman Muthu received his Masters degree in Zoology and has over 10 years of experience as an environmentalist, researcher and an activist for sustainable development. He is currently pursuing his doctorate from Pondicherry University, India. His research interest includes an extensive study to evolve policies and implement Green Campus Initiative in Pondicherry University. The main objective of this research is to assess and provide factual solutions to the educational institutions like schools and colleges to make it sustainable with special reference to water, energy and waste management.

Golda A. Edwin is a researcher at Pondicherry University. She has been involved in a number of green campus projects in her region and had implemented meaningful sustainability projects. She decided to pursue her research and career in water science because of her passion for addressing the challenges of sustainable water management in developing countries. Her core area of research is abatement of water pollution using eco-technologies. She authored several articles and presented her findings in several national/International conferences and workshops. She was awarded Gold medal from Pondicherry University for her outstanding academic excellence. She is also one of the Founders and Executive Director of Association for promoting sustainability in Campuses and Communities (APSCC).

Flag-Shipping 'Indicators' for Green-Campus Transitions and Sustainability: A Case-Study of Learner-Centered Projects at Loyola, Secunderabad

Sambamurthi K. Balachander

Abstract
The present study seeks a participatory '*eclectic'* approach towards indexing green campus initiatives at Loyola Academy, Secunderabad, in about two decades. The undergraduate learner-centered projects, reviewed 'a priori*'* and by backcasting, are apparently flagship indicators for green campus transitions and sustainability. Participatory action research and applied human ecology 'tools and techniques' are the real keys on the pathways to transitions. A participatory tool-box is a component of the learning curve and research experience.

Keywords
Participatory tool-box · Flagship indicators · Learner centered projects · Green campus sustainability

1 Introduction and Background

Loyola Academy (LA) is a Jesuit college, in a sprawling campus (138 acres), in Secunderabad, of Andhra Pradesh state, India. It is affiliated to Osmania University, Hyderabad. The College was granted autonomy by UGC in 1992 and re-accredited in 2011 by the National Accreditation counsel with an 'A' grade, for the second time. It is a college with a rare status known as 'College with Potential for Excellence' (CPE I & II). It is a job- and career-oriented college with 16 undergraduate programs (Table 1).

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Table 1 Time-line: list of courses (2013), Loyola Academy Degree and PG College, Secunderabad

1978	BSc	Agricultural Sciences and Rural Development
1983	BSc	Chemical Technology
1988	BSc	Computer Science and Engineering
	BSc	Electronics Technology
1991	BCom	Honours
1994	BCom	Advertising and Sales Promotion
	BSc	Computer Maintenance
2001	BSc	Biotechnology, Genetics, Chemistry
2003	BCom	Regular
2004	BSc	Mass Communication
2006	BA	Psychology, English, Journalism
2007	BSc	Maths, Statistics and Computer Science
2008	BSc	Animation Design
2010	BCom	Computers
2011	Bachelor of Business Administration	

2 Vision-Mission Statement of LA and Eco-centric Learner-Centered Projects

The vision statement of LA has the words 'competence, consciousness and compassionate commitment', which is to be realized in the mission by inculcating 'care of Mother Earth' in every student. The objectives of the fulfilling of the vision-mission is to be achieved through integrated formation of the individual student in academics by invocating an ambience for 'Ignatius Pedagogy Paradigm', namely, "Learning, Experience, Reflection and Action", developing in students knowledge as well as skills, to make them aware of socio-cultural realities and respond to them creatively and constructively. The vision-mission has been evolved 'a priori' with the changing times over the last two decades.

Learner-centeredness is at the core of practical education at the undergraduate level at LA. Experiential teaching aims of the BSc Agricultural Sciences and Rural Development, since the early 1980s, have been to seek out and to explore the 'project-reports' in the context of environmental education. Each student in the process is a self-directed learner. There is an active construction of knowledge by him/her which is goal-directed. There exists a link between new knowledge and prior knowledge, strategic thinking, learning and participatory 'action' research. Intrinsic motivation includes novelty, difficulty, relevance, choice and control, learning within and across domains, social interactions, inter-personal relations and communication skills. It also emphasizes competence, collaboration, teamwork and development of self-directed lifelong learning. This has been very evident in the timeline of eco-centric learner-centered projects in the course (Table 2).

Table 2 Time-line: eco-centric learner-centered projects

1984	Zero energy food cabinet
1985	Biological control of water Hyacinth
1986, 1987	Permaculture design form at Zahirabad
1988	Bird and tree biodiversity at KBR National Park, Hyderabad
1990–1992	Campaigning at world-wide fluid (WWF) for nature, Hyderabad
2007–2010	Study of Myxomycetes from Shola forests of Kodaikanal (Western Ghats—'hot spot')
2008–2011	Tree inventory at tree Arboretum at Forest Research Institute, Dullapalli, Hyderabad
2010	Seeking sustainability—documenting medicinal plants and IK at Nepal village, India
2012	Experiential learning in conservation ecology, bio diversity and ecodocumentation for campus sustainability
2013	Experiential learning for campus sustainability and permaculture design

3 Flag-Shipping Learner-Centered Projects for Green Campus Transitions and Sustainability

An ecological handprint, where all the undergraduate student–learners as well as the project workers (Christopher 2012; Kiran and Nelson 2011; Narendranath 2012; Sigamani 2008) and green 'volunteers' exchange and exhibit, their knowledge, skills, attitude, perceptions and experiential learning, has been the case study, along with participatory observation, naturalistic inquiry, and the participatory 'Tool-Box' (Table 7).

A few examples are introduction and practices of 'biofertilizers' and Low External Input Sustainable agriculture (LEISA) in the syllabi and field experiments:

- Inventory of insects on campus
- Tree inventory and floristics on campus
- Exhibition on 'natural dye' making
- Exhibition on 'conservation of natural resources'
- Development of a 'crop museum'
- Establishment of an in situ medicinal grove
- Establishment of a recycling water plant on campus
- Vermicomposting and treatment of urban-waste.

In 2013, with the focus on the Jesuit Mission and vision on care of the Earth, there was a student-centered tree-planting on campus, and a unique environmental exhibition on 'Conservation of Natural Resources.' It was an inter-disciplinary exhibition, with 'action projects' on solar-cells, uses of CFCs, botanicals as medicines, waste-water recycling, Gobar-gas production, traditional slow foods vs fast foods, permaculture and ecosystem services, energy from agricultural waste, in situ

Table 3 Case study: experiential learning in conservation ecology, biodiversity and ecodocumentation for campus sustainability

Objectives	• Understand and experience out-reach eco-programs
Collaboration	WWF for nature (Hyderabad) India
Learning and learner-centered skills	• Participatory experiential learning
	• Eco-documentation
	• Eco-entrepreneurship
Ecodocumentation	CD
Outreach programs	As volunteers and learners at
	• Amateur naturalist training program
	• Srisailam tiger sanctuary—census
	• Deer census
	• Eco-entrepreneurship at German centre
	• Celebration of biodiversity day at forest department.

and ex situ germplasm conservation, BOD analysis of effluents, adulterations of milk and food products, with student stalls of all courses (Table 1).

An environmental awareness week was celebrated, for the first time, with slogan-writing, animation, poster-making, essay-writing and group discussion. There was a 'unique' release of an electronic newsletter titled '*Neem*', aimed at eco-interpretation, ecodocumentation, and campus sustainability, to be facilitated by 'peer' staff and eco-volunteer students.

In phase I, every department of the college, internalized with the Internal Quality Assurance cell (IQAC), have student-teams as volunteers for action-plans towards (1) composting and vermiculture, (2) energy-saving campaigns for water and electricity, (3) no plastics and bottles on campus, (4) change to CFCs on campus,

Table 4 Case study: conservation and field ecology initiatives in sustainable science

Objectives	• Identification of trees in Visakhapatnam urban zones and preparation of checklist of trees
	• Indexing trees as invasive
	• Illustrative guide with field characters of trees
	• Documentation of nursery practices of the identified trees
Collaboration	• WWF for nature (Hyderabad), India
Learning and learner-centered skills	• Culture, taxonomy and field identification of Myxomycetes (Slime Mold Fungi)
	• Inventory and nursery practices of urban trees
	• Indexing invasive species
Ecodocumentation	• Myxoherbarimn of Loyola Campus
	• CD-tree species (plant description)
	• CD-lab and field Myxomycetes
Outreach programs	• Tree managers in urban cities can use the inventory Tree CD, for base- line studies

and (5) segregation of waste into degradable versus biodegradable bins. These are the start-initiatives perceived and ‘action-program’ operated at LA during 2013.

A few of the learner-centered projects (Christopher 2012; Kiran and Nelson 2011; Narendranath 2012; Sigamani 2008) displayed during the environmental exhibition, with models, to the peer-groups, are presented as case studies (Tables 3, 4, 5 and 6). They are vividly captured as a snap-shot, with objectives, project titles, collaboration, learning, eco-documentation, outreach and programs, as well as learner-centered skills.

Table 5 Case study: a floristic study of an arboretum and eco-interpretation, biodiversity, and conservation initiatives

Objectives	• To enable participatory learning and sharing of inventory of tree species at AP forest arboretum
Collaboration	WWF for nature (Hyderabad) India
Learning and learner-centered skills	Illustrative and descriptive taxonomy and flowering details of the forest trees
Ecodocumentation	CD
Outreach programs	The study, has been a benchmark, facilitating eco-interpretation of trees in the arboretum for visitors (110 plants)

Table 6 Case study: sustainable eco-campus initiative-permaculture, trees, canopy and ecosystem services

Objectives	• To understand permaculture design in semi- arids by participatory learning
	• To explore participatory tree inventory and multipurpose use in conservation
	• To seek possible ‘niche-matching’ at Loyola campus for eco-campus initiative and document ecosystem services
Collaboration	Deccan Development Society (DDS), Pustapur
Learning and learner-centered skills	• Tree design elements in a natural landscape
	• ‘Niche’ characterization and ecodocumentation, integration of tree architecture with butterfly scaping
	• Illustrative canopy drawings and field notes
Ecodocumentation	• CD
	• Manual illustrations of tree designs and local zones
	• Biodiversity harvest festival at DDS, Zahirabad
Outreach programs	• Campus sustainability and permaculture: A model and earthworks for Loyola Campus
	• Integrative field-ecology and conservation ecology programs for ecosystem services and natural resource management on campus

4 'Participatory Tool-Box' for Human Dimensions of Eco-Campus Transitions and Sustainability

Given the diversity and uniqueness of each campus, and by reflecting on the history of environmental movements in India, there is the need for seeking 'indices' in the participation to facilitate the first initiatives in benchmarking for green-campus transitions, in colleges and universities in India.

The above-mentioned case-studies and the 'dynamics' of change processes (Balachander 1999) at LA have been carried out using a participating 'tool-box' evolved 'a priori' by the researcher during the last two decades on campus (Table 7).

Table 7 Participatory tool-box for human dimensions of eco-campus transitions and sustainability

1. *Patterns*	
The mature capital, natural resource inventory, ecological landscape planning, monitoring, evaluation	SD, SS 1, M, OH
Case Study and c. the ecological 'niche'	
• Historical time-line	H1, PM, T, FGD, NI
• Social actors and communities	KO, SSI, X1, SM
• Land Use	SD, SSI, OH, M
• Seasonal work-use of resources	SSI, OT, KI
• Trends and patterns of use/misuse	HI, FCG, PM, T, NI
• Sustainability analysis (+ or − ?)	'All the participatory tools'
2. *Process (dynamics) and linkages*	DO, SSI, OH, K1, FGD, NI
• Institutional analysis	
• Stakeholder analysis	
• Decision—tree	
• SWOT analysis	
• Inventory of trees	K1, FGD
3. *Flows*	
• Bio-resource flow mapping across Transects	SSI, FGD, OH, IC, KI, DO, PH, SM, NI
• Recycling of natural resource base	
4. *Decision-making analysis*	
• Stress and shock	SSI, FGD, OH. IC, KI, DO,
• Disaggregated environmental entitlement analysis of campus	PH, SM, NI
• Indicators (surrogative, grass root, experiential)	
• Conflict resolution analysis	

Key SD secondary data review, *DO* direct observations, *SSI* semi structured interviews, *FGD* focus group discussion, *M* mapping, *PM* participatory mapping, *SM* social mapping, *T* transect, *TT/TL* time line/trend, *OH* oral history, *IC* indigenous categories, *KI* key informants, *NI* naturalistic inquiry

5 Conclusion

The present study offers itself as a pioneering one with a 'tool-box' to investigate undergraduate college campuses in Indian contexts and processes. To facilitate green campus initiatives, the 'indicators' which are broad-brush approaches, may be tailor-made, appropriate, local and campus-specific. The study concludes that sustainability (Jones et al. 2010) has more to do with learning curves, workplaces, green technologies, and the broad-brush dimensions of human ecology (Rambo 1982) on campus. A sustainable campus, in the making reflects knowledgeable Earth stewards, with holistic learner-centered skills subject to local, appropriate yet changing priorities on campus. We need to locate, design, and help professionals involved in conservation initiatives to identify the social concerns (Berkes et al. 2003) which are relevant to their work (Buchan 1997) in themes such as green campus, outreach 'common corridors' between NGOs, student project work, institutions, and governance. The participatory tool-box and projects are showcased to show pathways in the search towards transitions to a sustainable campus.

Given the trajectories of change processes, the 'tool-box' can facilitate qualitative indices for socio-ecological 'dynamics' and engage the campus audit, accreditation as a facilitating tool. The prime concern is conservation of the natural resources capital in campus in relation to biodiversity, ecosystem services, and natural resource management. This can fit into the real contexts of the interface corridor of NGOs, educational institutes, and sustainability programmes.

Universities and colleges (CEE 2012) in India weave unity in diversity and seek both change and conservation on a continuum. To enshrine human communities as contingent social actors in the socio-ecological processes, the non-equilibrium (May 1986; Botkins 1990) human ecology (NEQ-HE), as well as the 'new ecology' perspective, is sought (Balachander 1999). The tool-box is the way forward, amidst other methodologies, for multi-stakeholders, eco-sustainable communities in green campus transitions, and as facilitating participatory indexing of ongoing, dynamic, emergent, co-adaptive pathways (Berkes et al. 2003; Chaplin III et al. 2009) in eco-campus issues in the Indian context.

Seeking the picture of human communities 'in action' on campus, the dynamic human ecology perspective (Balachander 1999) can re-define thing on a continuum, with checks and balances, while weaving through the 'environmental entitlement analysis' (Leach et al. 1997) for a green campus now. This is the 'opening space' and the relevance of the study for environmental accountability and audit, for green campus transitions and accreditation for Indian colleges and Universities.

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Green Transport Solutions for Developing Cities: A Case Study of Nairobi, Kenya

Benedict O. Muyale and Emmanuel S. Murunga

Abstract

Cities have always been the loci for nationals as well as growth of cultural fusion and innovation. Over 50 % of global population dwells in cities and urban centers. This means that cities are prolific users of natural resources and generators of waste; hence they produce most of the greenhouse gases which are causing global climate change. The root cause of increase in the transport sector carbon curve is mainly the greater numbers of individually owned cars. Development in these cities is geared towards economic progress while environmental sustainability is ignored. Infrastructure projects focus on road expansion, electrification, and more parking spaces. These lead to more carbon emissions, traffic congestion, and air pollution. Recent development plans for Nairobi city are now on road expansion with little priority for electric train solutions. The Vision 2030, Kenya's development guide, has shed some light on the city with numerous road expansion projects. This chapter seeks to realize the following objectives; (1) to assess the current transport situation of Nairobi; (2) to review green transport solutions being undertaken in the city; (3) to give an overview of alternative green transportation solutions, and (4) to provide a green transportation framework matrix. This preliminary study will utilize primary and secondary data through mainly desktop research and analysis, literature, books, magazines and on-line information. This forms the basis for formulation of approaches for incorporation into the green transportation framework matrix of the main study report. The main

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goal is the achievement of a practical green transportation system for implementation by the City County of Nairobi to reduce carbon emissions and congestion and promote environmental sustainability.

Keywords
Cities · Transport · Nairobi · Green technologies

1 Introduction

Throughout man's history of urbanization, economic growth, and civilization, cities have always been the loci for nationals as well as growth of cultural fusion and innovation. Over 50 % of global population dwells in cities and urban centers (UN 2012). According to World Bank, the urban population including cities has been on an upward trend from 2.7 billion in 1998 to 3.6 in 2011 (World Bank 2013).

Similarly, transportation continues to be pivotal to more human beings and its usage is on the increase because of population growth. This contributes to the transport sector consuming slightly over one-fifth of global energy used (UNEP 2011). On a global scale, energy-related CO_2 emissions from transport were at 23 % in 2004 (UNEP 2011). This stamps cities as prolific users of natural resources and generators of waste; hence they produce most of the greenhouse gases which are causing global climate change. The root cause of the increase in the transport sector carbon curve is greatly dependent on the numbers of individually-owned cars. In 1970 there were only 200 million privately owned cars but by 2006 this had quadrupled to 850 million (UNEP 2011). This has continued to exact pressure on environmental changes in cities. In addition, developing cities have a faster growth in private car ownership because of growing incomes. Development in these cities is geared towards economic progress while environmental sustainability is ignored. Infrastructure projects focus on road expansion, electrification, and more parking spaces. However, environmental degradation is overlooked, and in time these parking lots and tarmac roads will form a desert with no living thing there.

Nairobi, a city with 3.1 million people (GoK 2009; OpenData 2013) has seen little change in the transport system in the last 50 years. The transport sector is highly congested by vans which are controlled by private sector and ferry residents on a small scale (Omwenga 2010). This leads to more carbon emissions, traffic congestion, and air pollution. Existing bus services are few in number, old, and have seen no change to environmentally friendly fuel solutions. Recent development plans for the city are now on road expansion, with little priority on electric train solutions. At such a piecemeal pace, Nairobi city will achieve no significant alternative transport solutions directed towards it becoming a green city. It will continue to score low on the green index and sustainable livelihoods will be questionable. The century-old train network has been ignored since construction and little has been done to improve passenger wagons or to expand the network.

While developed nations are using tunnel metro, electric trains, or trams, Nairobi stills depends on heavy diesel oil engines for trains.

Parking space has also been a major issue in Nairobi. There is limited or no space. Drivers spend a lot of time driving around the city looking for parking space. Private developers are slowly addressing this problem through the provision of underground parking. Access to city authority parking lots is limited and in most cases unavailable.

Not only is the transport infrastructure inadequate but there are no much-needed policies and institutional frameworks necessary to manage a sustainable transport network in Nairobi. The National Workshop on Promoting Sustainable Transport Solutions for East Africa [Sustran] in Nairobi pointed out this gap. The workshop held on 3 August 2012 recommended the establishment of a transport management authority and the formulation of relevant policies to spearhead sustainable transport solutions (UNEP 2012). This took into account that nearly 40 % of all Kenya's cars are in Nairobi (Omwenga 2010).

The Vision 2030, Kenya's development guide, has proposed numerous road expansion projects (GoK 2007). The just completed Thika road superhighway is remarkable. Long gone are the memories of the heavily congested four-lane Thika road which was a nightmare for motorists and passengers.

However, considering transport needs in the city of Nairobi, the construction of the Thika superhighway can be regarded as a drop in the ocean, and more needs to be done. A clear study on existing systems would provide an eye opener for relevant transport projects vis-a-vis the reduction of the carbon curve growth. This chapter seeks to realize the following objectives:

1. To assess current transport situation of Nairobi
2. To review green transport solutions being undertaken in the City
3. To give overview of alternative green transportation solutions
4. To provide a green transportation framework matrix

This preliminary assessment study provides advanced guidelines on sustainable transport solutions which are highlighted in the Nairobi Urban Transport Study (NUTRANS). The Japan International Cooperation Agency (JICA) focused more on reducing congestion and travel speed and saving traffic cost. This chapter delves into green transport infrastructure solutions for Nairobi city, with the overall goal being to recommend alternative green transportation which will cap daily air pollutants from the transport system in Nairobi to 2.8 tons in 2025 (JICA 2004).

There is little published documentation on green transport solutions in the region relating to Africa's cities. Continuous similar studies will eventually lead to formulation of policies for environmentally friendly transport systems in Nairobi. Teamwork efforts from GSC,[1] an initiative founded by environmentally concerned youths, will take 8 months to carry out this preliminary assessment.

[1] Green Sun Cities was started by Kenyan youths to create awareness on green cities concepts and provided much-needed technical support for green cities. Visit www.greensuncities.org.

The preliminary study includes primary and secondary data collection. The secondary data involved detailed desktop research, literature, books, magazines, and on-line information, while primary data collection included field visits, observation, photography, and focused discussions with key stakeholders. These approaches provided views for incorporation into the green transportation framework matrix of the main study report. The expected outcome is a practical green transportation system for implementation by the City Council of Nairobi to reduce carbon emissions and congestion and promote environmental sustainability.

2 Nairobi Transport Systems

Urbanization in Nairobi has been recorded to be growing at a faster rate since Kenya's independence but with little or no expansion of urban infrastructure and services. This has been accentuated by a high rural–urban migration. In 1948 Nairobi's population was just 119,000 while it currently stands at 3.1 million (GoK 2009; Omwenga 2011; OpenData 2013). An ever-increasing population has been dependent on a colonial master plan of infrastructures and services. The 1948 Nairobi master plan was formulated by the colonial government to guide sprawling horizontal expansion (Omwenga 2011). At independence the government adopted this master plan, which focused on road expansion and garden city planning with residential areas clustered into neighborhood units. However, challenges emerged because of increasing population, spatial growth, and industrial and economic development. Time-solution such as Nairobi Metropolitan Growth Strategy was put in place in 1973 (Omwenga 2011). This was to guide development of Nairobi into a metro city by the year 2000.

Currently, NUTRANS reveals that little was implemented of the 1973 urban development strategy. Other efforts spearheaded by Nairobi City Council through the 1993 convention dubbed "*The Nairobi We Want*" to transform Nairobi did not yield commensurate results. This convention recommended, among other development issues, road upgrading and expansion to address traffic congestion (see Fig. 1).

The NUTRANS program focused on urban transport and found that the condition of the roads was poor, inappropriate, and coupled with ineffective traffic management and enforcement. It led to low speeds of 30 km/h, delays, high costs, and traffic nuisance (JICA 2004). Furthermore, findings highlighted by JICA report that in 2004 traffic congestion stood at slightly over 0.5 rating but this is projected to double in 20 years to near 1 rating. Transport challenges were exacerbated by increased private car ownership, more users of *matatu*,[2] and limited alternative transport systems besides the road network. It is, however, notable that a large proportion (47 %) of Nairobi's working population walk to work; see Table 1.

[2] Kenyan slang word for mini-buses or 14-seater vans.

Fig. 1 Traffic congestion in Nairobi City. Motorists stuck in a traffic jam on the Uhuru highway, Nairobi. Note that there are no designated non-motorized routes for pedestrians. *Source* Wesangula (2009)

Table 1 Nairobi transport modality

Transport mode	Walking	Cycling	Private car	Matatu/mini-bus	Bus	Train	Institutional buses	Other
Modal split (%)	47	1.2	15.3	29	3.7	0.4	3.2	0.2

Source Omwenga (2011)

The century old train system has not improved and faces challenges of inadequate revenue generation, dilapidated wagons, and unmaintained rail network. These diesel powered engine trains hardly meet the transport needs of the majority of urban commuters who do not own cars. The system is always crowded and sometimes overloaded beyond capacity (see Fig. 2).

There is evident competition for the use of the already congested roads from numerous buses and private cars. Time wasted in traffic has been estimated to cost Nairobi's economy nearly Kshs 1.5 billion per month in 2010 (JICA 2004). According to JICA, travel expenses in the central business district were projected to reach Kshs 177 million per month by 2025. Therefore, the NUTRANS mission was to ensure the Nairobi metropolitan area has an efficient, cost effective, reliable, and integrated transport system.

Fig. 2 Overloaded commuter train in Nairobi City. The oldest diesel engine commuter train flooded with passengers during the morning rush to work in Nairobi. *Source* GSC (2012)

3 Current Improvements on the Nairobi Transport System

The 2008 coalition government established the Ministry of Nairobi Metropolitan Development which formulated The Nairobi Metro 2030 vision. This vision is to steer the Nairobi Metropolitan area into becoming a world standard city and aims at a spatially redefined metropolis. This will involve the construction of a world-class infrastructure such as roads, airports, and rail systems. The focus has been on reducing congestion through:

1. Road expansion and upgrading
2. Light train systems
3. Non-motorized transport

The Nairobi Metro 2030 vision recognizes satellite urban centers in the outskirts and suburban areas of Nairobi. One development goal is to provide an efficient transport system between the capital and these upcoming centers within an area of 32,000 km^2 which encompasses 15 local authorities (Omwenga 2010).

3.1 Road Expansion and Upgrading

The NUTRANS proposed numerous transport sector projects and programs for Nairobi. These included 22 road expansion and upgrading projects to be implemented by the year 2025 (JICA 2004). The first phase of short-term projects from

Fig. 3 Images of newly completed Thika superhighway. View of the eight-lane completed superhighway section underpass decongesting traffic in Nairobi. *Source* GSC (2012)

2005 to 2010 was characterized by widening of roads, junction improvement, and new construction near Nairobi Central Business District (CBD) within a radius of about 3 km. The medium phase up to 2015 includes projects in the first phase with non-motorized transport facilities but with a wider radius distance of 6 km. The long-term phases of the projects which will be completed in 2025 focuses on road projects linking Nairobi, the suburbs, and satellite towns. It comprises the Northern, Southern, Eastern, and Western bypasses which will reduce traffic in Nairobi's CBD.

Multi-national banks have boosted the NUTRANS projects by financing road expansion and upgrading. The construction of the Thika superhighway which expanded the four-lane road to an eight-lane superhighway is the current attraction in Nairobi. It reduced user conflicts and enhanced mobility whereby underpasses and culverts box roads replaced roundabouts (see Fig. 3). Other road construction projects which are in progress include the Langata road expansion (see Fig. 3) and the Southern bypass.

3.2 Light Train Systems

Nairobi was established as a major railway stopover station for the Mombasa to Kampala railway system. The suburban railway network which was built in the early 1900s only linked Nairobi to Thika, Athiriver, and Kikuyu. Currently, it is, however, notable that the suburban commuter rail link covers only 0.09 km^2 and serves a meager 19,000 commuters daily. Initially this was only for two routes (Omwenga 2011; Dagoretti and Ruiru) (see Fig. 4). It is only by late 2012 that the Rift Valley Railways Company launched a new commuter train rail route from Syokimau to Nairobi's CBD.

The new link to Syokimau is a light train system and represents a bold step towards reducing traffic congestion in Nairobi's CBD. Considering the increasing and continued growth in suburbs, this transport system reduces the number of

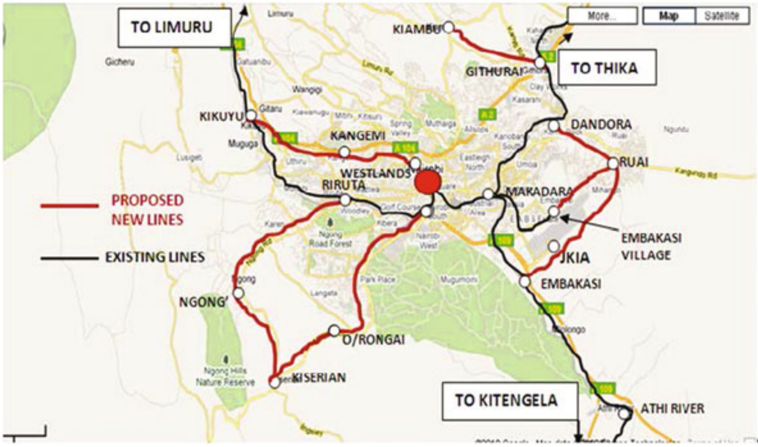

Fig. 4 Nairobi train routes before 2012. Before the Syokimau commuter train, there were only three commuter trains—to Embakasi, Kibera, and Ruiru. *Source* Omwenga (2011)

private motorists. The plan is a green "park and ride" commuter transport solution where residents of Syokimau and neighboring areas drive to the station and park their cars before boarding the train to Nairobi (see Fig. 5). With the purchase of a pre-paid swipe card, commuters can access the service which is traffic jam free.

Most users interviewed applauded the government for this initiative which saves time and is cost-effective. They suggested the need for more light train systems to be rolled out throughout the entire city, reducing the number of road users while providing a viable and affordable mass commuter transport for Nairobians.

Fig. 5 Syokimau light train station. Drive, park, and ride newly launched commuter train services from the suburban area of Syokimau to Nairobi City. *Source* Kenya Railways Corporation (2012)

3.3 Non-motorized Transport (NMTs)

Notably, a large proportion of Nairobi residents, comprising 47 %, walk to and from work. This population has been ignored in the past with little or no walkways for their use. The NUTRANS project provides construction of non-motorized transport facilities through the upgrading of roads, and the incorporation of NMTs in the designs of the newly constructed roads such as the Thika road and the Southern bypass (see Fig. 6). The use of pedal bicycles will be facilitated on these roads.

These measures are expected to attract more commuters to newly upgraded roads, making access to the CBD more challenging, especially for NMTs. High competition among road users is expected. The problem of insufficient and poorly designated parking spaces for non-motorized users is foreseen in the future. These are some of the risks and challenges which may impede non-motorized transport, even in the face of expanding road construction. The Green Sun Cities program targets are to rally city residents to adopt non-motorized transport, to go green, and to provide adequate provisions for NMTs in the design of new commuter systems for Nairobi.

Fig. 6 Non-motorized areas on the Thika superhighway. Pedestrians using the incorporated non-motorized lanes on the Thika superhighway. *Source* GSC (2012)

4 Green Transport Solutions for Nairobi City

A key question which begs an answer is how the transport systems in Nairobi will be improved to support sustainable city development and growth with a projected population of 7 million by 2025 (JICA 2004). The commuter transport sector in Nairobi is aggravated by the poorly regulated "*matatu*," the privately-owned transport systems that are currently in use within Nairobi. This mode of transport, which comprises 14- to 24-seater vans, caters for 90 % of commuter transport services in Nairobi city. Currently policies to ameliorate these challenges are being implemented by the relevant line ministries with the following aims:

1. To phase out or abolish the 14-seater *matatu* in order to decongest the high number of cars
2. To promote integrated transport system which includes non-motorized users
3. To promote engine technologies for public transport to conform to Euro III standards
4. To lower vehicle emissions through the promotion of cleaner fuels coupled with cleaner technology
5. To promote policies and incentives to move people out of cars and onto mass transport

To realize the implementation of these policies, there will also be a need for an effective institutional framework which is well coordinated for a greener transport network in Nairobi as discussed in following section.

4.1 Bus Rapid Transport System

The main menace on the roads in Nairobi are the *matatus*. A long-term solution to this begging problem will ease traffic and decongest roads. It is important that all modes of transport in the city are assessed and upgraded to complement one another. This can be done with construction and demarcation of central lanes, whether open or closed, where buses will be restricted to operate.

Because the public transport system has been left to liberal and free market forces and not well planned or regulated, scenes of rowdiness and a chaotic public transport system have resulted. A better public transport system should have regulated routes and time schedules. With ongoing phasing out of the 14-seater *matatus*, this can be realized because more buses will be operational on Nairobi roads. Without regulated routes, the traffic challenge which currently holds would not change.

The bus rapid transport implemented in Brazil (ITDP and GIZ 2012) would be a better option to adopt for Nairobi city public transport. A closed central lane would work with designated bus stages with safeguarded commuter-boarding lanes provided (see Fig. 7).

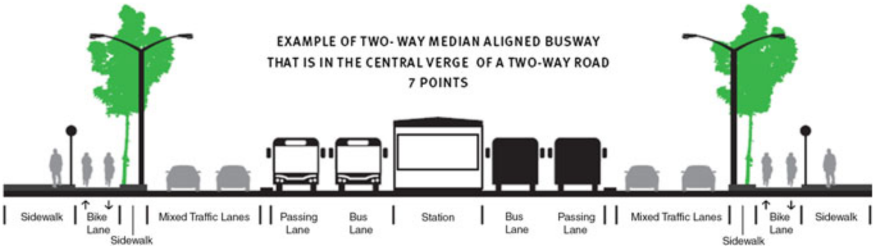

Fig. 7 Sketch of bus rapid lane. Ideal demarcated lanes for buses used for public transport and separate lanes for private cars as well as non-motorized transport users. *Source* ITDP and GIZ (2012)

The recommendation for closed lane system against open systems is because of challenges by law enforcement agencies in maintaining order in the use of the road. However, this may be addressed within the revised traffic rules of 2012 (GoK 2012). Bus drivers will strictly adhere to the central lane rather than be fined.

4.2 Integrated City Development Plan

A first step in the realization of a sustainable transport system is through the development of an integrated city development plan. As highlighted above, the need for bus rapid transit calls for re-planning and re-designing of transport routes. Even though the NUTRANS provides a plan, it focuses strongly just on road expansion and upgrading. It has not envisioned plans to accommodate rails, walkways, cycling, private cars, and buses in an integrated system within designated lanes.

There is an urgent need to revisit the NUTRANS plan and incorporate the planned changes in the rail network to service the entire city by 2025. It is important for the city council of Nairobi to steer preparation and implementation of a long-term transportation master plan which integrates road, railway, and non-motorized transport systems. It will include central bus lanes to complement the ongoing construction of bypasses around the city, interconnecting residential areas, suburbs, and satellite urban centers of Thika, Kiambu, Ngong, and Athi River. This plan will accommodate public transport systems such as light train systems and trams, as well as mass parking areas and buildings for both motor and non-motor travellers (e.g., pedal bicycles). The ultimate goal of the new development plan for the city will focus on reducing carbon emissions and adopt greener transport technologies which are being implemented through new policies.

4.3 Improved Non-motorized Transport (NMT) Infrastructure

The new Thika superhighway has provided outer lanes for *matatus*, shielding private car drivers from commuter traffic. The outer lane also has a cycling lane for non-motorized users and a lane for walking. Well-developed and guarded crossing footbridges are in place. However, this is lacking on other city roads, and, where they are provided, they are neglected and have become insecure for users, especially at night.

The study findings highlight that only 1.2 % prefer cycling in the city. This is a lower proportion compared to those who walk to work. Cycling is dangerous because of the high numbers of passenger and pedestrian accidents in the city, attributable to lack of non-motorized facilities. The city's urban planning department is advised to develop a comprehensive infrastructure network for non-motorized transport—footpaths, footbridges, zebra crossings, and cycle tracks. The NMTs facilities will promote planned campaigns to encourage commuters to cycle or walk to work. It will considerably reduce motor traffic volume, reduce the overall cost of transport in the city, and reduce carbon emissions. In addition, it will lead to improved traffic safety, reduced air pollution, and an enhanced and healthy urban environment.

5 Conclusion

This preliminary assessment chapter provides an overview of transport challenges in the developing countries, especially in African cities. Climate change is a global concern and change or reduction in carbon emissions can be realized through collated efforts from cities where most of the world's population are expected to reside within the next 30 years. Developing nations should not wait for what happened at the turn of the twentieth century to the cities of the industrialized world to happen to them before they act. It is through lessons and best practices in urban commuter transport for cities that we can borrow a leaf to implement practical strategies in Nairobi.

This calls for a review of existing and proposed development plans not just with the aim of decongesting the city of Nairobi but also reducing carbon emissions and adopting cleaner mass transport technologies. Through private–public partnership this can be realized. The public contribution brings on localized solutions and ownership of these development projects on the one hand, while on the other hand private stakeholders such as Green Sun Cities alongside international development partners can provide the research skills necessary in formulating relevant policies and the technical advice in transport infrastructure for a sustainable city.

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Authors Biography

Mr. Benedict Okutoyi Muyale is an environment expert in climate change, renewable energy and green concepts for cities with 8 years experience. He is a graduate of Environmental Planning and Management from Kenyatta University, Nairobi Kenya. Mr. Muyale also holds various postgraduate certificates in Climate Change and Sustainable Energy courses from international institutions. In his passion, Mr. Muyale has founded the Green Sun Cities, an initiative employing youths with the key aim of making cities in developing countries, especially Africa, better and greener. Besides being an Environmental Change Campaigner he is Kenya's Representative under YES Network and IAGETH both international organizations in earth sciences. Furthermore, he has been appointed representative for Advanced Power Plant Technologies Inc (Canada)—dealers in efficient energy technologies for agro-industries. Mr. Muyale has audited sugar factories among the first cogeneration factories in Kenya while working with a continental NGO in research, energy development, and policies. He was also part of the group that drafted a policy paper on potential for liquid biofuel development in Kenya. He has contributed to pro-poor energy solutions in research papers and presentations. Key to note, Mr. Muyale drafted the African Development Bank Energy Sector policy paper which led to development of a new energy strategy later in 2011. He has also been involved in the DANIDA funded project on Capacity Building for Renewable Energy SMEs in Africa, besides being the principal environmental expert of Cogen for Africa, a project funded by GEF/AfDB and UNEP.

Emmanuel Sande Murunga educated in Kenya, Mr. Sande, holds a bachelors degree in Environmental Planning and Management from Kenyatta University, Nairobi Kenya. His main areas of expertise include environmental planning and management, environmental assessment, resource surveys and data collection. He has designed, trained, and supervised field teams for resource assessment data collection programmes. He is also concerned with remote sensing, mapping and surveying, and has extensive experience in land and water resources assessment using ground survey methods, along with airborne and satellite remote sensing techniques, including mapped outputs and cartography. Currently, he is the environmental lead researcher with Green Sun Cities, an initiative he co-founded back in 2012.

National University's Integrated Approach Towards Sustainable-Green Campus: Leadership, Curriculum, and Outreach

Ben D. Radhakrishnan and Shekar Viswanathan

Abstract

National University (NU) has a multifaceted yet integrated approach towards a sustainable *or* '*green campus*' with a variety of programs led by the university's short-term and long-term commitments. The different actions taken towards a *sustainable-green campus* can be categorized in the following three key areas: administrative leadership, curriculum and research, and community and outreach. The administrative leadership starts at the top with our Chancellor's commitment to *incorporate sustainability practices in all facets of its operations.* One of the recent actions includes initiating the LEED certification process for a large campus building in San Diego, CA (see more under Curriculum and Research below). Other green operational activities include recycling and native landscaping. Students are encouraged to solve real world problems sponsored by a company interested in sustainability (or environmental) related issues. The LEED certification research work was actually completed by a team in the MS Environmental Engineering program. Currently, one team in the MS Sustainability program is researching the validity of awarding a real world LEED Neighborhood Development certification. Faculty members have introduced innovative pedagogy such as *Game Design, Creation, and Play* as part of graduate level courses to engage students effectively to understand better the difficult concepts of sustainability.

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The objective is for the students to understand and demonstrate *the triple bottom line of sustainable development,* namely*, Environment, Economy, and Equity* in their games and project. The feedback from students on this approach has been very positive. NU takes an active role in community and outreach programs. NU also holds an annual ECO Fair. This is part of NU's community outreach efforts to educate and demonstrate to the general public concepts about environmental and economic sustainability. NU has a multi-faceted and yet an integrated approach towards a '*sustainable*-*green campus*' through leadership, curriculum, and research and community outreach efforts.

Keywords
Campus · Green · Sustainability · LEED · Outreach · Recycling · eWaste · Eco-fair · Leadership · Curriculum · Environment · Economy · Equity

1 Introduction

The impetus that started with the Talloires declaration in 1990 at the international conference in France laid the foundation for the university leaders to move forward towards sustainability development (University Leaders for A Sustainable Future, 1990). The declaration put out a ten-point action plan for incorporating sustainability development. Over 400 universities in over 40 countries have signed up to incorporate sustainability and environmental literacy in teaching, research, operations, and outreach. This declaration not only recognized the lack of professional skills to implement *sustainable development,* but it also laid out broad guidelines in the agreed action-plans to remedy the situation. The university leaders took it upon themselves to further the cause of sustainable development. It is important to note that this came some 3 years after the famous UN Report (Brundtland Report, 1987) which defined the term *sustainable development*.

Some of the key action plans from the Talloires declaration that are important for the current study are the following:

- Educate environmentally responsible citizenship
- Practice institutional ecology
- Broaden service and outreach nationally and internationally

National University (NU, National University, 2013), as a leading private university, is the second largest private, nonprofit institution of higher education in California and the 12th-largest in the United States. Founded in 1971, NU consists of five schools and one college, including the Schools of Business and Management; Education; Engineering, Technology and Media; Health and Human Services; Professional Studies; and the College of Letters and Sciences.

NU has recognized the importance of sustainable development and is taking serious steps strongly related to the above-mentioned three action plans. The university is a non-traditional university with campuses spread over the states of California and Nevada. Most of our classes are held in the evening hours and the majority of our students are working adults. As is well known, much of southern California is considered to be a semi-desert environment, and as such the aspects of sustainability becomes significant in the operations of the campuses. Water is becoming a scare resource. Energy, land use, recycling, and waste management are becoming key elements in a holistic facility management approach.

NU leaders have recognized their responsibilities towards a sustainable green campus and are moving forward with initiatives to meet the above three action plans as priority.

NU occupies a total of about 1.2 million square feet, out of which about 50 % are owned and operated by NU's own facility management. For the purposes of this study, we will focus on those owned and operated by NU.

The commitment to address and move towards sustainable green campuses starts with our Chancellor. He is supported in this effort by senior administration, facility management, faculty, and the student population. The three-pronged approach adopted by NU for the implementation of a sustainable campus can be classified as follows:

- Administrative leadership
- Curriculum and research
- Community and outreach

Since California is in the leading edge of implementation of many actions relating to sustainability and climate change, NU takes its responsibility in this effort very seriously and wants to emerge as a responsible institution both at the community and state level.

A research paper from Harvard University (Sharp, 2002) laid out a very clear path for university campuses to learn from their experiences and to have a management framework for a systemic transformation. NU's approach follows many of the guidelines and learning from the various methods implemented and to further the cause for green campus.

2 Green Campus Leadership

Chancellor Lee in his March 2, 2009, letter to the National University System announced his plans for environmental conservation and sustainability. His message underlines the National University System's commitment to corporate social responsibility and environmental stewardship. As part of this plan the Chancellor created the Committee on Environmental Conservation and Sustainability (CECS) to work towards accomplishing the following mission:

> The National University System is committed to incorporating sustainability practices in all facets of System operations. The National University System pursues its goal of sustainability through a process of continuous improvement that incorporates environmental consciousness, economic viability and social responsibility.
>
> The mission of the Committee on Environmental Conservation and Sustainability (CECS) is to develop and implement processes for establishing sustainability goals and strategies in greenhouse gas reductions; resource conservation; and education, research and community engagement.

The committee consists of eight members from the faculty, staff and administration. This committee is chaired by the Vice Chancellor of the National University System. The committee meets regularly on a monthly basis. The committee reviews and recommends processes/policies related to environmental conservation. A process has been developed for the recommendation, review, and implementation of projects and plans that support this mission. Categories for potential projects have been developed and an application form has been put in place for National University System's employees to participate in this effort by recommending new projects.

Starting January 1, 2010, the committee started accepting recommendations from System employees regarding opportunities to pursue projects that support this mission statement and the Chancellor's vision for environmental conservation and sustainability. All recommendations from the staff and faculty are reviewed by the Committee. Once the recommendations are reviewed, discussed, and approved, the employee submitting the recommendation is invited to a CECS meeting to discuss the proposed project. All projects are then presented to the appropriate Affiliate President and to the Chancellor for approval and implementation.

In the first 2 years, the Committee has identified the following three projects:

- Establish a system-wide recycling program to minimize waste collection costs and reduce landfill requirements
- Develop a solar power system to provide renewable energy for electricity at the Kearney Mesa, Central Library, and Spectrum campuses
- Reduce the use of office paper consumption through electronic alternatives, system-wide use of recycled paper, and the installation of printer management software

Leadership responsibilities and related activities also cover sustainable management and operations as described below.

2.1 Building and Business Sustainable Operations

The operations part of the campus consists of a multitude of activities, each contributing its share to the green campus goals. These activities can be broadly categorized under the following two headings:

- Building operations
- Business operations

For this discussion, we will look at three important facilities owned and operated by NU—two learning centers, namely Kearny Mesa and Spectrum Learning, and the NU Library.

2.1.1 Building Operations

We will discuss data on the three major components of building maintenance, namely energy, water, and recycling of waste for the above two learning centers and NU library.

On the energy side, NU completed installation of solar plants on all the above three facilities and all are in full operation and producing energy. Table 1 shows the amount of energy produced in each of the buildings, the amount of energy they supply to each, and the amount of savings with respect to the electricity bill.

The physical layout of the solar panels in the three facilities is shown in Fig. 1.

The environmental impacts of the above solar installations include the following:

- Offset the equivalent emission of 24,646 tons of pollutants over the 25-year warranted life of the solar panels
- Annually remove the equivalent of 186 cars from our congested highways

The information about the real time operation of the solar plant is available in a kiosk in the main Kearny Mesa lobby and in the Spectrum lobby. This is an important display since it tells the students and the public about NU's green power generation. This would certainly be very important to some students (similar to employees wanting to work for a *green* company). Figure 2 shows live data from the Kiosk about the day's production of energy in the three different facilities. One can also see the figures for the week, month, year, and lifetime by clicking on the appropriate tab.

Waste recycling (paper, cardboard, plastic, aluminum cans) is done in all three buildings. Each building has separate bins to collect waste for recycling. Figure 3 shows the waste recycled in each of the three buildings. The Spectrum operation is a very large operation and, therefore, has the largest amount of waste recycled.

Table 1 Details of solar power generation and savings

Location	System size kW DC	Annual kWh	Equivalent of electricity bill (%)
Spectrum business park	208	339,826	35
Spectrum library	175	291,726	
Kearny mesa building AB	298	484,910	85
Kearny mesa building C	57	96,453	
Kearny mesa building D	114	192,337	
Total	852	1,405,252	

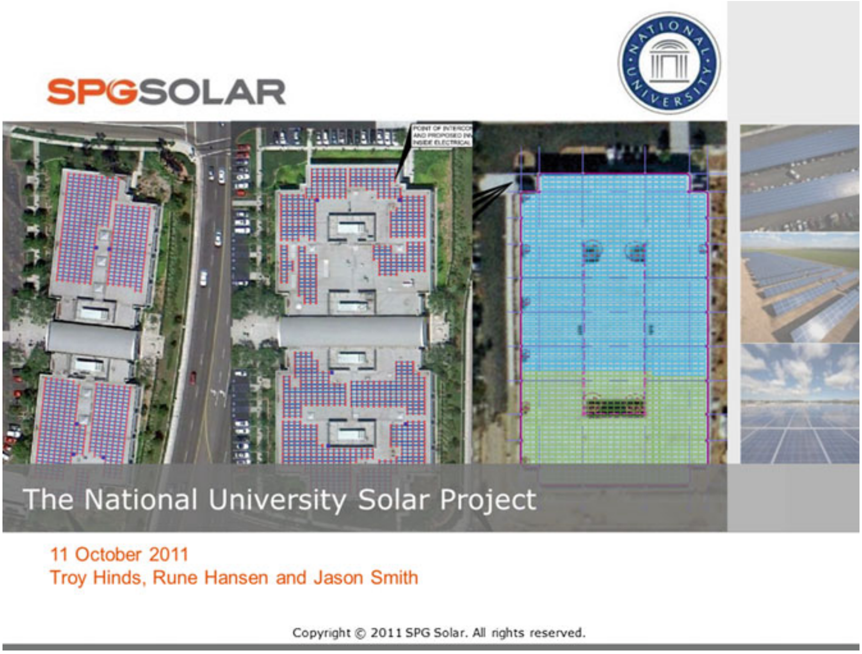

Fig. 1 The physical layout of the solar panels

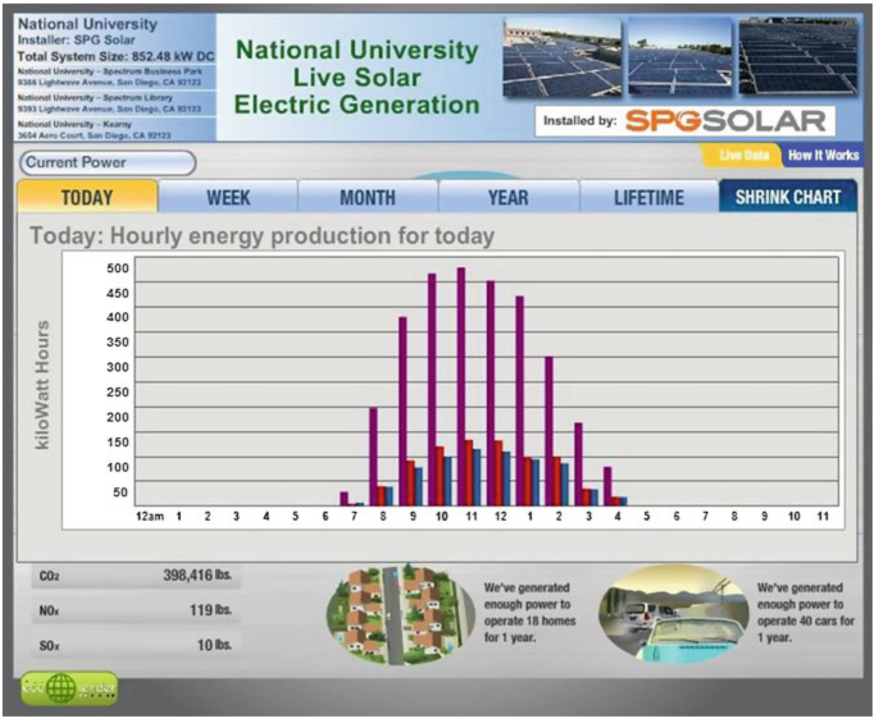

Fig. 2 Real time display of solar energy generation

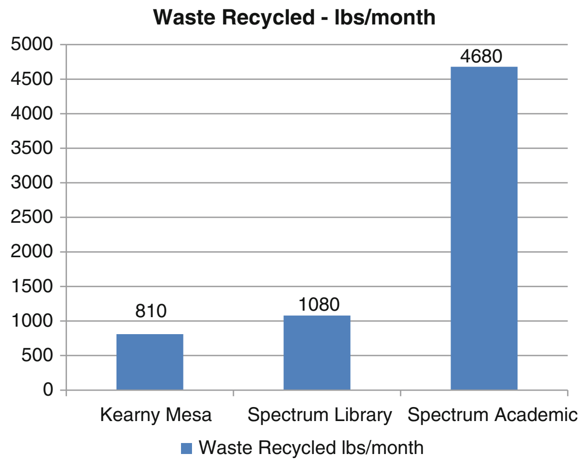

Fig. 3 Amount of waste recycled

Water savings are done in two ways in the three buildings—by embracing landscaping with native plants which need much less water and also by having waterless urinals in the main Kearny Mesa learning center. Each of the waterless urinals can save up to 40,000 gallons of water per year.

Similar water efficiency and landscaping will be spread with other NU-owned facilities. NU will work with leased property owners and strongly promote all these practices. In fact, many of these leased properties already have several building sustainable practices in place.

2.2 eWaste Management—Computer Recycling

In today's high technology teaching environment, most of our classes have a PC for each student. We are also conscious of the fact that technology changes continually and that PCs could become obsolete in about 3–4 years. NU refresh cycle for the class PCs is 3 years and an average of about 800 computers are replaced each year. There is a clear process in place for managing computer eWaste once it becomes

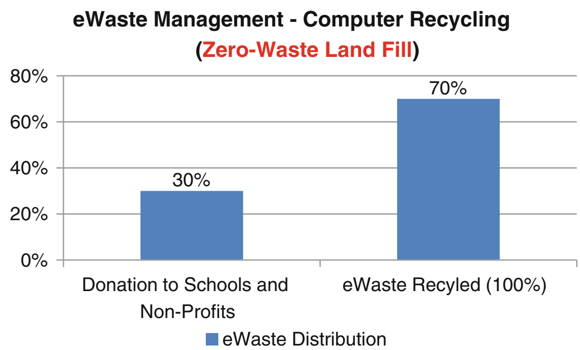

Fig. 4 Computer eWaste recycling program

obsolete. The news media is full of information about the ill-effects of the chemicals in electronics on the environment and on human beings when they are exported, dismantled, and melted in poor countries for their remaining precious metals.

NU recycles about 70 % of the computers it takes out of service (see Fig. 4: Outreach section about NU's computer donations). For computer eWaste management, NU Information Technology department contracts with a well-known electronic recycling company which has a well-recognized R2/RIOS recycling certification (Electronics Processing 2013).

The company recycles 100 % of the obsolete computers, has a zero-land-fill policy, and claims to have no eWaste exported outside of the US. This is a huge step for NU in managing its obsolete computers.

2.3 Business Operations

On the business side, we will discuss the following: procurement of printers and printing paper usage, building cleaning supplies, and data center operations.

Procurement: NU's office supplies vendor by default has to supply products which have recycled content and are environmentally safe and non-toxic. Paper is one of the most used office supplies in an educational environment. For copying and regular printing paper, there has to be a minimum of 30 % recycled material (see Fig. 5), and it should be acid free.

An action plan is prepared to have all the printers replaced to facilitate double-sided printing, and this is expected to save paper consumption. The paper manufacturer has the FSC seal (see Fig. 1) which further reinforces sustainability.

In order to reduce printer paper usage and storage, NU has installed an Electronic Document Management System (EDMS) called Singularity, which has over 11 million pages of documents. This system not only provides for storage and access, but also for distribution of documents and student records which would have otherwise been handled in the traditional paper format.

Table 2 shows some recorded savings of paper following top ten paper reduction strategies adopted by NU.

Forest Stewardship Council (FSC) seal

Fig. 5 Office 30 % recycled paper with FSC seal

Table 2 FY11 collective paper reduction and green initiative

EDMS = 1,003 reams saved[a]
30 % recycled paper = 10, 200 reams (ecological savings)
Margin settings = 1.615 reams (potential savings)
2-Sided print/copy = 3,544 reams (savings, assuming 30 % recycled paper usage)
Total environmental savings = 16,362 reams or 40.90 tons
40.90 tons × 24 trees = 981.6 trees saved each year
40.90 tons × 36.58 million BTU = energy savings of 1,496 million BTU
40.90 tons × 2.18 MTCE = GHG reduction of 89.16 MTCE
Reducing carbon footprint by 89.16 metric tons of CO_2 equivalent per annum

[a]Based on 34,000 reams of paper consumed

Fig. 6 Biodegradable cleaning supplies

All printer ink cartridges used in printers are recycled—they are sent back for ink refilling and not thrown away. This is just as important as the paper for printing since the commercial/heavy duty printers are huge with significant plastic content. Refilling ink cartridges, on the other hand, is highly economical.

2.3.1 Office Cleaning

The use of environmentally friendly and non-toxic sanitary supplies is also very important to ensure sustainability. Our office cleaning and sanitary chemicals come from a local company called Waxie (Waxie GPS Green Partner Support, 2013). They define green cleaning as "effective cleaning that protects health without harming the environment." Figure 6 shows some of the 'green' sanitary cleaning products used for cleaning our building facilities.

It should be noted that these are certified biodegradable products with ultra-low volatile organic compounds (VOCs). These are not only environmentally safe but also do not harm the sanitary workers who use these products.

Fig. 7 Liquid dispenser and mixer (economical and safe)

For safe dilution and dispensing of these chemicals by the cleaning staff, the following wall-mounted dispensers are provided—as shown in Fig. 7. This dispenser/mixing machine is deployed in all the buildings owned by NU.

The benefits of the above-mentioned tamper-resistant solution mixing and dispensing station include *preventing chemical exposure, and workers*' *safety* with simple product selection and identification. The dispenser is also a mixer which takes the concentrated liquid in bottles and mixes it with the right amount of water for the sanitary workers. Purchasing concentrated cleaning liquids is beneficial because the number of plastic bottle used becomes fewer, and thereby cause lower environmental damage. Through these products, Waxie supports building certification for their customers' buildings.

Besides being environmentally friendly, these recycled and eco-friendly products are, according to our procurement office, actually less expensive. Thus, by using these approaches, NU meets the three Es of sustainability: environment, economics, and equity (here it is the safety of building occupants and sanitary workers).

2.3.2 Sustainable Supply Chain Partnership

It is important that an enterprise works with companies whose supply chains are also active *sustainability* practitioners. This type of relationship is extremely important since *sustainability actions* need to be implemented across the supply chain. NU's procurement partners, Staples and Waxie, are such partners. Staples, a main office supply company, is a recognized partner in this venture as it maintains its own standard of sustainability Its vision is stated as follows: "*At Staples, our vision is to generate business and environmental benefits—for ourselves, our customers, and our communities—by leading the way in sustainable business practices.*"

Similarly, our cleaning supply company, Waxie, has a program called Waxie Green Partner Support (GPS). The following statement on its partnership with the customers is indicative of its support of sustainability efforts: *Green Partner Support is an ideal platform for customers who would like to implement a green cleaning program which combines low environmental impact cleaning products with good sound cleaning procedures, along with the training and consultative expertise needed in order to create a more effective and safe cleaning program*. The products illustrated in Figs. 2 and 3 are such examples.

2.3.3 Data Center Operations Consolidation

As noted earlier, NU now has campuses spread across the state of CA. Initially, the university had several small data centers serving individual regions. It is well known that data centers (small or large) are huge energy consumers. Recommendations were given to reduce the rate of increase of energy consumption by data centers in a special report to the U.S. Congress by the Environmental Protection Agency (Report to Congress on Server and Data Center Energy Efficiency, 2007). Two of the key recommendations were to consolidate data centers and to virtualize the servers. NU implemented both these and achieved significant economic gains and reduction of GHG.

The following were some of the key results produced by consolidation and virtualization (Fig. 8).

The power savings noted in Fig. 4 includes both the reduction in the number of servers and associated cooling. An estimated 195 tons of CO_2 is saved through these changes.

These are huge successes which have helped NU towards becoming a green operations center. We are currently looking at reviewing our current data center needs and operations so as to take these sustainable actions to another level.

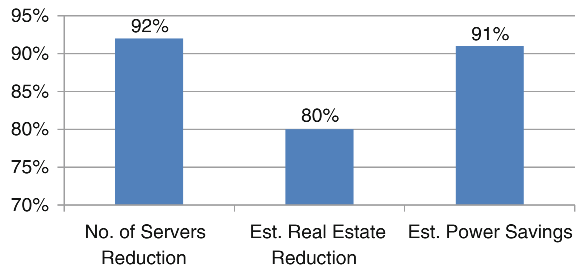

Fig. 8 Data center energy consolidation data

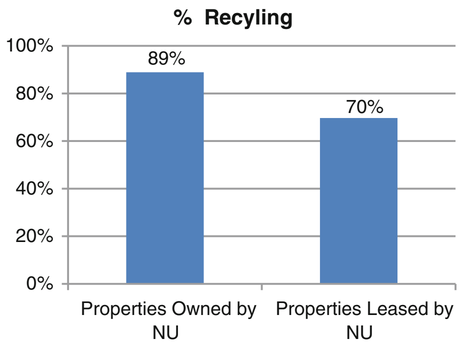

Fig. 9 Recycling in properties

2.4 Building Operations

NU has a dedicated facility division involved in all aspects of building management—construction and maintenance. On the construction side, any and all constructions are carefully reviewed to meet California's new building standards. Apart from owning some major campuses in the San Diego, Los Angeles and other large metro areas, NU also leases a number of facilities. The university works with property owners when buildings are leased to ensure that they are committed to sustainability practices.

The areas of great interest for building maintenance and operations include recycling, water efficiency, and landscaping. Besides these, efforts are also made to ensure that environmentally friendly chemicals are used for cleaning buildings. Our facility recycling includes bulk paper, cardboard, plastic, and aluminum cans. Figure 9 shows the amount of recycling done across the different properties in which NU operates.

3 Curriculum and Research

The main focus of a university is education: curriculum development, program offerings, and research. NU is very active in all the above functions as a vibrant university in this new, changing, and challenging field of sustainability.

The following environmental and sustainability degree programs are now offered at NU. MS Environmental Engineering was started in 2003, the Bachelor of Science degree in Environmental Sciences in 2005, and MS Sustainability Management Program in 2011. The sustainability management program is a blended program with NU's School of Business Management (SOBM). We believe that sustainability implementation will only be successful with buy-in from top management in any organization, and hence we decided to offer a blended program (courses are offered from both the business school and engineering school).

As noted earlier, one of the key action plans in the Talloires declaration is the need to *educate for environmentally responsible citizenship*. We believe the programs noted above support this action plan. The programs are geared not only to teaching and learning of the technical details of all aspects of sustainability, but also to development of leadership for the economically fast growing world. We believe we are developing world leaders since we have a good representation of international students. The MS Sustainability Management program focuses on business management and implementation aspects of sustainability in two special courses: SUS602 *Enterprise Excellence* and SUS603 *Sustainable Innovation*. As business experience has shown, excellence and innovation are key skills for management.

Sustainable products are also discussed at the graduate level product management course (Engineering Management program). We have expanded the course content in key programs such as Construction Management and Design Engineering by introducing sustainability concepts and problem solving.

Our belief and model of education is through student engagement and student-centric learning. Many of our MS students are already working in the environmental field. Most of these students have a Bachelor's degree and are pursuing their MS to get them ahead in their company and, typically, into management. These students frequently bring their company's problems/issues to the class for discussion and also take them up for projects (course and capstone research). We strongly encourage students to take on such projects as they give them an opportunity to find solutions to real world problems. For students' capstone research project presentations, we invite the company sponsors to be present.

One of the best examples of capstone projects being current and solving real world problems is the work done for the Leadership in Energy and Environmental Design (LEED) certification process. The importance and benefits of LEED certification has been well researched and documented (Auerbach 2011). Students do it for their own company buildings. In an effort to assess their own buildings for LEED certification, NU works with student teams to assess one of NU's buildings. After the student's initial assessment, NU has the option of officially applying for the certification. With this type of real world experience, our students gain greater credence and higher chances of success in the job market and stronger leadership capabilities in their current job than before.

NU's two learning centers have been assessed by students for LEED certification. NU is proceeding to implement the recommendations and officially applying for LEED certification for one of the buildings.

We have introduced an innovative teaching and student-centric learning of sustainability to solve a real world problem through games—student team design, creating, and playing games on sustainability problems. Examples of such games include those which focus on home water management plans and building energy management. Again, the focus here is to solve real world problems and make the course interesting and engaging for the students. We have had very positive results with this approach.

Fig. 10 National University's Eco-Fair

4 Community and Outreach

The third key action plan from the Talloires declaration is: '*Broaden service and outreach nationally and internationally*' NU has done well on both service and outreach efforts.

4.1 Computer Donations

As noted earlier, NU has a refresh cycle of 3–4 years for the computers. On an average, out of about 800 computers, some 30 % are donated to schools and non-profit organizations (see Fig. 4). NU seeks broad participation from their employees and through Associate Regional Directors to help seek out the schools and non-profit organizations to donate computers. This is an important and significant outreach to the community.

