DEVELOPMENT OF ENVIRONMENTAL SUSTAINABILITY CONCEPTS FOR THE ASIAN INSTITUTE OF TECHNOLOGY (AIT) CAMPUS

by

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Engineering

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Abstract

The study conducted was an effort towards the development of environmental sustainability within the AIT campus. The study comprised of environmental audits and CP options. The focused area of the study was on energy and water consumption, wastewater and solid waste generation. In addition, noise and odor issues were also addressed.

The result of the energy audit shows that AIT consumes around 36,000 kWh/day. Offices are the major source of energy consumption, about 50% of the total energy consumption. This amount of energy consumption causes about 13 tons of CO_2 emission. About 1,300 m^3/day of water is consumed by AIT residents. The residential areas contribute to more than 50% of total water consumption. Everyday, AIT generates about 2.03 tons of solid waste, only 4% of total waste is recycled. Organic waste covers about 60% of total waste, which are generated largely from the residential areas.

After the identification of problems, CP options have been proposed to define ways to develop environmental sustainability within the campus. For energy reduction, the awareness should be created among the staff and students, such as switching off the lights and all electric appliances when they are not used. Use of new technology appliances to reduce energy consumption, such as replacing conventional monitors with flat panel monitors, replacing the old chiller to the new high efficient one, or installing the automatic energy shutoff sensors in all office buildings, etc.

For water conservation, new technology water appliances should be used in the campus such as low flow toilets, non-water urinals, low flow shower heads, water leakage detector, etc. In this study, it is proposed that AIT's WWTP should be divided into two segments. The first part will treat only the wastewater from the offices and reuse this treated wastewater for watering the garden. The second plant will treat all wastewater from the residential areas, cafeteria and AITCC, then; discharge them into the public canal.

For solid waste reduction, 3R (reduce, reuse and recycle) programs are proposed, to reduce the amount of waste sent to the landfill. Furthermore, to reduce large amount of organic waste, organic composting or anaerobic digestion should be practiced within the campus. This organic fertilizer can be effectively and sustainably used in the garden.

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List of Abbreviations

AIT	Asian Institute of Technology
AFE	Aquaculture and Food Engineering
AITCC	Asian Institute of Technology Conference Center
AP	Aeration Pond
BOD	Biochemical Oxygen Demand
CIM	Chalerm Brakiat Building
COD	Chemical Oxygen Demand
CP	Cleaner Production
CW	Constructed Wetland
CRT	Cathode Ray Tube
dB(A)	Decibel (Ambient)
Eco-Map	Ecology Map
EEM	Environmental Engineering and Management
EMAS	European Eco-Management and Audit Scheme
EMS	Environmental Management System
EUE	Energy-University-Environment
GHG	Green House Gas
KFC	Kentucky Fly Chicken
Lao PDR	Lao’s People Democratic Republic
LCD	Liquid Crystal Display
MBR	Membrane Bio-Reactor
MC	Moisture Content
MFA	Material Flux Analysis
NGOs	Non-Governmental Organizations
NPC	National Processing Company
NTU	Nephelometric Turbidity Unit
PIR	Passive Infra Red
PWTP	Pathumthani Water Treatment Plant
REC	Regional Experimental Center
SAO	Student Accommodation Office
SERD	School of Environment, Resources and Development
SOM	School of Management
SPV	Solar Photovoltaic
TDM	Technologico de Monterrey
TDS	Total Dissolve Solids
TKN	Total Kjeldal Nitrogen
TS	Total Solids
TSS	Total Suspended Solids
UAM	Universidad Autonoma de Madrid
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
U.S. EPA	United States Environmental Protection Agency
WBCSD	World Business Council for Sustainable Development
WRE	Water Research Engineering
WSP	Waste Stabilization Pond
WWTP	Wastewater Treatment Plant

Chapter 1

Introduction

1.1 Background

Environmental Sustainability is a significant thing that nowadays many developed and developing world are considering about. There are various scenarios that have been established for several years ago, in order to focus on this purpose. Eco-campus or green campus is one of the main ideas that are established to preserve the earth environment. In which, many universities especially in European countries, the United State and some Asian countries have carried out recently. To preserve the environment within the campus, there are various viewpoints that several universities are applying in order to tackle with their environmental problems such as promotion of the energy saving, resource savings, recycle of waste, water reduction, etc.

Eco-campus or Ecological Campus has the meaning in itself. The meaning of eco-campus has been expressed in its targets and objectives. By all mean, eco-campus means “environmental sustainability within the school”. School is a center for generating of education; moreover, it is also a research center where the students and teachers are attempting to develop the best strategy for achieving their purposes. Due to this reason, the development of eco-campus has been pointed out and established in recently. Eco-campus is mainly focused on the efficient uses of energy and water; minimize waste generation or pollution and also economic efficiency.

Eco-campus is focusing on the reduction of the University’s contribution to emissions of green house gases, procure a cost effective of and secure supply of energy, encourage and enhance staff and student energy issues and promote personal action, reduce the University’s energy and water consumption, reduce wastes to landfill and integrate environmental considerations into all contracts and services considered to have a significant environmental impacts. While these various measures are promoted synthetically and systematically, an "Environmental Management System" is introduced, in order to realize certainly the "Eco-campus" which considered environment, and clarifying the posture of a university to society. It aims at establishing the organization which may be evaluated objective.

Most recently, the concept of cleaner production (CP) has entered the global environmental arena. CP fits within pollution prevention's broader commitment toward the prevention rather than the control of pollution. Cleaner production means the continuous application of an integrated preventive environmental strategy to processes and products to reduce risks to humans and the environment. For production processes, cleaner production includes conserving raw materials and energy, eliminating toxic raw materials, and reducing the quantity and toxicity of all emissions and wastes before they leave a process. For products, the strategy focuses on reducing impacts along the entire life cycle of the product, from raw material extraction to the ultimate disposal of the product. Cleaner production is achieved by applying know-how, by improving technology, and by changing attitudes.

Pollution prevention is an approach which can be adopted within all sectors, whether it is a small service operation or a large industrial complex. CP, on the other hand, directs activities toward production aspects. Unlike in the past when pollution was simply controlled, P2 and CP programs attempt to reduce and/or eliminate air, water, and land pollution. Therefore, the P2 and CP approaches benefit both the environment and society. Economically, P2 and CP can actually reduce costs and in some cases, generate profit. Both approaches are practical and feasible, and can consequently contribute to a sustainable future.

Cleaner production, pollution prevention, etc. are all subsets of the concept of sustainable development, which states the basic problem that the other concepts attempt to address: There are limits to what the environment can tolerate, and society needs to ensure that development today does not cause environmental degradation that prevents development tomorrow. There are many issues here but the role of industry and industrial pollution is obvious. Industrial systems and individual companies will need to make changes in order to prevent future generations from being unable to meet their own needs. Sustainable development is thus the long-term goal of individual companies rather than a business practice.

Eco-campus approaches must be implemented step by step. First of all, data collection has to be conducted in order to find out what the status of the campus is. After collecting all information and data, the next step is determining of problematic areas and find out what the reasons are. Finally, proposing the way that can solve the issues, in order to achieve the sustainable development. In this study, Cleaner Production is an option that is selected for implementing of eco-campus development at AIT.

1.2. Objectives of the Study

In order to contain a green environment within the AIT campus, certain parameters needed to be monitored and audited. These parameters would be then compared to the standard benchmarks. The main objectives of the study are to:

1. Study the prevailing solid waste management in the campus
2. Conduct water audit for AIT campus and analyze the present water usages and wastewater characterizations
3. Study the current electricity consumption at AIT campus and estimate the green house gas (GHG) emissions
4. Study the noise level pollution at AIT campus
5. Propose some effective Sustainable Development options to enhance the environmental perspective of AIT campus.

1.3 Scope of Study

This study looks forward to prepare an eco-campus report which would focus mainly on solid waste and water consumption within the AIT campus. Due to the limitation of time and availability of raw data, the following parameters would be monitored and investigated:

1. Solid waste management: study on solid waste generations and composition.
2. Noise pollution: measure the noise level at the specific areas.
3. Water consumption and wastewater generation including water characteristics

4. Electricity consumption including Green House Gas (GHG) emissions potential. Here only secondary data will be used for analysis this current situation and put forward from proposal.

Chapter 2

Literature Review

2.1 Introduction

Eco-campus is a concept that has been developed and attempted to achieve the word Environmental Sustainability. Its initiatives had been taken at the Universidad Autonoma de Madrid (UAM). This University, being a public institution devoted to knowledge through teaching and research, also taking on a leading role in spreading environmental awareness. The UAM Senate has unanimously approved a Charter of Commitment to Agenda 21 and to the agreements reached at the "Earth Summit" (Johannesburg, 2002) - the so-called Eco-campus Project.

2.2 Blueprint for a Green Campus Project of Heinz Family

Heinz Family Foundation during her speech at the opening of the Campus Earth Summit said that "A green campus is one that integrates environmental knowledge into all relevant disciplines, improves environmental studies course offerings, provides opportunities for students to study campus and local environmental problems, conducts environmental audits of its practices, institutes environmentally responsible purchasing policies, reduces campus waste, minimizes energy efficiency, makes environmental sustainability a top priority in land-use, transportation, and building planning, establishes a student environmental centre, and supports students who seek environmentally responsible careers". (Heiz Family, 1994)

The Campus Earth Summit brought together 450 faculties, staff and student delegates from 22 countries, 6 continents, and all 50 states at Yale University on February 18-20, 1994 to craft the Blueprint for a Green Campus, a set of recommendations for higher education institutions across the globe to work towards an environmentally sustainable future. The Blueprint was based on the principle that as multi-billion dollar consumers of higher education's services, students have the power to demand a more environmentally responsible campus and curriculum. In turn, faculty and staff can influence society by turning out environmentally literate citizens and by demanding environmentally sound goods and services. Since colleges and universities educate most of the people who run society's institutions and train the teachers who educate children, it becomes clear that transforming campuses into catalyst for environmental sustainability is a very good first step toward changing the world.

2.3 Eco-campus Collaboration

The Eco-campus Collaboration funded by the EU DGXVII THERMIE Program (Part of the work has been funded by the commission of European communities under contract EU DGXVII # STR 100696 FR), is one of the major consequences of the Energy-University-Environment seminar (EUE-95) organized by University of Bordeaux in March 1995. The main reason for this parallel moment in Europe was the realization of the facts that in a large university campus, electricity and water uses are similar to those of medium sized cities. As long as the energy/environment challenges are considered, i.e. the decrease of oil/natural gas resources, the nuclear waste/CO_2 debate, the growth of water demand, the ozone depletion, an overall knowledge will be available in all universities and research laboratories worldwide. Anyone may then have easy access to a comprehensive view. However, in universities and research laboratories, not least in Europe, most scientists are far from being aware of implementing in-house energy efficiency policies not yet regarded as a genuine, perfect and cheap resource. Not surprisingly, it is common to find campus managers paying little attention to such environmentally sound policies. The key issues addressed in the EUE-95 declaration were:

- Creation of a European network to bring together academicians and students interested in this concept.
- Inventory of technologies collect and analyze all data linked to energy use and/or environmental protection.
- Definition of specific methodology in order to manage specific suites such as university campuses.
- Feasibility studies to demonstrate the effects of energy efficiency programs.

2.4 Sustainable Development

The sustainable development had been initiated in the United Nations Conference on Environment and Development (UNCED), which took place in 1992 in Rio de Janeiro, Brazil. Government officials from 178 countries and between 20,000 and 30,000 individuals from governments, NGOs and the media participated in this event to discuss solutions for global problems such as poverty, war or the growing gap between industrialized and developing countries. In the centre was also the question of how to relieve the global environmental system through the introduction to the paradigm of sustainable development. It emphasizes that "economic and social progress depends critically on the preservation of the natural resource base with effective measures to prevent environmental degradation". (Johannesburg, 2002)

Apart from UN conference, a conference, which is called the "Global Forum" established in Rio, organized by hundreds of NGOs. The UN summit focused on three broad concepts: An "Earth Charter" covering a number of principles aiming at development and the protection of the environment, was the first focus for discussion. Secondly, "Agenda 21" was intended to be a global action plan for sustainable development. Thirdly, developing countries demanded a substantial increase in new funding from developing countries to contribute to sustainable development.

2.4.1 Environmental Policy

After that earth summit, several educational institutions, communities, governmental sectors, private sectors and organizations have concerned more about their environmental sustainability in their own places. They started to implement that concept by the establishments their own environmental policies. The example of environmental policy has been described below:

(1) Environmental Policy Statement of University of Tampere

The University of Tampere presents the guidelines for environmental education in the university. The objectives are to be achieved in reducing the environmental impacts of the daily activities of the university. Every department and unit of the university will set its own environmental aims on the basis of the objectives defined in the policy. The aims have to be challenging, clear and measurable. Regular environmental surveys will be carried out in the units to help define the aims more precisely. The following sections give an outline of the general principles and objectives of the environmental policy. Preliminary suggestions for aims and procedures for each unit are presented in the appended review report. (Ecocampus project, 2002).

2.4.2 Environmental Management System

An Environmental Management System (EMS) is a set of processes and practices that enable an organization to reduce its environmental impacts and increase its operating efficiency. EMS has been initiatives supported by the U.S Environmental Protection Agency (EPA). EPA is carrying out a number of programs and activities involving EMSs, including initiatives with the public sectors and private sectors. (U.S. EPA, 2001)

2.5 Environmental Audit

Environmental audit is a systematic, documented, periodic and objective process in assessing an organization's activities and services in relation to various descriptions such as assessing compliance with relevant statutory and internal requirements, facilitating management control of environmental practices, promoting good environmental management, maintaining credibility with the public, raising staff awareness and enforcing commitment to departmental environmental policy, exploring improvement opportunities and establishing the performance baseline for developing an Environmental Management System (EMS).

To conduct a campus environmental audit, these 3 priorities should be considered:

- Conduct an assessment of campus environmental impacts, including, but not limited to: solid waste, hazardous substances, radioactive waste, medical waste, wastewater and storm runoff, pest control, air quality, the workplace environment, water, energy, food, purchasing policies, transportation, campus design and growth, research activities, investment policies, business ties, environmental education and literacy, job placement and environmental careers.
- Providing recommendations for improved performance in each area, ranking priorities for action, and setting goals to be completed by the next audit.
- Distribute to all members of the campus community, including trustees, high-level campus officials, staff, faculty, students, alumni, foundation donors, corporate donors, government officials, environmental leaders, community leaders and the public at large.

2.5.1 Reduction of Campus Waste

In order to conduct the waste reduction programme into the campus, the following principles should be assigned: design and redesign facilities and technologies to reduce waste, reduce consumption by buying only what is really needed; pool resources wherever possible; when buying disposables, buy those that are recyclable; and establish a dialogue with vendors.

Apart from those principles, the campus should follow these general recommendations for all of their staff and students, which is really necessary to help in accomplishment of the waste reduction programme as below:

- Establish a program to reduce, reuse, recycle, and compost a high percentage of campus waste.
- Increase the percentage reduced, reused, recycled, and composted annually.
- Expand the scope of waste reduction programs to include the following: glass, steel/aluminum cans, plastic, food waste, cardboard, bond and computer, paper, mixed paper, magazines, newspapers, construction debris (steel, wood, concrete, asphalt), yard waste, oil, leaves, tires, scrap metal, hazardous chemicals, telephone books, contaminated soil, and mattresses at all areas and facilities of the campus.

(1) A Case Study of Success at University of Colorado

The University of Colorado is one of the first and best campus waste reductions, which was begun in 1976 at the University of Colorado at Boulder. The program, which is overseen by the University of Colorado Student Union and staffed by a recycling services director, students, and community service volunteers—collects separated recyclables from every campus building. To reduce the amount of waste generation, the university is training its staff to use electronic mail, encourages double-sided copying, as well as the use of recycled paper products, reusable mugs, retreated tires, and washable dishes. The program is supported by an extensive public education campaign, which includes press releases, public service announcements, newspaper articles, and audio-visual materials, as well as orientation for incoming freshmen. Future plans include a household-hazardous-waste reduction campaign, alternative chemical-waste disposal, and increased recycled product procurement.

2.5.2 Reduction/Conservation of Water Consumption

Agricultural, industrial, recreational, and human and animal life forms are dependent on the use of fresh water. Based on our daily water consumption, one might think that the amount of water available to us is infinite. Yet only about 3% of the earth's water is freshwater and over 66% of our fresh waters is in the form of glaciers.(1) In order to maintain a plentiful water supply, we must take measures to reduce our water usage. Conserving not only saves water, but it also saves energy and chemicals which are needed for treatment and purification.

(1) A Case Study of Brown University

Brown University began water conservation efforts in 1991 by retrofitting all dormitory shower heads with low flow utilities. The program saves 21,200 m^3 of water per year and a student survey has shown consumer satisfaction is high. In the spring of 1993, the University retrofitted all athletic facility buildings with water conserving show and faucet heads. The university is in the process of install 0.09 kg per hour toilets and flush valves in the dormitories. In addition, Brown has undertaken efforts to improve process cooling systems for laboratory equipment that significantly reduce water consumption. Finally, a campus water audit has been undertaken that revealed by continuing the types of conservation measures, Brown could save approximately 120 million gallons of water annually after all measures are completed. This would result in a savings of approximately $300,000 per year. (Isenberg, 1996).

2.5.3 Maximize Energy Efficiency

Energy is the cornerstone of the University's operations. It allows the lights to go on, powers the motors in laboratories, fuels the computers, and heats in campus. However, just as energy allows classes to run, it also represents an opportunity to conserve. Energy production affects land, air and water. Energy conservation is a means to reduce impacts, improve efficiency and lower costs.

The following recommendations have to be implemented in order to maximize energy efficiency and preserve the energy resources.

- Invest in energy efficient technologies for heating, cooling, lighting and water systems in all existing and future campus buildings and earmark the savings for further improvements in environmental performance.
- Install meters to measure the use of heat, electricity, and water by building or department and take ongoing meter measurements to set baseline data and determine progress.
- Raise campus awareness about the need for energy conservation and provide incentives for action, such as by establishing campus-wide “Eco-lympics” competitions among dormitories, departments, or schools.

(1) A Case Study of SUNY Buffalo University

SUNY Buffalo has taken an approach to conservation with 300 projects that have reduced energy bills from 22.5 million to 20 million dollars per year. Savings are expected to increase by another 2 million dollars in coming years. The projects were funded 25% by utility rebates and incentive programs. The energy officer, Walter Simpson, focuses on long term and short term projects. He believes it is important to concentrate upon long term projects because short term projects with quick paybacks run out quickly. A balance is the most holistic way to approach energy conservation. In addition, SUNY Buffalo is also approaching conservation by energy reduction and education. The University has found that they could reduce the corridor lights by 50% and still provide sufficient illumination. Many lights were identified through the building conservation contacts who volunteer to turn off unused lights and computers, report overheated and undercooled areas, and areas where wattage could be reduced. A final tactic used is that Simpson posts energy bills in building lobbies. (Isenberg, 1996)

2.6 Cleaner Production

Cleaner production has been adopted by UNEP as follow: Cleaner Production is the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase overall efficiency, and reduce risks to humans and the environment. Cleaner Production can be applied to the processes used in any industry, to products themselves and to various services provided in society. (UNEP, 2001)

NPC (National Processing Company) defined that "Cleaner Production is a new and creative way of thinking about products and process which make them. It is achieved by a continuous application of strategies to minimize the generation of wastes".

2.6.1 Definition of CP

CP is a new and creative approach towards products and production processes. It is the continuous application of waste and emission reduction strategies, practices and technologies. It helps companies find out how much energy, water and raw materials they consume, how much pollution (such as waste, air and water emissions and noise) they produce, and where costs can be reduced and customer satisfaction improved. (Visvanathan & Kumar, 2005).

2.6.2 Cleaner Production Processes

Cleaner production process is the continual effort to prevent pollution; reduce the use of energy, water and material resources; and minimize waste in the production process. It involves rethinking products, product components and production processes to achieve sustainable production.

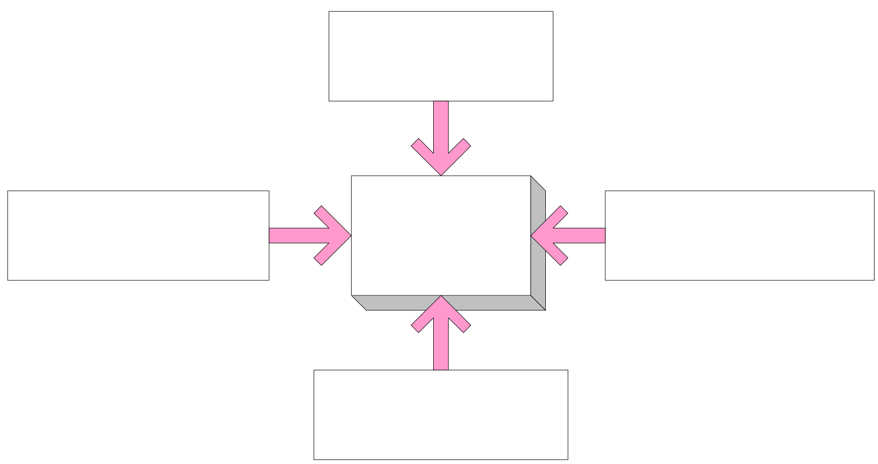


Figure 2.1 Cleaner Production Processes

2.6.3 Economic Benefits in Cleaner Production

Economic benefits or Eco-Efficiency was established by the World Business Council for Sustainable Development (WBCSD) in 1992 and defined as the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while reducing ecological impacts and resource intensity throughout the life cycle.

However, the concepts of eco-efficiency and Cleaner Production are almost synonymous. The slight difference between them is that eco-efficiency starts from issues of economic efficiency which have positive environmental benefits, while Cleaner Production starts from issues of environmental efficiency which have positive economic benefits. (UNEP, 2001)

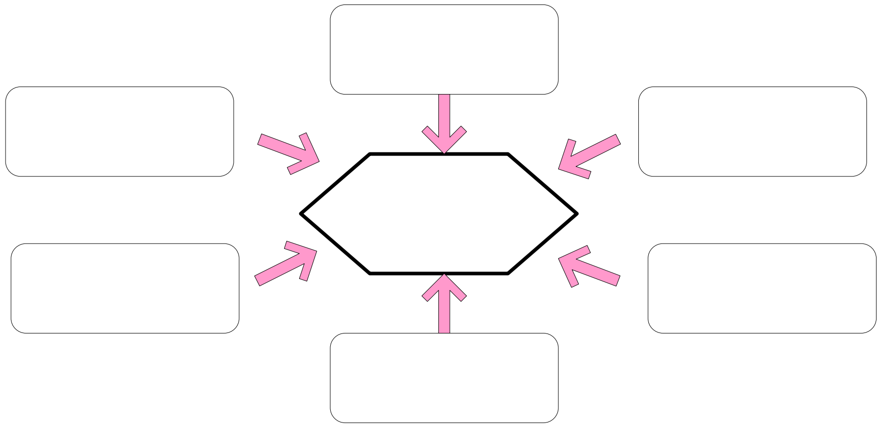


Figure 2.2 Economic benefits in cleaner production diagram

2.6.4 Cleaner Production and Sustainable Development

Due to the United Nations Conference on Environment and Development (UNCED), which was held in Rio de Janeiro in June 1992, established new goals for the world community that advocate environmentally sustainable development. Therefore, Cleaner Production is one methodology that aims at contribution to sustainable development, as endorsed by Agenda 21. Cleaner Production can reduce or eliminate the need to trade off environmental protection against economic growth, occupational safety against productivity, and consumer safety against competition in international markets. Setting goals across a range of sustainability issues leads to 'win–win' situations that benefit everyone. Cleaner Production is such a 'win–win' strategy: it protects the environment, the consumer and the worker while also improving industrial efficiency, profitability and competitiveness. Cleaner Production can be especially beneficial to developing countries and those undergoing economic transition. It provides industries in these countries with an opportunity to 'leapfrog' those more established industries elsewhere that are saddled with costly pollution control.

2.6.5 Cleaner Production Options

Cleaner production can be divided into 5 options depending on the types of environmental problems that each public sector or private sector are going to apply. These options are described as following:

- **Housekeeping**: Improvements to work practices and proper maintenance can produce significant benefits. These options are typically low cost.
- **Process optimization:** Resource consumption can be reduced by optimizing existing processes. These options are typically low to medium cost.
- **Raw material substitution**: Environmental problems can be avoided by replacing hazardous materials with more environmentally materials. These options may require changes to process equipment.

- **New technology**: Adopting new technologies can reduce resource consumption and minimize waste generation through improved operating efficiencies. These options are often highly capital intensive, but payback periods can be quite short.
- **New product design**: Changing product design can result in benefits throughout the life cycle of the product. It can be benefit from reduction the use of hazardous substances, reduced waste disposal, reduced energy consumption and more efficient production processes. New product design is a long-term strategy and may require new production equipment and marketing efforts, but paybacks can ultimately be very rewarding.

2.7 Eco-campus Implementations

2.7.1 Case Study of Leeds University

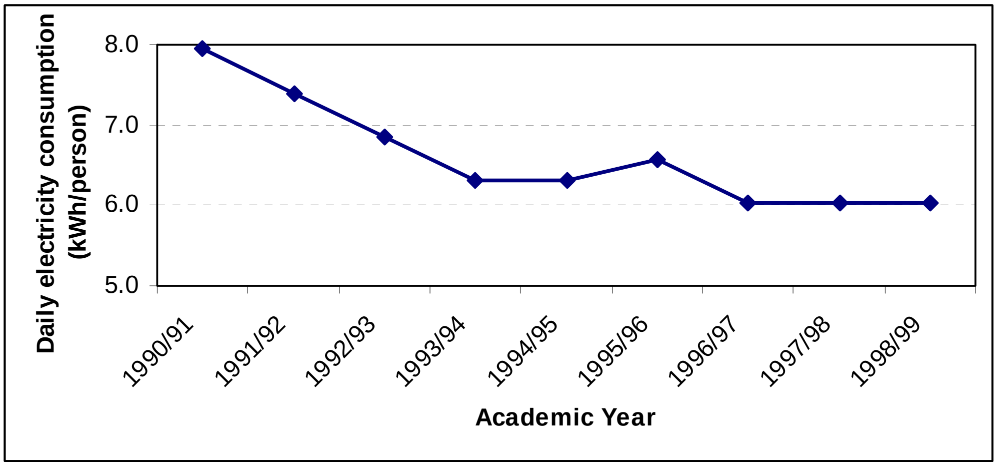
University of Leeds is responsible for the prevision of higher education to over 25,000 students and for the promotion of scholarship through its international class research activity. To carry out these services this University will contribute to the national commitment to sustainable development. The University has conducted its own activities and operations to reflect best environmental practice, implement an environmental management system in order to achieve the sustainability and continuous improvement and seek innovative ways of meeting the environmental objectives.

(1) Electricity Conservation

Electricity conservation is not only beneficial to the environment, but also save money. The university has undertaken several initiatives to reduce electricity use over the past few years. These include:

- Replacement of old lighting systems with more energy efficient types;
- Installation of lighting control sensors;
- Reorganization of air conditioning system in the Worsley Building;
- Modification of building plant operating regimes;
- Increased insulation to reduce heat loss;
- Computerized building energy management systems;

Further to the above initiatives, the University is actively promoting the need for energy conservation throughout the campus. It is an advertisement to encourage reduction of energy through switching off lights when not needed, closing door etc.



Source: (Stapleton and Fewtrell, 2001)

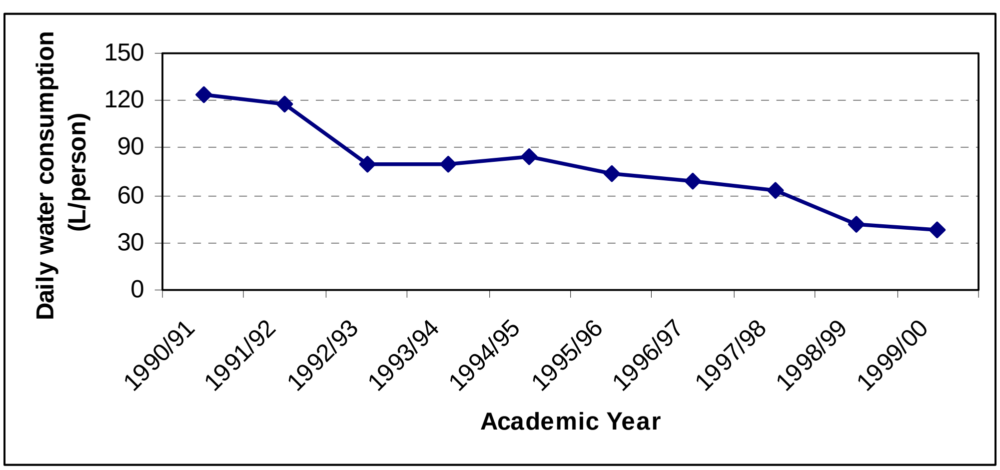
Figure 2.3 Electricity consumption at Leeds University during 1990 to 2000

Figure 2.5 presents electricity consumption for the academic year 1990/91 to 1999/2000 for the University campus. Total electricity consumption has increased over the past ten years, a reflecting of 86% increase in student numbers, the growing use of electronic equipment such as computers and the increase size of the University's estate. However, the electricity consumption per student has declined over this period, reflecting the energy conservation measures in place during this time.

(2) Water Conservation

Parallel to the electricity conservation, the University has also taken initiatives to reduce the water consumption in the campus. These include:

- Cistern and urinal control systems in toilet areas;
- Leak detection surveys;
- Best practice guidelines for water conservation incorporate into planning phase for new buildings or renovation;



Source: (Stapleton and Fewtrell, 2001)

Figure 2.4 Water consumption at Leeds University during 1990 to 2000

Figure 2.4 presents the water consumption per student from 1990 to 2000 has generally decreased with reflecting to the water conservation during ten years period. It means the program is very effective to the campus.

(3) Waste Management and Recycling

Large organizations such as the University generate a large amount of waste. The diverse nature of the University's operations, including varied research within individual academic departments, means there is the potential for almost any type of waste to be generated. Types of waste identified at the University include:

- Paper, and cardboard;
- Food waste (including cooking oils);
- Glass (domestic and laboratory);
- Plastic;
- Domestic refuse;
- Inert building materials/soil;
- Other hazardous wastes.

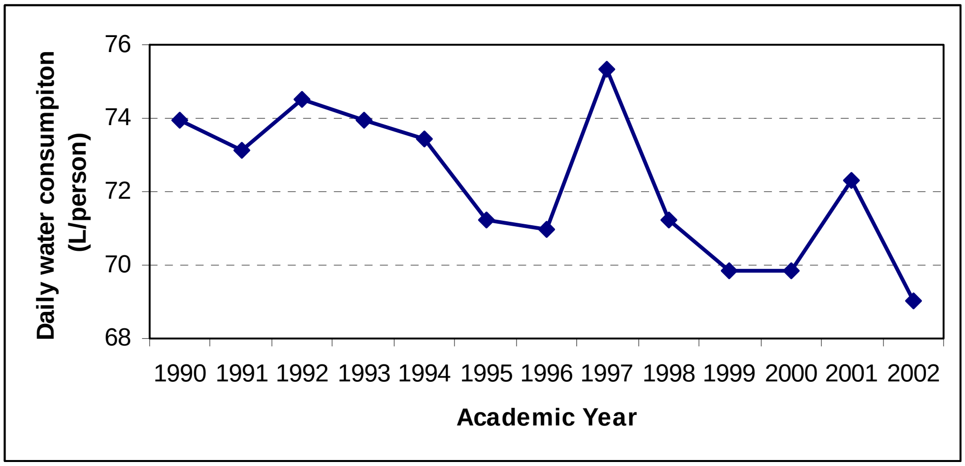
A limited amount of recycling of waste is evident within the University and there is an element of waste sorting at source in offices/departments. Recycling parts are in existence for paper and aluminum cans with the bins present at certain locations throughout the University. Other recycling stations (glass and plastic bottles, etc.) are provided by the local authority. Leeds University Union also operates an initiative to collect recyclable waste from students' accommodation. (Stepleton & Fewtrell, 2001)

2.7.2 Case Study of Sydney University

From 1990 to 2002, Sydney University has reduced its water consumption from 792,000 m^3/year to just over 500,000 m^3/year, through demand management initiatives and significant leakage reduction programs. The University is now at a point at which future potable mains water reductions from these programs will be harder to achieve, and is looking to other areas whereby reductions in water consumption can be attained.

(1) Water Consumptions

Since 1990, there has been nearly a doubling of the student population from 16,466 to 32,926. At the same time the gross floor area at the University has increased from 461,000 to 665,000 m^2. Conversely water consumption at the University has decreased significantly from 792,000 m^3/year to 500,000 m^3/year in 2002, as shown in Figure 2.7. (Ecological Engineering, 2000).



Source: (Ecological Engineering, 2000)

Figure 2.5 Estimated Water Usages for Buildings at Sydney University

The water saving made by the University is profound and significant. It is important to note that water has been monitored since 1990 and effectively managed since 1993, with most of the savings occurring in the past 5 years when the University has been conducting an extensive metering and leak detection program in parallel with the a demand management program. Initiatives that the University has taken over this time include:

- 60 water efficient irrigation systems controlled by timers and water sensors
- 1000 liter rainwater tank in the Nursery
- Replacement of all automatic urinal systems with Passive Infra Red (PIR) or pneumatic push button control
- Cooling towers - ongoing analysis of performance and water flow installation of water pressure reduction devices in specific buildings and laboratories
- 50 % of total flush toilets in buildings
- Comprehensive monitoring of water usage (for the purposes of analysis, reporting, benchmarking, selective sub-billing and procurement purposes)
- Formulation and implementation of cost efficient water saving initiatives (as determined by monitoring and related audits)
- Early identification and rectification of mains leaks or faulty irrigation delivery systems
- Rectification of irrigation systems that run during rainfall
- Identification and rectification of running toilets via real-time monitoring
- School of Chemistry – high priority project due to high water use-focused on for the last 3 years and also out of hours usage
- Vacuum pumps to replace inefficient aspirators and condensers (where feasible)

2.7.3. Case Study of Technologico de Monterrey University

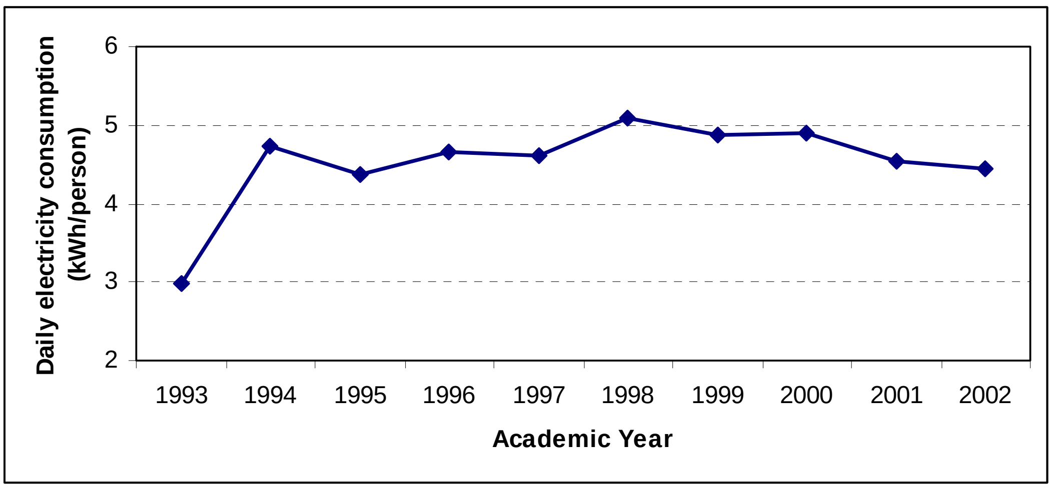
The purpose of Sustainable Campus Operation is to provide that the physical and biological campus systems function and maintenance is given according to the management practices of eco-efficiency in the following areas: energy, water, materials, health and safety, landscaping, construction, transportation and esthetics. But in this part, only energy and water usages are presented.

(1) Electricity Usages

It is coordinated by the electricity saving committee. Its main goal is to have efficient campus electricity consumption. It has implemented a series of actions that has allowed significant electricity savings, reducing the power factor and also providing a more efficient refrigerating system, as well as water distribution.

The following actions are being carried out:

- Real time readings of electrical energy
- Refrigerated water system operation and boiler operation.
- Lighting Program: pretends fluorescent lighting tubes substitution with lower electricity consumption ones, without diminishing lighting levels.
- Leak detection and repair for: water, natural gas, steam, as well as refrigerating water and steam pipe insulation maintenance and repair.
- Security guards check list.



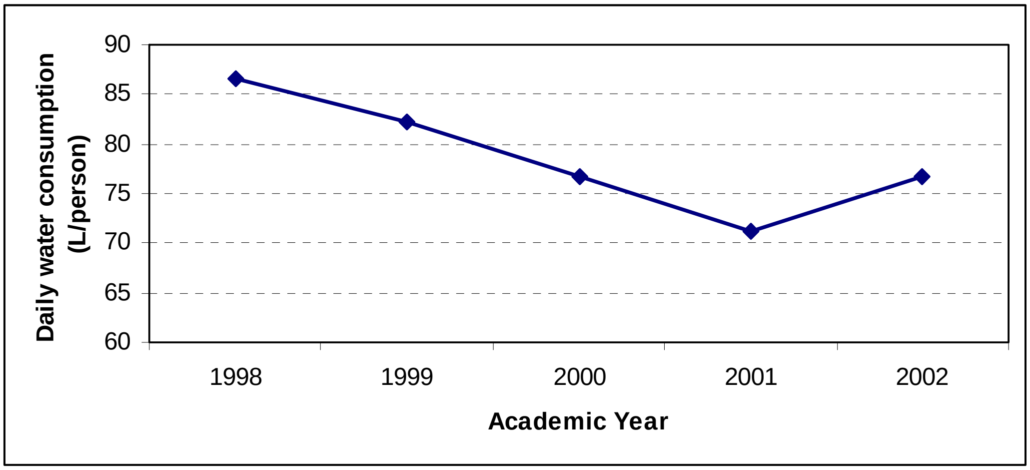
Source: (Technological de Monterrey, 2004)

Figure 2.6 Electricity Consumption Trends of Technologico de Monterrey University

(2) Water Usages

Monterrey Tec since 1993 has set an effort to take care of the environment and have better resource use. In its facilities there is a waste water primary treatment plant using the treated water for its garden catering. Waste water quality is checked by the National Water Commission, as well as by the Municipal Ecology Secretary, according to the Official Mexican Standard.

The waste water treatment plant handles approximately 70% of the flow rate generated in the Campus. In 2001 a program is implemented to use the treated water flow rate generated, plant operation is now 24 hours per day and a pre-treatment was included to improve water quality. (Technological de Monterrey, 2004).



Source: (Technological de Monterrey, 2004)

Figure 2.7 Trends of Water Usage for Gardening at Technologico de Monterrey University

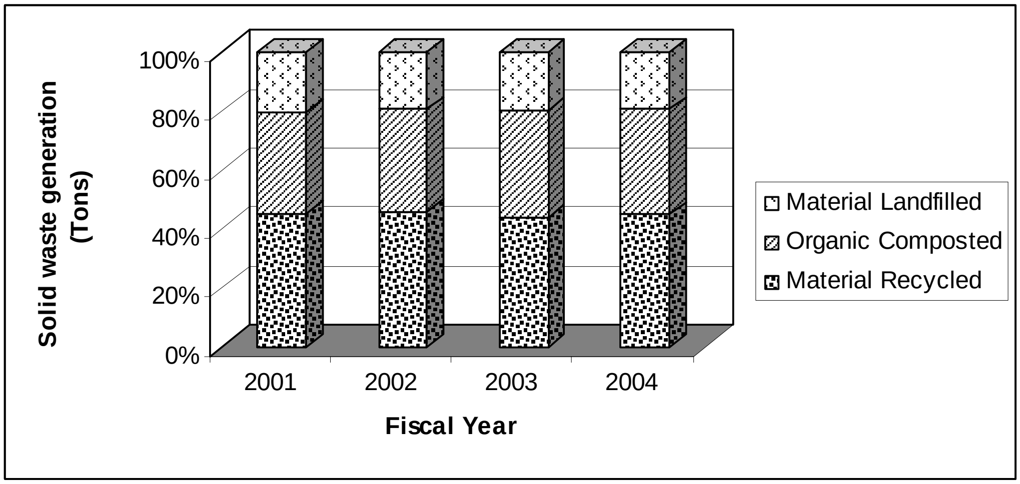
2.7.4. Case study of Cornell University

Cornell University has established a Cornell Sustainable Campus by emphasizing on the Solid Waste Management Program. The program has been initiated in 2001 and mostly focusing on the composting and recycling of solid waste.

(1) Solid Waste Management

Solid Waste Management is a program of the Grounds Department. The primary goal of the program is to provide environmental solid waste disposal alternatives to the Cornell Campus. The program promotes reduction and reuse of materials in addition to offering a comprehensive, convenient recycling program that includes free removal and recycling of old computers.

Currently, over 57% of the waste generated at Cornell University's Ithaca campus is diverted from the landfill. This is a 40% reduction in the amount of waste being landfilled since 1990; approximately 8,000 tons of waste was landfilled in 1990 compared with 4,800 tons in 2004. Of a total waste stream of around 11,300 tons, approximately 2300 tons of material was recycled in 2004 and 4150 tons of organics were composted. Recycled materials include 904 tons of office paper, 694 tons of cardboard, 410 tons of scrap metal, and 104 tons of computers and electronics.



Source: (Cornel Sustainable Campus, 2005)

Figure 2.8 Solid Waste Generations in Cornell University

All offices at Cornell are supplied with a desk-side recycling bin for paper products, and bins for beverage containers and cardboard are located all over campus. Motor oil, tires, scrap metal and some types of batteries, are also recycled (yard waste, organic greenhouse waste and food scraps produced on campus are composted in separate programs). Each week, Cornell custodians collect an average of twenty-five tons of recyclable materials from more than ninety campus buildings. These materials, generated by Cornell's 28,000 faculty, and staff members and students, are placed in large bins by custodians, then the recyclables are taken directly to the county transfer station, sorted and sold to brokers, who in turn sell them to large recycling companies. All revenues are recycled back into the Solid Waste Management budget. (Smithers, 2005)

2.7.5. Case study of Central Arkansas University

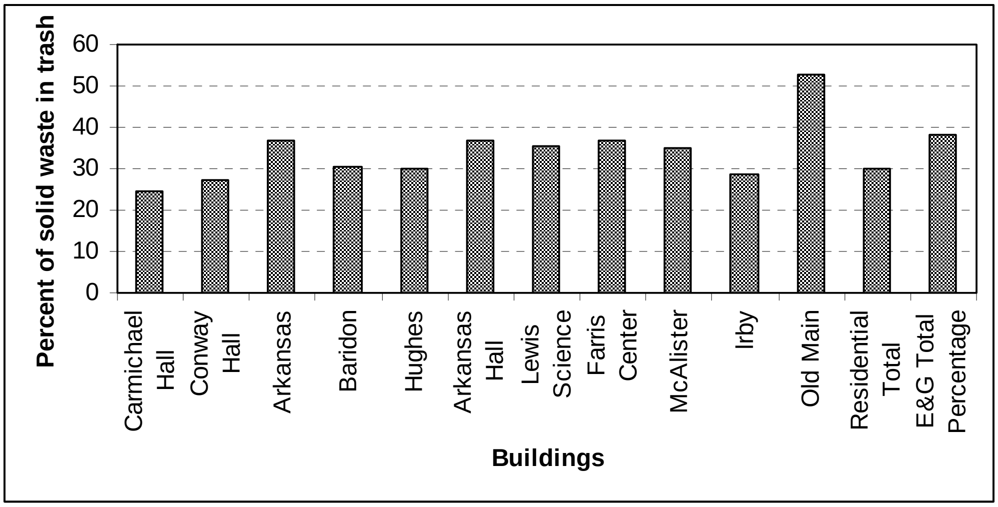
(1) Solid Waste Audits

Throughout the 2003 fiscal year, the University of Central Arkansas dumped 3,600 cubic meters of solid waste into the Faulkner County Landfill. This cost the university $40,770 or roughly $3,400 a month. These numbers are down from the previous year's 4,100 cubic meters of solid waste sent to landfills at a cost of $46,132).

This waste was collected from campus buildings by the university's accommodating waste management team, which works hard to keep the campus clean. Trash is picked up daily from all residential halls, and from Education and General (E&G) buildings on campus. The trash is picked up twice a day in locations considered "high profile." High profile locations include the E&G buildings Old Main, McCastlain, Toreyson Library, Meadors Hall, and New, Minton, Conway, and Baridon residence halls.

(2) Waste Composition Study

A waste composition study was conducted by the auditors and student volunteers to determine the percentage of recyclable material currently being disposed of on the university campus. With the help of Terry Starnes, the auditors selected ten buildings, five residence halls and five E&G buildings for the study, based on the average number of trash bags produced monthly by each building. These buildings included those with and without recycling programs in place. One hundred bags were collected for the analysis. The grounds crew collected two bags of trash randomly from each of the selected buildings for five consecutive days, to obtain the desired 100 bags.



Source: (Maes, Richardson& Walter, 2004)

Figure 2.9 Building audited in waste composition study

(3) Campus Recycling

The university currently has a recycling program that meets the requirement of the State of Arkansas. This program includes the recycling of white office paper and corrugated cardboard collected from E&G buildings on campus. Corrugated cardboard is collected in wire carts behind the Cafeteria and the Student Center, due to the surplus of cardboard Dining Services and the University Book Store discards. After collection, the cardboard is baled and stored onsite until about 15 bales have accumulated.

Due to the fluctuating recycling market, the revenue generated by recyclables varies from one pickup to the next. The revenue, unfortunately, does not go back into the recycling program but into the Physical Plant's general operating fund. However, the most important aspect of this program is that these efforts saved in 2003, 80 cubic meters of landfill space and numerous resources including 541 trees, 842,900 Liters of water, and 45,758 Liters of oil. (Maes, Richardchon & Walter, 2004).

2.7.6 Comparisons of Benchmarks from Each University

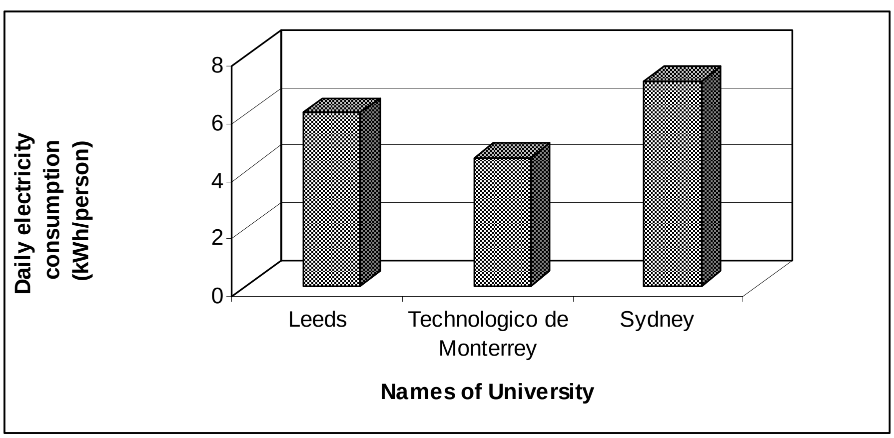
(1) Electricity Consumption

Table 2.1 Benchmarks of Electricity Consumption

No.	Items	Daily energy consumption (kWh/person)	(kWh/m^2)	Remarks
1	University of Toronto	-	0.56	In 2000 (Canada)
2	University of Leeds	6.03	0.30	In 2000 (England)
3	University of Central Arkansas	-	0.28	In 2002 (USA)
4	University of Technologico de Monterrey	4.45	-	In 2002 (Mexico)
5	University of Sydney	7.12	0.21	In 2002 (Australia)
6	Macalester University	-	0.32	In 2003 (USA)

Sources:
University of Toronto = Chagpa et al., 2000
University of Leeds = Stapleton & Fewtrell, 2001
University of Central Arkansas = Maes, Richardson& Walter, 2004
University of Technologico de Monterrey = Technological de Monterrey, 2004
University of Sydney = Ecological Engineering, 2000

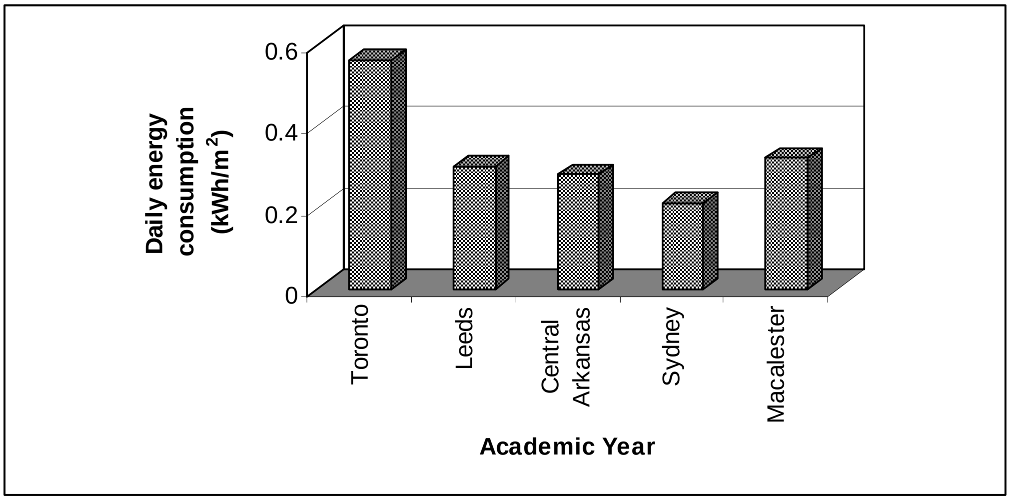
Table 2.1 presents the benchmarks of electricity consumption at various Universities into two units. The first unit is the daily electricity consumption per total residents in the campus and the second unit is the daily electricity consumption per floor space used. The data cannot be recorded in the same year because each University usually has different eco-campus development period. Therefore, it is hardly to get the same academic year. However, it is possible to compare because from 2000 to 2003 the data is not so different.



Source: Stapleton & Fewtrell (2001), Technological de Monterrey (2004), Ecological Engineering (2000)

Figure 2.10 Benchmarks of Electricity Consumption (kWh/person)

From Figure 2.10, it is obvious that Sydney University consumes more electricity comparing with other two Universities, which reach to 7.12 kWh/person. There are several reasons behind this such as Sydney has more electricity equipment usage in the campus, the density of the student is lesser while the electricity uses are higher, the environmental policy of the University more practical, the number of students stayed in the campus is limited, etc.



Source: Chagpa et al. (2000), Stapleton & Fewtrell (2001),
Maes, Richardson & Walter (2004), Ecological Engineering (2000),

Figure 2.11 Benchmarks of Electricity Consumption (kWh/m^2)

When considering the electricity per floor space used, Sydney is the lowest electricity consumption (only 0.21 kWh/m^2), while Toronto University has the highest electricity consumption which leads to 0.56 kWh/m^2. The possible reasons are as following: Toronto University has more density in electronic devices used per floor space. The amount of residential areas in the campus is limited, less awareness for electricity conservation etc.

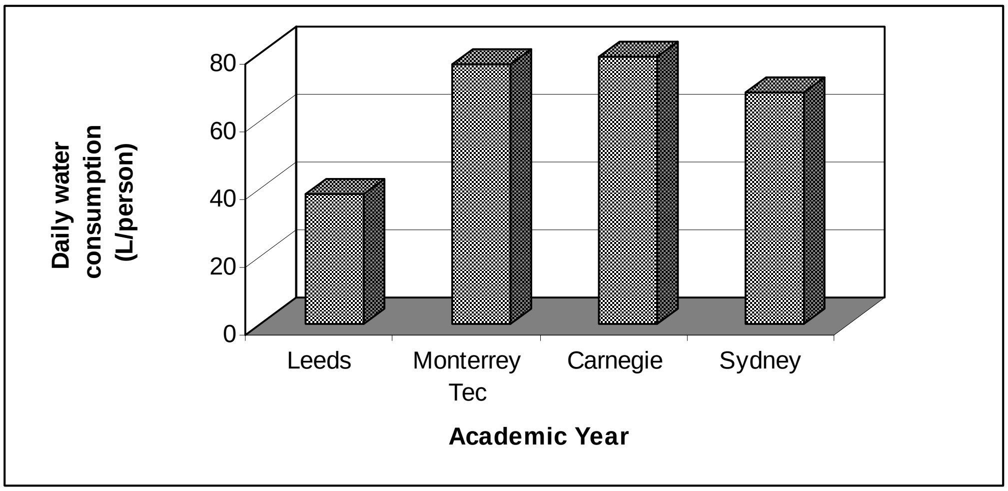
(1) Water Consumption

Table 2.2 Benchmarks of Water Consumption

No.	Items	Daily water consumption		Remarks
		L/person	L/m^2	
1	University of Toronto	-	6.05	In 2000 (Canada)
2	University of Leeds	38.36	-	In 2000 (England)
3	University of Technologico de Monterrey	76.71	-	In 2002 (Mexico)
4	Carnegie Mellon University	78.87	2.69	In 2004 (USA)
5	University of Sydney	68.50	2.06	In 2002 (Australia)

Sources:
University of Toronto **= (**Chagpa et al., 2000)
University of Leeds = (Stapleton & Fewtrell, 2001)
University of Central Arkansas = (Maes, Richardson& Walter, 2004)
University of Technologico de Monterrey = (Technological de Monterrey, 2004)
University of Sydney = (Ecological Engineering, 2000)
Canegie Mellon University = (Tipton & Dzombak, 2005)

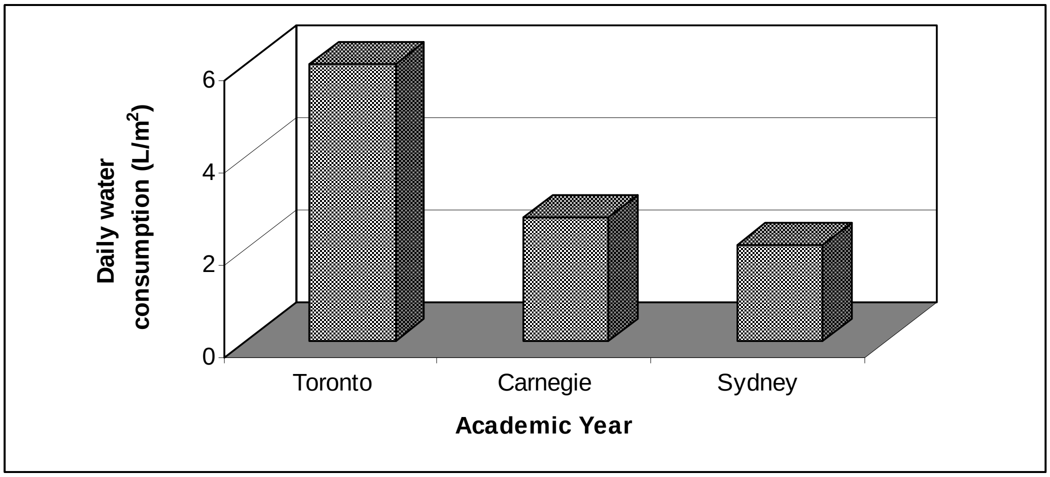
Table 2.2 presents that the University of Leeds consumes almost half of water comparing with other three Universities in various countries when considering in the unit of Liter per person. Conversely, if calculating the water consumption per floor space used. It is found that the water consumption in Toronto University is almost 3 times of water consumption in Carnegie and Sydney University.



Source: Stapleton & Fewtrell (2001), Technological de Monterrey (2004),
Tipton & Dzombak (2005), Ecological Engineering (2000).

Figure 2.12 Benchmarks of Water Consumption (L/person)

Carnegie, Technologico de Moneterrey and Sydney Universities have significantly high compare with Leeds University. The reason may due to Leeds University has less number of residents staying in the campus, the University has set up the leakage detector system which may help to reduce the amount of water leakage. Furthermore, the awareness of people for water conservation is better than other three Universities.



Source: Chagpa et al. (2000), Tipton & Dzombak (2005), Ecological Engineering (2000)

Figure 2.13 Benchmarks of Water Consumption (L/m^2)

Water consumption is quite the same as electricity consumption situation for Sydney University. Sydney has only 2.06 L/m^2 of water consumption. Sydney might have more floor space used and lesser water appliances, while Toronto is opposite. The climate of the region is also one factor that can affect to the water consumption. For the campus that applies heating or cooling, lower temperature may cause less amount of water for cooling but higher temperature may need high amount of water for heating.

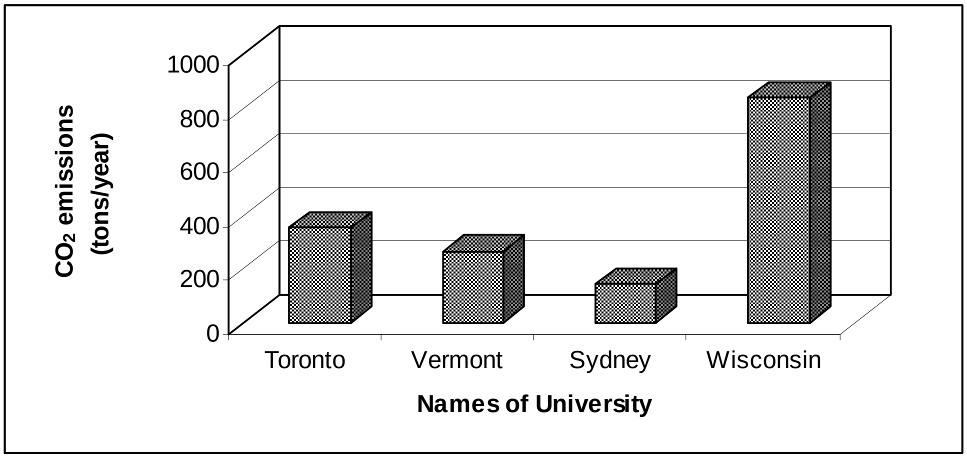
(3) GHG Emissions

Table 2.3 Benchmarks of CO_2 Emissions

Year	Items	CO_2 Emissions (tons/day)	Remarks
2000	Toronto University	355	-
2000	Vermont University	266	-
2002	University of Sydney	142	-
2002	University of Wisconsin Oshkosh	836	-

Sources:
Vermont University = (UVM Environmental Council, 2001)
University of Wisconsin Oshkosh = (Oshkosh, 2003)
University of Toronto **= (**Chagpa et al., 2000)
University of Sydney = (Ecological Engineering, 2000)

Carbon Dioxide is a gas which is not only harmful to the particular country but it leads to the global warming effects to the earth. Therefore, CO_2 emission is one substance that mostly considered by several industrialized countries. In order to solve this problem, several campuses have established more air Pollution Reduction Programs or GHG Emission Reduction Program.



Source: UVM Environmental Council (2001), Oshkosh (2003), Chagpa et al. (2000) Ecological Engineering (2000)

Figure 2.14 Benchmarks of CO_2 Emissions (tons/year)

Green house gases are emitted from several sources in both direct and indirect emissions. Direct emissions include GHG emissions from the landfills, composting site, incinerations, power plants, heating, transportation, etc. Indirect emissions include electricity consumption. Therefore, Wisconsin University may have more GHG emission activities and large amount of electricity consumption inside the campus. At which, Toronto, Vermont and Sydney are having lesser GHG emission activities, respectively.

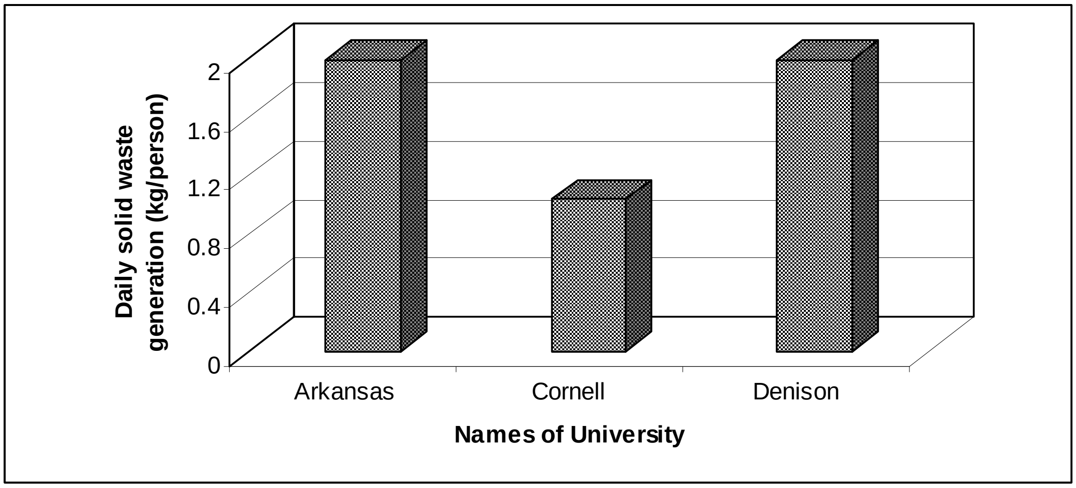
(4) Solid Waste Generation

Table 2.4 Benchmarks of Solid Waste Generation

No.	Items	Daily Solid Waste Generation		Remarks
		kg/person	kg/m^2	
1	University of Central Arkansas	1.99	-	In 2002 (USA)
2	Cornell University	1.04	-	In 2004 (USA)
3	Denison University	1.99	-	In 2000 (Ohio)

Sources:
University of Central Arkansas = (Maes, Richardson& Walter, 2004)
Cornell University = (Smithers, 2005)
Denison University = (Denison University, 2000)

- Cornell University has lesser amount of residents in the campus
- There are lesser recyclable waste in the campus
- Residents have less awareness for campus sustainability
- Packaging materials mostly are non-reusable
- Recycling program is not effective use in the campus
- Etc.



Source: Maes, Richardson & Walter (2004), Smithers (2005), Denison University (2000)

Figure 2.15 Benchmarks of Solid Waste Generation (kg/person)

Chapter 3

Methodology

3.1 Introduction

This study was carried out at the Asian Institute of Technology (AIT). This chapter presents the methodological details of the environmental audit conducted for this research work.

3.2 Primary Data Collection

Most of the primary data and information were obtained from the Student Accommodation Office (SAO), Physical Plant, Tha Kong Municipality. In addition, previous reports on water, waste and electricity were also reviewed. Wherever there was no reliable data, then data were obtained by direct sampling and analysis.

3.2.1 Electricity Consumption

Data that were recorded by Physical Plant from 2000 to 2005 were used, to compare and study the electricity consumption in each building. They were then plotted into a graph for more convenient interpretations. Two specific units that were used to interpret the results are kWh per person and kWh per square meter. However, the data were not always shown in these two units but it depended on the data availability.

3.2.2 Water Consumption and Wastewater Generation

Like electricity consumption, data from Physical Plant from 2002 to 2005 were used to get the initial picture of campus-wide water consumption. The total areas of the campus were divided into several zones and water consumption of each zone had been found in order to determine which zone had much or less amount of water usages. Then, the data were interpreted into two options. The first one was the average water usages per area and another one was the average water usages per person. Then, they were compared with the benchmarks of other campuses. Due to nature of the campus (residential), and most of all differences in climatic condition, culture and traditions, the European and American universities would have different reasons for water consumption compared with AIT campus.

3.2.3 Solid Waste Generation

Since the generations of solid waste from AIT were recorded by the Tha Kong Municipality. An interview with a Tha Kong Municipality's officers was prepared in advanced, in order to get the general information about the AIT waste collections and its disposal. The details of the questionnaires were attached in Appendix G.

3.2.4 Noise Level Investigation

During the primary data collection (campus walk-through), it revealed that noise pollution is not a major issue here in the campus. This depends on many potential indicators such as the environment within the campus, the activity of the students, the machinery used at the experimental works for each school, etc. Though at some selected spots (Chiller room, Ambient Lab and Cafeteria), the data were recoded.

3.3 Energy Audit

Energy auditing was carried out by carefully selecting those facilities and buildings that consumes the maximum power and has the potential to reduce its power consumption, if carefully monitored and maintained. These buildings were initially screened according to their daily power consumption by meter readings. Each selected buildings were monitored for their power consumption rate on three separate periods; (1) examination period, (2) weekend, and (3) semester break period. Then, the graph of hourly electricity consumption of each period was plotted, in order to compare the differences amongst these three graphs. The readings were recorded on hourly based power consumption and discussed for further possible options to reduce its power consumptions.

To estimate the amount of electricity usage at selected residential household, the amount of electricity used for each electronic appliance such as total electricity consumption for using of personal PC, watching television, cooking, etc were considered and recorded. These data were collected by personal communication and questionnaire with the inmate and with their clear consent (Appendix G). Then, a simple formula for estimation had been set up as an example bellow:

Total electricity consumption for an electrical appliance (kW/day)
= [time of use (h/day)] * [amount of electricity consumed in one hour (kWh)] * [No. of Units]

3.4 Water Audit

The procedure for estimation of water usage at selected household was similar to the energy audit. Daily water consumption (such as showering, cooking, toilet flushing, cleaning, washing hand, etc.) in a household was carried out by generating of questionnaires and manual measurement to determine the average and actual water demand (Appendix G). The formula to calculate has been set as an example below:

Total water consumption for showering (L/day)
= [duration of taking shower (min/day)] * [flow rate of showerhead (L/min)]

During water audit, the leakage of water consumption was traced from the pipes, shower heads or faucets of the household usages. This was done by observing the meter reading during the night time which is the time that was estimated as there was no usage of water.

3. 5 Wastewater Audit

For wastewater generation, the audit was conducted at the sump before discharged into AIT oxidation ponds. The difference between the inlet of water supply and the outlet of wastewater at the same duration is considered as “water lost”.

Water Lost = Water supply – Wastewater discharge*

*Wastewater discharge:
= (operational time of the pumps, h/day) × (pumps' capacity, m^3/h)

Figure 3.1 Estimation of Water Lost

For the audit of wastewater quality, the collections of sample were conducted at the inlet and outlet of AIT oxidation ponds and constructed wetlands. The wastewater at the inlet of oxidation ponds were collected 2 times per day (the peak hour of the day and at the normal time). The main purpose of wastewater sampling was for finding the efficiency of the treatment.

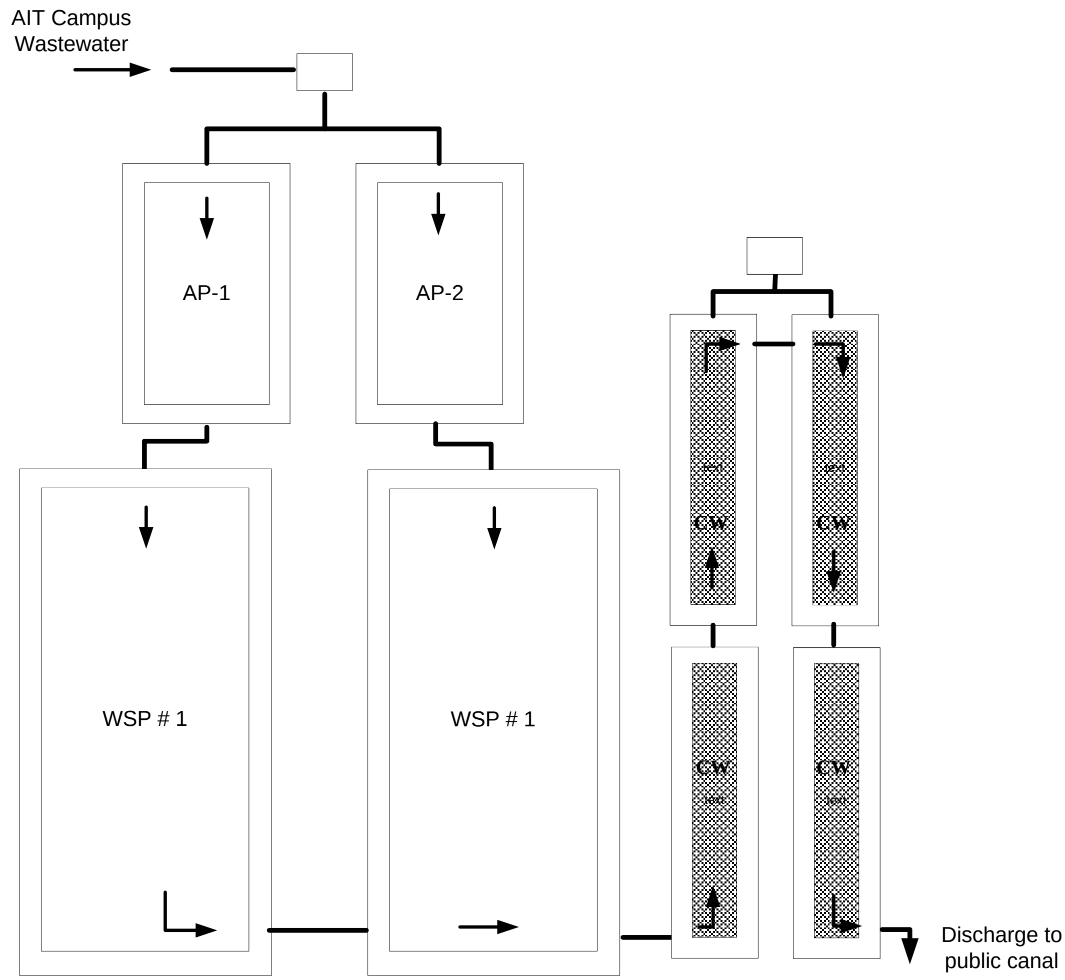


Figure 3.2 AIT Oxidation Ponds and Constructed Wetland

3.6 Noise Level Audit

Noise level audit was carried out by using “Sound Level Meter” equipment. In the selected zones, a sound level meter was used to determine the level of the noise.

- Since the sound level is dependent on environmental conditions such as ambient temperature, relative humidity, and velocity. These parameters were recorded together with the sound measurements.
- The noise spectrum characteristics were drawn base on the maximum sound level of the particular day and particular location.
- The outputs of the data were compared with the standard of noise permissions which were discussed later in Chapter 4.

3.7 GHG Emission Potentials

From total energy consumption, the amount of GHG (Green House Gas) emission was measured. GHG emission includes CO_2, CO, SO_2 and NOx which have been emitted from several sources. Here, in this study, only CO_2 emission from energy consumption was estimated and recorded. It was calculated on the basis of the amount of energy consumption and by using this relation; These conversion factors were obtained from the standard of GHG emissions in Asian countries.

The formula for converting of energy consumption to CO_2 emissions is as following:

CO_2 emission = (kWh of energy consumption) * (Emission Factor)

Where, Emission Factor = 0.58 kg/kWh (Ecosecurities Ltd, 2004)

3.8 Data Interpretations

Data collected from these studies were interpreted in way it could be explicable to most common people and also to those for decision makers.

3.8.1 Eco-Mapping

Following procedures were used for eco-mapping AIT campus;

- Outlining the campus using a scale and showing the interior spaces.
- Integrating different significant objects, identifying academic and residential areas, sports facilities etc. with different legends or colors.
- Developing several kinds of symbols and shapes, depending on types of data that are going to be shown and focused such as energy consumption, water consumption, solid waste generation, etc.

3.8.2 Electricity and Water Consumption Interpretation

- **Trends of Electricity and Water Consumption**

Data maintained and recorded by AIT Physical Plant was used to determine the trend in water and electricity consumption. They were interpreted by plotting the graphs for easier comparison and identifying the major consumers in the eco-map. For electricity consumption, the data were illustrated from the year 2000 onward and for water consumption the data were illustrated from the year 2002 onward. Seasonal Trend of Electricity and Water Consumption were also plotted.

- **Benchmarks of Electricity and Water Consumption**

In order to know whether the consumption of electricity and water at AIT campus is sustainable or not, it is necessary to compare with the benchmarks. These benchmarks are illustrated in Chapter 2.

- **Performance Indicators**

Performance Indicators were developed locally (where ever no suitable reference could be found) to compare for both energy and water consumption. The Performance Indicators are then compared and analyzed as to set a specific target for the coming year and also to interpret the Environmental Performances.

- **Rating of Electricity and Water Consumption at Each Building**

Electricity and water consumption at each building were rated by giving the scores for each building. The scores were ranged from A to C, at which A is the most efficient energy and water consumption, while C is the most inefficient consumption, respectively. The specific units of electricity consumption are kg/(m^2.day) or kg/(person.day) and the specific units of water consumption are L/(m^2.day) or L/(person.day).

3.9 Experimental Procedures

3.9.1 Solid Waste Segregations and Analysis

Different types of solid waste generated in AIT campus were studied for their composition and the possibility of extending its life cycle. Sample waste generated from different facility buildings were collected, studies and compared. The procedures are illustrated in Figure 3.3.

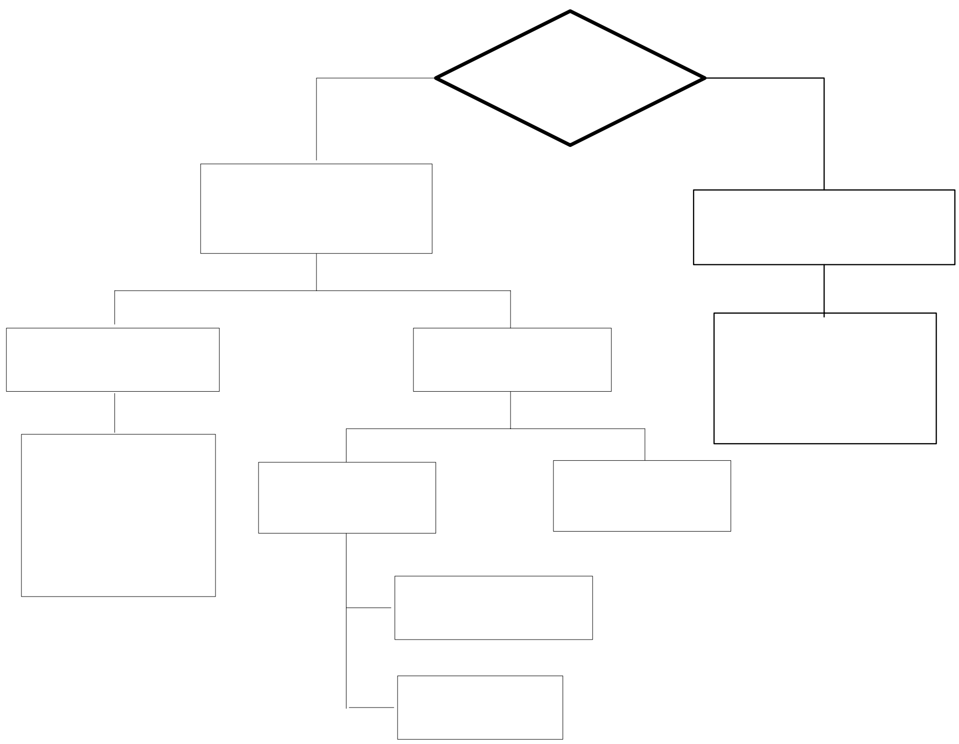


Figure 3.3 Procedures for Segregation and Analysis of Solid Waste

3.10 Analysis

3.10.1 Analyzing Parameters and Analytical Methods

(1) Water and Wastewater Parameters

Water quality was collected at Pathumthani Water Treatment Plant. PWTP has automatically sampled and analyzed the water quality frequently. These parameters indicated in Table 3.1.

Table 3.1 Analytical Parameters and Methods of Water Supply (cite references for each of the analysis)

Parameters	Units	Methods of Analysis	Interference
pH	-	pH meter	Undesirable matter attached to electrode
Color	-	Spectrophotometer	Turbidity interferes
Turbidity	NTU	Turbidimetric	Color or suspended matter in large amounts will interfere
Alkalinity	mg/L	Titration Method	- Soaps, oily matter, suspended solids, or precipitates may coat the glass electrode. - Do not filter, dilute, concentrate or alter sample
Chloride	mg/L	Argentometric	Bromide, Iodine, Cyanide, Sulfide, Thiosulfate, sulfite ions etc.
Free available residual Cl_2	mg/L	Iodometric	Color and turbidity may interfere

Source: (Standard Method, 1998)

Wastewater parameters and Methodology are summarized in Table 3.2.

Table 3.2 Analytical Parameters and Methods of Wastewater

Parameters	Units	Methods of Analysis	Interference
pH	-	pH meter	Undesirable matter attached to electrode
Temperature	° C	Digital Temperature detector	Temperature gradient, poor thermal contact, calibration drifts, etc.
COD	mg/L	Closed Dichromate Reflux Titrimetric	Volatile chain, , Cl^-, NO^{2-}, Cr.
BOD_5	mg/L	Azide Modification	pH, Cl^- residual, toxic metal, temperature
TSS	mg/L	Gravimetric analysis	Improper sampling procedure and weighing
TDS	mg/L	Gravimetric analysis	Improper sampling procedure and weighing

Source: (Standard Method, 1998)

(2) Solid Waste Characteristics

Methodology that was used in defining the solid waste's physical and chemical characteristics is the quartering Method. The parameters are as following:

Table 3.3 Physical and Chemical Characteristics of Solid Waste

Parameter	Units	Analytical method	Interferences
Solid waste Compositions	kg	Quartering method, hand sorting and weighting	-
MC	%	Gravimetric analysis	Improper sampling procedure and weighing
TS	%	Gravimetric analysis	Improper sampling procedure and weighing

Source: (Standard Method, 1998)

- Determination of Moisture Content

$$\% \, MC = \frac{(1000 - W_0)}{1000} \times 100\% \qquad \text{Eq. 3.3}$$

W_0 = Weight of solid waste after dried at 105°C

$$\% \, TS = 100\% - \% \, MC \qquad \text{Eq. 3.4}$$

- Determination of Volatile Solids

$$\% \, VS = \frac{(W_0 - W_f)}{W_0 - W_f} \times 100\% \qquad \text{Eq. 3.5}$$

W_0 = Weight of solid waste after dried at 105°C
W_f = Weight of solid waste after dried at 550°C

(3) Noise Level Parameters

Noise level parameters that are necessary to be analyzed are as bellow:

L_{eq} = Equivalent continuous sound pressure level
L_E = Sound exposure level
L_x = Percentile sound pressure level
L_{max} = Maximum sound pressure level

The measurement procedure for L_{eq},, L_E, L_x and L_{max} is referred from the instruction manual (NL-04/NL-14 Instruction Manual, 1996).

The detailed information of Integrating Sound Level Meter is as following:

Equipment: Integrating Sound Level Meter
Range: 40 – 100 dB
Accuracy: 0.1 dB

Interference: Error due to the depletion of battery
Manufacturer: RION co., LTD Tokyo, Japan

3.11 Determination of Environmental Issues and Recommendations for CP Options

Since the results of these campus audits had been obtained from the analysis of various parameters. These results were then compared with the standards emissions and compared with benchmarks in several European Universities such as Universities of Toronto, Leeds, Technological of Monterrey, Sydney, Carnegie Mellon, etc. The environmental issues concerning the campus and their causes were identified by campus walk-though and few Cleaner Production options were also proposed wherever needed.

Possibility of reusing the treated wastewater (for gardening and lawn spraying) was explored. This was done by comparing the type II water quality and the effluent quality of the treated wastewater from the AIT oxidation pond.

Chapter 4

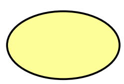
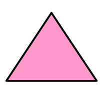
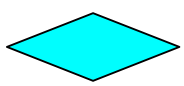
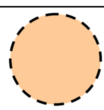
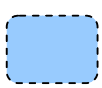
Results and Discussions

4.1 Eco-Map of AIT Campus

According to a walk-through inspection, primary and secondary data collections, the eco-map of the AIT campus has been established as shown in Figure 4.1. In the figure, five indicators of the problematic areas have been focused on: high water consumption and wastewater generations, high electricity consumption, major solid waste generation points, high noise zones and places of odor pollution.

Huge water consumption and wastewater generation are generally found in the residential areas and AITCC. High electricity consumption is usually seen at residential areas especially, especially dormitories with air-conditioners, North and South academic buildings and chiller room. Huge amount of solid waste generations is usually observed in the residential areas, with cooking facilities, AITCC and the cafeteria. Noise pollution is found in the chiller room and ambient lab. The last indicator is odor pollution, places where the interruption of odor always poses as an issue.