4.2 National University's Eco-Fair

National University's Eco-Fair is an outreach event initiated by some dedicated faculty and is open to the public as well as to the students, faculty, and all NU staff. The goals of the Eco-Fair include exposing and educating all NU students, and in particular, environmental sciences students, to the sustainability issues, and also get public exposure for NU and its environmental related programs. The exhibits include local green product merchants, non-profit organizations, and environmental/sustainability related movies and talks. See Fig. 10 for some of the pictures taken at a past Eco-Fair. NU funded the event and space was given free to the participating vendors who had the opportunity to sell their products and services.

After 4 years of organizing the Eco-Fair, NU has begun assessing the success of these events. One aspect which became clear was that the attendance for the events was less than anticipated. Based on this information, NU will seek different strategies to ensure that the Eco-Fair attracts a much larger audience than in the past.

4.3 Sustainability Workshops by Faculty

NU Faculty has broad and deep expertise and they reach out to the community by offering workshops which promote sustainability. Here are some examples:

- In collaboration with our local utility company, we provide a 1-day *Sustainability* workshop, which is open to the public. In this workshop, we discuss all aspects of sustainability relating to water and energy efficiency, recycling, and sustainable buildings. A similar workshop is also offered to the U.S. Army Corp.
- A specialized one day *Data Center Metrics and Energy Efficiency* workshop was given in collaboration with Lawrence Berkeley National Laboratory.
- Initial discussions are under way to work with a local school district for NU Faculty to help teach some advanced courses in sustainability.

5 Conclusion

Over the past several years, NU has been active in building both internal and external strengths towards being a more sustainable green campus institution. It is taking an integrated approach towards sustainability through administrative leadership, curriculum and research, and community outreach. A high level university committee on sustainability, driven by the Chancellor's vision, supports and encourages several *green* projects and events. The main objectives of these projects, as demonstrated with specific data in this report, are concerned with environmental impacts being reduced, resulting in savings and reductions in the area of energy, water, and waste management. NU has also demonstrated leadership in developing an outstanding curriculum at the Bachelor and Master level programs to train and develop future leaders. Program projects strive to solve real world problems. Outreach activities include Eco-Fairs, computer donations to schools and non-profit organizations, and teaching sustainability workshops to the community through partnerships with local utility and Berkeley National Laboratory.

Sustainability is a long journey, and we have many more mountains to climb and conquer, to demonstrate leadership to our educational and local communities. We will be reviewing our current *best practices* and expand them to all our university-owned facilities, and work with our leased facility owners. We also intend to promote the program further within the university faculty and students with specific actions to increase awareness and sustainability practices.

With these successes, we will evaluate the benefits of joining the larger university communities through alliances and membership with organizations such as, *University Leaders for a Sustainable Future* and *The Association for the Advancement of Sustainability in Higher Education*. We will also evaluate some standard university sustainability standard metrics such as STARS (Sustainability Tracking, Assessment and Rating System, 2012).

NU believes we are acting to help promote and practice the three key action plans of Talloires declaration noted earlier.

The future looks bright, green, and sustainable for National University.

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Food Waste Prevention and Management in Higher Education

Bhushan Girish Trivedi

Abstract

Over recent years, the problem of food waste has been faced all around the world. Various reasons contribute to this, most of which are highly avoidable in nature. Ideally, it is the responsibility of every individual/institution to make every effort possible towards preventing food waste, but this study focussed only on the role of higher educational institutions. The overall aim of this project was to assess the practicalities of developing and implementing a food and packaging waste prevention programme in a university setting using the University of Salford, Manchester Metropolitan University, University of Manchester, Newcastle University and Small World Cafe (Oxford Road, Manchester) foodservices as case studies. The research involved carrying out face-to-face semi-structured interviews with the cooks, chefs, cafeteria managers and estate managers from all the participating institutions to collect qualitative data on the factors associated with food waste and the current food waste management practices at their facilities. The responses were thoroughly analysed to highlight the good practises and areas for improvement with regards to their food waste prevention and management practises. These findings included best practices and ideas for preventing pre- and post-consumer food waste along with suitable options for managing food waste in a university setting. These findings were then used to recommend a food waste prevention and management program.

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Keywords
UOS: University of Salford • MMU: Manchester metropolitan university • UOM: University Of Manchester • NU: Newcastle University • SWC: Small world cafe

1 Introduction

Food wastage has emerged as one of the most significant environmental, social and economic concerns of the world today (Wiggins and Levy 2008). Food being wasted could account for up to one-third of the total food produced (WRAP 2008). The problems do not end just with food being wasted but also with the respective carbon emissions associated with the product lifecycle (FAOSTAT 2012). With the challenges the modern world faces today, and the threats we may face in the future with regards to food security, it is crucial to take firm steps which would result in better food waste prevention and sustainable waste management techniques. The need for quick action to be taken to prevent and manage food waste better has never been so strong, and ideally it is the responsibility of every individual to take adequate action to tackle this problem. However, this study focuses only on the higher education institutions contributing to successful food waste prevention and management initiatives. Higher education institutions have an important role to play in achieving sustainable development. Apart from being morally responsible for taking strong action towards betterment of the environment, higher education institutions are also expected to influence the attitudes and behaviour of students/ staff in a positive manner on the key environmental issues/concerns (Vega et al. 2008). Data obtained from the Universities UK indicate that there are 115 universities and 165 higher education institutions in the UK alone as of August 2011. Considering these high numbers, the higher education institutions are important stakeholders for achieving food waste prevention targets on a national scale.

2 Aim of This Study

The overall aim of this project is to assess the practicalities of developing and implementing a food and packaging waste prevention and management programme in a university setting using the University of Salford, University of Manchester, Manchester Metropolitan University, Newcastle University and Small World Cafe foodservices as case studies.

3 Methodology

The project included collecting qualitative data in the form of face-to-face semi-structured interviews directed towards the head chefs and cafeteria/estate managers, distribution of questionnaires to the cafeteria staff and general observations made during cafeteria inspections. The data was also obtained in the form of government reports, successful business case studies and research on the latest available technologies in this sector.

In this study, the face-to-face semi-structured interviews allowed interviewees to express their opinions freely, including their suggestions and criticisms about current food waste management strategy at their respective organisations. This approach was particularly useful as it provided us with a much more detailed idea of various topics and issues which was not included in the prepared questions. The questions were designed after extensive research on the topics of food waste audit procedures and business case studies which conducted successful food waste reduction programs.

4 Findings

The findings are compiled from the interviews with all the participants on the basis of the questionnaire presented to them. The answers for all the questions by each of the participants are compared, followed by highlighting the respective good practices and areas of improvement.

4.1 Internal Food Waste Handling

Internal food waste handling with regards to this study is defined as the handling of food waste inside the catering facility/area. With regards to this, most of the participants seem to have been following the same techniques with the collection but the best practice is displayed by the UoS. The internal food waste at the UoS is collected by general assistants, members of staff, and is placed in white see-through buckets. This food waste has recently (during the early period of this research) started to have been weighed by the staff member who is in charge and is recorded on the sheet supplied by the company. The situation is similar in the other institutions regarding internal food waste collection, but they do not measure their food waste in terms of mass or volume.

Proper segregation of the food waste is crucial for its best disposal/management options. In terms of the kitchen and post-consumer food waste segregation practices, UoS shows best practices where it segregates the dry and wet food waste for weighing, Cans, bottles, tin, cardboard and plastic are collected for recycling. The practice of recycling is also followed by other institutions. However, some institutions have been observed to discard the food waste in the general waste stream, which should be avoided, and therein lies a big area for improvement in terms of better managing their food waste. NU and two of the other participating institutes recycle their used cooking oil, which is collected by private operators, highlighting good practices. UoS and NU have macerators at their kitchen facilities where preparation and plate wastes are macerated.

4.2 External Food Waste Handling

External food waste handling for this study concerns the food waste being collected by an external agency once it is finally disposed of by the catering facility. The majority of the catering facilities have support from their university teams such as the estates, or the house services to collect the waste from their facilities. In the remaining cases, the local city council directly takes away the food waste produced by the facilities.

4.3 General Findings on Food Waste

The questionnaire presented to the participants had a section where general questions were asked on the issues relevant to the current food waste prevention and management at their respective organisations.

On being asked for a general assessment/view regarding the current food waste at the facilities, a mixed set of responses were obtained from all the participants.

It was very important to find out the reasons behind food waste occurrence at the respective organisations, and a question was put to the participants asking for their view on the wasteful activities they have noticed at their facilities. The executive chef at MMU believes that peelings and other preparation waste can be used in other preparations more effectively. One of the reasons put forward by a cafe operator for occasional food waste was that it is not cooked properly, i.e. is under/over cooked or burnt. The SWC said that a common wasteful activity they have noticed is food being left on the plate by consumers because of their personal preferences. With regards to the UoM it is mainly ‘over-ordering and over-preparing’. This is the main issue when it comes to hosting events and conferences at the university.

Two of the participating organisations in this research are more of a fast food outlet than a formal dining facility. According to Aarnio and Hamalaien (2007), these facilities are also classified in the restaurant sector. In this sector, packaging waste is mostly generated by transport packaging, such as corrugated cardboard boxes. In a unanimous agreement, it is found that fruit, vegetables and frozen food come with excessive packaging which increases the work for the catering facilities in order to dispose of the waste in a suitable manner. On the other hand, the UoM and NU seem to have no issues with packaging waste. This is mainly because fruit and vegetables, irrespective of delivery volume, come in reusable bags. These bags go back to the supplier and come back in a subsequent delivery. This practise at UoM and NU has enabled them to have almost negligible packaging waste at their facilities.

It was important for this study to establish the general view of the participants on where they feel their catering facilities could be more efficient in terms of reducing their food waste and, when asked this question, it turned out to be very beneficial to get a wide range of answers. One of the solutions proposed by the head chef at UoS was making ‘fresh food’. The strategy here is simple: avoid taking food out of boxes and putting it in the oven, and instead use the experience of the chefs to make fresh food and encourage innovative re-usage strategies such as with the case of peelings. This idea can save a considerable amount of packaging waste and also offers the consumers the option of having freshly made food. With regards to the MMU, the executive chef and the chef both presented two different ideas which covered not only the preparation but the post-consumer waste too. They suggested that more emphasis has to be given to the customers disposing off their waste properly. This again goes down with inducing a behavioural change aimed at food waste prevention and proper disposal among students/staff at higher education institutes. The cafeteria manager at MMU was also concerned about plate waste being high and presented an alternative of allowing the customers to taste the food before actually buying it in order to reduce post-consumer waste, but this method has got its own de-merits, as stated by the manager: "In cases when you have a massive queue, you just cannot do it". In the case of UoM, the room for improvement with regards to their food waste is to focus on getting the right number of consumers for the conferences and catered accommodation.

In any food waste reduction plan, one of the key supporting elements for its success would be the infrastructure and the equipment provided to achieve the goals and objectives. The UoS has a good infrastructure to support their food waste reduction efforts. It starts right from their kitchen facilities, where they have macerators in place for food waste in order to send it to the next stage of composting, and the catering area is provided with bins for all kind of waste placed at strategic locations.

With regards to specific improvements in the operations, the importance of stock management was discussed briefly in preventing food waste, focussing on stock rotation. The kitchen team should have a sound knowledge of stock rotation and menu planning.

The importance of having strong and successful food waste reduction policies is very high. In some cases there could be some university policies which may act as barriers for food waste reduction and management options. Because of this, a question aimed at finding any such barriers at the participating institutions was framed and it was discovered that none of the participants felt there were any university or restaurant policies which act as barriers in their food waste reduction efforts. However, with regard to the re-use and storage of food, the main concern of everyone was the element of health and safety.

The study also tends to find whether there are any fluctuations in the level of food waste produced with change of season. The manager at MMU stated, "Seasonality plays a big part in the food waste produced". It has been found from the majority of participants that the percentage of food waste out of the total food produced is higher in the down-time or during the non-peak time of the academic calendar.

The study also attempts to find the relation between the menu offered and the food waste produced. This question yielded some interesting answers; one given by the cafeteria manager at MMU emphasised the importance of advertising the menu in advance to the students/staff so that they know what is available on a particular day; providing they know whether or not they like it, they can make a firm decision on whether to buy it, which can help to reduce plate waste.

The concluding question—and the final one—was to get the views of the participants on their biggest challenge in their food waste reduction targets. This question yielded a wide range of answers and was quite interesting to see different perceptions in overcoming the challenges. The challenge presented by the head chef at UoS was to induce a behavioural change among the students/staff, persuading them, ideally, to have no plate waste at the end of their meals. A similar sort of challenge is also faced by the MMU, where it is important to change the mindset of the people. On the front of tackling preparation waste, one of the challenges presented was to have proper planning of the menu and see whether there is an option to re-use the food, if required, and to prepare only what is required. One of the challenges put forward by the cafe supervisor at SWC was making sure that the cafe has food for everyone while, at the same time, not wasting any because of not being able to sell it. Predicting the customers coming in on a particular day is their biggest challenge in order to plan better.

5 Discussion

The catering facilities at the UoS have, during the start of this study, started formally by recording food waste produced as a daily procedure. This formal system of recording food waste is crucial in setting up a Source Reduction program (Lean Path 2009). It serves as the first step in the entire program and helps to identify the trends relevant to bring about a continuous improvement in the food waste reduction efforts. The waste recording procedure should mention the type of food being wasted and the reasons associated with it. This action seems to be missing in the other participating institutes.

Several reasons were identified for food waste and possible areas of improvement at the participating institutes, one of them concerning the re-usability of food or using the peelings, or any such ‘possibly avoidable’ food waste.

The other area of improvement in terms of reducing food waste is regulating the size of the portion of food served. This was agreed by a majority of participants, who are aware of the importance of this idea but do not seem to have detailed information on some factors, such as, for example, the relationship between the dishware and portion control, as discussed by Steenhuis and Vermeer (2009).

Another way to prevent food waste, suggested by the cafe supervisor at SWC, is catering to the ‘personal preference’ of the customer. It would be logical to think that catering to personal preferences on food coupled with the right portion size would help tremendously to reduce plate waste.

Bringing about a behaviour change in the students/staff at the higher educational institutes towards preventing and better managing food waste was the factor most unanimously agreed by all the participants as an important area for improvement. The majority of the participants agreed on the importance of educating and creating awareness over the campus in order to inspire the behaviour of students/staff to be more responsible towards the issue of food waste. The UoM, as part of their food waste strategy, intends to have massive education campaigns aimed at this in the near future; the importance of this has been mentioned by Jurczak et al. (2002). According to them, these strategies have the highest potential to penetrate the mindset of the people as compared to any other strategy. The aim to bring about behavioural change and education is not only restricted to the student/staff but also to the kitchen crews.

Another noticeable point was that none of the participating universities, apart from the UoS and NU, have composting or any other food waste management technology at their campuses. The suitability of composting at the higher education institutes has been discussed by Chang et al. (2005). Other participating institutes currently dispose of food waste as general waste, which is not ideal.

6 Conclusions

The conclusions derived from the findings and discussions are as follows.

Food waste is being discarded into the general waste stream in some institutions. This action needs to be avoided as it adversely affects the environmental sustainability aims of the university and also contributes significantly to the overall carbon emissions associated with mismanagement and disposal. Some of the institutions do not have a strong food waste recording system at their catering outlets. This would make the task of finding and analysing the problem areas more difficult. Food not being cooked properly and over-preparation of food are reported to be major problems at the universities which cater for conferences, buffets and catered accommodation. Personal preferences should be taken care of while serving the food to the customer. This would help reduce post-consumer waste.

The importance of behaviour change towards food waste reduction efforts is widely emphasised by all the participating institutions. Another major problem identified during this study was that of food being wasted because of it being served in too large portions. Improper stock management and poor stock rotation practises were also discovered in contributing to the food waste at the pre-consumer stage.

Packaging waste has also been a big issue with some of the participating institutions, with relation to their fruit and vegetable deliveries.

In terms of managing the food waste after its disposal from the catering facility, the challenges identified are the logistical support, especially if the campus is widespread. Infrastructural support is also vital for such efforts, and one of the main challenges identified is to find the suitable staff with enthusiasm and motivation towards the job role of this nature.

7 Recommendations

The recommendations made are as follows.

7.1 Conducting a Baseline Audit

The overall food waste prevention and management program at the catering facility should start by conducting a baseline audit of pre-consumer and post-consumer food waste. Identifying the baseline would help to judge the performance of subsequent steps more accurately and would assist in formulating the correct strategies.

7.2 Food Waste Recording

It is proposed to record the pre- and post-consumer food waste before being discarded from the facility. The recording can be done in any suitable units, such as the food portions or in terms of mass/volume. During this stage, the type of food being discharged, quantity, along with the reason behind it must be explicitly noted down. It would be ideal to make use of suitable Information Technology to support this, which would help in observing relevant trends. These trends would help the concerned staff identify loopholes and to take adequate measures to rectify them. This process of constant monitoring would help in continuous improvement in terms of food waste reduction performance of the restaurant.

7.3 Kitchen Staff Training and Motivation

The contribution of kitchen staff towards reducing pre-consumer food waste is very substantial. The knowledge and experience of the chefs/cooks play a very important part in preventing preparation waste to its lowest possible value by employing several techniques of food preparation, which they have learnt or mastered over a period of time. Hence, it is very important to have competent staff in the kitchen to deliver the best performance in both the quality of food being prepared and the lowest possible food waste in doing so.

7.4 Portion Control

Portion control is one of the first areas to focus on in order to reduce post-consumer food waste. Portion control should be coupled with taking account of customer preference. The role of the serving staff at the catering facilities is crucial to ensure right amount of food is being served every time. It is also proposed to serve food in variable quantities of small, medium and large portions in order to give the customer more options. further reducing post-consumer food waste. The size of the dishware used to serve food also plays a vital part in reducing plate waste. Hence, the optimum size of dishware must be used.

7.5 Feedback from Customers

The customers must be persuaded to give their valuable feedback on the food they are served and must also be given the means to offer their ideas/suggestions which would help the restaurant in achieving their goal of food waste prevention.

7.6 Education Drives (Aiming at Behaviour Change)

One of the most significant contributors in terms of reducing post-consumer food waste is the behaviour of the customer towards this issue. Such a program gives results on a long-term basis but has a very high potential to bring about a positive change in food waste prevention, sorting and management on campus. The university/institute estates and sustainability teams have a major role to play in terms of organising these events and involving the maximum number of staff/students in it. The students' union/activity groups should hold events in the welcome week, and also at regular intervals for the same cause throughout the whole academic calendar. Communication on this issue should also be carried on through the use of posters, distribution of leaflets around the campus and use of images/information strategically located at the tables and counters used for food serving, persuading people to prevent food being wasted from their plates. Social networking sites should also be constructively used to spread the message.

7.7 Infrastructural Support

It is recommended to do an assessment on the present infrastructure at the cafeteria and the university to prevent and manage pre- and post-consumer food waste. Having good infrastructural support is absolutely crucial in such programs. Adequate steps should be taken following the assessment in terms of providing the right amount of infrastructure/equipment around the campus, strategically located to be highly visible and convenient, in order for users to dispose of and manage their food waste in the best way possible.

7.8 Food Re-use Options

Food re-use options must be explored by the higher education institutes, where they could donate the food which could not be sold to any suitable institutions, such as homeless shelters. The food should, however, need to comply with relevant health and safety standards before donation.

7.9 Packaging Waste Reduction

The catering facilities should adopt the practise of sourcing their inventory in the form of reusable boxes/bags, which are taken back by the vendor and used again for subsequent deliveries. This practise involves almost negligible packaging waste involved with food delivery to catering outlets.

7.10 Food Waste Management Options

Encouragement should be given to carry out food waste management options such as in-vessel composting on the campus. This method in the long term would not only result in a better environmental performance but also potential cost savings associated with the disposal of the food waste. Any composting project must be backed up by strong support from the university/institute management, the staff involved and the catering outlets to divert all their food waste to composting. Logistics play an important part in the overall success of such programs and hence a cheap and efficient way proposed here is to use the existing university mail or any other services to transport food waste from different locations to a central one. Sealable food waste buckets can be used for this in order to avoid spillage or spread of odour. Used cooking oil from such facilities should be recycled too.

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Renewable Energy on Campus at the University of Wyoming

Carrick M. Eggleston

Abstract
The University of Wyoming, though located in a state whose economy is perhaps more dependent on fossil energy resources than any other state and many other countries (and a state with very low energy prices and thus minimum incentives for renewable energy projects), has nevertheless developed a respectable array of "green" infrastructure, research projects which mitigate carbon emissions and which address renewable energy, public outreach, and educational opportunities. The School of Energy Resources hosts two renewable energy centers among its eight centers of excellence, and faculties in chemistry, engineering, physics, and geology and geophysics participate in renewable energy research. Recent building projects, including the new Visual Arts Facility, have received LEED gold and LEED platinum ratings from the U.S. Green Building Council. This level of commitment can be regarded as a benchmark for sustainable development on a campus within a broader environment of minimal incentives.

Keywords
Wyoming · University · LEED · Energy research · Sequestration

1 Introduction

Universities bear special responsibilities with regard to sustainability. They must set a good example by using energy more efficiently, using renewable energy, decreasing waste, and promoting sustainable practices, all while protecting the

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esthetic and environmental assets of the campus. "Sustainability" should also become part of the teaching, research, and outreach missions of the university. Students and the public should have opportunities to see sustainability and renewable energy in practice in order to understand how such ideas can be incorporated into everyday life. This chapter focuses specifically on aspects of the University of Wyoming (UW) which result in lower net carbon dioxide emissions. In order to understand the University of Wyoming's carbon-reducing actions, the chapter first briefly reviews its context within the State of Wyoming.

Wyoming is the least populated state of the United States. In 2010 Wyoming had a population of 564,000 (a 13 % increase in a decade) and a population density of 2.2 people per km^2 (U.S. Census Bureau 2012). Wyoming is famous for its breathtaking scenery (including Yellowstone National Park, the world's first, established in 1872), wildlife, and western lifestyle. Although tourism is very important, state revenues are based mostly on extractive energy industries. Wyoming produced 401 million tons of coal in 2012, down more than 14 % from a high of 467 millions tons in 2008 (U.S. Energy Information Administration 2013a) but still representing about 40 % of all coal produced in the United States and about 5 % of global fossil-fuel carbon emissions. Wyoming oil production was over 57 million barrels in 2012 (U.S. Energy Information Administration 2013b), along with over 2.5 trillion cubic feet of natural gas (U.S. Energy Information Administration 2013c). Taken together, and accounting for the proportion of carbon in each fuel, Wyoming generates about 5 % of the total annual global carbon emissions. Wyoming is known as "an energy state" or even as an "energy colony" within the United States.

In addition to fossil energy resources, Wyoming has excellent wind energy resources. For example, the Foote Creek Rim wind farm operates with a 43 % capacity factor (U.S. Bureau of Land Management 2011), which is considerably higher than most other wind farms globally. Wyoming currently has over 1.4 gigawatts (GW) of installed wind capacity, producing about 4,600 GW hours (GWh) of electrical energy annually (U.S. Energy Information Administration 2013d). Such extensive wind development has brought with it new problems, such as loss of wildlife habitat, noise concerns, wildlife mortality (particularly birds and bats), and visual alteration of the landscape. Wyoming has imposed a wind energy tax of $1 per generated megawatt hour (MWh) starting 3 years after a given turbine starts producing electricity, the only tax of its kind in the United States. The tax has hampered wind development since 2010. Revenue from the wind tax ($2.6 million annually in 2013) is dwarfed by revenue from mineral severance taxes of about $834 million annually (State of Wyoming Department of Revenue 2013). Another problem for further wind energy development is the lack of sufficient power transmission capacity. Transmission line projects are underway, but pose environmental, viewshed and permission problems in their own right.

For residents of Wyoming, the price of energy is relatively low. Electricity (with the understanding that there are variables depending on the amount and type of usage) costs between $0.07 and $0.08 per kilowatt hour (kWh), equivalent to about 4 rupees per kWh. At the time of writing, in Wyoming, the price of gasoline (petrol) for use in automobiles is about $3.70 per gallon (about 60 rupees per liter), which is similar to prices in India (over 60 rupees per liter). The price of natural gas has in the past been about $4 per therm (1 therm = 100,000 BTU), but has declined in the past few years (to about $3.60 per therm) because of the recent influx of new gas resources to the market from so-called "fracking" and other drilling methods. Low energy prices limit the economic incentive to adopt renewable energy technologies. Nevertheless, Wyoming has a modest solar energy incentive program, as well as net-metering for residential solar electric power.

This chapter focuses on the specific actions taken by the UW with regard to renewable energy and reduction of carbon emissions. UW was founded in 1886, prior to statehood in 1890. UW currently enrols over 13,000 students and is the only 4-year public institution of higher education in the state. If UW, in a fossil energy dominated state with low energy prices, has nevertheless incorporated renewable energy into infrastructure, teaching, research and outreach, then it offers a benchmark against which to compare other universities with a greater incentive to utilize renewable energy. With this in mind, this chapter explores examples of renewable energy infrastructure, research, and instruction at UW. It is beyond the scope of this chapter to explore other aspects of the "green campus," such as recycling (there is a substantial recycling program), land use, and beautification (substantial activity, including closing the inner campus to automobiles in favor of a walking campus), energy conservation (there has been investment in new windows with lower U-factor in some buildings, and other housing with poor insulation has been replaced with newer and better-insulated housing), water management, and ecosystem protection.

2 The School of Energy Resources

Recognizing the importance of energy to employment and the state economy, the legislature of the State of Wyoming funded the new School of Energy Resources (SER) (http://www.uwyo.edu/ser/) within UW. SER contains eight "Centers of Excellence":

1. Carbon Management Institute
2. Center for Energy Economics and Public Policy
3. Center for Fundamentals of Subsurface Flow
4. Center for Photoconversion and Catalysis
5. Center for Biogenic Natural Gas Research
6. Enhanced Oil Recovery Institute
7. Wind Energy Research Center
8. Wyoming Reclamation and Restoration Center

There is no center focusing on coal. One center focuses on enhanced oil recovery, and two centers focus on aspects of gas (most of the natural gas in coalbeds is biogenic) and oil (oil production depends on management of fluid flow in the subsurface). Two centers focus on environmental aspects of fossil fuel extraction and utilization (8 and 1), and two focus on aspects of renewable energy (4 and 7). Thus, of all the centers in the SER, 50 % are focused on the environment and renewables. Admittedly, the environmental and renewable energy centers do not enjoy 50 % of the funding, reflecting the fact that more money is available from industry in areas of fossil energy than in environmental or renewable energy industries. The Carbon Management Institute (CMI), the Center for Photoconversion and Catalysis, and the Wind Energy Research Center are briefly considered in the sections below.

2.1 Carbon Sequestration

Geologic sequestration of CO_2 is one way to prevent CO_2 from entering the atmosphere. The Carbon Management Institute (CMI) in the School of Energy Resources oversees work toward pilot scale CO_2 injections in the Rock Springs Uplift (RSU), a large-scale geological feature of southwestern Wyoming. The CMI can thus be considered as a response to mitigating global climate change. It is also true that injected CO_2 in the subsurface can often be used for enhanced oil recovery, which provides some of the economic incentive for injection. It is instructive to examine the scale of the global carbon emissions problem from the perspective of carbon sequestration.

A recent publication (Deng et al. 2012) estimates that 6.6 gigatons (Gt) CO_2 could be stored in the RSU of southwestern Wyoming over a 50-year period, and that about 1 km^3 of brine would have to be produced at the surface as a result. By this estimate, the amount of carbon which can be stored in the RSU over 50 years is less than 25 % of 1 year's global carbon emissions and equivalent to about 7 years of Wyoming's current carbon exports. In order to have a significant impact on global carbon emissions, sites with similar storage capacity would have to number about 60. This scale of industrial injection cannot be achieved quickly, during which time global carbon emissions will increase. Thus, even a major industrial-scale injection project in Wyoming would have little impact on global emissions.

However, because comparatively little of Wyoming's fossil energy resources are used in Wyoming, the RSU injections could contain the emissions of the Jim Bridger coal-fired power plant (2.2 GW) near Rock Springs, Wyoming. This plant currently emits about 24 million tons (Mt) of CO_2 per year. Indeed, the main power plants in Wyoming, taken together, emit about 90 Mt of CO_2 annually. Over 50 years, assuming no growth in emissions, these power plants would produce 4.5 Gt of CO_2, which is within the uncertainty bounds of the estimated 6.6 Gt CO_2 of storage capacity of the RSU.

Nevertheless, making an impact on global carbon emissions remains daunting. The world produces about 5 cubic kilometers (km^3) of oil per year, and about 6 km^3 of coal (this calculation ignores gas). In these materials, most of the atoms besides hydrogen (which takes up very little volume), about four out of five are carbon. One of the best-case scenarios for geological carbon storage is that carbon could be precipitated as the mineral calcite ($CaCO_3$). In calcite, only one in five atoms is carbon. Thus, if calcite is the most carbon-dense potential storage medium, then the volume of the stored carbon must be substantially greater than the volume of the extracted fossil fuel resources. Global carbon emissions in 2012, if converted to calcite, would occupy about 25 km^3. Other storage forms (e.g., supercritical CO_2 or compressed CO_2 gas) would occupy even greater volumes. To reach 1990 emissions levels, over 6 km^3 of calcite would have to be stored per year, which would require immediate creation of an industry equivalent in scale to the global coal industry (to say nothing of the energy used to make calcite, which would create more carbon emissions which would then need storing).

Another major problem is posed by the displaced brine. In the arid American west, threats to water quality are very controversial. A cubic kilometer of brine (Deng et al. 2012), displaced to the surface by CO_2 injection, is no small matter as a threat to freshwater resources in the entire region. This would probably require the construction of a major (many square kilometers) lake in the vicinity of the RSU, threatening the groundwater resources of all living things in the region. An alternative is a pipeline to carry brine to the Great Salt Lake. As with most "green" technologies, the rush to gain environmental benefits must be balanced against the inevitable creation of new environmental threats.

2.2 The Wind Energy Research Center (WERC)

The WERC (http://www.uwyo.edu/werc/) is primarily a research center focusing on technological advancements in wind energy. The WERC is composed of a faculty from engineering departments at UW, and acts as an "umbrella" organization by facilitating collaboration among researchers at UW and at other universities, National Laboratories, and companies. In addition to its research mission, the WERC promotes courses and curricula which will build the workforce needed to construct and maintain wind turbines and large-scale wind farms in Wyoming and across the U.S. One of the main research areas under WERC is computational modeling of wind turbine performance under turbulent airflow conditions.

2.3 The Center for Photoconversion and Catalysis (CPAC)

The CPAC (http://www.uwyo.edu/cpac/), similar to the WERC, is primarily a research organization. It serves to coordinate research among faculty at UW, foster collaboration, and foster new research in the areas of solar energy and associated catalysis. CPAC provides three kinds of funding to support research at UW:

1. Seed grants—small grants intended to support preliminary research to produce data needed for full proposals to outside funding agencies
2. Visiting Scientists—CPAC funds are used to bring outstanding scientists in the areas of solar energy and catalysis to UW to give lectures and short courses
3. Undergraduate research—the CPAC offers funding to support undergraduates to work on projects related to solar energy and catalysis in UW laboratories with the supervision of CPAC faculty

CPAC faculty are housed in the departments of Chemical and Petroleum Engineering, Geology and Geophysics, Chemistry, and Physics and Astronomy. Current projects involving CPAC faculty include $3.2 million in funding from the U.S. Department of Energy (DOE) and National Aeronautics and Space Administration (NASA) to conduct research on quantum-dot sensitized solar cells. Other research within CPAC includes Earth abundant semiconductors, photocatalysis for solar fuel production (instead of electricity production), and new photovoltaic materials.

An outgrowth of the research on solar water splitting is the Solar Hydrogen Activity research Kit (SHArK) project (http://www.thesharkproject.org/). The SHArK project was established at UW in 2008 with the support of a grant from the Camille and Henry Dreyfus Foundation, and is coordinated by the UW Department of Chemistry in cooperation with the SER and CPAC. The goal of the SHArK project is to screen, from among millions of possible candidate compositions, metal oxide semiconductors which can split water and produce hydrogen fuel over a long period of time. Because there are millions of possible semiconductor compositions which must be tested, successful screening of the bulk of these compositions must use the combined effort of many people, each with the ability to work with thousands of compositions. The SHArK project develops inexpensive kits which allow young scientists to participate in this screening process using combinatorial chemistry techniques utilizing consumer inkjet printers, a laser pointer, and LEGO® robotics. Because SHArK project participants across the US comprise secondary schools and undergraduate institutions, it serves the educational as well as outreach missions of UW and of the SER.

3 Renewable Energy Infrastructure at the University of Wyoming

UW signed on to the American College and University President's Climate Commitment. As part of this commitment, there is a policy that all new buildings on campus should be designed and constructed to a minimum of LEED Silver "or equivalent." Because several new buildings have been designed and built since the signing of the Climate Commitment, there has indeed been progress in this direction. The review of infrastructure below starts with these new buildings, and then proceeds to a few other physical and educational infrastructure features of UW.

3.1 Haub School of Environment and Natural Resources

The Haub School is housed in the Bim Kendall House, which was granted Leadership in Energy and Environmental Design (LEED) Gold status by the U.S. Green Building Council. This status recognizes attention to innovative design (the building integrates a new wing with a rebuilt 1954 building), sustainable materials, low water use, insulation, and renewable energy. The new part of the building supports a 25-kW photovoltaic array utilizing Enphase Energy microinverters. The inverter output, current as well as history from the lifetime energy production of the system down to the last 24 h, can be accessed online (http://www.uwyo.edu/haub/bim-kendall-house/).

3.2 Visual Arts Facility

The new Visual Arts Facility (VAF), built for the Art Department, including offices, classrooms, museum space, and studios. The 7,400-m^2 VAF is located near the Art Museum, creating a cohesive art complex on the UW campus. The integrated design combined with outdoor water management garnered a LEED platinum award as well as a Portland 2030 Challenge Design Award. The nonprofit Architecture 2030, which is responsible for judging entries for the Portland 2030 Challenge, made the award based on reduction in carbon dioxide emissions (among other design criteria). A full-scale mock-up of building parts allowed construction managers to plan full-scale construction efficiently, and "building information modeling" also streamlined the design and construction process. Fully 70 % of the building electrical power is provided from renewable resources by contract, and 37 % of all building energy use is provided by renewables. A main feature of the VAB is the evacuated-tube solar thermal system which provides hot water for building heating in Wyoming's cold climate. The result is a building which produces 54 % lower CO_2 emissions compared to the US national average.

3.3 SER Building (Energy Innovation Center)

The EIC, built for the School of Energy Resources, currently has no LEED rating, but was built to LEED Silver standards. A LEED rating application is in process. The building provides for laboratories which can be used for renewable energy research, and roof-top space is designed to be used for solar and wind demonstrator projects (http://www.uwyo.edu/ser/building/).

3.4 Berry Biodiversity Conservation Center

The UW Berry Biodiversity Conservation Center (BBCC) has been awarded LEED Gold status. The building incorporates a "living roof", and uses locally sourced materials, natural ventilation features, low-water landscaping, and exhaust air energy recovery technology. The 4,100-m^2 building houses many environmentally-oriented facilities, including the Biodiversity Institute, the Stable Isotope Facility, the Wyoming Natural Diversity Database, and the UW Vertebrate Museum.

3.5 Photovoltaic Power Plant at Field House

On the UW campus, a 40-kW photovoltaic array was constructed on the edge of a parking lot near the UW stadium. A new football practice facility was constructed in the parking lot, necessitating the relocation of the 40-kW array. In the relocation process, many of the panels were damaged and the array now produces less power than when originally commissioned.

3.6 Solar Energy for Outreach

The UW Extension, which provides outreach to Wyoming citizens in many areas, has a website covering various renewable energy options and provides links to information on renewable resources and renewable energy contractors in the region (http://www.wyomingrenewables.org/renewable-energy/solar/).

3.7 Courses Available

Faculty in various UW departments provides courses related to solar energy. For example, in the Department of Geology and Geophysics, a seminar course entitled "Semiconducting Oxides" has been offered on several occasions. The main courses directly addressing solar energy physics, chemistry, and devices, are: Chemistry 4050, Solar Energy Conversion; PHYS 4340, Semiconductor Materials and Devices; PHYS 5750, Optical Properties of Solids; and PHYS 5830, Physics of Solar Cells. More courses are being developed, and within 2 years it is anticipated that the array of available courses will have expanded substantially.

4 Conclusions

The UW is located in a state dominated by fossil energy extraction and export. Nevertheless, renewable energy and carbon-emissions reduction have a substantial presence in the education, research, and outreach missions of the university as well as in UW infrastructure. This level of commitment, while not matching that of many other U.S. universities, should nevertheless stand as a benchmark against which to compare other universities. The efforts at UW represent what is possible when overall support and incentives for renewable energy are relatively low. It has been estimated that there will be 330 GW of installed solar PV capacity by 2020 worldwide (Kaften 2013). Whether this estimate holds true depends on many factors, not least the development of "smart grid" and other technologies. These developments will take commitment, and perhaps somewhat more expense than would be possible with fossil energy resources. Everyone should understand, however, that the next 30 years will be a period in which the overall rising price of increasingly difficult-to-produce fossil energy will have a more and more difficult time competing with renewable energy technologies. Everyone should ask themselves what would be possible in the next 5 years in places where incentives are higher than in Wyoming? Perhaps all of us, working together, on and off campus, can have a significant impact on increased energy security, increased energy independence, and reduced greenhouse emissions through developments similar to those described here.

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Author Biography

Carrick M. Eggleston is a Professor of Geology and Geophysics who has studied the chemistry of mineral surfaces in environmental processes. This interest has led to an interest in solar energy using Earth-abundant materials such as iron and manganese oxides, along with other materials and bacterial enzymes. Eggleston recently utilized a Fulbright-Nehru Fellowship to teach a course and conduct research in the Center for Green Energy Technology at Pondicherry University in India.

BIOTECTURE—A New Framework to Approach Buildings and Structures for Green Campus Design

K. Chithra and K. Amritha Krishnan

Abstract

Despite the amount of scientific knowledge mankind has gathered, nature holds great mysteries which we may never be able to unravel, filling us with a sense of awe and amazement. Our survival is completely dependent on it. Over time, man has tried to control nature by enforcing order and by distancing himself from it. Attempts are now being made to regain a close connection with nature through 'natural architecture' which aims to create a new, more harmonious relationship between man and nature by exploring what it means to design with nature in mind. The natural architecture movement is a form of activism rather than a protest, postulating that mankind can live symbiotically with nature, using it for our needs while respecting its importance. The roots of this movement can be found in earlier artistic shifts such as the 'land art' movement of the late 1960s, expanding the formal link between art and nature and developing a new appreciation of nature in all forms of art and design. The movement is characterized by the work of a number of artists, designers and architects who express these principles in their work. The pieces are simple, humble and built using the most basic materials and skills, with results often resembling indigenous architecture, reflecting the desire to return to a less technological world. The forms are stripped down to their essence, expressing the natural beauty inherent in the materials and location. The

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movement has many forms of expression ranging from location-based interventions to structures built from living materials. This chapter overviews various methods employed in biotecture, also known as *arbor-architecture or arbortecture*, the form of architecture that uses live green media as the primary building component. It includes techniques developed from many disciplines, including arbor sculpture, botany and familiar gardening techniques such as grafting. All of these involve some method of controlling how a tree or a plant grows. These methods are illustrated through varied examples and advantages and disadvantages are analysed. Selections of tree species suited for biotecture in Indian conditions are identified through a structured interaction with experts. This chapter also reflects upon the potential applications of biotecture in campus design for a more sustainable and greener environment. An analysis of viability of utilising biotecture is carried out at the end in comparison with the conventional methods of construction in practice. From the sustainability point of view, no other form of construction could surpass biotecture. Hence the platform has been set for a more widespread use of this typology in architecture.

Keywords

Natural architecture · Arbortecture · Tree shaping · Aeroponic culture · Sustainable architecture

1 Introduction

The twenty-first century has so far seen an increased sense of consciousness towards our environment and responsibility for our future. Contemporary architecture in its part has tended towards greener materials and increased energy efficiency. Today, sustainability is an important aspect of any architectural project, constantly demanding innovative solutions for sustainability issues. In this search for eco-friendly building materials, one could turn to nature itself for inspiration.

The idea of ‘natural architecture’ first arose in an effort to demonstrate how humans can coexist symbiotically with nature. It proposes that buildings are formed of live green media, i.e. living plants and trees, instead of traditional construction materials. It allows us to construct without adversely damaging nature. Instead, arbour architecture, as it is better known, helps protect the environment and maintain the ecological balance. “*As organic as the materials with which they are built, these creations allow living landscapes to naturally overtake each structure till it finally decomposes*” (Alessandro 2007). Arbour architecture can change the face of architecture as we see it today.

This chapter primarily deals with the incorporation of biotecture into present day architecture. First, the techniques currently in practice are summarised along with an analysis on the selection of plant or tree species. This primary study is used to derive potential applications of biotecture in campus planning and design. Viability of this typology of design has been examined, considering its multiple benefits and various hindrances in its integration into present day architecture. The feasibility of using biotecture has been tabulated.

2 Methods of Arbour Construction

Arbour-architecture, also known as *biotecture or arbortecture*, includes techniques developed from many disciplines, including arbour sculpture, botany and familiar gardening techniques such as grafting. All of these involve some method of controlling how a tree or a plant grows. Arbour architectural designs require careful planning, planting and culturing over time. Designs may be of only living wood or incorporate inclusions such as glass, steel and stone, either as structural or aesthetic elements positioned in a project as it is grown.

The process of arbortecture may begin with detailed drawings of what is to be created, eventually working out how to achieve it, or with the tree species itself, and what it is intrinsically capable of. Each process has a different level of involvement from the tree trainer ranging from continual cutting, pruning and weaving to dramatic instantaneous measures. Most of these processes are still in the experimental and research stages of development. Some techniques are unique to a particular set of species, whereas other techniques are common to all, though implemented differently. The best known methods of creating arbortecture are discussed with examples.

3 Instant Tree Shaping

Instant tree shaping is a technique used on mature trees which have already grown to 2–3.5 m tall and 7.5–10 cm wide (Reames 2005). An instantaneous bow is achieved by making cuts or marks, bending and supporting it till it achieves a desired shape. Once the intervention is finished, the tree may be allowed to grow naturally. Understanding a tree's fluid dynamics is important to achieving the desired result (Reames 2005).Various methods adopted in tree shaping are bending, ring barking and creasing.

Bending is achieved by making a few cuts on one side of a trunk and applying pressure from the other. To prevent the tree from getting cut or the trunk breaking, several cuts are normally made, thereby un-localizing the pressure. The amount of resistance a tree offers depends on its rate of growth. Although the actual bending may be achieved in a few hours, the tree will have to be supported in its bent position till its tissues have overcome their resistance to the initial bending and grown enough annual rings to make the design permanent, which may take several years. *Ring barking*, also known as girdling, is a process of removing a portion of the bark that may be as small as a score or as large as a band 1 cm wide. It is used to reduce the rate or to stop completely the development of branches. It provides balance to the design by getting rid of unwanted growth. *Creasing* is a method of folding supple trees such as willow and poplar over on themselves. It is much more radical than bending and can achieve perpendicular bends (Reames 2005).

The Ash Dome, which was conceived by David Nash in 1977, used 22 ash saplings in a ring 30 ft in diameter. The dome was created using hedgerow methods, mulching and grafting. Bends are created by making one or more V-shaped notches across the trunk in the direction of bending. In some cases a fresh branch was grafted into the main trunk in the direction of the turn. The dome has a lifespan of around 200 years (Alessandro 2007).

The Auerworld Palace, built in Germany in 1998 by Marcel Kalberer and Sanfte Strukturen, is constructed with the living willow system, weaving multiple live saplings of a willow tree together to form structural supports. Over time the foliage grows back from these stems, covering the entire structure (Alessandro 2007).

4 Aeroponic Culture

This is one of the oldest techniques known, formally studied by W. Carter in 1942 when he described "*a method of growing plants in water vapour*" (Carter 1942) or air culture. It was F.W. Went, who coined the word *"Aeroponic"* in 1957 when he suggested spraying a nutrient mist onto roots to help them grow. In 2008, Ezekiel Golan, a root researcher, patented a process of aeroponically growing woody plants such that they may increase in length and thickness while still remaining flexible enough to mould. Once the roots reach around 6 m in length, they are shaped as desired and the plant is allowed to thicken further (Golan 2008). Tel Aviv University Professors Yoav Waisel and Amram Eshel along with researchers at Plantware Co. discovered "*soft roots*" (Green 2008), i.e. certain species of trees grown aeroponically that do not harden. Once the malleable roots grow long enough in the lab, they are moulded around metal frames and the root tips are tucked into the ground, triggering lignifications. The roots start to harden and thicken and the leafy buds begin to grow taller until they grow into the moulded shape.

In Living root bridges, Cherapunji, the people of the Khasi tribe, have, over the generations, developed a bio-engineered footbridge construction, handmade from the aerial roots of the banyan fig tree (Lewin 2012), *Ficus indicus*, which has exuberant root growth from the base, trunk and upper limbs. To accurately direct root growth, guidance systems were developed with betel nut trunks or bamboo sliced down the middle and hollowed out. When they reach the other side of the river, they're allowed to take root in the soil. The principal construction root runs may be up to 45 cm thick. These root bridges take 10–15 years to mature fully, becoming strong enough to support the weight of 50 or more people at a time and they have a life span of over 150 years (Reddy 2010).

5 Gradual Tree Shaping

Gradual tree shaping starts with the design of a support system or growth guide manipulating the way young seedlings grow. Initial saplings would be 7.5–30 cm in length. This is the process with maximum potential for use in architecture as a large amount of control rests with the designer as a continuing hands-on process (Cook 2012).

In the process of *training*, the growth of a plant is guided along predetermined design pathways which may be a wooden jig or complex wire design. The actual shaping of the tree requires day-to-day or weekly guiding of the new growth. However, *grafting* exploits the natural biological process of inosculation. An approach graft is made by winding two or more sections of bark and then binding the wound parts, allowing them to grow together. The vascular cambium of one branch joins with that of the other on extended contact. As new layers of cells form at each point of contact, living wood swells and perpetuates the intended shapes. The primary purpose of such a joint is to cause branches to fuse into a monolith (Cook 2012).

In Botany buildings, Oliver Storz, Ferdinand Ludwig and Hannes Schwertfeger designed structures by grafting young willow trees together. Using a conventional support structure to which young, flexible trees are attached, branches are manipulated into desired shapes over time. Scaffolds direct the growth of the trees. As the grafted trees reach a certain point, the roots are cut off, allowing them to merge into a single organism. The trees can be harvested once they are able to take their own load. At this point, the supports are removed and roofs and floors can then be installed. When they have matured to full strength, the trees will be able to support a tower up to 8 m tall (Beithge 2009; Bridgitte 2009).

Framing is another method of gradual tree shaping which consists of any one or a combination of several materials, such as timber, steel, tubes made of hollow plant parts, complex wire designs, wooden jigs or the tree itself (Reames 2005). It can be used to support grafted joints until the grafts are established or to support a shape created by bending mature trees. It may also be used to prop and shape the growth of young saplings until they are strong enough to maintain the intended shape or to guide the aeroponic roots into desired shapes. In Cathedral of Hornbeams, framing is used to guide the direction of growth of young trees. Wooden formwork, 12 m high, 1 m in diameter, is used to train 80 hornbeams, forming the living columns, straight and firmly upwards. Eventually the wood rots and becomes nutrient for the mature tree. The plants grow by 50 cm every year, eventually creating a botanical cathedral 80 m × 8.7 m, 12 m high (Alessandro 2007).

Pruning is a technique used to balance a design, controlling the direction and rate of growth. It is generally done above a leaf node, which increases rate of growth in that direction. Unwanted branches may also be pruned off. Repeated hard pruning may stunt the growth of a tree or even destroy it. *Pleaching (or plashing)* is a technique that was common in gardens during late medieval times for making hedges, fences and lattices. Deciduous trees planted in lines are shaped into flat planes above the ground with clear stems below. Branches are woven together and lightly tied. Those in close contact grow together because of inosculation (Fredric 1980).

In Patrick Dougherty's sculptures, he used saplings of indigenous trees specially grown for the purpose of sculpture. He first creates a structural skeleton of branches, worked randomly to prevent the ends breaking at the same spot. The second layer is aesthetic to make the surface safe. The last is the cosmetic layer, creating an interesting surface using hatch marks and raking diagonals, emphasis lines (heavier branches) and shading (adding white branches to swirls of red maple). Plant species are chosen for their colour, texture and strength (Huang 2006; Roberta 2000; Beithge 2009).

6 Fab Tree Hab or Prototype Homes: A Case Study

Dr. Mitchell Joachim of the MIT, the pioneer of this concept, proposed the method of growing homes from native trees. The primary load-bearing structure is composed of the thick trunks of trees such as elm, oak or dogwood. These trees are chosen for their self-grafting (or inosculating) properties. The trunks along with the branches are pleached to form a grid structure which is then filled in with smaller plants grown from soil pockets located on the wall. A dense protective layer of vines is woven along the wall. The early stages of plant growth are controlled by prefabricated Computer Numeric Controlled (CNC) reusable scaffolds which graft it into shape. In the interior, a clay and straw composite insulates the structure and blocks moisture. This is further plastered with a layer of smooth clay (Mitchell 2004).

Dwellings are fully integrated into the ecology. The propagators claim that they are:

- Composed with 100 % living nutrients
- Make effective contributions to the ecosystem
- Are accountable for removal of human impacts
- Are involved in arboreal farming and production
- Subsume technology within terrestrial environs
- Circulate water and metabolic flows symbiotically
- Consider the life cycle, from use to disposal (Mitchell 2004)

The structure is as self-sufficient as any tree. It can be watered with the greywater from the home and manure can be supplied from bio-waste generated. It also includes a system for rainwater harvesting, thus also replenishing ground water.

Advantages of this are that it improves the quality of life of the individual and the community and also gives back to nature rather than just taking from it. It has been designed to form food to some organism at every stage of its life cycle. The by-products of Fab Tree Hab are breathing products, instead of the processed and largely non-recyclable materials in the case of contemporary construction. These structures also have a much larger lifespan than brick and concrete structures. It adds a further layer of vegetation to the urban setting and can be a good solution to the problem of positioning urban green belts. As stated in the propaganda, "*the*

Table 1 List of tree species that can be used for arbour construction in India

Ficus Fig	Eucalyptus Eucalyptus	Bambusoideae Bamboo	Populus Poplar
Laburnum golden chain	Terminalia arjuna Arjuna	Malus Apple	Prunus avium Cherry
Prunus persica Peach	Prunus dulcis Almond	Psidium Guava	Pyrus Pear
Anogeissus latifolia Axlewood	Poinciana regia Gulmohar	Fagus Beech Betula Birch	Lagerstroemia indica Crape myrtle
Salix Willow	Quercus Oak	Tectona grandis Teak	Fraxinus Ash

adaptive, renewal, cooperative, evolutionary, and longevity characteristics" (Mitchell 2004) make it an ideal form of building design.

7 Selection of Species

The growth rate, strength, flexibility, adaptability in various environment conditions and lifespan are the most important criteria for selecting appropriate trees (Link 2008). The primary criterion for selection is the region being considered, i.e., how well they grow in a certain climate and geography. The disease and insect resistance of the tree determines its longevity. Since grafting and inosculation are the main means of construction, self-inosculating trees are preferred. Thin-barked species are easier to train and shape. No ultimate list of trees can be prepared but Table 1 lists some trees that grow in India which satisfy the above conditions.

Trees such as teak, gulmohar and wild jack are strong and can be used to form the main support structure of quite large buildings. Plants such as bamboo, willow and woody trunked vines are flexible and therefore can be used to form a variety of shapes. Fig trees such as the banyan, with their aeroponic roots, can be easily guided during growth. Ash is fast-growing and its tolerance for wind, salt and atmospheric pollution makes it ideal for larger constructions in the modern urban context.

8 Applications

A combination of the various techniques described in the previous section can result in a long-lasting as well as eco-friendly architecture. The diverse applications of biotecture in architecture in general and building sustainability in particular are documented here.

9 Building Structure and Skins

Multi-storied structures up to six floors (20 m) in height can be achieved by grafting suitable trees together into a structural framework. Curvilinear forms and meshed verdant skins can be easily achieved through interweaving and inosculation. In marshy or rocky terrains, the roots of the trees form a natural foundation.

10 High Population Areas

Arbortecture can play a large role in mitigating the carbon dioxide-oxygen imbalance in dense population centres. It can improve the microclimate and make it more conducive to human habitation. It can be used to create compound walls, pedestrian over-bridges, road medians, street furniture, bus shelters, playground equipment, etc. thereby increasing site green cover. It also ensures a continuous fresh wind channel within the site.

11 Pollution Intensive Areas

Buildings in industrial areas can be constructed largely of trees to compensate for pollution and clean up the air.

12 Energy Intensive Buildings

Large malls, IT parks, airports, etc. use a large amount of energy and incur tremendous HVAC loads which can be offset with a bio-structure buffer wall between the building and the environment, reducing cooling loads and heat intake and funnelling in wind.

13 Sustainability

They produce oxygen and, if fruit species are chosen, food for their occupants (agro-farms). They can harvest all their own water and energy needs on site. They can also be adapted specifically to site and climate. They operate pollution-free and the system is long-term and renewable: once the trees die, they fertilize the soil for the next construction.

14 Green Buildings

This organic structure incorporates a green roof, has minimal embodied energy because of the onsite availability of raw material, involves no pre-processing, provides thermal insulation keeping indoor temperatures stable and recycles greywater. On-site trees need not be transplanted. The long-term advantages far outweigh any maintenance or lifecycle cost.

15 Environmental Protection

It is a minimally invasive structure which can be used in protected environments, national parks and biosphere reserves. They control soil erosion, prevent landslides in hilly areas, and mitigate soil settlement in areas where the ground may undergo liquefaction. It provides a viable option to build over garbage dumps and landfills. Disposal of bio-waste and biodegradable wastes will go hand in hand with the growth of the structure.

Table 2 Viability analysis of biotecture

Sl. No.	Building component	Characteristics of biotecture	Techniques of building	Best suited for use in	Viability
1.	Structure	Strong, organic structure with a long lifespan, contributes to development of ecosystem, forest regeneration, large incubation period	Instant Tree shaping Aeroponic Training Framing Grafting	Almost any building type and any building site	1
2.	Non-structural walls	Organic forms, needs exposure to sunlight, forest regeneration, large incubation period	Aeroponics Training Grafting Framing Pleaching	Almost any building type and any building site	2
3.	Curtain walls/ Facades	Climate-responsive filtering of natural elements such as heat, light and precipitation, buffer against pollution	Aeroponics Training Grafting Framing Pruning	High density centres with little or no space for planting	1
4.	Roofs	Non-permanent, exposed to elements initially, but eventually foliage densifies to almost impermeable	Instant tree shaping Framing	Gazebos, structures in parks and playgrounds	3
5.	Floors	Can support floors, but a method of creating a stable biotecture floor has not yet been devised	Instant tree shaping Aeroponics	–	5
6.	Site development	Ideal for creation of street furniture such as lamp posts, seating, signage. Erosion control, overall greening of site, rain water management	Aeroponic Training Grafting Framing Pleaching	Large sites, protected environments and reserves	1
7.	Interiors	Internal microclimate modification, require large openings for sunlight	Training Grafting Framing	Furniture	4

16 Viability Analysis

The organic nature of arbour-architecture and its eventual disintegration into the environment facilitates constant renewal. The building materials (plants and trees) are easily available. The tools for bending and shaping are common garden tools such as pruners, shears, saws, shovels and hedge trimmers. Living buildings can produce enough oxygen, harvest water required by the inhabitants and re-use most of the waste generated from the building. It plays a vital role in microclimate moderation. Additionally, live trees are more resistant to rot than harvested wood as the sap keeps away rot by a process called compartmentalization (Alex 1979).They will be mechanically stronger and better rooted than man-made joints. Trees are largely resistant to tsunamis and earthquakes, and therefore these structures would be ideal for disaster resistant buildings.

Despite the infinite advantages of arbortecture, it has some inherent problems which have discouraged inclusion in mainstream construction. Architects have to work within the boundaries of the trees' growth ability. Growth may not be as planned and sometimes the designs have to be adjusted accordingly. The tree tops are the limit for this type of architecture, hence these buildings cannot go beyond a certain height. Harvestable structures have a defined finish point, but larger designs may take years to achieve the design height and several more for the wood calibre to increase to the desired size, and they require frequent maintenance (Link 2008). The size of targeted trees, growth rate, intended design height, local climatic conditions and cultivation and forming techniques used affect the growth period. Regardless, these structures survive as long as the lifespan of the living tree, which is much longer than typical contemporary structures.

The characteristics making biotecture suitable for construction along with its viability on a scale of 1–5, 1 being the best, is given in Table 2.

17 Conclusions

The last decade has seen the world increasingly moving towards greener and more sustainable architecture. Zero-energy homes, roof gardens, climate responsive buildings, agricultural skyscrapers, etc. have become indispensible aspects of this generation of architecture. Arbor architecture integrates all of these ideas into one concept. Analysis of the various methods shows the viability of this method of construction, and its adaptability into every aspect of campus planning and construction. It can be used in structural and non-structural components and is suited for a variety of purposes, both in sensitive environments and dense urban centres. Arbortecture also answers many other questions of sustainability such as availability of raw materials for construction, renewability, construction and environmental costs, waste management, and resource utilisation. From the sustainability point of view, no other single form of construction could surpass it. The platform has been set for a more widespread use of this typology in architecture.

[Query: Please format the references in this list – and in the corresponding lists in the following chapters - in the proper format (regarding capitalization, spacing, use of commas, parentheses and other punctuation). I have already done this in the first chapter as an example. I will check the English and correct it where necessary.]

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Strategies for Sustainable Development of Wetland Resources: Lake Ousteri, Puducherry

E. Devabalane

Abstract

Sustainable development is development meeting the needs of the present without compromising the ability of future generations to meet their emerging needs. The fact that environmental damage hurts people both today and in the future provides additional grounds for rethinking our measurement of progress. Sustainable development is the process of change in which the exploitation of resources, the directions of investment, the orientation of technological developments, and the institutional change are all in harmony and enhance both current and future potential to meet human needs, wants and aspirations. However, ever increasing, multiple demands on water resources for agriculture, irrigation, domestic and industrial supplies have greatly impacted upon the ecosystems. Yet little attention is paid to the restoration, conservation and sustainability of wetland ecosystems which contribute significantly to the food security and economy of the local community. In Puducherry, well-known wetlands are Ousteri and Bahour. During the year 2008, Ousteri wetland, the largest lake in Puducherry, was declared as a bird sanctuary, home for hundreds of species of migratory birds, variety of fishes, mussels and crabs, and breeding site of the common coot in South India. Physiographically, the lake Ousteri, located around 11° 56′–11° 58′ N and 79° 44′–79° 45′ E, is a large shallow wetland situated along the eastern boundary of Puducherry. However, recently the lake and its surroundings have been facing threats from anthropogenic

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activities such as pollution, urbanization, deforestation, encroachment and poaching, which have degraded the lake's ecosystem. Water governance arrangements should protect ecosystems and preserve or restore the ecological integrity of all natural water bodies and their catchments. This will maintain the wide range of ecological services which healthy ecosystems provide, and the livelihoods that depend on them. With this backdrop, the study deals with primary and secondary sources with survey methods on socio-economic and biological, flora and fauna parameters in and around the lake area. Conservation and sustainable management is urgently required with appropriate institutional arrangements for sustainable development, implementation of policy, and long-term planning strategies with sustainable management action plans, with the aim of achieving the desired objectives with the help of community involvement.

Keywords
Sustainable development · Wetland ecosystems · Planning strategies · Bio-physical · Anthropogenic · Food security

1 Introduction

Water and bio-diversity are resources of life and livelihood or the options for poverty reduction and enhancing the human welfare. Water is a prime natural resource, a basic human need for life and a precious national asset; hence its conservation is everyone's duty and human beings like to live near water. Wetlands are defined as "lands transitional between terrestrial and aquatic eco-systems, where the water table is usually at or near the surface or the land is covered by shallow water" (Mitsch and Gosselink 2000). The value of the wetlands are of increasing interest because their contribution to environment health in several ways has been experienced through conservation. Conservation means careful use of resources which may even lead to the sacrifice of present economic interests on behalf of posterity (Zimmermann 1951). Conservation also has the twin objectives of prevention and improvement so as to meet the need of future generations. Wetlands retain water during dry periods, thus maintaining the water table high and relatively stable. The removal of such wetlands in the name of globalisation, urbanisation and other human interventions can cause severe threat to such resources and supporting species diversity. Wetlands are areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 m (Ramsar Convention 1971). In India, wetlands estimated at 58.2 million ha distributed in almost all bioclimatic regions are an important repository of aquatic biodiversity. Puducherry, well known for water bodies, especially wetlands numbering 82 major and minor located around Puducherry, provides a livelihood for the local residents in the form of agriculture, fishing, fuel, fodder and other daily needs. In Puducherry there are two major wetlands—Ousteri and Bahour. The Government of India has been implementing the National Wetlands Conservation Programme (NWCP) in collaboration with the States and UTs since 1956. Under this programme, 115 wetlands had been identified (Anon 2009). In Puducherry, the Ousteri wetland had been selected and declared as a wetland of national importance and also as a bird sanctuary in the year 2008. The sanctuary is also known for a wide variety of fish, mussels and crabs. In the past, the lake has also served as the largest breeding site for the common coot in South India (Chari and Abbasi 2008). Recently, the lake has been facing serious threats and pressure from several anthropogenic activities such as poaching, unsustainable fishing and pollution. Encroachment, hunting of birds, dumping of solid wastes in and near the lake embankments, littering around the lake by tourists and local visitors, frequent vehicular movements by light and heavy motor vehicles, wastewater discharge into the lake, and rapid urbanization, infrastructural developments in the vicinity of the lake, agro chemicals, pesticides, weed infestation and soil erosion all call for an extensive field study which is urgently needed to ensure sustainable development and strategies for maintaining effective ecological balance, and, at the same time, achieving the objectives of sustainable wetlands in Puducherry, particularly Lake Ousteri.