Table 4.1 Legends and Descriptions of Eco-Map

Legends	**Descriptions**
	Huge water consumption and wastewater generation
	Huge electricity consumption
	Huge solid waste generation - Kitchen waste
	Noise pollution - From the chillers room
	Odor - From the solid waste collection site
	Bad practices

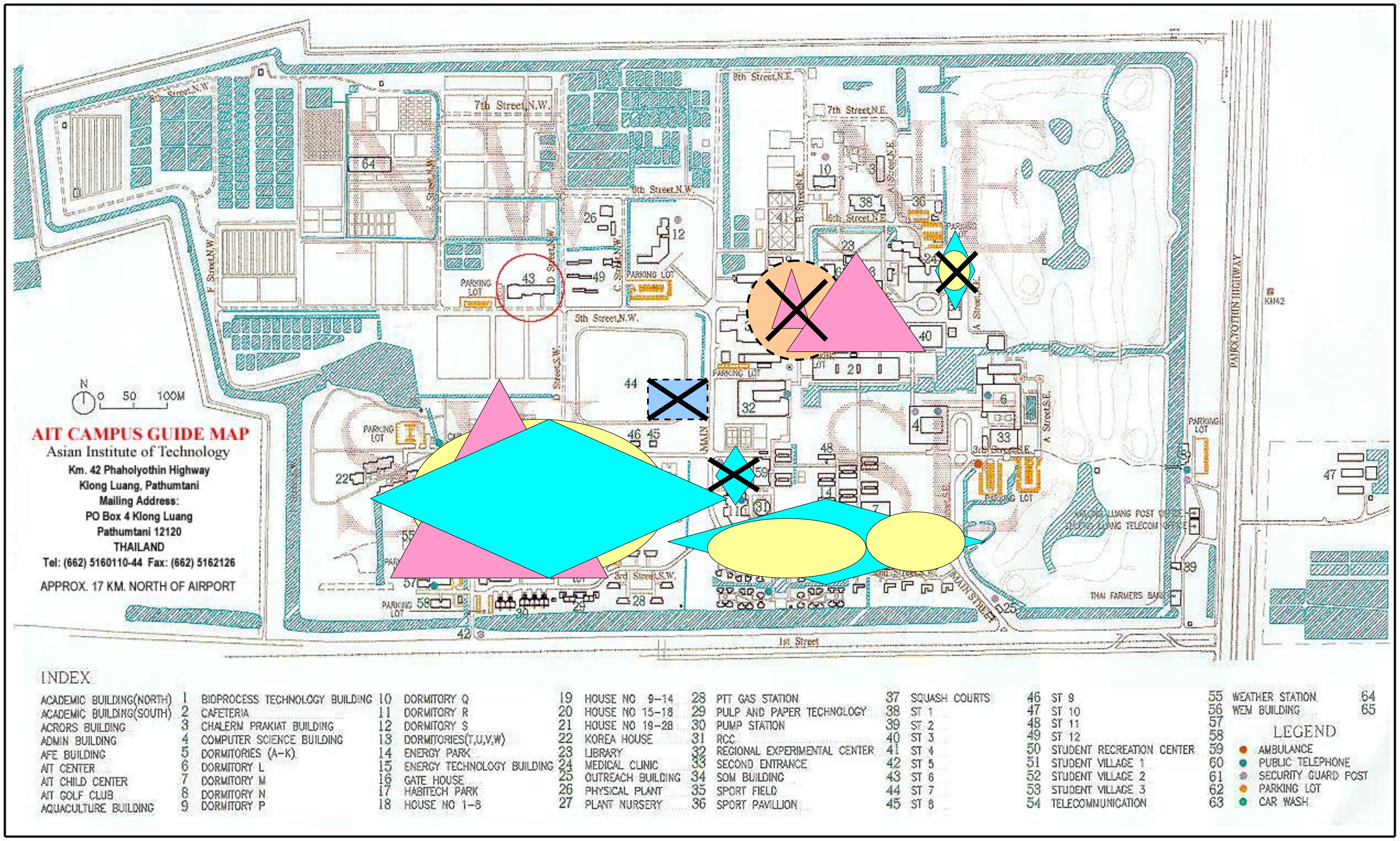


Figure 4.1 Eco-Map of AIT Campus

4.2 Electricity Consumption

The average population of AIT is about 3,800 (Physical Plant, 2005) and the average electricity consumption was about 13.50 Million kWh in 2005. Around 23 Million Baht was spent in 2005 (Appendix A) towards electricity bills alone. In simple terms, this is the amount to be spent on electricity, to operate AIT functionally (as of today) with the total enrolled staff and students, each individual consuming about 2.93 kWh/day, the academic and administrative buildings consuming about 7.50 kWh/day in 2005. Figure 4.2 shows that the trend of electricity consumption from 2004 to 2005 in the residential areas seems to be considerably increased. Even though the number of residents is increased in each year but the usage of electrical appliances has also been increased in each household such as computers, televisions, refrigerators, ovens, microwaves, etc. This may cause the increase of electricity consumption.

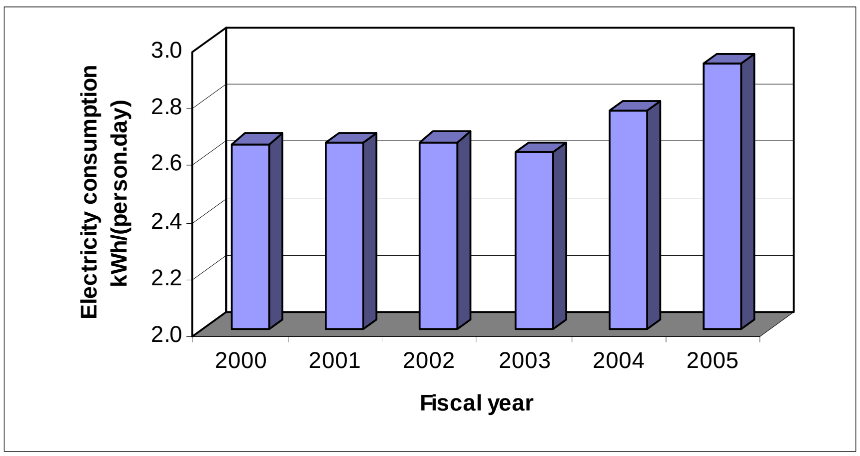


Figure 4.2 Electricity Consumption in Residential Areas (2000 – 2005)

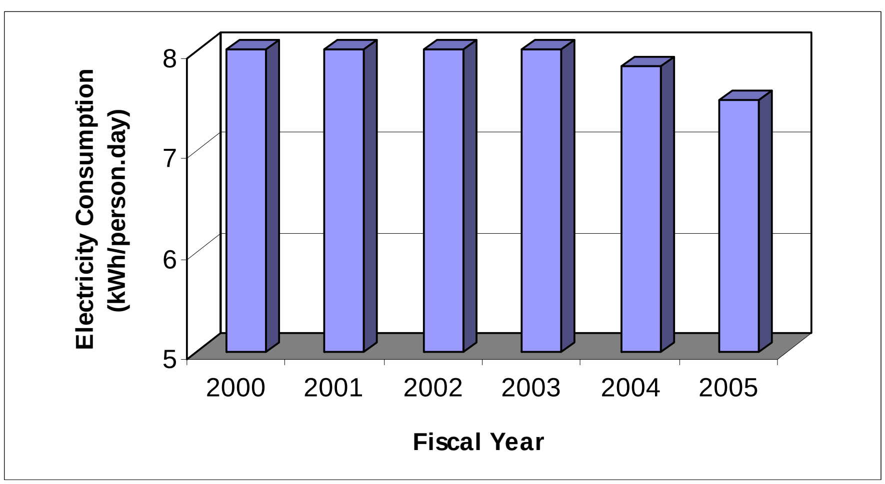


Figure 4.3 Electricity Consumption in Academic and Administrative buildings (2000 – 2005)

Figure 4.3 indicates that, the amount of electricity consumption has been slightly decreased from 8.01 to 7.50 kWh/day (2003-2005). The decreasing trend could be due to the technological advancement, many faculty, offices and students use more LCD monitor (flat panel) computers or laptops. These kinds of PCs reduce the amount of electricity consumption significantly (Bluejay, 2005). A typical desktop computer with a CRT monitor uses about 0.120-0.145 kWh, while that with an LCD monitor (flat panel) uses only 0.09-0.1 kWh and a laptop uses only 0.015-0.045 kWh. This shows that, even though the students increase every year, the electricity has been reducing compared to 2000 - 2003.

4.2.1 Comparisons of Electricity Consumption

Table 4.2 below shows the comparisons of electricity consumption between AIT and other countries. AIT campus is located in the urban area, several kinds of electric appliances are used, so, the daily electricity consumption per capita is higher compared with other countries. An average electricity consumption per capita in Thailand is highest compared to the neighboring countries, this depends on the availability of electricity in all over the country. Cambodia is one of the lowest per capita electricity consumption in Southeast Asia. In rural areas, electricity is available only to about 5 percent of the rural households (Asian Center for Electricity, 2004).

Table 4.2 Comparisons of Electricity Consumption in Residential Areas

No.	Items	Electricity Consumption kWh/(capita.day)	Remark
1	AIT	2.93	2005
2	Thailand	3.97	-
3	Laos	0.31	1999
4	China	2.26	-
5	Vietnam	0.78	-
6	Burma	0.19	-
7	Cambodia	0.09	-

Sources: Asian Center for Electricity. (2004), Imaging Our Mekong. (2005)

4.2.2 Benchmarks of Electricity Consumption

Table 4.3 Benchmarks of Electricity Consumption in Academic and Administrative buildings

No.	Items	Daily Electricity Consumption (kWh/person)	Remark
1	AIT	7.50	Thailand (2005)
2	University of Leeds	6.03	England (2000)
3	University of Technologico de Monterrey	4.45	Mexico (2002)
4	University of Sydney	7.12	Australia (2002)

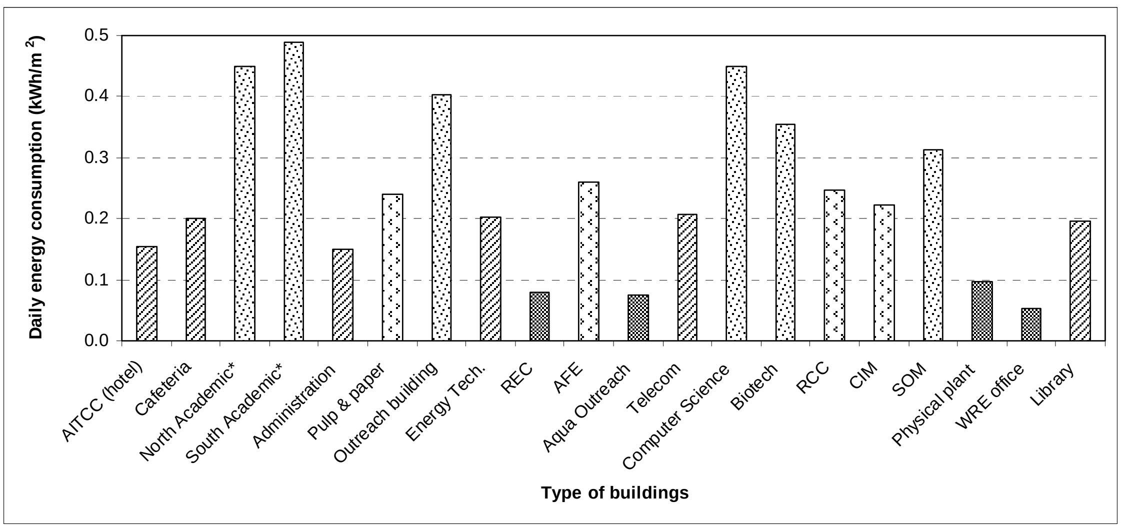
Sources:

Chagpa et al. (2000); Stapleton & Fewtrell (2001); Maes, Richardson & Walter (2004); Technological de Monterrey (2004); Ecological Engineering (2000)

The benchmark comparisons reveal that, the average electricity consumption at AIT is 7.50 kWh/person, which is considerably higher than the University of Leeds Metropolitan and the University of Technologico de Monterrey, respectively. The reason of higher consumption of electricity is because AIT has fewer residents compared to the number of electronic devices.

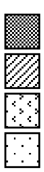
4.2.3 Rating of Electricity Consumption at Each Building

To figure out which building consumes high or less electricity or which building needs to be focused on. It is necessary to rate the electricity into different category. The high effiThe detailed electricity consumption at each building in AIT has been attached in Appendix F, Table F1. The targeted electricity consumption for the campus has been selected from the most electricity efficient building.

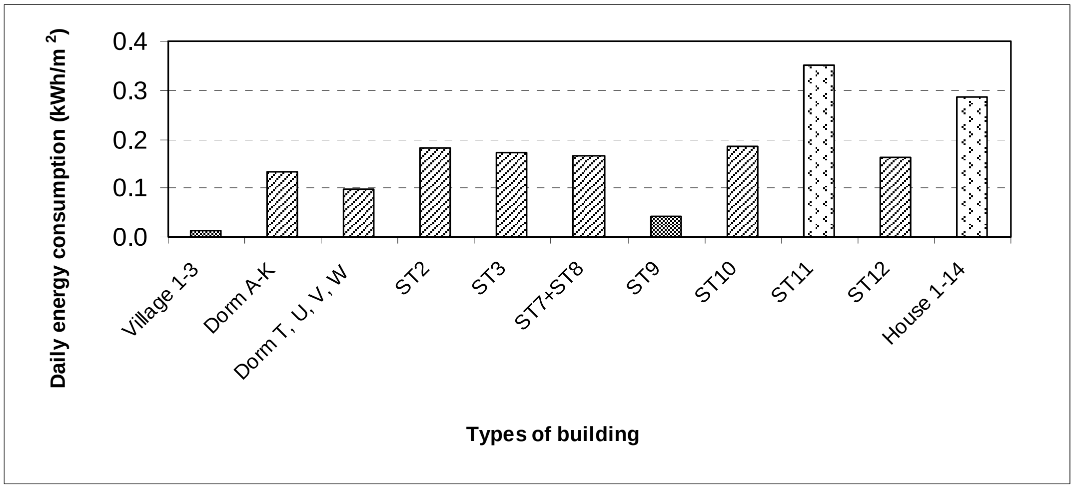


Source: Physical Plant (2005)

Figure 4.4 Rating of Electricity Consumption at each Office Building (2005)


Electricity consumption type "A"
Electricity consumption type "B"
Electricity consumption type "C"
Electricity consumption type "D"

The buildings that have electricity consumption from 0.01 to 0.1 kWh per square meter are rated "A", from 0.11 – 0.20 are rated "B", from 0.21 – 0.30 are rated "C" and more than 0.30 are rated "D", respectively. The most electricity efficient building is the WRE (Water Resource Engineering) office. It consumes only 0.052 kWh of electricity per square meter. This building has lowest Electricity consumption because the main compositions of this building are a non-air lab and offices that do not require much electricity. The most inefficient electricity consumption is the South Academic that consumes about 0.49 kWh per square meter.



Source: Physical Plant (2005)

Figure 4.5 Rating of Electricity Consumption at each Dormitory (2005)

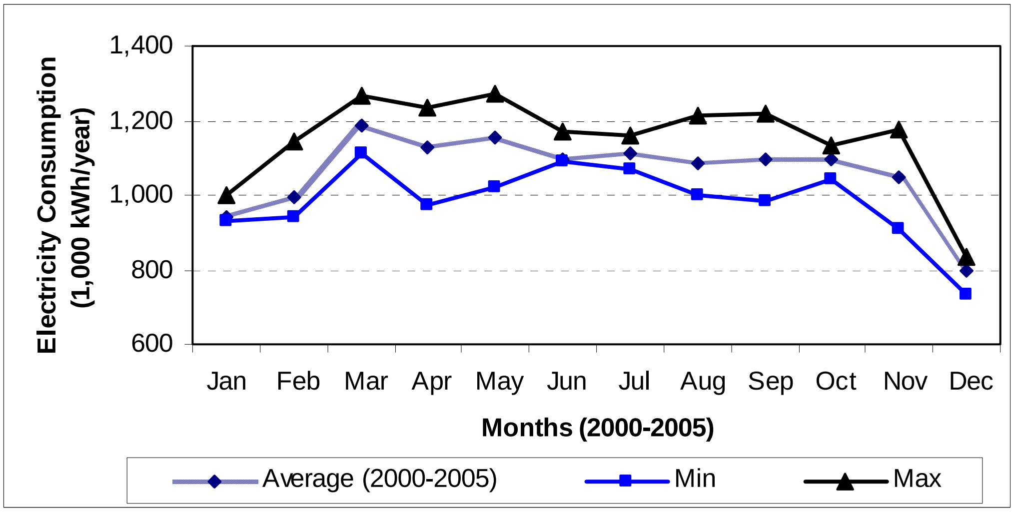
Electricity consumption type “A”
Electricity consumption type “B”
Electricity consumption type “C”

At the AIT campus, there are several types of accommodation as shown in Figure 4.7. The dwelling units hosted by staff are named ST, the rest are dormitories for students. From Figure 4.5, the most efficient electricity consumption is the Villages which consume about 0.0012 kWh of electricity per square meter. The reason being, these villages do not include air-conditioners, there is only one medium size refrigerator provided for each floor which also includes a bathroom with a toilet. The residents usually use cooking gas, they rarely use electronic plates. These reason all contribute to why the Villages consume lowest amount of electricity.

ST11 and houses usually consume the highest electricity each year. The majority of these buildings include air-conditioners and cooking facilities for each household. The electronic appliances normally vary in the staff dorms include: personal computers, televisions, radios, ovens, washing machines, electronic plates, water pots etc. These cause a shift in electricity consumption.

4.2.4 Seasonal Trends of Electricity Consumption

Figure 4.6 shows the seasonal variation of electricity consumption from the years 2000 to 2004. The average electricity consumption peaked in March to 1.17 Million kWh and steadily decreased between April and November. The minimum consumption of electricity was in December, with only 0.8 million kWh (Source: Physical Plant).

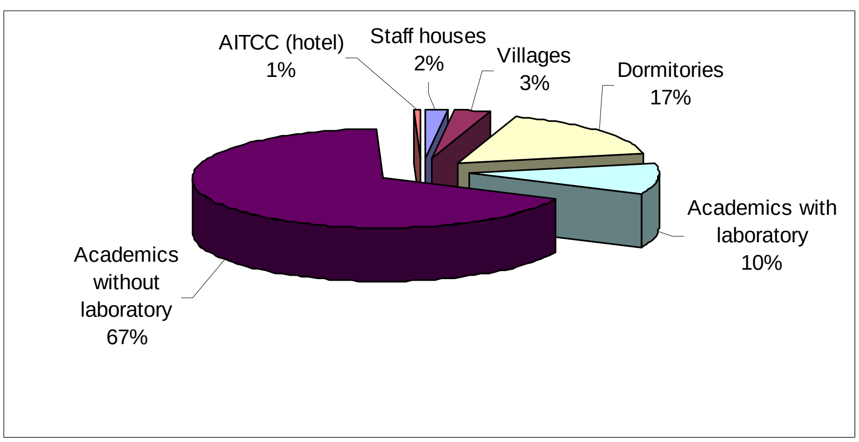


Source: Physical Plant (2005)

Figure 4.6 Average Seasonal Trends of Electricity Consumption from 2000 to 2005

The main reason for the maximum consumption of power in March is due to the temperature. Generally, Thailand experiences tropical climatic conditions throughout the year. The main power consumption is usually from the cooling device, air conditioners or fans. At AIT, all buildings and residential units are fitted with air conditioners (new and old models) which consume the maximum electricity compared to other devices.

With the warm temperatures in Thailand from March to November, the installed cooling devices are active almost throughout the year. Figure 4.6 depicts the Electricity consumption in each zone/ facility in AIT in 2004.



Source: Physical Plant (2005)

Figure 4.7 Percentage of Electricity Consumption at AIT (2005)

The academics without laboratory include offices, vendors, restaurants, child centers, library, shops, etc. This whole group consumes more than 60% of the total electricity. The second highest Electricity consumption is the dormitories areas and academic buildings with the laboratory which includes SERD building, Regional Experimental Center, etc. For the detailed electricity consumption of each building, please refer to Appendix A, Table A3 to A8.

4.2.5 Snapshots of Major Power Consuming Electrical Appliances

(a) Computer usages

(b) Cooling Towers in Chiller room

(c) Air conditioners

(d) EEM Lab

Figure 4.8 Snapshots of Major Power Consuming Electrical Appliances

Computer rooms are another area where high amounts of electricity are consumed each day. Computers in these rooms usually consume about 0.12-0.145 kWh. In one computer room, there are at least 40 computers along with other devices such as printers, servers, air conditioners and light bulbs. These devices are active all day.

The chiller room controls the temperature to most of the office buildings in AIT, except the residential areas. This facility consists of 4 chillers and other necessary electrical appliances such as cooling towers and pumps. Each year, about 30% of Electricity consumption in the campus is consumed by this room. Whenever a leak occurs, huge amounts of Electricity could be lost.

More often, laboratories consume both larger amounts of electricity and water than the office areas. This is true because electrical appliances including ovens, low temperature refrigerators, water baths or steamers, hoods, ventilations, etc. have been installed.

Furthermore, the light bulbs in this room have to be replaced more often than other places. In addition, the students usually are less aware in electricity conservation.

4.2.6 Green House Gas emissions

There are two types of GHG emissions, direct and indirect. In this study, only GHG emissions from electricity consumption are considered. CO_2 is the major emission from electricity sources.

Table 4.4 GHG Emissions from Electricity Consumption at AIT Campus

Year	Electricity consumption (kWh/day)	CO_2 emissions (tons/day)
2000	32,690	18.96
2001	33,390	19.37
2002	33,820	19.62
2003	35,930	20.84
2004	36,480	21.16
2005	36,970	21.44

Remark: Source: Physical Plant (2005)
CO_2 emission = (kWh of Electricity consumption) * (Emission Factor)
Where, Emission Factor = 0. 58 kg CO_2/kWh (Ecosecurities Ltd, 2004)

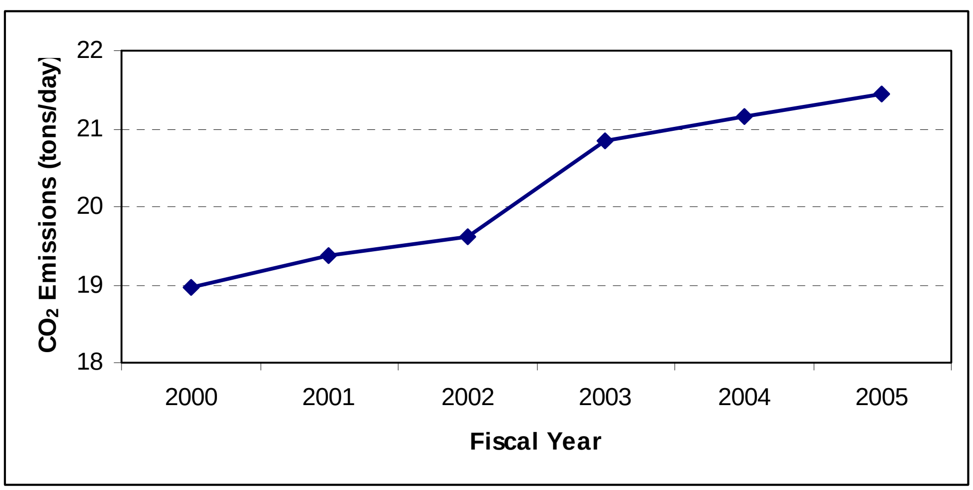


Figure 4.9 Yearly CO_2 Emissions

The trend of CO_2 emissions seem to be slightly increased from year to year (Figure 4.9) because the electricity consumption at the campus does not seem to be reduced. However, the potential factor that leads to more or less CO_2 emissions is not only the amount of Electricity consumption. But Emission Factor is also played an important role. Emission Factor depends mainly on the resources of raw materials used to produce Electricity Power Plant. Therefore, the most efficient way to reduce GHG emissions as well as CO_2 emissions can be implemented in two ways. The first way is “electricity conservation” and the second one is “clean electricity”.

4.2.7 GHG Comparisons

Table 4.5 Comparisons of CO_2 Emissions from Electricity Consumption

Year	Campus	Electricity Consumption (kWh/day)	CO_2 Emission Factors (kg/kWh)	CO_2 Emission (tons/day)
2005	AIT	36,970	0.580	13.20
2003	Atlantic Region	33,458	0.176	5.89
2003	Quebec	84,827	0.176	14.93
2003	Ontario	79,834	0.176	14.04
2003	Prairies	78,744	0.176	13.88
2003	British/Columbia and Territories	70,979	0.176	12.55

Source: Ecosecurities Ltd. (2004)
Natural Resources Canada (2003)

To calculate the volumes of GHG emissions, all campus in Canada used the emissions factors calculated on a national, not regional, basis. These factors are set by Environment Canada (2003).

National GHG Emission Factor in Canada = 0.220 kg/kWh, it is assumed that 80% of total GHG emission is CO_2. Therefore, CO_2 Emission Factor = 0.176 kg/kWh.

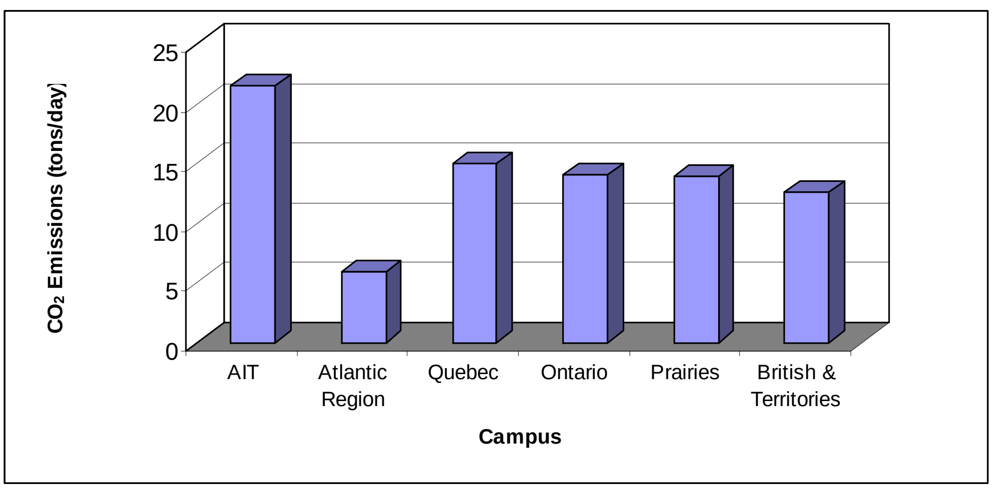


Figure 4.10 Benchmarks of CO_2 Emission based on Electricity Consumption

Figure 4.10 shows that Carbon Dioxide emission at AIT campus does not much different from other campuses in Canada, except Atlantic region. This region consumed about 33,458 kWh of electricity in 2003, which is slightly less than the electricity consumption at AIT. But CO_2 emission at Atlantic was 50% less than CO_2 emission at AIT. It is noted that the potential factor for making this big difference is Emission Factor. Emission Factor for electricity consumption in Thailand is double compared to Canada's. This depends mainly on the source of Power Generator for each country.

4.2.8 Renewable Electricity Potentials at AIT Campus

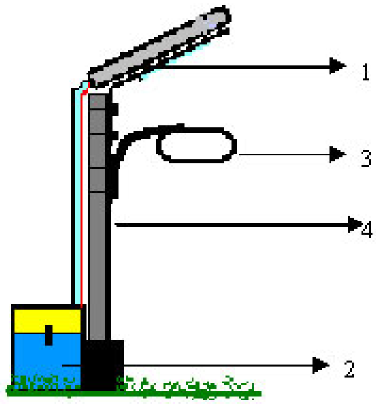
In contrast to fossil and nuclear fuels, renewable Electricity offers alternative sources of Electricity for the future that add little to the pollution and waste problems caused by fossil fuels (Bruce and Pickering, 2000). In case of AIT, the potential renewable Electricity can be the solar Electricity, biomass and burning waste. These would need to be deployed on a vast scale to replace our current use of fossil fuels.

To reduce GHG emission, there are many ways to do such as reduce Electricity consumption which can reduce large amount of CO_2 emission from the power plant. Solid waste generation reduction is the best way to reduce large amount of CH_4 generation.

- **Solar Street Light**

In 2005, AIT spent about 16,928 kWh for the street light around the campus that caused about 51,800 Baht/year. If all or some amount of Electricity consumption in the street light is replaced by solar Electricity, this can also save several hundreds Baht in each year.

Solar Street light is the well known solar Electricity implementation in several projects e.g. East Grand Forks, Green Sydney Olympic in Australia, etc. This system is designed for outdoor application in un-electrified remote rural areas. This system is an ideal application for campus and village street lighting. The system is provided with battery storage backup sufficient to operate the light for 10-11 hours daily. The system is provided with automatic ON/OFF time switch for dusk to down operation and overcharge/deep discharge prevention cut-off with LED (Light Emitting Diode) indicators. (Gujarat Electricity Development Agency, 2003).



1. SPV (Solar Photovoltaic) Module
2. Battery Box
3. Lamp with charge controller
4. Lamp Post

Source: Gujarat Electricity Development Agency. (2003)

Figure 4.11 Solar Street Lights

Figure 4.12 Solar Street Lights in East Grand Forks, Minnesota

4.3 Water Consumption

- **Type I**: **Water Supply from Pathumthani Water Treatment Plant**

There are two sources of water to AIT; Type I: water supplied from Pathumthani Municipality and Type II: is water generated from AIT's ponds and canal. Water from AIT's ponds and canal are used for gardening alone, for all other purposes water supplied from Pathumthani Water Treatment Plant is used. In 2005, AIT spent more than 8 million Baht for the water consumption of about 0.4 million cubic meters. The per capita water consumption in the residential areas and academic areas is about 253 L and 173 L which cost about 4.19 and 2.86 Baht/person in 2005. A schematic diagram of the treatment process in Pathumthani Water Treatment Plant is shown in Figure 4.13 below:

Figure 4.13 Pathumthani Water Treatment Plant

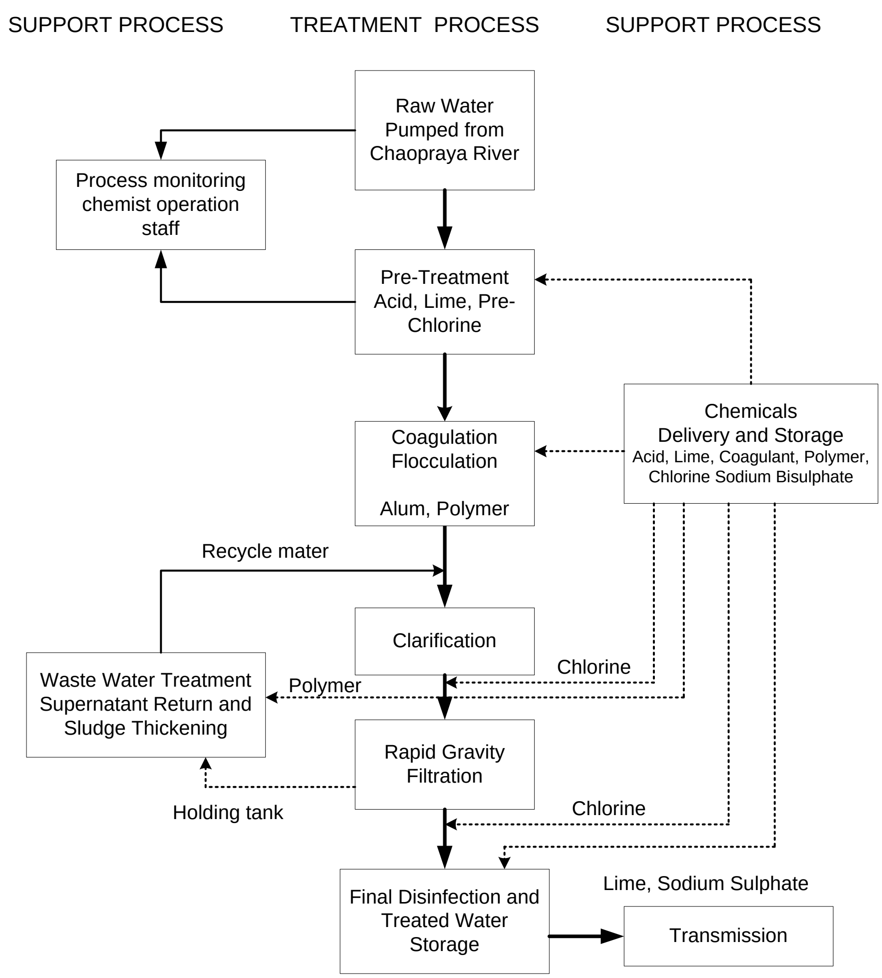


Figure 4.14 Process Diagram of Pathumthani Water Treatment Plant

Pathumthani Water Treatment Plant distributes water to three main zones; Rangsit, Pathumthani and Thammasat. AIT receives water from the Thammasat zone. The plant receiveing raw water from Chaopraya River has a capacity of 0.288million m^3/day. The intake is located about 1 km away from this plant. The characteristics of the distributed water are presented in Table 4.6.

Table 4.6 Water Characteristics of Pathumthani WTP

Parameters	Units	Raw water quality	Treated water quality	Removal efficiency (%)	Thai effluent standard
pH	-	7.3	6.86	-	6.5-8.5
Temperature	•C	28.53	28.42	-	-
Colour	Pt-Co	26	2	92.3	< 5
Turbidity	NTU	54	0.09	99.8	< 5
Electrical conductivity	μS/cm	253	282	-	-
Total Solids	mg/L	213	193	9.4	< 500
Total chlorine	mg/L	-	1.87	-	-
Free chlorine	mg/L	-	1.69	-	> 0.8

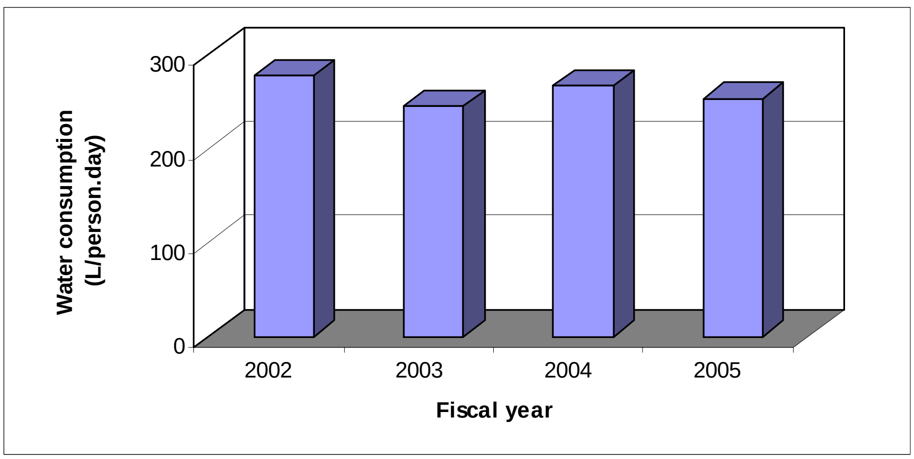


Figure 4.15 Water Consumption in Residential Areas (2002 – 2005)

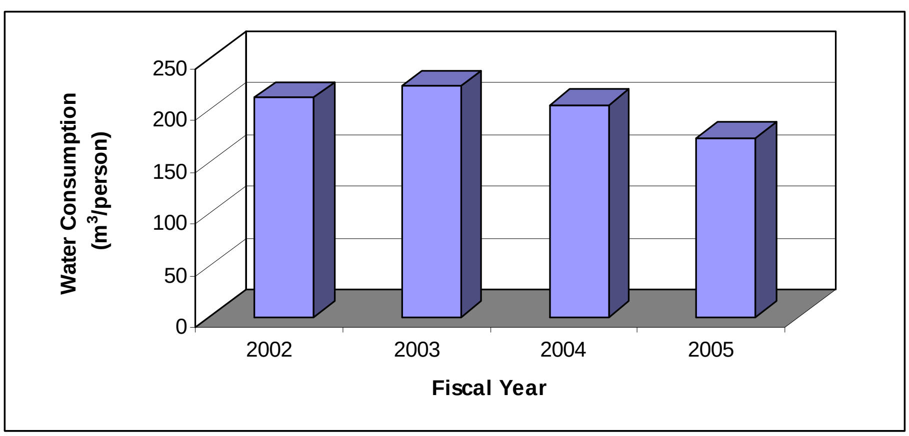


Figure 4.16 Water Consumption in Academic and Administrative Buildings (2002 – 2005)

Figure 4.15 and 4.16 indicates that the water consumption has gradually decreased from 2002 to 2004. The reasons are as follows:

- From 2002 to 2004, the number of residents has increased. But the accommodation facilities have not increased proportionally. Due to this reason, about 31% of students and staff have to stay outside the campus. (Housing Unit and SAO, 2005). Even though the number of students and staff has increased, only 31% of the people use the water supply during working hours. Therefore, per capita water consumption has decreased.
- The actual water consumption from 2002 to 2005 is 1,412 m^3/d, 1,436 m^3/d, 1,469 m^3/d and 1,357 m^3/d, respectively. These data show that the average daily water consumption in each year does not much different compared to the expected increase of the population. In contrast, the trend seems to be reduced. A possibility of water reduction may due to the repair and maintenance. The repair and maintenance of the old faucets, pipes, valves, etc. can reduce vast amount of leakage.
- Some kind of residential areas such as standard dormitories, about 50% of the rooms in M, N, P, Q, R and S dorms and some staff areas do not have cooking facilities People in these areas have their meals in the cafeteria and restaurants. This could be a potential cause of reduction in per capita water consumption.

4.3.1 Comparisons of Water Consumption in Residential Areas

The per capita consumption is related to the economic development of the country as this directly determines the lifestyle of the people. As illustrates in Table 4.7, AIT, Bangkok Metropolitan and Japan has per capita water consumption more than 253 L/person.day, while Lao PDR has only 94 L/person.day (average water consumption in all over the country). This shows that the urban areas where are more developed always consume high water compared to the rural areas.

Table 4.7 Comparisons of Water Consumption in Residential Areas

No.	Items	Water Consumption (L/capita.day)	Remark
1	AIT	253	2005
2	Lao PDR	94	2001
3	Bangkok	265	-
4	Hong Kong	112	-
4	Japan	300-400	-

Source: Lao PDR Country Report, (2001);
Safe Water and International Cooperation, (2005)

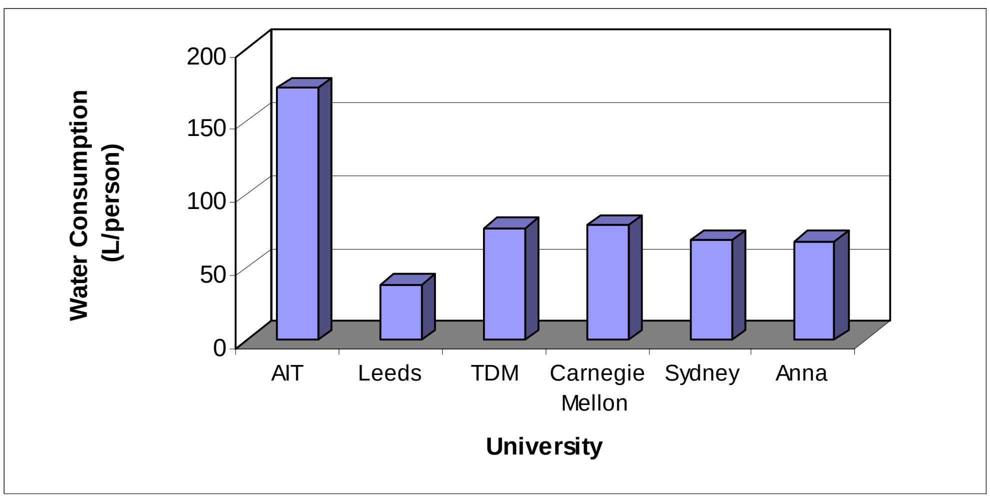
4.3.2 Benchmarks of Water Consumption in Academic and Administrative Buildings

Table 4.8 Benchmarks of Water Consumption in Academic and Administrative Buildings

No.	Items	Daily Water Consumption (L/person)	Remarks
1	AIT	173.00	In 2005 (Thailand)
2	University of Leeds	38.36	In 2000 (England)
3	University of Technologico de Monterrey	76.71	In 2002 (Mexico)
4	Carnegie Mellon University	78.87	In 2004 (USA)
5	University of Sydney	68.50	In 2002 (Australia)
6	Anna University	68.00	In 2005 (India)

Source:

Chagpa et al. (2000), Stapleton & Fewtrell (2001), Maes, Richardson & Walter (2004) Technological de Monterrey (2004), Ecological Engineering (2000), Tipton & Dzombak (2005)



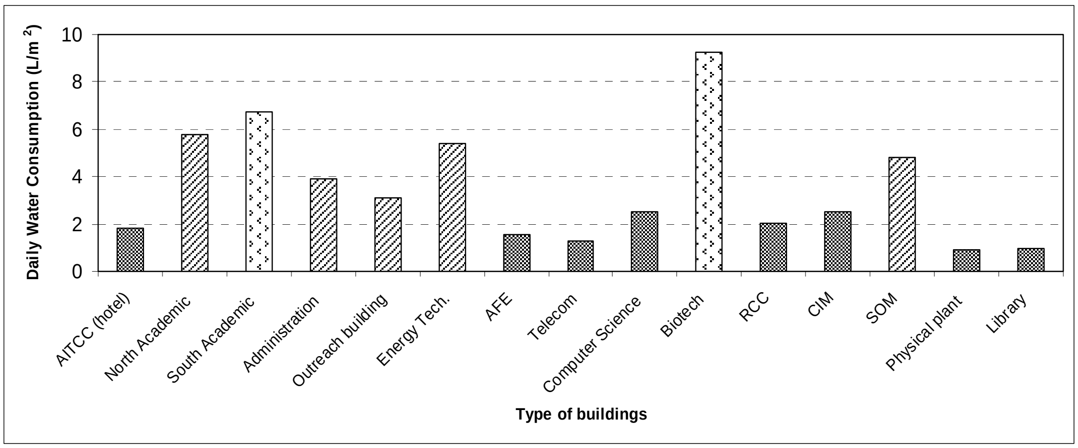
Sources: Stapleton & Fewtrell (2001); Technological de Monterrey (2004); Ecological Engineering (2000); Tipton & Dzombak (2005)

Figure 4.17 Benchmarks of Water Consumption in Academic and Administrative Buildings

AIT seems to have the highest specific water consumption in either liter per person or liter per square meter compared to the benchmarks. The reasons are as follows:

- Cost of water in Thailand is much less than compared with other developed countries. (Physical Plant, 2005).
- Warm climate condition causes more water consumption with showering and cooling (in the chiller room).
- There is no any water leakage detection in the water supply system. Therefore, water leakage is quite high, ranged from 6 – 21% in 2005 (Physical Plant, 2005).
- Some water appliances are inefficient such as toilets flush valves and faucets, high flow rates are required for these appliances.

4.3.3 Rating of Water Consumption at each Building



Source: Physical Plant (2005)

Figure 4.18 Rating of Water Consumption at Academics and Administrations (2005)

Water consumption type “A”
Water consumption type “B”
Water consumption type “C”

The detailed water consumption of Figure 4.18 has been attached in Appendix F. The most efficient water consumption at each building ranges from 1 to 3 L/m^2 that are set as grade A. Furthermore, the buildings that have water consumption from 3.1 to 6 L/m^2 and from 6.1 to 10 are set as grade B and C, respectively. As illustrated in Figure 4.18, Biotech and South Academic building seem to have the highest amount of water consumption compared to the floor space of the building, respectively.

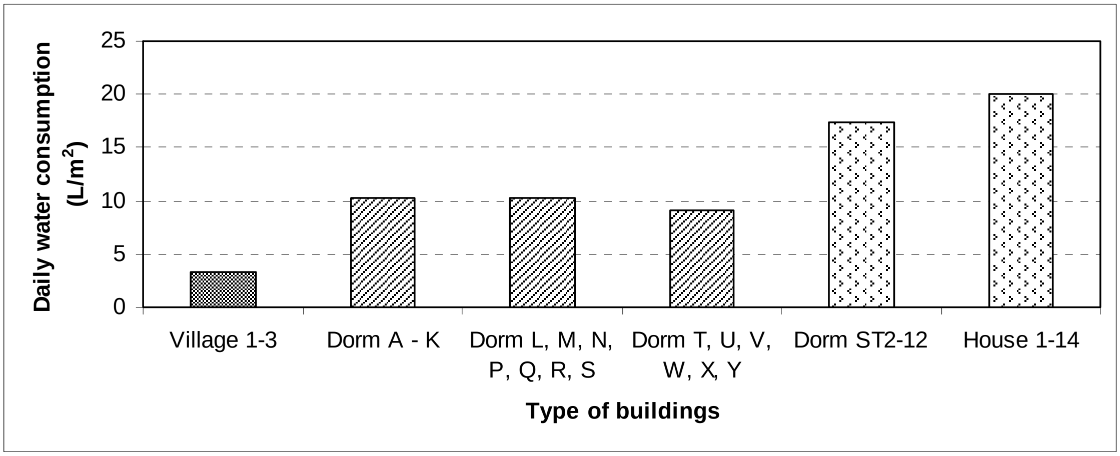


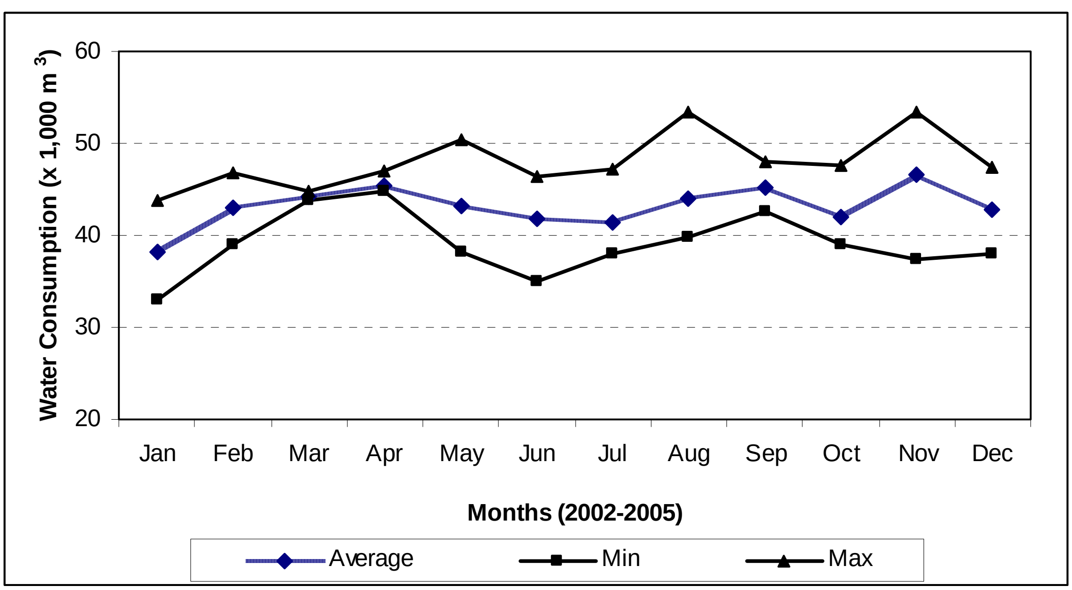
Figure 4.19 Rating of Water Consumption at each Dormitory (2005)

Source: Physical Plant (2005)

Water consumption type "A"
Water consumption type "B"
Water consumption type "C"

As illustrated in Figure 4.19, the staff residents especially houses numbered 1 to 14 seem to have highest water consumption compared with student dorms. The water consumption reaches 20 liters per square meter, while the water consumption at the village numbered 1 to 3 is only 3.24 liters per square meter. Houses and staff dorms usually have more water consuming appliances and cooking facilities compared to the student dorms. Staff houses usually have independent cooking facilities, whereas the students in the single units have to share cooking areas with their room mates. Therefore, majority of the students eat in the cafeteria. This is a potential reason for low water consumption.

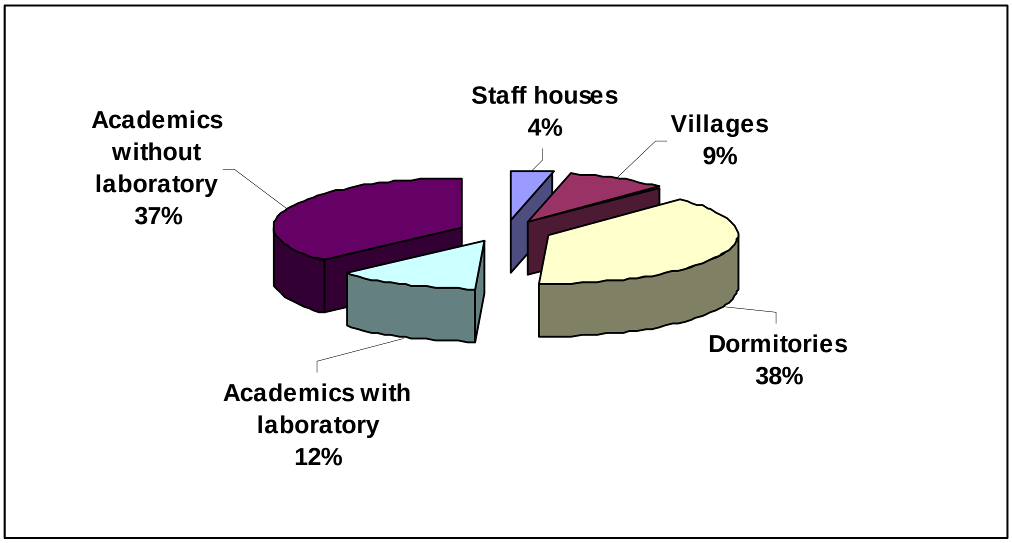
4.3.4 Seasonal Trend of Water Consumption



Source: Physical Plant (2005)

Figure 4.20 Average Seasonal Trend of Water Consumption (2002 – 2005)

The maximum water consumption in November has reached almost 47,000 m^3 while in January the water consumption is dramatically down to 38,000 m^3. Weather is one reason that affects the water consumption of people. Residential areas usually spend more water (about 51% of the total consumption) due to the daily water consuming behaviors. The rest (30%) is spent by the remaining office buildings, with each building consuming about 1-2 % (which is not considered to be a major source of water consumption).



Source: Physical Plant (2005)

Figure 4.21 Percentage of Water Consumption at AIT (2005)

Figure 4.21 also includes other office buildings such as Electricity Tech, Computer Science, AITCC, Administration, Pulp and Paper, etc.

4.3.5 Major Sources of Water Consumption

(a) High Flush Toilet

(b) Washing Dishes at the AITCC

Figure 4.22 Snapshots of Water Consumption

Residential units are major source of the water consumption in the campus. About 70% of the AIT populations live in the campus. Bathing, washing, toilet flushing, and cooking are major points of water consumption.

- **Type II: Water for Gardening**

  Water gardening is pumped from the canal around the campus and a pond at the back of X dorm. In the dry season, water is pumped daily and supplied to the whole area within the campus.

Table 4.9 Volume of Gardening Water

No.	Items	Locations	Horsepower (hp)	Flow rate (m^3/h)	Volume (m^3/d)*
1	Pump No.1	At the Vietnamese restaurant	40	10-15	75
2	Pump No.2	Old golf fields	40	10-15	75
3	Pump No.3	Next to CUC village	30	8-12	60
4	Pump No.4	At the back of X dorm	40	10-15	75
5	Pump No.5	At the back of ST 12	20	5-8	39
6	Pump No.6	At the back of House No.9	25	6-10	48
	Total				**372**

Remark: * Volume (m^3) = Q (m^3/h) x 6 (h/day)
- The flow rate has been determined by the manual measurements.

Table 4.9 presents the amount of water used for gardening. This water is usually supplied from the canal around the campus which never dries up in the summer season. Water can be supplied to the garden around the year. When considering the daily volume of 372 m^3 (89,280 m^3/year). If this amount of water is supplied from the Pathumthani Water Treatment Plant, it can cost almost 6,000 Baht per day or almost 180,000 Baht per month during the dry season only (1 m^3 of water = 16 Baht) (Source: Physical Plant, 2005). This shows that it is very effective to supply the water from the canal; the only capital investment is the purchase of pumps, pipe line, valves, and maintenance.

Figure 4.23 Pumps for Gardening Water

Table 4.10 Quality of Gardening Water

Parameters	Units	Water characteristics
pH	-	6.6 -6.8
BOD	mg/L	9-19
COD	mg/L	8-21
Turbidity	NTU	4.8-18.8
TSS	mg/L	13-26
TDS	mg/L	423-457

Table 4.10 illustrates the quality of the gardening water from the pond and canal, inside and around the campus. The data shows that the water has very little contamination, which is an acceptable amount for the growth of plants compared to the quality of treated wastewater from the AIT treatment as shown in Table 4.11.

4.4 Wastewater Generation

AIT has its own Wastewater Treatment Plant located near ST 2. Sewage is collected at a sump near the physical plant and pumped to the WWTP. On an average, the quantity of sewage pumped to the WWTP is about 1,122 m^3 while the water supplied 1,357 m^3 per day (2005). Therefore, the water lost is about 235 m^3 per day or about 17.3 % of total water supply, which is about 61 liters per person.

This loss may be due to different reasons such as:

- Cleaning vehicles, usually the wastewater from this operation is disposed into the ground water.
- Human consumption
- Water used for floor cleaning.
- Potable water is used for watering the plants (this is done by some residents).
- Some restaurants in the campus do not have drainage systems. So, the wastewater is disposed directly into the soil.
- Leakages in the pipelines, both at the supply and collection system.
- Evaporation

4.4.1 Snapshots of Wastewater Treatment Systems

(a) Wastewater Pumps

(b) Raw Sewage Influence

(c) Aeration Ponds

(d) Constructed Wetland

(e) Effluent from Constructed Wetlands

(f) Discharge to a Public Canal

Figure 4.24 Snapshots of Wastewater Generation

An overview of aeration ponds, waste stabilization ponds and constructed wetlands was presented in Chapter 3, Figure 3.2. The wastewater is collected at the sump inside the campus before it is pumped to the treatment facilities such as aeration ponds, waste stabilization ponds and constructed wetlands. The treatment efficiency of this plant is illustrated in Table 4.13.

4.4.2 Wastewater Characteristics

For several years AIT's Waste Water Treatment Plant has been treating the wastewater for the campus. From 2001 to 2003, there were some wastewater audits. (Table 4.11 – 4.13). In the raw sewage, it was observed there were some decreasing trends of wastewater characteristics during 2001 to 2003. BOD_5 decreased about 26%, perhaps due to the dilution of wastewater. In 2005, the trend of raw sewage seemed to double BOD_5 increased about 40%.

Table 4.11 Physical Characteristics of Influent (Raw Sewage)

Parameters	**Units**	**Wastewater characteristics**			
		2001*	**2002***	**2003***	**2005**
pH	-	6.8-7.5	6.9-7.8	7.1-7.9	7.2-7.6
BOD_5	mg/L	18-90	36-87	30-67	111
COD	mg/L	-	-	-	210
TSS	mg/L	-	-	-	120
TDS	mg/L	-	-	-	640
TKN**	mg/L	-	-	-	28.4

Remarks: * These tests were conducted by EEM Lab
** : Koottatep, (2005)

Comparing the characteristics of treated wastewater from 2001 to 2005, it is observed that BOD in 2005 is lower compared to 2003. The data from Table 4.11 shows that the BOD is relatively low; this means the wastewater is more diluted.

Table 4.12 Physical Characteristics of Effluent

Parameters	Units	Wastewater characteristics			
		2001*	2002*	2003*	2005
pH	-	7-7.9	7.1-7.8	7.1-7.8	7.2-7.7
BOD_5	mg/L	5-40	10-31	13-38	35
COD	mg/L	-	-	-	65
TSS	mg/L	-	-	-	50
TDS	mg/L	-	-	-	350
TKN**	mg/L	-	-	-	3.17

Remark: * These tests were conducted by EEM Lab
**: Koottatep (2005)

4.4.3 Removal Efficiency of AIT Wastewater Treatment Plant

Table 4.13 Removal Efficiency of AIT WWTP in 2005

Parameters	Units	Influent	Effluent	Removal efficiency (%)	Thai Effluent Standard
pH	-	7.2-7.6	7.2-7.7	-	5.5-9
BOD_5	mg/L	111	35	68	20
COD	mg/L	210	65	69	120
TSS	mg/L	120	50	58	50
TDS	mg/L	640	350	45	500
TKN*	mg/L	28.4	3.17	88	40

Source: Pollution Control Department (2004)
**: Koottatep (2005)

As illustrated in Table 4.13, the effluent quality of BOD does not meet the standard of discharge. Removal efficiency is only 45-70%, so, the treatment facilities need to be improved.

The data from Table 4.13 indicates that AIT has almost the highest concentration of BOD and SS in the effluent. BOD sometimes does not meet the Thai standard for wastewater's discharge to the public canal. From wastewater audits, it is found that BOD at the effluent was up to 35 mg/L in 2005. This happened due to the low removal efficiency of the oxidation ponds and constructed wetlands, which is only 68-69%. On the other hand, the effluent of Total Suspended Solids with the maximum of 50 mg/L could meet the standard of public effluent (Table 4.13).

4.5 Solid Waste Generations

4.5.1 Domestic and Office Wastes

Each year AIT generates about 740 tons of domestic waste which is about 2.03 tons generated daily or 0.53 kg/person. About 96% of the total waste has been transferred directly to the landfill site. Tha Kong Municipality has the responsibility of collecting the waste and depositing it to the landfill site in Pathumthani Province. Each month, AIT pays for the solid waste collection, which costs about 8,000 Baht or about 96,000 Baht/year.

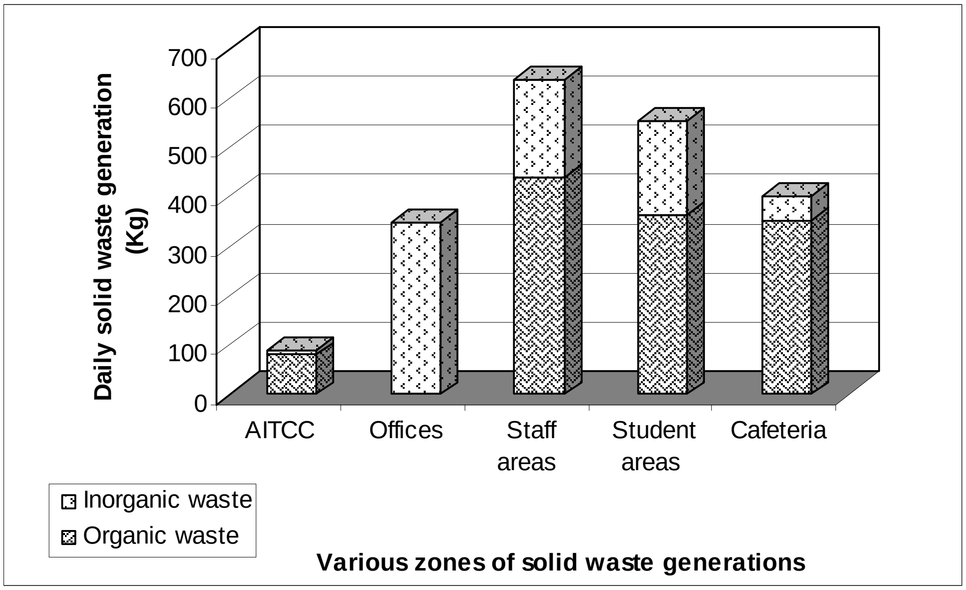


Figure 4.25 Generations of Domestic and Office Wastes in 2005

Sources of solid waste generation have been divided into 5 categories such as AITCC, student areas, staff areas, offices and cafeteria + other vendors. The details of solid waste generation have been attached in Appendix E. The major source of waste generation is the residential areas with about 59% of total waste. From Figure 4.11, organic wastes cover about 60.8% by weight and are mostly the office waste which is recycled.

About 96.2% of the total waste has to be collected daily at the solid waste collection site (near the football field) and transferred directly to the landfill site within the Pathumthani Province. Some small amounts of food waste from the cafeteria and AITCC are sold to the vendors outside AIT as animal feeding. The rest, 3.8% is the recyclable waste, which will be discussed in Section 4.8.

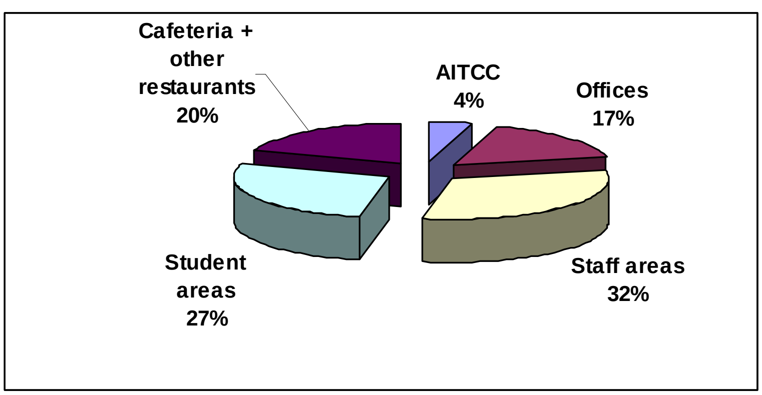


Figure 4.26 Domestic and Office Waste Generations in AIT (2005)

4.5.2 Comparisons of Domestic Waste Generations in Residential Areas

Table 4.14 shows that AIT has the lowest amount of domestic waste generation compared to other regions. The amount of solid waste generation depends on the economic of the country. Everyday, AIT generates only 0.61 kg/person. This number is relatively less compared to Bangkok and Vientiane Capital City. This data is less compared with Bangkok and Vientiane Capital City, due to 50% of total students in the student areas does not have cooking facilities; they usually have their meals in the cafeteria or other restaurants. Thus, the amount of domestic waste generations is less. In addition, the solid waste generation in the Vientiane Capital City does not include only the domestic waste, but gardening waste is also included.

Table 4.14 Comparisons of Domestic Waste Generations in Residential Areas

No.	Items	Domestic Waste Generations	Remarks
		kg/(person.day)	
1	AIT	0.61*	2005
2	Bangkok	1.20	-
3	Vientiane Capital City	0.75	-

Remark:
* = (Total domestic waste generations in the residential areas) / (Total number of staff residents in the campus + 50% of total students in the campus)

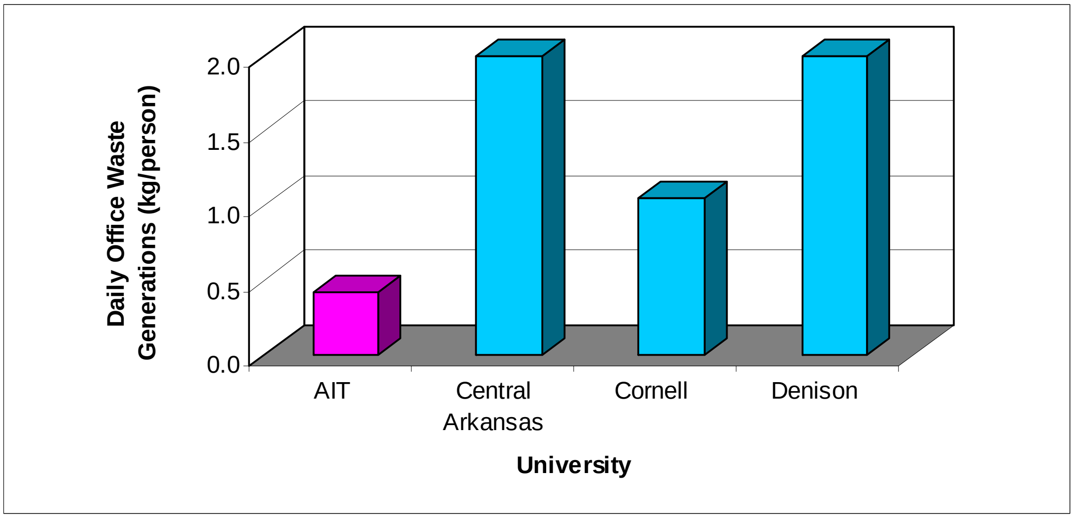
4.5.3 Benchmarks of Solid Waste Generation in Academic and Administrative Buildings

Table 4.15 Benchmarks of Solid Waste Generations in Academic and Administrative Buildings

No.	Items	Daily Solid Waste Generation (kg/person)	Remarks
1	AIT	0.41*	In 2005 (Thailand)
2	University of Central Arkansas	1.99	In 2002 (USA)
3	Cornell University	1.04	In 2004 (USA)
4	Denison University	1.99	In 2000 (Ohio)

Remark: * = (Office waste) / (Total staff)

Sources: Maes, Richardson & Walter (2004), Cornell Sustainable Campus (2005), Denison University (2000)



Source:
Maes, Richardson & Walter (2004), Cornell Sustainable Campus (2005), Denison University (2000)

Figure 4.27 Benchmarks of Solid Waste Generation in Academic and Administrative Buildings (kg/person)

Referring to Table 4.15, AIT has the lowest amount of solid waste generation compared to the benchmarks. The Universities in the developed countries as well as the United States always generate larger amounts of domestic waste compared to the developing countries'. In United States several kinds of "take-home" foods are popular e.g. Hamburger, Kentucky Fly Chicken (KFC), Sandwich, etc. This kind of foods is always kept in its packages like paper, cardboard, plastic which can be potential sources for solid waste generation. Furthermore, the total solid waste generations in other universities are high because the gardening wastes are also taken into account.

4.5.4 Rating of Domestic and Office Waste Generations

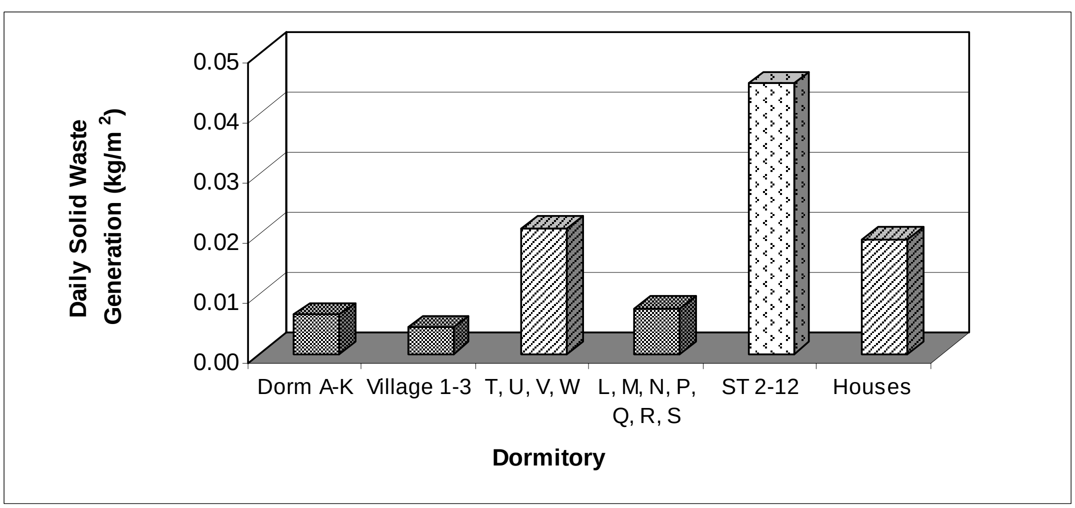


Figure 4.28 Rating of Domestic Waste Generations in 2005

Solid waste generation type "A"
Solid waste generation type "B"
Solid waste generation type "C"

Staff's dormitories are highest solid waste generation compared to student's dormitories. This due to the fact that staff has cooking facilities. While some students' dormitories such as standard dorms (A, B, C, D, F, G, H) and other dormitories such as L, M, N, P, Q, R & S (except Village 1,2 and 3) have cooking facilities, they make up only 50% of the total. Moreover, T, U, V, W dorms have to share the kitchens among two students. So, this may cause some students feel independently to cook.

4.5.5 Snapshots of Domestic and Office Waste Generations

(a) Solid waste collection site

(b) Recyclable waste from the cafeteria

(c) One type of waste bin

(d) Kitchen waste

(e) Bad practices

Figure 4.29 Snapshots of Domestic Waste Generations

4.5.6 Yard Waste Generations

Everyday, the AIT campus generates yard waste at an average of about 73 tons per year or 200 kg per day with the exception of wood. These wastes are disposed in the landfill site, which is located near the School of Management on the campus. The major compositions of the yard wastes are leaves and sticks.

The majority of yard waste is leaves. AIT uses this natural fertilizer. Once a year, AIT staff separate the leaves from yard waste and make compost in the proper ratio. Instead of using chemical fertilizers, this natural fertilizer is used for the plants all over the campus. It can be concluded that compost made of yard waste is an eco-friendly approach. Moreover, AIT does not have to spend money purchasing fertilizers. Figure 30 shows the composting site and plants that are added by this fertilizer.

4.5.7 Snapshots of Yard Waste Generations

(a) Open dump site for yard waste

(b) Composting site

(c) Plants used by yard waste fertilizer

Figure 4.30 Open Dump and Composting Sites

4.6 Energy Audit

From the collected data, three critical buildings have been focused on, which are the North and South Academic buildings, Chiller room and a student dormitory (P dorm). From these focus areas; it is necessary to identify the main reasons for electricity consumption by an energy audit. Different types of buildings have different indicators to identify the causes of high electricity consumption. The audit considers the input and output of the electricity in the particular area. The details of energy audit have been attached in Appendix C.

4.6.1 Energy Audit at North and South Academic Buildings

The main components of these buildings are laboratories, computer rooms, offices, classrooms and workshops. The hourly electricity consumption of these buildings have been audited and shown in Figure 4.31. In academic buildings, the electricity consumption during the examination and term break period does not differ much because all offices, faculties and laboratories are used during office hours. On the weekend, only some lamps at the corridors outside the offices are switched on; laboratories and computer labs are still being used.

The highest electricity consumption is usually between 10:00 to 18:00 h, at this time the air-conditioners work continuously, due to the warm climate. Normally, the electricity consumption shoots up at working hours and is blown down at off-work hours.

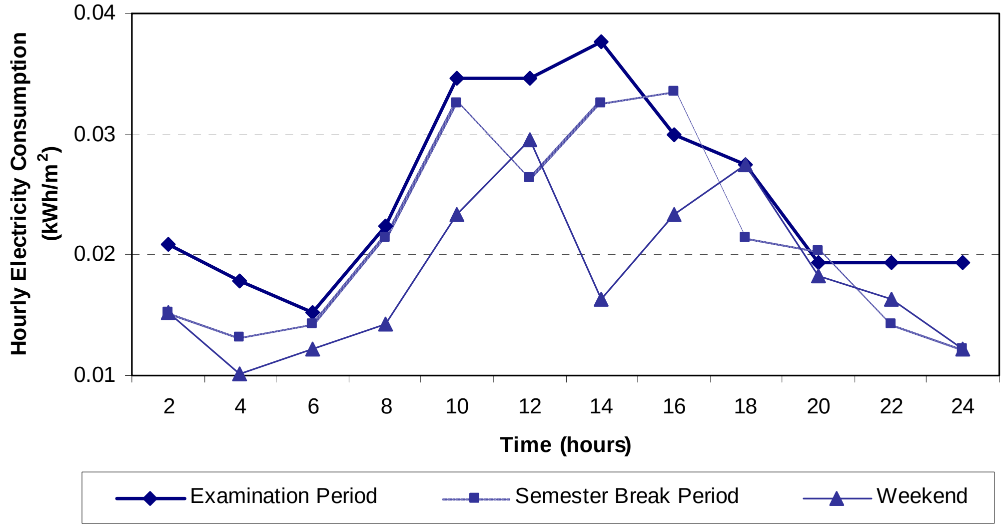


Figure 4.31 Hourly Electricity Consumption at North and South Academic Buildings

The EE Lab is a major source of electricity consumption in these academic buildings. More than 50% of the electricity is consumed by the EE Lab in the South Academic building. In the EE Lab several types of equipments are used, such as refrigerators, ovens, steamers, etc. These equipments do not only consume high electricity but also generate a large amount of heat which causes the air-conditioners to work more.

There are two major devices that are used in the offices. These are computers and air conditioners. From the walk-through in these areas, the total number of computers being used is about 510. About 90% are the old desktop computers (with CRT monitors) and the laptops and desktops with the flat panel (LCD monitor) making up about 10%. In addition, there are 290 air-conditioners used in these buildings which consume about 1500 kWh/day. The detailed calculations for these have been attached in the Appendix D and Table 4.16 as below:

Table 4.16 Estimation of Electric Consumption in North and South Academic Buildings during Examination Period

Items	**No. of Equipments (Units)***	**Daily Active Usages (h/d)****	**Daily Electricity Consumption (kWh)*****
Desktop computers + 17" CRT monitors	460	6-8	756.70
Laptop computers	50	6-8	15.75
Desktop computers + 17" LCD monitors	50	6-8	66.50
Air compressors (central) in the offices (2.5 tons)	10	6-8	245
Fan coils in the offices	278	7-8	729.75
Fan coils in the computer labs	12	17-19	75.60
Total	-	-	**1,889.30**

Remark:- * Number of equipments has been observed by walk-through in the North and South academic buildings.

- ** The daily active usages of the computers observed by the average computer usages in each day.
- *** The detailed calculations are attached in Appendix D, Table D1

Comparing between the estimated appliances use in Table 4.17 (1,889.30 kWh/day) and the meter reading in Table D.1 (3,522 kWh/day), at the same period. It was noticed that the gap between these values is 1,632.7 kWh/day. This value is an amount of electricity used in the laboratory and other office equipments such as printers, servers, photocopiers, head projectors, fax machines, telephones, light bulbs, etc. From this audit, it clearly shows that the equipments in Table 4.17 consumed more than 50% of total electricity used in the North and South Academic Buildings. So, if "Electricity Conservation" is promoted in all office buildings, this may reduce huge amount of electricity consumption within AIT campus.

Table 4.17 Estimation of Electric Consumption in the North and South Academic Buildings during Semester Break

Items	**No. of Equipments (Units)***	**Daily Active Usages (h/d)****	**Daily Electricity Consumption (kWh)*****
Desktop computers + 17" CRT monitors	330	6-8	542.85
Desktop computers in the computer rooms	130	1-2	45.82
Laptop computers	50	6-8	15.75
Desktop computers + 17" LCD monitors	50	6-8	66.50
Fan coils in the offices	258	7-8	677.25
Fan coils in the class rooms	20	0	0
Fan coils in the computer rooms	12	17-19	75.6
Air compressors (central) in the offices (2.5 tons)	5	6-8	122.50
Total	-	-	**1,546.27**

Remark:- * The number of equipments has been observed by a walk-through inspection in the North and South academic buildings.
- ** The daily active usages of the computers are observed by the average computer usages in each day.
- *** The detailed calculations are attached in Appendix D, Table D2

In the semester break, class rooms are not used and so are the air conditioners. The application of computers are lesser compared to the examination period. Offices and faculties still work in the regular work hours. Therefore, the electricity consumption for this building is lower in the examination period.

Table 4.18 Estimation of Electrical Consumption in North and South Academic Buildings during Weekends

Items	No. of Equipments (units)*	Daily Active Usages (h/d)**	Daily Electricity Consumption (kWh)***
Desktop computers + 17” CRT monitors	99	2-4	542.85
Desktop computers (in the computer rooms)	130	6-8	45.82
Laptop computers	50	2-4	15.75
Desktop computers + 17” LCD monitors	50	2-4	66.50
Fan coils in the offices	278	4-6	677.25
Fan coils in the class rooms	0	0	0
Fan coils in the computer rooms	12	17-19	75.6
Air compressors (central) in the offices	5	6-8	122.50
Total	**-**	**-**	**1,003.49**

Remark:- * The number of equipments has been observed by walk through inspection in the North and South academic buildings.

- ** The daily active usages of the computers are observed by the average computer usages in each day.
- *** The detailed calculations are attached in Appendix D, Table D3

The electricity consumption over weekend is lower than semester break period. Majority of the offices are closed, some faculties and doctorial students still work during this time. As usual, the computer rooms are always opened. As shown in Appendix C (Table C.3), the electricity consumption during weekend is 2,580 kWh while the laboratory consumes about 25% of the total electricity in the SERD building or about 645 kWh. Therefore, the estimated amount of electricity consumption for electrical devices and the meter reading is about 931 kWh. This amount is the rest of the electricity consumption that is not illustrated on Table 4.18 such as light bulbs, printers, servers, etc.

4.6.2 Energy Audit at P Dorm

Residential buildings are areas that consume high electricity. Therefore, P dorm has been chosen as a representative of a residential area. In this dormitory, there are two units. The first unit has been provided for the married students and the second unit has been provided for the single students. The ground floor and the first floor are for married students which include 14 rooms and the second floor is for the single students which include 16 individual rooms. The hourly meter reading for P dorm has been attached in Appendix C.

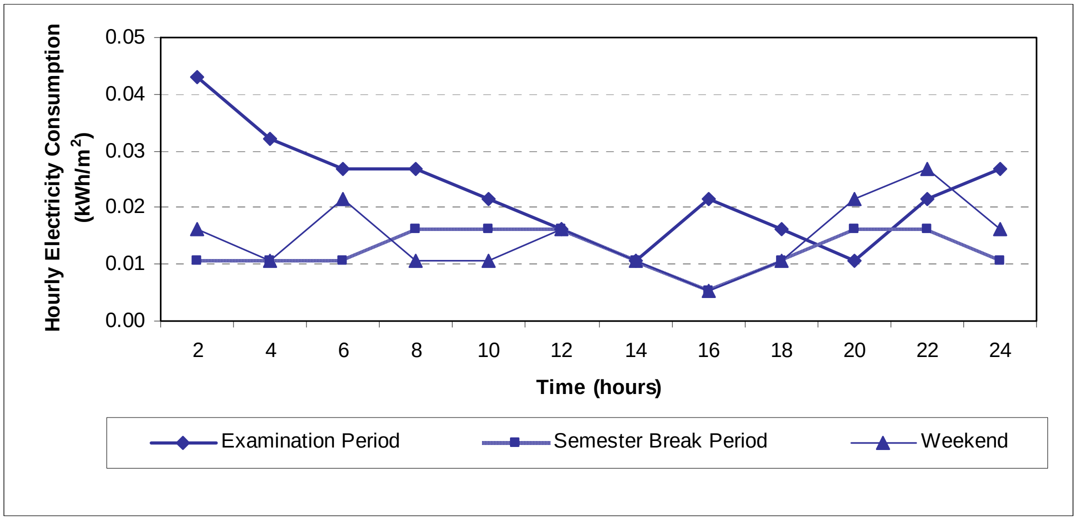


Figure 4.32 Hourly Electricity Consumption at P Dormitory

Note: During the examination period, the trend of electricity consumption at 2:00 h is not applicable. A mistake during the energy audits could be encountered from the record.

During semester break and weekends, the electricity consumption is usually lower than the examination period. During semester break, 15 kWh (0.86 kWh/person) is the highest electricity consumption at peak hour (Table C.5), while during the weekend people use more electricity than a work day (at semester break period). People might stay in their rooms during the weekend more often than in the work day. However, the consumption of electricity never hits zero because people still use some electricity while they are sleeping such as air conditioners, refrigerators, etc. The table 4.19 is an estimation of the electricity consumption in this dorm.

Table 4.19 Estimation of Electricity Consumption at P dormitory during Examination Period

Items	**No. of Equipments (Units)***	**Daily Active Usages (h/d)****	**Average of Daily Electricity Cons. (kWh)*****
Desktop computers	15	4-6	17.62
Laptop computers	15	4-6	3.37
Televisions	4	2-4	2.16
Refrigerators	24	24	57.60
Air-conditioners (12,000 BTU)	44	4-8	158.40
Cookers	22	0.3-0.4	6.93
Washing machines	5	0.5-0.6	1.37
Hot pots	21	0.2-0.3	4.72
Total			**252.17**

Remark: - * This data was observed by the walk-through in this dormitory.

- ** This data was observed by interview and behavior of electricity consumption of each person.
- *** The detailed calculations have been attached in the Appendix D.

The potential electricity consuming appliance in this dormitory is air-conditioner. It is clear that it consumes more than 60% of total electricity consumption during an examination day. Desktop computers also consume more electricity compared to the rest. If all students use laptop computers instead of desktop computers, electricity consumption can be considerably reduced also.

Table 4.20 Estimation of Electricity Consumption at P dorm during Semester Break

Items	**No. of Equipments (Units)***	**Daily Active Usages (h/d)****	**Average of Daily Electricity Cons. (kWh)*****
Desktop computers	7	1-2	2.47
Laptop computers	8	1-2	0.54
Televisions	2	4-6	1.80
Refrigerators	12	24	28.80
Air-conditioners (12,000 BTU)	22	6-8	92.40
Cookers	22	0.3-0.4	6.93
Washing machines	2	0.5-0.6	0.55
Hot pots	10	0.2-0.4	2.70
Total	-	-	**136.19**

Remark:- * This data was observed by the walk-through in this dormitory.
- ** This data was observed by interview and behavior of electricity consumption of each person. (Appendix G)
- *** The detailed calculations have been attached in the Appendix D.

From the above data, the use of the air-conditioner and computer is the main sources for power consumption. This dormitory has been supplied by old air conditioners; the chillers do not cool this dorm due to the distance between the chiller room and the dormitory. From the audit of hourly electricity consumption, in one day (during semester break period) the electricity consumption is about 140 kWh but the actual needed electricity consumption is 136.19 kWh. The gap between these, 3.81 kWh is the excess electricity consumption and other uses such as lamps, lights etc.

Table 4.21 Estimation of Electricity Consumption at P Dorm during Weekends

Items	No. of Equipments (Units)*	Daily Active Usages (h/d)**	Average of Daily Electricity Cons. (kWh)***
Desktop computers	15	2-4	10.57
Laptop computers	15	2-4	2.02
Televisions	2	4-6	1.80
Refrigerators	12	24	28.80
Air-conditioners (6000 BTU)	22	6-8	92.40
Cookers	22	0.3-0.4	6.93
Washing machines	2	0.5-0.6	0.55
Hot pots	10	0.2-0.4	2.70
Total			**145.77**

Remark:- * This data was observed by the walk-through in this dormitory.
- ** This data was observed by interview and behavior of electricity consumption of each person. (Appendix G)
- *** The detailed calculations have been attached in the Appendix D.

During the weekends, it is assumed that the average time of computer's use is between 2 to 4 hours which is lesser than computer use in the examination period. Other appliances are estimated to be used only 50% of total.

4.6.3 Energy Audit at Chiller Room

Referring to the yearly electricity consumption data which has been attached in the Appendix A. Chiller room has the second highest electricity consumption each year. The chillers cool the main and nearby buildings such as offices, academic buildings, administrative buildings, AITCC, school of management building (SOM) and E, J, K dormitories. The chillers cannot cool other residential areas because those buildings are far. So, it is not efficient to cool the far areas, because the distance of piping affects the cooler's efficiency. In most situations, chillers are monitored hourly by the technicians in the chiller room. The hourly electricity consumption in the chiller is shown in Figure 4.33 and 4.34.

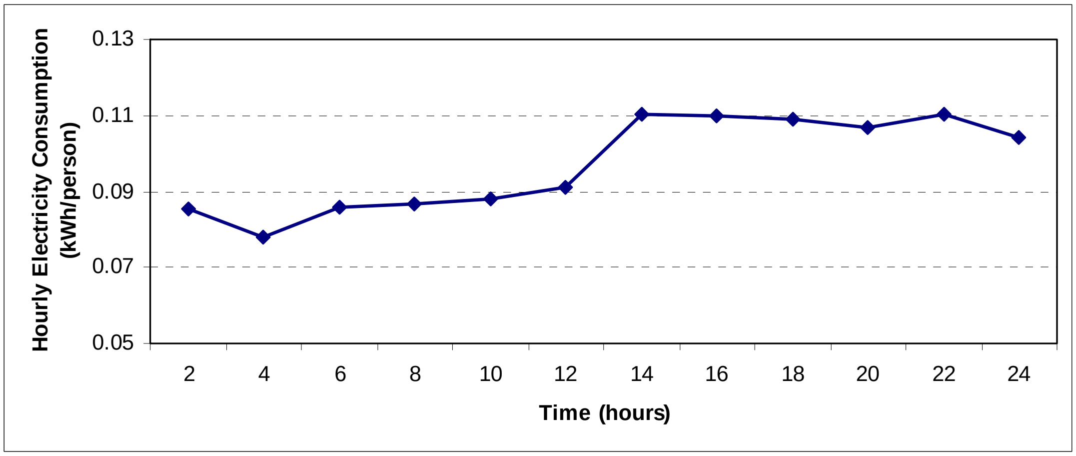


Figure 4.33 Hourly Electricity Consumption in Chiller Room during Cold Season

During cold season, two chillers are usually operated in the afternoon but in the evening and morning, only one chiller is operated. In the winter season (November to February), the maximum electricity consumption in the chiller reaches to 0.11 kWh/person at 16:00 hrs. From Figure 4.33, the warmer climate is started from 10:00 hrs to 16:00 hrs, that's why two chillers are required. After 16:00 hrs the temperature starts to decrease; only one chiller is needed, so the electricity consumption is decreased.