2 Wetlands as Water Resources: Challenges and Concerns

There has been widespread failure to recognize the vital role of water resources in providing food, energy, disaster relief and environmental sustainability, the reason being that there are no proper markets or values for the goods and services derived from the water ecosystems. The competition and conflict for water by divergent users in the society and community both upstream and downstream are an emerging issue. Wetlands provide many services and commodities to humanity, and they perform numerous valuable functions such as recycling nutrients, purifying water, maintaining stream flow, restoring groundwater levels, attenuating floods, providing potable water, fish, fodder, fuel, wildlife habitat, buffer shorelines, leisure, recreation and tourism activities to society and the local community. Wetlands are often considered as "Kidneys of the landscape" (Gosselink and Mitsch 1986). The interaction of human beings with wetlands during the last few decades has been of concern, largely because of the rapid population boom, intensified industrial growth, real-estate and commercial activities, residential development, tourism, and promotional activities, leading to pollution by air and water (fertilizers, weed killers and insecticides). Unfortunately, pollution from agriculture often constitutes a greater total pollutant load for the water bodies and proper management options are not in place. Hydrologic conditions can directly modify or change chemical and physical properties such as nutrient availability, degree of substrate anoxia, soil salinity, sediment properties and pH. These modifications of the physiochemical environment, in turn, have a direct impact on the biotic response in the wetlands (Gosselink and Turner 1978). Wetlands loss refers to the physical loss in the spatial extent or loss in the wetlands function. The loss of 1 km^2 of wetlands in India will have much greater impact than the loss of 1 km^2 of wetlands in low population areas of abundant wetlands (Foote et al. 1996). The demand for wetland products will increase with increasing population. However, the fact that the wetland products are overlooked has resulted in a threat to the resources and benefits which finally results in the degradation of wetlands. Realizing the importance of wetlands, the Ramsar Convention in 1971 has urged member countries to designate noted wetlands as Ramsar sites or wetlands of international significance. Many conservationists recognised this and a wetland conservation strategy should therefore receive widespread support (Choudary 2000). Investments for the conservation of wetland resources from private and public are insufficient. The strategy for sustainable development not only conserves precious aquatic biodiversity but also reserves of ecologically and economically useful flora and fauna genetic resources. The present study is a humble attempt to assist with initiating the green off-campus project on Lake Ousteri, a well known wetland in Puducherry, conducted by the Department of Tourism and Travel Management, under the direct supervision of the author.

3 Objectives of the Study

To estimate the current status of the lake
To study the socio-economic and flora and fauna values of the lake
To create a conservation model for the lake
To develop strategies for sustainable development of the lake

4 Methodology

The methodology adopted during the study is through primary and secondary sources. The primary data is collected through survey techniques by preparing questionnaires. Apart from this, community interaction is conducted so that perception and attitude towards the lake are also identified. The study period is short in duration, 2 months, November and December. Hence an in depth analysis of the study has its own limitations. More than 111 samples had been tested with the questionnaire, but 100 respondents had been taken for the study.

5 Lake Ousteri at a Glance

Ousteri lake is situated near the village Ossudu, at 11° 57′ N, 79° 45′ E, partly in Puducherry and Tamil Nadu state (Fig. 1). Whereas much of the Ousteri lake is located in Tamil Nadu, which consists of rural settlements and in Puducherry, the lake is predominantly suburban. Ousteri lake is the largest freshwater lake of Puducherry region, covering some 700 ha when full after a normal monsoon. It can store 540 million cubic feet of water, capable of irrigating close to 3,800 ha of land. According to the legend, in recognition of Oosi's selfless service, the lake was named Oosteri which, in due course of time, was rechristened Ousteri. The resulting lake has a perimeter of 7 km and 15 km^2 of catchment area. During the rainy season, the lake would resemble an ocean with a vast span of bluish water. During the French regime in Puducherry, the lake continued to be a major source of water resource and irrigation to more than seven villages. However, the command area of the lake has rapidly dwindled over the years; practically speaking, nothing is now irrigated by the lake. The local farmers of that region, encouraged by subsidies from the government and bank loans, have shifted to bore well irrigation. With the help of these bore wells, more groundwater is withdrawn, creating a major threat to the groundwater level table in terms of loss of height, salinity intrusion and pollution and disuse of canal networks to the surrounding areas. Despite this, the lake has its physical structures intact and stable ecosystems with moderate disturbances which need sustainable development to maximize its benefits for the future (Figs. 2, 3 and Table 1).

Fig. 1 Lake Ouster

Fig. 2 IRS IC LISS III satellite imagery of the study area

Fig. 3 Classified land use/land cover map of the study area

Table 1 Facts about Lake Ousteri

S. no.	Particulars	Details
1	Longitude	11° 56′–11° 58′
2	Latitude	79° 44′–79° 45′
3	Elevation above Mean Sea Level	~15 m above MSL
4	Name of the sub-taluk	Villianur
5	No. and name of the village	29-Oussudu
6	Survey field no.	8
7	Extent and capacity	390 ha–00A-39Ca.
8	Boundaries	South: Oussudu and Koodappakkam villages, West: Ramanathapuram and Thondamanatham villages; and North: Tuthipet and Karasur villages
9	Climatic conditions	Annual Mean Max Temp: 33.1 °C
		Annual Mean Min Temp: 24.1 °C
		Annual Total Rainfall: 1,338 mm
10	Major land use types around the lake	Agriculture, cash crop plantation and human habitation, Scrub jungle, water body
11	Nearest highway	State highway Pondicherry-Thirukkanur-Viluppuram (~35 kmSW)'
12	Nearest Railway Station	Puducherry RS (~13 km, NW)
13	Nearest Airport	Lawspet, Pondicherry (~12 km, NW)
14	Nearest Port	Chennai (~165 km, NE)
15	Nearest major habitation	Villianur (~km, SW)
16	Nearest major town	Pondicherry (10 km, SE)
17	Reserved Forests	Nil
18	Historically important places	(Auroville, ~10 km), Pondicherry Museum and Library and Arikamedu (~8 km), Gokilambal Thirukameshwara Temple at Villianur (~4 km), Sri Aurobindo Ashram (~10 km), Promenade (~10 km), Lighthouse near the sea (~10 km)
19	Rivers/streams around the lake	Sankarabharani river (~2 km, South) and Pennaiyar (~7 km S)
20	Major dams and barrages	Suthukeni barrage (~6 km, NW) Vidur dam
21	Other major industries (with distance from the lake in parentheses)	ABC Engineers (~1 km)
		REIL Electricals (~1.5 km)
		Hindustan National Glass and Industries Ltd (~1 km)
		Sunbeam Generators Pvt Ltd (~0.5 km)
22	Survey of India Topo sheet covering the lake and surroundings	58 m 1/16
23	Seismic zone	Zone-III

Wetlands play a vital role in maintaining the overall cultural, economic and ecological health of the ecosystem; their fast pace of disappearance and threats from the landscape is of great concern. The Wildlife Protection Act protects a few of the ecologically sensitive regions whereas several wetlands are becoming an easy target for anthropogenic exploitation. However, from a practical conservation planning and sustainable development point of view, the immediate need is to identify and classify the biological habitats and aquatic vegetation.

In the study area, and its environs, among the 480 species, 191 herbaceous plants are present (41 %), 103 tree species (21 %), shrubs 63 species (13 %), climbers 40 species (8 %), 20 species (4 %) and grasses 63 species are growing (13 %) in and around lake Ousteri. Of the 480 species, 11 are found to be endemic (*Andropogon pumilus*, *Asystasia dalzelliana*, *Barleria acuminata*, *Cynodon barberii*, *Drypetes roxburghii*, *Iseilema anthephoroides*, *Jatropha tanjorensis*, *Maba buxifolia*, *Phyllanthus rotundifolia*, *Sarcostemma brunonianum* and *S. intermedium*) and are distributed only in the Indian sub-continent, More than 20 species found to be on the endangered list have medicinal values. Ousteri is not only rich in flora but also in fauna. It has become a major attraction for tourists and visitors to the lake for watching butterflies, amphibians, reptiles, birds, mammals. There are 63 species of butterfly under 46 genera and spread over 5 families, Nymphalidea is dominant with 21 species (34 %), followed by Pieridea with 14 species (22 %) and Lycaenidea 10 species (16 %). Wetlands such as Ousteri have become a resting site for migratory birds and Lake Ousteri has been declared as a bird sanctuary because of its wealth of avifauna, 166 species of birds belonging to 47 families being recorded and spotted in the lake zone, both of terrestrial and aquatic habitats. Of the 47 families, Muscicapidae is the dominant one with 16 species followed by Accipitridae (12 species), Ardeidae (11 species) and Anatidae (10 species). Of this 166 species, the spoon-billed sandpiper is “critically endangered” and the white-bellied sea eagle comes under the category of “endangered”. Apart from these, birds such as the flamingo, darter, spot-billed pelican, great white pelican, painted stork, Eurasian spoonbill and pallid harrier are approaching the threatened category (Balasubramanian and Vijayan 2004). The lake and its surroundings are rich in amphibians with 10 species such as cricket frog, common Indian toad, Indian bullfrog and 29 reptile species recorded, including turtles, lizards, snakes. There are 25 species of fish in the lake. Species such as *Catla Catla*, *Mystus vittatus*, *Heteropneustes fossilis*, *Channa orientalis*, *Clarias batrachus*, *Etroplus suratensis* and *Mystus gulio* are vulnerable species. Two species, namely *Channa striatus* and *Gambusia affinis*, fall in the low risk—least concern category. Three species, namely *Oreochromis mossambica*, *Cyprinus carpio* and *Hypophthalmichthys molitrix*, are exotic. The remainder of the ten species are included in the less risk category. Fourteen species of mammals are also present in and around the lake. Species such as spotted deer, jackal, jungle cat, common mongoose, black napped hare, bonnet macaque, Indian porcupine, bandicoot rat, three stripped palm squirrel, Indian pangolin, Asian palm civet, mice, short nosed fruit bat and flying fox appear. From the ecological point of view, the diversity of species present in the wetland is an indication of its relative importance and its significant value to the overall ecosystem. The study is based on the primary data collected from the respondents and interaction with the population living near the lake. More than 21 villages are dependent directly and indirectly on the lake for several reasons of their own, especially for the socio-economic benefits. The lake is useful to the people in several ways, namely for providing potable water, irrigation, recharging groundwater level, climate regulation, pollination, water regulation, natural hazard regulation, commercial fishing, fodder and grass for cattle grazing, desilting, reed cutting, recreational, tourism, aesthetic reasons, water sports, nutrient cycling, soil formation, watershed and agriculture.

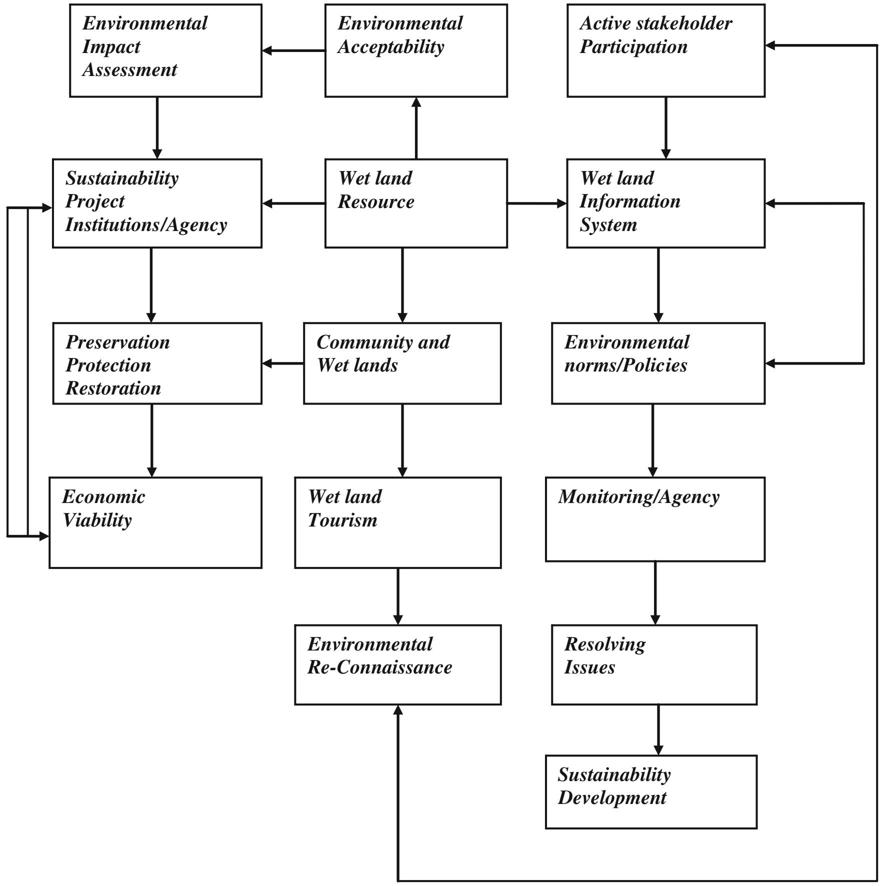
6 Some of the Findings of the Study

The important findings relevant to the study are:

- 44 % of people say that monoculture cropping is practiced, especially in paddy and sugarcane, casuarinas, coconuts and teak
- 21 % say the lake is the only livelihood for them
- 33 % believe that their alternative livelihood is self-employment, entrepreneurship and livestock rearing
- 24 % started poultry farms and aqua culture
- 55 % of the farmers around the lake are involved in organic farming instead of fertilizers; they are using eco friendly manures such as dried cow dung, azospirillium, vermicompost and phosphobacteria
- 12 % of the nearby population uses the lake for potable purpose
- 23 % of the population use it for agricultural irrigation
- 16 % of the population are involved in direct fishing from the lake, 10 % are involved in hunting and poaching birds (pelicans, coots, darters and frogs)

From the findings we are able to assess the necessity for a sustainable development module for the lake.

Module 1: Off - campus sustainability development module for wet lands: Lake Ousteri



Source: **The Author**

7 Shift from Obligation to Strategy Towards Sustainable Development

The general principle of sustainable development adopted by the World Commission on Environment and Development that current generations should "meet their needs without compromising the ability of future generations to meet their own needs" has been widely accepted. A society may in many ways compromise its ability to meet the essential needs for the future generations by over-exploiting resources. Sustainable development requires promotion of values to encourage consumption standards within the bounds of the ecologically possible and to which all can reasonably aspire. Long-term sustainable development requires an understanding of the interaction between human activities and natural processes. It means managing resources efficiently and maximising the benefits we get from them so as not to overload the water ecosystem. A strategy is “a combined set of participatory and continuously improving processes of analysis, debate, capacity strengthening, planning and investment which integrates the economic, social, cultural and environmental objectives of society, seeking trade-offs where this is not possible”. The strategies designed for the study area, Lake Ousteri, after considering the perceptions and opinion of the local population, government, NGOs, local bodies, planning departments, forest and environment authorities, are as below.

To ensure the sustainability of the natural resource base, the recognition of all the stakeholders in it and their roles and responsibilities in its protection and management is essential.

The traditional approaches to natural resources management in lake water harvesting and management system should be revived by creating institutional mechanism with ecological wisdom and the spirit of inherent community management.

To establish well-defined and enforceable rights and security of tenure and to ensure equal access to land, water and other natural and biological resources, to local communities, women and other disadvantaged group of the population.

Good water governance and restoring the ecological integrity of all water bodies and catchment areas and their livelihoods.

Lake clean development mechanism strategy (LCDM) can be achieved by providing financial assistance to sustainable development programmes with clear-cut objectives.

Education on Sustainable Development Strategy initiatives with functional literacy to create a responsible citizen for sustainable livelihoods with awareness, attitudes, skills and concerns is of paramount importance.

User community pyramid strategy by using integrated and appropriate technological solutions and the applications thereof for the success of the sustainable development of the people.

Societal Radar Development strategy should be applied to monitor and view how the targeted community had benefitted from the user community pyramid (Kalam 2012).

The objective of the pyramid model was providing safe drinking water and water for irrigation in a sustainable way, reducing pollution, and thereby bringing peace and economic prosperity to the dependents of the lake.

Adopting a 3R strategy—Reduce, Reuse, Recycle—will solve major issues in conserving water bodies is an ideal solution to address the sustainable development.

Value-based environmental education encompassing ethical standards of earth centric rather than human centric is urgently needed.

Change in lifestyle of the citizen should go a long way to attain sustainable development and water body conservation.

Empowering civil society through integrated participation management, by creating genuine partnership between government, business, community, voluntary organizations, panchayats, local bodies and municipalities since the problems are too complex to be otherwise resolved.

Create a pragmatic tool box for government sustainable development managers and policy makers.

Landscape beauty for the lake's scenic view, space for tourism, recreation and for the local residents with eco-friendly attitudes.

The need for a holistic and integrated approach to biodiversity and water management through developing an ecosystem approach strategy for integrated management of water, land and living resources, without compromising the sustainability of aquatic ecosystems, should be the benchmarks.

8 Conclusion

Our unique wetlands, which are rich in aquatic diversity and bird life, providing food and shelter as also the breeding and spawning ground for the freshwater fishes, are facing problems of pollution and over-exploitation. The excessive use of fertilizers and pesticides threaten the local population and the genetic stocks of the water bodies, and reduces the natural soil fertility in the long run. The water table is receding because of over use of ground water in the surrounding areas of the lake. Large numbers of industries and other development projects have resulted in pollution of water bodies, which is an undesirable phenomenon for the lake ecosystem. However, the benefits derived from the business are not shared equally by the local communities, so access and benefit sharing is the success mantra for preserving natural biodiversity such as wetlands.

To conclude, development has to be sustainable and all round, whether for the poor, village folk or urban people, and the sustainable development models have to be reviewed and followed. Hence the classification, zoning and regulations for maintaining the quality of water bodies to protect and enhance their capabilities to support the various designated use of wetlands must be considered. Promotion of tourism should be based on careful assessment of the carrying capacity and support facilities without affecting the lifestyles of the local people. Strengthening local bodies, panchayats, samitis, for optimal resource management and contingency plans is advisable for micro-level planning to develop appropriate methodology and implementation of action plans by involving people at village level in social forestry, land use planning, afforestation, watershed management through catchment treatment of drainage areas, protection of vegetal cover, fishing activities, environmental sanitation, GIS tools for monitoring, strengthening enforcement machinery, and the importance of water bodies renewable resources should be recognized. Therefore the task of sustainable development is never daunting if people's changes in concern over environment, the media, public, youth and children are effective and this beautiful Lake Ousteri, recognized as Oosi's selfless service, can appear on the international map of Ramsar as important "must see" wetlands of the world. Therefore, meaningful sustainable development can be achieved, and the people's involvement in managing water and other natural resources is very crucial.

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Developing Pondicherry University Silver Jubilee Campus as "Solar Campus"

Dwipen Boruah, R. Arun Prasath, G. Poyyamoli, M. Nandhivarman and Golda A. Edwin

Abstract

Pondicherry University. located at R.V. Nagar, Kalapet, Pondicherry, is a Central University established in 1985 by the Government of India. This is the fastest growing university in India. It is a collegiate university with a jurisdiction spread over the Union Territories of Pondicherry, Lakshadweep and Andaman and Nicobar Islands. It has successfully completed its 25th year of existence. The Silver Jubilee campus of Pondicherry University is a new campus of 110 acres in its 800 acres of campus. This area would soon house 12 buildings and 2,500 students. Prime Minister of India Dr. Manmohan Singh formally inaugurated the Silver Jubilee Campus of Pondicherry University on 30 June 2012. The Department of Ecology and Environmental Sciences and the Madanjeet School of Green Energy Technology of the University jointly have taken the initiative to develop the silver jubilee campus as "Solar Campus" which will be the first of its kind in India. The University is receiving financial assistance from the Ministry of New and Renewable Energy (MNRE), Govt. of India for preparing a master plan and detailed project reports for this purpose.

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The objective of preparing a master plan for the “Solar Campus” is to understand and assess the carbon footprint of the campus and prepare an action plan to implement energy efficiency, substitution/conservation measures and implementation of renewable energy projects to achieve a targeted goal of reducing conventional energy consumption and thereby cutting down GHG emission in the campus. This chapter will discusses the detailed master plan for the “Solar Campus” which includes assessment of the carbon footprint from energy consumption, transportation, water use and waste generated in the campus, proposed measures for energy efficiency and energy conservation, renewable energy resource assessment, proposed renewable energy projects and an action plan to achieve the set goal for the “Solar Campus”.

Keywords
Pondicherry University · Solar Campus · Carbon footprint · Renewable energy · Energy conservation

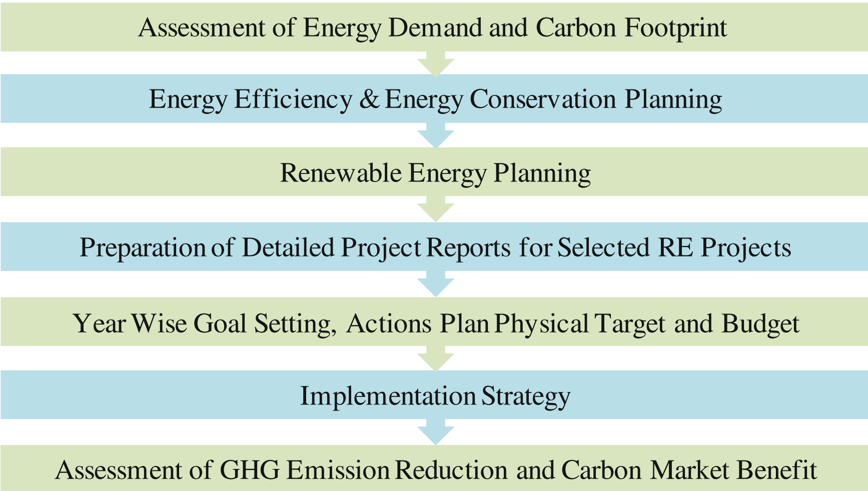
1 Introduction

Pondicherry University, located at R.V. Nagar, Kalapet, Pondicherry, is a Central University established in 1985 by the Government of India. Silver Jubilee campus of Pondicherry University called for a new approach and a modern development in a 100-acres pocket in its existing campus. This area was supposed to house 12 buildings and 2,500 students.

Pondicherry University is one of the pioneer universities, taking initiatives for promotion and use of renewable and green energy technologies both in academic practice and implementation. In 2010, Pondicherry University took a lead in creating a Centre for Green Energy Technology (CGET) to conduct teaching and research in the fields of environmentally benign “Green Energy Technologies”. This step was taken in order to develop the much-needed manpower as well as provide research and development in renewable energies for sustainable development. Currently, the center conducts M.Tech course for 26 students per year and research-level programs in green energy technologies (Fig. 1).

The objective of developing Pondicherry University Silver Jubilee Campus into a “Solar Campus” is to understand and assess the carbon footprint of the university campus as a whole and to prepare an action plan to take energy conservation measures and implement renewable energy projects to achieve a targeted goal to reduce conventional energy consumption and thereby reduce GHG emission in the campus. The master plan and Detailed Project Reports for Selected Renewable Energy Projects has been prepared following the steps below.

Fig. 1 Solar PV system in the Silver Jubilee Campus. *Source* Author



2 Assessment of Energy Demand

Electricity is the major energy component consumed by the facilities in the Pondicherry University Silver Jubilee Campus. All major facilities such as buildings, water supply, sanitation, outdoor lights, and electric vehicles consume electricity. Electricity is supplied from grid which is received at 22 kVA and stepped down to 430 V for distribution to buildings. There are five substations with 500 KVA, 22 KV/430 V transformers for different buildings and bocks. Diesel generators are used as standby power supply sources during load shedding. Five diesel generators of capacity 125 KVA each are installed attached to the substations. In the event of grid failure, diesel generators start automatically to supply power to the buildings concerned to power limited essential loads. Electricity consumed by the Silver Jubilee Campus is part of the entire electricity consumption

Fig. 2 Battery operated vehicle and pick and ride bicycle. *Source* Author

by the university campus. There is no separate energy meter to measure or monitor the electricity consumed by the Silver Jubilee Campus or buildings/establishments in the campus. A total of 60 solar streetlights with capacity of solar module of 2 × 75 Wp each have been installed in the campus.

The canteen in the campus serves tea, coffee, snacks and fast food. Most of the food served in the canteen is prepared in the major canteen in the main campus. As reported by the canteen manager, average LPG consumption in the canteen is 4–5 cylinders of 19 kg per month.

The Silver Jubilee Campus is about 2 km from the main gate No. 1 and about 2.6 km from the gate No. 2 of the university. The transport department of the university uses large buses with sitting capacity 30–36 passengers to and from the Silver Jubilee Campus. These buses make 15 trips during the working day to and from the campus. Estimated additional diesel consumption for the Silver Jubilee Campus from the main campus for 200 working days per year is about 3,000 L.

Battery Operated Vehicles with sitting capacity of 14 passengers run from gate No. 1 to Silver Jubilee Campus at scheduled times with an interval of 30–75 min. These vehicles make 11 trips each working day. These vehicles are rated with a maximum power of 5 kW and estimated electricity consumption for 11 trips per day for 200 working days per year is about 5,500 kWh.

There are 'pick and ride' bicycles freely available in stands near the main gates. Though there are 500 bicycles, most of them are not maintained properly and can be seen lying idle and scattered in the campus (Fig. 2).

3 Water Use

The water supply system in the Silver Jubilee Campus is under construction. There will be a central ground water lifting and storage system for the campus. A temporary arrangement has been made for supply of water for building sanitation, canteen and sprinkling irrigation for the gardens and plants. The estimated energy consumption by the water supply system is about 23,872 kWh of electricity per year.

4 Waste Generated

The Silver Jubilee Campus produces very little waste at present. However, the campus is going to generate a considerable amount of waste, both degradable and non-degradable, once it is fully expanded as planned. The Silver Jubilee Campus will accommodate 2,500 students in different hostels and 60 residential apartments, a contention centre of 2,500 capacity and a multipurpose auditorium in future. It is estimated that about 2,000 kg of bio-waste will be generated when the campus is fully occupied as planned.

5 Energy Consumption by Type of Energy Source

The estimated energy consumption by the Silver Jubilee Campus is 1,324.84 MWh per year. The major share (87.54 %) of energy is electricity supplied from the grid followed by electricity supplied by diesel generators (8.65 %). Consumption of diesel for transportation is 2.49 % and LPG 1.32 %.

6 Energy Consumption by Appliances

Air conditioners are the largest consumer of electricity, sharing 41 % of total consumption followed by the building lighting load (22 %), street lighting load (11 %), ceiling fans (9 %) and other appliances (17 %).

7 Future Loads

The Silver Jubilee Campus is under development and not all buildings are constructed or completed. Apart from the planned expansion of 7,100 m^2 of floor area in the existing buildings, the university has future plans to construct six buildings of aggregate area 69,600 m^2 within the silver jubilee campus. Total projected energy demand for additional buildings in the Silver Jubilee Campus will be about 253 lakh units of electricity equivalent, which is about 20 times the present energy consumption.

8 Suggested Energy Conservation Measures

Most electrical appliances in the Silver Jubilee Campus are new and energy efficient. Based on our survey and assessment in all the buildings, we are suggesting the following energy conservation and energy efficiency measures for the silver jubilee complex:

- Use of sensors for automatic ON/OFF of indoor lights and exhaust fans
- Use of LED lights
- Dusk to dawn sensors for automatic ON/OFF of outdoor/streetlights
- Use of power savers
- Energy efficiency measures in water pumping

9 Renewable Energy Planning (Stapleton and Neill 2012)

The mean annual average of global horizontal solar insolation in Pondicherry is 5.36 kWh/m^2/day. For calculating thermal energy generation through a concentrating dish, direct normal irradiance is considered. The Monthly Averaged Daily Direct normal irradiance at the given site is 4.72 kWh/m^2/day. Figure 3 shows monthly average global horizontal irradiance (GHI) and direct normal irradiance (DNI).

The Centre for Wind Energy Technology (C-WET) has installed four wind monitoring stations in the union territory of Pondicherry, out of which two stations were located in Puducherry. The best site has a mean average wind speed of 4.44 m/s and mean average wind power density at 25 m height is 88 W/m^2.

10 Potential Renewable Energy Projects

Based on energy demand assessment, resource assessment and site survey, the following projects have been identified for the Silver Jubilee Campus of the Pondicherry University (Fig. 4; Table 1).

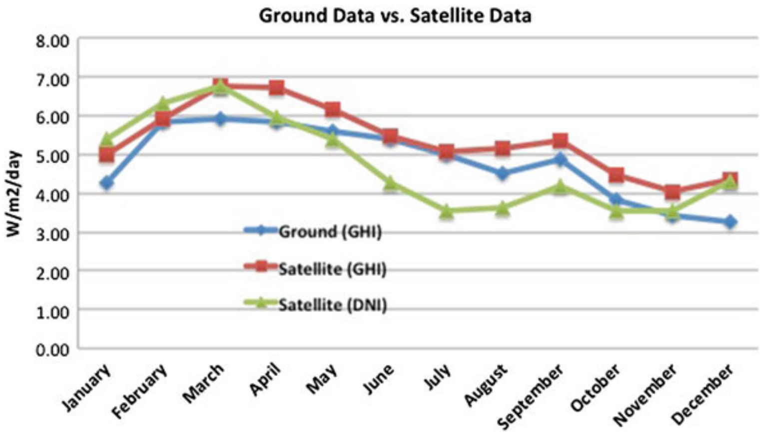


Fig. 3 Solar radiation in pondicherry. *Source* EOSWEB (2013)

Fig. 4 Placement of wind turbines in Silver Jubilee Campus. *Source* Author

Table 1 Capacity of renewable energy systems in different buildings

Locations	Capacity	Nos.	Total capacity
Solar photovoltaic systems			
Car parking sheds	10 kWp	4	40 kWp
Car parking sheds	13 kWp	2	26 kWp
Building roofs	30 kWp	3	90 kWp
Building roofs	38 kWp	8	304 kWp
Outer ring of inner circle landscape	40 kWp	4	160 kWp
Solar water heating system			
Academic Staff College	1,000 LPD	1	1,000 LPD
Canteen	500 LPD	1	500 LPD
Wind turbine systems			
Small wind turbines	10.8 kW	20	216 kWp

11 Annual Energy Savings Target

See Table 2.

Table 2 Total energy demand and fraction of energy to be saved from renewable energy and energy efficiency measures

Year	Energy consumption and savings in MWh per year				
	2013	2014	2015	2016	2017
Total energy demand	2,650	3,313	3,975	13,250	26,500
Energy from RE	337	674	1,713	3,533	6,566
Percentage of RE fraction	13	20	43	27	25
Energy savings from EE	398	497	596	1,988	3,975
Percentage of EE fraction	15	15	15	15	15
Percentage of RE and EE combined	28	35	58	42	40

12 Annual GHG Reduction Target

See Table 3.

13 Project Cost and Sharing of Budget

See Table 4.

14 Cost Benefit Analysis

The 620-kWp PV power plants will generate an average 939.99 MWh of electricity per year, which will be directly used as captive power. The university will save Rs. 31.96 lakh per year from the electricity savings from the grid at the rate Rs. 3.40 per unit. It is expected that using solar PV systems will totally offset the use of diesel generators in the silver jubilee campus which will save estimated 11,200 L of diesel every year.

It is estimated that use of 1,000 LPD capacity solar water heating system for 120 days a year will save about 50 MWh of electricity. This will save an amount of Rs. 1.70 lakh per year @ Rs. 3.40 per unit of electricity. On the other hand, use of 500 LPD capacity solar water heating system for 200 working days in the canteen will save 4.72 G Calories of energy per year which will save about 465 kg of LPG per year, saving about Rs. 36,000.00 per year.

Table 3 GHG emission and reduction per year

Year	GHG emission and reduction per year in $MtCO_2$ equivalent (considering emission factor for southern India as 0.84)				
	2013	2014	2015	2016	2017
Total GHG emission	2,226	2,782.5	3,339	11,130	22,260
Emission reduction from RE	283	567	1,439	2,968	5,516
Emission reduction from EE	334	417	501	1,670	3,339

Table 4 Project cost and sharing of budget

	Solar PV system	Wind energy system	Solar water heaters	Total
PV systems	866.14	208.08	4.52	1,079
MNRE share	259.84	104	1.36	365
PU share	606.30	104	3.16	714

Considering 20 % plant load factor, 216-kW wind farm will generate 37.84 MWh of electricity per year, which will save grid electricity worth Rs. 12.86 lakh per year @ Rs. 3.40 per kWh.

15 Renewable Energy Certificates

As per Central Electricity Regulatory Commission (Terms and Conditions for Recognition and Issuance of Renewable Energy Certificates (REC) for Renewable Energy Generation) Regulations, 2010, Pondicherry University will be eligible for benefit as a renewable energy generator and could avail this benefit by selling REC generated by the proposed PV power plants. The floor and forbearing price of REC is Rs. 9,880.00 and Rs. 13,690.00 per REC for the period 2013–2017. Considering an average REC selling price of Rs. 10.00 per unit of electricity generated by the PV power plant, the university can sell REC worth Rs. 94.00 lakh per year in addition to saving electricity and diesel. To register the project under REC mechanism, the university will not receive any subsidy or other benefit for the power plants (MNRE 2013).

16 Future Renewable Energy Projects

The expansion plan of Silver Jubilee Campus includes large hostels for 2,500 students, 70 apartments, a multipurpose auditorium and an international convention hall in the future. Once completed, the energy demand for the campus will be 20 times the present energy demand. To offset about 20 % of projected demand, we propose the following renewable energy systems for the future buildings and activities:

- Solar water heating systems for hostels and residential apartments
- CST based steam cooking system for hostel mess
- Bio waste based biogas systems

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Authors Biography

Dwipen Boruah graduated in 1990 as a Mechanical Engineer and completed his Postgraduate Programme on Renewable Energy (PPRE) from Oldenburg University, Germany. He has more than 22 years of experience in renewable energy engineering design, planning, research, project management and training. He has experience of working with a number of local, regional and national organisations in several countries and has proven knowledge of renewable energy technologies, barriers for deployment, methods and approaches applied in the field of technology roadmaps. Dwipen also authored or co-authored books and training manuals on solar PV system design installation, maintenance and inspection; he has to his credit training manuals on improved cook stoves, more than 60 technical and professional reports and several articles in the technical magazines and journals.

Dr. R. Arun Prasath obtained his doctoral degree in Chemical Science/Materials from Anna University, India. He was a recipient of prestigious DAAD fellowship, (1999–2001) for his doctoral research work at Max-Planck Institute for Polymer Research, Mainz, Germany. After his doctoral degree he worked as material researcher in several prestigious institutes; as research associate in Indian Institute of Science, Bangalore, India (2002–2004), as postdoctoral researcher in University of Strathclyde, Glasgow, United Kingdom (2004–2006) and in University of New South Wales, Sydney, Australia (2006–2008), and as senior researcher in Ghent University (2008–2010) with a special fellowship called BOF. He has published more than 20 peer-reviewed journal articles, more than 10 published articles in proceedings and book chapters, and is co-inventor in 3 International patents as well as in 2 European patent applications. For his profession development, he has visited Germany, United Kingdom, Australia, Belgium, Brazil, Italy and Bangladesh. He has given more than 45 oral presentations in various conferences/seminars/courses/invited talks. He is actively involved in teaching and research on renewable energy from 2010 onwards.

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Nandhivarman Muthu received his Masters degree in Zoology and has over 10 years experience as an environmentalist, researcher and an activist for sustainable development. He is currently pursuing his doctorate from Pondicherry University, India. His research interests include an extensive study to evolve policies and implement Green Campus Initiative in Pondicherry University. The main objective of this research is to assess and provide factual solutions to the educational institutions such as schools and colleges to make it sustainable with special reference to water, energy and waste management.

Golda A. Edwin is a researcher at Pondicherry University. She has been involved in a number of green campus projects in her region and had implemented meaningful sustainability projects. She decided to pursue her research and career in water science because of her passion for addressing the challenges of sustainable water management in developing countries. Her core area of research is abatement of water pollution using eco-technologies. She authored several articles and presented her findings in several national/international conferences and workshops. She was awarded the Gold medal from Pondicherry University for her outstanding academic excellence. She is also one of the Founders and Executive Director of Association for Promoting Sustainability in Campuses and Communities (APSCC).

University, County Government and Community Partnership for Wetland Conservation and Ecotourism Development on the Shores of Lake Victoria, Kenya

W.H.A. Olima, P.O. Hayombe and I.M. Nyamweno

Abstract

This chapter provides a comprehensive account of the institutional interface for wetland conservation and promotion of ecotourism on the shores of Lake Victoria, Kenya. This intervention is part of the ongoing Kisumu Local Interaction Platform (KLIP) under the *MISTRA Urban Futures Program* headquartered in Gothenburg, Sweden. Wetlands are fragile ecosystems which provide a stream of ecological services to mankind. These services are grouped into three broad categories: (1) hydrological processes, (2) water quality improvement and (3) wildlife habitat. However, wetlands the world over are critically threatened by anthropogenic activities such as land use conversion to farmlands, grazing, establishment of forest plantations, and encroachment by human settlements, among others. Cases in point are Dunga and Yala wetlands on the shores of Lake Victoria. Lake Victoria, the world's second largest freshwater Lake after Lake Superior in America, is also threatened by the stubborn water hyacinth, thereby impacting negatively on fishing and water transport with resultant loss of income to the local fishing community. MISTRA Urban Futures brings together local universities of Maseno and Jaramogi Oginga Odinga University of Science and Technology, Chalmers University (Sweden), City Council of Kisumu, the local fishing community, local NGOs and other

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stakeholders under an umbrella platform referred to as KLIP. The main objective of KLIP is to achieve sustainable development in Kisumu City and its environs. Ecotourism is being promoted as an alternative livelihood to the age-old fishing and peasant farming practices which have proved to be unsustainable. Local universities are involved in co-production of knowledge in partnership with the local community represented by Beach Management Units (BMUs) and other stakeholders. Currently 20 (10 Ph.D. and 10 Master's) candidates of Jaramogi Oginga Odinga University of Science and Technology are involved in trans-disciplinary research focusing on ecotourism. The research findings are to provide new and greater insights into development of ecotourism as a model for conservation of natural resources and improvement of local people's welfare. The platform provides a perfect example of the involvement of higher educational institutions in addressing society's problems and the role of such institutions in sustainable development goal attainment. Bonding among Jaramogi Oginga Odinga University of Science and Technology, County Government of Kisumu and the local community is now very strong, and this chapter argues that such partnership should be replicated elsewhere within the eastern Africa region and beyond.

Keywords
Community · County government · Ecotourism · Partnership · University · Wetland

1 Introduction

The role of higher educational institutions in sustainability goal achievement, while working in partnership with the community and other stakeholders, is perhaps one of the most important significant shifts in paradigm from the previous approach where such institutions were viewed as "ivory towers" with weak (if any) linkages with the community with whom they shared the physical environment. Strengthening of research, innovation and outreach (RIO) organs of higher educational institutions is a deliberate effort in the right direction to ensure stronger collaboration between such institutions and others for effective co-generation of knowledge for sustainable development.

This chapter gives a detailed account of the ongoing project involving two universities in Kenya (Maseno University and Jaramogi Oginga Odinga University of Science and Technology), Chalmers University of Technology (Sweden), the County Government of Kisumu of Kisumu and the local community under the auspices of Kisumu Local Interaction Platform (KLIP). KLIP is part of the MISTRA[1] Urban Futures program with its headquarters in Gothenburg, Sweden. The purpose of MISTRA Urban Futures is to contribute towards making a real difference to the

[1] MISTRA Urban Futures is an International Centre for Sustainable Urban Development.

environment and to people's lives in the cities of the world (Polk et al. 2013). Mistra Urban Futures offers an arena for the development and transmission of knowledge, in which cooperation with business, interest groups and the general public is developed.

Other local interaction platforms under Mistra Urban Futures include Shanghai (China), Cape Town (South Africa), Manchester (UK) and Gothenburg (Sweden). KLIP is currently focusing on two thematic areas: (1) ecotourism development and (2) marketplace development (Polk et al. 2013). This chapter focuses on the ecotourism component which is housed at Jaramogi Oginga Odinga University of Science and Technology. The focus on these thematic areas was decided by previous studies by postgraduate students from Chalmers University which recommended alternative livelihood systems from the traditional fishing and peasant farming practices which are unsustainable with the dwindling fish reserves in Lake Victoria, the presence of water hyacinth which makes fishing impossible, and limited employment opportunities in the agricultural sector. Interventions in ecotourism and/or improved markets are considered plausible alternatives for poverty reduction in Kisumu City and its environs.

2 The Concept of Sustainable Development

The World Commission on Environment and Development (WCED 1987) defines sustainable development as development meeting the needs of the present generations without compromising the ability of future generations to meet their needs. Robinson (2004, p. 369) argues for an approach to sustainability which is integrative, is action-oriented, goes beyond technical fixes, incorporates a recognition of the social construction of sustainable development and engages local communities in new ways. MISTRA Urban Futures operates within the framework of sustainability and envisions cities which are "*Green, Dense* and *Fair*" as shown in Fig. 1.

3 Rationale for Partnership Among Higher Educational Institutions

Providing solutions to the society's problems is perhaps one of the most important justifications for existence of higher educational institutions. Universities have always been viewed as centres for generation of knowledge but this position has since changed with increasing realization that a lot of knowledge is actually generated outside universities and hence the need for co-production of knowledge. This trans-disciplinary approach is referred to as mode 2 knowledge generation.

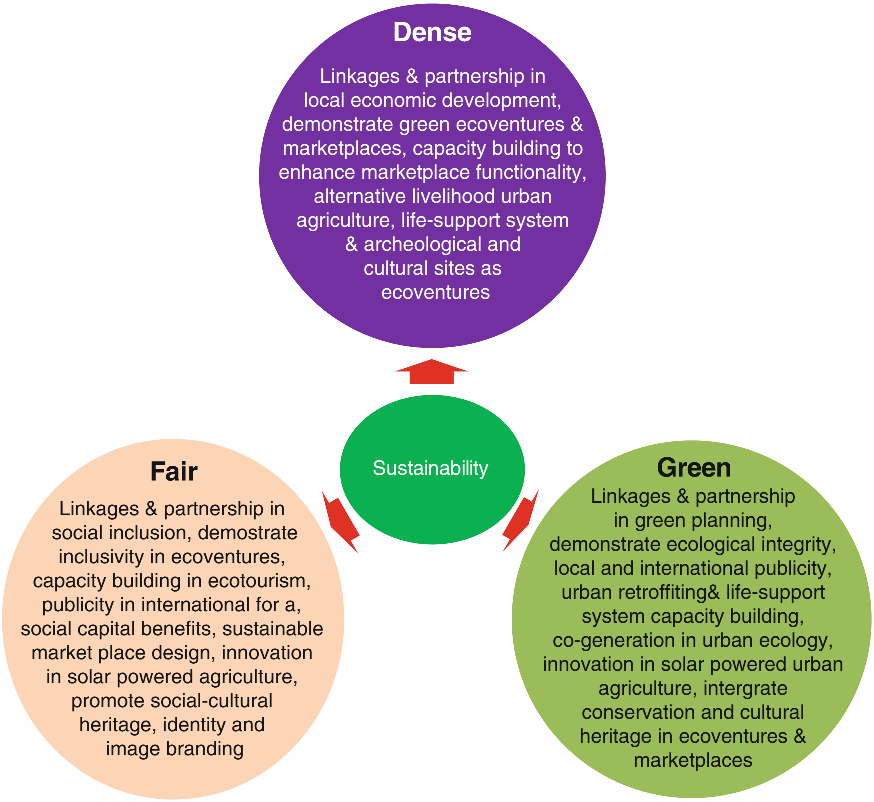

Fig. 1 Mistra Urban Futures' Philosophy of Green, Fair and Dense

4 Conservation of Wetlands on the Shores of Lake Victoria

Wetlands cover only about 6 % of the Earth's land surface and are found in every climate regime from the tropics to tundra and on every continent except the Antarctica (Chiras and Reganold 2010). Wetlands are fragile ecosystems of significant importance. Wetland functions can be grouped into three broad categories: (1) hydrological processes, (2) water quality improvement, and (3) wildlife habitat. Loss of such ecosystems through conversion into other land uses such as farming and livestock production; human settlements, among others leads to rapid and irreversible loss of life forms which are adapted to wetlands, and this explains why in 1971 the United Nations came up with the United Nations Convention on Wetlands of International Importance (Ramsar Convention).

Wetlands are said to be highly diverse ecosystems. They usually occupy transitional zones within landscape, since they lie between well-drained upland areas and permanently flooded deepwater habitat (Chiras and Reganold 2010). The authors argue that, in a legal context, the term *wetland* is not easily defined and therefore it continues to cause controversies. The Convention on Wetlands of International Importance (Ramsar Sites) of 1971 defines wetlands as "areas of marsh, fen peatland water natural or artificial permanent or temporary with water that is static or flowing, fresh or brackish or salt including areas of marine water, the depth of which at low tide does not exceed 6 m." Kenya's National Wetlands Standing Committee (NWSC) defines wetlands as areas of land that are permanently, seasonally or occasionally waterlogged with fresh, saline, brackish, or marine waters at a depth not exceeding 6 m including both natural and man-made areas which support characteristic biota. Currently, the legal definition used by most people in the USA in the regulation and management of wetlands is the one adopted by the Environmental Protection Agency [taken from the EPA Regulations listed at 40 CFR 230.3 (T)]:

> The term "wetlands" means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas (Chiras and Reganold 2010, p. 195).

Chiras and Reganold (2010) argue that wetland delineations are difficult for several reasons: for one, boundaries are inherently diffuse, almost never abrupt, and water levels vary from season to season. This is further compounded by the fact that human land uses such farming and logging alter vegetation, soils, and water regimes, changing the original land characteristics. In the United States, under recent law, if land is defined as a wetland, it cannot be drained, farmed, or built on (Chiras and Reganold 2010). Unfortunately, the same is not true in other countries such as Kenya, where wetlands have been converted into large scale farm enterprises despite the presence of comprehensive law (Environmental Management and Coordination Act of 1999).

5 Ecotourism and Sustainable Tourism

Sustainable tourism is a paradigm shift from traditional tourism which is considered unsustainable because of the negative impacts associated with the industry. Sustainable tourism evolved as a reaction to tourism's unprincipled growth in Europe in the 1970s. Among the first to write about the negative environmental impacts of tourism was a Swiss researcher, Jost Krippendorf. In 1996, the World Tourism Organization, the World Travel and Tourism, and the Earth Council released their action plan—Agenda 21—with a view to integrating tourism into broader sustainability discussions. The UNWTO declared 2002 as the International Year of Ecotourism with four themes: (1) ecotourism policy and planning, (2) regulation of ecotourism, (3) marketing and promotion of ecotourism, and (4) monitoring the costs and benefits of ecotourism.

Ecotourism is succinctly defined as “responsible travel to natural areas that conserves the environment and sustains the well-being of local people” (Bhatnagar 2010). It is different from its close “cousins” adventure tourism and nature tourism. “While adventure tourism and nature tourism focus on what a tourist is seeking, ecotourism is qualitatively different because it focuses on what the traveller does, plus the impact of this travel on the environment and the people in the host country” (Bhatnagar 2010, p. 86). The author argues that ecotourism is not just another niche market within the tourism industry but a philosophy and set of principles which, if properly understood and implemented, will transform the way we travel. It is an activity that attempts to achieve a balance between the economic exploitation of natural resources and native communities’ cultural heritage without threatening their existence. Ecotourism potentially provides a sustainable approach to development (Okech 2009)

Real ecotourism must involve seven vital interrelated characteristics: (1) travel to nature destinations, (2) minimizing negative environmental impacts, (3) building environmental awareness, (4) direct financial benefits for conservation, (5) financial benefits and empowerment for local people, (6) respect for local culture, and (7) support of human rights and democracy (Himberg 2006).

A study of Beach Management Units (BMUs) in Kisumu City and its environs by Hayombe et al. (2012) concluded that the local community’s willingness to participate in ecotourism-related activities must be upheld through direct engagement and prioritization of critical issues.

6 Study Sites

Figure 2 shows the location of Lake Victoria in East Africa while Fig. 3 shows the location of Lake Kanyaboli within the Yala Swamp Complex.

7 Major Achievements So Far

7.1 Joint Workshops

Joint workshops involve all stakeholders, the majority of which are grass root groups (BMUs, farmers, womens’ groups, youth groups, fishermen, among others). For instance, in 2012, KLIP convened a 2-day Ecotourism Sensitization Workshop at Jaramogi Oginga Odinga University of Science and Technology Assembly Hall which brought together a wide range of stakeholders in the ecotourism sector. The workshop served as an eye opener to all participants about the potential for ecotourism in Kisumu City and its environs. The workshop provided an arena for professionals and non-professionals alike to share ideas with a view to enhancing natural resources conservation and promotion of ecotourism. The workshop was

Fig. 2 Location of Lake Victoria in East Africa

held at Jaramogi Oginga Odinga University of Science and Technology in order to strengthen partnership between the university and the local community partnership. This may not be expressed better than the words of former chairman of Miyandhe BMU Mr. Joseph who said that "*today I am extremely happy. I never attained university education but I now feel like I am a graduate of Jaramogi Oginga Odinga University*."

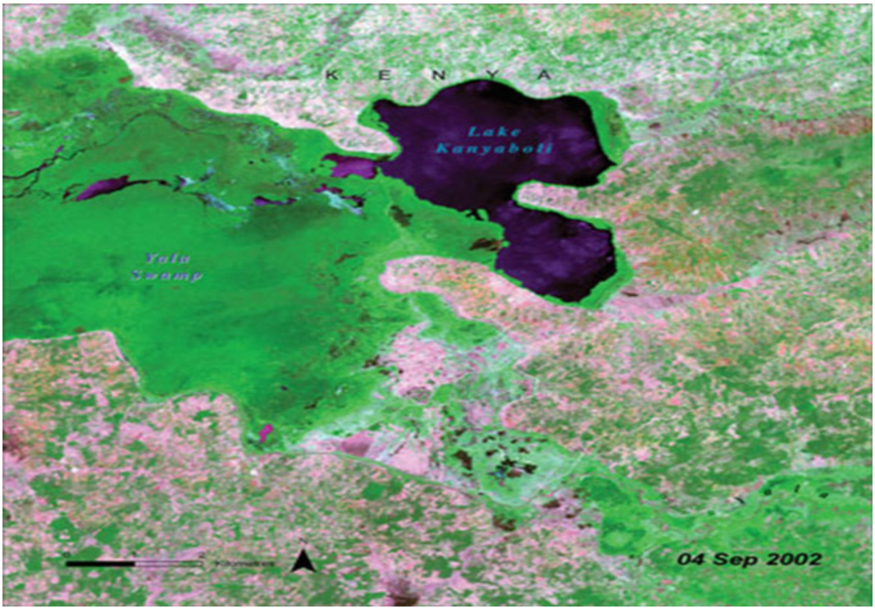

Fig. 3 Location of Lake Kanyaboli in Yala Swamp Complex. *Source:* Google Maps (https://www.google.com/search?q=IMAGES+OF+YALA+SWAMP-KENYA&client=firefox-beta&hs=ANf&rls=org.mozilla:en)

7.2 Training of Ph.D. and Master's Candidates

Mistra Urban Futures has continued to facilitate (through KLIP) intensive training of Ph.D. and Master's candidates through a series of week-long training by local and visiting professors and practitioners. The training sessions are meant to prepare postgraduate students to carry out trans-disciplinary research in ecotourism and marketplace with a view to improving local people's lives and achieving environmental conservation. Dunga Beach and wetland is one of the research sites where partnership among universities, City Council and local community is quite evident.

7.3 Reality Studios

Reality studios refer to field studies carried out where the real problems exist and are meant to equip student with situational analysis skills and ability to "think outside the box" as they find plausible solutions to society's "wicked" problems. Kisumu City and its environs have continued to serve as focal areas for Reality Studios for postgraduate students from Chalmers University of Technology (Sweden) together with postgraduate students from Maseno and Jaramogi Oginga

Odinga University of Science and Technology. The local community has demonstrated its hospitality and provided invaluable data for such studies.

7.4 Knowledge Co-production

In their book titled "*The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societi*es" Gibons et al (n.d). argue that the way in which knowledge is being produced is beginning to change. The authors argue that the new mode (Mode 2) of knowledge production involves different mechanisms of generating knowledge and communicating it, more people involved coming from different disciplines and backgrounds, but above all, different sites in which knowledge is being produced. Co-production of knowledge between academic and non-academic communities is a prerequisite for research aiming at more sustainable development paths. Researchers play various roles such as: (1) reflective scientists, (2) intermediary, and (3) facilitators of joint learning processes (Pohl et al. 2010). Robinson (2007) presents a view of interdisciplinary derived from actual practice. He proposes five characteristics of issue-driven inter-disciplinarity in the sustainability field, these being problem-based, integration, interactivity and emergency, reflexivity, and strong forms of collaboration and partnership.

Mistra Urban Futures strongly recommends knowledge co-production whereby universities work closely with the local community in two thematic areas: eco-tourism and marketplace. Ph.D. and Master's candidates at Maseno University and Jaramogi Oginga Odinga University of Science and Technology are encouraged to carry out joint research and share data and experiences. This approach has many benefits including but not limited to time saving, effective and efficient utilization of data, and creation of synergy in research. Currently, Ph.D. candidates in the two local universities are enthusiastically carrying out joint studies in Kisumu City and its environs under the supervision of senior lecturers/researchers and professors from local universities (Maseno and Jaramogi Oginga Odinga University of Science and Technology) and Chalmers University of Technology (Sweden).

7.5 Promotion of Beach Tourism

One of the core functions of KLIP is to promote ecotourism in Kisumu City and its environ. A recent "Fish Night" organized by KLIP served to promote Dunga Beach as a tourist destination and helped to promote local people's cultures including traditional foods (see Fig. 4).

Fig. 4 Visitors being entertained by local dance group and traditional dishes displayed during the Fish Night at Dunga Beach, Lake Victoria. *Source*: Field survey, 2012

7.6 Green Campus Initiative at Jaramogi Oginga Odinga University of Science and Technology

Jaramogi Oginga Odinga University of Science and Technology has since embraced the Green Campus initiative and over 35 students have registered as members of the Green Campus Club. The club is currently hosted at the School of Spatial Planning and Natural Resource Management which approved it during the School Board meeting held in February 2013.

8 Potential for Wetland Ecotourism

Wetlands are important wetland attractions as shown in Fig. 5.

9 Anthropogenic Threats to Dunga and Kanyaboli Wetland Ecosystems

Wetlands are under great threat from conversion into other land uses such as agriculture and livestock production (see Fig. 6). This leads to loss of unique species of fauna and flora and reduces the ability to attract foreign and domestic tourists. Other anthropogenic threats to wetlands and inland freshwater sources include uncontrolled planting of eucalyptus spp. (Fig. 7) and uncontrolled spreading of water hyacinth (Fig. 8).

Eucalyptus spp. is known for its ability to draw water from underground sources and may totally change the ecology of an area. Whether to plant *Eucalyptus* spp. in wetlands or not is still a controversial issue in Kenya.

Fig. 5 Abundance of frsh water, scenic plants and bird life at Lake Kanyaboli. *Source*: Field survey, January, 2013

Fig. 6 Inappropriate use of wetland for crop and livestock production. *Source*: Field survey, 2013

10 Institutional Interface for Wetland Conservation and Ecotourism Development

Conservation of wetlands and promotion of ecotourism on the shores of Lake Victoria is characterized by strong institutional integration in addition to financial and technical integration. KLIP provides an arena for various stakeholders to share ideas and knowledge for purposes of up-scaling wetland conservation and development of ecotourism. The institutions involved include local universities

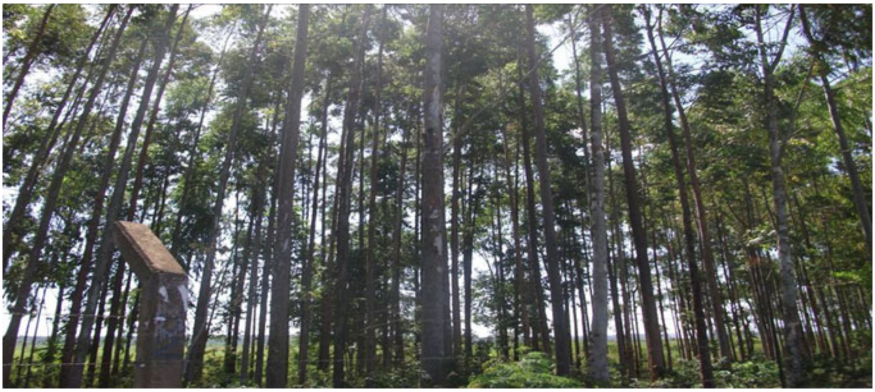

Fig. 7 *Eucalyptus spp*. plantation within Yala swamp complex. *Source*: Field survey, January, 2013

Fig. 8 Water hyacinth is a natural hazard at Dunga Beach and wetland, Lake Victoria. *Source*: Field survey, January, 2013

(Maseno University and Jaramogi Oginga Odinga University of Science and Technology), Chalmers University of Technology (Sweden), City Council of Kisumu, line government ministries/departments, NGOs, and the local community represented by BMUs.

11 Conclusions

The Green Campus Initiative is a relatively new but noble idea within the framework of sustainable development. The initiative provides platforms for higher educational institutions to partner with industry and community for sustainable development goal achievement.

Higher educational institutions have a major role to play under Kenya's devolved system of government that gives more powers to county governments. Universities and other tertiary institutions can now work closely with county governments and other development partners for sustainable growth and transformation on the regional scale.

The concept of a green campus has continued to receive increasing attention among the top management, students, and members of the teaching and non-teaching staff of Jaramogi Oginga Odinga University of Science and Technology. The university's outreach programmes have contributed to foster campus-community bonding in a "win-win" situation.

This chapter argues that the Green Campus concept should be mainstreamed in every school and department of the university.

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Advancing a Culture of Sustainability at the University of Michigan

John Callewaert, Robert W. Marans and Michael Shriberg

Abstract

Throughout 2010 and the first half of 2011, the University of Michigan (U-M) coordinated an Integrated Assessment (IA) to analyze the U-M's sustainability efforts to date, benchmark against other institutions, and chart a course for the future. Informed by an extensive stakeholder engagement process, the U-M CSIA represents one of the most comprehensive campus sustainability analyses completed at a US institution of higher education. Community Awareness was one of four themes that emerged from the CSIA, along with Climate Action, Waste Prevention, and Healthy Environments. The key actions within the Community Awareness theme were designed to work synergistically in fostering awareness and responsible behavior across the U-M campus. This focus on behavior change and culture is critically important for driving progress toward the quantifiable goals established by the CSIA within the other three themes. Key investment areas within the Community Awareness theme are awareness and education programs, reporting and communication, and longitudinal surveys designed to measure and track the culture of sustainability. This chapter provides

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an overview of the CSIA process and outcomes, with a focus on cultural change and the groundbreaking effort to develop and administer a comprehensive longitudinal study. This study—the Sustainability Cultural Indicators Program (SCIP)—used focus groups and then a comprehensive survey to measure and track sustainability knowledge, behavior, and attitudes. Starting in October 2012, more than 4,000 students and 2,000 faculty and staff members responded to the survey which included questions on transportation, waste prevention and conservation, the natural environment, climate change, and various campus sustainability initiatives. Using data collected in fall 2012, selected findings from the initial data collection are presented. Finally, plans for ongoing analyses, the use of the results by the University, possible coordination with other institutions, and subsequent data collections are outlined.

Keywords

Campus sustainability · Survey · Cultural indicators · Community awareness

1 Background

In October 2009, University of Michigan (U-M) President Mary Sue Coleman elevated the University's commitment to sustainability in teaching, research, operations, and engagement by creating the U-M Environmental Sustainability Executive Council.[1] One of the first actions of the Council was endorsing a Campus Sustainability Integrated Assessment (IA) (CSIA) to analyze the U-M's sustainability efforts to date, benchmark against other institutions, and chart a course for the future through identifying long-term goals for sustainable operations on the U-M Ann Arbor campus, including the Athletic Department and the Health System.

The geographic scope of the CSIA spanned the five Ann Arbor campuses (South, Central, Medical, North, and East Medical), which include 1,242 ha of land and 377 buildings comprising 2.9 million square meters. In 2009, these buildings and their 79,174 occupants consumed 6.7×10^{15} J of energy and 4.5 billion liters of water. Additionally, greenhouse gas emissions (GHG) from U-M buildings totaled 263,181 tonnes of CO_2 equivalents. The magnitude of energy consumption, water usage, and GHG emissions generated by the U-M suggests that aggressive sustainability goals for University campus operations could have significantly positive environmental, fiscal, and health impacts.

The CSIA builds on a long history of sustainability commitments in U-M campus operations, such as implementing natural gas cogeneration technology at the Central Power Plant in the 1960s, adopting the US Environmental Protection Agency Green Lights and Energy Star programs in the 1990s, and, more recently,

[1] The Council is comprised the University President, the Provost and Executive Vice President for Student Affairs, the Vice Presidents for Research, Student Affairs, Development, and Global Communications and Strategic Initiatives, the Executive Vice President for Medical Affairs, and the Executive Vice President and Chief Financial Officer.

establishing leadership in energy and environmental design (LEED) Silver certification as the standard for new non-clinical construction projects where the construction value exceeds US$10 million. While past commitments have moved the U-M campus forward, more can always be done, and the CSIA was pursued with this in mind.

As a means of undertaking this complex project, the Graham Institute and Office of Campus Sustainability employed an applied research framework known as IA. IA is a process which synthesizes natural, social, and economic information for particularly challenging problems. Among the many strengths of IA is that it brings together perspectives from government, academia, nonprofit organizations, and community stakeholders to support informed decision-making (Vaccaro et al. 2009; Lund et al. 2011).

The purpose of the CSIA was to develop collaboratively practicable ideas to guide efforts that would help solidify the U-M as a global leader in campus sustainability. It involved students, faculty, and staff throughout the U-M community to:

- Establish broad goals and specific targets for U-M campus sustainability efforts
- Develop frameworks to help guide U-M's overall campus sustainability strategy
- Identify opportunities to use the U-M campus as a sustainability learning laboratory
- Identify potential demonstration projects to foster campus sustainability research and learning
- Educate the U-M community on sustainability issues and help change culture as appropriate
- Publish a final report to share what we have learned as a community

The operational structure and process for the CSIA are depicted in Fig. 1.

During phase 1, seven faculty-led and student-staffed Analysis Teams focused on buildings, energy, land and water, food, transportation, purchasing and recycling, and culture. A unique aspect of the Culture Team is that it placed members within each of the other Analysis Teams to support coordination across teams. While conducting literature reviews, peer benchmarking, and assessing U-M practices, Analysis Teams also consulted with U-M operations personnel to gain institutional perspectives regarding their areas of study. At the conclusion of phase 1, the Analysis Teams submitted comprehensive reports and suggested ideas for further study in phase 2. The Integration Team reviewed the reports and conducted multiple meetings with the Analysis Teams and the Steering Committee to identify areas of intersection across these ideas. This review resulted in a priority list of proposed sustainability ideas that required further analysis during phase 2.