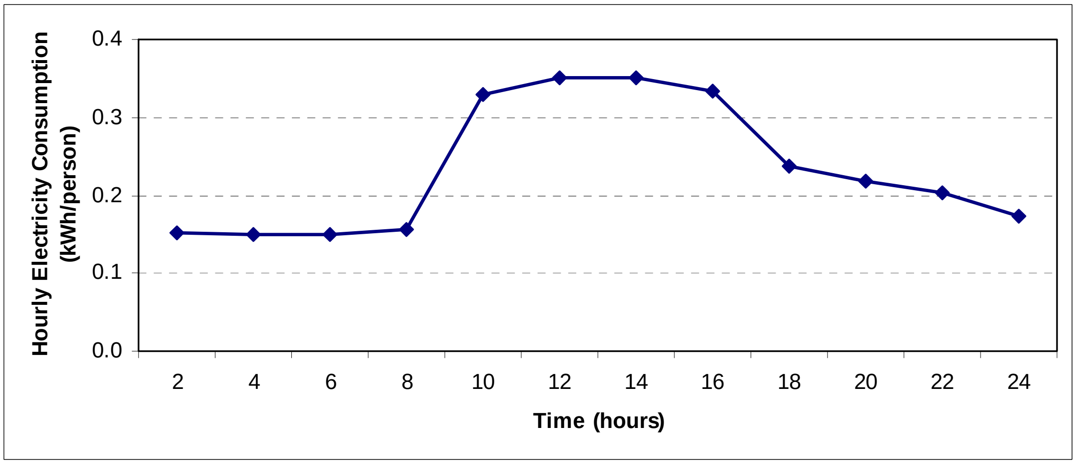


Figure 4.34 Hourly Electricity Consumption in Chiller Room during Summer

During the summer from March to May, the chillers consume highest electricity when two to three chillers are required to operate during the day, especially from 10:00 h to 16:00 hrs. The maximum electricity consumption in this period is between the 12:00 to 14:00 hrs, which is up to 0.352 kWh/person. From 2:00 h to 8:00 h, the electricity consumption is about 0.156 kWh/person but it is still higher than the maximum electricity consumption during the cold season (Figure 4.34).

The major appliances in the chiller room include: 4 chillers, pumps (to supply the cooling water and obtain the hot water back) and 2 cooling towers. The characteristics of the chillers are described in Table 4.22 as below:

Table 4.22 Characteristics of AIT's Chillers

No.	Items	Capacity (tons)	Efficiency (kW/ton)	Installed date
1	Chiller 1	600	0.69	May 1995
2	Chiller 2	500	0.69	September 1992
3	Chiller 3	300	0.67	September 1996
4	Chiller 4	500	0.61	October 1998

Everyday two chillers are normally operated, the rest are replaced after a certain time. From the above data, it can be seen that the second chiller is the oldest. The efficiency of chillers always depends on the age of chillers and maintenance. Good maintenance can keep chillers' long life.

4.6.4 Comparisons of Chillers' Efficiencies

Table 4.23 Benchmarks of Chillers' Efficiency

No.	Locations	Chillers' Efficiency (kW/ton)	Remarks
1	AIT' chillers	0.61-0.69	300-600 tons
2	Washington State University	0.66-0.68	Standard Efficiency (150-300 kW/ton)
		0.56-0.44	High Efficiency (over 300 kW/ton)

Source: Energy Efficiency (2003)

Washington State University set up the chillers' efficiency into two categories. Chillers that have efficiencies between 0.66 kW/ton and 0.68 kW/ton are categorized as the Standard Efficiency chillers. Chillers' efficiency between 0.56 to 0.44 kW/ton is called High Efficiency chillers. Referring to these data, AIT's chillers seem to be categorized in the Standard Efficiency chillers.

4.7 Water Audit

- **Type I: Water supply from Pathumthani Water treatment Plant**

  Huge amount water is consumed in the residential areas, almost 50% of the total consumption in the campus. From the observation, two types of residential areas have been audited, one staff accommodation (ST 6) and one student accommodation (SV 59). ST 6 is the couple unit which has about 3 people in one house; they have cooking facilities. SV 59 has 6 people with 2 kitchens and 2 bathrooms.

4.7.1 Water Audit at ST 6

The highest water consumption at ST 6 during examination period is about 71 L/person at 10:00 h (Table C.7). The majority of the people in this building cook, therefore, more water consumption usually reach at 10:00 h and 20:00 h because this is the normal time for preparing lunch and dinner. Between 7:00 h to 10:00 h, the water consumption is dramatically increased due to the normal activities of people in the morning such as bathing, preparing breakfast, washing, etc. From the midnight to around 6:00 h, people seem to reduce their water consumption but a certain amount of water is still used. There are several assumptions for this data. It might be because of the leakage in the pipes, toilets; or the use of toilets at night.

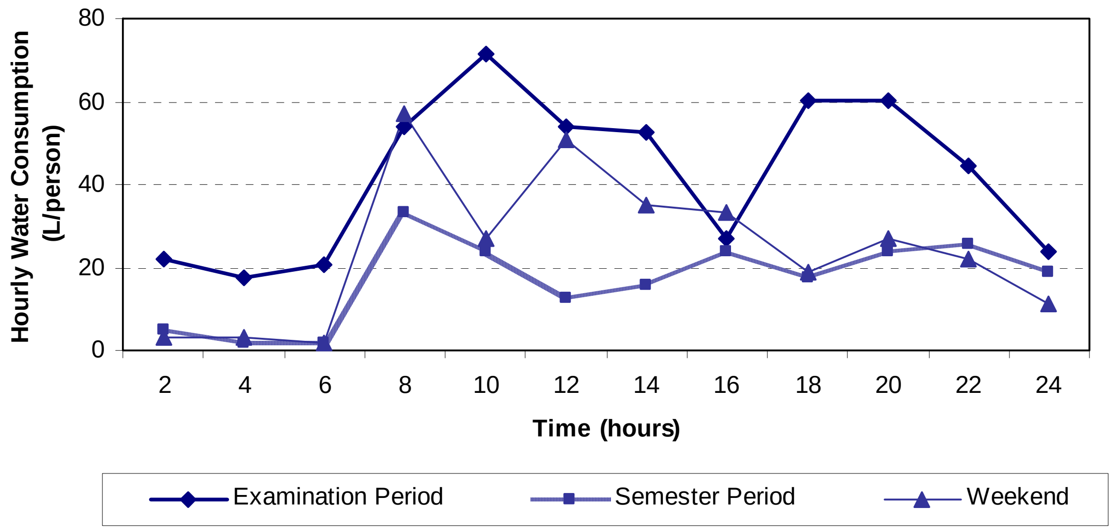


Figure 4.35 Hourly Water Consumption at ST 6

The above figure represents the daily water inflow in ST 6. For the water audit, it is necessary to analyze the outflow or water usage in each daily activity, arrive at the inflow data. Table 4.24 below is the estimation of daily water consumption for various activities in the household:

Table 4.24 Estimation of Water Usages at ST 6 during Examination Period

No.	Items	Amount of Water Used (L/person)*	Average Daily Water Consumption (L/household)	(L)	(L/person)
1	Bathing	150-200	-	11,025	-
2	Laundry	100-130	-	7,245	-
3	Cooking	20-30	-	1,575	-
4	Toilet	50-70	-	3,780	-
5	Dish wash	30-40	-	2,205	-
6	Faucets	40-60	-	3,150	-
7	Others	35-50	-	2,677	-
	Total		**1,758**	**31,657**	**502**

Remark: - * The data is estimated by the observations on daily usages.

- Average daily water consumption = (Amount of water used per person) × (No. of persons or family in the household)
- There are totally 63 people in this dormitory including 18 houses.

Residents in ST 6 consume about 502 L/person. From the above audit, the water consumption for bathing is quite high compared to the other types of consumption. This depends on the frequency of showering and the flow rate of the showerhead. Toilet flushing and faucet use are the second and third highest water consumption respectively. Toilets usually need a large amount of water per flush (more than 10 L), in this case the water can be reduced by the substitutions of the new low flow toilets (about 3-5 liters per flush toilet devices can reduce the water consumption more than 50%).

The faucets with small filter inside (new typed faucets) can save more water comparing with the faucets that do not have filters (old typed faucets). The filter is able to create more pressure on water. Therefore, when water flows from the new typed faucets, it mixed with the air bubbles. It is clear that within the same period of time, the water flows from new typed faucets has less volume than the old typed faucets.

Table 4.25 Estimation of Water Usages at ST 6 during Semester Break

No.	**Items**	**Amount of Water Used (L/person)***	**Average Daily Water Consumption**		
			(L/household)	**(L)**	**(L/person)**
1	Bathing	150-200	-	4,375	-
2	Laundry	100-130	-	2,875	-
3	Cooking	20-30	-	625	-
4	Toilet	50-70	-	1,500	-
5	Dish wash	30-40	-	875	-
6	Faucets	40-60	-	1,250	-
7	Others	35-50	-	1,062	-
	Total		**696**	**12,562**	**199**

Remark:
- * The data is estimated by the observations on daily usages.
- Average daily water consumption = (Amount of water used per person) × (No. of persons or family in the household)

During the semester break, a lot of people do not stay on the campus; they are doing other activities such as visiting their families, holiday trips, etc. Therefore, the average water consumption per person reduces to 199 liters and 696 liters of water is used in each house.

Table 4.26 Estimation of Water Usages at ST 6 during Weekends

No.	Items	Amount of Water Used (L/person)*	Average Daily Water Consumption (L/household)	(L)	(L/person)
1	Bathing	150-200	-	11,025	-
2	Laundry	-	-	-	-
3	Cooking	10-20	-	945	-
4	Toilet	20-30	-	1,575	-
5	Dish wash	15-20	-	1,102	-
6	Faucets	20-30	-	1,575	-
7	Others	20-25	-	1,417	-
	Total		**980**	**17,639**	**280**

Remark: - * The data is estimated by the observations on daily usages.
- Average daily water consumption = (Amount of water used per person) × (No. of persons or family in the household)

During the weekend people do not like to stay in their houses, they often go shopping, have lunch or dinner outside the campus, or visit somewhere. Due to this fact, the amount of water consumption is reduced to 280 liters per person or 980 liters per household.

4.7.2 Water Audit at SV 59

From the audit of water consumption in this village, the water consumption is only 201 m^3/person. This is less than 50% of water consumption in ST 6. The water consumption peaked at 6:00 pm and 8:00 pm which is the normal time for cooking and having dinner. Figure 4.37 shows that some leakages might occur between 2:00 h to 6:00 h because water consumption did not reach zero at this period.

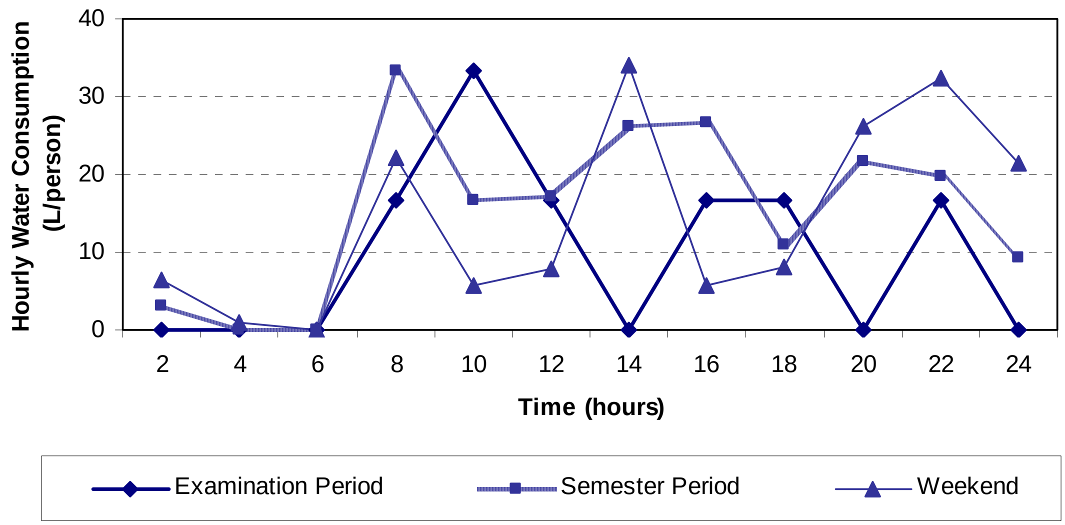


Figure 4.36 Hourly Water Consumption at SV 59

SV 59 is the single unit for the students, even though the students have cooking facilities, the frequency of cooking is lesser compared to the ST 6. Therefore, the water consumption in this village is less than that in ST 6. The water consumption for each type of activity has been mentioned in Table 4.27 as below:

Table 4.27 Estimations of Water Usages at SV 59 during Examination Period

No.	**Items**	**Amount of Water Used (L/person)***	**Average Daily Water Consumption**	
			(L)	**(L/person)**
1	Bathing	60-80	420	-
2	Washing	-	-	-
3	Cooking	5-10	45	-
4	Toilets	15-20	105	-
5	Dish wash	5-10	45	-
6	Faucets	5-10	45	-
	Total		**660**	**110**

Remark: * : This data was obtained from questionnaires (Appendix G)

In SV 59, the water consumption for bathing ranged from 60 to 80 liters which is less than the water consumption in the ST 6. This is because of the flow rate in the showerhead (L/min). In SV 59, the students did not cook frequently because it is an examination period. Normally, people who stay in the Student Village do not have washing machines, some people use laundry facilities and some hand wash.

Table 4.28 Estimations of Water Usages at SV 59 during Semester Break

No.	**Items**	**Amount of Water Used (L/person)**	**Average Daily Water Consumption**	
			(L)	**(L/person)**
1	Bathing	60-80	420	-
2	Washing	10-20	90	-
3	Cooking	20-40	180	-
4	Toilets	30-40	210	-
5	Dish wash	10-20	90	-
6	Faucets	10-20	90	-
	Total		**1,080**	**180**

Remark: * : This data was obtained from questionnaires (Appendix G)

During the semester break, it seems that the students have more free time to cook or do other activities in their households. The average daily water consumption reaches to 180 liters per person.

Table 4.29 Estimations of Water Usages at SV 59 during Weekends

No.	Items	Amount of Water used (L/person)	Average Daily Water Consumption (L)	(L/person)
1	Bathing	60-80	420	-
2	Washing	10-20	90	-
3	Cooking	20-30	150	-
4	Toilets	30-40	210	-
5	Dish wash	10-20	90	-
6	Faucets	10-20	90	-
	Total		**1,050**	**175**

Remark: * : This data was obtained from questionnaires (Appendix G)

During the weekend, the amount of water consumption is slightly lower than the consumption in the semester break and still much higher than the exam period's. This is quite different compared to the audit in the staff dormitory.

4.8 Solid Waste Audits

4.8.1 Solid Waste Compositions

Everyday, an AIT resident produces about 0.53 kg of waste. About 96% of solid waste generated is sent to landfilled. In such amount, the organic fraction is about 60.8% by weight. It means that about 39.2% by weight of landfilled waste is inorganic. This inorganic landfilled waste normally consist wastes from offices and houses. Major composition of these wastes is paper, foam, and plastic bag which are reusable. In addition, these solid wastes usually come from the packaging material. This data shows that everyday people purchase a lot of take-home foods. Sometimes, the recyclable wastes from the bins are very dirty due to the combination of all the solid waste into one bin. In this condition, scavengers do not want to get these waste, therefore, they dispose them to the landfill. This is one reason for the high amount of landfilled waste.

The composition of recyclable waste is shown in the Appendix E. These recyclable wastes are really valuable. Every month, the total income that AIT's scavengers can receive from the sale of these wastes is about 11,786 Baht/month or about or 141,432 Baht per year. If AIT provides proper waste segregation and collection system, it is sure that AIT will be able to earn more money than this.

Table 4.30 Compositions of Recyclable Waste

No.	Items	AIT Recycle Waste (% by weight)
1	Paper	75.72
2	Cardboard	12.75
3	Plastics Bottles	9.93
4	Cans	0.46
5	Others	1.14
		100

Bottles are the highest in the recyclable waste; most of them are drinking water bottles. About 89% of paper is generated from the offices: printed paper, copied paper, most of which are reusable. The amount of cardboards may be much in some occasions when some office equipments or computers are bought. Glasses and cans are normally less compared to the amount of their generations. They are usually generated from residential areas. Paper forms the major portion of solid waste. Wasted paper can be properly collected and sent to the recycled paper manufacturing industries.

Table 4.31 Physical Characteristics of Solid Waste

No.	Items	Total Garbage (kg)		Total Solid Waste (kg)	Composition of Solid Waste (%)
		Organic	Inorganic		
1	AITCC	80	10	90	5
2	Offices	-	348	348	17
3	Staff areas	439	197	636	31
4	Student areas	362	192	555	27
5	Cafeteria + other vendors	352	48	400	20
	Total	**1,233**	**795**	**2,028**	**100**
	% of weight	**60%**	**40%**	**100%**	

Remark: Detailed calculations are shown in Appendix E.

4.8.2 Solid Waste Audit at L Dorm

L dorm is a single student's dormitory, with 68 rooms. Thirty-four rooms have cooking facilities without refrigerators. From this dormitory, around 20 kg of solid waste (0.3 kg/person) is generated each day. Almost 80 % (15.9 kg) of the solid waste is collected and sent to the landfill and the rest 20% (4.1 kg) is the recyclable waste that includes paper, cardboards, plastic bottles, can, others. The details of waste composition are recorded in Table 4.24.

Table 4.32 Solid Waste Composition at L Dorm

Items	Amount (kg)	Amount (kg/person)
Landfilled wastes	15.9	-
Paper*	0.4	-
Cardboard*	0.7	-
Bottles*	1.9	-
Glass*	0.85	-
Can*	0.25	-
Total	**20**	**0.3**

Remark: * : These are recyclable waste

It is noted that 0.3 kg per person is the lesser amount of solid waste generation comparing with the average solid waste generation in residential areas (0.61 kg per person). The reason is, only 50% of total rooms have cooking facilities. Therefore, the generation of organic waste is quite less compared to other dormitories that have kitchens. Landfilled wastes include organic waste (food waste) and inorganic waste in the form of non-recyclables such as foam, small and dirty pieces of paper, plastic bags, tissues, etc.

4.8.3 Solid Waste Audit at South Academic Building

This building consists of faculty, staff, offices, seminar halls, classrooms, computer lab and project offices. It is estimated that there are about 120 people in this building. The majority of solid waste is usually inorganic waste such as paper, bottles, cardboards, and cans. About 45% of the waste is sent to landfill and the rest recycled. The details of composition are recorded in Table 4.33 as following:

Table 4.33 Solid Waste Composition at South Academic Building

Items	Amount (kg)	Amount (kg/person)
Landfilled wastes	8.8	-
Paper*	8.6	-
Cardboard*	0.7	-
Bottles*	1.4	-
Can*	0.04	-
Total	**19.5**	**0.2**

Remark: The data has been obtained by direct sampling
* These are recycled waste

Since this is an academic building, it is obvious that almost 50% of the solid waste is paper. Cardboards will be presented as larger numbers when new equipments or computers are bought. Bottles are usually drinking water bottles. Landfilled waste covers about 50% of total waste. Inorganic waste is in the form of non-recyclable wastes such as foam, paper, plastic bags, tissues, milk bottles, paper cups, etc. On an average, each person in this building generates about 0.2 kg daily.

4.9 Noise Level Audits

In the Eco-campus map (Figure 4.1), it is found that noise level is high around the chiller room. From the observations, there are three places that are marked as high noise level zones; these are chillers' room, ambient lab and the cafeteria. The chiller room consists of 4 chillers, 4 cooling towers and pumps. These are the sources of high noise. Technicians of chiller room are at risk due to their continuous exposure to high noise level.

For ambient lab, this does not create much effect to the people nearby because the noise level is lesser than chiller room. Students and staff do work there for 24 hours, so they have low risk compared to the technicians in the chiller room.

Table 4.34 Noise Level Emissions at AIT Campus

Places	**L_{max}**	**L_{eq}**	**Comparisons**
Chiller room	77.6 < Standard	76.5 > Standard	76.5-77.6 dB ~ Noise level in the business office
Ambient Lab	89.2 < Standard	80.3 > Standard	80.3-89.2 dB ~ Noise level in the street traffic
Cafeteria	73 < Standard	69.9 < Standard	69.9-73 dB ~ Noise level in the business office

Remark: Unit = dB(A)
L_{max} = maximum sound level should not exceed 115 dB (ambient condition)
L_{eq} = Equivalent continuous sound level 24 hours should not exceed 70 dB (ambient condition)
Source of Noise standard = (Pollution Control Department, 2004)

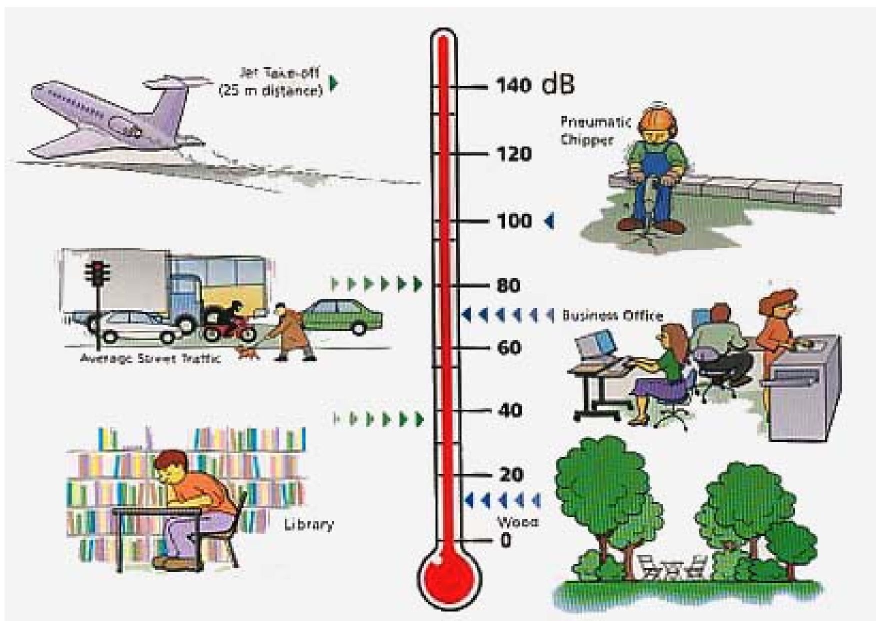


Figure 4.37 Comparisons of Noise Level in Decibel to Ambient Conditions

In chiller room, maximum sound level (L_{max}) is not harmful to the hearing of people who are exposed because it is lesser than the standard. But equivalent continuous sound level (L_{eq}) which is 24 hours operation is more than the standard. It indicates that the technicians may develop hearing problems when they work there for several years.

In ambient lab, L_{max} is acceptable because it does not reach 115 dB. L_{eq} exceeds the standard, if the students and staff who work at the source do not exceed 24 hours, than the noise may not be harmful. From Table 4.35, AIT's noise level at the cafeteria during lunch and dinner time does not affect the hearing capacity. Both indicators (L_{max} and L_{eq}) are lesser than the standards.

4.9.1 Snapshots of Noise Level Emission Sites

(a) Chiller room

(b) Ambient Lab

(c) AIT's cafeteria

Figure 4.38 Noise Level Emission Sites

4.9.2 Noise Level Benchmarks

Table 4.35 Benchmarks of Noise Level Emissions at Cafeterias

Name of Universities	**L_{max}**	**L_{eq}**
AIT	73 < Standard	69.9 < Standard
Kasetsat	85.7 < Standard	83.2 > Standard
Thammasat (Rangsit)	79.1 < Standard	76.8 > Standard

Remark:

All data have been obtained by direct measurement
L_{max} = maximum noise level emission
L_{eq} = equilibrium noise level emission
Thammasat Rangsit University has maximum 405 people during lunch time
Kasetsat University has maximum of 740 people during lunch time

Noise level depends on the number of people in the room. Thammasat and Kasetsat have larger number of people in the lunch time compared to AIT which has only about 300 people at the peak hour. Therefore, equivalent continuous sound level (L_{eq}) is higher than the standard of noise level emissions which equal the condition of the average street traffic as shown in Figure 4.39. However, this is not harmful to the people's health because the people are normally exposed to this noise level at only one hour maximum (not more than 24 hours). It can be concluded that the noise level emissions at the cafeterias from three Universities are acceptable.

4.10 Odor

Odor is an issue that can interrupt people and affect to their health. For years, people who walk through the AIT solid waste collection site near the football field complain about the odor or foul smell. Odor can not be measured by any equipment but it can be measured by individual feeling through the breath.

Solid waste collection site is a potential breeding place for insects, flies, cockroach, and rats. Various kinds of bacteria and virus are able to blown into the air and flown with the wasteater, which will be transmitted to the people who are exposure to the place.

4.10.1 Evaluation of Odor

One issue that the workers from the garbage trucks always complain is that the garbage from cafeteria, such as organic and food waste are not put in the proper black bag. Vendors in the cafeteria use very thin black bags, which tears every time the workers lift to the truck. Also some leakages from the bag occurred. Therefore, some amount of wastewater from the organic waste usually spill down to the floor.

Logically, the garbage from the cafeteria is really heavy (about 25 – 30 kg per bag). If the vendors use the thin black bags to carry this kind of garbage, the bags always tear off. The wastewater from organic waste usually creates very bad odor. This could be one reason for the odor problem.

During the transferring of garbage to the truck, the workers try to find and separate some recyclable waste; they also pour the garbage out of the black bags, in order to collect the bags and sell to another vendor. In this case, wherever they collect the garbage, there will be much wastewater flow down to the floor and drainage. Further more, It was observed that the drainage system of this collection site is not well maintained (as seen in the snapshots). The wastewater from the organic waste flows down to the drainage nearby and stagnates there.

In addition, some minor issues always prevail in this collection site, such as the gate usually remains open; many bags full garbage are not properly tied and garbage easily spills out of the bags. On the other hand, some scavengers try to find the recyclable waste at the collection site. They pour the garbage out of the black bags (mostly are inorganic waste), and then they leave it there (as shown in the figure). This disturbs the collection process and blocks the drainage system.

4.10.2 Snapshots of Solid Waste Collection Site

(a) The gate is opened all the times

(b) Blockage of drainage system

(c)Leachate spills down to the drainage

(d) Leachate spills down to the floor

(e) Untied garbage bags

(f) Improper garbage collection

(g) Improper garbage collection

(h) Garbage transferring

(i) Garbage collection in the truck

(j) Segregation of recycle waste

Figure 4.39 Snapshots of Solid Waste Collection Site

4.11 Proposing of CP Options

In order to implement CP options, four main steps need to be conducted. CP options can be firstly identified by defining the problematic areas in the campus, then, proposing of the solutions for these problems. The problems are further expected for the improvement. Finally, payback period should be calculated, in order to give the clear picture for decision makers to decide.

Table 4.36 List of Cleaner Production Options

Purposes	**Problems**	**Descriptions**	**Proposed Solutions**	**Payback (year)**
Electricity Conservation, reduce GHG emissions	Excessive electricity use	Electricity is used inefficiently during the operational time of electrical appliances.	1. Automatic sensor switches for all offices	-
			2. Replace conventional street light to the solar street light	-
		Some chillers are too old (13 years old). The efficiencies of these chillers are reduced.	3. Replace 2 old chillers to a high efficient chiller	5
Water Conservation	Excessive water use	Large amount of water is used unnecessarily via some kinds of water appliances. These need to be replaced.	1. Replace old manual faucets to the new self-closing faucets	1
			2. Replace the conventional Urinals to Non-Water Urinals at the public men's restrooms	10
			3. Replace high flush toilets to low flush toilets	4
			4. Repair, maintenance and audit of water leakage for the whole campus	-
	Wastewater discharged inefficiently	Treated wastewater sometimes does not meet the standard of effluent. This needs to be improved when the reuse of wastewater is required.	5. Reuse of treated wastewater for watering the garden	-
Resource Conservation	Resource's scarcity	Paper is the major office waste in the campus.	1. Encourage two sides photocopies in one paper	-
Reduction of Solid Waste	Improper Solid waste generation	To reduce pollution load in the landfill and environmental impacts. It is necessary to reduce some amount of solid waste.	1. Promoting of waste collection center within the campus	-
			2. Education campaign on campus with 3R concepts (reduce, reuse, recycle)	-
			3. Promote demonstration projects for waste segregation	
			4. Reuse of organic waste as organic fertilizers	-

4.11.1 Electricity Conservation

Detailed calculations are shown in Appendix H.

1) Install the automatic movement sensor switches for all offices
2) Replace an old chiller to a high efficient chiller
3) Replace the conventional street light to the solar street light

Table 4.37 Electricity Conservation Options

Option	Descriptions	Electricity Savings (kW/year)	Money Savings (Baht/year)	Conservation from its original %
1	Install the automatic movement sensor switches for all offices	656,833	1,878,542	11
2	Replace the conventional street light to the solar street light	16,928	48,414	100
3	Replace an old chiller to a high efficient chiller	495,000	1,415,700	65
	Total	**1,168,761**	**3,342,656**	**8.66**

Remark: Detailed calculations are indicated in Appendix H
For Option 3, please refers to Section 4.11.8

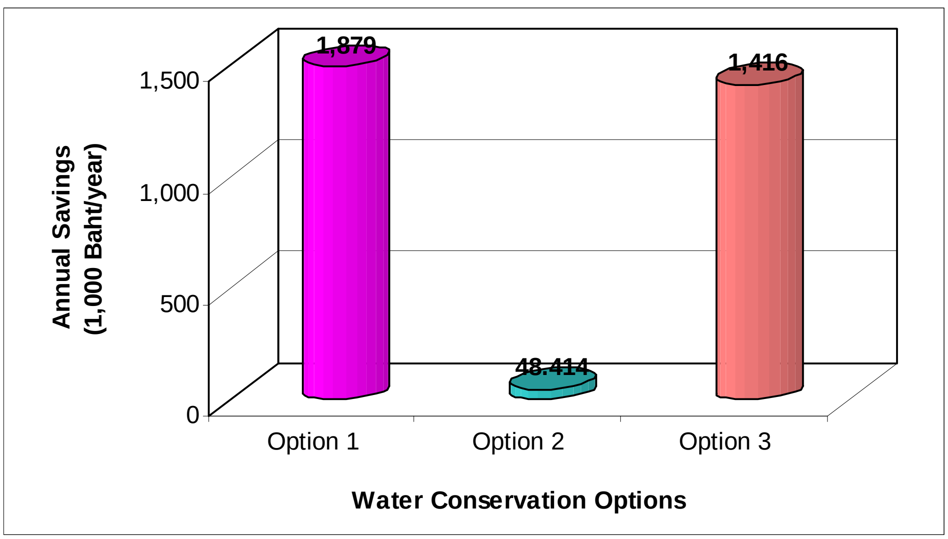


Figure 4.40 Electricity Conservation Options

4.11.2 Water Conservation

Detailed calculations are shown in Appendix H.

1) Replace of old manual faucets to new self-closing faucets
2) Replace the conventional Urinals to Non-water Urinals at the public men's restrooms
3) Replace high flush toilets to low flush toilets

   Toilets in residential areas and offices usually are the old model (high flush toilets), which needs about 10-15 liters per flush. If these toilets are replaced with the new model (low flush toilet) that needs only 3-6 liters per flush, almost 39,000 m^3 of water consumption or about 623,000 Baht will be reduced each year (Appendix H).

4) Reuse of treated wastewater for gardening

   During dry season or summer the water from canal or pond is quite scarce. The best way to do is to reuse the treated wastewater from the Wastewater Treatment Plant. Each year, there are about 296,000 m^3/year or 810 m^3/day of wastewater is discharged to the public canal (Appendix G). This amount of treated wastewater is enough for gardening. Furthermore, the reuse of treated wastewater helps to reduce huge amount of nitrogen flow into the water source or groundwater that may cause water pollution.

   Referring to the quality of wastewater discharge (Table 4.12) it is found that the effluents of treated wastewater for some parameters are met with the standard but some parameters are not. So, the quality of wastewater needs to be improved. There are many ways to improve the quality of the discharged wastewater, either to improve the quality of aeration ponds, stabilization ponds, wetlands or propose of additional wastewater treatment units.

   For AIT Wastewater Treatment, the most efficient way to reuse the wastewater can be conducted by aerating of ponds or lagoons. Aerated lagoons are essentially designed to work as a form of lowly loaded activated sludge. Mechanically supplied oxygen increases treatment efficiency and reduces land requirements. However, the high-cost power input is sufficient only for diffusing oxygen into the pond and not for mixing the contents.

5) Improve wastewater quality and reuse of treated wastewater

   AIT Wastewater Treatment Plant seems to be less efficient in treating the wastewater. Figure 4.41 shows how to improve the wastewater treatment plant in the campus. This can be done by separating WWTP into two plants. The first treatment plant is to treat the wastewater flowed from offices only, because offices are less concentration compared to other buildings. The second WWTP is used to treat the wastewater from the rest. On the other hand, treated wastewater from the offices can be reused for watering the garden.

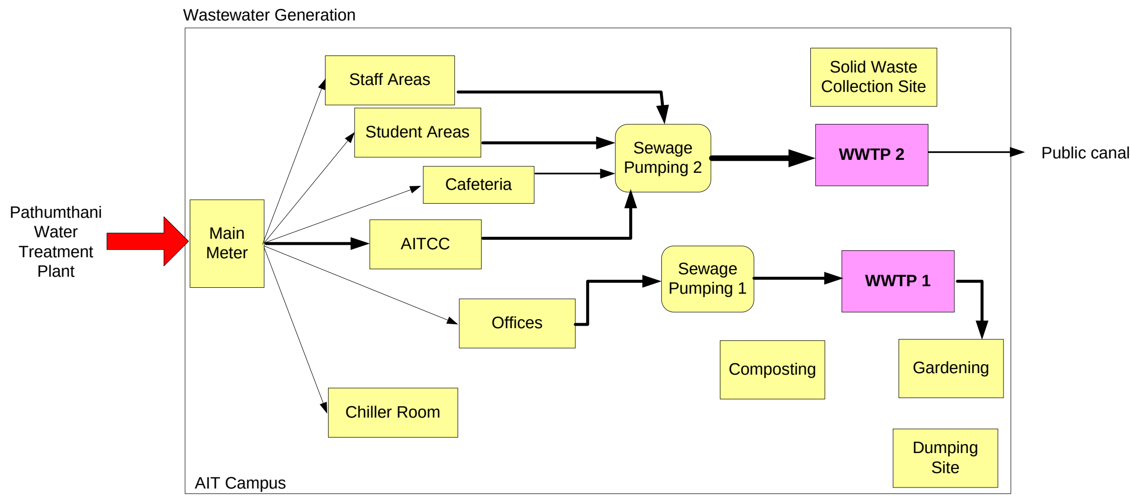


Figure 4.41 Improve wastewater quality and reuse of treated wastewater

Table 4.38 Water Conservation Options

Option	Descriptions	Water Savings (m^3/year)	Money Savings (Baht/year)	Payback (year)
1	Replace of old manual faucets to the new self-closing faucets.	12,158	195,260	1
2	Replace the conventional Urinals to Non-water Urinals at the public men's restrooms.	4,161	66,825	10
3	Replace high flush toilets to low flush toilets	38,836	623,706	4
4	Reuse of treated wastewater for watering the garden	-	-	-
5	Repair, maintenance and audits of water leakage for the whole campus	49,539	795,596	-
	Total	**104,694**	**1,681,387**	-

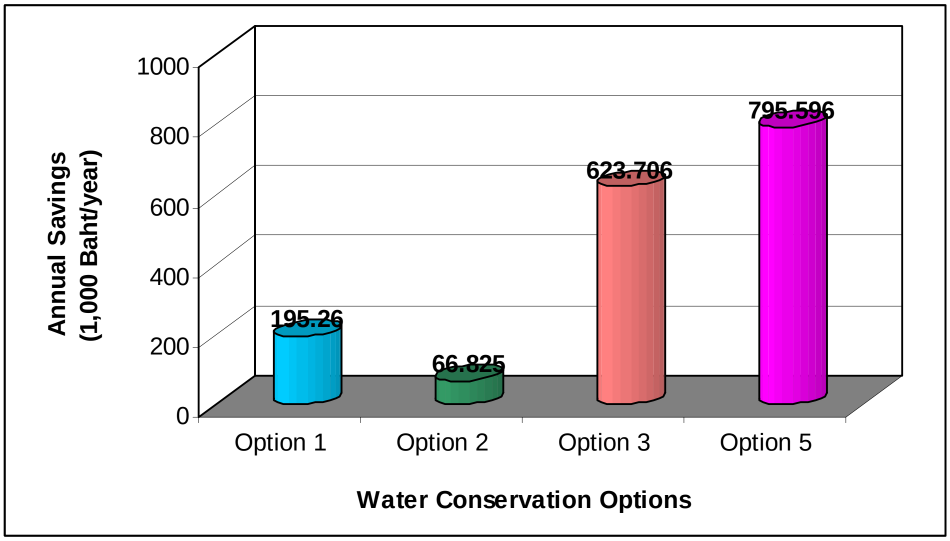


Figure 4.42 Water Conservation Options

4.11.3 Resource Conservation

1) Encourage two side photocopies in one paper

   Each year, photocopy shops in AIT campus need about 5,840 packs of paper for making photocopy or about 16 packs per day (1 pack = 500 pieces of paper) (Interview with the staff in the photocopy shop). Normally, the paper is used only one side because it is easier for the staff to make the photocopy. If it was encouraged to use 2 sides-photocopy, about 50% of the paper will be reduced. Thus, the amount of solid waste generation will be further reduced.

4.11.4 Reduction of Solid Waste Generation

1) Promoting of waste collection center within the campus

   The purpose for this option is to increase the amount of recyclable waste. The different kinds of solid waste therefore will not mix together. Waste collection center that is mostly used is the water bottle's collection center.

2) Education campaign on campus with 3R concepts (reduce, reuse, recycle)

   In these concepts, the people will be trained how to minimize the solid waste in their households. It starts with the simple things as following:

   Reduce:

   - Choose products with the least amount of packaging.
   - Choose packaging that can be recycled
   - Select non-hazardous cleaning and household products.
   - Buy canvas or string shopping bags you can use again and again.
   - Say "I don't need a bag" for small purchases.

- Buy razors and other products with a long life instead of one-use disposables.
- Use sponges and washable rags instead of paper towels.
- Use cloth instead of paper napkins.
- Use china or plastic dishes instead of paper plates.

Reuse:

- Buy a battery charger and recharge and reuse batteries.
- Bring paper and plastic shopping bags back to the store and use them again.
- Use paper and plastic shopping bags, rather than purchased bags, to hold your trash.
- Pass on magazines and books to friends--or to hospitals, senior centers, and others who would enjoy them.
- Give old clothing, household goods, and furniture to charitable organizations. Or hold a garage sale. Other people will pay you for things you no longer want.
- Create a market for what you recycle by buying products made of recycled materials.

Recycle:

- Paper from computer printouts, letters, memos, and copies can all be recycled.
- Make two-sided copies.

- Use the backs of old memos, envelopes, etc. as scrap paper.
- Reuse file folders and interoffice envelopes.
- Use a washable mug for coffee or tea instead of a Styrofoam or paper cup.

3) Promote demonstration projects for waste segregations

Some amount of recyclable waste such as paper cannot be recycled because they mixed with the wet solid waste. Due to this reason, the amount of recyclable waste is quite less (4% of total waste in the campus). Furthermore, if the waste segregations are proposed, the quantity of hazardous waste that was left in the landfill site will be reduced. Waste segregation projects plays significant role for promoting of composting site, the amount of organic waste that is sent to the landfill will be reduced.

4) Reuse of organic waste as organic fertilizers

Organic Waste Generations

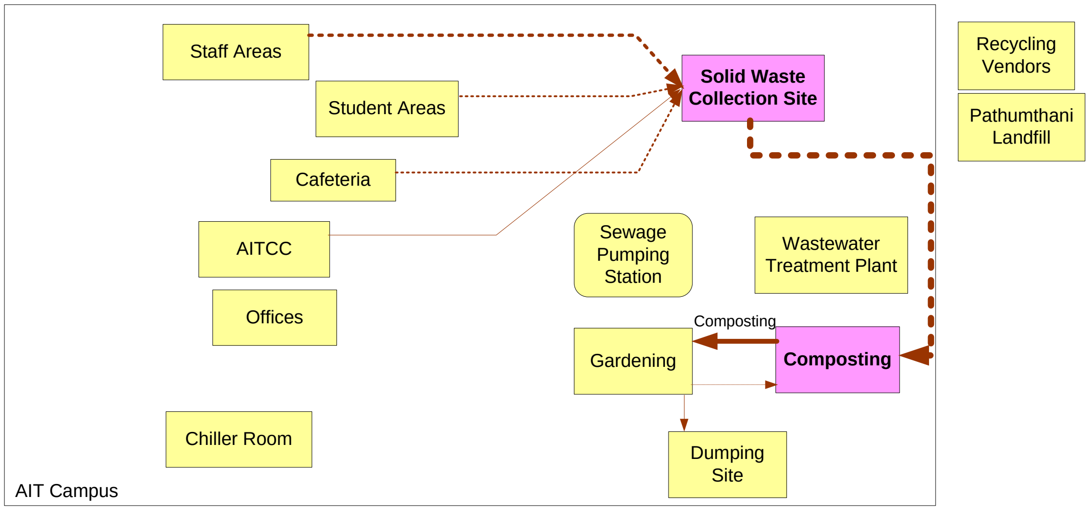


Figure 4.43 Reuse of Organic Waste as Organic Fertilizers

Each day, AIT generates about 2 tons of solid waste to the landfill, at which 60% of total waste is the organic waste. If this amount of organic waste is used as organic fertilizers for the plants, a lot of solid waste will be reduced from the landfill.

4.11.5 Performance Overview

The detailed predictions of electricity and water consumption and solid waste generation are shown in Appendix I.

- **Performance Overview of Electricity Consumption**

If AIT residents implemented these CP options, the amount of electricity consumption, will be reduced yearly as shown in Figure 4.44. A lot of initial implementations have been conducted in 2006; the electricity consumption therefore will be significantly decreased.

Table 4.39 Performance Overview of Electricity Consumption

Performance Indicators	**2005 Results**	**2010 Targets**
Daily electricity consumption in the whole campus (kWh/person)	9.65	8.06
Cost of daily electricity consumption in the whole campus (Baht/person.day)	27.60	28.03
Net CO_2 emissions (tons/day)	21.44	21.78
Unit Price (Baht/kWh)	2.86	3.48

Source: Physical Plant (2005)

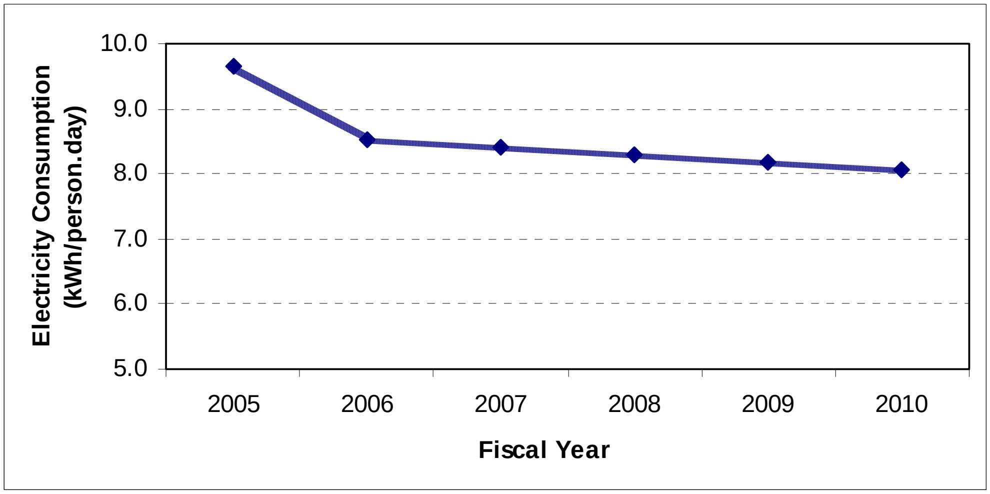


Figure 4.44 Electricity Consumption Predictions

- **Performance Overview of Water Consumption**

The amount of daily water consumption will be reduced significantly from 354 L/person to 249 L/person in each year, if the decision makers implement the proposed CP options in the campus. Referring to the trend of student's growth in the campus during 2002 to 2004, the amount of AIT residents have been estimated as 3% growth in each year. Even though the trend of electricity consumption has been estimated as 2.5% growth in each year, however, when compared to the increase of population's numbers the trend will be gradually decreased.

Table 4.40 Performance Overview of Water Consumption

Performance Indicators	**2005 Results**	**2010 Targets**
Daily water consumption in the whole campus (L/person)	354	261
Cost of daily electricity consumption (Baht/person)	5.69	4.19
Unit price of electricity consumption (Baht/m^3)	16.06	-

Source: Physical Plant (2005), SAO (2005)

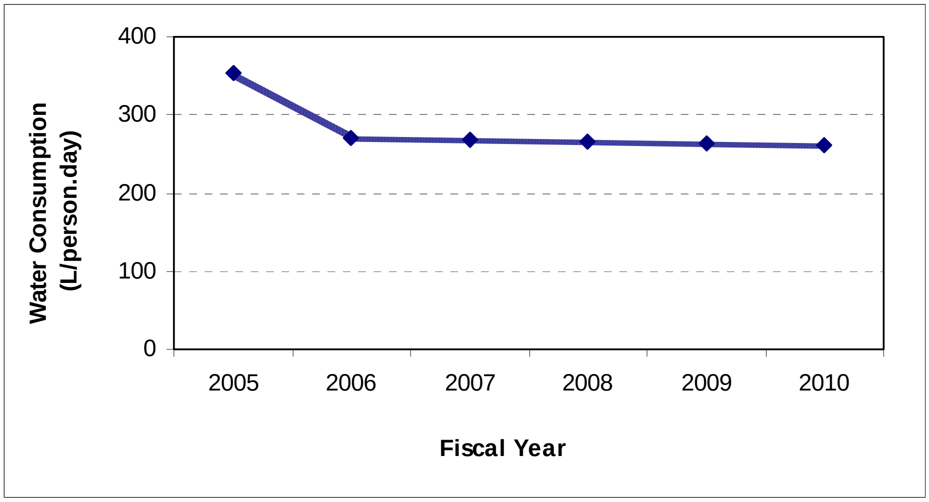


Figure 4.45 Water Consumption Predictions

- **Performance Overview of Domestic and Office Waste Generations**

If AIT implemented these CP options, the predicted solid waste generation in 2010 will be reduced from 740 to 687 tons/day. At the first year of solid waste reduction programme, the amount of solid waste will be significantly reduced at about 10%, then, they will gradually reduced by 2% each year.

4.41 Performance Overview of Solid Waste Generations

Performance Indicators	2005 Results	2010 Targets
Yearly solid waste generation in the whole campus (tons)	740	687
Daily solid waste generation (kg/person)	0.53	0.42
Recyclable waste (kg/day)	28,000	30,900
Amount of solid waste transported to the landfill (tons/day)	1.94	0.80
Cost of solid waste disposal (Baht/year)	96,000	-

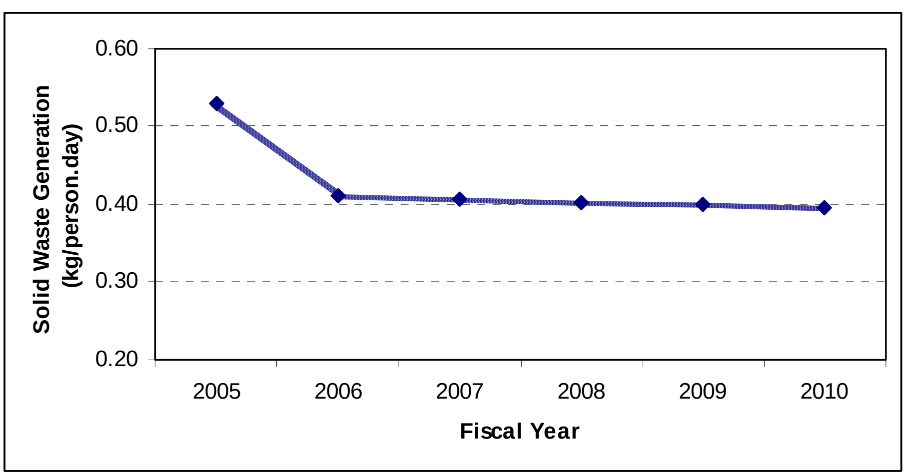


Figure 4.46 Predictions of Domestic and Office Waste Generations

4.12 Eco-Campus Webpage

Eco-campus webpage gives the overall view of AIT campus. It also performs as a benchmark for electricity consumption, water consumption and solid waste generation of a university in Thailand, as well as in the developing country. The frame work of Eco-Campus Webpage is shown in Figure 4.47 below:

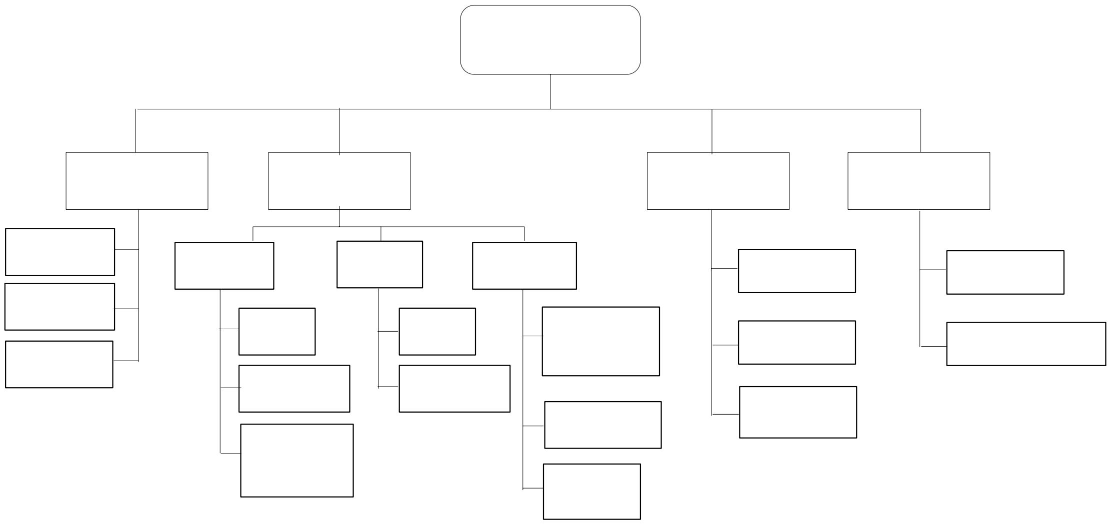


Figure 4.47 Frame work of Eco-Campus Webpage

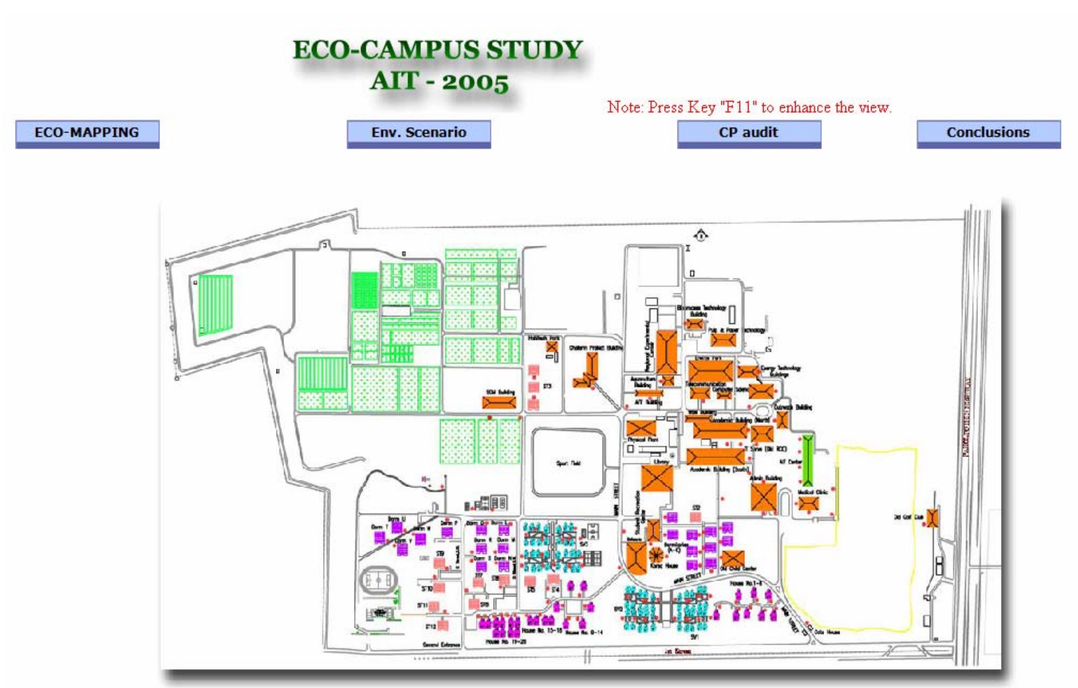


Figure 4.48 Eco-Campus Webpage

Eco-Mapping

Energy consumption

Water

The overview of the Eco-Mapping section shows the AIT campus map. The potential sources for highly electricity and water consumption is also highlight. This section consists of the overall consumption of electricity and water from 2003 to 2005, yearly trend and seasonal trend of electricity and water consumption. Solid waste generation in 2005 is also illustrated there.

Environmental scenario section: gives the perspectives of water source and Pathumthani landfill. It consists of the daily collection activity of the workers from the garbage truck and the yard waste collection of the gardeners.

CP audit section: shows the data of water, electricity and solid waste audits of some representative buildings such as North and South academic buildings, chiller room, ST 6 P and L dormitories. The audits were conducted during 3 periods, examination, semester break and weekends.

Conclusion section: shows the conclusion of all the works that were conducted and recommendations for the future needs.

Chapter 5

Conclusions and Recommendations

5.1 Conclusions

The following conclusions can be drawn from the study:

- From electricity consumption pattern in the campus it is clear that academic buildings without the laboratory consume more than 60%, academic buildings with the laboratory consume only 10% and the residential areas consume about 20% of total electricity consumption.

- Residential areas are the major source of water consumption; with around 51%. The second source is the academic and administrative buildings without laboratory 38% and the rest are the academic buildings with laboratory 12%.

- On an average, the wastewater generation from AIT is about 1,122 m^3/day. The water balance indicates a lost of 17.3%.

- The physical characteristics of influent and effluent of wastewater treatment plant indicates that BOD removal efficiency is only 68-71%. Compared to the Thai standard for wastewater, AIT's WWTP sometimes cannot meet the standard.

- Each day AIT generates about 2 tons of domestic waste of which only 4% is recyclable. The remaining 96% is sent directly to the landfill. Seventy five percent of the total recyclable waste is contributed by paper mostly from the offices.

- Solid waste generation is largely from the residential areas; especially the staff areas; about 32% of total solid waste. Student areas generate 27%, 17% from the offices and the rest are AITCC, cafeteria and others. Organic waste is estimated at 60% of total waste.

- Energy, water and solid waste audits were conducted at the representative buildings which consume large amount of electricity, water and generate huge amount of solid waste.

- Yard waste is about 0.2 tons per day, some of them are sent to the organic composting site in the AIT campus. The rest is dumped at the dumping site near the School of Management.

- After identifying the potential sources of electricity and water consumption and solid waste generation, CP options are proposed, to suggest measures to reduce electricity and water consumption and solid waste generation.

- If AIT implemented these CP options, the daily electricity consumption will be reduced from 9.65 kWh/person to 7.65 kWh/person by 2010. Moreover, the daily water consumption in 2010 will be reduced from 354 L/person to 226 L/person.

5.2 Recommendations

The author would like to make the following recommendations for further study

- The need is to implement all proposed Cleaner Production options including the promotion of electricity and water reduction programmes in the campus.

- Not only implementing the electricity and water reducing activities, the application of new technology also plays significant role for electricity and water reduction

- Moreover, leakage is estimated at about 6% to 20% of total water consumption. To reduce this amount, Leak detection should be done in AIT.

- The proposed scenario for improvement of wastewater treatment plant should be implemented. The best way to do is to divide the WWTP into two. The first WWTP is to treat only the wastewater from the office, this wastewater can be further reused for watering the garden in the campus. The second WWTP will treat the wastewater from the rest buildings and discharge into public canal.

- AIT needs to conduct some solid waste reduction programs on promoting of 3R concepts; reduce, reuse and recycle.

- An organic waste composting or anaerobic digestion should be started in the campus. Organic waste covers 60% of total waste in the campus of which 432 kg/day are generated from the cafeteria, AITCC and other vendors.

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Appendix A

Electricity Consumption

Table A.1 Trend of Electricity Consumption in Residential Areas from 2000 to 2005

Year	Total electricity consumption (million kWh)	Total cost (million Baht)	Electricity consumption kWh/(person.day)	Cost Baht/(person.day)	Unit Price (Baht/kWh)	Estimated No. of resident
2000	2.40	5.62	2.65	6.21	2.34	2479
2001	2.43	6.29	2.66	6.88	2.59	2506
2002	2.45	6.37	2.66	6.91	2.60	2524
2003	2.50	6.58	2.62	6.90	2.63	2611
2004	2.69	7.45	2.77	7.67	2.77	2663
2005	2.92	8.35	2.93	8.39	2.86	2726

Remark: No. of staff = 1,150

Table A.2 Trend of Electricity Consumption in Academic and Administrative Buildings from 2000 to 2005

Year	Total electricity consumption (million kWh)	Total cost (million Baht)	Electricity consumption kWh/(person.day)	Cost Baht/(person.day)	Unit Price (Baht/kWh)	Estimated No. of resident
2000	9.44	22.08	8.01	18.74	2.34	3228
2001	9.64	24.97	8.02	20.76	2.59	3295
2002	9.79	25.45	8.03	20.88	2.60	3340
2003	10.52	27.66	8.11	21.33	2.63	3554
2004	10.52	29.14	7.83	21.70	2.77	3679
2005	10.49	30.01	7.50	21.46	2.86	3831

Remark: AITCC is exceptional

It is assumed that No. of staff is not changed in each year

Table A.3 Electricity Consumption in 2005

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total MWh
Village 1-3	8,640	10,380	12,480	13,250	15,290	14,150	10,920	11,090	16,380	13,160	12,250	13,040	0.15
Dorm ST1-12	46,903	43,913	70,862	74,287	90,890	92,980	72,950	83,270	76,100	67,080	68,440	64,570	0.85
Dorm T, U, V, W	12,240	9,600	15,420	16,420	22,180	17,680	13,920	20,060	33,900	28,060	26,140	26,620	0.24
Dorm L, M, N, P, Q, R, S	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Houses 1-14	16,400	18,150	20,300	21,250	25,150	21,650	18,600	19,500	27,650	20,950	20,400	21,450	0.25
Dorm A-K	29,040	35,920	46,000	50,240	52,400	43,360	37,920	38,560	52,240	44,960	41,840	43,600	0.52
Ambient Lab	6,320	7,040	7,460	6,540	4,080	4,940	4,940	6,320	2,560	4,560	5,460	6,180	0.07
AITCC (hotel)	N/A	14,400	22,400	9,920	7,840	10,880	5,440	9,440	7,840	N/A	N/A	7,840	0.07
Cafeteria	2,772	2,413	2,713	2,615	34,747	18,634	16,702	20,436	17,478	16,453	17,353	14,622	0.17
North Academic Building	37,960	41,020	38,560	39,760	33,930	32,720	33,290	39,780	35,870	33,090	37,110	37,970	0.44
South Academic Building	42,000	47,340	50,340	50,540	40,590	41,540	40,850	52,780	46,770	44,500	48,750	41,490	0.55
Administration	20,640	21,560	22,320	20,960	20,840	22,480	21,000	24,520	20,640	18,600	20,680	17,000	0.25
SU Panel Board	11,532	12,737	13,028	12,367	12,081	11,574	11,401	14,744	12,204	12,260	12,789	10,603	0.15
Korea House	560	680	920	900	860	400	420	780	540	640	620	580	0.007
Siam Commercial Bank	N/A	N/A	N/A	N/A	1,416	1,615	1,464	1,877	1,590	1,503	1,598	1,766	0.01
Pulp & Paper	14,000	16,600	18,600	17,200	13,200	14,000	11,800	15,400	13,200	14,000	14,800	16,000	0.18
Child Center	9,900	14,200	15,200	12,500	16,500	9,500	6,600	16,300	13,900	12,500	14,600	7,000	0.15
Inter Lab	N/A	34,435	39,164	41,343	37,661	36,710	40,486	43,173	36,019	33,747	33,486	29,043	0.41

Locations	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total MWh**
Outreach Building	42,720	45,920	49,120	49,660	17,760	18,600	18,420	20,640	17,520	16,320	18,060	15,360	0.33
Energy-Tech	11,040	11,780	12,460	12,700	12,060	12,500	12,000	15,360	11,920	11,020	11,980	10,120	0.14
REC	7,800	10,110	11,390	9,580	6,890	7,080	8,600	10,180	9,630	8,930	9,270	9,670	0.11
AFE	9440	10,800	11,920	10,720	8,400	8,480	9,920	12,240	9,120	9,440	11,440	12,000	0.12
Aqua Outreach	1,080	1,100	1,220	1,160	940	1,060	860	1,200	840	740	940	740	0.01
Telecom	8,160	9,660	11,280	12,060	10,200	9,060	8,880	12,300	9,780	9,420	10,080	8,460	0.12
Computer Science	14,040	17,340	18,780	19,500	16,920	15,480	14,880	18,660	16,860	14,820	16,920	12,300	0.20
Habitech Park	N/A	N/A	N/A	N/A	4,000	4,000	5,000	5,800	3,400	3,400	4,400	3,200	0.03
Biotech Building	13,260	15,600	14,560	13,580	8,380	6,660	6,000	6,840	6,600	6,880	6,740	7,000	0.11
RCC	20,600	21,400	23,000	22,000	22,200	22,800	21,600	26,200	23,000	20,400	22,600	21,600	0.27
CIM	21,800	25,000	27,600	28,800	25,200	22,800	22,800	27,000	23,200	21,800	24,200	23,600	0.29
SOM	14,520	16,640	19,080	18,200	15,640	13,040	11,560	17,840	15,920	15,800	16,960	11,240	0.19
Physical Plant	5,920	6,320	6,960	6,720	6,560	6,960	6,560	7,520	6,320	5,600	6,400	5,200	0.08
WRE Office	4,060	4,700	5,080	5,080	4,540	4,500	4,260	4,720	4,140	4,200	4,580	3,960	0.05
Golf Club	1,380	1,680	1,920	2,100	3,240	2,700	2,520	3,180	2,520	2,220	2,100	1,680	0.03
Chiller Room	58,140	151,980	141,080	127,780	124,980	107,420	122,660	105,940	96,640	125,900	123,280	58,660	1.34
Library	N/A	36,900	38,100	37,800	35,100	43,500	90,300	45,000	35,700	31,800	37,200	24,800	0.46
DEC	2,461	3,085	2,822	2,772	3,282	3,360	3,374	3,309	3,594	2,120	3,238	1,496	0.03
RS & GIS	9,540	10,160	8,220	8,000	8,380	8,440	8,060	9,300	7,400	7,260	7,660	7,500	0.10
Total Consumption (MWh)	1.00	1.15	1.27	1.22	1.27	1.13	1.07	1.21	1.17	1.13	1.08	0.79	13.50
Price (Million Baht)	1.70	1.95	2.16	2.08	2.16	1.93	1.83	2.06	1.99	1.93	1.84	1.34	22.99

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total MWh
Unit Price (Baht/kWh)	2.87	2.82	2.78	2.85	2.80	2.81	2.83	2.82	2.83	2.94	2.96	3.06	

Remark: Unit of electricity consumption from January to December is kWh

Table A.4 Electricity Consumption in 2004

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total MWh
Village 1-3	29,120	33,120	37,040	47,760	33,852	29,840	36,000	31,520	35,680	38,560	43,040	32,560	0.43
Dorm ST1-12	41,600	49,000	66,700	96,900	64,400	65,100	80,700	68,400	61,100	61,000	63,700	36,300	0.75
Dorm T, U, V, W	8,500	10,000	14,750	21,000	12,750	13,000	15,250	11,250	13,250	14,000	15,000	7,750	0.16
Dorm L, M, N, P, Q, R, S & Houses	52,560	62,160	83,160	116,280	75,960	77,760	88,560	69,120	77,520	76,500	75,120	42,720	0.90
Dorm A-K	29,040	33,200	32,560	38,720	28,080	35,600	38,000	40,800	43,760	47,760	49,920	36,240	0.45
Ambient Lab	3,320	4,240	4,820	5,680	5,140	5,060	5,520	4,740	5,680	6,720	6,780	7,640	0.07
AITCC (hotel)	7,840	7,840	8,640	8,320	9,280	7,680	10,240	7,840	8,640	9,600	8,800	9,600	0.10
Cafeteria	13,920	13,760	12,560	14,160	11,440	12,080	14,080	12,480	14,080	14,560	14,000	13,520	0.16
North & South Academic Building	153,680	178,514	159,129	184,800	138,995	146,333	176,090	186,957	182,694	180,244	172,966	169,786	2.03
Administration	17,360	22,320	20,160	22,320	19,280	20,560	23,960	19,960	22,760	22,160	23,720	20,280	0.25
SU Panel Board	6,840	7,840	7,320	9,720	8,440	9,360	9,600	8,360	8,880	9,080	8,880	7,960	0.10
Pulp & Paper	10,600	16,200	17,400	19,000	14,600	13,200	14,600	9,800	12,400	12,800	13,400	11,200	0.17
Child Center	14,710	17,960	22,610	24,900	21,250	16,920	20,630	31,550	31,840	33,590	39,770	22,950	0.30

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total MWh
Outreach Building	14,160	16,740	15,120	17,040	15,240	15,240	18,300	14,640	16,800	15,900	18,180	14,460	0.19
Energy Tech.	11,580	12,680	12,480	13,540	11,380	11,800	14,440	11,720	12,880	12,780	14,060	11,260	0.15
REC	6,310	8,060	8,610	9,120	6,930	7,170	7,180	6,770	9,160	9,640	9,650	8,260	0.10
AFE	1,267	772	747	989	1,198	767	672	972	1,342	437	11,360	632	0.02
Aqua Outreach	960	1,100	1,020	1,140	1,140	1,240	1,420	1,020	11,660	1,160	1,180	940	0.02
Telecom	7,500	8,820	8,460	9,780	8,460	8,400	9,480	8,280	9,900	9,660	10,680	7,860	0.11
Computer Science	13,320	15,360	14,940	18,840	14,880	14,640	19,140	15,180	17,820	17,940	19,860	15,300	0.20
Habitech Park	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3,400	3,800	3,000	0.01
Biotech	8,900	10,860	11,560	9,520	17,480	12,600	151,400	9,560	11,660	13,340	12,840	13,400	0.28
RCC	21,600	24,400	25,000	29,000	24,200	25,600	29,600	23,600	23,200	24,400	26,200	24,400	0.30
CIM	20,000	22,800	21,600	25,400	19,600	20,000	24,400	19,800	24,000	24,200	24,400	20,600	0.27
SOM	13,640	16,320	15,520	17,600	14,240	13,480	16,600	13,040	17,160	17,680	19,920	13,240	0.19
Physical Plant	5,840	6,640	6,000	6,560	6,560	6,000	7,040	6,240	6,640	6,880	7,040	5,840	0.08
WRE Office	3,740	3,920	4,020	4,660	4,220	4,520	4,300	5,000	4,920	5,140	4,940	4,480	0.05
Golf Club	1,560	1,680	2,100	2,460	1,800	1,860	2,160	2,040	1,860	1,920	1,680	1,440	0.02
Chiller Room	66,340	76,360	114,480	155,880	127,760	143,640	159,380	124,860	137,140	132,020	121,800	116,138	1.48
Library	34,200	38,700	34,500	38,700	34,800	34,200	39,900	30,900	35,700	37,500	42,900	31,500	0.43
Total Consumption (MWh)	0.95	0.98	1.24	1.23	1.18	1.09	1.16	1.14	1.22	1.11	1.18	0.83	13.31
Price (Million Baht)	2.52	2.78	3.38	3.41	3.24	3.00	3.15	3.15	3.31	3.11	3.32	2.42	36.81
Unit Price (Baht/kWh)	2.65	2.84	2.74	2.76	2.75	2.75	2.72	2.76	2.71	2.80	2.82	2.91	

Remark: Unit of electricity consumption from January to December is kWh

Table A.5 Electricity Consumption in 2003

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (MW)
Village 1-3	16,880	11,760	13,600	15,920	11,520	11,840	36,320	23,440	34,480	39,840	36,880	31,200	0.28
Dorm ST	43,200	51,600	59,700	92,100	69,300	63,000	80,700	46,900	56,200	66,600	54,600	41,400	0.73
Dorm T, U, V, W	8,250	11,000	13,000	18,250	15,250	13,500	15,750	7,000	11,500	13,250	12,000	7,500	0.15
Dorm L, M, N, P, Q, R, S & Houses	51,480	62,280	75,840	95,400	78,000	71,640	93,480	51,600	67,440	77,640	71,520	47,880	0.84
Dorm A-K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	97,280	39,120	43,840	39,120	31,440	0.25
Ambient Lab	3,840	4,880	5,680	7,240	5,640	5,940	6,160	3,260	4,860	5,080	4,580	4,420	0.06
AITCC (hotel)	8,000	6,650	7,520	9,600	6,720	7,680	11,520	5,600	7,840	8,320	8,480	7,040	0.09
Cafeteria	12,640	11,680	12,720	14,560	12,240	13,440	18,800	10,800	16,880	21,120	16,480	15,440	0.18
North & South Academic Building	79,660	68,620	90,320	86,260	N/A	78,540	100,040	111,582	157,840	166,260	155,377	145,137	1.26
Administration	12,720	11,320	12,000	21,440	3,120	12,200	15,680	4,880	6,640	7,040	6,400	6,560	0.12
SU Panel Board	9,386	14,024	10,526	14,198	10,476	6,808	7,127	6,040	7,320	7,040	6,360	5,640	0.10
Pulp & Paper	10,200	11,400	12,400	14,600	13,200	19,200	20,000	11,200	9,000	12,800	13,400	11,600	0.16
Child Center	23,445	114,136	30,237	33,524	33,039	32,384	36,396	12,885	19,429	17,654	21,630	14,040	0.39
Outreach Building	15,240	14,460	15,660	19,380	13,740	15,420	20,520	12,480	16,560	17,400	16,920	16,320	0.19
Energy Tech.	11,580	10,820	11,180	14,360	12,420	13,360	17,420	9,820	12,780	13,080	12,740	12,120	0.15
REC	6,010	21,000	7,710	11,780	7,490	7,440	8,010	4,830	5,800	7,060	8,100	6,860	0.10
AFE	10,240	5,820	7,600	11,780	9,280	9,840	12,800	7,120	9,120	10,640	5,840	13,680	0.11
Aqua Outreach	840	780	940	11,680	1,080	1,100	1,380	840	1,120	1,280	1,100	1,060	23,200
Telecom	11,640	9,900	9,360	13,860	10,080	14,640	8,640	11,040	11,760	10,440	8,580	10,900	0.13

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (MW)
Computer Science	16,080	14,580	16,140	18,840	14,940	14,220	18,840	11,880	17,280	17,960	16,500	14,040	0.19
Habitech Park													
Biotech	11,380	11,340	12,340	16,420	13,820	14,560	16,960	9,120	11,620	11,960	10,100	10,180	0.15
RCC	23,800	21,000	44,000	9,800	22,200	25,400	30,400	18,200	23,000	24,000	24,200	26,800	0.29
CIM	19,200	17,800	19,200	23,200	19,800	20,200	28,400	15,400	21,000	23,800	22,000	22,800	0.25
SOM	17,680	16,360	17,520	17,560	16,280	16,880	22,080	11,480	18,080	16,480	15,960	12,440	0.20
Physical Plant	8,590	8,080	8,000	8,400	6,640	6,880	9,360	5,280	6,560	6,720	5,920	6,160	0.09
WRE Office	4,000	3,420	4,140	4,640	9,280	4,000	5,140	2,940	4,040	4,000	4,200	13,680	0.06
Golf Club	2,700	2,040	1,860	3,900	1,800	1,740	2,460	1,380	1,800	2,340	1,740	1,800	0.03
Chiller Room	73,500	126,160	83,800	202,280	139,900	111,920	123,840	90,560	121,360	98,620	98,200	35,000	1.31
Library	39,900	33,900	38,400	38,100	36,000	36,600	48,300	27,600	37,500	39,000	36,000	31,800	0.44
Total Consumption (MWh)	0.91	0.99	1.21	1.18	1.22	1.17	1.14	1.11	1.11	1.17	1.13	0.78	13.11
Price (Million Baht)	2.36	2.68	3.15	3.07	3.20	3.07	3.00	2.86	2.90	3.03	2.96	2.12	34.37
Unit Price (Baht/kWh)	2.67	2.70	2.61	2.61	2.62	2.62	2.62	2.60	2.61	2.61	2.63	2.72	

Remark: Unit of electricity consumption from January to December is kWh

Table A.6 Electricity Consumption in 2002

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total MWh
Village 1-3	27,900	20,600	28,900	30,200	25,400	26,200	23,120	21,360	20,960	20,320	22,320	18,880	0.29
Dorm ST	43,500	46,200	69,000	72,600	70,500	64,200	75,300	48,300	54,900	52,200	56,700	50,100	0.70
Dorm T, U, V, W	8,750	8,250	13,500	13,000	12,500	12,750	17,000	9,250	11,000	9,750	11,000	8,500	0.14
Dorm L, M, N, P, Q, R, S & Houses	52,560	51,960	80,400	77,640	77,040	75,600	92,160	53,640	71,160	66,000	69,720	55,200	0.82
Dorm A-K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ambient Lab	6,820	5,280	7,740	7,320	7,500	6,580	5,760	3,520	3,980	4,040	3,580	2,480	0.06
AITCC (hotel)	9,280	7,040	9,280	8,800	8,480	8,320	9,120	8,480	9,600	8,480	8,960	7,040	0.10
Cafeteria	13,280	9,840	12,800	10,960	12,800	12,240	11,840	11,520	12,320	11,520	11,760	10,400	0.14
North & South Academic Building	87,180	N/A	77,260	85,680	108,500	86,920	25,240	121,980	76,520	74,960	129,420	110,720	1.00
Administration	11,840	8,680	11,240	10,640	11,320	11,280	10,960	11,240	11,960	10,640	11,600	10,800	0.13
SU Panel Board	7,906	7,469	8,928	9,162	9,396	10,317	10,401	10,349	7,600	7,138	8,784	8,779	0.11
Pulp & Paper	13,000	10,400	14,600	13,000	15,000	11,800	14,000	12,000	11,600	7,800	10,200	8,600	0.14
Child Center	28,611	24,768	30,537	24,439	32,234	34,100	30,803	23,684	28,180	28,435	29,309	18,730	0.33
Outreach Building	18,420	14,400	17,820	16,800	18,300	16,800	17,160	18,180	14,100	14,400	15,480	13,380	0.20
Energy Tech.	7,320	5,600	9,260	8,320	10,200	11,200	12,900	11,180	12,880	12,020	6,620	15,620	0.12
REC	9,820	6,410	8,690	7,270	8,450	8,790	7,500	6,190	6,790	6,600	6,940	5,740	0.09
AFE	9,840	6,960	9,520	9,520	9,760	9,680	9,360	8,880	9,200	9,120	8,720	8,560	0.11
Aqua Outreach	820	540	800	580	720	760	820	840	960	900	1,040	680	0.009
Telecom	12,000	8,820	12,060	10,260	11,940	11,820	12,480	11,580	13,200	12,420	12,420	11,160	0.14

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (MW)
Computer Science	17,040	13,200	19,800	15,660	17,040	16,920	20,280	17,460	18,840	17,160	19,980	15,180	0.21
Habitech Park	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Biotech	13,380	9,560	14,180	12,700		13,420	11,980	9,820	10,980	10,220	10,480	9,520	0.13
RCC	27,000	20,600	26,400	24,200	25,200	24,600	24,000	24,400	25,200	23,200	23,400	21,600	0.29
CIM	33,600	13,800	18,400	15,400	17,800	17,600	20,800	18,800	21,200	19,600	21,600	17,000	0.24
SOM	17,600	10,320	14,320	10,240	12,880	12,800	14,720	12,520	16,800	17,320	19,000	13,120	0.17
Physical Plant	11,920	10,000	12,560	12,480	11,840	11,600	10,320	10,400	11,760	10,800	11,520	10,320	0.14
WRE Office	4,080	3,160	3,820	3,400	3,920	4,180	4,000	3,760	4,300	4,060	4,220	3,620	0.05
Golf Club	4,500	3,540	7,075	10,347	5,171	6,061	6,616	4,791	2,760	2,280	2,640	2,760	0.06
Chiller Room	79,260	103,040	163,240	143,900	164,300	125,280	103,520	112,020	112,160	89,360	119,780	209,620	1.53
Library	42,300	28,500	39,000	31,800	37,500	38,700	40,800	34,200	39,900	N/A	41,100	31,800	0.53
Total Consumption (MWh)	0.88	0.94	1.14	1.08	1.11	0.98	1.11	1.02	1.06	1.09	1.03	0.88	12.34
Price (Million Baht)	2.33	2.48	2.93	2.77	2.86	2.59	2.84	2.63	2.72	2.79	2.67	2.33	31.95
Unit Price (Baht/kWh)	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	

Remark: Unit of electricity consumption from January to December is kWh

Table A.7 Electricity Consumption in 2001

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total MWh
Village 1-3	23,800	25,500	33,030	24,700	25,600	26,500	27,500	22,900	22,300	23,300	22,900	20,900	0.30
Dorm ST	51,600	51,600	64,500	68,400	61,200	61,500	60,600	62,400	57,300	55,500	39,600	33,900	0.67
Dorm T, U, V, W	24,750	28,750	36,250	31,750	30,750	34,750	26,250	12,250	13,250	11,750	8,750	6,500	0.27
Dorm L, M, N, P, Q, R, S & Houses	55,644	59,964	76,716	67,548	70,200	73,008	73,656	65,844	65,172	67,080	50,040	41,760	0.77
Dorm A-K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ambient Lab	6,214	6,848	6,342	8,820	9,450	7,194	5,896	3,760	4,180	5,500	4,440	2,840	0.07
AITCC (hotel)	6,752	8,246	7,868	6,816	8,816	8,400	8,912	N/A	N/A	8,800	9,120	6,560	0.10
Cafeteria	13,920	14,832	15,048	11,432	15,456	13,168	13,232	11,440	11,920	13,920	12,560	8,960	0.16
North & South Academic Building	78,786	97,652	89,158	118,680	80,050	524,806	92,000	76,740	70,320	132,500	52,060	114,160	1.53
Administration	10,872	11,720	11,888	9,948	11,676	10,384	11,328	1,080	10,320	11,480	10,400	8,880	0.13
SU Panel Board	1,801	1,500	1,816	1,525	1,882	3,116	3,181	3,788	2,893	5,157	7,174	4,522	0.04
Pulp & Paper	10,460	14,760	17,700	14,340	15,500	16,160	13,140	12,380	10,000	11,400	13,200	8,800	0.16
Child Center	24,071	27,559	25,207	19,250	25,778	25,574	26,332	28,398	30,691	35,104	24,292	15,273	0.31
Outreach Building	16,566	17,910	18,732	14,742	17,988	15,792	11,996	18,720	15,480	17,880	16,140	13,140	0.20
Energy Tech.	10,418	8,728	9,914	8,152	8,872	9,864	9,180	8,600	7,620	8,180	7,960	5,680	0.10
REC	5,616	7,445	8,560	8,014	8,864	9,390	5,718	4,916	5,410	6,130	6,870	5,080	0.08
AFE	9,784	10,368	10,608	8,824	10,536	10,264	10,544	9,200	8,480	8,880	8,880	7,520	0.11
Aqua Outreach	616	560	538	544	590	700	608	740	580	700	800	520	0.007
Telecom	10,374	9,690	12,306	9,996	11,478	11,340	11,970	12,438	11,640	12,840	13,320	8,700	0.14

Locations	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total (MW)**
Computer Science	14,934	14,958	12,846	14,418	14,928	15,990	15,840	15,918	15,060	17,100	17,460	11,880	0.18
Habitech Park	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Biotech	9,878	10,890	13,168	12,680	12,458	14,310	11,996	11,540	10,420	12,080	11,960	9,140	0.14
RCC	27,120	29,820	31,560	27,620	32,180	28,940	31,260	29,600	26,000	29,800	29,600	24,000	0.35
CIM	14,620	15,380	17,820	15,040	15,660	17,120	17,220	18,260	17,000	19,400	19,000	12,000	0.20
SOM	13,280	12,888	14,976	9,312	11,776	13,152	13,256	10,736	11,840	13,680	13,280	7,760	0.15
Physical Plant	12,256	12,256	13,176	10,320	12,960	12,224	12,536	14,160	11,760	157,680	11,040	8,640	0.29
WRE Office	3,960	4,434	4,440	8,824	3,882	3,752	4,220	3,900	3,600	4,100	3,960	3,180	0.05
Golf Club	4,740	4,560	5,580	4,860	5,040	4,956	5,160	5,640	4,860	4,980	4,560	4,380	0.06
Chiller Room	60,324	115,196	116,312	105,070	90,484	171,789	112,844	102,480	94,440	60,460	31,460	21,620	1.08
Library	35,430	38,220	38,190	27,990	39,210	46,470	25,170	33,900	34,200	66,000	35,700	24,300	0.44
Total Consumption (MWh)	0.98	0.96	1.11	1.07	1.11	1.10	1.12	1.03	1.03	1.05	0.91	0.73	12.19
Price (Million Baht)	2.32	2.55	2.87	2.79	2.86	2.81	2.94	2.68	2.72	2.68	2.38	1.97	31.56
Unit Price (Baht/kWh)	2.36	2.66	2.58	2.62	2.58	2.57	2.62	2.61	2.65	2.57	2.61	2.69	