During phase 2, the Analysis Teams were charged with conducting more detailed analyses which included costs, benefits, technical guidance, uncertainties, and reasonable implementation time frames for potential actions. The final CSIA report contains the recommendations developed by the Integration Team, and informed by the phase 2 Analysis Team reports with additional input from U-M

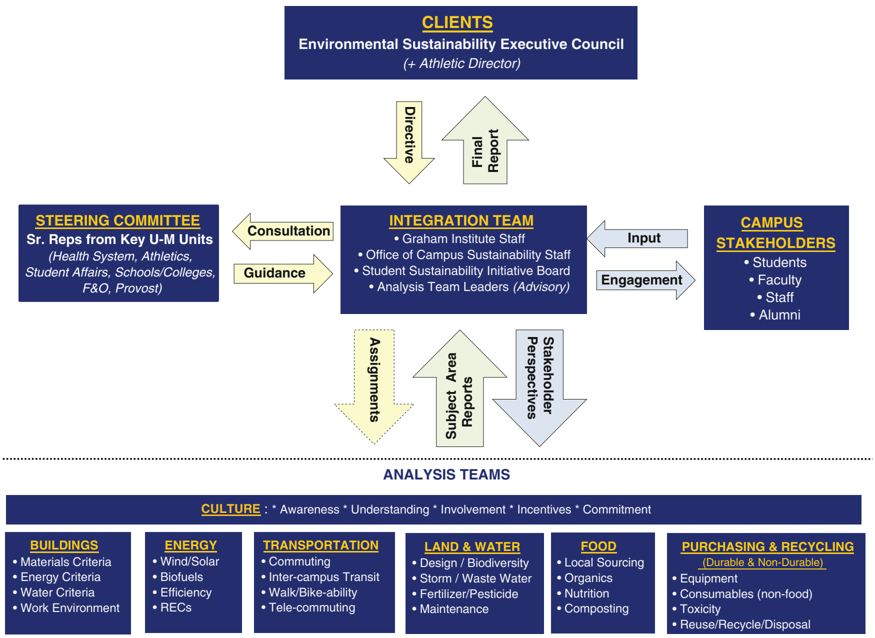

Fig. 1 CSIA operational structure

operations staff and the Steering Committee. The report outlines four high level themes—Climate Action, Waste Prevention, Healthy Environments, and Community Awareness. Accompanying the themes are Guiding Principles to direct our long-range strategy and 2025 Goals which are time-bound and quantifiable (see Table 1).

A hallmark of this 2-year process was deep and broad community engagement which powerfully informed and shaped the CSIA. This included seven faculty-led Analysis Teams staffed by 77 student research assistants who completed over 10,000 h of work, close involvement of dozens of operations staff members, nearly 200 comments and ideas submitted by the campus community, several town hall events which drew several hundred unique participants, as well as focused workshops involving other academic institutions, businesses, and local community organizations.

A year after the CSIA, the Graham Institute sponsored an evaluation of the assessment process. One of the overall evaluation themes was a common appreciation for how the CSIA process was conducted. Evaluation participants commented that the CSIA helped establish and build upon informal relationships around the topic of sustainability. They also credited the process for broadening their understanding of sustainability and for raising awareness about sustainability on a larger level on campus. Participants admired how inclusive the process was and felt that a great deal of effort was made to ensure it was as all-encompassing and

Table 1 CSIA themes, guiding principles, and 2025 goals

Theme	Guiding principle	2025 goals
Climate action	We will pursue energy efficiency and fiscally-responsible energy sourcing strategies to reduce greenhouse gas emissions toward long-term carbon neutrality	Reduce greenhouse gas emissions (*scopes* 1 *and* 2) by 25 % below 2006 levels
		Decrease carbon intensity of passenger trips on U-M transportation options by 30 % below 2006 levels
Waste prevention	We will pursue purchasing, reuse, recycling, and composting strategies toward long-term waste eradication	Reduce waste tonnage diverted to disposal facilities by 40 % below 2006 levels
Healthy environments	We will pursue land and water management, built environment, and product sourcing strategies toward improving the health of ecosystems and communities	Purchase 20 % of U-M food from sustainable sources
		Protect Huron River water quality by: • Minimizing runoff from impervious surfaces (*outperform uncontrolled surfaces by* 30 %), and • Reducing the volume of land management chemicals used on campus by 40 %
Community awareness	We will pursue stakeholder engagement, education, and evaluation strategies toward a campus-wide ethic of sustainability	There is no goal recommendation for this theme. However, the report recommends investments in multiple actions to educate our community, track behavior, and report progress over time

transparent as possible. As a result of the CSIA, more and more cross-disciplinary and cross-operational dialogue and collaboration is taking place on campus. This is evidenced in the evaluation survey results as well as the statement made by one analysis team member who said she/he felt that the assessment process "opened up an avenue of dialogue between faculty, administration, and staff which has resulted in other project initiatives and discussions taking place that otherwise never would have happened."[2] Ideas for improvement included the need to focus on all members of the campus community, not just those directly involved in sustainability efforts, and the need to build more sustainability awareness. This connects directly to the guiding principle of the Community Awareness goal of the CSIA—*we will pursue stakeholder engagement, education, and evaluation strategies toward a campus-wide ethic of sustainability.*

[2] More information on the CSIA process, outcomes, and evaluation can be found at http://graham.umich.edu/ia/campus.php.

2 The Sustainability Cultural Indicators Program

The scientific and technical challenges of sustainability on which universities and colleges as well as practitioners have focused the bulk of their efforts represent only part of the necessary intellectual and social transition to a sustainable society. Institutions of higher education play a pivotal role in addressing the more difficult yet powerful part of the sustainability transition. That role is in creating and maintaining a "culture of sustainability" among members of the university community. A culture of sustainability has been defined as "a culture in which individuals are aware of major environmental (and social/economic) challenges, are behaving in sustainable ways, and are committed to a sustainable lifestyle for both the present and future" (Marans et al. 2010). To achieve this ideal state within institutions of higher education, Sharp (2002) calls for a rethinking of organizational action and actors which questions the prevailing assumptions of organizational rationality that stays within the confines of the current systems. Similarly, Senge (2000) stresses the importance of cultivating a "learning organization", rather than a "knowing organization", since change at higher education institutions is a "complex learning and unlearning process for all concerned" (Scott 2004). Therefore, nothing less than a paradigmatic shift in organizational thinking is needed for colleges and universities to promote cultural transformation.

This organizational transformation is needed in all sectors of society. Yet institutions of higher education can and should be at the forefront, with the collective mission of fostering sustainability through our actions and through cultivating future sustainability leaders. To date, however, most campus sustainability efforts stop either at "greening" or at the level of institutional commitments to eco-efficiency, climate and waste mitigation, and increasing environmental education. Though calls for institutional and cultural transformation are multiplying at a rapid rate, rarely do institutions address the deeper cultural change necessary to transform into sustainable organizations which empower citizens with a sustainability perspective; instead, focus is often on implementing many individual projects, isolated initiatives, or broad commitments (Sharp 2002, 2009). This is partly attributable to the lack of guidance for institutions attempting to follow this more uncertain and uncomfortable path.

U-M cultural change initiatives stem from the principles outlined under CSIA theme of Community Awareness. They indicate that the U-M will "pursue evaluation strategies toward a campus-wide ethic of sustainability" as articulated in President Coleman's September 2011 speech announcing the sustainability goals. Specifically, she stated that "we will scientifically measure and report our progress and behavior as a community… Institute for Social Research (ISR) researchers will measure the sustainability attitudes and activities of students, faculty and staff, as well as identify where we can improve." The evaluation strategies involve a groundbreaking program for monitoring the U-M's progress in moving toward a culture of sustainability. Progress will be determined by tracking a set of cultural indicators over time.

To create these indicators, a small group closely involved with the CSIA met for over a year, working on what came to be known as the Sustainability Cultural Indicators Program (SCIP). The group started with examining the recommendations from the Campus IA Culture Team report, reviewed related literature, spoke to key national leaders working on similar efforts, ran focus groups with students and staff to determine current understandings of sustainability, and analyzed more than 30 existing campus surveys from numerous institutions (including the U-M) about topics such as recycling, transportation, etc.

One of the most useful resources for this work was the North American Association for Environmental Education's report "Developing a Framework for Assessing Environmental Literacy" (Hollweg et al. 2011). It provided a very useful frame for developing questions under three categories: knowledge, dispositions or attitudes, and behavior. This went beyond many of the existing campus surveys which focus primarily on sustainability literacy or environmental literacy, or which focus exclusively on operational outcomes. The focus also on behavior and attitudes provides a more complete measurement of the culture of sustainability.

As a guide for drafting questions and writing questionnaires, an analytical model was prepared showing relationships to be explored between different types of cultural indicators and contextual and antecedent conditions. The model shown in Fig. 2 has several parts. First, it suggests that indicators could consist of possibly

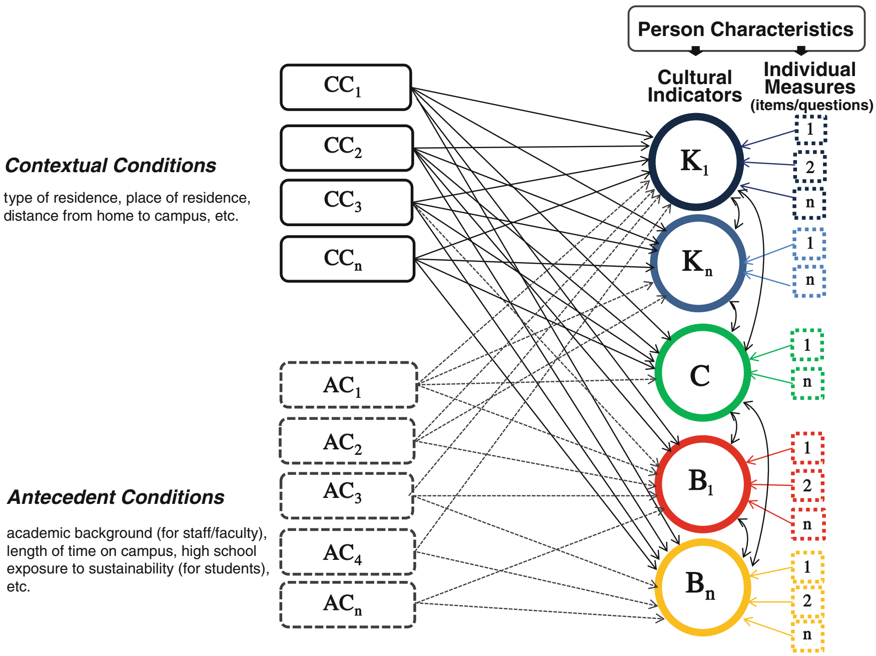

Fig. 2 Analytic model for investigating determinants of cultural indicators

two or more questions. For example, an indicator capturing the travel behavior of students could consist of responses to questions about automobile ownership, mode of travel to campus, and intra-campus bus use. Second, the number of indicators reflecting knowledge (K), commitment (C)—also understood as attitudes or dispositions, and behaviors (B), and the number of variables reflecting contextual and antecedent conditions will vary. Third, the model suggests that contextual variables such as type and place of residence, and distance from residence to campus may be related to selected cultural indicators. Similarly, antecedent conditions such as length of time on campus and academic background in high school and college could affect selected cultural indicators. Finally, the model suggests possible relationships between cultural indicators. The questionnaires would need to include items that capture contextual and antecedent conditions as well as those used in creating the different types of indicators.

Two separate questionnaires were developed—one for staff and faculty, and one for students. While many of the questions were similar, different time frames and sequences were used in the two versions. For example, the staff and faculty survey asked questions within a time frame of the past year while students were asked to answer questions based on their experience since the start of the fall semester. Also, students were asked several demographic questions at the start of the survey such as whether they live in campus housing or not in order to skip certain questions which did not apply to students living in campus housing, while staff and faculty demographic questions were asked at the end of the survey. A primary objective of the program was to work closely with the goals of the CSIA. Modules were developed with questions focusing on transportation, waste prevention, the natural environment, food, climate change, as well as U-M efforts, and respondent demographics.

The instruments were pretested with 30 staff and faculty from ISR and the College of Engineering, and a diverse group of 46 students. The questionnaires were revised based on that input and were then presented to two groups of key operations staff members for input and suggestions with the objective of developing questions which would be highly useful for campus efforts. Table 2 offers an

Table 2 SCIP survey questions by module and question type

Survey module	Question type					
	Knowledge	Disposition	Behavior	Other	Demographic	Total
Transportation	9	10	21	1	0	41
Conservation	5	5	33	1	0	44
Environment	4	2	9	1	0	16
Food	7	6	19	2	0	34
Climate	1	2	0	2	0	5
Sustainability (general)	0	20	13	3	0	36
University of Michigan	8	0	8	8	0	24
Demographics	0	0	0	0	42	42
Total	34	45	103	18	42	242

overview of the question types and modules. In total, the questionnaires each contained 242 questions, although respondents could skip any question they did not want to answer, and responses to some questions generated a skip sequence for subsequent questions.

The questionnaires were administered online for the first time in the fall of 2012. Starting in late October, invitations to complete the survey were sent to a representative sample of students, faculty, and staff, with the goal of getting responses from 4,000 undergraduate students, 400 graduate students, 750 faculty, and 750 staff. Novel techniques were also employed to test strategies for participant recruitment. This included an initial invitation to complete the survey from U-M President Mary Sue Coleman. Most invitees received an email invitation but a small number received paper letters in the mail. The paper letters had no impact on improving response rate and will not be used in future. In addition, for individuals who did not respond to the initial invitation within the first week, a reminder message was sent. One group received an email reminder with a video message from the U-M Men's Basketball Coach, John Beilein, encouraging recipients to complete the survey. Another group simply received an email reminder without the video message. Including the video in the reminder did have an impact and generated an 8 % increase in the overall response rate. A third recruitment strategy involved offering a 1:100 chance to win a US$50 gift card (iTunes, Amazon, Barnes and Noble) for submitting the survey.

The online link to the questionnaire was kept open through the end of November. Overall, the response rate was approximately 40 % for all participant groups with a slightly higher response rates from first-year students, graduate students, staff, and faculty. Upon an initial review of the data, the research team determined that, in order to support the desired analyses, only responses which included more than 161 completed questions would be included in the datasets. This resulted in 2,166 completed questionnaires from staff and faculty combined and 4,018 completed questionnaires from students. Respondents averaged about 20 min to complete the survey. Through funding from the U-M Provost's Office, the Graham Institute, and ISR, the questionnaire will be repeated annually for the next 5 years with a smaller cohort of first-year students (300) being tracked over time. This will allow the research team to assess changes (if any) that occur in our indicators and identify factors that contribute to those changes. Reporting plans include an annual program report providing an overall summary as well as specific reports for key areas (transportation, student affairs, etc.).

3 Preliminary Results

Data analysis of the first year's results has only just begun and will require several months to complete. However, some preliminary results are included below to provide examples of the types of questions which were asked as well as plans for reporting the data.

Table 3 How much do you know about recycling (response percentages)

	Students				Staff and faculty			
	Glass	Plastic	Paper	Electronics	Glass	Plastic	Paper	Electronics
A lot	14	20	26	5	19	21	32	12
A fair amount	30	38	38	12	33	36	40	23
A little	33	30	27	31	30	30	23	32
Not much/nothing	23	12	9	52	18	13	5	33
Number of respondents	4,018	4,018	4,018	4,018	2,166	2,166	2,166	2,166

3.1 Knowledge Questions

Many sustainability questionnaires focus on knowledge, either about specific practices or general topics such as environmental impacts or definitions of sustainability. As the SCIP questionnaire built from the CSIA goals areas, it was important to develop knowledge questions focused on key campus activities. Recycling is one such key activity and was also one of the topics focus group participants most frequently associated with sustainability. Table 3 offers an overview of what respondents reported in terms of knowledge about recycling on campus. In general, staff and faculty reported knowing more about recycling—particularly electronics—than students. This is to be expected, given the regular turnover of the student population. What is surprising though is that for those who responded “a lot” or “a fair amount” did so at a higher percentage for paper than glass or plastic. This will be an interesting result to follow as the U-M recently shifted to single stream recycling which should simplify understanding the process of recycling on campus.

3.2 Behavior Questions

The largest category of SCIP questions focus on behavior. This was intentional, as understanding behavior is a key objective of SCIP. Table 4 demonstrates an area of major behavior difference between staff, faculty, and students. It is not that surprising that staff and faculty reported that they are more likely to drive to campus than anything else. It is very interesting, though, to know that nearly 90 % of students report they most often travel to campus by means other than car, particularly since nearly two-thirds of respondents reported living off-campus. For staff and faculty, the percentage of those reporting most often driving a car alone to work is the same as the national percentage—76 % (McKenzie and Rapino 2011). In addition, the percentage which said they most often bike to work, 5 %, is not that different from the percentage for the City of Portland, Oregon, which reported that, in 2011, 6 % of respondents on the American Community Survey said they bicycled to work, making Portland the number one city in bicycle commuting among the 70 largest cities in the US (Maus 2011).

Table 4 Travel to campus/work (response percentages)

	Students	Staff and faculty
	Since the start of the fall semester how do you most often travel to and from campus?	How do you most often travel to and from home to your work place?
Drive a car	11	76
Walk	53	8
Bike	8	5
Ride the bus	24	7
Park and ride/ride share	3	1
Other	1	3
Number of respondents	4,018	2,166

Another set of behavior questions asked respondents about engagement in sustainability activities such as donating money, volunteering, serving in a leadership capacity, and voting. Several interesting results stand out and are shown in Table 5. For example, the higher percentages of first-year students among all other students responding affirmatively in all areas except voting—this could be because of the lack of experience with voting. Also, the differences in responses by staff and faculty regarding donating money and voting (higher affirmative responses) and providing one's time (lower affirmative responses). These results may provide some insight for the types of programs which may appeal more to certain segments of the campus population.

Table 5 Engagement in sustainability activities (percent responding affirmatively)

	All students	Undergraduate students					Graduate students	Staff	Faculty
		FY	Soph	Junior	Senior	All			
During the past year, have you done any of the following to promote environmental protection, energy or water conservation, open space preservation, etc.									
Given money to an organization/advocacy group supporting a sustainability issue	18	20	15	17	16	17	19	27	52
Volunteered for an organization/advocacy group supporting a sustainability issue	22	31	24	24	21	25	16	8	9
Served in a leadership position in an organization/advocacy group supporting a sustainability issue	7	10	7	8	9	9	5	2	3
Voted for a candidate for a public office because of his/her position on a sustainability issue	31	26	33	29	30	29	34	41	56
Number of respondents	4,007	1,075	825	902	755	3,558	449	1,007	1,081

Table 6 Commitment to sustainability (response percentages)

	Students	Staff and faculty
	Overall, how committed are you to sustainability?	
Very committed	14	19
Somewhat committed	60	64
Not very committed	24	16
Not at all committed	2	1
Number of respondents	4,014	2,150

3.3 Disposition Questions

A third category of questions asked respondents about their dispositions or attitudes and commitments. Disposition questions were asked in nearly every module of the questionnaire. Results for a general commitment question are presented in Table 6. This question was asked near the end of the survey. Only a few respondents reported no commitment to sustainability with 60 % or more reporting that they are somewhat committed to sustainability.

3.4 Other Types of Questions

Nearly all the modules on the questionnaire included a combination of knowledge, behavior, and disposition questions. The module on climate is unique in that it focused less on questions directly built from the CSIA and asked more general disposition and knowledge questions. In addition, several of the questions in this module were modeled after questions from the Yale Climate Survey Tool to allow for comparisons with national results.[3] Complete climate module results are provided in Table 7 to offer an example of how results will be reported to the campus in table format, providing information for all students, students by class, staff, and faculty. From the SCIP questionnaire, faculty are much more convinced that climate change is happening than students or staff. Over 70 % of faculty report they are "completely convinced" compared to about half of the students and staff. From the Yale Survey, nationally 70 % say that climate change is happening but of those, just a quarter say they are "extremely sure" it is happening. Similarly, less than half of the students and staff on SCIP said climate change is "extremely" and "very" important to them personally compared to 76 % of the faculty who gave similar responses. Less than a quarter of the national sample responded this way. Finally, more than half of faculty (55 %) report they think climate change is caused by human activity compared to students and staff (39 and 32 %, respectively). Students and staff were more inclined to respond that climate change is caused by both

[3] Yale Project on Climate Change Communication. School of Forestry and Environmental Studies Yale University environment.yale.edu/climate.

Table 7 Climate change (response percentages)

2012 Percentages	All Students	Undergraduate students					Graduate students	Staff	Faculty
		FY	Soph	Junior	Senior	All			
How convinced are you that climate change is happening?									
Completely convinced	48	39	46	47	48	45	52	45	71
Mostly convinced	35	40	33	35	35	36	33	32	21
Not so convinced	11	12	14	11	11	12	11	12	5
Not at all convinced	3	4	3	3	2	3	2	5	1
Don't know	3	5	4	4	4	4	2	5	2
Total	100	100	100	100	100	100	100	100	100
Number of respondents	4,013	1,077	827	905	755	3,564	449	1,078	1,097
How important is climate change to you personally?									
Not at all important	3	4	4	4	3	4	2	3	2
Not too important	14	16	14	17	16	16	12	12	6
Somewhat important	39	39	41	39	43	40	36	39	26
Very important	30	30	27	28	24	27	34	33	42
Extremely important	14	11	14	12	14	13	16	13	24
Total	100	100	100	100	100	100	100	100	100
Number of respondents	4,008	1,077	826	903	753	3,559	449	1,076	1,097
How well can you explain climate change to someone?									
Very well	21	20	23	19	20	20	21	11	24
Fairly well	44	49	44	46	42	45	43	37	49
A little bit	31	28	28	29	33	30	33	43	24
Couldn't explain it at all	4	4	5	6	5	5	3	9	3
Total	100	100	100	100	100	100	100	100	100
Number of respondents	4,005	1,074	824	904	754	3,556	449	1,076	1,098
Assuming climate change is happening, do you think it is:									
Caused mostly by human activity	39	34	33	38	35	35	44	32	55
Caused mostly by natural causes	5	6	6	6	5	6	4	6	3
Caused by both	55	59	59	55	59	58	51	59	41
None of the above because climate change is not happening	1	1	2	1	1	1	1	3	1

(continued)

Table 7 (continued)

2012 Percentages	All Students	Undergraduate students					Graduate students	Staff	Faculty
		FY	Soph	Junior	Senior	All			
Total	100	100	100	100	100	100	100	100	100
Number of respondents	4,011	1,076	827	905	754	3,562	449	1,076	1,094
How many of your friends share your views about climate change?									
All	7	5	5	7	6	5	10	6	9
Most	44	43	43	43	44	43	46	36	52
Some/few	31	31	32	32	31	32	29	35	21
None	1	1	1	1	*	1	1	*	1
Don't know	17	20	19	17	19	19	14	23	17
Total	100	100	100	100	100	100	100	100	100
Number of respondents	4,010	1,077	827	904	754	3,561	449	1,078	1,097

Sustainability Indicator	Code
Behavior: Transportation	B-TR
Behavior: Conservation	B-CO
Behavior: Environment	B-EN
Behavior: Food	B-FO
Behavior: Climate	B-CL
Sustainability Knowledge	SK
Sustainability Behavior	SB
Sustainability Disposition	SD
U-M Sustainability Awareness	UM-A
U-M Sustainability Engagement	UM-E

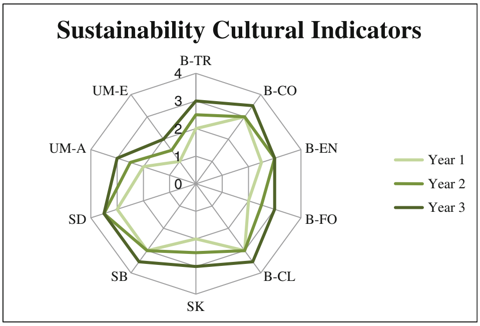

Fig. 3 Conceptual plan for sustainability indicators

human and natural activities (55 and 59 %, respectively) than faculty (41 %). These early results perhaps suggest the need for different strategies or programmatic emphases for promoting the U-M's climate action efforts.

4 Conclusion

As noted above, data analysis has only just started and it is too early to provide definitive results from our Year-One data. Following the completion of reporting tables for all questions on both surveys, a key next step will involve the creation of a standard set of sustainability indicators. The left side of Fig. 3 provides the initial set of ten indicators which will be developed using two or more questions from various modules within the questionnaires. Criteria which will guide the selection of those questions include consistency in responses, correlations between questions, and principal component analyses. As a primary objective of SCIP is to provide results over time, the research team is developing plans for displaying and sharing that information with campus. The image on the right side of Fig. 3 offers an initial concept of how this could be done. Each year indicators will be reported and any changes (positive or negative) can be displayed over time.

The U-M CSIA provided a comprehensive analysis and plan for guiding sustainability activities toward specific goals including Community Awareness. The SCIP will be an important tool for examining knowledge, behavior, and dispositions with respect to progress towards those goals. Annual reports from the initiative have the potential to provide key insights for guide programming efforts.

While program results will be important for efforts at the U-M, the program team sees great potential for collaborative and comparative efforts with other institutions in the US and elsewhere. This could involve other colleges and universities, together with efforts at the community, state, and national level. Future plans include building a program website for sharing the questionnaires and annual results, and over time providing data sets from each year to support inquiry and scholarship on a broad range of sustainability questions. The program team is eager to explore these opportunities and welcomes inquiries from other investigators.

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Energy Efficiency in the Adoption of Renewable Energies in Schools

José Baltazar Salgueirinho Osório De Andrade Guerra, Luciano Dutra, Norma Beatriz Camisão Schwinden and Suely Ferraz de Andrade

Abstract

The Brazilian population is increasingly implementing energy efficiency actions across the country. The initiative dates from 2000, when Law 9991 (Lei 9991, 2000) and Decree 3867 (Decreto N° 3867, 2001a) were enacted by the Federal Government to regulate investments in research and development and energy efficiency as activity required by the oil companies, licensees and authorized electricity sector. Law 10295 (Lei 10295, 2001) regulated the National Policy for the Conservation and Rational Use of Energy. The different actions proposed to combat electricity waste throughout the country aim to establish an institutional basis for setting priorities, support, coordinate and monitor actions to ensure the rational use of electric power and, as a result, to optimize efficiency. The purpose of such measures is to facilitate the use of the same product or service with lower energy consumption, eliminating waste and ensuring overall reduction of costs and investments in new power system facilities. The fight against waste and the

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pursuit of efficient use of various forms of energy, especially from renewable sources, should be encouraged, since they will allow savings and contribute to environmental preservation. In this chapter, the authors intended to demonstrate the progress in implementing new sources of sustainable energy, because, according to the Brazilian constitution, everyone has the right to an ecologically balanced environment, an asset of common use and essential to a healthy quality of life. It is the duty of the Government and society to defend and preserve it for present and future generations. This chapter also presents the application of energy efficiency strategies within the context of the REGSA project (Promoting Renewable Electricity Generation in South America), which supports an elementary school in a rural area. The energy efficiency project includes the use of a solar water heating system made of PET bottles, wind power, and a micro-hydroelectric system installed in a stream. Five classrooms and a library will benefit from these techniques, which will bring a more comfortable environment for the students and teachers.

Keywords
Energy efficiency · Bioclimatic architecture · Renewable energy

1 Introduction

The different actions proposed to combat the waste of energy in Brazil are intended to establish the institutional basis with prioritization, support, coordination, and monitoring of measures and actions to be developed. These actions are aimed at rationalizing the use of electricity and, as a result, improve energy efficiency. They propose the use of the same product or service with less energy consumption, eliminating waste and ensuring the overall reduction of costs and investments in new facilities in the national electric system.

The fight against electricity waste and the search for new sources of energy, especially renewable ones, should be encouraged, since they allow saving of costs and preserve the environment.

In Brazil, public schools face serious problems of environmental comfort, and this translates into low productivity, little learning, lack of motivation, energy waste, and, therefore, public money. There has been a steady growth in energy consumption in Brazil in recent years, according to the National Energy Balance 2012 (EPE 2012). Therefore, environmental comfort problems should be solved with minimal expenses. School buildings should have some autonomy and greater efficiency in energy use, qualities that are directly related to their architectural design. The energy consumption of a public building, according to Eletrobras (2007), is linked to technology standards and energy efficiency of various systems and equipment installed, as well as its architectural features, local climate, the activity it is intended for, and the users' habits and degree of awareness for the

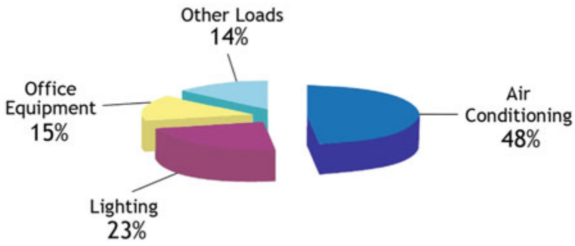


Fig. 1 Profile of electricity consumption of public buildings in Brazil. *Source* Eletrobras (2007)

adequate and rational use of energy. Figure 1 shows the profile of the electric consumption in public buildings in Brazil. It can be seen that lighting and air conditioning are by far the two items with the highest percentage of electricity consumption.

Based on the problems described above, this research focuses on public school buildings, with emphasis on the design of classrooms. The study will characterize the performance of classrooms in a public school in the city of Rancho Queimado with regard to "visual comfort" and "energy efficiency" issues. The school was visited by our team and measurements were made that revealed problems, which can be solved through simulation models by using analysis tools further specified in the Methodology section. Several parameter values were tested, and the results were converted into guidelines associated with integrative tools to aid the architectural design of classrooms.

2 Methodology

The school presented in this paper was selected because it is a public primary school, located in a rural community far from major urban centers. The methodology used for analysis includes the following:

- The school was visited on different days with overcast skies and light levels were measured using a light meter (Fig. 2)
- The measurement results were entered into a modeling computer software (Surfer 2002)
- The values were compared with the NBR 5413 (ABNT 1992) and some energy efficiency strategies were formulated from it

The results will help in the diagnosis of natural lighting in classrooms and other school environments, and offer some suggestions and recommendations for an adequate design and use.

Fig. 2 Instrutherm LD-200 light meter

3 Energy Efficiency in Brazil

Brazil is a world leader in the use of renewable energy. According to EPE (2012), the share of power generation from alternative sources such as hydro, biomass, and ethanol, in addition to wind and solar energy, increased from 86.3 to 88.8 %, while the world average is only 13 %, falling to 6 % among developing countries.

The Brazilian energy model has a great potential for expansion, stimulating long-term investment opportunities. According to the National Energy Plan 2030, public and private resources to the amount of US$ 352 billion will be invested in the expansion of power generation in the country (MME 2012).

Renewable resources are easily accessible and plentiful enough to supply about six times more energy than the amount consumed on the planet today, and yet, without exhausting them. In Brazil, the total energy that could be used with current technologies is 26.4 times the national demand (EREC 2010). Table 1 shows the potential of renewable energy sources in the country.

A study by the International Energy Agency and the National Energy Balance in 2008 showed that 77.3 % of the energy produced in the country came from hydropower. The study also showed that coal accounted for only 1.4 % of the energy produced. Elsewhere in the world this result was quite the reverse, since coal

Table 1 Potential of renewable energy sources in the country

Sun energy	20 times
Wind power	3 times
Hydropower	3 times
Biomass	0.2 times
Ocean energy	0.15 times

Source EREC (2010)

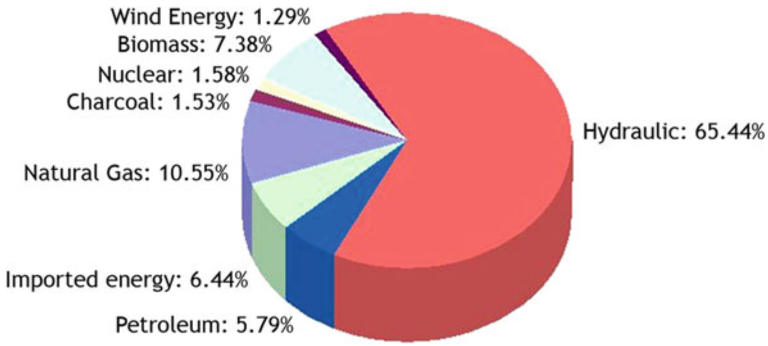


Fig. 3 Brazilian energy matrix. *Source* ANEEL-BIG (2012)

accounted for 40 % of the energy produced, while hydropower accounted for just 16 %.

The report on power generation by ANEEL (2012), by the end of 2011, showed that the country reached an installed capacity of 117,134.72 MW. This amount of energy comes from 2,608 different power systems such as hydroelectric, thermoelectric, wind, nuclear, and small hydro power plants. The data included in the inspection report of the National Electric Energy Agency (ANEEL) show that the national power generation system is updated to 31 December 2011.

The installed capacity demonstrates the intense participation of renewable sources in the current Brazilian energy matrix, as shown in Fig. 3.

However, preliminary data from the National Energy Bulletin 2012, available as of June 2012, added significant information that there was an increase in energy efficiency in 2011. Although the domestic energy supply grew 1.3 % in 2011 compared to 2010, reaching 272.3 million tons of oil equivalent (Mtoe), a lower percentage than that of GDP, which grew 2.7 %, according to the Brazilian Institute of Geography and Statistics (IBGE 2012). The lower growth in energy demand means that the Brazilian economy has spent less energy to produce the same amount of goods and services. The energy consumption per capita remained at 1.41 toe per person in 2011 (EPE 2012).

Brazil has considerable experience in the area, with projects developed since the 1980s, by the Brazilian Labeling Program (PBE), the National Program for Energy Conservation (Procel), and the National Program for the Rational Use of Oil and Natural Gas (Conpet). The PBE program has the support of Eletrobras, Procel, and INMETRO. The institutions involved directly with energy efficiency include the ministry of mines and energy (MME), the ANEEL, and the National Agency of Petroleum, Natural Gas and Biofuels (ANP), according to Nunes (2010).

In July 2000, the Brazilian government enacted Law 9991, which established the requirement for the application of a portion of the net operating profit in research and development of energy efficiency by concessionaires, licensees, and authorized companies for power generation and distribution. A portion is allocated to the

CTENERG fund, which should be applied in accordance with the regulations established by ANEEL (Nunes 2010).

Similarly, the enactment of Law 10925 in 2001 established the National Policy for Conservation and Rational Use of Energy. Following this law, labeling and inspection began as a tool for conformity assessment for energy-efficiency rating of machines and energy-consuming devices.

On December 19, 2001, Decree 4059 (Decreto N° 4059, 2001b) established energy performance levels which should be met by appliances and energy-consuming machines manufactured or marketed in Brazil, as well as construction buildings. The Decree also created the "Steering Committee of Indicators and Levels of Energy Efficiency" and, specifically for buildings, the "Technical Group for Energy Efficiency in Buildings in the Country" to regulate and develop procedures for the assessment of energy efficiency in buildings constructed in Brazil (INMETRO 2013).

According to EPE, Energy Research Corporation under the MME, efficiency actions were also proposed for other energy sources. This applies to the labeling of gas appliances, established by a technical cooperation agreement signed on October 24, 2002, including the Ministry of Industry and Commerce, the MME, INMETRO, CONPET, Petrobras, ANP, and the ABINEE Eletros. The labeling program of domestic gas appliances through the use of more energy-efficient ovens, furnaces, and heaters aims to stimulate a more rational consumption of gas, particularly LPG (Nunes 2010).

According to the Brazilian Ministry of Foreign Affairs, as of 2006, Brazil is a founding member of the International Partnership for Energy Efficiency Cooperation (IPEEC) established with the European Union for energy security and sustainability, aiming to strengthen cooperation in issues such as: (1) major international energy developments; (2) policies to improve energy security; (3) regulatory issues for competitive energy markets; (4) energy efficiency and demand management; (5) energy efficiency at the international level; (6) technologies to lower carbon fuels, including gas and clean coal; (7) cooperation on nuclear safety, with special attention to safe and sustainable technologies; (8) development and dissemination of renewable energy technologies and biofuels (consolidation of markets, technical standards and technological innovation in bioenergy production); and (9) security of vulnerable energy infrastructure. Highlighted actions include the sharing of lessons in formulating public policies on energy efficiency, technology transfer, and joint review of the monitoring plan by 2050.

Brazil has a significant international participation, taking part in the G8+G5 which created the "Heiligendamm Process" in 2007, when the member states committed to keeping the goals of limiting carbon emissions as established by the Kyoto Protocol. In the 2009 Symposium of the Americas, the government launched the project Urban Development in Low-Income Areas with energy efficiency: sustainable buildings and public transportation. It should be noted that, according to the Brazilian Association of Energy Efficiency (ABEE), Brazil is the tenth largest consumer of energy, but its consumption is expected to double by 2030, when the building sector will be responsible for 44 % of electricity consumption, including the use of home and office appliances (ABEE 2008).

In 2010, the fourth report was published in Brazil, which highlights the seventh and broadest Millennium Development Goal related to assuring environmental sustainability. For this to be achieved, goals relating to environmental quality of the physical, biotic, and human settlements were set, which are monitored by various indicators such as forest cover, carbon dioxide emissions, destruction of the ozone layer, biodiversity conservation, potable water access, adequate sewage, and urban population in slums.

On October 19, 2011, the MME issued the Ordinance 594 approving the "National Action Plan for Energy Efficiency—Assumptions and Basic Guidelines," which set out guidelines for the actions to be implemented in order to achieve the energy saving goals. A working group was formed to detail the established guidelines and put them into practice.

Brazil has been working heavily on actions to mitigate the inefficient consumption of energy to achieve the goals. For that purpose, many agents are involved in order to accelerate the goal attainment, which is vital for the nation's welfare.

4 Analyses and Interventions

The local government of Rancho Queimado is aware of sustainable development and is receptive to this research, which has educational and consciousness raising purposes, to be implemented at the "Escola de Educação Básica Roberto Schütz," a public school located in the district of Taquaras, municipality of Rancho Queimado, southern Brazil.

The venue was selected because it is near the UNISUL campus and because it is a public primary school that provides education for the children of the community.

The study began with a climate survey of the region and the climatic and physical conditions of the school. The analysis of architectural features and compatibility with the climate of the region can help reduce energy consumption in the building.

4.1 Bioclimatic Architecture for the Climate Zone of Rancho Queimado and Taquaras

The climate of Rancho Queimado is much colder than the state capital Florianópolis, despite the short distance. According to the Köppen classification, both cities have a humid mesothermal climate, with rainfall distributed throughout the year. According to Nimer (1979), the climate of Rancho Queimado is subsequent temperate tropical, super humid, sub-dry, with the presence of hot summer and mild winter.

The climate differences between Florianópolis and Rancho Queimado occurred because of the higher altitude of the latter, being 750 m in the district of Taquaras and 800 m in Rancho Queimado. High humidity during most of the year and the presence of two well-defined seasons are common characteristics of both cities.

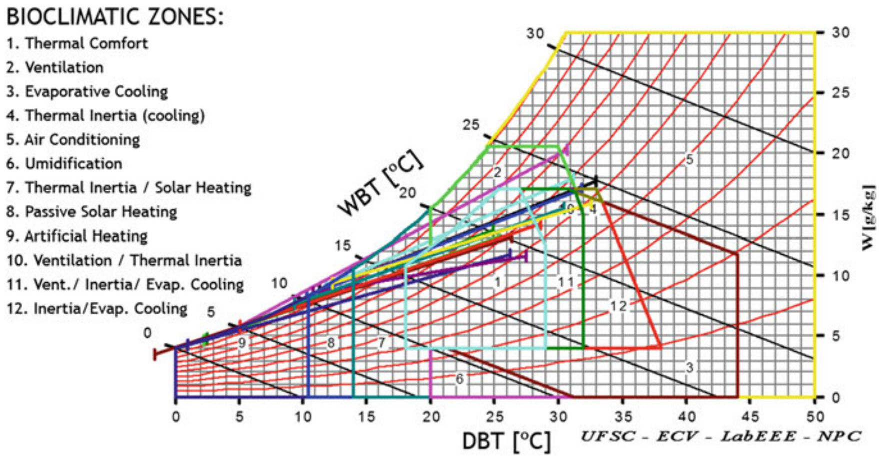


Fig. 4 Climate normals of Angelina plotted on the psychrometric chart. *Source* AnalisysBio (2013) computer software

The most suitable bioclimatic architecture for each region can be determined by plotting the climate data on a psychrometric chart with the delimitation of bioclimatic strategies, called bioclimatic zones, adopted in Brazil. Since there were no data available on the climate normals for Rancho Queimado, the authors used those of Angelina, which has the same altitude and climate characteristics, and is only 30 km away from the surveyed city. So, the climate normals of Angeline were entered into the AnalisysBio (2013) computer software to obtain the percentages of bioclimatic strategies most appropriate for this location, as shown in Fig. 4.

The strategies recommended for Angelina are presented in Table 2. It can be seen that the percentage of comfort is 37.88 % throughout the year. Passive solar heating/thermal mass (thermal inertia) for heating is 22.83 % through the year on average, ranging from 14.29 to 31.09 %. Passive solar heating is 13.97 %, and thus warming strategies are indicated for the whole year period. Annual passive heating strategy is 36.8 % (adding up the year average for passive solar heating/thermal inertia plus passive solar heating, columns 7 and 8, respectively) plus 12.7 % of artificial heating (necessary all through the year, except for the summer), totalling about 50 % annual heating demand.

Cooling strategies are required only in the summer season, totalling 12.62 % for the full-year period (this value was obtained by adding up the average values of the columns 3, 4, 5, 6, 9, and 11). Cooling in other seasons is not representative. It can be concluded that the need for air-conditioning is merely 1 % of the time.

The school bioclimatic architecture should prioritize good insulation on the walls and into the windows throughout the year. Moreover, the walls must have a certain thickness and be exposed to sunlight. Cooling must be primarily passive with good ventilation and natural cooling mass (thermal inertia for cooling). Following is a school design analysis.

Table 2 Percentage of bioclimatic strategies recommended for Angelina, obtained by using the AnalisysBio (2013) computer software

Month	Comfort	Thermal mass for cooling	Ventilation/ Mass	Mass/ Evaporative cooling	Ventilation	Passive solar heating/Thermal mass	Passive solar heating	Ventilation/Mass/ Evaporative cooling	Artificial heating	Air-conditioning
January	30.74	0	0	0	8.93	31.09	10.89	9.76	0	1.1
February	34.71	0.06	0.88	0	0.77	27.78	12.5	15.82	0	7.47
March	37.31	1.69	0.2	0	0	26.83	16.36	16.63	0.47	0.52
April	0	0	39.88	0	0	17.5	0	0	1.13	2.08
May	30.18	0	0	0	0	18.48	15.62	0	20.53	0
June	32.03	0	0	0	0	17.32	15.15	0	35.5	0
July	30	0	0	0	0	14.29	12.5	0	18.25	0
August	32.8	0	0	0	0	15.81	13.83	0	37.55	0
September	57.23	0	0	0	0	24.1	18.68	0	0	0
October	43.97	0	1.32	0	0	17.1	14.95	0	22.65	0
November	47.33	0	0	0	0	19.44	16.59	11.42	5.22	0
December	45.33	0	0	4.03	0	24.33	8.38	17.93	0	0
% for the entire year	37.88	0.16	3.8	0.36	0.87	22.83	13.97	6.43	12.7	1

4.2 Analysis for the Bioclimatic Design of Roberto Schütz School

Rancho Queimado and Angelina belong to Zone 3, according to NBR-15220-3 (ABNT 2005a), as processed by the ZBBR software (Roriz 2004). Because of the proximity, the district of Taquaras is also situated in Zone 3, which has certain climate features that will be commented on as follows.

The strategies indicated for this kind of bioclimatic zone (passive thermal conditioning) are cross ventilation and passive solar heating. The norm states that "*A cross ventilation is achieved by using air movement through the buildings.*" This means that the building must have windows facing opposite directions to facilitate air circulation.

The direction of the prevailing winds over the region is a key factor for the effectiveness of the ventilation strategy; the environment itself may significantly change wind direction. The prevailing winds in the Florianópolis area (Figs. 5 and 6) are north and northeast, and they occur throughout the year, mainly in the northeast direction. However, southwest and south winds are important in the cold season, and they come with cold fronts.

Roberto Schütz School only has windows on the south façade. So, to allow cross ventilation, the door should be kept open because there are no windows in the classrooms on the north façade.

The NBR 15220-3 (ABNT 2005a) norm recommends that the form, orientation, and construction of the building, and the correct orientation of glazed surfaces, should help to optimize heating during a cold season through sun exposure. The

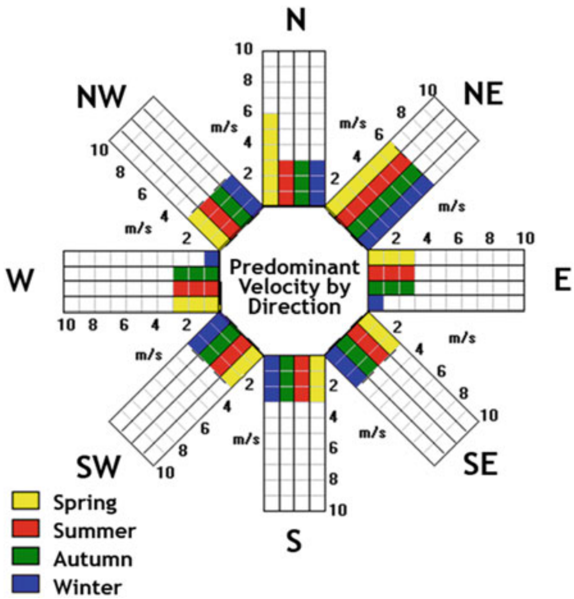


Fig. 5 Win Rose with prevailing wind direction. *Source* Analisys Sol-Ar (2013) software

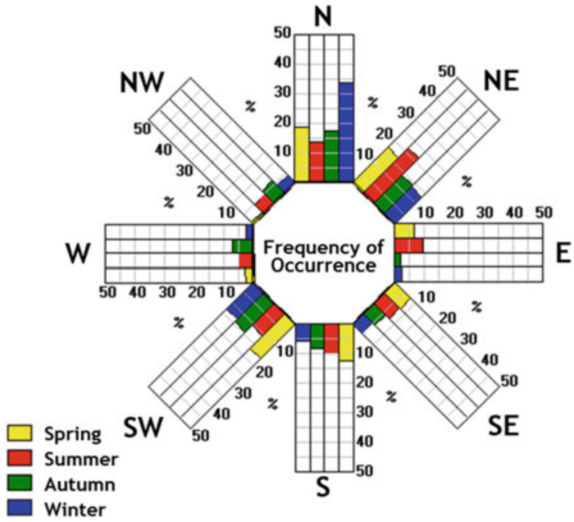


Fig. 6 Wind rose with frequency of winds. *Source* Analisys Sol-Ar (2013) software

color of external components also plays an important role in heating environments from sunlight. The classrooms of the school in question (Fig. 7) face the south façade. This causes an excessive cold during periods of low temperatures. Furthermore, passive solar heating strategy is also impaired since the north façade is shaded by the circulation area, and the windows do not receive sunlight.

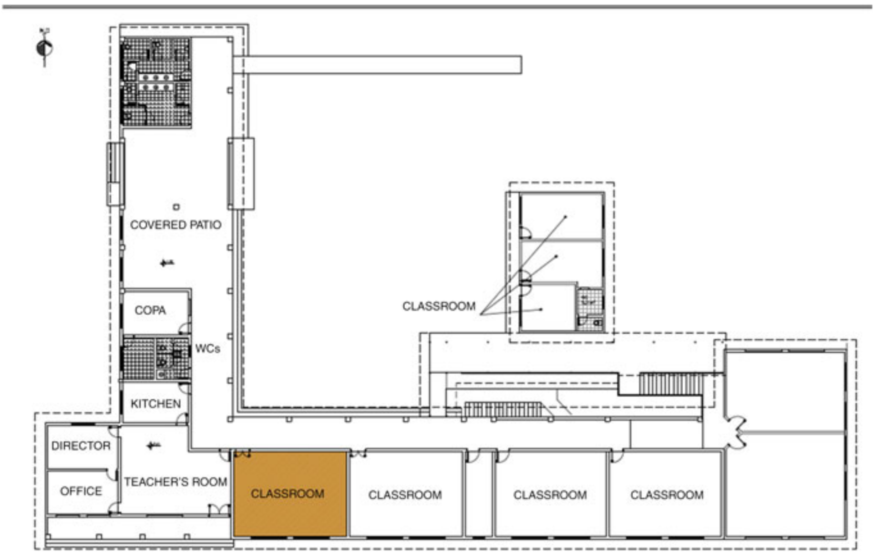


Fig. 7 Blueprint of Roberto Schütz School, highlighting the room analyzed

Decree 30436 (Decreto N° 30.436, 1986) recommends that the orientation of the classrooms, reading rooms, libraries, etc. should not have their external openings facing south, or be located along the side of the building at an angle less than 45° to the east–west direction. This means that the best position for the windows is facing north, northeast and northwest direction. For blurring reasons, the rooms should not be in the east and west direction, and, because of thermal problems, not in the south direction. When facing the northeast or northwest direction, brise soleil or sun-shading elements are recommended if the eaves have less than 1 m projection.

Confronting the school design under review with the norms and patterns, it can be seen that the classroom windows are facing south instead of north. Also, the corridor should be closed and face south. The school construction project should have taken the terrain into account.

Construction projects must be well-designed to avoid future problems. According to the school employees, it is very chilly inside the school building. Tap water is very cold during the winter season, and only the kitchen faucet has electric heating.

The purpose of this study is to develop and implement a retrofit which will focus on the environment of the classrooms and library, which are the most important and more frequently used spaces in the facility.

4.3 Lighting Requirements for Classrooms as Established by the Regulations

There are several requirements for a proper design of the classroom, and the lighting level is one of the most important.

Decree 30436 (Decreto N° 30.436,1986) determines that the lighting of classrooms should be natural, predominantly from the left side the room. In addition, artificial lighting will help during unfavorable weather conditions and at night. If zenithal illumination is needed, it should be around 23 % of the floor area and should avoid glare problems by using filter elements or baffles if necessary. The windows must cover at least 30 % of the area of the environment.

The NBR 5413 (ABNT 1992) recommends lighting levels for indoor and provides three illuminance values to be considered in various school environments. The values are tabulated, and, in the case of most rooms, they must meet the medium illuminance values, as demonstrated in bold in Table 3.

According to the regulations, the highest values must be used when the environment has high reflectance or low contrasts. In such conditions, the completion of tasks may be difficult, especially when high precision and productivity are required.

Table 3 Lighting levels (lux) in schools according to NBR 5413 (ABNT 1992)

Environment	Low	Medium	High
Class room	200	**300**	500
Drawing room	300	**500**	750

Additionally, higher illuminance levels should be available for those visually impaired, as is the case for elderly people, for example.

The lowest value is used when the reflectance or contrast is relatively high or when speed and accuracy are not important, and when the tasks are performed occasionally. As an example of precision, for instance, one can compare reading a newspaper with reading a medical prescription, the former being unimportant, while the latter is critical.

NR17 (2002) recommends that all workplaces must have adequate lighting, natural or artificial, general or supplemental, appropriate for the nature of the activity. These requirements can be extended to intellectual activities, such as a classroom. This norm also recommends that the general lighting should be evenly distributed and diffused. And both general and supplement lighting must be designed and installed to avoid glare, uncomfortable reflections, shadows and excessive contrasts.

4.4 Survey of the Lighting Levels in the Classrooms of Roberto Schütz School

The room available for the measurements was empty, and the others were identical to that wing (see Fig. 7). The walls were painted light green, and the ceiling had a sandy color in a darker tone than that of the walls (Fig. 8). According to the recommendations, the reflectance of the floor must be between 20 and 40 %, the walls between 50 and 70 %, and the ceiling between 70 and 90 % (Lechner 2001). Therefore, the ceiling should be as clear as possible, preferably white.

The measurements of lighting levels in the classroom were performed on November 9, 2012 (close to the summer solstice) on a cloudy day at 15:40 h. The number of measuring points in the room, calculated according to the NBR 15215 (ABNT 2005b), resulted in a minimum of 16 points. The height of the room was

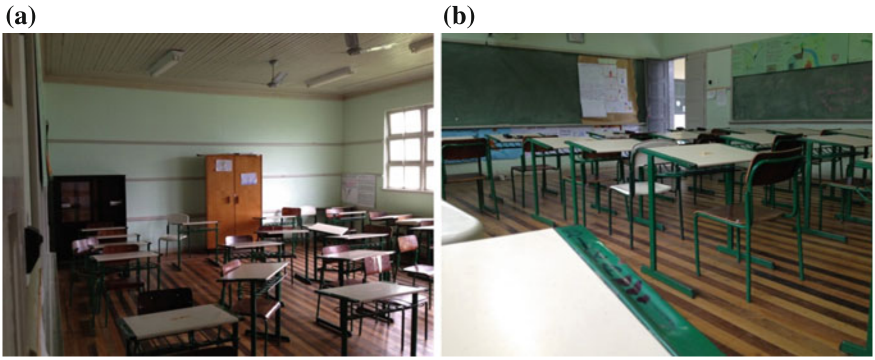


Fig. 8 Overview of the school classroom. **a** View from the classroom door. **b** View from the window

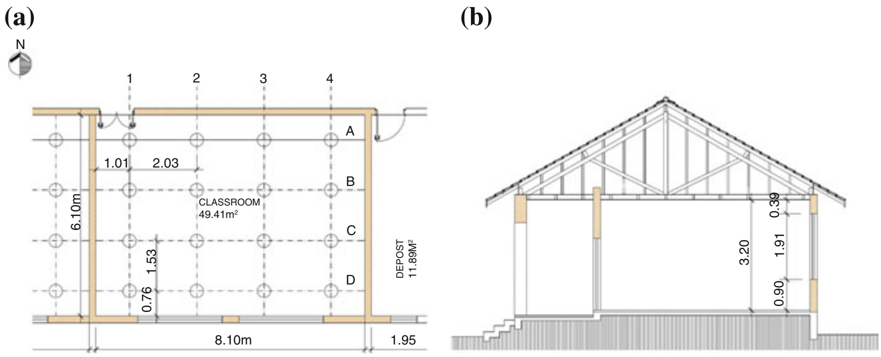


Fig. 9 Schematic design of the classroom analyzed. **a** Schematic drawing of the classroom with measuring points. **b** Schematic cross-section of the classroom

3.20 m, and Hm = 2.00 was obtained by measuring the distance from the working plane to the top of the window (Fig. 9).

Measurements were taken only with natural light between 15:00 and 15:30 h. The sky was anisotropic with 37,500 lux of external illumination level measured at this hour.

The measurements with natural light only (Fig. 10) showed more contrasting values, ranging from 1,300 to 45 lux, between the points near the window in relation to the opposite wall, respectively. The lighting only reaches an acceptable level in the center of the room. The lighting results are excessive near the window and insufficient along the wall. The lowest level recommended by the NBR 5413 (ABNT 1992) is 200 lux for classrooms, but the optimal value would be 300 lux, considering the activities involved in the environment.

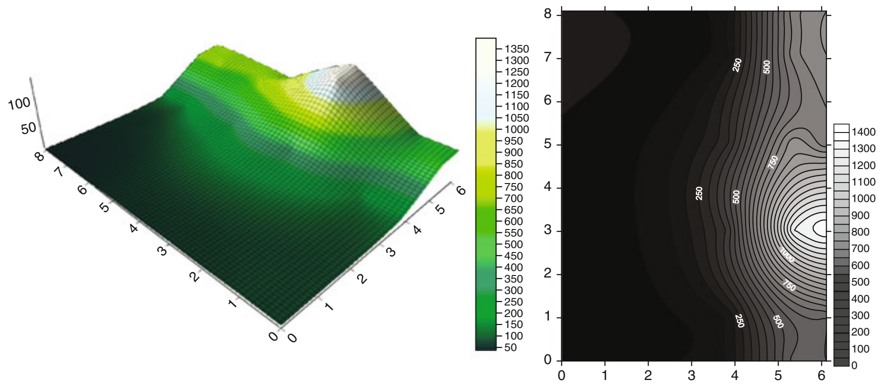


Fig. 10 Images with 3-D lighting levels of data obtained from natural lighting measurements only. *Source* Surfer (2002) computer software

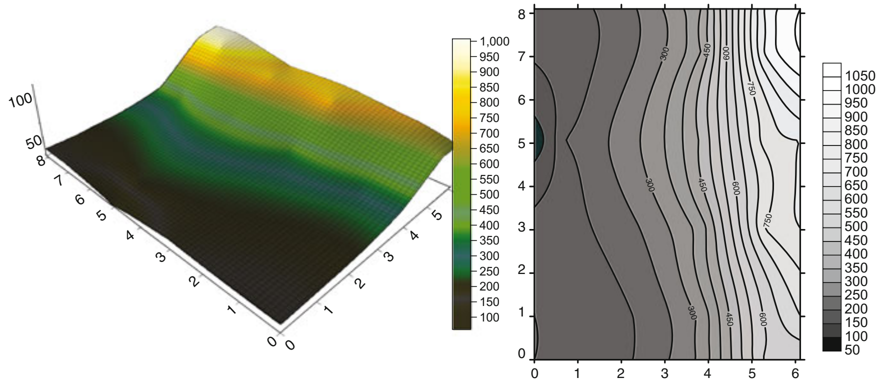


Fig. 11 3-D and 2-D images of lighting levels obtained with natural and artificial lighting. *Source* Surfer (2002) software

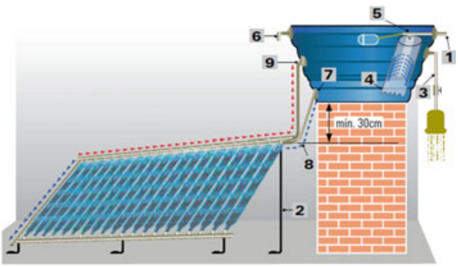
The second measurement was performed at 15:40 h with natural light associated with artificial lighting. The external illuminance was 32,500 lux. These measurements (Fig. 11) showed more uniform lighting levels within the room, ranging from 163 lux (by the wall) to a maximum of 920 lux (by the window). It could be seen that the classroom lighting was far from reaching the pattern levels, indicating the need for supplementing with artificial lighting inside the room.

4.5 Solar Water Heating System

As mentioned earlier, the climate of Rancho Queimado is very cold during winter, and passive heating is recommended all the year round. For this reason, solar water heating systems are recommended.

A low-cost solar water heating system made of PET bottles is proposed to be implemented in the Roberto Schütz School, as shown in Fig. 12.

Fig. 12 Solar water heating system with PET bottles—PET bottles with Tetra Pak boxes. *Source* Alano (2009)



BASIC SCHEME FOR A SOLAR HEATING

[1] Water inlet
[2] Fixture
[3] Hot water circulation
[4] Turbulence reductor
[5] Float Tap for water control
[6] Spillway
[7] Flange
[8] Cold water for the colector
[9] Hot water return

Fig. 13 Solar heater system with its constituent parts. *Source* Alano (2009)

This solar heater is composed of disposable products, primarily PET bottles and milk cartons (Fig. 12).

The system works by thermosiphon effect, in which the heated water rises naturally to be stored in a water tank, which should be above the solar collector plates at a distance between 30 cm and 3 m for proper operation (Fig. 13).

A system comprised of 100 PET bottles and 100 milk cartons covers an area of approximately 1.80 m^2 and is capable of heating around 100 L of water (Alano 2009).

Currently, the school just has hot water in the kitchen through an electric faucet. The proposal is to replace the current kitchen faucet and extend the hot water to the refectory, showers, and lavatories.

5 Proposals and Conclusions

Following are some improvement proposals for the school retrofit, based upon the measurements and analysis performed.

The measurements and diagnostic analysis revealed that monthly energy consumption of the school averages 2,366 kW, and consumption is primarily derived from artificial lighting and an electric faucet (Fig. 14).

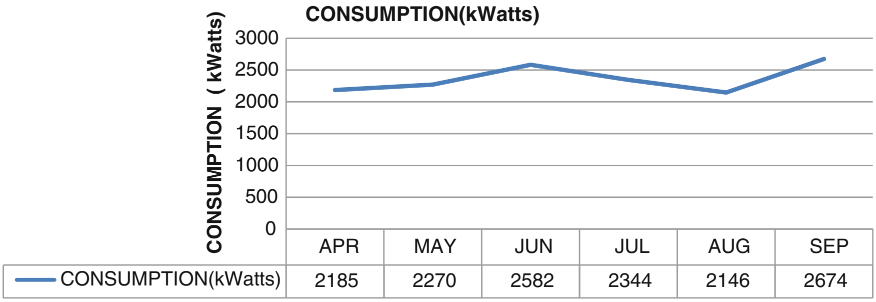


Fig. 14 The school's monthly energy consumption in kilowatts

It was observed that the classrooms had insufficient artificial lighting both in quantity and in quality. It was estimated that the average illumination level did not reach 300 lux inside the classrooms, as recommended by the NBR 5413 (ABNT 1992). The lamps were not efficient and the bulbs were T12 fluorescent, also inefficient compared to newer models, such as T8 and T5.

Improvement proposals include the following:

- Painting the walls and ceilings, according to the recommendations. Higher levels of illumination can be leveraged with adequate colours.
- Lighting system retrofit, including analysis of existing electrical installation to check their safety, capacity, and reliability. A new design of artificial lighting must be prepared, not only to increase the lighting levels, but also to replace lamps and lighting fixtures by more efficient ones. Each luminaire should be reflective, suitable for two fluorescent lamps (28 W power and 220 V) type T5. They must have a mounted diffuser and aluminium reflector fins.
- Install a passive solar water heating system, which will provide more comfort to school children, and reduce the energy bill, especially because of the electric faucet replacement.

All these measures will bring comfort to students and teachers, providing greater visual acuity and higher quality to the learning environment. In addition, there will be a financial return with consequent energy saving and a decrease in the electricity bill. Another aspect relates to education, since the installation of more efficient, sustainable devices are important issues in today's world. Students will have the opportunity to learn and understand the importance of sustainability and its relationship with the regional development.

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Integrated Land Use Development for Green Campus

N. Lakshmi Thilagam

Abstract

This study analyzes the concept of integrated land use management for sustainable development of educational campuses. In ancient India, educational campuses were places of learning and living built in harmony with nature. The traditional knowledge system ensured a more symbiotic and sustained relationship between the centers of learning and various levels of the social fabric. With modern developments of science and technology these have essentially transformed into large resource-intensive urban parasites. This chapter focuses on sustainable development for educational campuses through an integrated approach to land use management. Key factors such as density control, common pool facilities, and proximity between compatible building use and pedestrian friendly transportation networks are discussed in a holistic design framework. A list of desirable and undesirable aspects of design for each factor is characterized. These are discussed using case studies of three Indian Institutes of higher education, and in conclusion the study proposes a model land use plan for green campuses.

Keywords

Integrated land use development · Conflict resolution · Model land use plan

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1 Introduction

A university is equivalent to a small city, consuming vast resources and growing continuously. Although India has been the seat of excellent ancient systems of education such as the Nalanda, Vikramasila, and Taxilla, the notion of the modern university is a relatively new concept established during colonial rule. Unlike its traditional counterpart, the modern university has essentially transformed into a large resource-intensive urban parasite. The apex statutory body of the Government of India for co-ordination, determination, and maintenance of standards of university education in India, the University Grants Commission (UGC), was established in 1956. The UGC has the unique distinction of being an apex grant-giving agency in the country and hence has the highest potential and responsibility for ushering in a new system of education for the promotion of sustainable development and maintenance of Indian universities and places of higher education. With the establishment of more colleges and universities, it is imperative that the UGC advocates a sustainable development policy for the judicious consumption, conservation, and management of the natural resources of each individual campus.

2 The Concept of Sustainable Development

Sustainability is an all-encompassing concept and philosophically promotes the notion of basic human needs instead of the current trend of lifestyle based on "human greed and human wants." At its simplest, sustainability is:

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs"—Gro Harlem Bundtland, 1987 Director General of WHO (Brundtland 2001), wherein development itself encompasses all the actions we take to improve our environment. The Concept of Sustainable Development is not a fixed state of harmony but rather expresses the fluid nature of interconnectedness of all natural and manmade systems which impact one another. As highlighted in the Rio declaration on Environment and Development (1992), the critical balance of the interconnections between environment, economy, and society is important for a sustained global development.