Remark: Unit of electricity consumption from January to December is kWh

Table A.8 Electricity Consumption in 2000

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total MWh
Village 1-3	22,630	25,000	34,410	23,100	28,110	29,240	25,950	23,900	25,000	25,520	5,120	41,800	0.31
Dorm ST	37,830	41,790	74,460	45,000	69,870	83,890	53,820	52,800	50,820	54,960	42,870	45,300	0.65
Dorm T, U, V, W	23,075	26,200	40,525	23,550	33,850	30,775	29,850	27,500	28,350	29,775	26,150	21,750	0.34
Dorm L, M, N, P, Q, R, S & Houses	46,200	54,564	85,668	49,632	74,568	75,216	69,540	57,684	59,220	55,400	52,092	47,568	0.73
Dorm A-K	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ambient Lab	4,598	4,012	5,622	4,570	5,364	5,632	3,458	2,960	3,076	4,014	4,014	5,084	0.05
AITCC (hotel)	6,848	8,128	8,848	7,736	8,016	8,208	7,776	8,480	8,496	8,912	8,912	6,400	0.09
Cafeteria	12,480	14,192	18,304	11,728	16,048	13,144	13,600	17,440	14,464	14,920	14,920	12,560	0.17
North & South Academic Building	22,500	137,000	93,000	28,500	128,500	36,000	25,040	120,540	176,924	94,986	94,986	24,416	0.98
Administration	9,424	10,376	12,128	9,080	10,832	11,220	10,624	10,880	11,568	11,832	11,832	10,260	0.13
SU Panel Board	2,056	2,139	2,810	2,157	2,648	1,517	1,534	1,248	1,488	1,427	1,427	1,229	0.02
Pulp & Paper	10,560	13,800	17,940	14,020	15,600	174,400	11,920	22,440	7,000	6,020	6,020		0.30
Child Center	5,607	6,144	7,918	6,682	7,379	17,687	24,784	20,860	26,344	23,713	23,713	17,806	0.19
Outreach Building	18,594	15,534	19,716	13,860	18,468	17,160	15,738	17,100	17,484	18,294	18,294	15,174	0.21
Energy Tech.	8,592	8,964	12,578	N/A	12,132	10,610	10,270	8,862	8,794	10,076	10,076	8,770	0.43
REC	5,090	7,234	10,261	7,549	10,009	8,206	5,376	5,677	5,870	6,013	6,013	5,329	0.08
AFE	9,776	10,176	12,680	8,024	10,048	10,824	9,944	9,120	9,432	10,792	10,792	9,952	0.12
Aqua Outreach	512	490	776	522	618	700	710	496	534	660	660	430	7,108
Telecom	8,268	9,846	12,192	8,778	11,646	12,066	11,772	11,094	11,916	13,332	13,332	9,888	0.13

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (MW)
Computer Science	13,824	14,778	19,752	14, 130	16,362	16,696	19,356	18,060	17,748	20,220	20,220	12,558	0.20
Habitech Park													
Biotech	8,974	10,682	12,824	9,232	11,438	12,328	12,156	8,284	9,972	10,406	10,406	7,988	0.12
RCC	27,400	31,500	37,480	25,160	30,100	31,520	27,360	29,800	29,180	33,660	33,660	28,420	0.37
CIM	13,180	14,180	17,400	11,940	14,460	16,840	14,700	14,680	16,020	19,740	19,740	12,160	0.19
SOM	10,104	11,328	15,120	9,168	13,400	15,288	14,016	10,800	13,128	16,800	16,800	8,264	0.15
Physical Plant	10,560	11,040	15,096	10,376	13,488	13,184	11,288	12,880	12,160	11,664	11,664	8,944	0.14
WRE Office	3,160	3,642	4,324	3,074	3,688	4,436	4,384	4,200	3,810	4,316	4,316	3,602	0.05
Golf Club	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5,040	5,280	4,488	4,488	4,860	0.02
Chiller Room	224,302	236,034	213,118	149,080	281,510	199,620	115,731	155,420	78,534	126,988	126,988	52,440	1.96
Library	31,170	33,900	43,050	27,840	36,150	39,690	38,750	33,300	37,260	38,040	38,040	27,060	0.42
Total Consumption (MWh)	0.93	0.94	1.15	0.98	1.02	1.11	1.07	1.00	0.98	1.04	0.95	0.78	11.93
Price (Million Baht)	2.12	2.19	2.58	2.36	2.41	2.51	2.48	2.33	2.31	2.43	2.26	1.91	27.90
Unit Price (Baht/kWh)	2.29	2.33	2.25	2.42	2.36	2.26	2.32	2.33	2.35	2.33	2.39	3.46	

Remark: Unit of electricity consumption from January to December is kWh

Appendix B

Water Consumption

Table B.1 Trend of Water Consumption in Residential Areas from 2002 to 2005

Year	Total water consumption (m^3)	Total cost (million Baht)	Water consumption (L/person.day)	Cost (Baht/person.day)	Unit Price (Baht/m^3)	Estimated No. of Residents
2002	255,927	3,669,993	278	3.98	14.34	2,524
2003	232,663	3,329,408	244	3.49	14.31	2,611
2004	258,452	5,125,103	266	5.27	19.83	2,663
2005	251,580	4,168,681	253	4.19	16.57	2,726

Table B.2 Trend of Water Consumption in Academic and Administrative Buildings from 2002 to 2005

Year	Total water consumption (m^3)	Total cost (million Baht)	Water consumption (L/person.day)	Cost (Baht/person.day)	Unit Price (Baht/m^3)	Estimated No. of residences
2002	256,962	3,684,835	211	3.02	14.34	3,340
2003	288,969	4,135,146	223	3.19	14.31	3,554
2004	274,308	5,439,528	204	4.05	19.83	3,679
2005	241,398	3,999,965	173	2.86	16.57	3,831

Table B.3 Water Consumption in 2005 (m^3)

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Village 1-3	2,060	3,688	3,974	4,790	3,159	2,295	2,851	3,458	4,926	3,231	3,901	4,056	42,389
Dorm A – K	2,199	4,742	4,288	3,360	2,436	2,368	1,915	2,775	2,860	2,899	3,124	2,621	35,587
Dorm L, M, N, P, Q, R, S	3,319	4,976	3,987	4,469	3,005	3,805	3,799	3,569	3,116	3,179	3,501	3,008	43,733
Dorm T, U, V, W	1,328	2,029	1,292	1,737	1,104	1,052	1,275	1,853	1,896	2,513	3,398	3,115	22,592
Dorm ST2-12	4,624	7,940	6,803	9,015	6,117	6,808	7,220	7,772	7,692	8,144	8,567	8,926	89,628
Houses 1-14	866	1,466	1,454	1,469	1,150	1,164	1,509	1,850	1,984	1,378	1,486	1,875	17,651
Ambient Lab	276	420	728	515	272	294	334	380	417	424	456	533	5,049
AITCC (hotel)	151	283	252	242	324	155	108	142	243	172	193	148	2,413
Cafeteria	586	940	858	1,212	638	766	740	1,012	950	852	938	616	10,108
North & South Academic Buildings	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Administration	466	781	731	677	565	574	519	350	565	370	413	588	6,599
SU Office	373	524	251	278	262	225	302	144	157	118	135	123	2,892
Korea House	8	14	12	16	15	9	10	11	12	12	12	13	144
Pulp & Paper	284	386	199	250	89	149	82	78	92	199	137	416	2,361
Inter Lab	30	65	39	52	42	53	44	49	38	11	92	53	568
Outreach Building	85	165	343	299	117	152	237	138	136	109	465	177	2,423
Energy Tech. Building	289	451	424	517	325	296	507	549	569	596	649	660	5,832
Energy Park	42	34	46	21	24	140	30	29	46	36	29	93	570
REC	571	916	1,970	821	514	1,939	2,766	1,925	2,522	2,078	957	1,868	18,847
AFE Office	34	51	53	9	42	45	49	57	50	58	62	42	552
Aqua Outreach	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Telecom	36	64	63	73	46	46	47	100	23	59	65	44	666
Computer Science	47	186	121	102	91	109	87	154	10	63	67	48	1,085

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Habitech Park	36	113	127	164	207	272	137	148	117	85	162	202	1,770
Biotech Building	831	467	197	241	165	118	225	136	135	0	142	115	2,772
RCC	49	75	138	303	468	585	137	96	88	117	139	100	2,295
CIM	396	364	385	772	387	162	165	223	120	127	215	131	3,447
SOM	588	965	912	1,048	867	491	388	434	425	518	653	586	7,875
Physical Plant	36	43	71	83	95	108	88	84	80	55	59	23	825
Golf Club	30	57	41	77	29	29	25	31	32	36	27	25	439
Library	115	204	202	304	160	182	185	176	215	190	256	143	2,332
Chiller Room	1,893	3,351	2,477	4,157	3,669	3,658	3,185	5,700	3,169	3,731	3,164	3,690	41,844
Total Water Consumption (m^3)	**32,957**	**46,855**	**43,825**	**46,914**	**38,114**	**34,968**	**37,906**	**39,788**	**42,629**	**40,785**	**43,282**	**47,368**	**495,391**
Price (Million Baht)	**0.75**	**0.77**	**0.82**	**0.74**	**0.61**	**0.61**	**0.58**	**0.62**	**0.69**	**0.65**	**0.64**	**0.66**	**8.14**
Unit Price (Baht/m^3)	22.81	16.38	18.81	15.76	16.07	17.33	15.22	15.63	16.19	15.91	14.78	13.96	

Table B.4 Water Consumption in 2004 (m^3)

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Village 1-3	2,774	2,563	3,736	3,885	3,547	2,876	3,274	2,968	3,352	4,105	3,073	3,582	39,735
Dorm A – K	1,710	1,731	2,345	2,455	2,523	2,009	1,798	1,929	2,614	2,916	2,338	2,473	26,841
Dorm L, M, N, P, Q, R, S	3,071	3,022	3,759	3,696	2,930	3,690	4,159	3,757	4,133	5,486	5,942	4,579	48,224
Dorm T, U, V, W	2,465	1,841	2,058	2,186	1,597	2,108	1,004	3,383	2,328	3,000	3,132	2,301	27,403
Dorm ST2-12	7,472	6,797	6,966	7,829	7,022	9,155	7,838	6,653	11,159	9,432	7,224	8,029	95,576
Houses 1-14	1,354	1,133	1,523	2,162	1,802	2,225	2,620	2,064	1,359	1,595	1,368	1,468	20,673
Ambient Lab	50	73	81	76	144	126	80	111	191	380	335	536	2,183
AITCC (hotel)	270	170	248	241	160	269	247	214	331	369	353	427	3,299
Cafeteria	374	332	413	360	314	818	351	407	523	593	736	374	5,595
North Academic Buildings	331	299	306	263	331	360	972	1,090	853	2,546	1,152	1,265	9,768
South Academic Buildings	1,300	523	587	510	469	432	423	914	861	1,085	1,508	667	9,279
Administration	1,181	853	714	939	747	854	1,138	777	784	701	436	615	9,739
SU Office	323	313	361	272	487	456	433	432	317	307	257	443	4,401
Pulp & Paper	211	324	506	416	415	261	186	108	217	367	232	284	3,527
Outreach Building	277	144	487	186	152	156	168	176	139	136	110	105	2,236
Energy Tech. Building	217	257	260	287	276	294	468	579	508	509	431	439	4,525
Energy Park	25	89	55	206	78	29	59	24	105	102	152	36	960
REC	540	811	1,002	1,279	848	1,157	969	1,426	781	401	751	477	10,442
AFE Office	81	68	60	49	51	58	53	47	64	58	53	41	683
Aqua Outreach	1,597	1,873	2,198	2,339	1,798	2,446	2,227	1,757	1,045	1,710	1,046	1,661	21,697
Telecom	91	184	3,677	200	65	58	75	224	104	36	67	45	4,826

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Computer Science	171	194	320	385	48	48	64	72	126	77	85	390	1,980
Habitech Park	99	78	52	60	108	11	31	20	34	32	132	142	799
Biotech Building	101	135	244	143	176	146	152	159	158	903	901	668	3,886
RCC	220	60	99	66	60	76	87	86	82	99	99	139	1,173
CIM	413	314	325	399	252	271	235	179	161	391	547	423	3,910
SOM	661	442	559	594	487	600	391	937	795	23	991	987	7,467
Physical Plant	112	68	144	103	83	115	101	64	70	64	50	22	996
Golf Club	60	44	52	51	56	36	33	55	59	51	56	68	621
Library	138	144	179	153	176	162	149	158	186	206	209	166	2,026
Chiller Room	2,456	2,346	3,232	4,016	3,031	2,988	3,066	3,547	3,752	3,085	3,683	1,973	37,175
Total Water Consumption	**42,323**	**42,850**	**44,323**	**44,814**	**40,093**	**46,450**	**41,603**	**42,963**	**47,974**	**47,576**	**53,325**	**41,765**	**536,059**
Price (Million Baht)	**0.95**	**0.97**	**01.00**	**1.01**	**0.90**	**1.05**	**0.94**	**0.69**	**0.77**	**0.76**	**0.86**	**0.67**	**10.56**
Unit Price (Baht/m^3)	22.52	22.52	22.52	22.52	22.52	22.52	22.52	16.50	16.50	16.50	16.50	16.50	

Table B.5 Water Consumption in 2003 (m^3)

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Village 1-3	3,769	3,219	3,839	3,707	3,607	3,343	3,759	2,761	3,321	3,104	3,401	2,469	40,299
Dorm A – K	1,869	1,609	1,889	3,086	2,044	1,605	2,074	1,761	2,950	2,659	2,729	1,649	25,924
Dorm L, M, N, P, Q, R, S	2,485	2,432	3,756	3,369	3,104	3,184	3,408	3,171	3,476	2,978	3,360	3,172	37,895
Dorm T, U, V, W	1,610	2,306	2,820	2,653	2,579	2,611	2,777	1,882	2,980	3,224	2,728	1,816	29,986
Dorm ST2-12	5,324	6,340	6,697	6,614	6,171	6,568	6,496	6,497	7,942	7,427	8,618	8,088	82,782
Houses 1-14	1,048	1,341	1,322	1,448	1,753	1,277	1,237	1,103	1,173	1,075	1,406	1,594	15,777
Ambient Lab	577	1,105	1,922	810	747	789	735	297	787	475	845	145	9,234
AITCC (hotel)	148	232	311	243	155	373	230	188	145	159	230	167	2,581
Cafeteria	488	527	646	494	462	509	569	544	866	868	893	562	7,428
North Academic Buildings	704	1,266	1,543	1,351	852	903	872	986	1,019	857	968	387	11,708
South Academic Buildings	1,323	1,799	1,865	2,027	1,979	724	632	829	1,137	1,131	1,179	529	15,154
Administration	237	383	417	517	572	634	612	688	795	743	372	439	6,409
SU Office	332	441	438	363	338	391	509	399	230	131	178	222	3,972
Pulp & Paper	2,260	2,329	2,557	2,668	2,261	2,214	2,250	2,580	2,592	2,666	3,410	2,275	30,062
Outreach Building	104	118	119	241	119	121	157	157	176	148	154	569	2,183
Energy Tech. Building	321	331	334	334	313	347	115	476	336	323	312	253	3,795
Energy Park	427	583	553	625	129	37	26	46	2	56	74	31	2,589
REC	463	1,114	1,427	2,283	2,245	1,866	884	1,320	1,396	555	1,734	1,291	16,623
AFE Office	54	71	75	63	57	102	100	75	105	97	117	111	1,027
Aqua Outreach	1,402	2,330	3,085	3,389	3,917	2,861	1,105	3,545	2,758	2,420	2,372	2,630	31,814
Telecom	50	49	57	44	100	11	55	52	65	70	82	68	703

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Computer Science	27	31	48	34	19	32	64	64	N/A	103	167	243	832
Habitech Park	N/A	31	29	67	N/A	48	55	76	45	33	88	92	869
Biotech Building	184	195	224	159	151	119	79	52	325	103	157	138	1,886
RCC	76	91	84	76	71	73	81	437	1,544	392	639	1,519	5,083
CIM	470	518	517	464	209	361	376	605	383	176	741	405	5,225
SOM	348	408	468	395	318	466	487	383	786	452	582	202	5,295
Physical Plant	95	109	116	111	100	121	N/A	247	137	115	119	114	1,467
Golf Club	114	108	202	239	166	186	1,050	48	108	71	75	59	2,426
Library	131	109	125	139	148	152	160	137	191	189	215	135	1,831
Chiller Room	1,617	2,248	3,749	3,347	3,310	3,681	3,178	3,398	3,772	3,156	3,622	1,947	37,025
Total Water Consumption	**43,714**	**43,541**	**44,815**	**45,259**	**43,923**	**42,291**	**38,624**	**40,203**	**45,234**	**40,453**	**52,517**	**43,639**	**524,213**
Price (Million Baht)	**0.63**	**0.63**	**0.57**	**0.65**	**0.63**	**0.61**	**0.56**	**0.58**	**0.65**	**0.58**	**0.76**	**0.63**	**7.50**
Unit Price (Baht/m^3)	14.45	14.45	12.78	14.45	14.45	14.45	14.45	14.45	14.45	14.45	14.45	14.45	

Table B.6 Water Consumption in 2002 (m^3)

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Village 1-3	2,620	3,070	7,062	3,852	4,443	4,285	4,423	3,572	5,338	3,501	3,305	5,025	50,496
Dorm A – K	4,003	1,848	2,273	1,659	2,226	1,946	4,410	2,899	1,789	2,350	2,217	1,835	29,455
Dorm L, M, N, P, Q, R, S	3,131	3,265	3,432	2,923	3,592	2,894	4,405	4,376	3,873	3,491	3,552	3,689	42,623
Dorm T, U, V, W	2,292	2,550	2,322	1,575	1,799	1,639	2,235	2,217	2,378	2,000	2,188	2,688	25,883
Dorm ST2-12	5,978	6,661	6,790	6,188	7,085	5,935	7,991	8,366	7,130	7,336	8,070	6,676	84,206
Houses 1-14	1,701	2,148	1,949	2,295	2,520	1,836	2,052	2,003	1,882	1,627	1,513	1,738	23,264
Ambient Lab	282	231	484	258	475	480	561	585	330	285	329	100	4,400
AITCC (hotel)	195	194	210	207	157	143	299	239	234	237	218	153	2,486
Cafeteria	559	606	712	511	660	603	569	233	429	473	435	368	6,158
North Academic Buildings	346	454	673	510	600	562	724	772	546	699	638	404	6,928
South Academic Buildings	1,295	785	2,857	2,327	2,674	1,607	1,599	1,705	1,026	829	1,051	1,279	19,034
Administration	393	306	332	359	264	323	355	521	520	464	671	752	5,260
SU Office	496	487	368	167	332	353	624	527	637	658	701	536	5,886
Pulp & Paper	106	145	146	116	164	93	155	94	54	53	80	37	1,243
Old Child Center	324	377	372	255	186	127	177	125	195	180	290	205	2,813
Outreach Building	316	351	881	233	302	251	141	207	193	188	125	163	3,351
Energy Tech. Building	493	562	635	489	363	351	584	534	444	459	399	493	5,806
Energy Park	558	606	611	629	679	537	N/A	807	541	569	574	680	7,908
REC	558	783	590	764	1,513	625	840	1,368	1,042	1,160	751	860	10,854
AFE Office	63	61	92	55	77	64	93	87	70	76	68	55	861

Locations	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Aqua Outreach	1,320	1,603	1,931	1,902	2,222	1,485	1,823	2,251	1,989	2,287	1,998	1,908	22,719
Telecom	48	49	58	41	60	50	85	70	65	76	84	55	741
Computer Science	230	56	138	913	200	200	603	39	68	7	68	643	3,165
Habitech Park	102	80	127	103	65	51	31	91	73	171	105	52	1,051
Biotech Building	166	237	279	258	199	302	139	75	80	205	98	135	2,173
RCC	61	69	111	63	66	59	71	93	75	79	71	77	895
CIM	319	423	511	477	547	333	469	532	418	457	421	643	5,550
SOM	134	255	576	612	748	402	486	238	360	412	1,424	91	5,738
Physical Plant	96	89	102	88	113	87	131	136	104	111	120	102	1,279
Golf Club	198	87	104	96	130	102	148	181	154	218	130	194	1,742
Library	149	173	218	206	168	225	263	221	170	226	210	175	2,404
Chiller Room	1,843	2,472	2,829	2,067	2,532	2,352	3,638	3,774	2,601	2,750	2,530	2,634	32,022
Total Water Consumption	**33,944**	**39,085**	**44,176**	**44,395**	**50,496**	**43,667**	**47,174**	**53,326**	**44,768**	**38,911**	**37,334**	**38,099**	**515,375**
Price (Million Baht)	**0.49**	**0.56**	**0.61**	**0.64**	**0.73**	**0.63**	**0.68**	**0.77**	**0.65**	**0.56**	**0.54**	**0.52**	**7.39**
Unit Price (Baht/m^3)	**16.05**	**16.05**	**16.05**	**16.05**	**16.05**	**16.05**	**16.05**	**16.05**	**16.05**	**16.05**	**16.05**	**16.05**	

Appendix C

Meter Reading

Table C.1 Energy Audit at North and South Academic Buildings during Examination Period

Time (hours)	**Flow Meter**	**Differences**	**Hourly Electricity Consumption (kWh)**
22-00	9932.3	-	-
00-02	9934.35	2.05	246
02-04	9936.1	1.75	210
04-06	9937.6	1.50	180
06-08	9939.8	2.20	264
08-10	9943.2	3.40	408
10-12	9946.6	3.40	408
12-14	9950.3	3.70	444
14-16	9953.25	2.95	354
16-18	9955.95	2.70	324
18-20	9957.85	1.90	228
20-22	9959.75	1.90	228
22-24	9961.65	1.90	228
Total			**3,522**

Remark:
- Warm climate
- During Mid-semester Examination period
- Mul-Factor = 120 (factor of the Current Transformer)
- kWh = (Differences) x (Mul-Factor)

Table C.2 Energy Audit at North and South Academic Buildings during Semester Break

Time (hours)	**Flow Meter**	**Differences**	**Hourly Electricity Consumption (kWh)**
22-00	1734.7	-	-
00-02	1736.2	1.50	180
02-04	1737.5	1.30	156
04-06	1738.9	1.40	168
06-08	1741	2.10	252
08-10	1744.2	3.20	384
10-12	1746.8	2.60	312
12-14	1750	3.20	384
14-16	1753.3	3.30	396
16-18	1755.4	2.10	252
18-20	1757.4	2.00	240
20-22	1758.8	1.40	168
22-24	1760	1.20	144
Total			**3,036**

Remark:
- Warm climate
- During Mid-semester Examination period
- Mul-Factor = 120 (factor of the Current Transformer)
- kWh = (Differences) x (Mul-Factor)

Table C.3 Energy Audit at North and South Academic Buildings during Weekend

Time (hours)	**Flow Meter**	**Differences**	**Hourly Electricity Consumption (kWh)**
22-00	1640	-	-
00-02	1641.5	1.50	180
02-04	1642.5	1.00	120
04-06	1643.7	1.20	144
06-08	1645.1	1.40	168
08-10	1647.4	2.30	276
10-12	1650.3	2.90	348
12-14	1651.9	1.60	192
14-16	1654.2	2.30	276
16-18	1656.9	2.70	324
18-20	1658.7	1.80	216
20-22	1660.3	1.60	192
22-24	1661.5	1.20	144
Total			**2,580**

Remark:
- Cool climate
- During Mid-semester Examination period
- Mul-Factor = 120 (factor of the Current Transformer)
- kWh = (Differences) x (Mul-Factor)

Table C.4 Energy Audit at P Dorm during Examination Period

Time (hours)	**Flow Meter**	**Differences**	**Hourly Electricity Consumption**	
			(kWh)	**(kWh/person)**
22-00	21133.2	-	-	-
00-02	21134.0	0.8	40	-
02-04	21134.6	0.6	30	-
04-06	21135.1	0.5	25	-
06-08	21135.6	0.5	25	-
08-10	21136.0	0.4	20	-
10-12	21136.3	0.3	15	-
12-14	21136.5	0.2	10	-
14-16	21136.9	0.4	20	-
16-18	21136.9	0.3	15	-
18-20	21137.3	0.2	10	-
20-22	21137.9	0.4	20	-
22-24	21138.4	0.5	25	-
Total			**280**	**4.83**

Remark:
- Warm climate
- During Mid-semester Examination period
- Mul-Factor = 50 (factor of the Current Transformer)
- There are totally 58 people in this dorm
- kWh = (differences) x (Mul-Factor)
- The first and second floor are for the couple student, the third floor is for the single student

Table C.5 Energy Audit at P Dorm during Semester Break Period

Time (hours)	**Flow Meter**	**Differences**	**Hourly Electricity Consumption**	
			(kWh)	**(kWh/person)**
22-00	33077.6	-	-	-
00-02	33077.8	0.2	10	-
02-04	33078.0	0.2	10	-
04-06	33078.2	0.2	10	-
06-08	33078.5	0.3	15	-
08-10	33078.8	0.3	15	-
10-12	33079.1	0.3	15	-
12-14	33079.3	0.2	10	-
14-16	33079.4	0.1	5	-
16-18	33079.6	0.2	10	-
18-20	33079.9	0.3	15	-
20-22	33080.2	0.3	15	-
22-24	33080.4	0.2	10	-
Total			**140**	**2.41**

Remark:
- A little bit cool climate
- During Mid-semester Examination period
- Mul-Factor = 50 (factor of the Current Transformer)
- There are totally 58 people in this dorm
- kWh = (differences) x (Mul-Factor)
- The first and second floor are for the couple student, the third floor is for single student

Table C.6 Energy Audit at P Dorm during Weekend

Time (hours)	**Flow Meter**	**Differences**	**Hourly Electricity Consumption**	
			(kWh)	**(kWh/person)**
22-00	33070.7	-	-	-
00-02	33071.0	0.3	15	-
02-04	33071.2	0.2	10	-
04-06	33071.6	0.4	20	-
06-08	33071.8	0.2	10	-
08-10	33072.0	0.2	10	-
10-12	33072.3	0.3	15	-
12-14	33072.5	0.2	10	-
14-16	33072.6	0.1	5	-
16-18	33072.8	0.2	10	-
18-20	33073.2	0.4	20	-
20-22	33073.7	0.5	25	-
22-24	33074.0	0.3	15	-
Total			**165**	**2.84**

Remark:
- Warm climate
- During Mid-semester Examination period
- Mul-Factor = 50 (factor of the Current Transformer)
- There are totally 58 people in this dorm
- kWh = (differences) x (Mul-Factor)
- The first and second floor are for the couple student, the third floor is for single student

Table C.7 Water Audit at ST 6 during Examination Period

Time (hours)	Flow Meter (m^3)	Differences (m^3)	Hourly Water Consumption	
			(L)	(L/person)
22-00	43882.7	-	-	-
00-02	43884.1	1.4	1400	-
02-04	43885.2	1.1	1100	-
04-06	43886.5	1.3	1300	-
06-08	43889.9	3.4	3400	-
08-10	43894.4	4.5	4500	-
10-12	43897.8	3.4	3400	-
12-14	43901.1	3.3	3300	-
14-16	43902.8	1.7	1700	-
16-18	43906.6	3.8	3800	-
18-20	43910.4	3.8	3800	-
20-22	43913.2	2.8	2800	-
22-24	43914.7	1.5	1500	-
Total			**32,000**	**508**

Remark:
- Warm climate
- Total staff in this building = 63

Table C.8 Water Audit at ST 6 during Semester Break Period

Time (hours)	**Flow Meter (m^3)**	**Differences (m^3)**	**Hourly Water Consumption**	
			(L)	**(L/person)**
00	45204.2	-	-	-
02	45204.5	0.3	300	-
04	45204.6	0.1	100	-
06	45204.7	0.1	100	-
08	45206.8	2.1	2100	-
10	45208.3	1.5	1500	-
12	45209.1	0.8	800	-
14	45210.1	1	1000	-
16	45211.6	1.5	1500	-
18	45212.7	1.1	1100	-
20	45214.2	1.5	1500	-
22	45215.8	1.6	1600	-
24	45217.0	1.2	1200	-
Total			**12,800**	**203**

Remark:
- Warm climate
- Total staff in this building = 63

Table C.9 Water Audit at ST 6 during Weekend

Time (hours)	Flow Meter (m^3)	Differences (m^3)	Hourly Water Consumption (L)	Hourly Water Consumption (L/person)
00	45170.6	-	-	-
02	45170.8	0.2	200	-
04	45171	0.2	200	-
06	45171.1	0.1	100	-
08	45174.700	3.6	3600	-
10	45176.400	1.7	1700	-
12	45179.600	3.2	3200	-
14	45181.800	2.2	2200	-
16	45183.900	2.1	2100	-
18	45185.1	1.2	1200	-
20	45186.8	1.7	1700	-
22	45188.2	1.4	1400	-
24	45188.9	0.7	700	-
Total			**18,300**	**290**

Remark:
- Warm climate
- Total staff in this building = 63

Table C.10 Water Audit at SV 59 during Examination Period

Time (hours)	**Flow Meter (m^3)**	**Differences (m^3)**	**Hourly Water Consumption**	
			(L)	**(L/person)**
22-00	2440.8	-	-	-
00-02	2440.8	0	0	-
02-04	2440.8	0	0	-
04-06	2440.8	0	0	-
06-08	2440.9	0.1	100	-
08-10	2441.1	0.2	200	-
10-12	2441.2	0.1	100	-
12-14	2441.2	0	0	-
14-16	2441.3	0.1	100	-
16-18	2441.3	0.1	100	-
18-20	2441.6	0	0	-
20-22	2441.7	0.1	100	-
22-24	2441.7	0	0	-
Total			**700**	**117**

Remark:
- Warm climate
- Total students in this village = 6

Table C.11 Water Audit at SV 59 during Semester Break Period

Time (hours)	**Flow Meter** (m^3)	**Differences** (m^3)	**Hourly Water Consumption**	
			(L)	**(L/person)**
22-00	2532.23	-	-	-
00-02	2532.249	0.019	19	-
02-04	2532.249	0	0	-
04-06	2532.249	0	0	-
06-08	2532.449	0.2	200	-
08-10	2532.549	0.1	100	-
10-12	2532.652	0.103	103	-
12-14	2532.809	0.157	157	-
14-16	2532.969	0.16	160	-
16-18	2533.035	0.066	66	-
18-20	2533.165	0.13	130	-
20-22	2533.284	0.119	119	-
22-24	2533.34	0.056	56	-
Total			**1,110**	**185**

Remark:
- Warm climate
- Total students in this village = 6

Table C.12 Water Audit at SV 59 during Weekend

Time (hours)	**Flow Meter** (m^3)	**Differences** (m^3)	**Hourly Water Consumption** (L)	
			(L)	**(L/person)**
22-00	2528.984	-	-	-
00-02	2529.022	0.038	38	-
02-04	2529.027	0.005	5	-
04-06	2529.027	0	0	-
06-08	2529.16	0.133	133	-
08-10	2529.195	0.035	35	-
10-12	2529.242	0.047	47	-
12-14	2529.446	0.204	204	-
14-16	2529.48	0.034	34	-
16-18	2529.528	0.048	48	-
18-20	2529.685	0.157	157	-
20-22	2529.88	0.195	195	-
22-24	2530.008	0.128	128	-
Total			**1,024**	**171**

Remark:
- Warm climate
- Total students in this village = 6

Table C.13 Energy Audit at Chiller Room

Time	**Average Daily Electricity Consumption (watts/person)**	
	during Summer	**during Winter**
22-00	-	-
00-02	152	86
02-04	149	78
04-06	150	86
06-08	156	87
08-10	330	73
10-12	350	91
12-14	352	110
14-16	334	110
16-18	238	109
18-20	219	107
20-22	202	110
22-24	173	104

Appendix D

Energy Audit

Table D.1 Analysis of Electricity Consumption at North and South Academic Buildings during Examination Period

No.	**Items**	**No. of Equipments (Units)**	**Daily Active Usages (h/d)**	**Rate of Electricity Consumption (kW/h)***	**Daily Electricity Consumption (kWh)**
1	Desktop computers + 17” CRT monitors	460	6-8	0.235	756.70
2	Laptop computers	50	6-8	0.045	15.75
3	Desktop computers + 17” LCD monitors	50	6-8	0.190	66.50
4	Air compressors (central) in the offices (2.5 tons)	10	6-8	3.500	245
5	Fan coils in the offices	278	7-8	0.350	729.75
6	Fan coils in the computer labs	12	17-19	0.350	75.60
	Total				**1,889.30**

Remark: Daily electricity consumption = (No. of equipments) × (Average daily active usages) × (Rate of electricity consumption)
* : Bluejay (2005), Ames City Government (2002)

Table D.2 Analysis of Electricity Consumption at North and South Academic Buildings during Semester Break Period

No.	**Items**	**No. of Equipments (Units)**	**Daily Active Usages (h/d)**	**Rate of Electricity Consumption (kW/h)***	**Daily Electricity Consumption (kWh)**
1	Desktop computers + 17” CRT monitors	330	6-8	0.235	542.85
2	Desktop computers in the computer rooms	130	1-2	0.235	45.82
3	Laptop computers	50	6-8	0.045	15.75
4	Desktop computers + 17” LCD monitors	50	6-8	0.190	66.50
5	Fan coils in the offices	258	7-8	0.35	677.25
6	Fan coils in the class rooms	20	0	0.35	0
7	Fan coils in the computer rooms	12	17-19	0.35	75.6
8	Air compressors (central) in the offices (2.5 tons)	5	6-8	3.500	122.50
	Total				**1,546.27**

Remark: Daily electricity consumption = (No. of equipments) × (Average daily active usages) × (Rate of electricity consumption)
* : Bluejay (2005), Ames City Government (2002)

Table D.3 Analysis of Electricity Consumption at North and South Academic Buildings during Weekends

No.	Items	No. of Equipments (Units)	Daily Active Usages (h/d)	Rate of Electricity Consumption (kW/h)*	Daily Electricity Consumption (kWh)
1	Desktop computers + 17” CRT monitors	99	2-4	0.235	69.79
2	Desktop computers (in the computer rooms)	130	6-8	0.235	213.85
3	Laptop computers	50	2-4	0.045	6.75
4	Desktop computers + 17” LCD monitors	50	2-4	0.190	28.50
5	Fan coils in the offices	278	4-6	0.350	486.50
6	Fan coils in the class rooms	0	0	0	0
7	Fan coils in the computer rooms	12	17-19	0.350	75.60
8	Air compressors (central) in the offices (2.5 tons)	5	6-8	3.500	122.50
	Total				**1,003.49**

Remark: Daily electricity consumption = (No. of equipments) × (Average daily active usages) × (Rate of electricity consumption)
* : Bluejay (2005), Ames City Government (2002)

Table D.4 Analysis of Electricity Consumption at P Dorm during Examination Period

Items	No. of Equipments (Units)	Daily Usages (h/d)	Rate of Electricity Consumption (kW/h)	Daily Electricity Consumption (kWh)
Desktop computers	15	4-6	0.235	17.62
Laptop computers	15	4-6	0.045	3.37
Televisions	4	2-4	0.180	2.16
Refrigerators	24	24	0.100	57.60
Air-conditioners (6000 BTU)	44	4-8	0.600	158.40
Cookers	22	0.3-0.4	0.900	6.93
Washing machines	5	0.5-0.6	0.500	1.37
Hot pots	21	0.2-0.3	0.900	4.72
Total	**-**	**-**	**-**	**252.17**

Remark: Daily electricity consumption = (No. of equipments) × (Average daily active usages) × (Rate of electricity consumption)
* : Bluejay (2005), Ames City Government (2002)

Table D.5 Analysis of Electricity Consumption at P Dorm during Semester Break Period

Items	No. of Equipments (Units)	Daily Usages (h/d)	Rate of Electricity Consumption	Daily Electricity Consumption (kWh)
Desktop computers	7	1-2	0.235	2.47
Laptop computers	8	1-2	0.045	0.54
Televisions	2	4-6	0.180	1.80
Refrigerators	12	24	0.100	28.80
Air-conditioners (6000 BTU)	22	6-8	0.600	92.40
Cookers	22	0.3-0.4	0.900	6.93
Washing machines	2	0.5-0.6	0.500	0.55
Hot pots	10	0.2-0.4	0.900	2.70
Total				**136.19**

Remark: Daily electricity consumption = (No. of equipments) × (Average daily active usages) × (Rate of electricity consumption)
* : Bluejay (2005), Ames City Government (2002)

It is assumed that only 50% of total population stayed in this dormitory during semester break period.