3 Why Universities?

Universities and institutions of higher learning are the most appropriate centers for the promotion of sustainable development as they can make a unique contribution by knowledge creation and communication through research, student initiatives, outreach programmes etc. Colleges and universities are an integral part of the place they are located and thus possess the potential to influence the community on campus and off campus too (Barlett and Chase 2004). Universities employing sustainable development initiatives can be role models for small-scale applications.

Moreover, unlike cities, universities have a smaller decision-making body and stakeholder group and thus can be appropriate testing grounds for multi-level participation-based implementation of new sustainable measures.

Moreover, recent concepts of sustainability based on the 1992 Rio Summit and the 2002 World Summit have expanded beyond the physical environment with its natural resources. Sustainable development now encompasses three closely interlinked important components—ecological integrity, social well-being, and economic well-being. Thus, by embracing sustainable practices universities not only benefit from campus operations but also influence the lifestyle and value enhancement of its human resource (Leal Filho 2010). It is for this reason that universities and institutes which influence the formative years of a human being are viewed as fertile ground for furthering the philosophy of sustainable development.

4 Focus of Study

The main focus of this chapter is the application of sustainable concepts and development through land use planning and management in institutes of higher learning. Since land is the primary resource; the initial nature of planning and design of the site will have a long lasting impact on the qualities of the overall environment and thus needs to be well thought out before implementation.

5 Integrated Land Use Development

Land use is a term which describes the way in which we use space (both built and open space).

Integrated land use development and management is, conceptually, a conflict-resolving measure aiming at sustainable development of educational campuses. The World Conservation Strategy Report (IUCN 1980) states that development must be compatible with conservation for a sustainable future. For such a holistic growth, sustainable development in a land use management context must embrace all three dimensions—environmental, social, and economic. Thus land use-planning needs to be integrated to allow for a more inclusive growth. Indian universities are often well-serviced, isolated, gated communities, and exist as parasitic components in the local urban fabric, causing animosity between the locals and the institute dwellers. Such an exclusive development of a public institution generates hostile surroundings and defeats the very purpose of its establishment. This chapter focuses on an integrated approach to land use management by identifying factors such as density control, common pool facilities, compatible building use proximity, community services, and a pedestrian friendly transportation network.

6 The University Campus

> A university stands for humanism, for tolerance, for reason, for the adventure of ideas and the search for truth–Jawaharlal Nehru, 1947

Establishment of universities involve the investment of large economic, physical, and human resources. The term campus as applied in this study refers to the complete physical environment of habitation, including the natural and manmade factors of an institution of higher learning.

As highlighted by Ar. Kanvinde, students, faculty, physical infrastructure, and the academic programme form the four fundamental components of any institution of learning.

> The quality of the social-living-work-study environment of an educational campus has a direct bearing on the ability of an institution to discharge its educational responsibilities effectively (Kanvinde and Miller 1969).

Attributes of a university campus that influence the site planning and design in the formative stages:

- Guiding philosophy—vision and mission
- Size and scale of operations
- Location and geographic features
- Project requirements—nature of academic, administrative, and supporting activities
- Projected nature of growth and expansion
- Anticipated pattern of change to accommodate inclusive growth

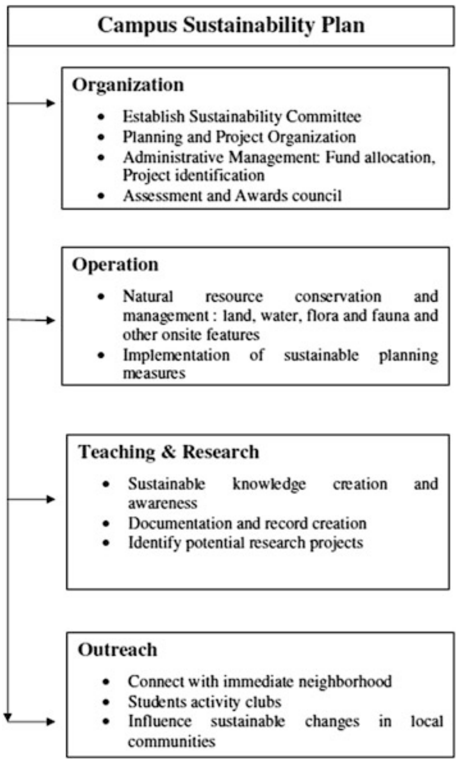
A university campus must not be seen in isolation, rather a university and its surrounding region/community must mutually benefit from each other. Hence the location for a new university should consider the projected impacts of the new project and only decide on a location that allows for a positive growth of the city region. The site often has an overriding influence in the initial planning of a new university campus, hence the choice of site must be based on various economical, cultural, geographical, and feasibility factors. A sustainable site selection process must include a public debating forum for the choice of site, with more than one site option and not be merely influenced by political will.

A clear guiding education philosophy and an outline of mission statement can form a sound springboard for the initial conceptual evolution of the planning of the campus. A clear understanding of the project requirements vis-à-vis spatial requirements based on capacity data, resource requirements based on state of the art technology and operations requirement based on functional nature of institute will also allow for a clear need based strategic evolution of the campus.

> A campus must be designed to the measure of man himself, his physical dimensions, his habits, responses and impulses (Kanvinde and Miller 1969).

Any university campus is a constantly growing phenomenon, and therefore foresight for change and flexibility based on future demands and expansion must be robustly built into the conceptual evolution of the campus planning and design. Although the above list outlines the logical beginnings of any campus design, it is the measure of sensitivity towards each factor which determines the long-term sustainability of the campus. To ensure this, a first step would be the establishment of a campus sustainability plan right at the beginning.

The main components of a campus sustainability plan are:



For a campus to achieve sustainable means of development, the following policy formulation is essential:

1. Land—conservation and preservation of specific natural habitat zone, pooling and sharing amongst compatible use zones, densification of use to avoid dispersed and spread growth.
2. Energy—minimum and efficient utilization, prevention of loss and energy auditing to assess consumption, encouragement of alternate source; allocation of land for alternate energy generation such as windmill farm or solar plant.

3. Waste—management starting at source, processed recycling and on-site composting.
4. Transportation—reduced travel time, encouraging mass transportation and vehicle pooling, prioritized pedestrian network.
5. Environmental quality—reduced pollution of air, water, and noise.
6. Building design and architecture—green practices for the architecture of individual buildings ensuring sustainable practices in the mode of construction and choice of materials.
7. Landscape and ground cover—develop and maintain wood cover, reduce impenetrable ground cover, plantation using native flora, reduce building footprint and increase open space.
8. Community interface programme—resource sharing, expert knowledge provision and common local area development programmes.

Design issues for consideration during site planning and campus design are:

- Pattern of growth—the pattern of growth determines the structural form of the campus, linear, concentric, zonal, sectoral etc.
- Movement network—the network of movement of vehicles and people determines the efficient conservation of energy in the long term. Streamlined network integrating uninterrupted pedestrian lane throughout the campus is the single biggest challenge.
- Location of core—the core denotes the main operational/functional spaces of the institute and needs to be well accessible for its users. The core often forms the pivotal point of reference for future growth and expansion.
- Overall zoning—delineation of land under wood cover, future occupation and for community interface activities must be done at the initial planning stage itself and not as a retrospective measure. The overall activities of the institute can be basically zoned into the core activities and support activities.
- Building organization—a compact central campus with higher density, centralized common services for library, administrative offices and common labs. Interconnection between buildings through covered walkways increases connectivity. The maximum walking distance for students from hostel to classrooms can be approximately 10–15 min.
- Open space structure—apart from a central large open space intended for large institute gatherings, smaller open green covers adjoining buildings are more effectively usable as informal outdoor spaces.

The above list of design issues describes the skeletal organization of a campus and needs to be deliberated in detail for each specific campus.

7 Case Studies

To understand the impact of site planning principles, a case study of existing campuses is undertaken. Three institutes of higher learning from three different regions and on three different scales are selected for an understanding of the various design issues considered. The selected case studies are:

1. Thiagarajar College of Engineering, Madurai, established in 1957, spread over 140 acres with a faculty strength of approximately 240 and student strength of approximately 3,000.
2. National Institute of Technology, Trichy, established in 1964, spread over 800 acres with a faculty strength of 246 and students strength of 3,200.
3. Indian Institute of Technology, Kharagpur, established in 1950, spread over 2,100 acres with a faculty strength of 550 and students strength of 9,000.

(The data pertaining to each college has been obtained from the individual college websites in March 2013: www.tce.edu, www.nitt.edu, www.iitkgp.ac.in).

8 Case Study 1: Thiagarajar College of Engineering, Madurai

Established in 1957, spread over 140 acres with a faculty strength of approximately 240 and student strength of approximately 3,000. The college has an industry-interaction interface at the very entrance to the college which forms an enterprising welcoming image for visitors to the college.

The core of the institute is the main administrative block and is interlinked by covered corridors with adjoining departments. The core encloses large courtyards which form interactive open spaces for the student. The playing fields and grounds are in front of the core and form a very vibrant space in the evenings as evident in Fig. 1. The food joints, student services, and library are also in the near vicinity of the core, making the campus a close knit personal space for its inhabitants. Both the boys' and girls' hostels are within a walking distance of 5 min.

The schematic structural organisation of this campus as seen in Fig. 2 is based on a spinal organization. The main spine is the traffic network which runs through the entire campus, with the various components arranged along this spine.

Planning aspects: playing field adjacent to residential and academic areas encourages large student participation and enhances the spirit of the campus. The single traffic spine connecting the various academic zones reduces traffic flow while allowing for easy connectivity.

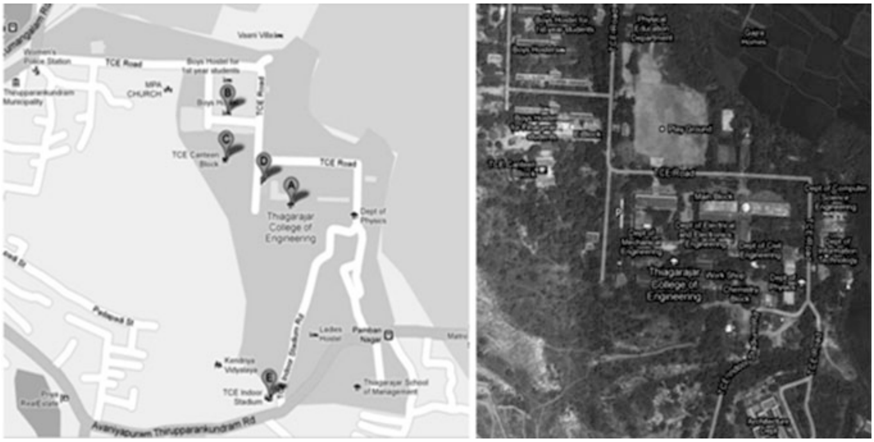
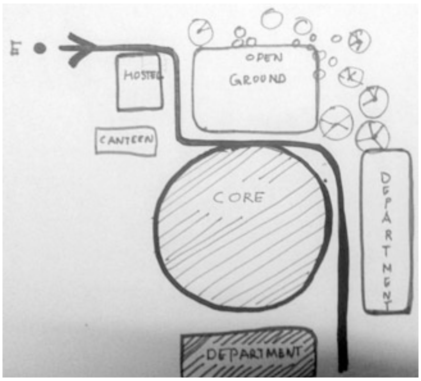


Fig. 1 Google image and map of Thiagarajar College of Engineering, Madurai. *Source* Google images (Accessed March 2013)

Fig. 2 Schematic spinal pattern of organization



9 Case Study 2: National Institute of Technology, Trichy

Established in 1964, spread over 800 acres with faculty strength of 246 and students strength of 3,200 is a large low density spread out campus with long travelling distances between its departments.

The campus constitutes of two main arteries which feed into the two distinct zones of the campus: the institute part and the residential part. Running between the two arteries in an east–west direction is the main traffic network which forms a sector pattern of organization of the overall site, as seen in Fig. 3.

Fig. 3 Google image and map of National Institute of Technology, Trichy. *Source* Google images (Accessed March 2013)

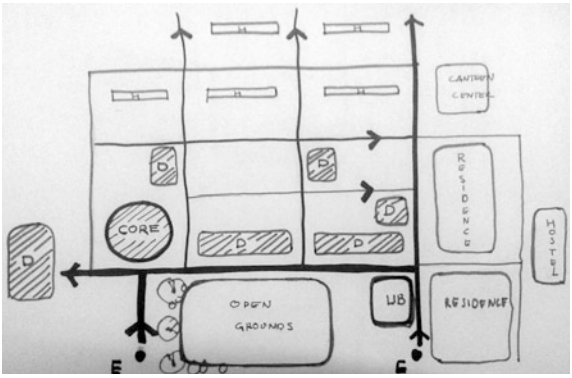


Fig. 4 Schematic sectoral pattern of organization

The institute core with the administrative block is offset to one corner of the campus with some of the departments being located very far from the core. The students' services such as banking are situated far from the core at a walking distance of at least 10 min. The recreation facilities are cut off from the students residential area and are in close proximity to the institute departments, thus not ensuring efficient incidental usage of these spaces.

The schematic structural organization of this campus as evident from Fig. 4 is based on a sectoral organization. The entire site is divided in chess board fashion with each department sitting in its own plot, resulting in a very much less interactive and informal academic rigour.

The campus is totally compounded and has no interface with the local community. The walking distance between the farthest hostel to the core is approximately 20 min, thus necessitating the use of vehicles for movement within the campus.

Planning aspects: lack of street/road hierarchy combined with sectoral planning enforces a rigid movement pattern. Plotted development of individual departments further increases the distance between them and reduces incidental/informal interaction within departments. Student residential area is relegated to the backyard of the campus.

10 Case Study 3: Indian Institute of Technology, Kharagpur

Established in 1950, spread over 2,100 acres with faculty strength of 550 and students strength of 9,000. Although the scale of this institute is much larger in comparison with the other two institutes, it presents an interesting study in sustainable site planning.

The campus is bisected by a main spine running north–south (Fig. 5), the eastern zone being devoted to institute–academic use and the western and southern zones to residential facilities for students and faculty.

The core housing the main administrative and academic services is located close to the entrance and in close proximity to the different academic departments. The library is located within the core, unlike the other two case studies, and thus allows for a secure operation till late.

The students' residential facility is located in close proximity to the recreation facilities such as the playing fields, grounds swimming pool, food joints etc.

However, the major drawback of this site plan is the organization of the staff quarters. Typically fashioned in the colonial mindset, each quarter is located in a large plot, hence the staff quarters alone occupies nearly 40 % of the plot area. This dispersed spread-out layout resembling "the broad-acre" concept of housing has resulted in a loss of land conservation for future growth or wood cover preservation.

The schematic structural organization of this campus is based on a spinal and sectoral arrangement as is evident from Fig. 6. This institute too is strongly guarded and does not allow for nonintended users to enter in spite of its scale.

Planning aspects: an academic space centered around a core allows for easy access and intermixing between departments. A students' residential space centered around recreational facilities acts as a binder between the various student

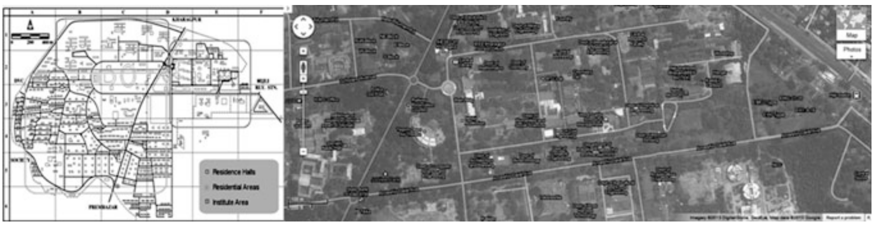


Fig. 5 Google image and map of Indian Institute of Technology, Kharagpur. *Source* Google images (Accessed March 2013)

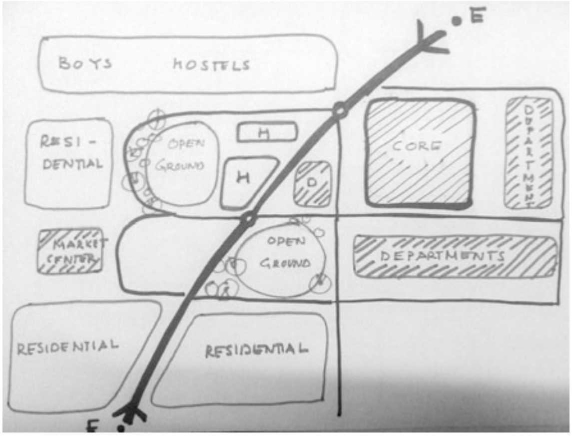


Fig. 6 Schematic spinal and sectoral pattern of organization of the campus

communities. The main drawback is the dispersed planning of facilities which has not allowed for a major land reserve for future largescale endeavours.

11 Conclusion

Based on the above discussions and case studies, an ideal model encompassing sustainable principles is proposed for the site planning and design of new campuses. In creating ideal campuses, the basic concept of integrating the built space into the natural setting of the site must be the fundamental design ideology. Some of the key design parameters which influence the sustainable infrastructure and growth of the institute are:

- Establishing the core—it is important to evolve conceptually the whole institute around a core to develop a sense of belonging for the residents. A functional and symbolic core will become the genius loci guiding all future growth.
- The core needs to be closely connected to the student's residential zone such that study and living become integrated during residency in the campus.
- The core can ideally be connected by exclusive bicycle tracks and pedestrian paths to the residential zones to encourage walking.
- Establishing an efficient transport network—mass transport route to connect to all zones/sectors of the campus, restricted vehicular motorways, uninterrupted bicycle and pedestrian paths and peripheral routes to provide emergency/service access for heavy vehicles into the sectors.
- Establish a buffer zone between institute zone and the local region to house community services which can be provided by the institute for dissemination of knowledge and skill to the local people. Provision of suitable value services can also be encouraged.

- Identify and earmark land pockets for conservation as green/wood cover. Community led reforestation programmes may be developed to generate awareness and involvement. Delineate suitable pockets of land for establishing on-campus alternate energy sources. Provide for protection and preservation of local flora and fauna, if found within institute premises, through a natural biodiversity management plan.
- Encourage medium/high-density building usage to gain on open land cover. Encourage smaller and more interactive green spaces instead of large monumental open lawns/green covers. Provide for pervious ground cover and design landscapes for rainwater harvesting.
- Encourage green building practices and energy conscious approach in the architectural design of buildings.

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Evaluation of Current Laboratory Waste Management: A Step Towards Green Campus at Amirkabir University of Technology

Mina Yekkalar, Somayeh Panahi and Morteza Nikravan

Abstract

One of the main challenges to achieve sustainability at universities is to set an integrated waste management system. Laboratories of universities are significant producers of a wide range of waste streams, including hazardous wastes requiring special management to dispose of in a safe, efficient and ecologically sound method. This chapter mainly aims to investigate the current waste management in the laboratories of Amirkabir University of Technology (AUT) based on a study conducted in June 2012 as well as determining the major challenges in the pass of implementation of such waste management systems. According to the results, it was determined that the laboratory waste stream at AUT had a considerable potential risk and also recycling potential. Moreover, reported experiences showed that the scarce attention had been paid to laboratory waste management at AUT because of some barriers including, lack of economic resources, lack of enough personnel, lack of policies and regulation to support and supervise the environmental activities, lack of environmental awareness and practical experience, lack of incentives and motivation to draw attention to

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environmental issues, lack of clear performance measures for environmental activities, resistance to change behaviour, lack of coordination, and uncertainty about ultimate fate of collected waste.

Keywords
Amirkabir University of Technology (AUT) · Sustainability · Laboratory waste management · Potential danger of laboratory waste · Recycling potential of laboratory waste

1 Introduction

In recent years, high disposal costs, lack of landfill, raising the public awareness of environmental protection and legislative mandates have caused greater attention to waste management as one of the most prevalent sustainability plans in different sectors of society (Watson 1990). The educational sector has an infrastructure role in leading society towards sustainable waste management (SWM) because of their moral and ethical obligation (HENSE 2000). In addition, universities with thousands of students and staff and different laboratories generate a wide range of wastes. Therefore, they are expected to be leaders of environmental protection activities through the education of the students as future managers and their own practices (Watson 1990). While waste management plans in universities in developed countries began more than 20 years ago in both volunteer efforts and institutionalized ones (Armijo et al. 2003), there exist few studies within higher education institutions in developing countries. Thereupon, it would be informative to learn from the reported cases of environmental initiatives in universities of industrialized countries and think about obstacles to perform such innovative programs to offer proper solutions.

Some of the documented and published waste management activities at pioneer universities around the world are as follows. In a study carried out at University of British Colombia (UBC), a guideline has been prepared by Health, Safety and Environment (HSE) to provide UBC hazardous waste generators, including information on pollution prevention, waste minimization, and details of hazardous waste disposal methods (Environmental Services Facility 2009). Also, a manual has been documented by the Office of Radiation, Chemical and Biological Safety (ORCBS) to provide guidance to Central Michigan University (CMU) employees for disposal of hazardous chemical waste, radioactive waste, and bio-hazardous waste. This manual contains university procedures for handling and packaging such wastes in a safe and environmentally sound manner (Environmental Health and Safety 2009). Another study is accomplished by office of Environmental Health and Radiation Safety (EHRS 2011) to the development and implementation of proper management practices for all aspects of the handling, storage, and disposal of chemical wastes that are generated at the University of Pennsylvania according to applicable regulation.

Meanwhile, the lack of such studies in Iranian universities suggests documenting the results of the current study to implement appropriate waste management in the future. In this sense, the main aim of this chapter is evaluation of present waste management in laboratories of Amirkabir University of Technology (AUT) as well as determining the barriers to establishing a sustainable waste management in laboratories of AUT. The data generated by this research would produce the necessary information to set up an integrated waste management program in future plans.

1.1 Description of Study Area

AUT started its activities in 1958 and over time expanded its size and quality to the point that it is currently referred to as "Iran's mother industrial university" (Amirkabir Monthly Magazine 2004). AUT, third authoritative university in Iran, has chosen the strategy of "pioneer of sustainable development in Iran," for the next decade (Moghaddam et al. 2007). Based on the main targets of sustainable development, AUT's Office of Sustainability was committed and adopted the environmentally sustainable development principle. Today, the Office of Sustainability has made remarkable inroads at AUT during the two most recent academic years through environmental activities of its different committees, including sustainable construction, SWM, sustainable energies, HSE, sustainability and higher education, and sustainability and local partnership. The SWM committee is responsible for the development and implementation of proper management practices for laboratory wastes in order to dispose of hazardous waste in a safe, efficient, and ecologically sound method and also divert generated waste away from landfill as much as possible through reducing the laboratory waste generation and separation of recyclable waste. To achieve the mentioned goals, concrete actions called "Laboratory Waste Management" have been leading since June 2012 headed by SWM committee.

2 Methodology

Since an effective waste management requires a comprehensive understanding of current management systems, the methodology of the program focuses on the study of the current situation and investigation of major problems. So the laboratory waste management program has been developed in two phases. The first phase of the plan took place at the end of the academic year of 2012. While the first phase has progressed significantly and the results have been reported, the second one is starting to reach its potential. Phases of laboratory waste management program implemented are described in Fig. 1.

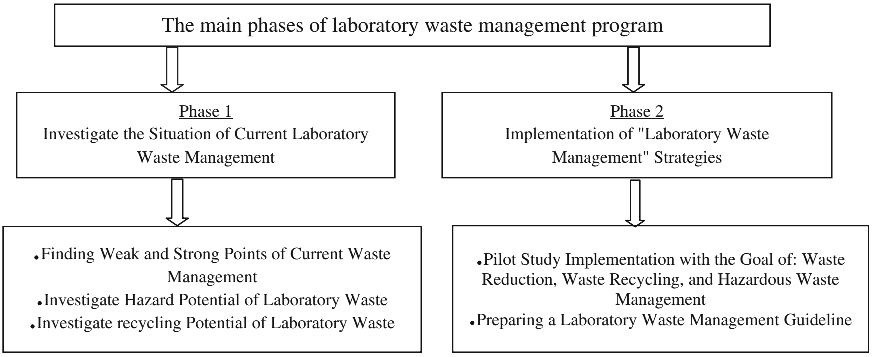

Fig. 1 Main phases of laboratory waste management program at AUT

According to Fig. 1, the objectives of this program are analysis of the current laboratory waste management at AUT and implementation of a "laboratory waste management" program. It is worth mentioning that the present chapter has focused on the results of the first phase which covers the following:

- To study current laboratory waste management and find its strong and weak points
- To discover the major reasons behind weak points of current laboratory waste management
- To investigate the hazard potential of laboratory waste stream
- To investigate the recycling potential of laboratory waste stream

Methodology undertaken for phase 1 is outlined two stages. (1) Desktop review: first stage involved a desk study in which documents and records relating to laboratory waste management are studied to obtain background information as well as preparing a checklist to enable construction of a conceptual model on laboratory waste management at AUT. (2) Site visiting: in this stage a site visit is conducted to interview the officers' of laboratories by the SWM committee to obtain a more detailed understanding of (1) characteristics of laboratory waste stream, (2) current situation of different laboratory waste management factors, including waste collection and temporary storage, hazardous waste separation, recyclable waste separation, on-site waste disposal, and waste delivery to the disposal center, (3) educational background of laboratory officers and the role to improve current laboratory waste management, and (4) barriers on path towards implementation of a SWM.

All information gathered in phase 1 is used to improve the efficiency and sustainability of AUT waste management services in the second phase. Phase 2 of the program attempts to evaluate alternatives to diminish waste generated and to create a waste management system which includes recycling waste with the potential to dispose of hazardous wastes in an environmentally friendly way.

3 Results and Discussion

3.1 Characteristic of Laboratory Waste Stream Generated in Laboratories

Laboratory activities generate a significant amount of chemical and biological waste streams. Waste streams generated through laboratory activities can sometimes be considered hazardous, requiring special disposal (Cardno 2008). So the primary step in performing a SWM program in laboratories is characterized by the waste stream. Laboratory waste streams generated at AUT, current disposal methods, and proper disposal methods are outlined in Table 1 according to EPA recommendations.

As shown in Table 1, the common laboratory waste stream has been categorized into two general classifications, including non-hazardous waste and hazardous wastes. Such classification has been selected because the worrisome environmental issues are disposal of hazardous waste in laboratories (Moghaddam et al. 2007). Hazardous wastes are substances that have flammable, corrosive, reactive, toxic, radioactive, poisonous, carcinogenic, or infectious characteristics. On the whole, wastes which have some of these characteristics are considered hazardous because they carry a potential risk to humans and the environment (Office of Radiation, Chemical and Biological Safety 2009). According to waste streams showed in Table 1, a wide range of hazardous wastes (e.g. bio-hazardous waste, oil waste, strong acids and bases, batteries, paints, etc.) are generated in AUT's laboratories.

Moreover, the waste stream generated in AUT's laboratories has shown a considerable recycling potential (e.g. oil waste, paint waste, batteries, metals, construction and demolition waste, broken glass, plastics, etc.). Recycling is a method to process wastes which can be used as raw materials for manufacturing other products (Armijo 2006).

3.2 Evaluation of Current Waste Management Situation

Prior to producing an integrated laboratory waste management, it is essential to evaluate current waste management and study its strong and weak points. Therefore, the next step of the study is dedicated to the evaluation of different waste management factors. A scoring system has been suggested in this chapter to compare the level of waste management in separate facilities. This system is based on the questionnaire which was filled in by laboratories' officers. Table 2 presents the results of the current situations of laboratory waste management in six faculties which are main laboratory waste generators at AUT.

As shown in Table 2, evaluation of current waste management performance has a focus on six major laboratory waste generators and has been divided and summarised into four elements including collection and storage at source, waste separation process including both recyclable and hazardous waste, on-site waste

Table 1 Characterization of laboratory waste streams at AUT and associated disposal methods

Waste stream	Example	Standard of disposal method	Current disposal method
None-hazardous waste	• Weak acids and bases	• Weak acid and bases are diluted with large amounts of water and disposed of via the drain	• All non-hazardous liquid waste (e.g. weak acid and bases) is discharged to the sanitary sewer system with no treatment
	• Debris contaminated with low concentration of hazardous chemicals	• Any waste contaminated with trace levels of a poison or carcinogen should be collected for incineration	• All contaminated debris with trace levels of a poison or carcinogen is disposed of in municipal solid waste bins
	• Construction and emollition waste (e.g. gravel and sand, concrete, asphalt)	• Construction and demolition wastes, metals, broken glass, plastics, and textiles are collected in specially designed containers for recycling	• Construction and demolition waste dumped in an area at the side of the civil faculty and then collected to transfer to landfills
	• Metals (e.g. steel, aluminium foils)		• Metals are collected for sale
	• Broken glass		• Broken glass, plastics, and textile are disposed of in municipal solid waste bins
	• Plastics		
	• Textiles		
Hazardous wastes	• Strong acids and bases	• Collect strong acids and bases separately and neutralize one with the other. If additional acid or base is required, sulfuric or hydrochloric acids and sodium or magnesium hydroxide, respectively, can be used	• All hazardous liquid waste (e.g. strong acids and bases, oil waste, etc.) is discharged into the sanitary sewer system with no treatment
	• Oil waste (e.g. hydraulic oil, lubricating oil, emulsion, refined petroleum based products)	• If the acid or base is highly concentrated, first dilute it to a concentration below 10 %	• Biohazardous wastes are disposed of in municipal solid waste bins or via the sanitary sewer with no treatment
	• Biohazardous waste (e.g. bacterial cultures, plant and animal tissue)		• All hazardous solid wastes (e.g. batteries) are disposed of in municipal solid waste bins
	• Heavy metals	• Oil waste should be collected in a proper waste container for recycling	

(continued)

Table 1 (continued)

Waste stream	Example	Standard of disposal method	Current disposal method
	• Batteries	• Waste streams and equipment coming into contact with the biological products are collected in plastic bags and autoclaved for 15 min at 121 °C	
	• Paints	• Batteries should be collected for recycling	
	• Solvents	• Wastes containing heavy metals, explosives, oxidisters, toxic and poisons,carcinogenic should be disposed of according their MSDs (material safety data sheets)	
	• Explosives		
	• Flammable waste		
	• Oxidisers		
	• Toxic and poisons		
	• Carcinogenic		

disposal, and waste delivery to disposal center. The following is a description of each element:

1. Collection and storage at source. The collection stage is the part of a waste management system and its main goal is to preserve health through waste collection from the generation centres in an efficient way and at the lowest cost (SEDESOL 2002). At AUT, storage areas are deficient and have not been designed or built with the goal of reducing risks to health, environment and the economy of the waste generators. This situation has provoked the generation of smaller dumps similar to what has happened in civil and environmental engineering and has caused plants to be damaged.
2. Waste separation. With regard to the results of Table 2 and interviews conducted with laboratory officers, it was indicated that, in spite of the high importance of hazardous waste management, performance related to hazardous waste separation is quite weak and they are typically disposed of into temporary dump site at AUT's campus and then carried to landfills or sanitary sewer without any treatment. It is important to note that landfills do not comply with the required technological characteristics and the majority of the final waste disposal sites are open air dumps in the city.

Table 2 Scores of current waste management performance

Faculty	Score (Proper performance has been scored 100)					
	Waste separation		Temporary storage of waste		On-site waste disposal	Waste delivery to disposal center
	Hazardous waste separation	Recyclable waste separation	Proper storage equipment	Proper storage area		
Civil and environmental engineering	55	79	42	38	18	25
Chemical engineering	23	60	38	35	16	23
Polymer engineering	33	42	40	36	15	29
Petroleum engineering	0	13	21	0	11	9
Textile engineering	33	50	28	24	10	28
Mechanical engineering	52	46	32	38	20	20
Mining and metallurgical engineering	52	64	36	30	32	23

In addition, the laboratory waste stream at AUT showed high potential for recycling. Nonetheless, none of the local companies which were called to be contacted with AUT to buy recyclable wastes were willing to receive mixed waste. Therefore, regarding the described situation, waste separation must be a high priority in a future laboratory waste management program.

3. On-site waste disposal. According to scores outlined in Table 2, on-site waste disposal is perhaps one of the elements of the waste management system that has received the least technical and professional attention. In addition, regarding the results in Table 1, it is clear that the typical waste disposal practices are dumping the majority of hazardous solid waste into landfills and discharging hazardous liquid waste to the sanitary sewer system without any treatment. So it can be concluded that current waste disposal methods at AUT do not meet the proper methods and it is essential to pay undivided attention to the on-site waste disposal parameter.
4. Waste delivery to disposal center. At AUT the wastes are transported to landfills for their final disposal. The satisfaction level of the waste delivery system is very low and it can be said that no organisation has been selected to deliver the separated waste to the recycling centre or special disposal sites. To face this issue, a private company should be hired to take the waste from the university's temporary storage and transport it to the treatment centres or municipal landfills.

3.3 Educational Background of Laboratory Officers

Based on the study conducted by SWM committee, about 97 % of laboratory officers believed that a training course including course materials, which would develop the awareness of SWM as well as increase inspired participation in environmental

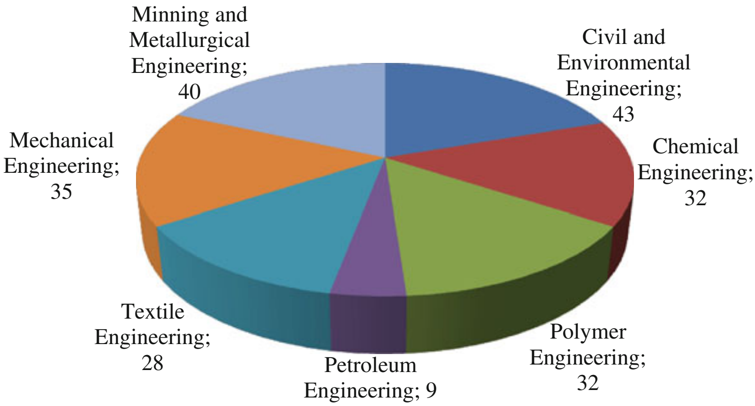

Fig. 2 Total scores of current laboratory waste management in different faculties at AUT

activities, is indispensable to all officers, students and staff connected with hazardous wastes.

Another considerable result is related to the variation of current laboratory waste management performance from faculty to faculty. As shown in Fig. 2, the performances of civil and environmental engineering and mining and metallurgical engineering faculties are better in comparison with other engineering faculties. Although it is hard to reach a general conclusion, it is worth mentioning that these two faculties have an environmental course in their syllabus which may offer an opportunity to familiarise their students with sustainability and environmental concepts compared with other faculties.

3.4 Barriers on the Path Towards Implementation of Sustainable Waste Management

SWM committee's experiences showed that the major barriers to a sustainable laboratory waste management are:

- Uncertainty about the ultimate fate of collected waste. Results showed that uncertainty about the ultimate fate of collecting waste is the main barriers to separation of wastes at source. Almost all laboratory officers believed that, because of the lack of strict environmental regulation, the ultimate fate of separated waste is delivery to landfills without attention to the nature of the wastes. In such situations it is obvious that a waste separation process is waste of time.
- Lack of policies and regulation to support and supervise the environmental activities. Although in some cases one observes that laboratory wastes are managed, no official regulation is applied. Absence of policies leads to uncoordinated, unfocused and short-lived efforts (Allen 1999; Bowers 1997; Creighton 1998). Several universities in developed countries have started waste

management programmes in recent years through the stronger discipline and a larger dedicated budget (Turpin et al. 2004).

- Lack of enough personnel. Despite some laboratory officers and students voluntarily spending their own time to establish a SWM at AUT, lack of enough personnel is another barrier to have a proper performance in sustainability efforts.
- Lack of clear performance measures for environmental activities. In order to promote active and voluntary environmental efforts, it is necessary to measure precisely the outcomes of environmental efforts. Environmental performance measurement provides information which helps with evaluation and decision-making within organisations engaging in environmental efforts and also gives interested parties a proper understanding of the activities of the organizations and their environmental efforts.
- Lack of economic resources. Funding is one of the problems of the university on a path of establishment of sustainability initiatives. Fiscal pressures on colleges and universities have been increasing in recent years, forcing campuses to operate more as corporations and to focus on economic performance (Shriberg 2002).
- Lack of environmental awareness and practical experience. Sustainability is a novel concept in developing countries such as Iran. This matter hampers any effort towards sustainability because of authorities' lack of environmental awareness and practical experience.
- Lack of coordination. The lack of coordination is an obstacle to communication between leading stakeholders, including academics, staff and students, leading to misunderstandings, unnecessary repetition of work and weak relations between them in environmental plans (Allen 1999; Shriberg 2002; Ching and Gogan 1992).

4 Conclusion and Recommendations

Based on the adoption of sustainability principles by AUT, SWM committee established the "laboratory waste management program" in June 2012. The main objectives of the program were:

- To study the current laboratory waste management and find its strong and weak points
- To discover the major reasons behind weak points of current laboratory waste management
- To investigate the hazard potential of laboratory waste streams
- To investigate the recycling potential of laboratory waste streams

The results in this chapter indicate that:

1. Attention has to be paid to laboratory waste management at AUT, which has led to the current situation of waste management to be a matter of concern.

2. The laboratory waste stream has shown considerable hazard potential (e.g. strong acids and bases and reactive, explosive, flammable, oxidizing and toxic substances, etc.).
3. A considerable proportion of waste is found in the recyclable and potentially recyclable categories (e.g. metals, construction and demolition waste, oil waste, etc.).

Moreover, the SWM committee's experience showed that the major barriers to achieving sustainable laboratory waste management are uncertainty about the ultimate fate of collected waste, lack of policies and regulation to support and supervision the environmental activities, lack of enough personnel, lack of clear performance measures for environmental activities, lack of economic resources, lack of environmental awareness and practical experience and lack of coordination.

With regard to the above, a strong tendency among laboratory officers to raise awareness of waste management and a better performance of faculties which run environmental courses, providing academics, students and staff with proper training courses, would be invaluable for expanding participation, commitment and success in environmental initiatives within AUT in future.

In addition, one of the most frequently mentioned elements in environmental initiatives is implementation of a pilot study under a waste management expert's supervision. A pilot study to test the effectiveness of a program, a new piece of equipment, policy, or other changes on a small scale can be invaluable for identifying unforeseen problems and working them out before a program is instituted university-wide. So, a pilot programme on laboratory waste management will be carried out before large-scale work, in an attempt to avoid waste of time on an inadequately designed project in phase 2. This pilot program involves action to design and develop SWM strategies across the laboratories of AUT. The following actions in the pilot programme will include:

- Diagnosis and inventory of waste generated
- Design of alternatives to eliminate or reduce the generation of laboratory waste
- Design of alternatives to separation of hazardous/recyclable wastes and material from the waste stream
- Development of training courses and workshops for laboratory officers
- Provision of a laboratory waste management guideline for students

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Gujarat Vidyapith: On the Way to Greening of the University

Nimisha Shukla and Rajendra Khimani

Abstract

Gujarat Vidyapith (GV), a university founded by Mahatma Gandhi in 1920, has a number of campuses in Ahmadabad city and other rural areas of Gujarat. Gandhi was not an environmentalist, but the lifestyle he had lived and inspires us to live, can solve many environmental problems. Of his 11 vows, 4 relate to the environment. They are Asety (non-stealing), Apaigrah (non-possession), Bread labour (work to live) and Swadeshi. The main tenets of Gandhi—Self-reliance, Swadeshi, Decentralisation and Limiting wants—also speak of environmental sustainability. Environment plays an important role in economy, viz., source, sink and services. As a source, the environment provides energy and natural resources in economic activities. The waste of these activities is released into the environment for which it acts as a sink. There are a number of environmental services—recreational and spiritual—which increase efficiency and productivity levels of an individual. Gandhi is often quoted—the Earth has enough to satisfy everybody's needs but not anyone's greed. For the last 7–8 years, GV has been trying to tread the path prescribed by Gandhi, which is now known as sustainable development (SD). The concept of SD includes the aspects of production and consumption and GV has kept both of them in mind. This chapter is divided into three sections. The first presents the case for greening the campus. The second describes various activities of GV which encompass a

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number of environmental aspects. It includes environment education at various levels in graduate and postgraduate courses, the water harvesting structures that GV has made, waste management by way of research in bio-gas and composting, the use of LED and solar lights and the energy park, self-sufficiency in the case of food grains and milk, construction of an auditorium which is based on the principle of green architecture, and purchase of steam cooking system and eco-friendly coolers. It would also include environmental learning by *Udyog*. The third and last section tries to look critically at each effort of GV with regards to environmental perspective. It also includes the future way as envisaged by the concerned individuals to make GV campus and the mindset of people working at GV more eco-sensitive.

Keywords
Sustainable development · Eco-sensitive · Water harvesting structure · Green architecture · Lifestyle

1 Introduction

In recent times, environmental issues have attracted lots of attentions of scholars as well as common citizens. However, the debate over environmental problems is not new (Seneca and Taussing 1979). Roman historians have recorded stench and stink in the capital city of the Roman State. During Victorian times too, London and other industrialised towns recorded pollutions of air, noise, and water. The sustainability issue in economic development of society has been raised since the times of the classical economists such as Malthus. He initiated the concept of sustainable development (SD) whereby he proposed that population increase was exponential as against a linear increase in food production. In such circumstances, population would exceed food production, and in modern terms, population could exceed Earth's carrying capacity. Unless human species keeps checks on population, nature will use its own checks and balances in the form of natural calamities to regain equilibrium.

The pace of economic development and the leaps in technology during the post-Second World War period brought the environmental problems on the global radar. In the more recent past, Hardin[1] (1967) put forward the theory of Tragedy of Commons. The Limits to Growth[2] (1972) showed that with advances in technology

[1] Hardin, 1968. Tragedy of Commons. Science. When property rights are not clearly defined, there would be no economic disincentive not to use up resources which would lead to overuse and pollution of resources, since every user would be a free rider, and eventually to environmental collapse.

[2] The Limits to Growth (1972) showed that advances in technology the world cannot support present rates of economic and population growth for more than a few decades from the time of the publication of the report. Daly (1999) producing a sharp concludes by saying, "in sum, both the theoretical and empirical arguments against finitude fail utterly. Since everything else in Simon's position depends on the abolishing finitude, the game is effectively over."

the world cannot support the present rates of economic and population growth for more than a few decades from the time of the publication of the report. Against this report, Simon[3] (1981) almost proved the case for more economic growth and more population growth without limits in his *The Ultimate Resource*. Daly (1999) has reached a sharp conclusion by saying "in sum, both the theoretical and empirical arguments against finitude fail utterly. Since everything else in Simon's position depends on the abolishing finitude, the game is effectively over."

United Nations appointed the UN Commission in 1983 for SD chaired by Gro Harlem Brundtland. In 1987, the Brundtland Commission published 'Our Common Future'. It has defined SD simply as:

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs. In more detail, it said, *SD is a process of change in which exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations.* At regular intervals, attempts have been made for achieving SD.

Environment plays three types of roles in the survival game of the human species. Its first role is as a supplier of resources. Its second role is to provide local and global environmental and ecological services. Its third role is to act as a sink which receives the waste generated in the process of production and consumption. Thus, environment has close linkages with the economy. The implication of the first law of thermodynamics is that the more the economy produces using natural resources (first role of environment), the greater will be the waste generated. We can neither destroy matter nor energy, we simply change the form. As a result, residue increases with increase in production. The waste will have to be returned to nature. Thus, any society trying to achieve fast economic growth has to contend with the issue of environmental problems and the sustainability of resource use.

Shift from soil economics to oil economics drastically changed the rate at which natural resources were used by humanity. With industrialisation, the rate of economic growth became rapid, followed by a rise in income and consumption. This, in turn, led to increased demand for energy and natural resources for production. Forests, water resources and fuel sources started being used at a very rapid rate (Schumacher 1973). However, there was no serious effort to replace and regenerate what was being drawn from nature. In the last few decades, humanity has realised that many of these natural resources are exhaustible and might not be available for future generations. Further, if they were exhausted, economic activities might also almost come to a standstill.

[3] Against this report Simon (1981) almost proved the case for more economic growth and more population growth without limits in his *The Ultimate Resource*.

The human species has been utilising energy in one or another form since its existence. In fact, no life on earth is possible without energy. Energy is also one of the most critical requisites for economic growth. The following data reveals the comparative analysis of energy status over the years the world over (Tables 1, 2 and 3).

Fossil fuels have continued their dominance on the world energy scenario. Out of the total primary fuel supply of the world, crude oil and coal are the most important sources of energy. In 1973, they contributed more than 70 % of energy supply. In 2008, there has been a decline in their contribution to about 60 %. The share of natural gas, for the same period, has increased from 16 to 21 %. In 1973, the world was consuming 76.5 % of total primary energy supply; it has come down to 68.7 % as a result of the economic crisis in 2008–2009 (Tables 4 and 5).

India produces about 67 % of its energy consumption. Out of the various sources of energy, except for electricity, all major sources, i.e., oil production, natural gas and coal show a deficit, in other words, consumption is exceeding production (Table 6).

The major source of energy consumed was electricity, accounting for about 51 % of the total consumption during 2010–2011. Coal and lignite were second (25 %), while crude petroleum (20 %) was third. The total consumption of energy from conventional sources increased from 40,354 peta joules during 2009–2010 to 42,664 peta joules during 2010–2011, showing an increase of 5.73 % (Energy Statistics 2012).

The estimated electricity consumption increased from 43,724 GWh during 1970–1971 to 6,94,392 GWh during 2010–2011, showing a CAGR of 6.98 %. Of the total electricity sales in 2010–2011, the industry sector accounted for the largest share, followed by domestic (23.8 %), agriculture (19.6 %) and commercial sectors (9.89 %). The electricity consumption in the domestic and agriculture sectors has increased at a much faster pace compared to other sectors during 1970–1971 to 2010–2011. Loss of electricity caused by transmission problems has increased from 17.55 % during 1970–1971 to 32.86 % during 2000–2001 and declined to 18.04 % during 2010–2011 (Energy Statistics 2012) (Table 7).

1.1 Universities in India

As of 22 June 2012, the total number of universities in India is 567 (en.wikipedia.org/wiki/List_of_universities_in_India). In a typical college or university facility, lighting, ventilation, and cooling are the largest consumers of electricity, and space heating accounts for the vast majority of natural gas use. As a result, these areas are the best targets for energy savings. By implementing economical energy efficiency measures, many colleges and universities have the potential to cut their energy bills by 30 % or more (Managing *Energy* Costs in Colleges and *Universities*—Touchstone 2012). Gujarat Vidyapith aspires to cut its energy bill by the same amount by its centenary year, i.e. 2020. The issue of energy saving is important in universities, as any public office, as it can be termed as Common Property Resource de facto, if

Table 1 Basic energy status 1973 [in million tonnes of oil equivalent (*mtoe*)]

1973	Coal	Crude oil	Oil products	Gas	Nuclear	Hydro	Combustible renewable and waste	Others	Total
TPES	1,500.95	2,866.65	−51.37	978.85	53.05	110.19	646.76	6.00	6,111.08
	24.56	46.91	−8.41	16.01	0.87	1.80	10.56	0.10	100.00
Consumption	638.71	22.15	2,226.56	657.61			618.71	515.61	4,674.35
	13.66	0.48	47.63	14.07			13.24	11.02	100.00
Industry	360.39	16.42	432.55	357.44			89.40	296.35	1,542.54
	23.36	1.05	28.04	23.14			5.80	19.21	100.00
Transport	33.00	0.00	1,018.37	17.72			0.24	10.60	1,079.93
	3.10	0.00	94.30	1.64			0.02	0.94	100.00
Other	239.31	0.00	520.83				529.07	218.67	1,766.97
	13.54		29.48				29.90	12.38	100.00
Non-energy use	6.01	5.73	254.81	18.37					284.92
	21.30	2.00	89.43	5.77					100.00

TPES Total primary energy supply
Other includes geothermal, solar, electricity and heat, wind etc
Transport includes international aviation and international marine bunkers
Source compiled from World Energy Statistics, 2010; International Energy Agency

Table 2 Basic energy status 2009 [in million tonnes of oil equivalent (*mtoe*)]

2009	Coal	Crude oil	Oil products	Gas	Nuclear	Hydro	Combustible renewable and waste	Others	Total
TPES	1,500.90	2,866.21	−46.21	978.94	53.05	110.23	646.09	6.00	6,115.21
	24.5	46.9	−0.8	16.0	0.9	1.8	10.6	0.1	100.00
Consumption	621.16	22.11	2,227.86	671.37	–	–	617.51	515.63	4,675.64
	13.3	0.5	47.6	14.4			13.2	11.0	100.00
Industry	356.98	16.38	432.09	362.02	–	–	90.79	286.35	1,544.52
	29.01	1.06	28.00	23.44			5.85	18.54	100.00
Transport	33.00	0.00	1,019.51	17.72	–	–	0.33	10.59	1,081.15
	3.05	0.00	94.30	1.64			0.03	0.98	100.00
Other	225.18	0.00	521.07	273.26	–	–	526.39	218.68	1,764.58
	12.76	0.00	29.53	15.49			29.83	12.99	100.00
Non-energy use	6.01	5.73	255.19	18.37	–	–	–	–	285.10
	2.11	2.01	89.51	6.47					100.00

Table 3 Comparison of energy consumption from different sources

	1973		2009	
	Consumption (mtoe)	Industry (% of Con)	Consumption (mtoe)	Industry (% of Com)
Coal	638.71	56.4	831.90	77.4
Crude oil	22.15	74.1	31.45	34.6
Oil products	2,226.56	19.4	3,430.68	9.4
Gas	652.61	53.9	1,265.86	35.0
Biofuels and waste	618.71	14.7	1,080.04	17.2
Others	515.71	55.5	1,712.94	40.3
Total	4,617.35	33.1	8,352.77	27.3

Source Compiled from World Energy Statistics 2012; International Energy Agency

Table 4 Key energy indicators 2009

Region	TPES (mtoe)	Electric consumption (TWh)	CO_2 emissions (Mt of CO_2)	Per capita TPES (toe)	Per capita electric con (kWh)	Per capita CO_2 emissions (t)
World	12,150.00	18,456.00	28,999.00	1.80	1,797	04.29
USA	2,162.92	3,961.56	5,195.02	7.03	12,884	16.89
China	2,272.00	3,545.00	6,877.00	1.70	2,650	05.14
India	675.83	689.54	1,585.82	0.59	596	01.37

Source International Energy Agency, 2012

Table 5 Total energy production and consumption in India (2011)

No	Oil production (thousand barrels per day)	Natural gas (billion cubic feet)	Coal (million short tons)	Electricity (billion kilowatt-hours)	Total primary energy (quadrillion Btu)[b]
Production	934.41	1,682	639,627	904.13[a]	14,585
Consumption	3,360.00	2,261	721,419	698.82	21,689
Net imports	2,425.59	579	81,792		6389[c]

Note [a]Net generation 2010; [b]2009; [c]Energy Intensity (Btu per 2005 US$) *Source* www.eia.gov/cabs/india/fullhtml

Energy Intensity is defined as the amount of energy consumed for generating one unit of gross domestic product (at constant prices)

not de jure. Such resources face the 'Tragedy of Commons' (Hardin 1967). Tragedy of Commons is depletion of a common resource by members of a particular group, acting rationally according to each one's self-interest, despite their understanding that depleting the common resource is contrary to the group's long-term best interests.

Table 6 Trends in consumption of conventional energy (peta joules)

Year	Coal and lignite	Crude petroleum	Natural gas	Electricity	Total
1970–1971	1,491	770	25	1,574	3,859
1980–1981	2,288	1,082	59	2,965	6,393
1990–1991	3,800	2,168	492	6,853	13,312
2000–2001	5,396	4,331	1,073	11,396	22,198
2010–2011 (*P*)	10,179	8,632	1,974	21,879	42,664
Growth rate of 2010–2011 over 2009–2010 (%)	1.36	6.94	10.21	7.00	5.73
CAGR 1970–1971 to 2010–2011 (%)	4.80	6.07	11.25	6.63	6.04

Source Energy Statistics 2012, Central Statistics Office

1.2 Gujarat Vidyapith

Gujarat Vidyapith campus area is 23 acres. It has a number of buildings. Apart from an administrative block, it has three colleges, one primary school, a library and a swimming pool for which electricity is charged on commercial basis. Since Gandhian lifestyle is better learnt by staying in community life, the hostel is mandatory for every regular postgraduate student. Hence, four hostels are situated on the campus for which electricity charges are of a residential nature. The electricity bill of the main buildings for the years 2009 and 2012 can tell a story of the energy use (Table 8).

2 II Experiments at Gujarat Vidyapith

Dayal (2006), one of the Gandhian scholars, argues 'Gandhi's primary concern was to revolutionise human life itself, to remake a man capable of cultivating Soul Force, by transforming his motivations and the modes of his nature so that he could meet the demands of life in *sattwic* way.' Gandhi understood that the State or the Market cannot regulate or limit demands, tastes and preferences, and hence it was the individual's behaviour which should be regulated. By consciously choosing lower materialistic standards, an individual quest for achieving a higher quality of life would be better satisfied. His use of a tiny tumbler on the banks of the flowing Sabarmati River near his Ashram in Ahmedabad is an illustrative case. When asked why he was using such a small tumbler when so much water was flowing in the Sabarmati River, his reply that 'he would draw only the amount he needed and the rest was for all who survived in nature' revealed the values he held and practiced. Later he also made somebody's remark popular—that there was enough for everybody's need and not enough for anybody's greed (Shukla et al. 2011a, b). In attempting to improve the quality of personal life, a sustainability problem would be solved as almost a positive social triumph. This is reflected in the lifestyle of GV

Table 7 Consumption of electricity (from utilities) by sectors (gigawatt hour)

Year	Industry	Agriculture	Domestic	Commercial	Traction and railways	Others	Total electricity consumed
1970–1971	29,579	4,470	3,840	2,573	1,364	1,898	43,724
1980–1981	48,069	14,489	9,246	4,682	2,266	3,615	82,367
1990–1991	84,209	50,312	31,982	11,181	4,112	8,552	190,357
2000–2001	107,622	84,729	75,692	22,545	8,213	17,862	316,600
2010–2011 (*P*)	272,589	131,967	169,326	67,289	14,003	39,218	684,392
Growth rate of 2010–2011 over 2009–2010 (%)	15.14	9.78	15.91	11.04	12.85	7.17	13.34
CAGR 1970–1971 to 2010–2011 (%)	5.57	8.61	9.67	8.29	5.84	7.67	6.98

Source Energy Statistics 2012, Central Statistics Office

Table 8 Electricity usage in main buildings of GV

Building	2009	2012	Growth rate
Admin. building	112,551	96,847[a]	NA
Library	357,909	452,152	26.33
Auditorium	33,238	63,249	90.29
Postgraduate college	256,974	310,141	20.69
Computer centre and other buildings	335,648	621,313	85.11
Bore well	169,446	431,367	154.58
Postgraduate hostel	312,643	336,503	07.63

[a]Electricity charges for only 8 months. *Source* Estate department, Gujarat Vidyapith

and the changes it is making to the campus. A description of the lifestyle and experiments at its Ahmedabad campus are as follows. The lifestyle at GV is very simple and consumes little energy.

GV has been working on two critical environmental issues for almost a decade—energy saving and natural resource management. GV has been experimenting on energy saving devices with the help of appropriate technological solutions. With the help of its University Science and Instrumentation Centre (USIC), the administrators are taking a keen interest in feasible solutions for energy saving and natural resource management.

The syllabi of various disciplines at under-graduate and postgraduate levels include environmental aspect of the particular discipline. Hence, in Economics, the students are taught Environmental Economics as well as Natural Resource Economics. The thrust of research also has environmental issues, albeit rural environmental issues, as the education at GV is centred on rural matters.

The first law of thermodynamics states that, similar to matter, energy cannot be created or destroyed. The implication of this law is, as we consume more, more waste is created. Disposal of this waste is a serous matter to be solved. GV has a Biogas Research Centre at one of its rural campuses, where gas is generated from human, animal and other organic wastes using bio-gas plants. Different types of bio-gas models are made by the scientist and popularised in nearby villages. The sadra gobar gas plant satisfies the hostel energy need. The campus of Ahmadabad also has two bio-gas plants.

In almost all centres of GV, composting is a regular feature. Mixtures of kitchen waste, leaves and other degradable waste are collected and earthworms are added. Also added is the waste on the campus collected by the students who sweep the entire GV campus every day as part of their daily routine. The organic manure, a ton per month on Ahmadabad campus, thus created is used for greening the campus as well as for increasing production from vegetable and terrace gardens.

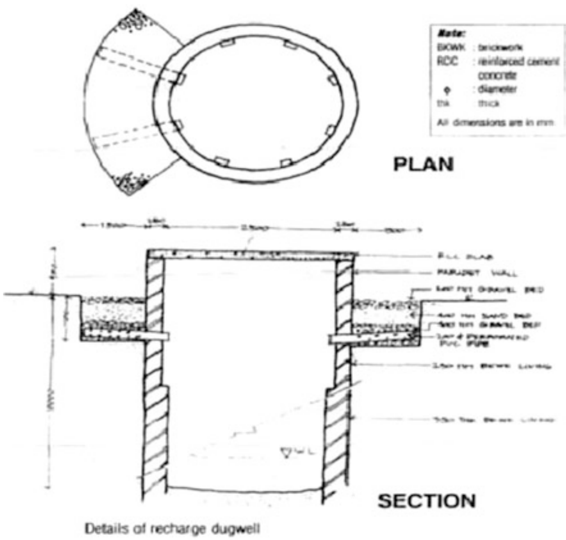
The Indian experience with the green revolution has produced mixed results. Although production of wheat and rice has increased with the introduction of high-yielding variety of seeds, chemical fertilisers and pesticides along with irrigation, the negative externalities on soil health and declining productivity are causes for concern. The story of GM crops is also not encouraging. Since the West started going organic, concerned institutions and scholars in developing countries have also been trying to reintroduce organic farming. GV is one such institution of higher learning. All three Krishi Vigyan Kendras (KVKs) of GV have been promoting organic farming to the neighbouring farmers along with their regular activities. The production of organic rice is a positive externality as it satisfies the rice demand of our hostels. The gaushalas on our rural campuses satisfy the milk demand of the students. The terrace and kitchen gardens at the Ahmadabad campus grow spinach and coriander along with other vegetables to be used in the hostels.

Water is one of the important natural resources. It is often said that water wars will lead to a third world war. GV has been making conscious efforts for water harvesting. These efforts have been made in two ways (Figs. 1 and 2).

First, about seven water harvesting structures have been made on the campus. The 'Khambhati Kuva' is 25–30 ft deep till the sallow aquifer is reached. Each structure has the capacity to absorb 40,000–50,000 L/h. After 2–3 h of continuous rain, water is absorbed. They are traditionally stock pit-type constructions with a diameter of 8 ft that decreases to 5 ft as one goes deeper. The average cost of each structure is around Rs. 55,000. Indirect benefits can be seen in terms of the increasing surrounding water table, less mud and hence more cleanliness and no mosquitoes and mosquito-dependent diseases.

The other water harvesting structure is a 450-ft deep ***bore well***. The rainwater gets filtered in a 10 × 10 tank and infiltrates through a 10-in pipe. There is no saturation level; and slow but sure water infiltration. Both these structures have reduced the TDS level on the campus from 2500 to 800–1,200. There is one existing well about 100 ft deep. A pipeline 1 ft in diameter has been put in this well. Rainwater is collected through gravity from a surrounding 200–300 ft diameter area. The well is

Fig. 1 The plan of Khambhati Kuva at GV



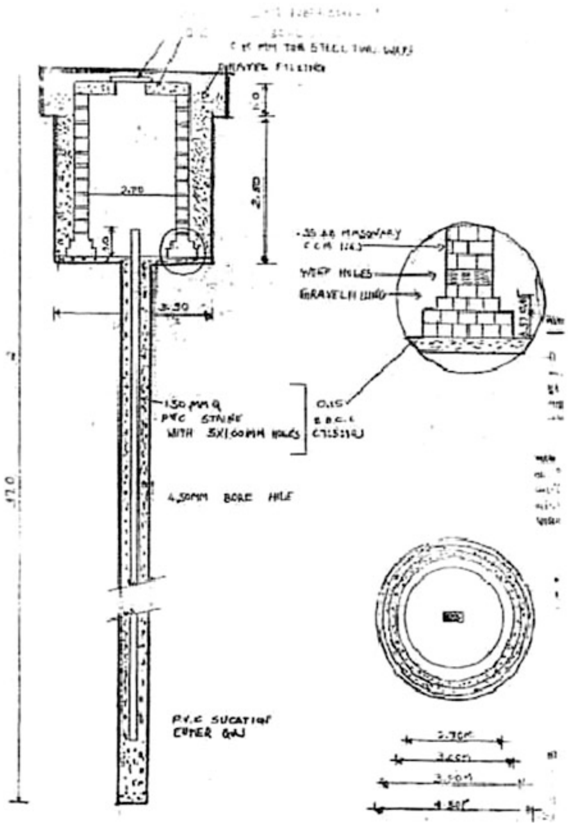


Fig. 2 The detailed plan of bore well at GV

filled during the rainy season and the water is infiltrated. This tube-well helps the water table to rise. GV has also constructed a tank with a capacity of 5,000 L for rainwater harvesting. There are five tanks of a traditional pot (mataka) shape in the girls' hostel, each with a 25,000-L capacity. The construction cost is less than the usual RCC water tank. However, the water turned sour last year because of the presence of cement and was used to water the kitchen and medicinal gardens (Fig. 3).

GV has an eco-friendly *auditorium* with a 750 seating capacity. It is constructed from the local materials such as bricks, lime and silica in the traditional manner of crushing lime and making mortar out of it. The construction is based on the Earth Cooling System. The temperature is found to be 8–10 °C less 3 ft underground. Hume pipes of NP2 size are used to make the tunnel below the ground. Air passing through this tunnel to the hall is cooled. These pipes open into two open tanks 30 ft deep at a distance of about 150 ft. There are three ducts in the auditorium which release air into the hall. In the open wells, exhaust fans push air onto a water spray; thereby making the air cool. There are hot air ducts in the hall which throw out the

Fig. 3 Eco-friendly auditorium

thin hot air through roof ridges located on the ceiling and cool air replaces hot air. Natural wind spin also throws out hot air without using electricity. Exhaust fans are during the monsoon period when humidity is high. In summer, it is 8–10 °C cooler inside the auditorium. It should be remembered that this is *not* an alternative to air conditioning, it merely improves the comfort level. The total cost of construction is one crore seventy lakh rupees, which is about Rs. 22,667 per capita. There is 70-W lighting equipment, floodlights or halogen use having been avoided. The auditorium can be used for academic purposes such as a seminar venue. The system needs to be started 1–1.5 h before needed to achieve its full potential.

Natural water cooler saves energy to a great extent. GV started with this system way back in 2005, but the issues of maintenance, limited storage capacity and a defective fabrication system led to failure. Since August 2012, GV has once again taken the initiative. GV has installed five water coolers; 150-L capacity with six taps and 100-L with two taps. They are made of stainless steel 304 along with a solar panel and DC fan. Although the water cooler is expensive in monetary terms, it has a lifetime guarantee, uses no electricity and has no moving parts which could create maintenance problems. The operating system of the cooler is simple: the water passes from a copper coil and hence it is hygienic. The water also tastes sweet. The coil has been insulated. The fan on the coil is operated by solar energy. The water is 2–3 °C cooler than a new pot. The system is good for schools, colleges and public places.

Fig. 4 Solar PV module at the rooftop of one of GV buildings

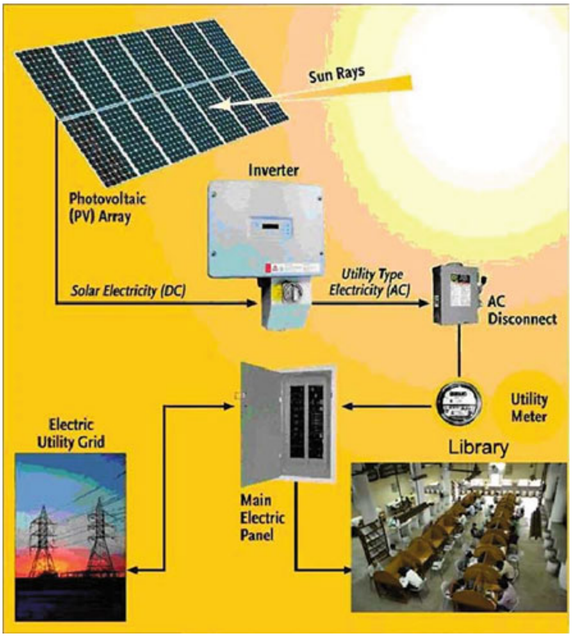


Fig. 5 The diagram depicting source of energy generation at GV library

Another energy saving gadget is a *steam cooking system*. This accelerates the speed of cooking with better performance and is more hygienic. GV has such a system for 100–500 students. It saves about 50 % of energy cost and 40 % cooking time. However, one complaint that students have is about the taste of the food.

Solar street light consists of an electronic photovoltaic cell which produces energy with the help of sunlight. Energy is stored in the battery for use during the night. Once fully charged, it can be used for 8–10 h. The institute has one plant at its State Resource Centre. The economics of it is as below (Figs. 4 and 5).

Solar PV module	
100 WP/48 V photo voltaic cell	20 units
Power conditioner unit	01
2 kW input/2 kVA, 230 V, 50 Hz output	
Battery bank (2-V cell × 24 cells = 48 V)	01
Meter cable, modular structure, junction box and other accessories	
Total cost	Rs. 5,04,000/-
After 30 % subsidy	
Total cost	Rs. 3,52,800/-
After 30 % depreciation	
Total cost	Rs. 2,01,600/-
Power generation details	
Average solar power generated per day	10 units
Street light (14 W)	60 units
PC cost of torrent power	Rs. 8/-
Saving per day (10 × 8)	Rs. 80/-
Saving per year (Rs. 320 × 365)	Rs. 29,200/-
Pay back period	6–7 years
100 kW *grid connected hybrid solar power plant*	
Solar PV modules	44
230 WP/24 V multi-casting photovoltaic cell	
Power conditioner unit	02
5 kW input/5 kVA 230 V, 50 Hz output	
Meter, cables, modular structure, junction box, MCB and other accessories	
Total cost	Rs. 10,58,000/-
After 30 % depreciation	Rs. 3,17,400/-
Actual cost	Rs. 7,40,600/-
Total power generation details	
Average solar power generated per day	40 units
PC cost of torrent power	Rs. 8/-
Saving per day (40 × 8)	Rs. 320/-
Saving per year (Rs. 320 × 365)	Rs. 1,16,800/-
Pay back period	6–7 years

2.1 Energy Park

GV has demonstrated a number of gadgets in its energy park such as a paddle power cycle, cooker, distillation plant, paddle power water pump, Ambar Charkha, lamp, parabolic dish dryer, musical instrument, paddle power compressor, etc., but they are not widely used. The efforts of the institute are to publicise them for general use, but they have not achieved the expected results (Fig. 6).

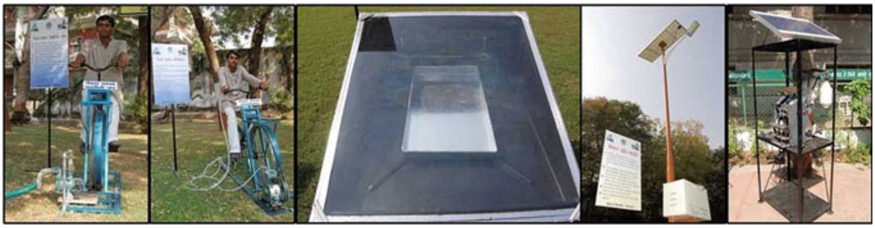


Fig. 6 Examples of energy saving tools at energy park

2.2 Khadi

The energy efficient cloth. Efficiency in energy utilisation can be achieved either by adopting a technology using low energy or renewable energy inputs. *Khadi*—a cloth made by hand spinning and hand weaving is an example of production using low and renewable energy. Shifting part of the cloth production to the *Khadi* sector has the potential to reduce significantly the use of fossil fuel energy. Protection and subsidy for this activity would be the green investment in Indian economy. In Gujarat Vidyapith, cotton khadi clothing is compulsory. One of the Udyog is production of hand spun Ambar Khadi.

When we suggest *Khadi* production as an energy saving device, its production process needs to be reviewed comprehensively. For saving all forms of energy other than human energy, one should start from the production of cotton in the field. We present a stage by stage picture (Shukla and Iyengar 2011a, b).

Cotton production. Modern agriculture which uses agro-mechanical and bio-chemical energies in the form of tractors and other mechanised farm implements including cotton pickers makes use of electricity or diesel for lifting and delivering water to the fields. Treated and transported seeds, chemical fertilisers, pesticides, herbicides and many other inputs make cloth production more energy intensive. Organic cotton is the most energy efficient and eco-friendly source for producing eco-friendly cloth.

Pressing and Ginning. Presently, most of the pressing and ginning process involves the use of electricity. Hence the cotton used for *Khadi* production uses electricity. This is one stage where energy saving is possible.

Making of cotton slivers for Ambar Charkha. The *Charkha* reintroduced by Gandhi, which took various forms, uses slivers that can be and are produced mechanically using human labour. However, in using *Charkha* there are limitations in producing enough output. *Charkha* is a good mechanical device using human labour for producing yarn for self-consumption which Gandhi called *Swavalamban*—self reliance.

Spinning and weaving. The traditional system of spinning had various forms. *Takli* and *Charkha* were the generic names. In the 1920s, hand spinning was re-established. Weaving was also a traditional occupation which was revived with great enthusiasm.

Dyeing. In India, dyeing has long been an activity using human energy. In the present context, using traditional labour-based dyeing not only provides employment but also promotes decentralised dyeing activities using organic colours. Use of organic colours reduced the adverse environmental impact considerably.

Let us now look at some calculations. Out of 1 kg of cotton, considering 10 % wastage, one hank of 1,000 yarn can be produced on *Ambar Charkha* with two spindles using human energy. The process would take 50 min. For producing 1 m *Khadi*, six to seven hanks are required. To weave 1 m of *Khadi*, 1.33 human hours are required. In all, it takes 2.25 human hours to produce 1 m of *Khadi*. If we apply human work output in agriculture equal to 0.1 HP or 0.074 kWh[4] to *Khadi* production, we would get 0.225 HP or 0.17 kWh energy-equivalent for producing 1 m of *Khadi*. Hence, assuming that labour uses only one one-hundredth of power, the estimate would give us 11.1 million meters of charkha yarn production from the population employed solely in agriculture. As against *Khadi*, to produce 1 m mill cloth, 0.45–0.55 kWh of electrical energy is required.[5] This means that *Khadi* is approximately 3.24 times more energy efficient than mill cloth.

India's population was 1.21 billion in 2011.[6] Assuming average consumption of 8 m of cloth, India requires 9.68 billion meters of cloth production. In 2002, *Khadi* contributed less than 0.5 % to the Indian textile market.[7] In 2008–2009, textile production was 54.20 billion m^2, with per capita availability of 39 m^2.[8] A recent survey shows that *Khadi* production was 1.11 billion m^2.[9] Hence, *Khadi* should take up the challenge to provide at least the average cloth consumption.

3 III Bottlenecks and the Solution

It is, indeed, difficult to tread the path prescribed by Gandhi. Although GV has been trying to go green, there is a 'long way before we sleep.' Various attempts, as described in the previous section have been made, but there is still a lot of scope for improvement. The change has to come from the employees, especially from teachers, as their behaviour significantly influences the behaviour of the students. The difficulties can be listed as follows:

- Inadequate coordination among the concerned groups: lack of coordination among various groups such as administration, faculty and students makes it difficult to understand the utility of environmentally friendly devices such as solar panels, LED lights, etc. It may happen that, except for a few individual

4 dieoff.org/page69.htm, retrieved on 27/04/2011.

5 oecotextiles.wordpress.com/…/what-is-the-energy-profile-of-the-textile-industry, retrieved on 27/04/2011.

6 censusindia.gov.in, retrieved on 29/04/2011.

7 www.scribd.com/doc/44313735/Reviving-Khadi-in-India, retrieved on 29/04/2011.

8 www.texmin.nic.in, retrieved on 25/04/2011.

9 www.scribd.com/…/Introduction-Khadi, retrieved on 30/04/2011.

involved in the experiments, hardly anyone has knowledge of such experiment. What is needed is more effort of coordination, especially by students. Since GV believes in community living and hence has made hostel compulsory, it can prove a positive externality. A student who learns about such experiments can dissipate such information to the rural community when he returns to his village.

- Issues of maintenance and monitoring: it has always been easy to initiate a project or introduce a new machine, but the difficulty lies in maintaining it. With the burden of other responsibilities, it may happen that the person who initiated that project or introduced that machine may not be able to maintain it. In the absence of skilled human power, there will be a question mark on the maintenance of the project or machine. Also, what is maintained and what is not should also be monitored. Attitude also matters. Skill development is a continuous process and it so happens that the person is not ready or not capable to cope up with the changes. The maintenance of existing infrastructure such as taps and lights can save natural resource and electricity.
- Demonstration effect: technology has made the wealthy classes of developing nations imitate the comforts of the developed nations. Highly energy consuming or energy intensive gadgets are the fashion of the day. The wealthy classes of GV are no exception. The carbon footprints of this class has been growing over time, especially after the pay scale recommended by the sixth pay commission.
- Inadequate exposure because of lack of interest/concern/opportunity: despite a number of efforts made by administration, there is a scope for more response from the stakeholders. Theoretical knowledge and its applications such as seminars for appropriate technology, demonstration of energy efficient machines, visits to green campuses are some of the examples. However, such efforts are yet to be translated into reality in a significant manner as a result of the indifferent attitude of people. One of the reasons can be attributed to lack of opportunity for the common public regarding environmental consciousness. Seminars or exposure visits mainly involve academia, but the information may not reach the common employee and ignorance about such issues would not be reduced.
- Scientific temperament and computer literacy: Gandhi's autobiography entitled 'My Experiments with Truth.' He welcomed machines if they were used to remove the misery and drudgery of human being. He would have willingly used modern age gadgets if they could pass his test. However, the environment at GV lacks scientific approach to a greater extent. There, apathy among the people regarding the application of computers is a serious issue. Although the use of computers need not help in conserving energy, it can help to dissipate knowledge and information.
- Mindset of people: perhaps the most important matter that needs to be drastically changed is the mindset. All the above factors imply the same. There are no questions or doubts raised against the prevalent style of living. The non-sustainability of the present model of 'development' is yet to be recognised. As with neo-classical economists, who have complete faith in omnipresent and omnipotent science and technology, for the majority of GV people, generation of

consciousness for a green campus is yet to be developed. Gandhi was the one who used to set an example for what he was saying. In recent times, GV lacks such a motivational force.

To end on an optimist note, the situation is not so bleak. There can be a turn around in the circumstances. There is a need to change the mindset of the people at GV and make each one accountable. A few operational steps can be summarised as follows:

- TINA stands for 'There Is No Alternative' approach, accepting that there is an alternative. For people at GV, we do not have to go far to look at the solution. Gandhi has shown us the way, we have to follow him. Although difficult, it is not impossible. He demonstrated by the way he lived.
- Changes have been taking place. According to the USIC, GV can save up to 50 % of energy by changing the existing fixtures of tube lights and fans. To give an example, the GV library has 750 tube lights and 160 fans. If one changes only the choke from copper to electronic, it would save 30–40 % of the power supply. Stick is the tube-light stick to energy saving T5 would save another 10–15 % power. Although the initial investment would be Rs. 400 per stick, it would be energy efficient in the long run. Similarly, from ceiling fans, if GV adopts wall fans, energy consumption would be halved. What is needed is a separation of civil and estate departments.
- Sense of accountability can also be generated by giving each employee one tree to look after. It should be mentioned that the postgraduate hostel at GV Ahmedabad campus has been successful in looking Pendula is a specie of the tree. A number of Pendula trees are Pendulas. They are proud that they trees cannot speack, hence 'devoid of speech; looking after them should not be a big challenge for students as the students have the advantage of expressing themselves!

4 Conclusion

It is important to understand the issue of greening the campus. What does it mean? Does it mean the greenery on the campus? Does it include the attempts of conserving conventional energy? Does it mean the introduction of energy efficient machines or use of alternative energy in the offices, library and classrooms? All these attempts would assume that we accept the existing model of continuous and limitless growth for the human species. Supporting this model, we also accept the neo-classical economics premise of economic man. A debate is going on in the literature regarding the sustainability of the current economic paradigm. The focus has been shifted to the carrying capacity of the Earth. The implications of the laws of thermodynamics in the economic sphere have raised doubts regarding the desirability of current policies. The non-negotiability of the lifestyle of industrially advanced countries and its demonstration effect on the 'haves' segment of the developing countries has resulted in extensive, and in some cases irreversible, damage to the ecological systems the world over. The answer to the problem lies in the change in the mindset of people. The often quoted 'Simple Living and High Thinking' is not merely a quotation—it has to be followed with concern and sincerity.

It is appropriate to remember Gandhi at this juncture. Gandhian vision of society based on an ethical man with limitation of wants shows a different lifestyle. Answers to the economic activities of both production and consumption are found in his socio-economic model. The production side is characterised by production en masse with utilisation of critical minimum technology (Iyengar 2008). Use of locally available resources and self reliance would mean decentralisation of production, less demand for energy and less of a problem of pollution. The appropriate technology would either generate no waste or minimum waste which can be recycled. The consumption side is equally important in the Gandhian frame. Gandhi's approach to consumptive issues was based explicitly on ethical considerations. The economic man argument of mainstream economics is based on the acceptance of the premise that human wants are insatiable. This has been accepted without any serious scrutiny of morals and ethics in society. Gandhi understood this phenomenon. The societal approach to accept the insatiability of human demands and then use science and technology for want satisfaction was not a sustainable approach according to him. Hence, Gandhi brought in the concept of self-restraint and talked about limiting one's wants. Wants cannot be unlimited and hence they would have to be controlled. Gandhi suggested a consumption pattern and behaviour for the affording classes which was to be moderated by ascetic and paternalistic values. Raval has termed this as the 'Gandhi Effect' (as quoted by Iyengar 2008). In this regards, the 11 vows of Gandhi are a way to self-actualisation and a sustainable society.

The all important question is: are we ready to change the mindset and accept the lifestyle that is less body-oriented and more humane and ethical, and hence sustainable?

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Potentials and Constraints for Adopting Campus Carbon Neutrality Strategies in Indian Higher Educational Institutions

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Abstract

India has one of the largest number of higher education systems in the world next to China and the US. With an increase in demand for higher education in recent years, Higher Educational Institutions (HEIs) are required to manage more students than they can afford, demanding more energy/other vital resources such as water and predominantly, more fossil fuels, exerting more pressure on the campus ecosystems, contributing more to the emission of green house gases (GHGs). This fact is never duly recognized, neither at the level of the concerned

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campus nor at state/national policy levels. However, the breadth and depth of climate change issues/problems/concerns have prompted greater international interest/commitment in the need for campus sustainability through Campus Carbon Neutrality (CCN). To become carbon neutral, universities in the developed world are striving to reduce their emissions of GHGs, cut their use of energy, use more renewable energy, and emphasize the importance of sustainable energy sources. Our insights/experiences have indicated several key barriers and major strategies which could be adopted for CCN in India and which are discussed in this chapter.

Keywords

Campus carbon neutrality · Carbon footprints · Green campus · GHG emissions · Higher educational institution

1 Introduction

Though climate change is one of the hotly debated topics, it is now widely established that global warming is occurring and human-driven emissions of carbon dioxide and other greenhouse gases, as well as land-use change, are primarily responsible. Given current trends, temperature extremes, heatwaves and heavy rains are expected to continue to escalate in both frequency and intensity, and the Earth's temperature and sea levels will continue to rise (Marcott et al. 2013). These will have significant impacts at the local, regional, national and global levels. The breadth and depth of climate change issues/problems/concerns and the fact that universities can nowadays be regarded as 'small cities' because of their large size, population, and the various complex activities which can generate green house gases (GHGs) both on site and offsite have prompted greater international interest in/commitment to the need for campus sustainability through Campus Carbon Neutrality (CCN) (Leigh and Mascarelli 2009). To become carbon neutral, universities are striving to reduce their emissions of GHGs, cut their use of energy, use more renewable energy, and emphasize the importance of sustainable energy sources. Of late, several countries, including India, and, more specifically, several states such as Tamil Nadu and Gujarat, have enacted substantial regulatory limits on GHG emissions. Higher educational institutions (HEIs), being swept up in such legislative/regulatory pressures, will soon have to begin to measure and abate campus GHG emissions or face potential fiscal repercussions.

The purpose of this chapter is to provide a roadmap by providing the background and a broad conceptual framework for planning/implementing CCN strategies for sustainability in the HEIs of India, based on best practice case studies elsewhere (Arnaud et al. 2009; Brase (undated); Heun et al. 2009; USEPA 2010; Rowan et al. 2011; Brylinsky et al. 2012; http://www.climateneutralcampus.com; http://www.thegreenmarketoracle.com/2012/08/national-wildlife-federations-campus.html).

CCN is either rarely taught or researched in India, though very few HEIs such as IITs (Kanpur, Madras and Delhi), IIMs (Calcutta, and Ahmedabad), Asian School of Business, Trivandrum and universities (Hyderabad, Jadavpur, Jammu, Madras, Periyar Maniammai, Pondicherry and Pune Universities) have implemented green energy demonstration projects such as solar street lighting, solar hot water for hostels, solar thermal cooking, institutional biogas plants, cycling, etc. Recently, Pondicherry University received funds for the country's first solar campus project. Today, several students, faculty, and administrative staff from Indian HEIs are often interested in knowing what initiatives a campus can undertake to lessen its environmental impacts. Unfortunately, the inherent desire to do as much as possible to be a good steward of the environment can conflict with the everyday reality of managing expenses and allocating limited capital budgets/time.

2 Background

India's higher education system is the third largest in the world after China and the United States in terms of enrolment. However, in terms of the number of institutions, India is the largest higher education system in the world with 26,455 institutions (504 universities and 25,951 colleges) (Gupta and Gupta 2012). Presently about 12.4 % of students go for higher education in India. If India were to increase that figure of 12.4 % at present to the desirable 30 %, then it would need another 800–1,000 universities and over 40,000 colleges in the next 10 years (UGC 2012). Thus, there is an unprecedented expansion, marked by an explosion in the volume of students, because of the huge increase in the demand for higher education in recent years. Consequently, the HEIs are poised for a phenomenal expansion of the infrastructure than they can afford, demanding more energy—predominantly more fossil fuels, exerting greater pressure on the campus ecosystems/resources, and contributing more to the emission of GHGs. This fact is never duly recognized either at the level of the campus or at the state/national policy levels.

3 Barriers to CCN

Our insights/experiences from developed countries have indicated several key barriers to work towards CCN in India, such as the typical hierarchical structure and rigidity of overcrowded university curricula, hindering sweeping change, and transformative learning/actions which are often required for integrating CCN into curricula, lack of motivation among some faculty/researchers, lack of training/capacity for building opportunities, time intensive bureaucratic and consultative phases of advocating desirable changes within an institution because of red tape, dynamic changes in carbon footprints even with retrofitting and adoption of renewable energy technologies because of growth/expansion, the inability to accommodate any additional responsibility, lack of communication channels and collaboration between faculty and operations staff, etc. Besides, there could be low current energy prices (i.e., avoided cost), price/performance ratios for renewable technologies which have not yet reached break-even feasibility, economy-of-scale limitations and less optimal geography of many onsite renewable installations compared to offsite renewable power which may discourage the adoption of carbon neutral technologies. However, such barriers have to be perceived as guidelines so that we can try to avoid or reduce these bottlenecks by analyzing the root causes of the same to facilitate CCN.

4 Operational Boundaries

Consistent with GHG protocol standards, climate neutral campuses are expected to track and report emissions of the six greenhouse gases covered under the Kyoto Protocol—carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). The main focus should be on CO_2 since emissions of PFCs or SF_6 are unlikely to originate on campus, and emissions of CH_4, N_2O and HFCs are likely to represent only a small percentage of the institution's total GHG emissions. Completing the inventory in-house provides an opportunity to engage students, faculty and staff at a level difficult to match when hiring an outside firm. The process of collecting institution-wide data, conducting surveys, and communicating results and goals encourages collaboration, builds community and fosters institutional pride. Conducting a GHG inventory in-house provides educational opportunities for those establishing the scope and boundaries of the inventory, performing calculations and writing the final report. Because the inventory can be completed on a regular basis over the course of many years, the long-term institutional awareness and cost savings associated with completing the inventory in-house can be significant (Brylinsky et al. 2012).

The GHG Protocol defines three "scopes" for GHG accounting and reporting purposes:

- *Scope 1: Direct Emissions* are those which are physically produced on campus (e.g., on-campus power production, campus vehicle fleets, refrigerant leaks). These sources are "owned or directly controlled" "fugitive and process emissions" by the institution.
- *Scope 2: Indirect Emissions* are mostly associated with purchased utilities required for campus operations, such as electricity, steam and cooling. They are indirect emissions resulting from activities that take place within the organizational boundaries of the institution but occur at sources owned or controlled by another entity.
- *Scope 3: Other Indirect Emissions* include embodied emissions from sources not owned or controlled by the campus, but which are central to campus operations or activities (e.g., non-fleet transportation, employee/student commuting, air travel paid for by the institution, waste).

However, no single strategy will achieve carbon neutrality for any campus. Hence we need a comprehensive Climate Action Plan (CAP) which aims to reduce campus greenhouse gas (GHG) emissions by a specific amount over a certain time period and includes specific actions and focus areas incorporating a climate neutrality target date (including setting interim target dates) and prioritizing Mitigation, Education, Research, and Outreach strategies. The CAP includes tracking measures to ensure progress on goals and actions and is an evolving plan which is revisited every couple of years and is updated based on changes in campus conditions and available technologies (http://www.radford.edu/content/sustainability/home/climate-plan.html). The CAP can be viewed as a series of aspirational statements of intent rather than binding commitments. It is better to "under-promise and over-deliver". Each CAP will need to address emissions across all three scopes and will require a portfolio of strategies which accounts for the on-campus and off-campus emissions sources. The CAP should explain how the institution intends to achieve climate neutrality by its target date, describe planned actions to make climate neutrality and sustainability a part of the curriculum and/or other educational experience for all students, describe actions to expand research (if applicable) and community engagement to support efforts toward the achievement of GHG reductions for the institution and/or the community and society, and outline mechanisms for tracking progress on goals and actions.

A more inclusive, collaborative approach to facilitate CCN is to create a multi-stakeholder committee headed by a coordinator, and (optionally) multiple sub-committees focussing on different areas of GHG mitigation, academic curricular development, community outreach, and institutional research. Students are valued for their enthusiasm, idealism and energy, and they can use the learning opportunities provided by the project. This multi-stakeholder structure offers the benefits of distributing the work burden, leveraging the expertise of numerous participants, and fostering buy-in from all the groups on campus. A drawback is that organising these committees requires significant time and effort, resulting in a longer and potentially unwieldy CAP development process. The commitment of all the concerned groups has to be recognised/rewarded and institutionalised by working it into their day-to-day responsibilities so that they can be confident in having the support of their superiors.

Education and outreach is vital to the overall success of a campus carbon mitigation strategies. When climate action planning ends, implementation begins, and to sustain the movement schools/departments/centres need to motivate stakeholders by keeping them "in the loop". Failure to do so jeopardizes the support and buy-in that a collaborative, inclusive planning process can create. Establishing a sustainability website, connecting into social media networks, and creating an email listserv are all ways in which CAP planners can keep the campus aware of the work they are doing and the lessons learnt.

CAP can be a long, complicated process, especially if dozens or even hundreds of individuals across campus are involved. USEPA (2010) suggests that a team (CCN steering and advisory committees) starts as quickly as possible after signing —preferably in the first 1–3 months. A GHG inventory is usually completed in the first 9–12 months of work. Then the actual climate planning can begin in earnest. The CAP development process works best if it can be compressed into an academic year. This accelerated schedule is challenging, but confers advantages such as ensuring that the participants maintain their enthusiasm and momentum, the constitution of the CAP development team remains more stable—this is particularly an issue for students (interns) who may otherwise graduate if it drags out over multiple academic years, faculty members do not have to volunteer unpaid time during the summer months to work on the CAP, and decreased risk of missing reporting requirement deadlines. To make progress, a CAP needs to be embedded in sound operational logic and a policy environment of the campus concerned that removes obstacles which raise risk and thwart success.

5 Incorporating Climate Neutrality and Sustainability into the Educational Experience

The CCN action plan will be highly institution-specific and should take into account the specific institution's particular strengths. It should start by describing the institution's current educational offerings (both curricular and extracurricular) related to climate change and sustainability. It should then set out planned actions to make climate neutrality and sustainability a part of the curriculum and other educational experience for all students.

Example actions we may consider include:

- Initiation of faculty development workshops on climate change and sustainability
- Creation of new academic programs related to climate change and sustainability
- Establishment of a graduation requirement in CCN wherever possible
- Development of institution-wide incentives or programs to encourage faculty across the institution to address CCN in their courses
- Participation in climate-related educational initiatives such as Focus the Nation (http://www.focusthenation.org), Energy Action Coalition (http://www.energyactioncoalition.org,) or 350.org (http://350.org/)
- Inclusion of students on building, operations and facilities committees; implementation of student life educational initiatives related to climate change and sustainability, such as peer-to-peer outreach and education efforts such as "Eco-Rep" programs; sustainability pledge programs (e.g., Graduation Pledge or Sustainability Pledge); First Year Experience and/or New Student Orientation sustainability sessions; sustainability themed housing; and sustainability competitions between residence halls and among other stakeholders such as "recyclemania", experiential/service learning opportunities, etc.

6 Critical Path Issues on the Way to Carbon Neutrality

Among the critical path issues on the way to carbon neutrality, the following are considered important in the context of India (modified from Brace, undated—http://www.nacubo.org/Documents/business_topics/CriticalPathways_WendellBrase.pdf; Turner 2013):

- Two types of scales need to be exploited: central plant and infrastructure efficiencies, with scale across an entire campus; and small improvements which can be repeated hundreds of times, such as extending lighting innovations.
- Energy retrofit programs need to encompass "smart" sensors and controls that provide continuous commissioning of laboratory facilities, consistent with Labs21 best practices–"smart labs" (http://www.i2sl.org/resources/toolkit.html).
- Complete lighting retrofits consistent with the low-carbon prototype designs developed by the California Lighting Technology Center (http://cltc.ucdavis.edu); "greening up" information technology consistent with ideas being advanced by EDUCAUSE (http://www.educause.edu/library/green-it) and the Silicon Valley Leadership Council (http://www.svenergymap.org/); all 24/7, demand control, and daylight-wasting opportunities, campus wide (http://ecmweb.com/green-building/submeters-measure-energy-savings-help-drive-campus-wide-building-system-upgrades).
- Reduce consumption of non-renewable energy/non-energy resources by conservation/substitution/augmentation—biogas and other renewables, green purchasing, recycling, sustainable transportation, organic horticulture—will lead to 25–35–75 % energy savings—national action plan on climate change.
- Facilitating soft loans, IT concessions, campus green funds.
- Align CCN strategies with Design for Sustainability (D4S), Leadership in Energy and Environmental Design (LEED), Energy Conservation Building Codes (ECBCs), Indian Green Building Council (IGBC), Green Rating for Integrated Habitat Assessment (GRIHA), Jawaharlal Nehru National Solar Mission (JNNSM), National. Mission on Enhanced Energy Efficiency (NMEEE), solar/eco campus/city.
- We may need to "provide cover" for facilities staff when they adjust illumination levels, install motion sensors in private offices, cut the hot water in restrooms, install occupancy controls on restroom exhaust fans, install HVAC setback features on facilities that traditionally have been considered 24/7, and broaden the "comfort band" settings for heating and air conditioning (http://lecture.civilengineeringx.com/bdac/control-of-computerized-hvac-systems).
- A portion of the projects' utility savings will need to be reserved to pay the highly skilled staff needed to maintain, adjust, recalibrate, monitor and continually commission the building of increasingly sophisticated systems in terms of sensors, digital logic and fine tuning. This continuing investment will be necessary to sustain the performance and guarantee the project payback.

- We have to provide leadership to ensure that risks associated with more finely tuned building systems are evaluated based on data and evidence, rather than dogmatic application of criteria originating when energy was considered "essentially free," and "carbon footprint" was unheard of; ensure a team approach to sustainability that engages not only facilities management, but also design and construction services, environmental health and safety, procurement, information technology, environmental planning, housing, food services and transportation services.
- Design professionals, such as mechanical engineers and security lighting experts, may defend status quo practices because the risk of variance from established standards may increase their professional liability. HEIs may need to get involved in a new activity: influencing building codes, standards, and regulations.
- We need to understand that large-scale carbon emissions savings may be attainable—perhaps 30–40 %—but large-scale investment also will be required over a sustained, 5–7-year program.
- Priorities need to be set, since most facilities organizations are unable to carry out both a large energy retrofit program and a renewable energy program simultaneously.
- We need to assist facilities management in understanding and applying a more sophisticated financial planning perspective for energy retrofit projects than was required for the smaller, simpler projects of the past.
- We have to adopt dematerialization—the substitution of high-carbon products and activities with low-carbon alternatives—for example, replacing face-to-face meetings with videoconferencing or using online systems instead of paper-based processes, digital textbooks/journals which can save a large chunk of carbon foot prints, etc.

CCN can also be approached through smart/intelligent buildings and smart grids. A smart/intelligent building is the integration of technology, building, and energy management systems to produce complete IT-based hardware and software solutions (cloud-based technologies) which makes the building as efficient as possible. The control technologies of smart buildings allow integration, automation and optimization of all the services and equipment of the buildings. Building automation systems combine the various control functions into a single integrated solution which coordinates the systems for maximum efficiency (with a potential energy savings of up to 30 %), user comfort, and cost reduction. The integrated systems and their functions include controls for lighting, HVAC, air quality, fire/life safety, CCTV. Integrated Building Management System (IBMS) is a complete information delivery system which monitors and controls a variety of systems and functions at an optimal level of efficiency. Globally, buildings account for 40 % energy use, 70 % of electrical energy use and 30–42 % GHG emission, and hence buildings in HEIs should be one of the key focus areas. In most existing buildings, carbon emissions can be attributed to the following four categories called "Carbon4Square": Watts (building energy use), Water (energy use for pumping, treating. moving and disposing of water), Waste (emission from waste generation/treatment, and Wheels (transportation to and from buildings). Directly or indirectly, these four "squares" are the major components of a commercial office building's "carbon footprint." Focusing on these four categories provides a simple framework to assess, analyse and priorities strategies for overall environmental performance of buildings (http://www.carbon4square.com/about).

A smart grid is an electrical grid that uses IT to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity (http://energy.gov/oe/technology-development/smart-grid). Smart power generation is a concept of matching electricity production with demand using multiple identical generators which can start, stop and operate efficiently at chosen load, independently of the others, making them suitable for base load and peaking power generation.(Hotakainen 2011). Ultimately, university campuses may play a central role in developing and testing smart grid concepts to improve the national utility grids.

For establishing a climate neutral campus, the following standard greenhouse gas inventory resources will be very useful (Smith et al. 2012, http://www.aashe.org/resources/campus-greenhouse-gas-emissions-inventories):

- Climate Action Planning Wiki (AASHE): Chapter The Role of Higher Educational Institutions and Other Training Organizations to Promote Renewable Energy in India Determining Your Carbon Footprint and Emissions Trajectory (http://www.aashe.org/wiki/cool-campus-how-guide-college-and-university-climate-action-planning/4-determining-your-carbon)
- ACUPCC Reporting System GHG Inventory Reporting Instructions (http://rs.acupcc.org/instructions/ghg)
- List of over 1,600 GHG Inventories submitted to the ACUPCC Reporting System (http://rs.acupcc.org/stats/complete-ghg)
- Clean Air-Cool Planet Campus Carbon Calculator FAQs (http://www.cleanair-coolplanet.org/toolkit/inv-faq.php#transportation, http://cleanair-coolplanet.org/campus-carbon-calculator, http://campuscarbon.com/)
- Greenhouse Gas Protocol Corporate Accounting and Reporting Standard (http://www.ghgprotocol.org/standards/corporate-standard)
- Carbon Payback Calculator (http://wwwscotland.gov.uk/Resource/Doc/917/0117391.pdf)

Buildings, climate, dining, services, energy, grounds, purchasing, transportation, waste, water and biodiversity correspond to categories in AASHE's Sustainability Tracking, Assessment and Rating System (STARS) which can be used as tools to assist campuses in advancing sustainability in operations for facilitating CCN. The Indian HEIs can plan to employ 4 broad strategies to achieve carbon neutrality, with 12 related goals as suggested by American University (2010):

6.1 Reduce Consumption

1. Reduce electricity consumption by at least 1 % annually
2. Reduce transportation emissions
3. Eliminate emissions from paper
4. Eliminate emissions from waste
5. Eliminate emissions from agricultural/horticultural inputs both on site/offsite

6.2 Produce Renewable Energy

6. Produce maximum viable solar energy
7. Produce maximum viable energy from waste
8. Produce maximum viable wind energy

6.3 Buy Green Power

9. Buy renewable energy credits (RECs) for 100 % of electricity
10. Buy grid-delivered green power for 100 % of electricity consumption

6.4 Buy/Develop Offsets

11. Buy offsets for travel and other unavoidable emissions
12. Develop offset projects for travel and other unavoidable emissions

Besides the above strategies, carbon sequestration/carbon offsets by indigenous multipurpose plant communities can be used as an effective long-term strategy for working towards a carbon neutral campus as has been indicated by several workers (e.g., American University 2010; Chung and Chung 2011; Ellis et al. undated).

As part of their educational experience, students on campuses with climate neutral energy systems can be asked to track system performance over time, evaluate returns on investment and educate the wider campus and public communities. When energy systems are metered and incorporated into real-time energy monitoring, students and building occupants can begin to visualize energy and resource use, compare operational performance and follow trends across monthly climate variation and/or building types. Thanks to the Internet, the HEIs can educate not only their campus community but also the world beyond by showcasing their innovative campus systems and other sustainability initiatives with descriptive narratives and real-time performance 'dashboards' posted on campus websites. In short, as with any project on campus which conserves resources, the benefits beyond purely environmental or financial aspects can be substantially educational for students, faculty, staff and the wider community (USEPA 2010). To facilitate all these campus innovations, we need to establish a dedicated Office of Sustainability for inter-departmental coordination and a Campus Green Revolving Fund (CGRF) for each HEI. The latter can provide seed funding for projects promoting environmental sustainability and CCN. CGRF can be supported by university/college funds, sponsored/sanctioned projects from the State/Central Government organizations and national/international funding agencies, student fees and other items administered through the University Sustainability Council. CGRF can also mobilize funds through Corporate Social Responsibility/tax incentives for individuals/industries. HEIs can hire an energy services company (ESCO) to identify and implement energy efficiency projects which also achieve large emissions reductions. The ESCO absorbs all upfront costs of the project and is paid for over time through the energy savings associated with the project.

7 Conclusion

Based on the best practice case studies and the distilled lessons learnt throughout the world on CCN initiatives, key strategies which could be adopted in India would include adding CCN to the existing mission and vision statement of the HEIs, promotion of CCN in curricula, action research and community outreach, empowering and rewarding "CCN champions" in the campus using innovative pilot projects to build capacity, mobilising financial sources through various strategies which include industry sponsored technology innovation/up gradation/demonstration projects in the campus, institutionalizing the participation, cooperation, understanding and commitment of the campus community to ensure responsibility/accountability for long-term commitment to CCN through applied behavioral change, periodic assessment /monitoring and reporting using carbon footprints disseminated through a dedicated website, etc. HEIs in India, uniquely positioned to tackle the challenge of carbon neutrality because of their critical mass, research funding, diversity of skills, and influence on current and future generations, have to facilitate CCN strategies at the earliest opportunity.

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Integrating Energy and Environment in Postgraduate Management Education: A Case Study from Symbiosis Institute of International Business, Pune, India

Prakash Rao and Yogesh Patil

Abstract

In recent times, environment and sustainability have caught the attention of various sections of society as issues threatening the very fabric of global business and polity. Climate change as a major environmental challenge is now at the centre stage of attention by world leaders, academia, business and industry and civil society. The sluggish market conditions across the world as well as recessionary pressures has led to renewed thinking amongst the various business and industry entities about integrating sustainable environment practices into mainstream business practices for cost effectiveness. The recent Rio +20 summit in 2012 has further reiterated the role played by education in building sustainable development, recommending among other issues the internationalization of educational systems at all levels of learning. The present chapter seeks to focus on a new direction in management education which has significant implications for environment protection as a major driver of corporate business action at international level. Recent advances in environmental protection and sustainability have become relevant as an important business opportunity for many companies, apart from being seen as a green branding exercise. The chapter discusses the case of a unique and integrated mechanism aimed at building capacity in energy and environment at the Symbiosis Institute of International

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Business through designing sustainability-based curricula and implementing courses matching the needs of business and industry. These include recent and emerging areas such as sustainable energy development, global carbon markets, renewable energy, corporate environmental management, sustainability reporting, etc. The case study draws upon some of the current approaches of global educational institutions in promoting sustainability as part of the UN decade of Education for Sustainable Development (2005–2014). In a rapidly growing Indian economy, the corporate sector sees the importance of environmental sustainability as an integral part of legitimate business strategy. The study also addresses some of the key issues and challenges in embedding a sustainability domain in management education in comparison to the existing curriculum at international level. Key recommendations are proposed in integrating environmental sustainability as an important part of curriculum development in management education.

Keywords

Energy · Integrated curriculum · Management education · Natural resources · Sustainability

1 Introduction

In recent times, at least in the last 200 years, man has made rapid strides in economic growth across the world. While an agrarian economy might have remained a major base and perhaps so even today in many parts of the world, the desire to expand horizons and explore vast frontiers has led to creation of an industrialized economy. Such an economy, while bringing about large economic benefits to millions of people by way of access to better living standards, access to communications, transport, health care, education, etc., has nevertheless also resulted in impacts to the environment in general over several decades.

The past few decades have perhaps been one of the most tumultuous phases in the development of man in the context of three important sectors, namely industrialization, education and environment. While the first two sectors have seen a phenomenal increase in intellectual thought processes leading to innovation and the creative desire to excel, the third sector, namely the environment, has perhaps borne the brunt of the rapid progress made by industrialization.

While most of the industrialized world, including the developed group of nations, has moved ahead rapidly to create a welfare system, many countries which were under the rule of foreign nations or were just emerging from colonialism were seen to lag far behind in terms of improving education standards and industrialization. In India this could be seen as the pre-independence era and the post-independence era.

Post-independence India has coincided with the period when much of the world's efforts have gone into building institutions of governance across the world, involving political, economic, social and environmental paradigms. Education has played a key part in driving the paradigm of growth across these sectors in the past 50 years or so. Since 1947, independent India has had a major thrust towards, industrialization and building the country's granaries to fulfil the needs of its citizens has been a key priority. On the other hand, building capacity and strengthening the knowledge base of its citizens, has been an equally important initiative of successive governments. While the food security issue saw the advent of the green revolution, the age of industrialization saw the development of management training as an answer to building a cadre of management professionals across the rest of the country to serve the needs of the industrialized world.

2 Sustainable Development Education in the Post-Liberalisation Era in India

Sustainable development at Universities and academic institutions in India (Rao 2011; Rao and Patil 2011) and at global level (Leal Filho 2012) has been mainly seen from the point of introducing curriculum which is related to various aspects of sustainability and environmental conservation. Since the introduction of environment sciences as a subject across postgraduate education institutions in India in 1984–1985, many Indian universities have introduced energy and environment related courses as part of their conventional curriculum as compared to niche-based universities which have emerged only recently. Traditional science-based colleges and engineering institutions have at some stage incorporated energy efficiency, power sector-related courses as part of their electrical engineering discipline. Apart from this, courses at Architecture and Planning Schools have also been imparting training on green buildings, certification for green buildings through their conventional academic programmes. Institutions such as the Bharathidasan University, Centre for Environmental Planning and Technology (CEPT), School of Planning and Architecture have, through their programmes on environment management, environmental sustainability, and sustainable habitats, addressed the demand of industry for such courses.

2.1 Business and Industry and Sustainability Education in India

The economic liberalisation process in India after 1991 as well as evolution of a robust regulatory environment and international focus on critical energy and environmental issues has led to increasing interest shown by business and industry in environmental protection. With rising energy costs, businesses now see investing in environment protection efforts not only as a business proposition but also in terms of significant economic gains by way of cost reduction and optimization of resource use and reduced carbon footprint towards achieving the sustainability goal. The recent UN climate change negotiations have brought to the fore some of the important industry initiatives in promoting clean technologies, processes and capacity building efforts. Various industry associations in India such as the

Table 1 Management schools and industry oriented institutes offering energy- and environment-based curricula and courses in India

S. no.	Institution[a]	Course	Duration	Degree
1.	Indian Institute of Management, Ahmedabad	Carbon trading, Carbon finance	One year	Diploma
2.	Amity School of Natural Resources and Sustainable Development, Noida, Delhi	Natural resource management	Two years	MBA
3.	DeenDayal Petroleum University, Gandhi Nagar, Gujarat	Oil and gas, Petroleum management, Petroleum economics	Two years	MBA
4.	Symbiosis Institute of International Business, Symbiosis International University, Pune	Energy and Environment	Two years	MBA
5.	Indian Institute of Forest Management, Bhopal	Forestry management	Two years	Postgraduate Diploma
6.	Management Development Institute, Gurgaon	Energy management	15 months	Executive Postgraduate Diploma
7.	National Institute of Industrial Engineering, Mumbai	Industrial safety, Environmental management	Two years	Postgraduate Diploma
8.	Indian Institute of Social Welfare and Business Management, Kolkata	Public Systems management	Two years	Masters degree
9.	TERI University, New Delhi	Business sustainability	Two years	MBA
10.	University of Petroleum and Energy Studies, Dehradun	Oil and Gas management, Energy Trading	Two years	MBA
11.	Rajiv Gandhi Institute of Petroleum Technology, Rae Bareli	Petroleum and Energy management	Two years	MBA
12.	Management Development Institute, Gurgaon, Haryana	Energy management	15 months	PGP in Management
13.	National Power Training Institute, Faridabad, Haryana	Power management	Two years	MBA
14.	Institute of Energy Management and Research, GLIMS, Haryana	Energy management	Two years	PGP in Management
15.	Chh. Shahu Institute of Business Education and Research, Kolhapur, Maharashtra	Environmental management	Two years	MBA

[a]Only an indicative list; Rao et al. (2013)

Confederation of Indian Industry (CII), Federation of Indian Chambers of Commerce and Industry (FICCI), and the Associated Chambers of Commerce and Industry of India (ASSOCHAM) have strongly advocated environmental responsibility as a key mandate of business operations and sustainable practices.

In this scenario, Indian business entities are looking at skilled manpower with managerial competence not only in core technical disciplines such as engineering and environmental sciences but also in emerging business areas such as carbon trading, renewable energy financing, power trading, energy and power management, oil and gas management, etc. with added knowledge in conventional management subjects. From an industry perspective, this is important as it helps to develop a talented pool of young managerial talent to build sustainable business models in specialized areas such as global business practices, global energy scenarios, carbon financing and market economics, environmental standards, energy policies and regulations, etc.

In India, a few business schools and academic institutions have begun to introduce new—and to alter existing—curricula to meet not only the requirements of students but also the needs of business and industry for sustainability initiatives (Park et al. 2012; Tikoo 2009). The inclusion of an integrating environment as an important component of corporate sustainability efforts has only been a recent development across Indian business schools with limited intervention.

Various models are being followed across the country in management institutions of higher learning to include environment related issues and subjects. While some use full-time residential courses on the energy and environment, others follow a paradigm of undertaking short courses to meet specific needs of industry (Table 1). Most of these academic programmes commenced after 2005 during the high growth economy era of the country.

3 Integrating Energy and Environment Discipline in Management Education at Symbiosis International University, Pune

In 2009, the Symbiosis International University through its constituent institute, the Symbiosis Institute of International Business, conceptualised a unique postgraduate programme which was aimed at integrating energy development and environment concerns and equipping aspiring global managers with managerial, socioeconomic and technical knowledge skills. The programme provides a holistic view to developing competencies in emerging technologies, economic issues and global environmental strategies. Core focus areas include sectors such as sustainable energy development, conventional energy (coal, oil/gas), renewable energy, energy economics, carbon markets and trading, corporate environmental sustainability, energy management, environmental assessments, natural resources management, etc.

While most educational institutions have developed niche-based courses with specific focus on creating particular domain knowledge for students, the present programme has been conceived with a view to integrating some of the critical issues linking the environment sector with energy development as well as current issues of social development and equity. Some of these integrated approaches are detailed below.

3.1 Power Sector

The recent power sector reforms in the country following the Electricity Act, 2003 has mandated the development of a transparent, fair and equitable process in the generation, transmission and distribution of electricity across the country. This has led to several private sector entities trying to capture a market share of the power sector generation. As a consequence, several environmental concerns such as mining, rights acquisition, loss of ecologically rich ecosystems, wetland reclamation, forest cover loss, etc., have often been neglected in the desire to set up new and ultra modern power plants (Areendran et al. 2013). The postgraduate programme has tried to include these issues as part of a rigorous curriculum which will also sensitise future managers with developing an ability to integrate social and environment concerns through a curriculum focused on environmental impact assessment rules and regulations, wastewater management, sustainable energy development, etc.

3.2 Corporate Sustainability Management

The increasing rate of urbanization in the Asia Pacific geographies and local environmental stresses from over population, industrial development, migration, etc. (Mukhopadhyay and Revi 2009) are a strong indicator of how important environmental concerns are for businesses to adopt. Building a strategic involvement of regulatory institutions, business and industry, research institutions and civil society in an alliance will help create an economy which will foster a low carbon growth economy (Saqib et al. 2007).

The current initiatives in Indian industry to build environmental sustainability as a key mandate of businesses is limited and seem grossly inadequate given the enormous efforts needed to tackle global and domestic problems in the environmental, social, economic and technological space. The adoption of the triple bottom concept of environmental, social and economic performance of a business entity towards total sustainability can go a long way in ensuring both environmental and economic security amongst corporate sector. The corporate sustainability curriculum at SIIB, incorporates the business case of sustainability through industry best practices. This is expected to help professionals develop clarity and thinking on the balance between infrastructure growth and sustainable development through the use of methodologies and tools for developing sustainability standards and guidelines.

3.3 Water-Energy Nexus

It is often said that, in the path to sustainable development, two of the most important indicators are access to water and energy services. High water consumption patterns in urban and rural areas coupled with inefficient energy technologies have often led to serious environmental impacts. While most knowledge-based sectors discuss water and energy management as separate entities, the curriculum at Symbiosis has attempted to integrate the two disciplines in an effort to provide a holistic approach to the water energy nexus. The curriculum seeks to study the linkages between water–energy use through adoption of demand-side management options, optimizing efficiency of existing systems, e.g. steam engineering and water savings, recycling of wastewater, alternate energy use. The World Business Council on Sustainable Development (WBCSD) has stressed the importance of water and energy as directly relevant to sustainable business operations. The WBSCD initiative (WBCSD and WRI 2004) has also helped in further strengthening the bonds between industry and academics in understanding key industry needs and linking them to curriculum development.

3.4 The Business Case of Climate Change and Energy Development

In recent times the issue of climate change has been seen as perhaps the most important global environmental threat affecting the fabric of society and economic growth. According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Pachauri and Reisinger 2007), average global temperatures may rise by 1.1–6.4 °C by 2100. This is likely to have tremendous impacts on biodiversity, natural resources, abundant freshwater resources, local livelihoods and many other sectors. From a business perspective, serious challenges are seen as many industries rely on natural resources for production and operations. The role of business schools in creating leadership to tackle sustainability challenges has been a key factor (Adams et al. 2011) in driving the development of curriculum aimed at creating sustainable or low carbon universities. The Symbiosis programme has tried to integrate climate change risk management through the development of a curriculum which focuses on the direct linkages between climate change impacts and energy development. The curriculum also delves into global policy mechanisms including understanding the concepts of innovative market mechanisms such as the Clean Development Mechanism (CDM) and Joint Implementation (JI) and emissions trading as a way to get the corporate world into meaningful involvement on sustainable development activities (www.unfccc.de).

Future sustainability-driven activities of business and industry are also likely to be driven by innovative market based mechanisms which might make these sectors lucrative in terms of return on investment, apart from achieving the objective of sustainable development. Such mechanisms offer a vast scope for various business and industry players, including small and medium enterprises (SMEs) (Saini et al. 2012). The recently established PAT scheme (Perform, Achieve and Trade) of the Government of India through the Bureau of Energy Efficiency is one such step, which is likely to provide a major impetus to strengthening energy efficiency practices. Similarly, the concept of Renewable Energy certificates (REC) is also a recent attempt to involve industry players in providing market-based incentives to project developers in the renewable energy space in increasing the overall share of renewable energy in the overall energy mix of India.

3.5 Public Private Partnerships in the Energy-Environment Sector

The Symbiosis Integrated Programme has also introduced an innovative course module which seeks to conceptualise the governance model of public private partnerships as a solution to rapid economic growth. While this has had mixed results globally, it is of interest to note that several PPP lead initiatives have been taken up in water and sanitation, sustainable transport, and power sector to promote sustainable infrastructure growth. We believe that the PPP-led governance model with a focus on sustainable development is of great relevance as a course element for management education.

3.6 Industrial Ecology

For most developing countries, economic development has been the issue of top priority as a machine to enhance social prosperity. In the process, eventually, for the sake of development, the environment protection/conservation part was left far behind (World Bank 2000).

In the light of the above background, the present integrated programme at Symbiosis decided to introduce a new integrated industrial planning and management mechanism in its curriculum. “Industrial Ecology/Symbiosis/Ecosystem” is one such emerging concept in the evolution of environmental management paradigms (Ehrenfeld 1997) and springs from interests in integrating notions of sustainability into environmental and economic systems (Ehrenfeld 1997). This concept was first introduced by Frosch and Gallopoulos in 1989 (Heeres et al. 2004) and since then industrial development has entered a new perspective of production and process systems. Industrial development should thus resemble the natural ecosystem because, in such a system, energy and resources are optimally used and wastes are absent. In contrast to the old viewpoint, industrial ecology considers industrial waste or any other waste (both hazardous and non-hazardous) as an “economic resource” (Ehrenfeld and Gertler 1997), which upon reduction, reuse, recycling and recovering means greater profit to the industries/companies in that ecosystem. Industrial Symbiosis is designed such that industrial areas are developed mimicking a natural ecosystem (Garner and Keoleian 1995). Natural ecosystems are self-contained, self-sustained and generate zero waste through complex interactions of food chains. Industries are visualised as interacting systems rather than isolated components in a system of linear flows. Waste materials and energy emanating from one source is used as feedstock by another (life cycle approach—cradle-to-reincarnation). Thus, a model of industrial symbiosis in developing and underdeveloped countries would have an opportunity to manage their waste to become source without much investment in technology of waste management (Patil 2012; Patil and Rao 2014). It will also (1) help industries to improve their environmental performance, strategic planning and will become more competitive, (2) help local communities develop and maintain a sound industrial base and infrastructure without sacrificing the quality of their environments and (3) help local, regional and national government to formulate policies and regulations in order to improve environmental protection with simultaneous building of business competitiveness.

Similarly, we have also brought in course content related to Life Cycle Assessment (LCA) as a method to assess environmental impacts associated with all stages of a product's life "from cradle to grave" (Finnveden et al. 2009). LCA completely avoids the restricted viewpoint towards environmental concerns by way of (1) accounting an inventory of relevant energy and material inputs and environmental releases, (2) evaluating the potential impacts associated with identified inputs and releases and (c) interpreting the results to help make a more informed decision (Hubbard and Bowe 2010).

4 Conclusion

The importance of environmental sustainability as the future direction for corporate action is perhaps the need of the hour. This is particularly relevant in the context of some of the most challenging and complex global environmental issues the world is facing. Our current understanding of some of the key issue of impacts of climate change (Pachauri and Reisinger 2007) only seems to suggest that there is very little time for the world to take action in mitigating the effects of greenhouse gas emissions which are likely to increase in an exponential way in a business as usual scenario (Meinhausen et al. 2009). The rising demand for energy and its consumption in order to achieve higher economic growth is cited as a key driver of higher GHG emission rates (IEA 2008). The increasing urbanisation rate and local environmental stresses from over-population, industrial development, migration, etc. (Mukhopadhyay and Revi 2009) are indicators of some of the imbalances humans are likely to face. This could mean strategic involvement of not only country governments but also business and industry, academic institutions and civil society in an alliance which will help to build a sustainable and low carbon economy.

The importance of integrating energy and environment into sustainability-based education across academic institutions is a necessity. The adoption of the triple bottom concept of environmental, social and economic performance of a business entity towards total sustainability can go a long way to ensuring both environmental and economic security amongst corporate sector. At the same time, there is an urgent need to build and strengthen interdisciplinary energy-environment sustainability-based curricula across management institutions. Strengthening regulatory frameworks and framing policy guidelines across industry and academic institutions and inclusion of new governance paradigms which focus on sustainability need to be made mandatory across management institutions. This will only help in developing managerial competence across a wide range of industry, including the larger issues of supporting an ethics-based governance model and value systems driven by sound social, environmental and economic performance of business operations.

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Campus Greening in Open and Distance Learning: Curriculum Initiatives in the Department of Geography, University of South Africa

Rudi W. Pretorius, David W. Hedding, Melanie D. Nicolau and Ernestina S. Nkooe

Abstract

This chapter presents and reflects on two campus greening initiatives by the Department of Geography at the University of South Africa (Unisa). The first initiative is the environmental management degree programme, which was implemented in 2000 as the first multidisciplinary, cross-faculty study programme offered at the institution. Successes and challenges as experienced with this programme and how they have been addressed will be reflected upon, with emphasis on implications for campus greening. The second initiative is the signature module "Environmental awareness and responsibility" implemented in 2012, which is available to any student from any discipline at Unisa. This module is part of a group of signature modules, offered exclusively online at Unisa. The reflection on this module will focus on implementation challenges in terms of the online offering, together with the extent to which the main thrust of the module has been achieved, namely to take students from "knowing" about sustainability to "doing" something for sustainability and thereby contributing to campus greening. The experience gained with these two initiatives points to a number of additional measures which can be embedded into the curriculum to achieve full engagement of students with reference to environmental sustainability within their local contexts. As an open and distance learning (ODL) institution, these measures could include the sharing of sustainable practices and experiences on an online platform. This will enable students and academic staff to generate and disseminate good sustainable practices between each other in such a way that both parties can

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become critical voices in a global but sustainable world. Moving from a contents-driven to an application-based approach to sustainability will contribute to a shift in the values and attitudes of successful graduates who will be able to apply the outcomes of the curriculum to strengthen localised innovation and sustainable practices in their living and working environments.

Keywords
Campus greening · Curriculum transformation · Geography · Open and distance learning · Environmental sustainability

1 Introduction

Responses of institutions of higher learning to calls for campus sustainability vary from comprehensive efforts to transform operations, planning, research and curricula, to some institutions which struggle to move beyond declarations and promotion of departmentalized sustainability courses or projects (Bacon et al. 2011). Analysis of institutions of higher learning shows that it is often their internal structuring limiting their ability to transform themselves to address the sustainability agenda effectively (Haigh 2005). This is especially true in terms of the way that knowledge is fragmented through disciplinary boundaries, thus hampering the ability to prepare students adequately to deal with the complexity of real-world sustainability issues.

It needs to be acknowledged that greening of institutions of higher learning is a multi-faceted process which requires integration of environmentally sustainable practices in operations together with embedding education for sustainability (EfS) in academic offerings. Savelyeva and McKenna (2011) point out that the curriculum is influenced by campus greening in that an environmentally sensitive academic environment is created, through which a culture of sustainability is fostered by all role players. In open and distance learning (ODL), the praxis of campus greening has a unique context, presenting various challenges and opportunities to institutions and students alike. This chapter concerns itself with campus and curriculum greening experiences in the University of South Africa (Unisa), the largest university on the African continent and a major role player in ODL worldwide.

The aim of this chapter is to provide a reflection on two initiatives towards curriculum greening in the Department of Geography in the College (Faculty) of Agriculture and Environmental Sciences (CAES) at Unisa. The first is a cross-faculty environmental management degree programme (hereafter EM programme), which was implemented in 2000, when institutionalization of sustainability at Unisa was minimal. The second is the third level signature module entitled "Environmental awareness and responsibility". This module was implemented in 2012 under a completely new set of circumstances, when Unisa had already adopted the sustainability agenda as part of its institutional mandate. Separate, compact narratives will be presented for each of these initiatives, using reflective writing (Jasper 2005) to consider the context, essential elements and implementation experiences. As reflexive practitioners, we then stand back to reflect on the experience gained and, based on that, map future activities and developments.

As geographers, our experience with this degree programme and signature module is valuable to share since it is generally recognized that, although geography could play a key role in curriculum greening (Chalkley 2002; Haigh 2005), its contribution in this regard is, to say the least, not very visible. This potential contribution follows from the emphasis in geography to consider environments and societies in an integrated way, with the aid of methodological frameworks such as the systems approach. The linkage between this approach and the agenda of EfS is obvious. The authors trust that reflection on their experiences will give direction for geography and geographers to play a more prominent role in this field.

2 Contextual Setting

2.1 The International Scene

Institutions of higher learning worldwide are continuing to respond to calls for environmental sustainability by aligning their operational activities and curricula with green practices (Cotgrave and Kokkarinen 2011). In greening their operations and infrastructure, institutions of higher learning are demonstrating (in practice) principles of environmental awareness and responsibility. Curriculum planning and design are important areas in green campus initiatives. De Ciurana and Leal Filho (2006) note that efforts to green curricula should be the result of solid decisions and of attempts by academics to transform the way in which undergraduate students, who are the future professionals and leaders in society, think and work. This process touches on the concept of EfS (Savelyeva and McKenna 2011; Woo et al. 2012), which outlines criteria for effective implementation of green curricula in institutions of higher learning, in order to address issues related to environmentally unconscious and unskilled graduates.

For Sherren (2005), such problems can be addressed by an interdisciplinary curriculum centered on people-environment interactions. In order for such initiatives to be successfully implemented, certain challenges first have to be addressed. Initiatives for campus and curriculum greening at institutions of higher learning are often suppressed because of the presence of generic challenges such as lack of funding and resources for greening of infrastructure, compartmentalisation of disciplines, lack of collaboration among faculties and even among students and the presence of ivory tower teaching traditions (Dahle and Neumayer 2001; Bacon et al. 2011). In addition, the geographical, social and cultural contexts of institutions of higher learning can also act as barriers to campus and curriculum greening. In developing countries, for example, these institutions do not share the same experiences as those in developed countries (UNESCO 2002). The digital divide is one such aspect, alongside differing socio-economic realities presenting real barriers to implementing campus and curriculum greening initiatives in poorer countries, including South Africa (Oyedemi 2012). However, the digital age provides opportunities for greening operations at some universities, such as Unisa, as they move from print to electronic/digital modes of teaching and learning.

2.2 ODL, Unisa and Geography

Responses to international calls for campus and curriculum greening are slowly but surely taking shape in many South African institutions of higher learning. The Department of Higher Education and Training of the South African government acknowledged the leading role of institutions of higher learning in social transformation. According to the South African Minister of Higher Education and Training (SouthAfrica.info 2012), African universities should be in a position to meet contemporary demands for sustainability by providing undergraduate students with the necessary skills and academic and social competencies to address environmental and sustainability issues in their everyday living and working spaces.

Unisa joined other institutions of higher learning around the world in the call for greater sustainability by implementing policies, operational practices and curricula supporting green campus initiatives. The physical expansion of Unisa at the Science Campus in Johannesburg, where the Department of Geography is situated, attests to the efforts by the university towards environmental sustainability (Unisa 2011). In terms of greening curricula, barriers experienced by Unisa to implement environmental sustainability lie in the socio-economic realities defining the university. With more than 300,000 students enrolled across seven colleges (Unisa 2012), the shift from teaching ‘about’ sustainability to teaching ‘for’ sustainability (Woo et al. 2012) presents a manageable, though complex transition with distinct challenges.

In terms of the transition of Unisa from a print-based mode of teaching to an ODL model, the once distant student–lecturer and student–student relationships are now facilitated and mediated electronically by the Internet-based learning management system known as *my*Unisa. This asynchronous learning management system is the primary teaching tool used by Unisa as a means of achieving EfS and addressing simultaneously technological and environmental illiteracies in southern Africa and beyond. In addition, *my*Unisa enables virtual interaction through online activities especially designed to give students authentic learning experiences aligned with the emerging ODL pedagogy and heutagogy. Progress made by Unisa in this regard is nonetheless hampered by national realities such as lack of access to information and communication technologies (ICTs) by many students in South Africa, which presents a serious constraining factor (Oyedemi 2012). This reality conflicts with the requirement that, upon completion of their undergraduate studies, students should not only achieve discipline-specific competencies but also have the capacity to be able to function effectively in their respective societies and in the world of work (Unisa 2010). This is an essential aspect of “graduateness” that Unisa seeks to address in the light of ODL principles and ongoing sustainability curriculum debates.

At Unisa, the Department of Geography responded proactively to the call for curriculum greening by approaching the sustainability agenda through study programmes and modules at undergraduate level which address the outlined barriers, opportunities and challenges in the African context. This is done by embracing a multi-inter-trans-disciplinary (MIT) approach to curriculum design within the ODL context (Unisa 2008, 2010). Documenting and sharing this African university's green experience through the lens of two prominent initiatives by the Department of Geography marks an important contribution by this discipline to the international dialogue on EfS. For the purpose of this chapter, the EM programme and signature module "Environmental awareness and responsibility" serve as case studies of the manner through which Unisa contributes to ongoing global discussions on sustainable people-environment interactions and relationships.

3 The Environmental Management Programme at Unisa

The undergraduate EM programme at Unisa was implemented in 2000 largely in response to an industry need which identified a B-degree which equips students for entry level positions in this field. Graduates with an environmental background at this level are required to, among other things, fulfil the role of coordinators and facilitate community involvement and participation in environmental decision-making (Pretorius 2004). Since many decisions regarding environmental issues in Southern Africa are taken at grassroots levels, where participants are in need of environmental knowledge, skills and insights, a first degree in environmental management seemed the obvious route to go.

Methodologically, the Unisa EM programme links with Aplin and Batten (2004, pp. 355–356), who maintain that, because of their training and experience, geographers "can provide the integrative skills required to adopt flexible approaches and to take location and scale into account. They are also well placed to consider the interests and concerns of a wide range of people and groups. Ideally, they are trained to step back from the detail and look at the broader picture." However, offering such a programme through ODL is tricky, particularly with regard to the inclusion of authentic learning experiences in real-world contexts. The issue of the programme being perceived as too theoretical because of the ODL mode of delivery also needs to be addressed.

3.1 Structure and Unique Elements

The principles underpinning the development of the Unisa EM programme include recognition of the value of multi-inter-transdisciplinarity (MIT), a holistic approach and a focus on the management of human decision-making about the environment. The traditional reductionist approach of science (Armstrong and Rutherford 1999) is therefore abandoned. Geography is a truly inter- and multidisciplinary subject with an integrative approach and sensitivity towards place and scale (Aplin and Batten 2004) and is the major for the EM programme. It examines interactions between humans and nature, therefore straddling the biophysical and social sciences, which is exactly what is required. As explained by Zietsman and Pretorius (2006), no other subject is better aligned and equipped than geography to form a major in an undergraduate learning programme in environmental management.

The EM programme provides for a BA and a BSc degree, thus respecting the integrity of a qualification in either the biophysical or the social sciences. The geography major, however, was completely redesigned to do away with the differentiation between BA and BSc. This was facilitated through a problem-based approach, integration of human and physical geography and adoption of environmental sustainability as focus for the geography curriculum at undergraduate level. Depending on the choices students make, modules offered by the Department of Geography can make up anything from 11 to 14 of the 30 modules to be taken. To broaden the scope, modules from the following groups are added: skills, environmental, specialization and elective modules. These modules are from different departments in six of the colleges of Unisa, therefore enhancing the multi-inter-transdisciplinarity of the EM programme.

The fact that the Unisa EM programme is offered through ODL contributes to its uniqueness within the South African context. The implication of the ODL teaching mode is that the EM programme is accessible to a much wider audience of students than would conventionally have been the case. Since Unisa students can remain in their jobs and/or communities while studying, the opportunity exists for applying what is learnt in these contexts. In terms of the urgency of the environmental agenda, this synergy between what is learnt and what is done in practice is invaluable. With the increased utilisation of communication and information technologies, the diversity of students enrolled for the EM programme has significant potential to allow horizontal exchange of ideas, thus enhancing the learning experience.

3.2 Successes Versus Challenges

The success of the EM programme is evident in that it is one of a few long-standing structured degree programmes at Unisa. This observation is based on financial viability, trends in student numbers, and relevance for society. Pretorius (2004) and Zietsman and Pretorius (2006) observed that student numbers for the programme were gradually increasing, with students from all over South Africa and farther afield. Although it can be anticipated that this growth will level off, a baseline in terms of the minimum number of students required to continue to offer this qualification, has been established. Earlier in 2000, Pretorius (2004) found that a large majority of students in the EM programme were already employed in the environmental industry, and that the programme provided a means to receive formal education in environmental management. This indicated that the programme was an option for people already employed in the environmental industry, and lacking the required theoretical background. It also proved popular for people considering a career change to the environmental field.

As is the case with most universities, the presence of institutional silos creates huge obstacles for the development and implementation of multidisciplinary study programmes at Unisa. With the transformation of Unisa to a structure comprised of semi-autonomous colleges, the problems associated with maintaining a multidisciplinary study programme have increased rather than decreased. The organisational restructuring of Unisa in the mid-2000s posed huge challenges for the ongoing survival of the EM programme. Several serious administrative hiccups were experienced with the migration from the "old" to the "new" structure; however, these could fortunately be dealt with effectively. To this end, the good standing and academic visibility of the Department of Geography, as one of the leaders in the field of innovative teaching and learning at Unisa, specifically in the field of EfS, contributed to a smooth transition.

The inclusion of modules from different departments in the EM programme adds to its richness and is crucial in order to support the aims in terms of sustainability. Challenging, however, is that, because of departmentalisation, modules do not always speak to each other or to the overall aims of the EM programme as well as they should. The coordinators of the EM programme are also not in a position to prescribe to other departments *how* they should teach their modules or *what* they should teach in them. It therefore happens that some of these modules do not bring the sustainability message across strongly enough by means of authentic learning strategies. As a result, a perception to address is that the EM programme is too theoretical because it is offered through ODL, with not enough practical work included to skill students properly for the requirements of the workplace.

3.3 Link and Role Within Campus Greening

The EM programme at Unisa was one of the first, and remains one of the few multi-inter-trans-disciplinary study programmes at Unisa. During its planning and implementation it was (and still is) constantly under institutional (administrative, operational and academic) scrutiny. Inadvertently, this contributed significantly to spreading the green message within the institution and has created awareness of the unique requirements in terms of EfS. The fact that the EM programme is perceived, institutionally, as a successful study programme has largely assisted in legitimizing "green" practices and the pursuit of the "green agenda" as a valid academic cause. Academic staff in the Department of Geography have also carried out research, made presentations and published internationally (e.g., Pretorius 2004) on the EM programme. This helped to raise the external profile of the department (as coordinators of the programme) and the discipline of geography, and contributed to safeguarding the future existence of this programme.

In terms of feedback obtained through interaction with students during discussion classes, video conferences and discussion forums on *my*Unisa, it is clear that the EM programme is perceived as the qualification to enrol for if you care for the environment and want to do something to preserve it for future generations. By establishing and coordinating this programme, the Department of Geography has created a niche for itself in the institution. This holds true for other stakeholders as well, including colleagues from other universities, who refer students who cannot study full-time, but have an interest in the environment, to Unisa. The presence of the EM programme among other offerings of Unisa therefore plays a significant role in signalling to students that the institution cares enough about the environment to offer a complete study programme on environmental management. This represents a visible contribution to the greening of Unisa (an ODL institution), as perceived by the student body.

Conspicuously, the institutionalisation of sustainability at Unisa lagged behind the implementation of the EM programme. Therefore, much of the groundbreaking work of the EM Programme occurred during an era when not many MIT programmes were offered and sustainability was not yet on the agenda of the institution. In the face of initial hostile reception (because of turf protection by other departments), the programme managed to rise above institutional and cultural/pedagogical challenges experienced at the time and lived up to its potential and relevance in modern society. It is currently regarded as a flagship study programme with the largest student numbers of any of the study programmes offered in the CAES, where the Department of Geography is situated. The Department of Geography therefore has benefitted and continues to benefit from the EM Programme in terms of student numbers and funding from the institution.

4 The Environmental Awareness and Responsibility Module Offered by Unisa

The signature module 'Environmental awareness and responsibility' is a third-level module open to any undergraduate student from any discipline who studies at Unisa. This module is compulsory within the EM programme and from 2013 it is one of a choice of six modules which every new student at Unisa is required to complete during their undergraduate studies. This exposure to every student at Unisa places environmental awareness and responsibility at the forefront of the institutional greening agenda. The module was developed as a capstone in order to improve the "graduateness" of students completing their undergraduate degrees.

To this end, this module aims to cultivate a sense of environmental awareness and responsibility for students because the incorporation of the concept of environmental responsibility in the professional activity of bachelors, engineers, architects and other graduates will play a key role in the evolution of society towards sustainability (De Ciurana and Leal Filho 2006). Ideally, all graduates should be trained in their respective fields of thought in relation to environmental and sustainable criteria and values, so that, in future, they can approach their professional activities from the point of view of sustainability (Tilbury 2004).

4.1 Point of Departure

Sustainability has found its way into all dimensions of academia (Savelyeva and McKenna 2011) and geography is an excellent discipline to take students from "knowing" about sustainability to "doing" something for it. This module is based on the premise that scientific knowledge and political intervention will not solve any environmental problem on its own and that something additional is required to change behaviour (McKeown-Ice and Dendinger 2000). Cotgrave and Kokkarinen (2011) state that behaviour changes can only occur if attitudes change and that this can be achieved through education. Fien (1997) shows that environmental education can play a key role by creating awareness and transforming people's values, skills and behaviour. Thus the main impetus of the module is to transform the attitudes of students by addressing sustainability issues across different spatial and temporal factors. The module also focuses on critically reflective, inter/trans-disciplinary, experiential and place-based learning, which is aligned with transformative sustainability teaching and learning (Sipos et al. 2008).

4.2 Approach to Learning

Mutual learning acts as a guiding principle of the module and faculty and students often launch dialogues and discussions on sustainability issues which are not limited to the curriculum, particularly from an African perspective. The module tackles many environmental and societal issues surrounding sustainability on the African continent. In the first part of the learning material, learners are tasked with calculating their ecological footprint. The reason for this is to place their lifestyles in the context of sustainability. Jucker (2002) points out that students and faculty should rigorously assess their unsustainable presence and the reasons why this is unsustainable before they can establish the principles on which a sustainable society ought to be built.

Many students who register at Unisa are from disadvantaged backgrounds and the module touches on the need to adopt sustainable living practices in the face of the daily need for survival. Other students are affluent and might be guilty of wasting resources without realising it. This juxtaposition presents an interesting contrast which forms the theme of many discussions which students appear to enjoy and also makes the module interesting and relevant to teach. Many students provide different perspectives to the same environmental problem, because of their personal circumstances, but upon reflection almost all the students recognize the need to incorporate concepts of sustainability into their daily lives. Students also appear to embrace and enjoy this online method of teaching as opposed to correspondence-based teaching.

4.3 Assessment

Critical reflection and experimental learning through a series of online assignments, which require students to apply knowledge such as debating the benefits and drawbacks of using nuclear power in a developing country and selecting the locations of new nuclear power plants in South Africa, are applied in the module. Another activity which puts theory into practice (praxis) focuses on recycling over a 2-week period and aims to take students from “knowing” about sustainability to “doing” something for it. First, students are required to locate the nearest recycling depot to their place of residence or work which presents an informal location-based learning opportunity; similar to the possibilities identified by Clough (2010). Students are then required to set aside home refuse (e.g. glass, paper, plastics, etc.) for recycling. At the end of the 2-week period, students drop off their recyclables at a depot and then submit a blog-based assignment in which they reflect on their experience. Many students noted their ignorance of the variety and accessibility of recycling depots, even in rural areas. In cases where students could not find recycling depots some presented ingenious initiatives whereby they started reusing waste materials. An interesting comment made by some students was of their guilt about taking away informal jobs from people who sort through refuse for recyclables on collection days. The module culminates with the online submission of a portfolio which addresses environmental awareness and responsibility in a real world context chosen by the student. The portfolio is also marked online and assesses theoretical understanding, critical thinking, practical application and digital competencies.

4.4 Challenges and Concerns

The module is delivered entirely online, which represents a major shift for an ODL institution on the African continent and exemplifies Unisa’s commitment towards improving institutional sustainability and embedding sustainability in curricula. Whether one believes that it is appropriate or not, e-learning is now a mature area of application in geographic education (Lynch et al. 2008), although teaching and learning of science in ODL still presents challenges (Scanlon 2011) in countries on the African continent, where broadband Internet penetration lags behind many developed countries. Interestingly, students did not formally complain about the requirement of access to the Internet during the module.

Oyedemi (2012) recently showed that Internet penetration amongst university students in South Africa is very low, particularly in rural areas. According to Oyedemi (2012), this trend reinforces social inequalities in South Africa. Online education in developing countries such as South Africa therefore needs to consider balancing the limited access of students to the Internet with the need to prepare them for the digital age. Unisa is trying to address this by providing students with “digibands” since the lack of familiarity and/or access to technology can hamper learning in an online environment. These “digibands” are flash-drives which students receive upon registration. All the online learning material is duplicated on the flash-drive, but it only represents a static copy, so students still have to go online to post comments on discussion forums, create blogs and submit assignments.

Notwithstanding these concerns, it is an exciting experience to teach online and the benefits far outweigh the challenges. During the development and implementation of the module, an approach found to be particularly useful involves incorporation of typical student (mis)conceptions of topics prior to engaging with the material. Muller (2008) and Muller et al. (2008) have shown, in the context of physics education, that misconception-based multimedia can alert students to key inconsistencies in their reasoning, and help tether their old ideas to new, scientifically accurate ones. This approach may be a real asset to getting the learning material across to students and promote conceptual change in students, but must take into account that Internet penetration, typically used to convey multimedia content, lags behind much of the developed world in Africa and South Africa (Oyedemi 2012).

4.5 Implications of Campus Greening in an ODL Context

The EM Programme and "Environmental awareness and responsibility" module are not only cultivating a sense of environmental awareness and responsibility among students but also helping to green Unisa from within. Various initiatives such as campus recycling and on-screen marking to reduce the carbon footprint of Unisa (and improve institutional efficiency) have recently sprung up to push campus greening across all sectors and functions of the ODL context. Similar to the observations of Koester et al. (2006), the whole-systems approach bridges campus operations, administrative policies and facility management practices. In addition, the increased exposure of campus greening at Unisa will have a direct and positive impact within the institution and, as the largest ODL institution in Africa, the greening of curricula will have potentially far-reaching impacts as graduates from all over South Africa, Africa and the globe incorporate sustainability into their work and daily lives.

5 Reflection on Experience Gained Through Current Curriculum Initiatives

Over the centuries, universities have fundamentally been major agents of social change (Lozano 2010), and Unisa is no exception. Since 2000 the Department of Geography at Unisa has increasingly attempted to incorporate environmentally sustainable practice into its curricula, tuition and assessment. This is reflected in the EM programme and the signature module on environmental awareness and responsibility, which are presented and analysed in this chapter.

Similar to the Department of Geography, many other disciplines in Unisa are in the process of incorporating environmentally sustainable practice into their curricula and teaching. The mainstreaming of environmentally sustainable practice into the curriculum of the EM programme is varied because of its multi-inter-trans-disciplinary nature. Within this context it has been noted that the participating disciplines in the EM programme vary in the way they have incorporated environmentally sustainable practices into their respective curricula. It is also evident that each discipline attaches a different meaning and thus understanding of what is meant by the mainstreaming of environmentally sustainable practice. The EM programme is targeted at graduates who will work within the environmental field, and thus the mainstreaming of environmentally sustainable practice in this curriculum makes sense to these graduates, despite the number of challenges highlighted in this chapter.

Similar to many universities, the mainstreaming of environmentally sustainable practice at Unisa has until recently been limited to specific courses and modules in the environmental field (McMillan and Dyball 2009). The introduction of the environmental awareness and responsibility module in the Department of Geography was a strategic decision of the Department, with the major aim of embedding a level of "graduateness" into the curricula of not only its own students but also students from other disciplines and programmes who might not pursue a career in the environmental field. The module seeks to provide students with a moral compass based on a higher conception of environmentally sustainable practice in their everyday lives. Although still very much in its infancy, the potential success of this module is evident from the responses of students.

The experience of the past decade at Unisa has shown that the curriculum initiatives of the Department of Geography have started showing some success in ensuring that environmentally sustainable practice becomes part of the value system of its graduates. However, this is only a start in the direction of embedding environmentally sustainable practice into the "graduateness" component of its curriculum.

6 Factors Underpinning Future Initiatives

6.1 Campus Greening Projects: Residential Versus ODL

The literature abounds (Wemmenhove and de Groot 2001; Hayles and Holdsworth 2008; Lozano 2010) with examples of how higher education institution use campus greening projects to provide students with opportunities to become involved in projects which focus on environmentally sustainable practice. However, Unisa, as an ODL institution, does not have students who come to campus on a daily basis. Thus, although Unisa has embarked on a "Going Green Campaign", this campaign is mostly for the benefit of faculty and administrative staff. The dilemma is therefore how to teach environmentally sustainable practice as a tangible concept relating to the everyday lives of students who are geographically located across South Africa, Africa and the rest of the world.

6.2 Call for Bottom up Approaches to Mainstreaming Environmentally Sustainable Practice into Curricula of ODL Institutions

In the knowledge society of the twenty-first century, the more traditional ways of transmitting and assessing knowledge are becoming increasingly inappropriate. The emphasis is now on the reflections of students and their opinions in relation to theory. Learning from each other and from non-academics within their own lives is becoming more and more important (Wemmenhove and de Groot 2001). All of this points towards a bottom up approach to environmentally sustainable practice within curricula, implying a move away from traditional lectures to a more hands-on approach. These approaches also involve challenging of preconceptions, and convince students that they can make a positive difference in the collective move towards a sustainable future (Hayles and Holdsworth 2008).

6.3 Call for a Less Compartmentalised Approach

A number of positive initiatives have already been implemented by the Department of Geography at Unisa to ensure that they produce graduates who are sensitive to environmentally sustainable practice. However, it has to be admitted that this has been done in a compartmentalized manner. Within the whole university approach, the idea is to prevent universities from tackling environmental sustainability issues in a compartmentalized manner. By linking research, teaching and community engagement, Unisa can produce graduates who would be able to provide innovative solutions to environmental sustainability problems within their chosen vocational fields, while providing meaningful learning experiences for students at the same time (Parece and Aspaas 2007; Hayles and Holdsworth 2008). The Department of Geography at Unisa is involved in projects related to environmentally sustainable practices within a number of communities. Allowing Unisa students to participate in these projects would mean that students would be able to experience and/or implement holistic environmentally sustainable practices within a real world context and at the same time assist faculty with their research mandate.

7 Possible Future Initiatives

While empirical and qualitative data need to be collected to establish the effectiveness of the introduction of the EM Programme and the signature module in the Department of Geography, the introduction of an aspect of in-service learning incorporating a level of volunteerism within the student's own community would result in a broader and deeper engagement with environmentally sustainable practice. Such a move would be in line with a "bottom up" approach in greening of the curriculum and lead to a less compartmentalized approach. Students will be able to work in their own communities to learn about indigenous environmentally sustainable practice from non-academics, to share aspects of environmentally sustainable practice within their own lives with fellow students and community members and to reflect critically on the theory and knowledge learnt at the institution of higher learning. Ideally, the introduction of in-service learning into the module on environmental awareness and responsibility would be a logical step forward.

The introduction of an in-service learning component into the present curricula of the offerings of the Department of Geography would have to incorporate the following components. These have been adapted from Coppola (1999) and Parece and Aspaas (2007), with the inclusion of the National Qualification Framework indicators required for a degree in South Africa to ensure the future mainstreaming of environmentally sustainable practises:

- The curriculum would have to prepare students for realistic problem solving in an authentic context
- The curriculum must include a human element in the search towards solutions to environmental problems
- The curriculum must be multi-inter-trans-disciplinary
- Communication would have to form a major component of the curriculum
- The curriculum must provide a rational approach to environmental problem sharing
- The experience has to move students towards action

8 Conclusion

In order to provide geography graduates with the necessary knowledge and skills which would enable them to contribute more meaningfully to a more sustainable world, the Department of Geography had to move away from a contents-based curriculum. The contents-based curriculum was in many ways contributing to unsustainable economic principles and it was clear that a new curriculum focussing on a new way of thinking more relevant to meeting the global trends towards a more sustainable world was needed. The fundamental focus of the two initiatives presented in this chapter is environmental sustainability. This, together with the ODL nature of Unisa, allows lecturers to encourage students to draw attention to real-world problems within their own communities. The learning process has moved from a contents-based curriculum with a top down approach to a curriculum focussed on addressing problems and with stronger emphasis on peer learning. Our experience has shown that this has gone a long way to assist students to think in terms of sustainability. The possible introduction of an in-service learning component will assist in providing students with a richer learning environment which could mirror real-world problems and, in this way, allow them the opportunity to share creative, innovative and transformative ideas on present and future issues concerning environmental sustainability.

In conclusion, the various strategic initiatives of the Department of Geography at Unisa has gone some way to transforming the learning experiences of our community of students who, despite their geographical dislocation, varied socio-economic-political and cultural differences, are able to use the electronic learning platform of Unisa to share authentic learning experiences related to environmentally sustainable practises, and, in the same way, embed a value system which will go a long way to addressing value systems related to environmentally sustainable practises in the everyday life of individual students.

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From Correspondence to Online Provisioning in Open and Distance Learning: Greening Implications versus Practical and Organisational Imperatives

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Abstract

This chapter provides a reflection on the alignment between the ideal of campus greening and realities while moving towards greater sustainability in open and distance learning (ODL) in a developing world (Global South) context. The case study presented involves the University of South Africa (Unisa), a leading ODL provider and the largest university on the African continent. The focus is on the junior postgraduate (honours level/fourth year) offerings of the School of Environmental Sciences (SES), with greening implications and challenges associated with the shift from correspondence to online provisioning. Until recently, Unisa was a "traditional" distance education institution with heavy reliance on print-based material. The transformation from print-based to online offerings had a slow start because of issues related to access within the developing world context. These issues have to be addressed because of the direct greening implications of going online in the higher education sector. This reflection on the move from correspondence to online provisioning will be conducted against the backdrop of the transformation Unisa went through over the last decade, and which was triggered by the merger of the three former

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distance education institutions in South Africa into one mega institution. Developments such as a huge increase in student numbers, implementation of ODL as business model and becoming a signatory to the United Nations Global Compact (UNGC), had various impacts on Unisa. Within the latter context, a reflexive account is provided of the greening implications, challenges and solutions associated with the facilitation of online learning experiences and specifically online learning design, assessment and student support. Successful implementation and positive spinoffs for campus greening, however, will depend on buy-in from students, staff and college faculty. In order to achieve success, the attitudes and perceptions of these stakeholders need to be considered. By way of conclusion, some preliminary findings in this regard for the SES (Unisa) are made, thus contributing to the limited body of knowledge about the infusion of information and communication technologies in ODL provisioning in developing world (Global South) contexts.

Keywords
Attitudes · Campus greening · Correspondence model · Online provisioning · Open and distance learning (ODL) · Perceptions · Transformation

1 Introduction

1.1 Position Statement

In general terms, campus greening refers to the way in which universities conduct their business towards better alignment with the sustainability agenda. This should include campus management, operations, academic curricula, research and community engagement (service learning), with the best results obtained in the case of synergistic interaction between these aspects. On a different level, campus greening can be described as the process of mitigating the negative environmental impacts resulting from campus activities and decisions (Dahle and Neumayer 2001). At this stage, it is common for institutions of higher learning to undertake large-scale environmental sustainability efforts. However, few plans are in place to address cultural or behavioural aspects of environmental sustainability on their campuses (Levy and Marans 2012).

Many institutions of higher learning consider it sufficient to have institutional policies and directives about environmental sustainability (James and Card 2012). These policies and directives, however, are often far removed from practices at grassroots, where students interact with their learning experiences (Moore et al. 2005). The role of faculty and staff as drivers of transformation should also not be underestimated (Brinkhurst et al. 2011). In addition, the greening drive needs to be aligned with other imperatives universities are faced with, such as political, funding or socio-economic. Ultimately academic plans on curricula and research need to be linked to policies on environmental sustainability in terms of strategies to infuse sustainability throughout the organizational culture of the university (Moore et al. 2005). Unisa can relate directly to these concerns.

1.2 Open and Distance Learning

In open and distance learning (ODL), with students not on campus and communication increasingly electronic, campus greening has a unique context, on which this chapter will focus. Research on the environmental impacts of delivering courses through various modes indicate significant differences in impacts whether offered by full- or part-time face-to-face teaching, by print-based or online distance learning, or by blends of these methods (Roy et al. 2008). These researchers found that distance learning reduces energy and emissions associated with studying a higher education course dramatically to only 13–15 % of those arising from an equivalent full-time, face-to-face campus-based course.

However, research points towards little gain in terms of environmental impacts between print-based and online distance learning (Roy et al. 2005). These findings are based on the offerings of the Open University (UK) functioning in a developed country. It remains to be seen whether their findings can be applied successfully to the developing country context of Unisa. In addition, the perceived benefits of online provisioning need to be weighed against issues of which system results in the best learning. Last, but not least, moving towards online provisioning in the Unisa context presents challenges because of Internet penetration, which is hugely skewed amongst South African students (Oyedemi 2012).

1.3 Methodology

The aim of this chapter is to take a reflexive position on the transformation from correspondence (paper-based) to online provisioning of courses at Unisa, to objectively consider the implications of greening. This chapter is the result of a collaborative effort between staff members involved with implementation and teaching of a variety of sustainability-related courses at Unisa over a period of time. Most of them were at Unisa long before the move towards increased use of information and communication technologies (ICTs), and are in a unique position to reflect on the transformation from correspondence to online delivery of the offerings of Unisa.

The research question considered concerns practicalities versus organizational imperatives associated with the transformation to online provisioning and associated gains in greening. By taking a reflexive position, it is possible to point out not only obstacles to change but also opportunities, to indicate the possible future direction for initiatives and to correct misconceptions. The position taken in this chapter was developed through collaborative group enquiry, during which all researchers became part of the process of knowledge construction.

The institutional context of greening at Unisa will first be dealt with, followed by a critical review of two online initiatives at Unisa. The progress with and greening implications of these initiatives will be reflected upon, followed by discussion and concluding remarks.

2 Unisa: The Institutional Context for Greening

Unisa is the only dedicated ODL institution of higher learning in South Africa. According to its mission, Unisa is a comprehensive, open distance learning institution which produces scholarship and research, provides quality tuition, and fosters active community engagement (Unisa 2011a). In its 2015 Strategic Plan (Unisa 2005), Unisa declares that it "aims to establish itself as a leading provider of world-class higher education opportunities through ODL; nationally, on the African continent, and internationally". Unisa's size, aggregated resources and capacities ensure that Unisa makes vital contributions to education and development in Southern Africa (Unisa 2005).

2.1 Policies and Directives

Sustainability resonates in the vision of the University of South Africa (Unisa) as being "the African university in the service of humanity" (Unisa 2007) and signifies how sincere Unisa is about the African continent's and national educational, developmental and social challenges (Unisa 2011b). Unisa took the lead in 2007 and became the first South African university to sign the United Nations Global Compact (UNGC), thereby committing the institution to integrate UNGC principles about the following into curricula and research focus areas:

- Human rights
- Labour
- Anticorruption
- Environment (Unisa 2011a)

In its Transformation Charter (Unisa 2011b), Unisa declared its commitment to: "CONSERVATION: preserving and utilising what is best from our legacy, making choices and decisions and taking actions in the present, which ensure a sustainable future", and "CREATIVITY: nurturing an environment that is open and receptive to new ideas, that liberates potential and leads to imaginative and innovative thinking and action". With these, Unisa confirmed its commitment to the "principle of sustainability not only to protect but also to enhance the environment and to make a significant contribution to the development of staff and the society" (Unisa 2011b).

2.2 From Policy to Action

Unisa recently developed a plan of action to become an environmentally friendly institution. This plan focuses on individual activities as well as the composite institution. Since Unisa is just beginning to understand the full ramifications of environmental sustainability, this plan is an open, living document. However, Unisa has also already put several institutional measures in place, such as (Unisa 2011a):

- Management of electricity consumption
- Water management and conservation
- Reduction of carbon emissions
- Application of green building principles
- Promotion of recycling by providing recycling stations and bins
- Office automation project to reduce the number of desktop printers and the number of hardcopies being printed

As stated by Moore et al. (2005, p. 79) "Institutional commitment needs to be more than just a policy and a few programmes. Universities need to consider sustainability in the decision-making structures and everyday practices of the whole university". The transformation charter of Unisa (Unisa 2011b) acknowledges that, to succeed in its greening agenda, transformative leaders at all levels in all sectors of the organization need to be empowered as change agents. They are distinguished from mere actors by their resolve and capability to act catalytically in pursuit of institutional and societal change imperatives in the face of opposition, resistance and limited resources.

2.3 Growth in Student Numbers

Ultimately the growth of Unisa in terms of student numbers, approaching 300,000 by 2010 (Unisa Facts and Figures 2010), necessitated an overall rethink and redesign of systems. Technology was an obvious option, and had to be deployed innovatively, from administration to teaching, in order to provide the increasing number of students with a quality overall experience of Unisa. Using technology to migrate from printed mode to computer-mediated communication to serve a student population of approximately 300,000 has the potential to contribute significantly to reduce the carbon footprint of an institution of this size.

Since 2005, Unisa has implemented several technologically-based innovations, with the side effect of curbing the consumption of paper. Some of these initiatives are:

- Online student registration
- Online access to university brochures and registration information
- Online submission of staff leave applications and procurement requests
- Launch of the *my*Unisa virtual learning environment
- Library e-book project

The growth in student numbers, together with the current semesterized tuition periods, have huge implications for teaching related activities at Unisa. The semester system reduces the tuition period to 12–16 weeks. With assignments received via the postal system and then administered by the Department of Student Assessment Administration (DSAA), bottlenecks and delays frequently occur. This hampers the effectiveness of feedback when eventually received by students and was an important consideration underlying the decision to implement and gradually move to online submission and on-screen marking (OSM) of assignments.

2.4 The School of Environmental Sciences

The College of Agriculture and Environmental Sciences (CAES) at Unisa, and specifically the School of Environmental Sciences (SES) have taken a leading role in many pilot online projects with greening implications since 2008 (Unisa 2011b). The first pilot project for "on-screen marking" in Unisa was established in CAES in 2008 and provided valuable feedback for systems improvement. In 2010, the CAES management decided that all assignments received electronically have to be marked "on screen" from 2012. This was followed in 2011 with a decision that all post-graduate courses in CAES must be offered online through *my*Unisa from 2013.

In the following two sections of this chapter, the greening impacts associated with both these initiatives by CAES are considered reflexively, specifically with regard to the junior postgraduate (honours level/fourth year) offerings in the SES. These offerings comprise the honours degrees in respectively Geography, Environmental Monitoring and Modeling as well as in Environmental Management. The student numbers for the modules comprising these degrees are usually not that large (typically less than 100), which makes them ideal for testing and fine tuning of teaching and learning endeavours in the context of online provisioning.

3 Campus Greening and Learning in the Online Environment

The sustainability discourse (Haigh 2005) runs as a golden thread through the curricula of the honours level modules offered in the SES. Because of the nature of the disciplines in this school, the capacities developed through the teaching and learning endeavour are focused on delivery of rounded-off professionals for a variety of jobs in the environmental field. With the move to go online, the teaching and learning environment as well as practices are changing and therefore need to be considered, together with the associate implications for campus greening. If the only change is that hard copy study guides are now provided in digital format, the cost of printing is merely transferred to the student without real greening implications.

Pedagogical approaches can range from transmission modes of teaching with the lecturer as source of knowledge to social constructivist approaches, where communication and networking between students plays an important part in the learning process. Mentis (2008) argues that technology, pedagogy and context need to be closely aligned in order to realize the potential for e-learning. Students who are connected to the Internet can access large volumes of information within seconds. Changes in pedagogy suggest the potential for more individualized, user-controlled informal learning contexts relying heavily on social networking via technology. There are, however, realities in the South African learning context impacting on practical implementation.

3.1 Changing Teaching and Learning Environment

Until approximately 2000, Unisa was a traditional, single mode distance education institution heavily reliant on printed matter and a huge investment in equipment and infrastructure for printing and posting of large volumes of study material. During this dispensation, a typical study package for an honours module in the SES consisted of a study guide, tutorial letters and a prescribed text book or *Reader*. Lecturers compiled *Readers* from relevant material such as journal articles, case studies and/or book chapters (de Jager 2004; Pretorius 2002). Most study packages also included recommended additional material. Students could order printed copies of academic articles from the Unisa library. In terms of formative assessment, students generally had to do two or three essay-type assignments and for summative assessment a formal venue-based examination was written at the end of the academic year.

The rapid advance in the development of ICT initiated a gradual move since 2000 towards augmented study packages in which ICTs are used to enhance the learning experience. Honours modules in the SES have, to a varying degree, adapted to the online mode of delivery ranging from augmented to blended and fully online delivery (Unisa 2011c). In terms of the Unisa ICT-enhanced teaching and learning strategy 2011–2015, "learning innovation involves a complex relationship between research, pedagogy, learning and technology" (Unisa 2011c). The honours modules in the SES are therefore at various stages in the process of being re-curriculated and re-designed for online delivery. According to the "Statement on graduateness" in Unisa's Curriculum Policy (Unisa 2010a), the online strategy is student centered to enhance teaching and learning and to prepare students for "critical citizenship in a networked world". A more interactive teaching and learning strategy is followed in the online environment, which is becoming increasingly complex (Siemens 2011). Formative assessment is done on a more regular basis (with different types of assessments) and a variety of summative assessment options are applied, including portfolios.

3.2 Application of ICT Tools

The variety of tools available to support teaching and learning in the context of the online electronic platform, are summarised in Table 1.

Technological changes enable lecturers to provide student support by means of a variety of electronic options such as e-mails, text messages and through the

Table 1 Tools available on the online electronic platform, *my*Unisa

Home page	Includes a welcome message, announcements and schedule
Announcements	Used to inform about issues related to module, e.g. meetings and new material
	Often used together with SMSs reminding to check the website
Official study material	PDF documents of study guide and tutorial letters can be downloaded
Prescribed books	Information regarding prescribed material for module
Additional resources	Variety of support material e.g. electronic versions of different types of documents, photographs, PowerPoint presentations or links to websites
Schedule	Important dates e.g. events, discussions, submission dates of assignments, portfolio submissions and examinations
Learning units	Structure of module, learning activities and links to external resources are provided
FAQ	Answers to frequently asked questions posted by lecturer
Discussion	General discussion between students about various aspects of module
Questions and answers	Questions about module content which students can answer/discuss
Dropbox	Large documents can be submitted to lecturer
Blogs	Blogging by students and lecturers used in activities and for reflection
	Students can create own blogs or comment on the blogs of fellow students
Polls	Polls created by lecturers for students to vote on
Podcasts	Voice messages can be uploaded onto the module site
Wiki	Students can work together to collaboratively compile a document

electronic learning platform. Students can download a variety of resources from the module sites and via the Unisa library, including academic journal articles, e-books and other e-reserves. Since the library subscribes to a multitude of electronic databases, students can access and download this material without incurring additional costs. The library website and the resources it offers can be accessed by registered honours students in the SES via the Internet from anywhere in the world, thus presenting a powerful tool for reading and research activities.

In addition, video conferencing can also be used at honours level to enhance communication between lecturers and students, as already successfully done with Master's and Doctoral students, not only at various South African regional centres but also for the regional centre in Ethiopia (Unisa 2010b). Using videoconferencing technology is a greener option than students having to travel physically to the Unisa campus to discuss their research proposals with supervisors.

As an outcome of a Unisa student survey, a variety of information and technology support strategies were proposed (Tustin et al. 2012) to integrate studies with personal considerations (Table 2).

Table 2 Proposed ICT support strategies based on a student satisfaction survey (Tustin et al. 2012)

On-campus access to computers and wireless Internet
More satellite broadcasts
Skype contact with tutors/lecturers
Introduce chat rooms on the Unisa portal for students to have live chats with lecturers
Prevent website failures at all cost
Computer labs at learning centres
More DVDs or videos of tutorial classes and satellite broadcasts
Free Internet services
Improve assistance with online troubleshooting
Introduce cyber education, lectures on DVD which can be uploaded onto a website and downloaded by students at convenient times
All Unisa centres should have electronic student cards
Podcasts for all modules
Post tutorials online
Radio broadcasting of lectures
Satellite broadcasting of lectures
Use online blogs for discussion of problems with lecturer

3.3 Ongoing Discussions Regarding Greening and Teaching and Learning Practices

Fillar Williams (2011) explains that, unlike previous generations, the millenials grew up with multimedia-enhanced learning and that the teaching and learning environment needs to be adapted accordingly. The reality at Unisa is that age cohorts in modules or on year levels are not homogeneous. In addition, the student population is diverse in terms of economic level and not all students are connected to the "flat world" (Friedman 2005). There is a huge digital divide in South African society and also in the student population of Unisa, and this remains a challenge in the ODL context. There are advantages and possibilities for teaching and learning in the online environment and it is acknowledged that students obtaining a honours degree should be able to navigate and operate in an online environment.

Even though material is provided in digital format for the honours modules offered by the SES, it is not necessary for students to be online all the time. They can download material from *my*Unisa or from the Internet and then read it from an electronic device. While this may be a greener option than printing and posting the material to students, online learning is more than merely placing printed matter behind glass and shifting the printing costs to students. The discussion regarding access to ICTs, costs of downloading of digital material and the relative importance of online activities and authentic learning experiences is continuing in the SES. The mode of delivery is one of the components of a greater awareness of the sustainability discourse.

4 Campus Greening and Assessment in the Online Environment

4.1 The Era Prior to Going Green with Assessment

The increasing inability of the previous paper-based systems at Unisa to deal with growing student numbers within the semester system had huge implications for assessment. In their audit report, the Commonwealth of Learning (2007, p. 40) commented that "… it is critical that students should receive timely personal feedback on their work. The systems, both management and operational, to ensure that this happens are a core element of any ODL institution." Ryan (2009) commented on several aspects regarding management of assignments at Unisa which were unsatisfactory. These included assignments received electronically but being printing out, marked and posted back to students by snail mail. Given the realities of the postal system in South Africa, delivery is too slow for students to receive feedback in time to be of any use. Timely evaluation and provision of effective and constructive personalized feedback on assignments became a major challenge. Möller and Myburgh (2010) detected that lecturers were starting to reduce the number of assignments and rather make use of multiple choice assignments which could be marked automatically by computer using a pre-compiled memorandum.

4.2 Implementation and Functionality of the Unisa On-screen Marking Toolset

The unsatisfactory state of affairs prompted an investigation (Möller and Myburgh 2010, p. 377) to search for a solution to "reduce these processing bottlenecks when handling large numbers of assignments, reducing the turnaround time and keeping the levels of feedback high and constructive at all times." They gave priority to putting a system in place that makes the marking effort more effective and efficient and which has such appeal that lecturers would prefer using the new methodology rather than conventional marking by hand.

The proposed on-screen marking (OSM) toolset consisted of four components. The basic marking toolbar (first component) and commenting tool (second component) were designed to be embedded within Adobe Professional PDF files. An optional rubric tool (third component) was designed to function independently from the other tools and, once finalised, the scored rubric can be automatically attached to the assignment upon returning it to the student. The fourth component, a router tool, catered for the flow and tracking of assignments from the moment of submission via *my*Unisa to returning the marked assignment to the student via email and capturing the mark on the assignment system.

The toolset was piloted during 2009 and 2010 and launched in 2011. The toolset made it possible to route assignments to lecturers or predefined marking panels. Assessment could be done using one or more of five different scoring strategies. Upon completion, the final mark is calculated automatically and upon finalization it is embedded in the file name. The "send to student" function triggers the upload of the mark on the assignment system, the creation of an archive copy and emailing a copy of the assignment to the students with the final mark and comments of the marker, embedded in the file.

4.3 On-screen Marking Within the SES

The view of Ryan (2009, p. 398) that Unisa "academic staff are technological immigrants who are wary of web portals and, despite all efforts at training, are unwilling to commit to even a once a week digital input" definitely does not apply to academics in the SES with regards to OSM. The adoption of OSM in SES was generally very successful. The university has set 2015 as the date by which all modules should be set up for OSM. In the case of postgraduate modules offered by SES, this target was already achieved in 2012. A number of factors contributed to the embracing of OSM in the SES:

- The dean was convinced that it makes sense from the perspective of environmental sustainability and that CAES should set the example for the university.
- Ample training opportunities on OSM were available on the Science Campus for interested lecturers.
- A lecturer from each department was involved during the initial experimentation with the toolset. SES thus had expertise in their midst which diffused to other colleagues.
- The bottlenecks and delays earlier referred to were compounded by relocation of CAES from Pretoria to the Science Campus in Florida, Johannesburg. Systems were not in place to bridge this geographic space and swiftly reroute assignments between Pretoria and Florida. OSM was a logical option to put lecturers more in control of the flow of at least the category of electronically submitted assignments.

4.4 Advantages of and Frustrations and Challenges Related to OSM

The biggest frustration originally associated with OSM was router-related instabilities. "Mistakes" made by markers created the wrong impression that allocated marks or assignments went astray. Other frustrations relate to network downtime and the restriction on the size of assignment files for uploading. Fortunately the advantages outweigh the frustrations. Some lecturers commented that students find it easier to read their typing than their handwriting. During a colloquium on the process and benefits of OSM, Immelman and Vlok (2011) expressed the opinion that:

- The 17 steps they identified in the workflow of a printed, but electronically submitted assignment can be reduced to five steps
- It is more convenient to save 200 assignments on a flash drive for marking at home than to carry and transport 200 printed assignments

- Although OSM is initially slower than marking by hand, the process later speeds up dramatically
- OSM is easy and a more satisfying way of marking
- Lecturers can put themselves in control of the marking process by short-circuiting delays experienced with delivery of printed assignments

As regards challenges, research is required on how students perceive the electronic feedback. Do they print the feedback? Are sticky notes placed in the PDF document not influencing the legibility of the feedback? Do they prefer feedback in Word format (e.g. by means of tracked changes) or in PDF format? Another challenge is to persuade lecturers to opt for marking in more than one format. A dilemma is that, should a student refrain from converting his or her assignment to PDF format and a lecturer has indicated PDF format as the one and only format for OSM, an assignment submitted in a format other than PDF will be routed to DSAA for printing and eventual marking by hand.

4.5 Greening Implications

Paper consumption at Unisa is enormous. It has been estimated (Commonwealth of Learning 2007) that the volume of material produced and dispatched to Unisa students in 2005 was in the order of approximately 700 million pages. How many trees were used to provide so much paper? It is not easy to provide an objective answer to such a question. What constitutes a typical tree and what kind of paper are we talking about? The Conservatree website (Conservatree 2012) provides a guideline: "based on a mixture of softwoods and hardwoods 40 ft tall and 6–8 in. in diameter, it would take a rough average of 24 trees to produce a ton of printing and writing paper using the kraft chemical (freesheet) pulping process." The same web page then equates 1 tree to 16.67 reams of copy paper or 8,333.3 sheets of copy paper. By using this guideline and applying basic arithmetic, the 2005 paper usage by Unisa is equivalent to a staggering number of trees, just under 84,000.

Although the implementation of OSM at Unisa was triggered by system inabilities and failures, it was soon realised that OSM has a huge potential to limit the use of resources. Möller and Myburgh (2010) as well as Immelman and Vlok (2011) alluded to "greenness" in the titles of their presentation on OSM at Unisa. Immelman and Vlok (2011) calculated that, if the estimated 36,000 compulsory undergraduate assignments submitted to Unisa in the first semester of 2011 were all a conservative 3 pages, the university had to use approximately 288 reams of paper (approximately 25 m in height when stacked) to print the assignments and cover dockets. The presenters argued that a staggering amount of paper could easily be saved with the implementation of OSM. They further argued that, although electronic submission of assignments by students are supposed to be more environmentally friendly and contribute to a quicker turn-around time, it is not "greener" if the lecturer failed to flag the module as a module in which electronically submitted assignments will be marked on-screen. Based on the embracing of OSM by SES in 2012, their appeal to go green was taken to heart.

5 Reflection on Progress with Going Online and Contribution to Greening

The rapid development, innovation and changes in ICTs have influenced and are continuing to influence teaching and learning praxis considerably at Unisa. Following a visit to the University of Leicester in 2010, the Unisa Senate Tuition and Learner Support Committee (STLSC) accepted the recommendation that "All new course materials and revisions of course materials will be designed for e-learning, providing for a variety of blended delivery options" (Prinsloo 2011). Designing and implementing study material for e-learning thus relies heavily on the adoption of new ideas concerning ICTs by academic staff members.

5.1 Diffusion and Sustained Use of ICT in Teaching and Learning by Academic Staff

Whether individuals adopt particular technologies and the time frame involved has been researched across multiple disciplines. Rogers (1995) provides a framework for understanding the diffusion process, the decision-making process related to adoption and the varying adoption categories within a social system. In accordance with theory of adoption of Rodgers, Panda and Mishra (2007) and Mishra and Panda (2007) investigated faculty attitude, barriers and motivators relating to e-learning in a mega open university in a case study of the Indira Gandhi National Open University (IGNOU). In a similar study to examine the attitudes of academic staff towards adopting *my*Unisa as online teaching tool in the SES, results indicated that academic staff have fairly favourable attitudes towards *my*Unisa as learning management system (Coetzee and Potgieter 2012).

General trends that came to light, as reported by Coetzee and Potgieter (2012), include the following. Academic staff have positive attitudes towards *my*Unisa as an integral component of ODL and also in terms of the improvement in communication, because it is user friendly and because it can also be accessed off-campus. Interestingly, academics indicated that the use of *my*Unisa can increase the aspect of "openness" associated with ODL. The tools mostly used on *my*Unisa revolve around communication, including the discussion forum, announcements and frequently asked questions. This reflects the sentiment of academics that *my*Unisa has the potential to improve communication.

Negative attitudes, according to Coetzee and Potgieter (2012), relate to inadequate training and the perception of staff that some students may be disadvantaged because of the nature of the student profile. For the most part, *my*Unisa is used mainly as a course material repository and for facilitation of communication through announcements and the discussion forum. Very little authentic online teaching is taking place and online assessment is limited to voluntary non-formal assessment.

This picture can change as academics get more experience with deciding about, trying and implementing the different tools to adopt *my*Unisa fully for e-learning. The fact that Internet access for students has been indicated as a concern cannot be ignored and decisions will have to be taken on how to deal with students for whom Internet access is problematic. Another conclusion of the research by Coetzee and Potgieter (2012) concerns uncertainty about the extent to which *my*Unisa can cater for all the teaching needs as well as integration of ICTs. This is confirmed by the statistical analysis of *my*Unisa tool usage.

The uncertainty indicated by academics may be a reflection of the lack of a clear and well-established pedagogical framework for a fully online delivery. Interrogation of the *my*Unisa tool usage data shows that the most used tool is additional resources. This fits in with the academic attitude that *my*Unisa is mostly used for uploading study material. From this research, Coetzee and Potgieter (2012) conclude that the attitudes of academic staff correspond well with the current *my*Unisa tool usage and the body of knowledge relating to the theory of diffusion as postulated by Rogers (1995).

6 Conclusion

6.1 Challenges

The transition to online teaching and learning presents new challenges as the roles and expectations of both staff and students evolve. An online lecturer must create a cohesive learning experience for students with whom they may not meet face-to-face and, therefore, must develop new support strategies that not only sustain but also increase student motivation and encourage interaction. Adapting student-centered approaches to the online environment requires development of new skills and changes to teaching practices (Bennett and Lockyer 2004).

A Unisa student satisfaction survey completed by Tustin et al. (2011) highlighted the challenges and positive aspects associated with *my*Unisa. A positive factor is that students experience the use of ICTs by Unisa as positive and this bodes well for Unisa's intention to make more use of technology. The outcome of the 2011 survey showed a positive student satisfaction overall, particularly with the *my*Unisa e-learning environment.

However, this same survey emphasize that some barriers need to be addressed. The availability or ease of getting hold of lecturers by students via *my*Unisa, email or telephone as well as the turnaround time of handling queries are major concerns. The survey further indicated that only 30 % of students are aware that *my*Unisa can also be used to communicate with lecturers. A further concern is that only 70.8 % of students are aware that study material is available on *my*Unisa. According to this report, more than 50 % of students use *my*Unisa in general to download official study material. The general awareness level of students of the different services of *my*Unisa was indicated to be low. The survey suggested that the participation of lecturers on the *my*Unisa discussion forum needs to improve, including the overall utilisation of the e-learning environment.

6.2 The Way Forward

This chapter has its origin in the belief that there is a need for a text that would outline some of the issues involved in the transformation from correspondence (paper-based) to online provisioning of courses at Unisa, in order to consider objectively the greening implications. We would do well to remember that no online provisioning in ODL could claim to be the panacea for higher education. Some aspects of online provisioning are far-reaching and obvious while other features may at best be tenuous. Online provisioning in ODL is not an arbitrary process but, ideally, should reflect the greening implications within the context of the practical and organisational imperatives of a university. An optimal approach to campus greening will need to consider aspects such as growth in student numbers, sustainability, flexibility, transparency, assessment in the online environment, diffusion and the sustained use of ICTs in teaching and learning by academic staff and appropriate application of these ICT tools, costs and student centredness. These factors should be integrated into a plan of action to help facilitate an environmentally friendly institution. This chapter provides clarity on what this online provisioning vision could be and crucially addresses the complexities, expected benefits and greening implications vs practical and organisational imperatives. It is strongly suggested that there is no single way of defining the greening implications of online provisioning in ODL. The boundaries of online provisioning in ODL are multifaceted and dependent to a large extent on the context within which institutions are functioning.

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Smart Campus: Recent Advances and Future Challenges for Action Research on Territorial Sustainability

Sophie Némoz

Abstract

The integration of technology for campus sustainability emerges as a new way forward to bridging the perceived gap between science and society. The perspective of carbon fossil resources depletion and the likely major impact of climate change fundamentally question the processes of energy production and consumption. Often termed "energy transition", their change requires an important sharing of knowledge to deal with the complexity and uncertainty of innovations. This chapter aims at addressing the green campus revolution as an issue of socio-technical learning and collective intelligence. In this regard, our ongoing research analyses the major fields of territorial ecology underpinning the Smart Campus concepts. To what extent do they cover the latest in innovative technologies and services that enable the campuses to produce green energy and to optimize its uses for sustainable living and transportation? First, a review of existing research on these systems called "smart grids" will show the recent advances in their experimentation within the territories of university institutions. Among them, the project of Smart Campus carried out by the University of Versailles Saint-Quentin-en-Yvelines is proving to be of particular interest. Gaining ground in academic, industrial and public works, its collaborative platform connects a solar photovoltaic system integrated into green buildings to the lighting of local campuses and to electric car sharing between their areas. This case study gives the opportunity of bringing back our

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early findings about the interactions between social and technical systems, and how those interactions define and influence sustainability on the different scales of campuses. Second, through various lenses, including technology, policy and practices, the investigation will demonstrate how social science methodologies are applied to meeting the needs of cooperation between industries, members of university administrations, local governments, research and teaching staff as well as students. From the technological promises of Smart Campus project to its current development, the achievements and the challenges for action research will be deepened so as to provide an understanding of the dynamics by which knowledge and expertise are transformed, reshaped and put to use in people's everyday lives on the campuses. The conclusions drawn will highlight the relevance of collective learning acquired in the execution of such a project. Finally, it will allow us to discuss the role of campuses for the pursuit of sustainability, as a pillar of territorial development.

Keywords

Energy transition of campuses · Collaborative innovation · Smart grid · Sustainable living and transportation

1 Introduction

Since the Earth Summit held in June 1992 in Rio, growing concerns for making the transition to sustainability have caught attention on the interactions between technical and natural systems. To create change, education seems increasingly important. As can be seen in the recently concluded Rio + 20 and "World Symposium on Sustainable Development at Universities" (WSSD-U-2012), many institutions of higher education all around the world are making projects of teaching, research and outreach to address the challenges of environmentally sustainable innovation, or eco-innovation for short. A new social contract for sciences and scientists is announced at the same time as an information society. This is an opportune time to examine the areas of campuses as privileged territories for socio-technical learning and collective intelligence. In the perspective of carbon fossil resources depletion and the likely major impact of climate change, the complexity and uncertainty of innovations raise a common set of questions relative to knowledge production and its circulation between research and training. The present action research analyses these issues from the main fields of territorial ecology underpinning the Smart Campus concepts. Gaining ground in urban agendas, 'Smart Grid' technology aims at optimizing distributed electricity generation, in particular from renewable resources, and promoting the use of smart devices such as smart buildings, photovoltaic systems of street lighting or rechargeable electric vehicles.

The purpose of this chapter is to throw light on the role of universities in these local processes of energy production and consumption, often termed "energy transition". To what extent is it becoming a significant topic of concern within campuses? Is "Smart Campus" a new lab for territorial sustainability? The first section provides an international overview about the practices and concrete capacities of campuses to implement this eco-innovation. Among recent advances, the project carried out by the University of Versailles Saint-Quentin-en-Yvelines is proving to be of particular interest. The second section goes further into this case study covering the latest in innovative technologies and services which enable the campuses to produce green energy and to optimize its uses for living and transportation. Through local lenses, it also gives the opportunity of sharing and discussing sociological knowledge, ideas and experience acquired in the execution of such a project as this. Finally, the author investigates not only the societal embedding of science and technology, but also how social science methodologies can be applied to meeting the needs of cooperation between industries, members of university administrations, public policies, research and teaching staff as well as students. The ongoing action research on Smart Campus project furthers the understanding of dynamics, by which knowledge and expertise are transformed, reshaped and put to use in people's everyday lives.

2 Addressing the Challenges of 'Smart City' at Universities

The "Green Campus Summit" (GCS-2013) is a historical initiative to participate actively in the discussion about campus-based transformations for the pursuit of sustainability. An acute circulation between research and training is required to accompany these changes. In the urban field, a focus on the integration of smart grids within the territories of universities can contribute to a skilful demonstration. Recently, many local governments have been presenting "smart city" projects which promote increasing use of information communication technologies in energy transition (Fig. 1).

In the knowledge societies, this is an interesting development for territorial sustainability whose anchor in campuses is studied here. This first approach to 'Smart Campus' experimentations consists of intersecting views of an international review and local experience in one of the leading academic communities.

2.1 An International Overview of Scientific Literature and Practical Applications for Smart Pilots

The distributed infrastructures called "smart grids" have gained some ground during the last decade. Among the 90 projects listed by the World Economic Forum and Accenture in 2012, most were developed in North America, Europe and Australia.

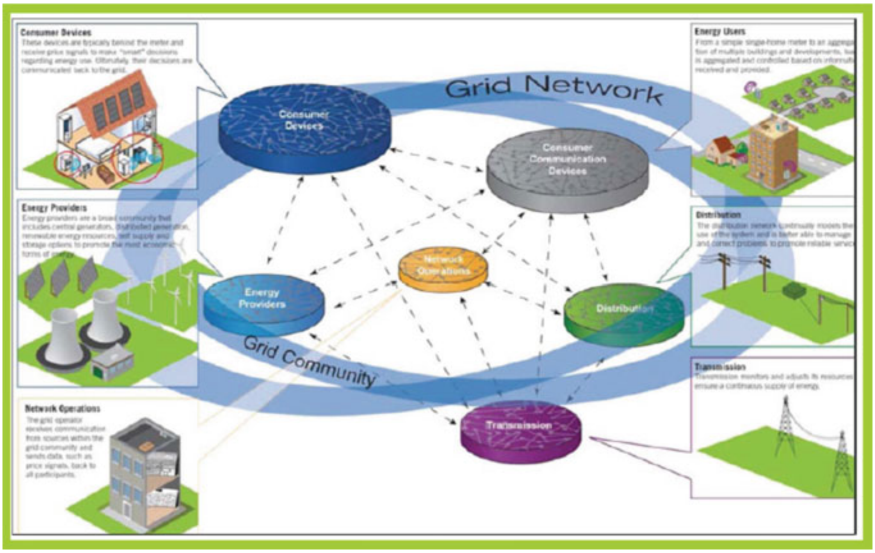

Fig. 1 Smart grid concept (*source* sequovia.com)

Studying the implementation of existing pilots, one can receive the impression that empirical work is spreading, especially in the cities of South America, South Africa, China, Japan and South Korea. Taking the scientific contents into consideration, a distinction can be made between the projects of researchers from engineering and physical disciplines focused on technical network development, and the more cross-disciplinary research projects designed to study users' behaviour. Today, the latter are more and more diverse. For instance, among the 20 ongoing projects of smart grids in France, these scientific approaches pay attention to various uses of new technologies. Indeed, their technical infrastructures and energy resources are not only different from each other according their location in eco-districts, private companies and public administrations, including islands that can manage such electric structures, but also their methods of use and management are becoming simultaneously more diversified. They imply heterogeneous ways of balancing local energy supply and demand.

If the notion of 'Smart Campus' starts to make sense in this international overview, practical applications are still rare. The UCR IntelliShare, "an intelligent shared electric vehicle testbed at the University of California, Riverside", is the exception proving the rules of past years (Barth and Todd 2003). More generally, cities with tremendous advantages, education and leading companies in technical industry, launched pioneering efforts to integrate sustainability thanks to this kind of entrepreneurial urban development strategy. This was notably the case for

Saint-Quentin, a new town created in 1968 in the southern Paris region, where the municipality undertook a public-private partnership with local high tech firms in order to implement a European project of electric car stations named “Praxitele” (Massot et al. 1999). Since the 1990s, the experimental technologies as well as their stakeholders have evolved. In what follows, the new modes of leadership and the linkages between urban scales will be under investigation at the University of Versailles Saint-Quentin. Contextualizing its campus-based integration of smart grids leads to being aware of specific advances. The ability of this academic community to acquire knowledge and technology is not entirely mirrored in the mainstream. If other French university institutions address the challenges of ‘Smart City’ projects, the latter are not implemented in their own territories.

This background paves the way for alternative studies. As a matter of fact, a review of the scientific literature demonstrates the prominence of energy economics in the field of smart grids, more particularly regarding the methods of use and management. They are focused on “the customer side of the meter” (Hamilton et al. 2012) whether it be in the residential sector (Bartusch et al. 2011; Gottwalt et al. 2011) or in a business context (Giordano and Fulli 2012). So they are not necessarily relevant in the specific case of Smart Campus. Even if the technical systems can be relatively similar insofar as they are also based on smart devices to improve territorial sustainability (Carvallo and Cooper 2011), their uses within campuses refer to different social behaviours. This observation is indicative of a more general state of art. The lessons learned from existing pilots of smart grids underline a lack of investigations about the current diversification of their energy services. Although acknowledging the need of insights in the populations concerned, the scientific literature still has difficulties coping with this recent evolution. Social implications are mentioned but not defined (McGranaghan et al. 2008). They are not taken into account by the theoretical framework of “Demand side management” to the extent that it consists of an in-depth approach to the economic behaviour of energy consumers under variable prices (Gottwalt et al. 2011). It is only very recently that the scope of behavioural researches has widened (Krishnamurti et al. 2012). Among these studies, the ongoing research intends to deepen a sociological analysis of smart grids which are becoming widespread at the University of Versailles Saint-Quentin-en-Yvelines.

2.2 A Sociological Inquiry into the Smart Campus of Versailles Saint-Quentin

Working from a base in the UniverSud Paris consortium of 21 university institutions, addressing the challenges of ‘Smart City’ involves creating the next generation of green technologies and social innovations needed to renew the campuses as vital contributors to territorial sustainability. To this end, the local project of “Smart Campus” brings together a group of professors (REEDS, Laborelec), students (UVSQ) and partners from associations (Fondaterra), small enterprises

(FBY, Solaredge) and industry (INEO GDF-SUEZ, Alstom Grid FR and BE, Embix, Renault). In the home cities of Versailles and Saint-Quentin-en-Yvelines, the higher education and research institution works in close coordination with the different expertises of its partners coming from three countries—France, Belgium and Israel. The international dimension of its experimental project also builds on the European initiative of EUREKA network whose label called "EUROGIA+" is delivered to innovative energy technologies which reduce the carbon footprint of energy production and use. Thus, multi-level interactions are fostered in the future-focused network of researchers and practitioners so as to operate in and between rapidly changing research, business and political environments. In this institutional context, the collaborative platform connects the campuses of Versailles Saint-Quentin to smart grid technologies which integrate a solar photovoltaic system into the green buildings for the lighting of university territories and for electric car sharing between their multi-polarized areas. The aim of new technical infrastructures tackles some of the greatest challenges: responding to energy needs, fighting against climate change and maximizing the use of resources.

Furthermore, to manage information more efficiently and effectively, smart devices are combined with societal learning. I contribute to the latter as a sociologist and an associate professor specializing in the field of environmental innovations at the University of Versailles Saint-Quentin. On this ground, the need for a sociological inquiry has emerged. The higher education and research institution expressed this concern after noticing the lack of investigations into the uses of first electric car stations experimented with by the local public authorities of Saint-Quentin. Community participation is considered as a key success factor for the Smart Campus of Versailles Saint-Quentin. This project of eco-innovation does not only rely on technical challenges, but social innovations are also part and parcel of the rescaling processes involved in this energy transition based on campuses. The emergence, implementation and stabilization of electric car sharing in connection with smart grid technologies depend on important changes in individual representations, norms and ordinary practices of private vehicles. The social acceptance of collective uses between the multi-polarized areas of campuses and their electric car stations is uncertain and more complex than a matter of economic behaviour under variable prices. This new local public transport service is offered free-of-charge to the members of university administrations and their staffs. Before thinking about a business model for future developments and urban commercialization, the request for sociological expertise focuses on alternative methods of use and management. To fill this gap, the next section is going to analyze the methodological and epistemological issues of cross-disciplinary knowledge in the specific contexts of campuses where eco-innovation has gained further prominence.

3 Knowledge Construction and Circulation Between Research and Training as an Integrating Lab for Campus Sustainability

3.1 Potentials and Constraints for Developing a Cluster of Interconnected Eco-Innovation Actors

After outlining the need for integrated approaches towards Smart Campus, this second section shares concrete experience from the case of Versailles Saint-Quentin. Its pilot project at the University immerses in the theory and practice of eco-innovation. First defined by researchers in Ecological Economics (Coulbaut-Lazzarini and Némoz 2013), eco-innovation consists of what Stengers called a "nomadic concept" (1987). While the idea is moving among other disciplines such as technical sciences, town planning or marketing, it is more or less understood as "an innovation that reduces environmental burdens and contributes to improving a situation according to given sustainable targets" (Faucheux and Nicolaï 2011, p. 2021). As the latter have many meanings, it is difficult to prejudge the nature of changes in practice. Regarding the inclusion of innovative energy technologies which reduce the carbon footprint of energy production and use within campuses, the first step refers to a new service for the local mobility of university staff based on a solar photovoltaic system. The potentials of this eco-innovation in sustainable transportation depend on a series of technical changes linked to a new fleet of ten electric vehicles as well as social innovations required for their collective use and local sharing.

Both dynamics of transformation are investigated in a concomitant way. Inspired by the practice theory (Shove 2003; Shove et al. 2007), the sociological framework drew attention to the reciprocal determinations between technology and behaviour. That's why the empirical material relies on a collaborative methodology that I coordinate between the various disciplines of sociology, economy and geography in the research centre on the one hand and engineering sciences and expertises of its industrial partners on the other. Indeed, the booking software for electric cars is thought of and designed so as to collect many data. If smart technologies can contribute to the studies conducted in the fields of technical sciences as well as social sciences, the information and communication systems also entail some limitations.

With regard to the protection of privacy, a set of personal data is not available as an automatic service. So the empirical material for the sociological analysis needs to be complemented by other tools. To investigate the matter of change in mobility practices, quantitative and qualitative methods are also combined to capture viewpoints and behaviour with electric car sharing. Thus the samples can include users and managers. The latter are key actors in coping with this evolution. They have to optimize distributed electricity generation according to the use of rechargeable electric vehicles.

From the technological promises of Smart Campus project to its development, other limits need to be overcome. By "limitations", the author also means technical difficulties and uncertainties. Currently, they are involved with the constraints for developing a cluster of interconnected eco-innovation actors and they postponed the experimentation of Smart Campus by one year until 2014. In this nonlinear process, the sociological inquiry seeks to provide insights into the barriers to socio-political and market acceptability. More than consent of community participation, the concept of social acceptance is analyzed from three scales of observation: macro-social (socio-political acceptability), meso-social (market acceptability) and micro-social (community acceptability). This multi-level approach leads to understanding of the current reservations of the higher education institution and its industrial partners about the implementation of Smart technologies, the efficiency of which is not guaranteed. There are many concerns for excellence and risks for the dissemination of good practices. Notwithstanding, these early findings about the complex interactions between social and technical systems give the opportunity of advancing in cross-disciplinary learning.

3.2 An Innovative and Cross-Disciplinary Learning for Sustainable Development in Higher Education

Since the first occurrence of the term (Fussler and James 1996), eco-innovations have referred to creative processes of sustainable development and they have exhorted a transdisciplinary knowledge production. The rhetoric of sustainable development has also produced a discourse on education, especially since the initiative of UNESCO called the "United Nations Decade of Education for Sustainable Development—DESD". At the postgraduate level, the professional Masters in "Management of Eco-Innovation" and in "Energy and Urban Mobility" developed by the University of Versailles Saint-Quentin constitute an attempt to creating an innovative learning organization, composed of researchers, students, industry and government workers, and small and medium enterprise aided by responsive finance personnel. As a sociologist and an associate professor, my contributions to the Masters' programmes tackle the issue of social acceptance beyond removing the behavioural obstacles in new technological uses.

From inspiration to solution, Smart Campus project not only represents a field of inquiry but also a rich learning environment for students. As would-be managers of environmental innovations, their cross-disciplinary training in academic terms is integrated and applied to this real-life eco-city innovation problem. It raises the level of awareness of the usefulness of sociology regarding the diversity of the socio-technical processes at stake. The understanding of the social background—empirical as well as theoretical—has real importance in the emergence, the reception and the diffusion of eco-innovations within societies. Between problem-creating technologies and problem-solving technologies, the local case study of Smart Campus allows students' attention to be captured on the societal embedding of science and experimentation. The multi-level approach to social acceptance of eco-innovations is taught to help these future decision-makers to understand the interdependence of human societies to deal with the issue of survival of the globe. These lectures offer multi-scalar modelling regarding the social adoption of new ecological technologies and services.

Through methods, concepts and authors, three scales of observation are distinguished in order to understand the diversity of processes at stake and the possible gaps between the different levels of development. The macro-social scale of acceptance examines the development of big imaginations and values in circulation in the long term and through cultures. By questioning the hegemonic and imperative nature of sustainable development, students can stand back from the normative conception of acceptance in terms of standards and good practices. At the meso-social level of eco-innovations, the actors' interactions between political forces, organizations and firms are under observation around the control and regulation of markets. Lastly, the close-up view of micro-social study discloses personal decision-making and the effects of competence from the objects, spaces and time in which individuals are involved and give meaning. Moreover, students benefit from special training on data collection methodologies. Under my supervision, the students are carrying out a quantitative study upon the future users of Smart Campus. A questionnaire has been conceived on their images, perceptions of car sharing, electric vehicles and mobility behaviour in the current situation and the local context of Versailles Saint-Quentin. The results are analyzed and used for the exploratory phase of action research. Throughout the different sessions, it aims at acquainting students with the major social challenges which pave the way for environmental innovations.

4 Conclusion

Finally, this chapter explores new fields of research on the issue of education for sustainable development. Regarding the problems and promises of eco-innovation such as Smart Campus project at the University of Versailles Saint-Quentin, the recent advances for action research on territorial sustainability comprise cross-disciplinary and collective learning acquired in the ongoing execution. In this top-down institutional and industrial-led project, the interest is to embody the urban interface in citizens' practices. The analysis conducted in the exploratory phase laid the foundation for much-needed future evaluation studies on the uses of Smart Campus. The quantitative survey of around 200 local people suggests the relevance of this new service for the mobility of university staff. There is a need for motorized vehicles between the different areas of campus whereas students are characterized more by having to frequent one of these areas. If bus and suburban rail are proving to be used by the majority of the university public, electric car sharing is likely to fill the gap in sustainable transportation for local workers.

As the author has noted above, these findings are the product of several dynamics in knowledge production between research and training. They report the social issues of eco-innovation and appraise options according to the users' needs. Thus the first results refer to future professionals comprehensively educated regarding the social acceptance of energy transition and exposed to the multi-faceted issues faced by eco-innovators. Beyond students' opportunities to enrich their knowledge and experience in the field, the integration of their expertise into governance structure puts out institutional challenges for universities' administrations. Their ability to put the findings of educational research to use in campus life requires a strengthening of participatory planning. It leads to questioning the idea of "open innovation" outside its original definition as a business strategy (Chesbrough and Appleyard 2007). The conclusions drawn from this real case not only underline possible strategies to push sustainability actively with available resources at universities but also the need for further research on cluster-building approaches to what is called the "green campus revolution".

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Food Production as an Integrating Context for Campus Sustainability

Thomas Eatmon, Eric Pallant and Samantha Laurence

Abstract

Allegheny College has gradually integrated principles of sustainability into campus operations and decision-making since becoming a charter signatory of the American College and University President's Climate Commitment in 2007. Recent building renovations, purchasing policies, energy consumption, and water management strategies have all been influenced by Allegheny's environmental guiding principles. A growing interest in food production has led to programming and initiatives which involve a variety of campus and community stakeholders. Administrators, dining service personnel, faculty, students, and local community members are all working together to produce food locally and sustainably. These efforts have contributed to environmental education, sustainability research, food service operations, and food-based community outreach programs. Practical models for achieving sustainability can provide a useful tool for overcoming barriers created by separate campus activities and stakeholders. Here the authors consider food production as an integrating context for sustainability at Allegheny College as well as the beneficial outcomes the whole-systems approach has produced for the campus and local community.

Keywords

Education for sustainability · Campus food production · Integrative learning · Aquaponics

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1 Introduction

Institutions of higher education are important vehicles for developing the values, knowledge, and skills needed to create and sustain a viable future (Herrmann 2007; Cortese 2003; Lozano 2006). The importance of integrating sustainability into higher education has been acknowledged by international declarations and commitments to sustainability such as Agenda 21 and the Taillores Declaration (United Nations 1992; University Leaders for a Sustainable Future 1999). In the United States, national goals for sustainability in higher education such as the American College and University President's Climate Commitment (ACUPCC) have called for environmental leadership through the integration of sustainability into institutional infrastructure, operations, curriculum, research, and funding.

American colleges and universities have chosen a variety of methods and frameworks in fulfilling these commitments toward sustainability. While a number of indicators point towards progress in recent years, much of the progress has resulted in improvements to campus infrastructure and operations, and less evidence has pointed towards curricular transformation (EfS Blueprint Network 2011). Achieving effective curricular transformation spanning the environmental, economic, and social dimensions of sustainability can be difficult when teaching, research, campus operations, and community relations are thought of as separate activities. Scholars have suggested that all parts of a system must be considered in order to create this type of transformation (Boulding 1985; Cortese 2003; Meadows 2008). A whole-systems approach which acknowledges the distinct but interconnected parts of higher education institutions is necessary for overcoming the conventional tendency towards isolation (Koester et al. 2006; McMillin and Dyball 2009).

At Allegheny College in Meadville, Pennsylvania, a growing interest in sustainable food production and consumption has led to programming and initiatives involving a variety of campus and community stakeholders. For example, since 2008 the campus has hired a dining service provider which strives to purchase food locally, establishes student discounts for the use of reusable containers, donates unused food to community organizations, and utilizes a campus composter to process food waste and biodegradable serveware. However, similar to many campus sustainability initiatives, the *integration* of supporting campus operations, coursework, research, and co-curricular activities varies.

Recently, a number of campus-based food production initiatives have demonstrated significant progress in integrating separate yet interrelated components of the campus community. In this chapter the authors focus on one initiative that utilizes combined aquaculture and agriculture for year round food production. Three characteristics of the program support a whole-systems approach to campus sustainability including (1) integration of programming into campus operations, (2) student research which improves food production, and (3) integration of service-learning projects into environmental science coursework. As a result, the initiative has created an integrating context for sustainability which has increased the number of partnerships and interactions across the campus and community while creating an "insulated space" for students to explore new ideas (Barlett 2011).

2 Campus Food Production as a Whole-Systems Approach to Achieving Sustainability

As issues of sustainability become increasingly complex, it is critical for students to learn how to integrate various values, perspectives, and knowledge bases into critical thinking and problem solving (Lourdel et al. 2005; Alshuwaikhat and Abubakar 2008; Yarime et al. 2012). An integrating context for sustainability encourages the use of interdisciplinary and transdisciplinary efforts around a single theme. It does this by capitalizing on distinct and often opposing perspectives, amalgamating skills and knowledge from multiple sources and experiences, demanding that issues and positions are framed contextually, and applying theory to practice in multiple environments (Alshuwaikhat and Abubakar 2008; Lieberman and Hoody 1998; Cortese 2003; Schneider 2003; Sterling 2004; Huber and Hutchings 2004). Integrating contexts also help to increase the efficiency of campus operations through concentrated and collaborative efforts that create a mutually beneficial relationship between institutions and their surrounding communities (Alshuwaikhat and Abubakar 2008; Cortese 2003). As a result, students are given the opportunity to experiment with a variety of "real-world" solutions, thus utilizing campuses and surrounding communities as problem-solving laboratories (Barlett 2011; Huber and Hutchings 2004; Herrmann 2007; Lieberman and Hoody 1998; Orr 1992; McMillin and Dyball 2009).

Campus-based food initiatives have proliferated in recent years and have become a new focal point of sustainability efforts within higher education (Barlett 2011). These initiatives have largely developed in reaction to the negative social and environmental impacts of conventional agricultural food systems (Hamm 2008; Kloppenburg et al. 1996). Most initiatives are characterized by interrelated components which include environmental education, sustainability research, food service operations, marketing opportunities (i.e., farmers' markets and community supported agriculture), and community outreach programs which have the potential to impact the surrounding food system (Barlett 2011; Hassanein 2008; Lyson 2004). These efforts advance community objectives of public health, social justice, economic development, and environmental protection while enhancing analytical skills, creativity, social networks, and commitment to service within the community (Pothukuchi 2012).

3 The Development of Campus Food Initiatives at Allegheny College

Allegheny College has a long history of improving its sustainability practices (Pallant et al. 2012). The success of its programs stems from the confluence of simultaneous top-down and bottom-up approaches to producing environmental change on campus. Allegheny's first foray into increasing the sustainability of its food system occurred when a junior seminar class in environmental science created a plan for the acquisition of an in-vessel composter. When the composter arrived on campus, its presence generated a need for educational programming in student dining halls, new receptacles for compostable materials, training for cook staff, and purchase of biodegradable serveware.

The in-vessel composter exceeded expectations and generated enough compost to satisfy the needs for annual ornamental plantings around campus, saving a considerable sum of money previously spent on purchasing topsoil. Groundskeepers began applying compost tea produced from captured leachate to lawns as part of the campus' organic landscaping services. Efforts surrounding the composter have been well publicized (Sullivan 2010) and the campus's physical plant receives regular calls from a variety of institutions interested in emulating the example. Although these initial efforts focused more on waste than food, they provide an early benchmark in the incorporation of systems thinking into campus sustainability practices.

In 2008, the college switched from a national contractor of dining services to a regional company which acquires more than one-third of the college's food supply from less than 100 miles from campus. This non-incremental change quickly encouraged new thinking about food systems on campus. At campus level, products from well-known local vendors were introduced to the campus menu. The college's sustainability coordinator identified possibilities for closing the campus food loop by using campus compost to grow herbs in small plots for the campus dining service. Student groups became active in affecting change by expanding the presence of gardens on Allegheny's campus and incorporating them into educational programming, initiating a food rescue program to bring unused food to community organizations serving those in need, and promoting the use of reusable take-out food containers.

At the community level, a professor of environmental science helped to revive a moribund farmer's market by organizing local growers. The success of the project intersected with the college by means of an annual local foods dinner comprised almost entirely of foods sourced by area farmers. The dinner, prepared and organized with the aid of students and staff, has been so successful that in most years more than 50 % of the student body chose to participate. In addition, students working on senior research projects and as long-term volunteers in low-income housing facilities have planted gardens and worked with both children and adults to teach them how to grow and prepare food (Abbott 2012; Lauer 2012). More recent steps in promoting new thinking about food and food systems at Allegheny include the creation of an eating co-op for students interested in preparing healthy, natural, locally sourced food for themselves (Neff et al. 2013).

In summary, the history of sustainable food systems at Allegheny has been piecemeal and largely grassroots. There has not been a concerted and sustained effort to establish clear goals for new food initiatives, nor to integrate separate activities to achieve shared goals. These historical developments are significant because they reflect the often disconnected nature of campus sustainability efforts, and many campus efforts follow this pattern. However, the recent renovation of a campus building, creating the Richard J. Cook Center for Environmental Science, has propelled the development of new initiatives. The building, which has achieved LEED gold certification by the US Green Building Council, includes a commercial indoor aquaponic system and an outdoor garden, both created to produce food for Allegheny's dining service. These features have been integrated into new courses that teach students about food production with focuses on food justice, environmental education, introductory agronomy, and systems approaches to sustainability (Pallant and Choate 2013; Eatmon et al. 2012). What follows is one example of how the most recent campus food developments are building on past experiences in order to use food systems to facilitate a whole-systems approach to sustainability.

4 Food for Sustainability: A Practical Model for Integrated Campus-Based Food Production

The goal of the Food for Sustainability project at Allegheny College is to demonstrate the interconnectedness of living organisms by integrating principles of sustainability into the process of food production. The project seeks to cultivate meaningful relationships and promote lifelong learning by engaging students and community members in cooperative projects which empower them to develop new ideas. The project utilizes aquaponic systems for indoor, year round tilapia and lettuce production. The products are sold to Parkhurst dining services and are incorporated into the campus dining menu throughout the year. The integration of food production into campus operations, faculty-student research, and service-learning experience has supported a whole-systems approach to achieving campus sustainability. The benefits of this approach include increasing interactions and partnerships across the campus and local community which create a "real life" problem-solving laboratory.

The term "aquaponics" is commonly used to refer to an integrated system of aquaculture (fish farming) and hydroponics (soilless plant growth). These food production systems utilize fish waste from aquaculture as nutrients for hydroponic crops, conserving water resources while potentially lowering the operating costs of each isolated process (Diver 2006). For cities in cold weather regions, this technology, when established indoors, could provide advantages over other methods of food production which are more vulnerable to climate conditions. Communities in the Great Lakes region of the US are increasingly taking advantage of these systems for intensive, year round local food production (Eatmon et al. 2013).

Although the technology is becoming increasingly popular as an urban agriculture innovation, the financial benefits of commercial aquaponics vary according to the technological, business, and environmental context in which food production takes place (Eatmon et al. 2013). For example, in an economic study of a media-filled aquaponic system growing tilapia and tomatoes, McMurtry et al. (1997) found that the system could produce a gross return on tomatoes of \$50–100/m^2 as compared to \$77–157/m^2 for conventional greenhouse tomatoes. Bailey (1997) tested an early system design from the University of the Virgin Islands (UVI) and found that a farm with 24 production units was needed to be profitable. Some of the revenue from lettuce in this system was necessary to make up for operational losses from fish production. More recently, however, Rakocy and Bailey (2003) found that a large scale commercial system that raised 5 metric tons of tilapia, 46,800 heads of lettuce, and 5 metric tons of basil annually demonstrated profitability, earning a return to risk and management of $185,248 per system. The UVI system, however, benefited from a niche market in the Virgin Islands, where most tilapia, lettuce, and basil is imported (Rakocy and Bailey 2003). Commercial operations in the United States, particularly in cold-weather regions, do not share the same advantages. Goodman's (2011) cash flow analysis, using data collected from Milwaukee's growing power and sweet water organics, found that the sale of tilapia, perch, and lettuce did not produce sufficient revenue to outweigh the development, operating, and taxable income costs of operating a for-profit aquaponic system in a temperate climate. As a result, the author recommended that potential adopters of the technology in temperate climates consider increasing income and reducing expenses through alternative business models and diversified revenue streams (Goodman 2011).

5 Integrating Aquaponic Food Production into Campus Operations

Can an indoor food production system that utilizes conservation methods while promoting healthy eating practices and community interactions be profitable and sustainable? Allegheny College students and faculty first grappled with this idea in 1996 through the creation of a business plan for an aquaponic facility which would be located in the local community (Pallant et al. 1996). The business plan identified opportunities for locating the facility on a brownfield site that would utilize waste heat produced from adjacent manufacturing facilities. The proposal also identified marketing, production, and financial plans, including the identification of the products to be sold on the market, distribution channels, potential customers, operating costs, and forecasted revenue from sales. Ultimately, barriers to raising financial capital for start-up prevented the realization of the project's goals.

However, the idea was reinvigorated in 2010 when students enrolled in a junior seminar in sustainable development decided to reexamine the feasibility of the idea based on changes in the technology, market prices, and a growing local food movement on the college campus and throughout the region. In addition to updating the marketing, financial, and production plans, students also enlisted the help of a local ornamental and game fish vendor with 10 years experience in aquaculture and a newly developed interest in aquaponics. The partnership not only provided the space and equipment needed for students to test out new ideas for improving the production process, but also a local resource for ongoing conversations concerning best practices and strategies for commercial aquaponics. Through coursework and subsequent summer internship and research opportunities at the fish farm, students experimented with alternative system designs, water quality conditions, and lighting strategies.

A newly developed business plan won local, regional, and international awards the following year. However, the plan still faced the challenge of raising start-up funding. Students also discovered that the abandoned industrial building targeted to be the production site was in need of thousands of dollars of health and safety upgrades and repairs. With this challenge in mind, the 2011 cohort of junior seminar students created a plan for implementing the business plan by integrating the production process into campus operations. During this time, the new campus dining service had begun to purchase small quantities of herbs and vegetables from garden plots located around campus. In addition, plans for the renovation of the environmental science center were underway. These developments created a window of opportunity for the student-designed proposal for commercial aquaponics to be included in the blueprint of the new building. In creating the new proposal, students worked with dining service administrators to select the best crops for production and to determine a fair purchase price. Seminar students also worked with the campus physical plant and building architects to determine the optimal size and location for the system, communicating their results through a three-dimensional architectural sketch.

Today the production system is operating at full capacity and produces 25–50 heads of Romaine lettuce each week, and 100 pounds of tilapia per year. Production is managed by a team of work-study students who maintain the system throughout the year. In addition to purchasing lettuce and fish, the campus dining service provides equipment and support for harvesting and transporting crops to a campus dining hall and has increasingly become involved in integrating the project into its marketing activities to raise awareness. These activities have brought the spirit of the business plan which began in 1996 back to life on campus, and have provided a vehicle for connecting the traditionally isolated areas of research and teaching with campus operations.

6 Improving Aquaponic Food Production Through Student Research

Optimizing the production and marketing of fish and lettuce in the commercial aquaponic system in order to meet economic and environmental objectives requires ongoing research. In order to fulfil this need, students have pursued relevant research questions as components of coursework, summer internships, and senior projects. As a result of these studies, not only is new information produced to aid in our understanding of aquaponic systems, but students are also able to see the immediate impacts of their work as their research is used continuously to improve the quality of the production process over time.

For example, one study performed by a junior seminar class in 2010 investigated the effects of photoperiods on plant growth and electricity consumption. Northwestern Pennsylvania, where Allegheny College is located, experiences long and cloudy winters where the lack of sunlight and cold temperatures significantly reduce the benefits of using a greenhouse for year-round food production. However, replacing natural sunlight with artificial grow lights significantly increases operating costs, decreasing the profitability of a business venture. An experiment was conducted in order to determine whether savings could be achieved by reducing the photoperiod for Romaine lettuce in an indoor, artificial lighting environment. The results of the experiment showed that, over the course of a year, the costs of reducing the photoperiod to 12-h cycles (approximately $90 per year) were significantly higher than the savings in electricity consumption. The students used this information to establish a photoperiod of 16 h/day for the pilot commercial system.

Similar research questions which examine opportunities for eliminating system inefficiencies have been the focus of senior projects in recent years. One study concerned with the environmental impacts of fish feed production found that barley sprouts could be used to supplement up to 15 % of daily feed intake without affecting growth rates of tilapia (Gaudi 2011). Another senior project questioned whether food waste from the campus dining hall could be used to lower the pH of water in an aquaponics system. While the study found that orange peel was effective in achieving this end, the volume of peel necessary to do so was impractical (Cavagnaro 2012).

A life cycle analysis was recently performed in order to quantify the environmental impacts of the pilot aquaponics system (Eatmon et al. 2013b).[1] Students enrolled in a junior seminar collected data on energy and material inputs for the production of fish feed, system infrastructure, electricity, and water consumption. Using Gabi 5.0 life cycle analysis software to analyze their data, the students found that fish feed had the greatest impact in each of the environmental impact categories analyzed. When comparing Allegheny's indoor aquaponic system to a greenhouse system, the indoor operation produced less global warming potential, energy use, and acidification potential. However, Allegheny's system used more water and had a higher eutrophication potential than the greenhouse operation. As a result of the study, several recommendations were implemented in order to decrease the environmental impact of the commercial operation.

Student research interests have also explored the potential for selling whole fish on campus, a practice common around the world but less popular in the United States (Eatmon et al. 2013a).[2] By avoiding whole fish, American consumers also avoid the benefits of fraud prevention, reduction of environmental resource consumption and pollution, local food support, and decreased dependence on imported fish. In order to determine whether students at Allegheny College would be willing to eat whole fish in campus dining halls, a junior seminar class randomly sampled 182 individuals at 3 campus dining halls at Allegheny College. The students found that 74 % of the individuals surveyed were willing to try whole fish. Fifteen

[1] Eatmon TD, Burkhart J, Fuhrer S, Gongaware A, Hesch E, Juodisius E, Koeberle K, McBride K, Mukherjee D, Nelson P, Rick B, Smith J, Tolliver W (2013b) A life cycle analysis of soilless food production at Allegheny College. Unpublished manuscript. Allegheny College.

[2] Eatmon TD, Baxter M, Bedford S, Biskup E, DiFrancesco P, Garrett K, Perez J, Rynes J, Stickel J, Thomasson M, Thompson K, Wagner K (2013a) Heads and tails: a sensory evaluation of whole fish at Allegheny College. Unpublished manuscript. Allegheny College.

participants selected for a 3-week panel study indicated that the taste, appearance, texture, and experience were generally acceptable. The study found that, contrary to the social stigma surrounding whole fish consumption, Allegheny College students are supportive of this dining menu option. After presenting these results to the campus dining service, plans are being made to prepare whole fish on campus.

7 Extending Coursework into the Local Community Through Service-Learning

An environmental education course at Allegheny College has been designed to provide students with practical experience in promoting sustainable values, attitudes, and behavior. Understanding emergent properties of ecological systems such as interdependence, cycles, flows, hierarchy, and dynamic behavior is critical for increasing the public's understanding of sustainable systems. In order to accomplish this goal, the class has utilized aquaponic systems as ecosystem models to demonstrate the two essential ecosystem services of supplying renewable resources and absorbing pollution and waste.

Since the course was designed in 2008, local awareness of sustainable food production has grown significantly. In addition to a demonstration aquaponic system at the local market house, miniature desktop systems have been established in seven local sixth grade classrooms. The market house system serves as a public demonstration project, while classroom replicas of the demonstration system serve as a tool for formal environmental education facilitated by Allegheny College students.

Allegheny College students enrolled in the environmental education course currently work with the seven classrooms to address state mandated academic standards in Science, Technology, Engineering, and Mathematics as well as Ecology and Environment. Throughout the year, sixth grade students are taught scientific skills of observation by tracking water quality data as well as data on plant growth, and each classroom compares its data with the other participating classrooms. In order to create a connection to the local community, all food grown in the sixth grade classrooms is donated to a local soup kitchen. This design allows Allegheny College students to transcend the boundaries of the classroom through work in the local community, while the sixth grade students they teach share a similar experience through their connection to the local soup kitchen. In this way, the service learning project extends the reach of sustainable food production far into the local community.

8 Conclusion

Campus food production can provide an integrative context for sustainability through the application of a whole-systems approach. Here we have considered how the food for sustainability project at Allegheny College has served to bring together campus operations, research, coursework, and community engagement activities.

This approach creates transformative learning experiences for undergraduate students by bringing together various actors across the campus and local community which can offer a variety of talents, skills, and resources for achieving the goals of campus sustainability.

Even greater benefits, though, are the advantages gained from the "insulated space" that the project creates for new ideas (Barlett 2011). Today, the project serves as a platform for students to advance creative ideas which traverse traditional disciplinary and structural divisions. By utilizing food production as an integrating context, we prepare students to face a changing world where there are more questions than answers and where success will depend on the ability to bring members of their communities together in working towards a common goal.

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Constructed Wetlands for the Treatment of Grey Water in Campus Premises

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Abstract

With increasing population and urbanization, water and wastewater management has become a top priority for the planners and architects in many parts of the world. Recent studies have confirmed that the poor infrastructure to manage and treat wastewater properly has led to the deterioration of water bodies which in turn leads to freshwater scarcity. Several studies have found that treating greywater is a better alternative than treating blackwater because the former leads to a lesser pollutant load, especially involving pathogenic pollutants, and is increasingly emerging as an integral part of water demand management, providing water for non-potable residential and industrial uses. Among the total wastewater generated in developing countries, 50–80 % is comprised of greywater originating from bathroom, laundry and kitchen sources. With many

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advanced technological methods available for water treatment, the constructed wetland system appears to be a preferred option because of reduced capital cost, lower energy demand and maintenance required compared to the conventional systems. In this context, this experimental study on a full-scale constructed wetland system was developed jointly by the researchers from Pondicherry University and Association for Promoting Sustainability in Campuses and Communities at Jawahar Navodaya Vidyalaya (JNV) campus. It was found that greywater treatment and reuse using constructed wetlands offers a cost effective, nature-based, energy efficient alternative to other means of conventional wastewater treatment. It is estimated that the developed system will save 25–30 % of the water requirement for horticultural activities of the school.

Keywords
Green campus · Constructed wetland · Wastewater treatment · Greywater

1 Introduction

The vast majority of people in developing countries still do not have access to a safe drinking water supply. In recent years, rapidly expanding population, industrial development and urbanization have exerted immense environmental pressures on freshwater sources. Discharging wastewater into receiving water bodies has a number of problems, including impact on human health and aquatic ecology. Therefore, the pollutants must be removed/remediated in order to preserve the water environment, protect the aquatic life and health of water users downstream. Therefore efficient wastewater treatment and reuse is critical for sustainable development (Edwin and Poyyamoli 2012; Poyyamoli et al. 2013).

In general, greywater means wastewater generated from domestic activities such as baths, hand basins, washing machines, dish washing, laundry and kitchen. It does not include wastewater from toilets. It is considered to be the largest potential source of water for reuse, accounting for around 50–80 % of total water use. Recent scientific advancement in cost-effective greywater (GW) treatment for non-potable reuse (including gardening, irrigation and toilet flushing) suggests that there is a greater potential for GW reclamation and reuse (Jamrah et al. 2006). Table 1 shows the composition of the greywater from various sources. Among total GW generated, the GW from laundry and all washing requirements account for about 25–35 % of total GW (Edwin and Poyyamoli 2012; Edwin et al. 2012; Poyyamoli et al. 2013).

2 Why This Study?

The aims and objectives of this study are as follows:

- To design a subsurface flow constructed wetland system for JNV Puducherry campus which can be easily maintained by the students and staff and can provide

Table 1 Composition of the greywater generated from various sources (Poyyamoli et al. 2013)

Description	Percentage generated (%)	Composition
Bathroom	50–60	Soap, shampoo, hair dye, toothpaste and cleaning products
Washing/laundry	25–35	Detergents and associated chemical agents
Kitchen	10	Detergents, cleaning agents, food particles, oils, fats and other wastes

environmental education to the students and improve the surrounding environment by providing economic benefits of water reuse
- To assess the capability of the subsurface flow constructed wetland system in reducing the pollutant load to the acceptable concentration for reuse for gardening and landscaping purpose

This study addresses the pressing issue of water security and wastewater management through cost effective and energy efficient means for its practicability in the scenario of a developing country. The rationale for the study is (Poyyamoli et al. 2013):

- Wastewater is a significant and growing problem in many urban areas of both the developed and developing world
- The available freshwater sources are dwindling and getting scarcer
- Increased freshwater pollution from human activities
- Uncontrolled discharge of wastewater into streams and oceans, which causes a range of external costs, including cost to human health and ecosystems
- Current wastewater treatment systems are at a rudimentary stage in developing countries and are grossly inefficient or ineffective, at a time of rapid growth
- Constructed wetland being one of the series of engineered and managed natural systems is receiving worldwide attention for wastewater treatment and recycling

3 Constructed Wetlands

Although conventional wastewater treatment technologies have been used by municipalities and industries for over three decades, they are rather expensive for use in small communities or institutions of developing countries. A constructed wetland system (CWS) pre-treats wastewater by filtration, settling and bacterial decomposition. It basically emulates natural wetlands, which constitute swamps, bogs and marshes found in many parts of the world. Recent studies evaluate wetlands function as a nature's kidney which performs many ecological functions including hydrological, biological and biogeochemical functions (Kadlec et al. 2000; Hernández Leal 2010).

The use of the CWS in urban areas on both small and large scales is now being recognized across the world because of their good treatment performances and low construction and operating costs (Kadlec et al. 2000; Poyyamoli et al. 2013). It has been accepted as a low cost eco-technology alternative to conventional treatment methods (especially beneficial to small communities who cannot afford expensive treatment systems). Some of the most prominent benefits of small-scale CWS include water reuse, energy and cost saving.

4 Types of Constructed Wetlands

There are different types of constructed wetlands which are classified based on many different factors. Wissing (1995) classified the systems as Aquaculture Systems, Hydrobotanical Systems and Soil Systems. Aquaculture systems are without any active soil filters but with submerged/free floating plant species. Hydrobotanical Systems are similar to Aquaculture Systems but with a few soil filters and intensive growth of helophytes. Soil Systems are mainly classified based on the flow pattern of water, as free water system (FWS) or surface flow system and sub-surface flow (SSF) systems, where water is primarily treated in the root zone of the porous media substrates. The water flow is horizontal in the FWS and either horizontal or vertical in the SSF system.

In horizontal flow systems the water flows from one end to the other end horizontally, whereas in vertical flow systems the water is intermittently fed from the surface and flows through the bottom where it is collected. Wastewater here gradually percolates down through the substrate and is collected by drainage pipes at the bottom. The system drains completely and allows the air to refill the bed. This method of working leads to a good oxygen transfer and therefore has an excellent nitrifying capacity (Cooper et al. 1996).

The wastewater is applied two or four times a day on the surface of the reed bed by gravity. The wastewater slowly percolates down through the filter material. This allows filtration and contact with the dense microbial populations growing on the surface of the substrate, roots and rhizomes of Typha and Arundo species. Water is collected at the bottom of the wetland by a network of drain pipes. Treatment is a series of cycles with pumping and draining phases and is therefore mainly aerobic.

Based on the species of macrophytes, the CWS is classified as free floating, submergent and emergent types. The wetland cells can be single stage or multi stage serving primary/secondary/tertiary treatment of different types of wastewater. The wetlands are also classified based on the type of substrate used. Apart from these prominent types, there are also hybrid systems and floating island type (Ayaz et al. 2012; Zhao et al. 2012; Vymazal 2013).

5 The Role of Macrophytes

Macrophytes play a vital role in the removal of pollutants and the maintenance of the overall system. Apart from providing an ecologically aesthetic value to the environment, plants provide the beneficial microbes in the system with carbohydrates and surface area for their growth. Plants also aid in the removal of pollutants by adsorption of the nutrients into the plant tissues. Overall, they form an integral part of nutrient cycling which varies by season, locality and other environmental and ecological factors. Although many species are found to survive in the wastewater with high amounts of nutrient concentrations, only a few are found to be more effective for nutrient removal through assimilation into their tissues. Plants that have high growth rate and the ability to assimilate nutrients are desirable for man-made wetlands.

6 Pollutant Removal Mechanisms

Removal mechanisms in a constructed wetland can be physical/chemical (abiotic) in nature or microbial or plant uptake (biotic). The removal process is cyclic in nature, involving plant roots, stem, leaves, sediments, substrate, water and microbes. The mechanisms used for removal of a contaminant depend on the specific contaminant and the site conditions:

Organic matter: organic matter is broken down by micro-organisms present in the wetland, by fermentation and mineralized as a source of energy or assimilated into biomass.

Suspended solids: gravitation plays an important role in the removal of suspended solids.

Nitrogen: nitrogen is an essential nutrient which can be removed through plant uptake. The ammonium and/or nitrate taken up by plants are stored in organic form in the wetland vegetation.

Phosphorus: similar to nitrogen, phosphorus is an essential nutrient for growth of plants and organisms. Wetland plants will store phosphorus during the growing season and release it later. However it is reported that less than 5 % of P is removed from a typical municipal wastewater treatment system (Kim and Geary 2001).

Metals: metals can be removed by accumulation into the plants, settling, precipitation and other means such as oxidation, co-precipitation, microbial sulfate reduction and ion-exchanging capacity of the mineral.

Xenobiotics: according to Stottmeister et al. (2003), the metabolism of xenobiotics in plants takes place in three phases—transformation, conjugation and compartmentation.

Pathogens: constructed wetlands show different processes to decrease substantially the number of microorganisms of anthropogenic origin. Microorganisms are trapped in the system by filtration, sedimentation and adsorption. In general, more than 90 % of the coliforms and more than 80 % of the fecal streptococci could be eliminated (Kadlec and Knight 1996).

7 Case Study

An experimental full-scale Horizontal Sub-Surface Flow constructed wetland system was set up in the campus of Jawahar Navodaya Vidyalaya (JNV), to treat the greywater originating from laundry sources. JNV is a residential central higher secondary school with over 500 students (age group 11–18 years) staying on campus. This project serves as a living laboratory for them to design a simple biological water treatment system with technical inputs from the researchers of Pondicherry University. The system is maintained by the trained teachers and volunteering students on campus.

8 Experimental Design of the Constructed Wetland

Figure 1 shows the schematic layout of the constructed wetland designed for the JNV campus. Presently 1,000 L of laundry water is being generated every day by campus activities. The constructed wetland system is designed to treat 600 L of laundry water per day while the remaining 400 L are sent directly to the sewer. In future, all greywater originating from laundry, bathroom and washbasin will be treated using similar technology by adding more blocks to the constructed wetland.

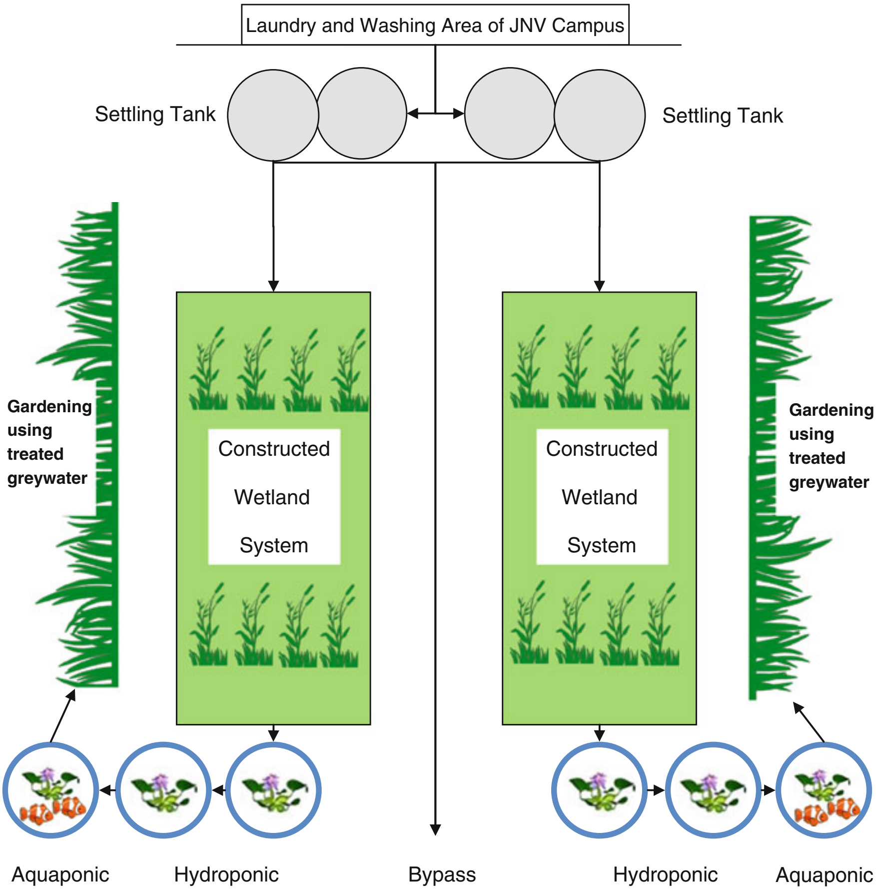

Fig. 1 Experimental setup of the constructed wetland system implemented at JNV

Among all the species of wetland plants available, the prominent species found to be growing in the surrounding localities are Arundo sp., Scirpus sp., Typha sp., and Eichhornia sp. Among this, Arundo donax (giant reed) and Typha latifolia as a native species are chosen for the experimental design since they are found to be better suited to water purification as reported by earlier workers (Idris et al. 2012).

9 Methodology

The input water and output water were sampled on a weekly basis and sent for laboratory testing. The physical, chemical, microbiological, nutrients, ground elements and heavy metals properties of the samples are analysed. The collected samples were analyzed for pH and EC using the respective meters, whereas the other parameters were estimated through standard laboratory methods (APHA 2005). This phase is in progress as this is a long-term study under the guidance of environmental researchers and the results will have a broader scope for outreach among other schools, other educational institutions and local communities.

10 Observations

Laundry water reclamation and reuse is found to be an easy alternate source of non-potable water which directly reduces the sewage flow rates and indirectly reduces the cost of treating sewage at a centralized facility. Besides the water saving advantages these systems offer, they also close the water and nutrient cycles on campus itself. Results show that the ability of the system to remove BOD, COD, TSS and coliforms from influent greywater is much higher (67–80 %) than for nutrients (25–40 %). The study also concludes that, based on the observation of a working model of constructed wetland system, around 25–30 % of the horticultural water requirement at the JVN-Puducherry campus can be reduced by utilizing a small-scale Constructed Wetland System to treat and reuse greywater.

11 Prospects and Hazards of GW Reuse on Campus

One of the biggest prospects of reusing treated GW is the reduction in freshwater demand and blackwater footprint, thereby enabling the municipal systems to lower cost and increase treatment effectiveness. In spite of several reuse options which are considered relatively safe, there are different factors which influence the selection of reuse requirement, including effluent quality, technology, supply and demand, infrastructure, economic feasibility and environmental considerations (Asano et al. 2007). The potential hazards of reusing the treated GW can be physical, chemical and biological in nature. The physical hazards include water volume and contaminants. The chemical hazards include salts, nutrients and chemicals originating from various sources and the biological hazards are caused by the pathogens present in GW.

The major problem is that the affected environment can either be within the campuses affecting humans, animals and soil health or it can even extend beyond the premise affecting the neighboring areas through run off, seepage, etc. (NSW 2007). Risk in this case is a source of danger, a possibility of incurring loss through mismanagement of GW treatment systems or by not taking enough precautions in determining the potential usage of treated GW complying with the standards.

At present there are no uniform quality standards for greywater reuse and the available treatment technologies are mostly proprietary and unclear on many aspects. There are also no laws or regulations on the treatment and reuse of GW in many countries including India (Allen et al. 2010; Comino et al. 2013). Only recently the Brihanmumbai Municipal Corporation (BMC) of the Indian state of Mumbai has passed by-laws to make it mandatory for all new residential and commercial buildings to have rainwater harvesting systems and GW reuse systems. Recycling of water is also a condition under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) to get funds for projects in India, which is an encouraging step towards better water security and sustainability (Alam and Muzzammil 2012). Common standards for GW reuse are presented in Table 2.

In general, there are reduced health risks associated with GW reuse compared to those of combined raw wastewater. However, careful analysis needs to be carried out to ensure that the treated GW complies with the established reuse standards for the purpose of reuse. However, if the GW is stored for more hours, it will turn septic and promote the multiplication of the harmful microorganisms which cause potential health risks to the residents, especially the young, elderly and those with less immunity (Hernández Leal 2010). Disinfection is considered to be an option for all purposes of reuse, including toilet flushing, to ensure the protection of residents. There are numerous examples from across the world where treated GW is being successfully reused for the purpose of toilet flushing, laundry, irrigation and gardening (Anderson 2003).

In the developed part of the world, the countries that promote research and reuse of GW include UK, USA, Canada, Japan, Germany, Israel, Sweden and Australia. Although the treatment and reuse of GW at a community level would prove to be economically advantageous, some countries such as UK had seen huge acceptance for reuse within households (Bixio et al. 2006). However, in developing countries such as India, GW treatment and reuse is still at a primitive stage and a decentralized option for GW treatment would prove to be beneficial in these contexts. Reuse for toilet flushing alone can reduce water demand by 10–20 %, which is very significant in the water stress regions (Friedler 2004), and reuse for toilet flushing and garden irrigation can reduce demand by up to 50 % (Maimon et al. 2010).

Care should be taken while plumbing to separate the freshwater from GW because accidental cross connections would be a major risk for residents. Seriousness and a change of behavior are essential among the campus community where the treated GW is being reused. Although the reclaimed water may contain traces of xenobiotic compounds from cosmetic and detergent products, the associated risks

Table 2 Water quality standards for reuse in different countries

Standards		pH	Turbidity NTU	SS mg/L	DO mg/L	BOD mg/L	COD mg/L	N mg/L	P mg/L	Free ammonia (as N) mg/L	SAR	Boron mg/L	TC	FC cfu/100 mL	Total residual chlorine mg/L	References
WHO	Restricted irrigation												≤1E5**			WHO (2006)
	Unrestricted irrigation[a]												≤1E3**			
	Drinking quality[b]	6.58–5	≤5					50								
USEPA	Unrestricted use[c]	6–9	<2			<10								0	>1 ppm	USEPA (2012)
	Restricted use[d]	6–9		<30		<30								≤200	1	
CPCB India (for quality of treated wastewater)	On land for irrigation[e]	5.5–9	–	200		100	–								–	CPCB (2008)
	Into inland surface water[f]	5.5–9		100		30	250								1	
	Into public sewers[g]	5.5–9		600		350	–								–	
CPCB—India (for discharge of effluent)	Drinking water source[h]	6.5–8.5			≥6	≤2							≤50*			CPCB (2008)
	Outdoor bathing	6.5–8.5			≥5	≤3							≤500*			
	Drinking water source[i]	6.5–9			≥4	≤3							≤5,000*			
	Propagation of wildlife and fisheries	6.5–8.5			≥4					≤1.2						
	Irrigation, industrial[j]	6.5–8.5									26	≤2				

**cfu/100 mL *MPN/100 mL
[a]Crops eaten raw
[b]Drinking water quality, 1993
[c]Urban uses, landscape irrigation, crops eaten raw, toilet flushing, recreational impoundments
[d]Restricted access area irrigation, processed food crops, non-food crops, aesthetic impoundments, construction uses, industrial cooling and environmental reuse
[e]Indian standards: 3307(1974)
[f]Indian standards: 2490(1974)
[g]Indian standards: 3306(1974)
[h]Without conventional treatment but after disinfection
[i]After conventional treatment and disinfection
[j]Irrigation, industrial cooling, controlled waste disposal

still need to be thoroughly researched. Although most of such compounds are non-toxic to humans, accumulation of such micro-pollutants over time in a closed loop system may be a problem. Awareness would be needed to enable the residents to choose eco-friendly household products with high biodegradability, thereby reducing the risks associated with micro-pollutants. A few initial effluent samples indicate that the water quality standards for non-potable reuse are met. The treated greywater in this case study is primarily being used to water landscaped areas. Based on long-term data collection and analysis, other potential uses will be recommended.

12 Conclusion

It is a well known fact that wastewater is a significant and growing problem in many urban areas of both the developed and the developing world. Available freshwater sources are also getting scarcer every day, which is further threatened by the increase in freshwater pollution. To counter this scenario, maximum amounts of wastewater should be treated and reused at the source of generation itself. There are several eco-technologies for greywater reclamation and reuse, of which constructed wetland system are found to be more suitable and economical for developing countries. Among the different types of constructed wetlands available, subsurface flow constructed wetland is found to be better suited for on-campus treatment because of its simple design requirements and the need for lesser space to treat the same amount of greywater by other types of CWS. The treated water is stored in a hydroponic and aquaponic system before being utilized for gardening purposes. The understanding of the complex processes involved between the plants, micro-organisms, soil matrix and substrates during the nutrient removal process is still incomplete. Frequent laboratory tests need to be performed to ensure that the system is performing as per the guidelines set by the regulatory bodies. Further research is recommended to study the various potential local species of macrophytes that were never studied before. The results of this research and the past literature suggest that the use of constructed wetlands as part of water treatment offers not only an opportunity for considerable savings in wastewater treatment costs for small campuses and communities but also an activity under environmental education for sustainable development.

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Authors Biography

Golda A. Edwin is a researcher at Pondicherry University. She has been involved in a number of green campus projects in her region and had implemented meaningful sustainability projects. She decided to pursue her research and career in water science because of her passion for addressing the challenges of sustainable water management in developing countries. Her core area of research is abatement of water pollution using eco-technologies. She authored several articles and presented her findings in several national/International conferences and workshops. She was awarded a Gold Medal from Pondicherry University for her outstanding academic excellence. She is also one of the Founders and Executive Director of Association for Promoting Sustainability in Campuses and Communities (APSCC).

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Dr. R. Arun Prasath Ph.D. (Chemical Science/Materials, Anna University, Chennai). He was a recipient of prestigious DAAD fellowship, (1999–2001) for his doctoral research work at Max-Planck Institute for Polymer Research, Mainz, Germany. After his doctoral degree he worked as material researcher in several prestigious institutes; as research associate in Indian Institute of Science, Bangalore, India (2002–2004), as postdoctoral researcher in University of Strathclyde, Glasgow, United Kingdom (2004–2006) and in University of New South Wales, Sydney, Australia (2006–2008), and as senior researcher in Ghent University (2008–2010) with a special fellowship called BOF. He has published more than 20 peer-reviewed journal articles, more than 10 published articles in proceedings and book chapters, co-inventor in 3 international patents as well as in 2 European patent applications. For his profession development, he has visited Germany, United Kingdom, Australia, Belgium, Brazil, Italy, and Bangladesh. He has presented more than 40 oral presentations in various conferences/seminars/courses/invited talks. He is actively involved in teaching and research on renewable energy from 2010 onwards.

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Urbanization and Green Spaces—A Study on Jnana Bharathi Campus, Bangalore University

M. Kumar, N. Nandini, M. Vijay Kumar and M. Raghavendra

Abstract

Global warming is amongst the most alarming problems of the new era. Carbon emission is evidently the strongest fundamental factor for global warming. So increasing carbon emission is one of today's major concerns, which is well addressed in the Kyoto Protocol. Trees are amongst the most significant elements of any landscape, because of both biomass and diversity, and their key role in ecosystem dynamics is well known. Trees absorb the atmospheric carbon dioxide and act as a carbon sink, since 50 % of biomass is carbon itself and the importance of carbon sequestration in forest areas is already accepted, and well documented. With this background, a carbon sequestration potential study was carried out in Jnana Bharathi campus, Bangalore University using the Quadrat method. The total geographical area is about 449.74 ha with a rich vegetation sector and the total amount of both above ground carbon (AGC) and below ground carbon (BGC) was estimated as an average of 54.8 t/ha. The total amount of carbon dioxide assimilated into the vegetation in terms of both above ground and below ground biomass was estimated as an average of 200.9 t/ha. Urbanization and habitat fragmentation seem to be increasing worldwide,

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substantiated by a case study in Bangalore City. The analysis revealed that increase in built-up area at the city level was by about 164.62 km^2, while the vegetation and water bodies decreased by about 285.72 and 7.2 km^2 respectively. However, Bangalore University, Jnana Bharathi campus attains a good vegetation cover and is seen as one of the 'green lungs' of Bangalore city.

Keywords
Urban sprawl · Carbon sequestration · Landscape · Biomass · Bangalore

1 Introduction

Urbanization can be defined as the alteration of rural society into an urban society and is a result of expansion of urban agglomerations and city centres along with changing land use patterns (Roberts and Kanaley 2006). With only 2 % of the world population urbanized in 1,800, global urban population reached the 15 % mark in 1,900 and today almost 180,000 people are added to the world's urban population every day (Pitale 2011) and, worldwide, 65 % of the population are expected to reside in urban areas by 2025 (Schell and Ulijaszek 1999). Rapid and haphazard urbanization has caused many environmental impacts associated with the reduction of green space, making urban settlements a major source of Greenhouse Gas (GHG) emissions and creating additional vulnerabilities to global environmental changes. Green spaces in urban areas are an integral part of the landscape, providing the metropolis and its population with several benefits both tangible and intangible (Gaodi et al. 2010), ecosystem services such as pollutant sequestration and ambient temperature policy, etc. (Nowak et al. 2006; Jim and Chen 2008).

Green spaces act as hot spots in urban biodiversity (Kulkarni et al. 2001), and Bangalore city has major green spaces such as Cubbon Park, Lalbagh, BBMP Parks and Jnana Bharathi campus Bangalore University. Carbon sequestration is a phenomenon for the storage of CO_2 or other forms of carbon to mitigate global warming and is one of the important clauses of the Kyoto Protocol whereby through biological, chemical or physical processes, CO_2 is captured from the atmosphere. Carbon sequestration is a way to mitigate the accumulation of GHG in the atmosphere released by the burning of fossil fuels and other anthropogenic activities. The importance of forested areas in carbon sequestration is already accepted, and well documented (FSI 2009; Tiwari and Singh 1987), although not many attempts have been made to address the potential of trees in carbon sequestration in an urban scenario. Hence, the study of carbon sequestration potential assessment in Jnana Bharathi campus, Bangalore University, is very crucial in conserving green spaces in the city.

2 Materials and Methods

In the present study, the measurement of the quantity of carbon has been carried out and was based on the amount of above ground biomass and below ground biomass of trees in Jnana Bharathi campus, Bangalore University. Among the different methods for estimating above ground biomass, the most commonly used method is the quadrat method wherein 1 % of the total area (4.49 ha) is sampled for the biomass assessment. The quadrat size of 25 m × 25 m was laid and all trees having >1.5 m heights or >5 cm girth at breast height (GBH) were scrutinized individually with their respective measurements of GBH in centimetres and Basal area (square metres). Based on GBH and basal area values, biomass (t/ha) and carbon sequestration rate of trees were calculated using a value of 0.5 of the biomass as carbon content; a default conversion factor of 0.26 was used to convert above ground biomass to below ground biomass (Ravindranath and Ostwald 2008). For the wood density of the tree species, the standard average of 0.45 gm/cm^3 or 450 kg/m^3 was taken. The quantum of carbon was then converted to the quantum of carbon dioxide using the following formulae (Kumar and Singh 2003).

The following formulae were used:

$$\begin{aligned}
&\text{Basal area} = (\text{GBH})^2/4\pi \\
&\text{Biovolume} = \text{Basal area} \times \text{Height} \\
&\text{AGB} = \text{Biovolume} \times \text{Wood density} \\
&\text{BGB} = \text{AGB} \times 0.26 \\
&\text{AGC} = \text{AGB}/2
\end{aligned}$$

where

GBH Girth at Breast Height
AGB Above Ground Biomass
BGB Below Ground Biomass
AGC Above Ground Carbon

$$\text{Quantum of CO}_2 = \frac{\text{Quantum of carbon} \times 44}{12}$$

where

44 molecular weight of CO_2
12 atomic weight of carbon

3 Results and Discussion

3.1 Jnana Bharathi Campus, Bangalore University—A Green Urban Lung Space

Urban green spaces are one of the most significant elements of any urban ecosystem, both because of the ecosystem dynamics and the essential influence in human well-being. Jnana Bharathi campus, Bangalore University is located in southern part of Bangalore, Karnataka, India. The total geographical area of Jnana Bharathi campus is 449.74 ha with a longitude of 77º 30′ 05.604″E and latitude of 12º 56′ 57.608″N of precious land with rich vegetation, next to Cuban park and Lalbagh in Bangalore urban district. The Jnana Bharathi campus has different land use systems, namely evergreen forest, Madhuvana, Charakavana, Sanjeevinivana, bio-energy plants, ecologically conducive plants, natural vegetation, and 98.38 ha is allotted for various organizations such as institutions, buildings, hostels, offices, residential quarters, etc. The trees are present in the form of gardens and avenue trees, in and around the departments. The topography of the area is mostly flat or with moderate slope. The elevation of the division varies from 717 to 801 m at mean sea level. April is usually the hottest month with mean daily temperature at 33 °C and mean daily minimum at 21 °C. In the hottest season the temperature usually goes above 36 °C with the onset of the monsoon early in June, when there is appreciable drop in day temperature but that of night temperature is less. In October the temperature decreases. December is generally the coolest month with a mean daily maximum temperature of 26 °C and mean daily minimum of 15 °C nights during January which are, however, slightly cooler than during summer. The mean annual rainfall is about 875 mm spread over 50 days in a year. Over half of the annual average rainfall is obtained in the months of August, September and October. In November and December, cyclonic rains caused by the depressions on the eastern coast are experienced. From January to March almost no rain is received. The division has five check dams seasonally filled during the rains and dry in summer and Vrishabhavathi River is flowing in the same area. The soil in the valleys is good and loamy and is formed of fine particles of the decomposed rocks. The soil on the higher grounds is gravelly and reddish in color (Hanjagi 2007) (see Fig. 1).

3.2 Carbon Sequestration Potential of Jnana Bharathi Campus, Bangalore University

The Kyoto Protocol to the UN Framework Convention on Climate Change (UNFCCC 1992) has provided a vehicle for considering the effects of carbon sinks and sources, as well as addressing issues related to fossil fuels emissions. In recent years the urban cities account for 78 % of carbon emissions (Prachi et al. 2010), not only because of rapidly increasing population but also because of the vehicular traffic apart from industrial pollution (Wallace et al. 2009).

Fig. 1 Jnana Bharathi Campus, Bangalore University—study area

In the present study, 449.74 ha of Jnana Bharathi campus, Bangalore University was assessed to calculate total carbon capture and more than 55 different species were recorded in the campus as well as major trees such as *Acacia chundra, Azadirachta indica, Butea monosperma, Cassia fistula, Delonix regia, Dalbergia paniculata, Ficus bengalensis*, *Ficus glomarata, Ficus religosa, Santalum album, Syzigium cumini*, *Tabebuia argentia, Tamarindus indica, Tectona grandis, Terminalia species, Millingtonia hortensis, Pongamia pinnata, Feronia elephantum, Acacia nilotica, Albizzia odoratissima*, *Artocarpus integrifolia, Albizia saman and Polyalthia longifolia.* The carbon sequestration potential of trees in terms of both Above Ground Biomass and Below Ground Biomass in university campus was estimated as an average of 54.8 t/ha. The total amount of carbon dioxide assimilated into the vegetation in terms of both above ground and below ground biomass was estimated as an average of 200.9 t/ha. The study carried out by Chavan and Rasal (2010) in selective tree species of university campus at Aurangabad, Maharashtra, India showed the Above Ground Biomass for trees as follows; *Ficus religiosa* is 4.27 t/tree, *Ficus Benghalensis* 3.89 t/tree, *Mangifera indica* 3.13 t/tree, *Delonix regia* 2.12 t/tree, *Butea monosperma* 2.10 t/tree, *Peltophorum pterocarpum* 2.01 t/tree, *Azadirachta indica* 1.91 t/tree and *Pongamia pinnata* 1.57 t/tree; in another study carried out by Warran and Patwardhan (2005) in and around Pune on Carbon Sequestration Potential of Trees in 2002 showed the rate of carbon sequestered by the trees was found to be 15,000 t/yr. Urbanization and habitat fragmentation seem to be increasing worldwide, substantiated by a case study in Bangalore City. Bangalore has witnessed extensive growth in the last two decade substantially by globalization and urbanization. The demand on amenities is haphazardly increasing and the city spreads beyond into the peri-urban areas, the metropolitan area and outwards, into the Bangalore Metropolitan Region. Hence, the green spaces in Bangalore city are quickly declining. The analysis revealed that increase in built-up area at the city level was by about 164.62 km^2, while the vegetation and water bodies decreased by about 285.72 and 7.2 km^2 respectively (Shetty et al. 2012). However, Bangalore University, Jnana Bharathi campus attains a good vegetation cover and is seen as one of the 'green lungs' of Bangalore city and also helps in reducing global warming at regional level to some extent.

4 Conclusion

Most of the environmental impacts of urbanization are associated with green space. The presence of green space can mitigate these impacts, such as urban heat island effect, energy flow, and urban trees also remove large amounts of air pollutants which consequently improves urban air quality. The strengthening of green space in urban cities can be a potential contributor in reducing concentration of CO_2 in the atmosphere by its accumulation in the form of biomass and also offers citizens aesthetic enjoyments, recreational opportunities and physical and psychological well-being (Chen and Jim 2008). One tonne of carbon storage in the tree represents removal of 44/12 or 3.67 t of carbon from the atmosphere, and the release of 2.67 t of oxygen back into the atmosphere (Prachi et al. 2010) helping to improve the general liveability and quality of urban life.

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Campus Greening: Why It Is Worth It

Walter Leal Filho

Abstract

Campus greening is one of the pillars of sustainability in higher education. However, even though this component is an essential part of the formula successfully used by many successful universities, its use is not as widespread as it can and should be. This short, final chapter, outlines why campus greening is worthwhile and the advantages of its full integration in institutional sustainability efforts.

1 Introduction: The Role of Campus Greening in the Sustainability Debate

Campus greening is, along with sustainability oriented teaching and research, one of the areas where higher education institutions can demonstrate their commitment towards, and degree of engagement in the implementation of the principles of sustainable development. Apart from previous publications where this matter has been outlined (Creighton 1996; Leal Filho 1999, 2010), the various examples and case studies provided in this book have illustrated the range of campus greening activities which can be performed, and the many ways of implementation.

The international literature on sustainability has also documented many examples which outline the relevance and effectiveness of campus greening. This varies from Jabbour (2010), who analysed the usefulness of a systemic view towards greening business schools, to Disterheft, Caeiro, Ramos and Azeiteiro (2012), who emphasised the role of EMAS in realising sustainability principles, at the same time

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Table 1 Advantages of campus greening efforts

Items	Advantages
Visibility	Campus greening activities showcase what an institution is doing and promote it—locally, regionally and internationally
Students'engagement	Campus greening efforts are inclusive and may engage students in practical implementation
Demonstration nature	Innovative approaches, methods and projects can be tested and demonstrated
Documentation	Activities on campus offer a permanent or semi-permanent record of what an institution is doing
Economic gains	Initiatives in campus greening often leads to decreases in wastage and hence saves money
Curriculum link	Many subjects can be taught and many principles can be illustrated via suitable campus greening schemes
Mobilisation of students and staff	Academic staff and students tend to get equally mobilised in campus greening schemes

as it focused on the improvements needed at institutional level. Wright and Wilton (2012) also performed an assessment focusing on facilities management, and have outlined the many possibilities that particular area of universities operation offers. Clark and Button (2011), in a paper discussing the interface of arts, science and community, suggest a sustainability transdisciplinary education model (STEM) to which campus greening can play an important role.

One can better understand the usefulness of campus greening when looking at its many elements in a comparative manner. Consistent with this, Table 1 illustrates some of the advantages campus greening offers in support of wider institutional efforts to pursue sustainability at higher education institutions.

However, perhaps one of the main advantages of campus greening is the possibility of replicability at home and in offices in the later stages of a student's life: students who study at universities where campus greening is practiced are more likely to adopt more sustainable behaviour themselves when they leave university. This may include a wide range of areas—for instance, cycling instead of using cars, or using energy saving bulbs instead of conventional ones.

A question one can pose at this point in time is: if campus greening is so advantageous, why there are so many universities across the world (and not only in developing countries) reluctant to engage more actively in this area? The next section of this short chapter will address this matter.

2 Why Don't Universities Engage in Campus Greening?

It is a matter of fact that many institutions do not feel they should systematically engage in campus greening efforts. This is so for a number of reasons. However, perhaps the answer to the question as to why many universities do not take part in campus greening efforts is threefold:

1. Many universities are reluctant to engage because of the perceived costs of some campus greening programmes. Yet they seem to overlook the fact that initial costs are amortised by savings at later stages. Universities investing in campus-wide waste prevention schemes, for instance, are promptly able to reduce the costs associated with waste disposal. The investments in energy and/or saving are also translated by lower bills, often in the medium term.
2. A number of higher education institutions fear the amount of staff time to be spent on campus greening schemes is substantial. This is a well-founded fear, but can be addressed by a smart distribution of staff time. Even if universities do not have a sustainability coordinator to oversee campus greening schemes, they often have technical staff employed to make sure materials and equipment are in order. Such technical staff, combined with academic staff (faculty) and students, provide sufficient manpower to run campus greening schemes, with little or often no additional costs for personnel.
3. A number of universities worry about the long-term commitment needed. The nature of campus greening schemes makes them essentially long-term exercises. This means that measures, once initiated, need in most cases to be continued for long periods of time, even over decades in some cases. However, instead of being a burden, the commitment to campus greening initiatives in the long run is positive for any university, since it allows them to benefit from the improvements brought about. Moreover, cost-reducing measures are also likely to yield the same benefits for longer periods of time, hence providing a compensation for the efforts made. In summary, a long-term commitment pays off.

Bearing in mind the clear advantages offered by systematic and long-term campus greening efforts, the author defends the view that they should, on the one hand, be intensified, but, on the other, be more closely integrated with further institutional sustainability efforts. This requires efforts from the side of university administrators—which are often the driving forces behind campus greening and also from academic staff, who should perhaps provide more attention to the wide range of opportunities offered by campus greening to their research and teaching, right on their doorsteps. There are many fantastic teaching, research and demonstration projects which may be undertaken on campus, which may help to both teach and build the awareness of students about sustainability issues. Some possible areas include:

1. Energy saving in buildings, facilities and operations
2. Waste prevention and management
3. Water use and consumption
4. Biodiversity on campus
5. Transport

among many others. The choice(s) to be made depend, of course, on a campus' own design and structure, as well as the priorities set by the university administration and academic staff.

3 Conclusions

As this chapter has tried to demonstrate, campus greening efforts are central to institutional sustainability efforts, and can be advantageous to higher education institutions in many ways. The many positive elements it brings about mean that it is not primarily a cost-intensive exercise, but a worthy one. The many examples outlined in this book have shown how much can be achieved by adopting a pragmatic approach to campus greening, which can help to deliver teaching and support research in meaningful ways.

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