Table D.6 Analysis of Electricity Consumption at P Dorm during Weekends

Items	No. of Equipments (Units)	Daily Usages (h/d)	Rate of Electricity Consumption	Daily Electricity Consumption (kWh)
Desktop computers	15	2-4	0.235	10.57
Laptop computers	15	2-4	0.045	2.02
Televisions	2	4-6	0.180	1.80
Refrigerators	12	24	0.100	28.80
Air-conditioners (6000 BTU)	22	6-8	0.600	92.40
Cookers	22	0.3-0.4	0.900	6.93
Washing machines	2	0.5-0.6	0.500	0.55
Hot pots	10	0.2-0.4	0.900	2.70
Total				**145.77**

Remark:

Daily electricity consumption = (No. of equipments) x (Rate of electricity consumption)

Appendix E

Solid Waste Generation

Table E.1 Daily Domestic Waste Generation in AIT Campus (2005)

No.	Items	Total Garbage (kg)		Total Solid Waste (kg)	Composition of Solid Waste (%)
		Organic	(kg)		
1	AITCC	80	10	90	5
2	Offices	-	348	348	17
3	Staff areas	439	197	636	31
4	Student areas	362	192	555	27
5	Cafeteria + other vendors	352	48	400	20
	Total	**1,233**	**795**	**2,028**	**100**
	% of weight	**60%**	**40%**	**100%**	

Table E.2 Composition of Recycle Waste (2005)

No.	Items	AIT Recycle Waste (% by weight)
1	Paper	75.72
2	Cardboard	12.75
3	Plastics Bottles	9.93
4	Cans	0.46
5	Steel	1.14
		100

Table E.3 Amount of Recyclable Waste (2005)

No.	Items	Amount of Recyclable Waste	
		(kg/month)	(Baht/month)
1	Newspaper	92	547
2	Cardboard	223	817
3	Plastic	174	2,107
4	Black-white paper	842	4,357
5	Small piece paper	391	620
6	Cans	8	228
7	Steel	20	110
8	Others*	597	3,000
	Total	**2,348**	**11,786**

Remark: * : Amount of recyclable waste that collected by the workers at the collection site

Table E.4 Physical Characteristics of Solid Waste (2005)

No.	Items	MC (%)	TS (%)
1	Food waste (AITCC & Cafeteria)	85.3	14.7
2	Office waste	23.1	76.9
3	Household waste	66.1	33.9
4	Yard waste	34.0	66.0
	Total domestic waste	**63.6**	**36.41**

Calculations:

- Organic waste from cafeteria and AITCC:

  % MC = (1000-47) × 100 / 1000 = 85.3
  % TS = 100 – 8.53 = 14.7

- Office waste (inorganic):

  % MC = (195-150) × 100 / 195 = 23.1
  % TS = 100 – 23.1 = 76.9

- Inorganic waste from the household:

  % MC = (205-175) × 100 / 205 = 14.6
  % TS = 100 – 14.6 = 85.4

- Gardening waste:

  % MC = (235-155) × 100 / 235 = 34
  % TS = 100 – 51 = 66

- Total domestic waste:

  MC (%) = (85.3 × 0.25) + (23.1 × 0.17) + (66.1 × 0.58) = 63.59
  TS (%) = 100 – 63.59 = 36.41

Appendix F

Rating of Electricity, Water Consumption and Solid Waste Generation

Table F.1 Rating of Electricity Consumption for Office's Buildings in 2005

No.	Type of buildings	Daily electricity consumption (kWh/m^2)	Area (m^2)	Electricity Rating
1	AITCC (hotel)	0.155	1,344	**B**
2	Cafeteria	0.200	2,285	**B**
3	North Academic*	0.450	5,558	**D**
4	South Academic*	0.490	6,243	**D**
5	Administration	0.150	4,589	**B**
6	Pulp & paper	0.241	2,029	**C**
7	Outreach building	0.402	2,249	**C**
8	Energy Tech.	0.202	2,948	**B**
9	REC	0.079	3,778	**A**
10	AFE	0.261	1,300	**C**
11	Aqua Outreach	0.075	431	**A**
12	Telecom	0.208	1,573	**B**
13	Computer Science	0.450	1,197	**D**
14	Biotech	0.354	864	**D**
15	RCC	0.247	2,961	**C**
16	CIM	0.223	3,605	**C**
17	SOM	0.312	1,638	**D**
18	Physical plant	0.096	2,200	**A**
19	WRE office	0.052	2,838	**A**
20	Library	0.196	6,382	**B**

Remark:
A = 0.01 - 0.1
B = 0.11 - 0.2
C = 0.21 - 0.3
D > 0.3
*: is obtained from electricity consumption in 2004

Table F.2 Rating of Electricity Consumption for Dormitories in 2005

No.	Types of building	Electricity consumption (kWh/day)	Area (m^2)	Specific electricity consumption kWh/(m^2.day)	Water Rating
1	Village 1-3	414	35,863	0.012	**A**
2	Dorm A-K	1,435	10,780	0.133	**B**
3	Dorm T, U, V, W	664	6,849	0.097	**B**
4	ST2	136	750	0.181	**B**
5	ST3	217	1,258	0.173	**B**
6	ST7+ST8	780	4,725	0.165	**B**
7	ST9	84	2,046	0.041	**A**
8	ST10	285	1,539	0.185	**B**
9	ST11	556	1,583	0.351	**C**
10	ST12	167	1,032	0.162	**B**
11	House 1-14	689	2,413	0.286	**C**

Remark:
A = 0.01-0.09
B = 0.1-0.2
C > 0.2

No.	Type of buildings	Water consumption (m^3)	Area (m^2)	Daily water consumption (L/m^2)	Water Rating
1	AITCC (hotel)	2,413	1,344	1.80	**A**
2	North Academic	32,000	5,558	5.76	**B**
3	South Academic	42,000	6,243	6.73	**C**
4	Administration	18,000	4,589	3.92	**B**
5	Outreach building	7,000	2,249	3.11	**B**
6	Energy Tech.	16,000	2,948	5.43	**B**
7	AFE	2,000	1,300	1.54	**A**
8	Telecom	2,000	1,573	1.27	**A**
9	Computer Science	3,000	1,197	2.51	**A**
10	Biotech	8,000	864	9.26	**C**
11	RCC	6,000	2,961	2.03	**A**
12	CIM	9,000	3,605	2.50	**A**
13	SOM	7,875	1,638	4.81	**B**
14	Physical plant	2,000	2,200	0.91	**A**
15	Library	6,000	6,382	0.94	**A**

Remark:
A = 0.1 - 3
B = 3.1 - 6
C = 6.1 - 10
D > 10

Table F.4 Rating of Water Consumption for Dormitories in 2005

No.	Type of buildings	Water consumption (L)	Area (m^2)	Daily water consumption (L/m^2)	Water Rating
1	Village 1-3	109,000	35,863	3.04	**A**
2	Dorm A - K	74,000	9,504	7.79	**B**
3	Dorm L, M, N, P, Q, R, S	132,000	11,590	11.39	**B**
4	Dorm T, U, V, W	75,000	6,849	10.95	**B**
5	Dorm ST2-12	262,000	14,101	18.58	**C**
6	House 1-14	57,000	2,413	23.62	**C**

Remark:
A = 0.1 - 5
B = 5.1 - 15
C > 15

Table F.5 Rating of Solid Waste Generation in 2005

No.	Type of buildings	Area (m^2)	Daily solid waste generation (kg/m^2)	Solid waste Rating
1	Dorm A-K	9,504	0.006	**A**
2	Village 1-3	35,863	0.004	**A**
3	T, U, V, W	6,849	0.021	**B**
4	L, M, N, P, Q, R, S	11,590	0.007	**A**
5	ST 2-12	14,101	0.045	**C**
6	Houses	2,413	0.019	**B**

Remark:
A = 0.001-0.010
B = 0.011-0.030
C > 0.030

Appendix G

Questionnaires

Questionnaires 1

Date:

Location:

Interviewee:

Position:

1. How much is average solid waste generated in AIT?
2. How much AIT has to pay for the waste collection per month?
3. How frequently does the garbage truck come to AIT per week?
4. Where is the location of the landfill?
5. Do they separate the waste before transporting to the landfill?
6. What is the major category of waste generated by AIT? Household waste, garden waste or food waste?
7. Do they find any problems for the AIT waste during the collection? If yes, what type of problems?

Questionnaire 2 – Energy Audit

Date:

Location:

Interviewee:

Position:

Note: During ☐ Examination Period ☐ Semester Break ☐ Weekend

1. What kind of electrical appliances do you have in your household? And how often do you use these appliances in your house?

☐ Television,

How often do you watch Television? At the average of ……… minutes per day.

☐ Air-conditioner

How often do you use the air-conditioner? At the average of …………. minutes per day.

☐ Refrigerator

☐ Personal Computer

How often do you use the personal computer? At the average of ………. minutes per day.

☐ Hot Pot

How often do you use the coffee pot? At the average of ………. minutes per day.

☐ Cooker

How often do you use the cooker? At the average of ………. minutes per day.

☐ Washing Machine

How often do you use the washing machine? At the average of ………. minutes per day.

2. Other appliances? (if any)
……..……………………………………………………………………………………
……………………………………………………………………………………….

Summary of Questionnaires 2

Date:

Location: P Dorm

Position: students

Total population =

1. During Examination Period

Table G1. Estimation of Electricity Usage during Examination Period

No.	Items	Total Numbers of Device Used (Units)	Estimated Time of Use (h/day)
1	Televisions	4	2-4
2	Air-conditioners	44	6-8
3	Refrigerators	24	24
4	Computers	30	4-6
5	Hot Pots	21	0.2-0.4
6	Cookers	22	0.3-0.5
7	Washing Machines	5	0.5-0.6

2. During Semester Break Period

Table G2. Estimation of Electricity Usage during Semester Break Period

No.	Items	Total Numbers of Device Used (Units)	Average Time of Use (h/day)
1	Televisions	2	4-6
2	Air-conditioners	22	6-8
3	Refrigerators	12	24
4	Computers	15	1-2
5	Hot Pots	10	0.2-0.4
6	Cookers	22	0.3-0.5
7	Washing Machines	2	0.5-0.6

3. During Weekends

Table G3. Estimation of Electricity Usage during Weekends

No.	Items	Total Numbers of Device Used (Units)	Average Time of Use (h/day)
1	Televisions	2	4-6
2	Air-conditioners	22	8-10
3	Refrigerators	12	24
4	Computers	15	1-2
5	Hot Pots	10	0.2-0.4
6	Cookers	22	0.3-0.5
7	Washing Machines	2	0.5-0.6

Remark:

During semester break and weekends, the people did not use these electrical appliances so often. Therefore, it is assumed that there were only 50% of the total population stayed at their households during these periods.

Questionnaire 3 –Water Audit

Date:

Location:

Interviewee:

During ☐ Examination Period ☐ Semester Break ☐ Weekend

1. How many people in your family? ……………… person.

2. How often do you use the water devices for your purpose?

    2.1 Flushing toilet …………times per day.

    At the average of …………..minutes per time.

    2.2 Showering….. …………times per day.

    At the average of …………..minutes per time.

    2.3 Cooking…………times per day.

    At the average of …………..minutes per time.

    2.4 Laundering …………times per day.

    At the average of …………..minutes per time.

    2.5 Dishwashing…………times per day.

    At the average of …………..minutes per time.

    2.6 Faucets…………times per day.

    At the average of …………..minutes per time.

    2. Other purposes? (if any)
    ……..……………………………………………………………………………………
    ………………………………………………………………………………………
    ……..

Summary of Questionnaires 3

Date:

Location: ST 6

1. Total population = 63

2. Total households = 18

3. During Examination Period

Table G4. Estimation of Water Usage for one Person during Examination Period

Items	Frequency (time/day)	Time of Use (h/time)	Amount of Water Used (L/person)
Shower	2	0.38	150-200
Laundry	0.3	0.7	100-130
Cooking	3	0.2	20-30
Toilet	4	-	50-70
Dish wash	3	0.25	30-40
Faucets	4	0.1	40-60
Others	-	-	35-50

Remark: Amount of water used = Frequency × Time of use × Flow rate

4. During Semester Break Period

Table G5. Estimation of Water Usage for one Person during Semester Break Period

Items	Frequency (time/day)	Time of Use (h/time)	Amount of Water Used (L/person)
Shower	2	0.38	150-200
Laundry	0.3	0.7	100-130
Cooking	3	0.2	20-30
Toilet	4	-	50-70
Dish wash	3	0.25	30-40
Faucets	4	0.1	40-60
Others	-	-	35-50

Remark: Amount of water used = Frequency × Time of use × Flow rate

4. During Weekends

Table G6. Estimation of Water Usage for one Person during Weekends

Items	Frequency (time/day)	Time of Use (h/time)	Amount of Water Used (L/person)
Bathing	2	0.38	150-200
Washing	0.3	0.7	-
Cooking	3	0.2	10-20
Toilet	4	-	20-30
Dish wash	3	0.25	15-20
Faucets	4	0.1	20-30
Others	-	-	20-25

Remark: Amount of water used = Frequency × Time of use × Flow rate

Appendix I

Calculations for CP Options

1. Electricity Conservation

1) Automatic movement sensor switches

- **Switch off the lights during the lunch time**

An average wattage used for a light bulb (compacted fluorescent light bulb) is 38 watts/hr. Suppose, there are totally 1,000 light bulbs in all offices. If each light bulb was switched off every one hour break for each day, then, the amount of electricity can be saved is as following:

Full time operation = 1,000 light bulbs × 38 watts/hr × 9 h/day × 240 day/year
= 82,080 kWh/year

One hour break = 1,000 light bulbs × 38 watts/hr × 8 h/day × 240 day/year
= 72,960 kWh/year

Electricity savings = Full time operation – One hour break
= 9,120 kW/year

Full time payment = 82,080 kWh/year × 2.86 Baht/kWh
= 234,749 Baht/year

Payment after one hour break = 72,960 kWh/year × 2.86 Baht/kWh
= 208,665 Baht/year

Money savings = 9,120 kW/year × 2.86 Baht/kW
= 26,083 Baht/year

- **Turnoff computers during the lunch time (propose in the offices)**

Suppose there are totally 1,000 desktop computers use in the offices. One desktop computer with 17” CRT uses about 140 – 330 watts/hr. How much 1,000 personal computers can be saved when the staff and students turnoff their computers 1 hour during the break time?

Full time operation = 1,000 units × 330 watts/h × 9 h/day × 240 day/year
= 712,800 kWh/year

One hour break = 1,000 units × 330 watts/h × 8 h/day × 240 day/year
= 633,600 kWh/year

Electricity savings = 712,800 kWh/year – 633,600 kWh/year = 79,200 kWh/year

Full time payment = 712,800 kWh/year × 2.86 Baht/kW
= 2,038,608 Baht/year

One hour break payment = 633,600 kWh/year × 2.86 Baht/kW
= 1,812,096 Baht/year

Money savings = 2,038,608 Baht/year – 1,812,096 Baht/year
= 226,512 Baht/year

- **Switch-off all computers in the computer rooms during the night time**

Suppose there are totally 1,000 desktop computers use in the computer rooms. One conventional computer consumes about 3.5 watts/h when the computers were only log off (not switch off). How much 1,000 PCs can be saved when the students turnoff and switch off their computers after they finish using?

During the day time: suppose there are 40% of computers do not be used during the day time and they also did not switch off (only log off):

Normal electricity consumption:
= (1,000 units × 0.6 × 300 watts/h × 17 h/day × 365 day/year) + (1,000 units × 0.4 × 6 watts/h × 17 h/day × 365 day/year) + (1,000 units × 6 watts/h × 7 h/day × 365 day/year)
= 1,147,122 kWh/year

Normal payment:
= 1,147,122 kWh/year × 2.86 Baht/year = 3,280,769 Baht/year

Electricity consumption after electricity conservation is proposed:
= 1,000 units × 0.6 × 300 watts/h × 17 h/day × 365 day/year
= 1,116,900 kWh/year

Payment after proposing:
= 1,116,900 kWh/year × 2.86 Baht/year = 3,194,334 Baht/year

Electricity saving = 1,147,122 kWh/year - 1,116,900 kWh/year
= 30,222 kWh/year

Money saving = 3,280,769 Baht/year - 3,194,334 Baht/year
= 86,435 Baht/year

- **Turnoff air conditioners during the lunch time**

In 2005, AIT spent about 63,000 Baht/day for electricity consumption in the chiller room (Physical Plant, 2005). If one hour of the electricity is saved daily during the break time, the amount of savings is as below:

Full time operation = 1,540 kW/h × 9 h/day × 240 day/year
= 3,326,400 kWh/year

One hour break = 1,540 kW/h × 8 h/day × 240 day/year
= 2,956,800 kWh/year

Electricity savings = 3,326,400 kWh/year - 2,956,800 kWh/year
= 369,600 kW/year

Full time payment = 3,326,400 kWh/year × 2.86 Baht/kW
= 9,513,504 Baht/year

One hour break payment = 2,956,800 kWh/year × 2.86 Baht/kW
= 8,456,448 Baht/year

Money savings = 9,513,504 Baht/year – 8,456,448 Baht/year
= 1,057,056 Baht/year

- **Lighting during the night**

According to the energy audit in the offices, it is found that electricity is consumed during the night is about 10% of total light. It is assumed that 50% of total electricity consumption during the night contributed to the light bulb.

Electricity consumption during the night for the light bulb:
= Total electricity consumption × 50% (use in the office) × 5% (use during the night)
= 337,383 kWh/year

Cost of electricity consumption during the night:
= 337,383 kWh/year × 2.86 Baht/kWh = 964,915 Baht/year

Electricity saving after installing the new automatic switch-off system:
Suppose that 50% of total electricity consumption can be saved:
= 337,383 kWh/year × 50% = 168,691 kWh/year

Cost savings:
= 168,691 kWh/year × 2.86 Baht/kWh = 482,456 Baht/year

2) Replace 2 old chillers with one high efficient chiller

The oldest chiller in AIT campus was initially operated in 1992 and 1995 (13 and 10 years ago). They have the efficiency of 0.69 kW/ton with 500 and 600 tons capacity. If this chiller was replaced by a high efficiency chiller (0.44 kW/ton) with a capacity of 300 tons, how much electricity will be saved for each year? And how much payback time can be determined?

Assume: each chiller operates at 1,000 h/year
Yearly electricity consumption:
= (0.69 kW/ton × 500 tons ×1,000 h/year) + (0.69 kW/ton × 600 tons ×1,000 h/year)
= 759,000 kWh/year

Yearly cost = 759,000 kWh/year × 2.86 Baht/kWh = 2,170,740 Baht/year

Assume: the new chiller operates at 2,000 h/year

Yearly electricity consumption = 0.44 kW × 300 × 2,000 h/year

= 264,000 kWh/year

Yearly cost = 264,000 kWh/year × 2.86 Baht/kWh = 755,040 Baht/year

Annual electricity savings = 759,000 kWh/year - 264,000 kWh/year
= 495,000 kWh/year

Annual cost savings = 495,000 kWh/year × 2.86 Baht/kWh
= 1,415,700 Baht/year

Payback time:
Estimated cost of a chiller = 7,800,000 Baht
Payback = (7,800,000 Baht) / (1,415,700 Baht/year) = 5.5 years

4.13.2 Water Conservation

6) Replace of old manual faucets to the new self-closing faucets

Everyday, a people need to use 10 times of faucets
Each time, the people use about 10 seconds
Flow rate of water for a manual faucet is not more than 6 L/min
Flow rate of water for a self-closing faucet = 0.2 – 0.5 L in 3 – 6 seconds
Assume that there are 1,000 faucets in the campus

Annual water consumption for manual faucets:
= 3,831 people × 10 times/person.day × 1 L/time × 365 days/year
= 13,983 m^3/year

Annual water consumption for self-closing faucets:
= 1,000 units × 10 times/unit.day × 0.5 L/time × 365 days/year
= 1,825 m^3/year

Annual water savings = 13,983 m^3/year - 1,825 m^3/year = 12,158 m^3/year

Annual money savings = 12,158 m^3/year × 16.06 Baht/m^3
= 195,260 Baht/year

Payback time:
Estimated cost of a self-closing faucet = 150 Baht
Estimated installing cost = 20% × 150 Baht/unit = 30 Baht/unit
Payback = (150+30) Baht/unit × 1,000 units / 195,260 Baht/year = 0.9 years

7) Replace the conventional Urinals to Non-water Urinals at the public men’s restrooms

Assume: there are 1,900 men in the campus
One man needs to flush 4 times of a urinal
Flow rate of water for one flush valve = 1.5 L
Replace of 100 non-water urinal in the offices

Annual water needs for using urinals:
= 1,900 men × 4 times/flush.day × 1.5 L/time × 365 days/year
= 4,161,000 L/year = 4,161 m^3/year

Annual expenditures:
= 4,161 m^3/year × 16.06 Baht/m^3 = 66,825 Baht/year

Payback period:
100 non-water urinals are replaced with 100 water flush urinals
Estimated cost of a Non-Water Urinal = 6,000 Baht
Estimated installing cost = 20% × 6,000 Baht/unit = 1,200 Baht/unit

Payback = (6,000 + 1,200) Baht/unit × 100 units / 66,825 Baht/year
= 10.7 years

8) Replace high flush toilets to low flush toilets

Assume: There are 3,800 people in the AIT campus
A people need to flush 4 times of toilets
An old model toilet needs to flush 13 L/time
A low flush toilet needs to flush 6 L/time

Annual water consumption for old model toilets:
= 3,800 people × 4 times/flush.day × 13 L/flush.time × 365 day/year
= 72,124,000 L/year = 72,124 m^3/year

Annual water consumption for low flush toilets:
= 3,800 people × 4 times/flush.day × 6 L/flush.time × 365 day/year
= 33,288,000 L/year = 33,288 m^3/year

Annual water savings:
= 72,124 m^3/year - 33,288 m^3/year = 38,836 m^3/year

Annual money savings:
= 38,836 m^3/year × 16.06 Baht/m^3 = 623,706 Baht/year

Payback time:
Estimated cost of a low flush toilet = 5,000 Baht
Estimated installing cost = 20% × 5,000 Baht = 1,000 Baht/unit
It is assumed that 500 units need to be replaced
Payback = (1,000 + 5,000) Baht/unit × 500 units / 623,706 Baht/year
= 4.8 years

9) Repair, maintenance and monitor for water leakage

AIT has average 10% of leakage
Water flow for the leakage = 10% × 495,391 m^3/year = 49,539 m^3/year
Annual cost = 49,539 m^3/year × 16.06 Baht/m^3 = 795,596 Baht/year

Table I.1 Electricity Consumption Predictions

Year	Population	Electricity consumption		Cost	CO_2 emissions
		(kWh/year)	kWh/person.day	(Baht/person.day)	(tons/day)
2005	3,831	13,495,320	9.65	16.41	13.87
2006	3,984	12,415,694	8.54	14.51	12.76
2007	4,144	12,726,087	8.41	14.30	13.07
2008	4,309	13,044,239	8.29	14.10	13.40
2009	4,482	13,370,345	8.17	13.89	13.74
2010	4,661	13,704,604	8.06	13.69	14.08

Remark: Increasing rate of population = 4% (estimation)
Increasing rate of electricity consumption = 2.5% (estimation)

Table I.2 Water Consumption Predictions

Year	Population	Water consumption		Cost
		(m^3/year)	L/person.day	(Baht/person.day)
2005	3,831	495,391	354	5.69
2006	3,984	390,697	269	4.31
2007	4,144	398,511	263	4.23
2008	4,309	406,481	258	4.15
2009	4,482	414,611	253	4.07
2010	4,661	422,903	249	3.99

Remark: Increasing rate of population = 4% (estimation)
Increasing rate of electricity consumption = 2% (estimation)

Table I.3 Predictions of Solid Waste Generation

Year	Population	Solid Waste Generation		Recyclable Waste
		(kg/year)	L/person.day	(kg/year)
2005	3,831	740,000	534	28,000
2006	3,984	666,000	458	28,560
2007	4,144	679,320	449	29,131
2008	4,309	692,906	441	29,714
2009	4,482	706,765	432	30,308
2010	4,661	720,900	424	30,914

Remark: Increasing rate of population = 4% (estimation)
Increasing rate of solid waste generation from 2006 to 2010 = 2% (estimation)

DEVELOPMENT OF ENVIRONMENTAL SUSTAINABILITY CONCEPTS FOR AIT CAMPUS

Present by: Vongdueane Soulalay

Examination Committee: Prof. C. Visvanathan (Chairperson)
Dr. Thammarat Koottatep
Prof. Sivanappan Kumar

Date: April 27, 2006

Introduction

Negative environmental impacts of energy consumption:

Fossil fuel	Nuclear plant	Coal burning	Hydropower
CO_2, SO_2, NO_x	Air borne radioactive gas	37% of GHG emissions	Water scarcity for people in the down stream
Pollutants	Hazard to mined works and nearby population	Smog, acid rain, global warming, air toxic	Biodiversity impacts
Health impacts	No available solutions for storage or disposal	Health impacts	

Contribution to sustainable development

Introduction

Negative environmental impacts of water consumption:

Large water consumption

Wastewater generation → Water pollution → Economic

Water scarcity → Sanitation → Health impacts

Contribution to sustainable development

Introduction

Negative environmental impacts of solid waste generation:

Solid waste generation

Disposal problems

Gas emissions

Toxic substances

Global Warming

Leachate

Water pollution

Contribution to sustainable development

Objectives

- ✓ Study the prevailing solid waste management in the campus
- ✓ Conduct water audit for AIT campus and analyze the present water usages and wastewater characterizations
- ✓ Study the current energy consumption at AIT campus and estimate the green house gas (GHG) emissions
- ✓ Study the noise level pollution at AIT campus
- ✓ Propose some effective Sustainable Development options to enhance the environmental perspective of AIT campus.

Methodology

Investigations (walk-through)

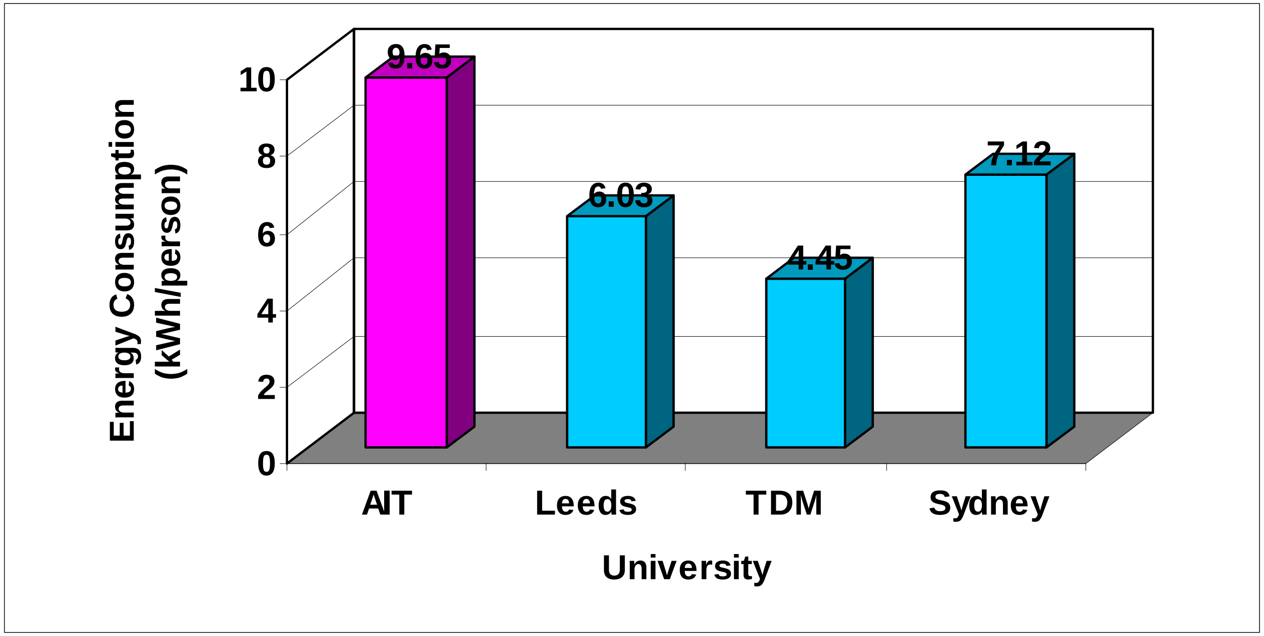
Secondary data collection

Energy, water & solid waste audits

- Waste analyses
  - Solid waste segregations
  - Wastewater analyses: pH, COD, BOD, TSS & TDS
- Data record
- Interviews, questionnaires, web search
- Observations
- Manual measurement

Energy Consumption

- Trend of energy consumption (web link)
  - ✓ Daily energy consumption: 9.65 kWh/person
  - ✓ All other information are provided in the Eco-campus webpage
- Benchmarks



Energy Consumption

Energy audit (web link)

Excessive energy use:

Computer rooms

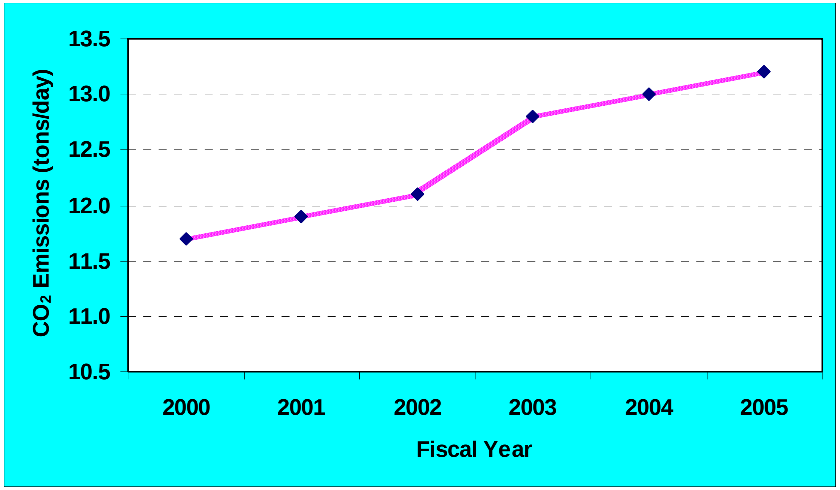
Laboratory

Old Air conditioner in the residential areas

Cooling tower

GHG Emissions

Trend of CO_2 emissions



Benchmarks' comparisons

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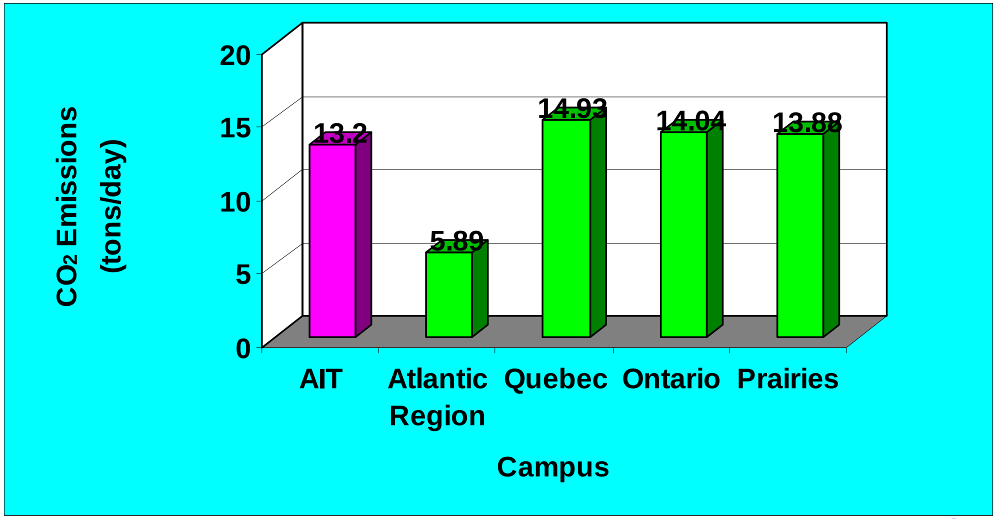

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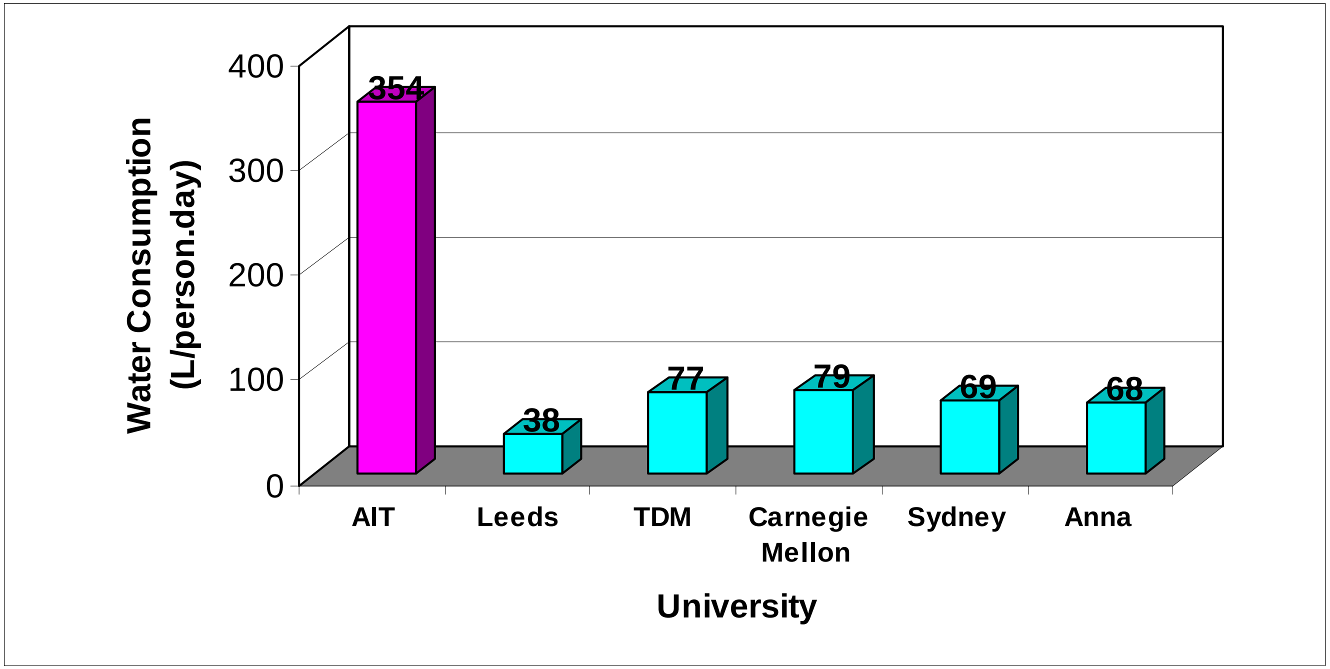
Water Consumption

- Trend of water consumption (web link)
  - ✓ Daily water consumption (AIT): 1,600 m^3/ day
  - ✓ All other information are provided in the Eco-campus webpage
- Benchmarks



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Wastewater generation

View of Wastewater Treatment Plant (web link)

- ✓ Daily wastewater generation = 1,122 m^3/day
- ✓ Estimated water lost = 17%
- ✓ All other information are provided in the Eco-campus webpage

Water Consumption

- Water audit (web link)
- Excessive water consumption/ loss

High flush toilet

7 - 10 L/ flush

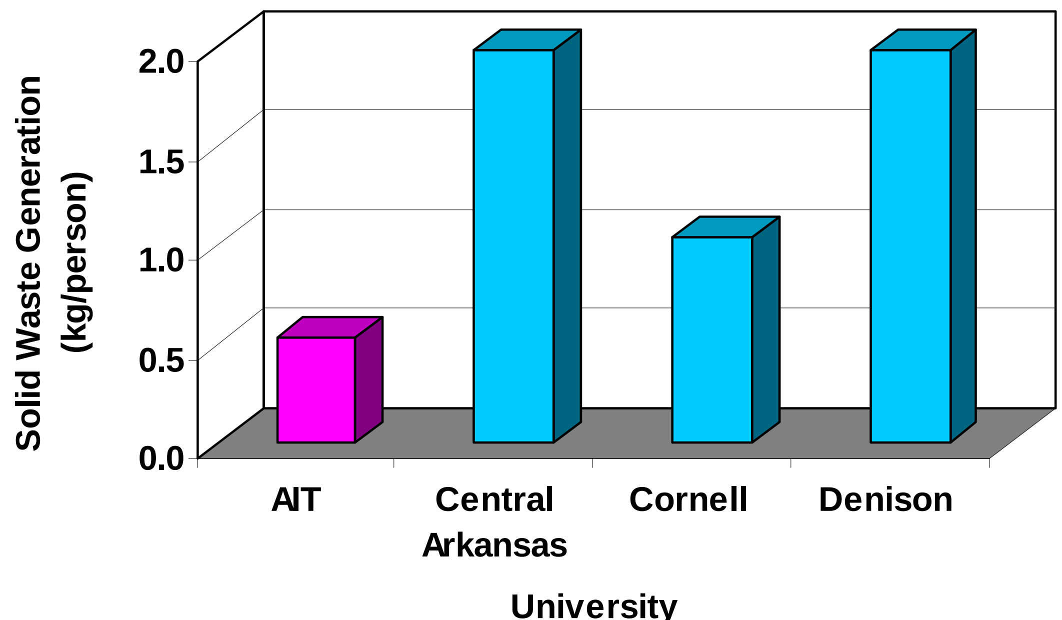
Leakage from faucet

Leakage in the cooling system

Improper water use

Solid waste generation

- Solid waste generation in 2005 (web link)
  - ✓ Daily solid waste generation: 0.53 kg/person
  - ✓ All other information are provided in the Eco-campus webpage
- Solid waste composition (web link)
- Benchmarks



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Solid waste generation

Solid waste audit (web link)

Improper solid waste generation

Uncollected solid waste

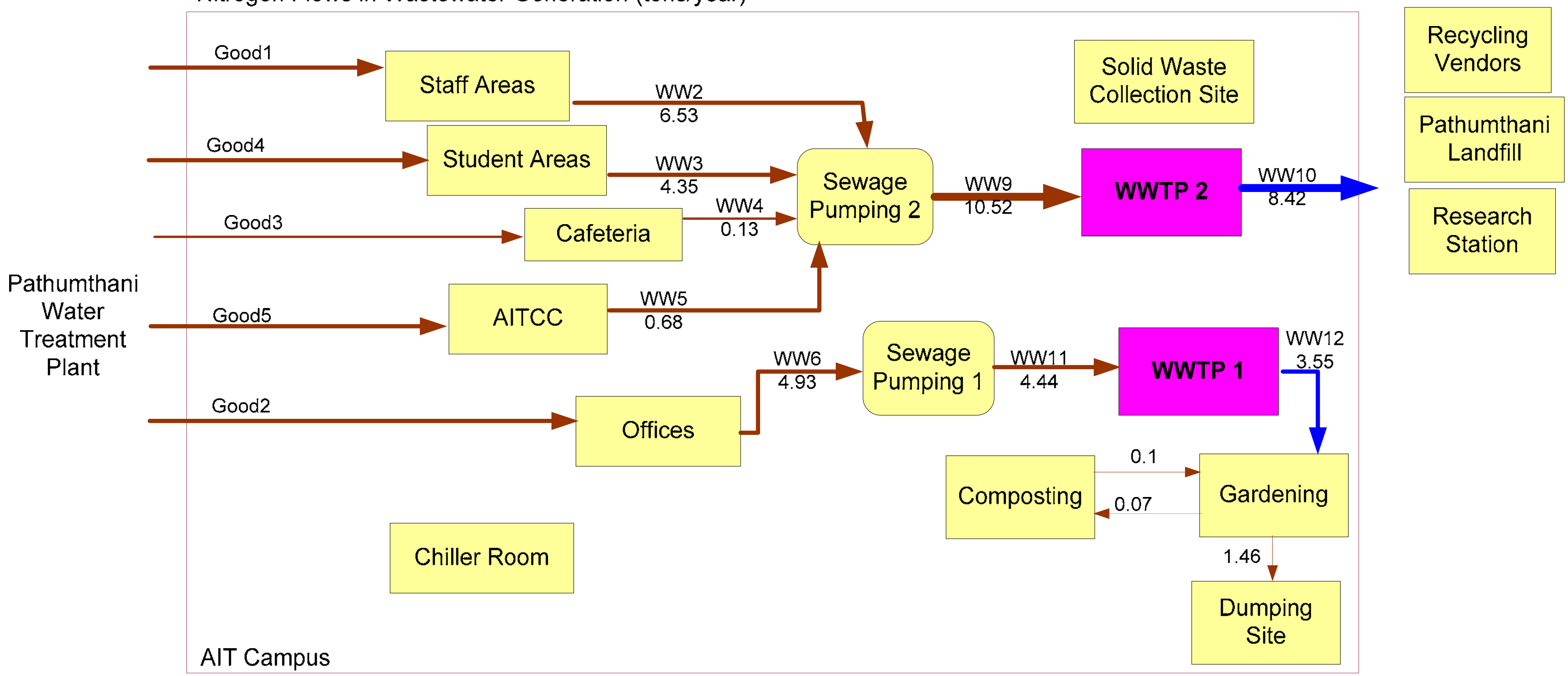
Improper solid waste segregation

Heterogeneity of solid waste

Material Flux Analyses

Scenario 1: The Improvement of WWTP for wastewater reuse

Nitrogen Flows in Wastewater Generation (tons/year)



Remark: W: Water supply WW: Wastewater and Excreta
SW: Solid waste

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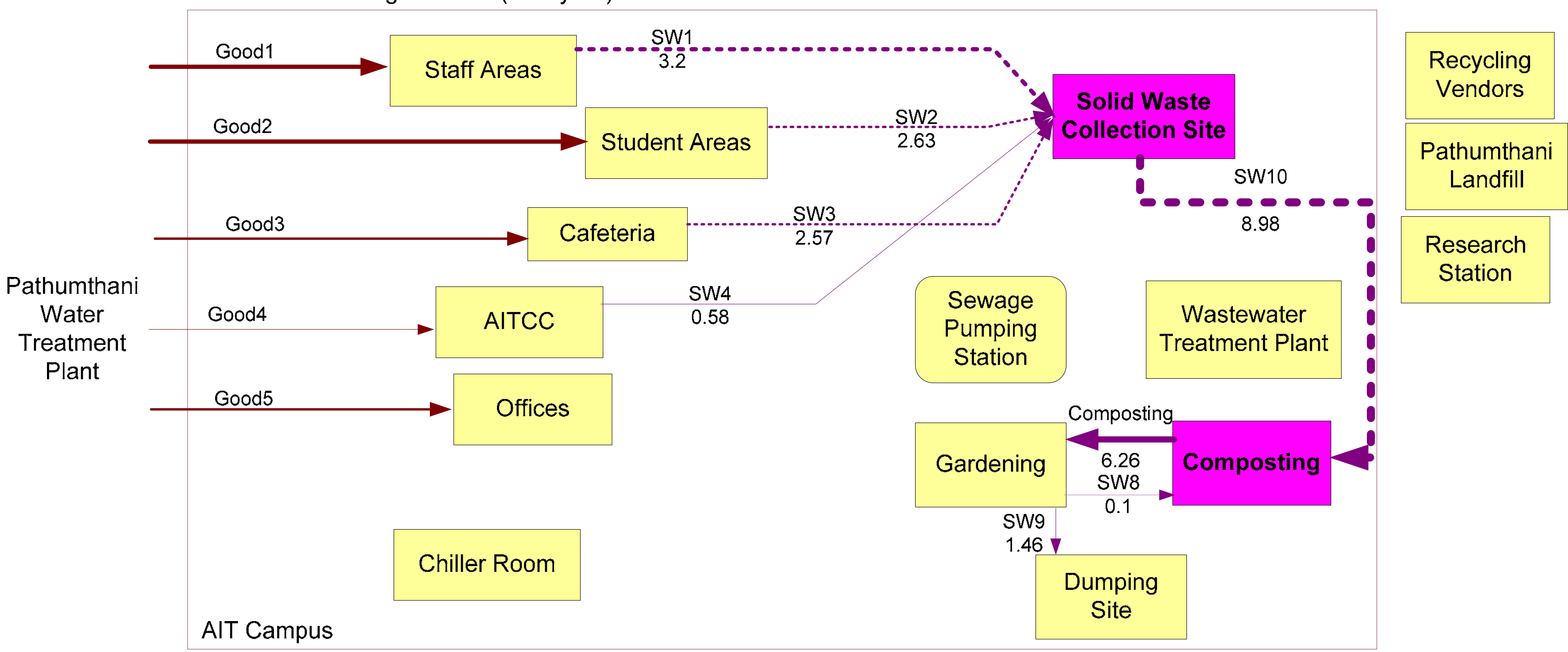
Material Flux Analyses

Scenario 2: Reduction of solid waste disposal to the landfill

Nitrogen Flows (tons/year)



Remark: W: Water supply WW: Wastewater and Excreta
SW: Solid waste

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Current waste flow

(A) AIT collection → (B) Landfill

Cleaner Production Options

Energy conservation

Option 1 — Automatic sensor switches: large amount of energy can be reduced during the day and night times.

Option 2 — Replace the conventional to solar street light

Option 3 — Replace the old chillers to the new efficient one

Option 4 — Encourage the staff and students to conserve the energy

Chiller

Solar Energy

Cleaner Production Options

Energy conservation

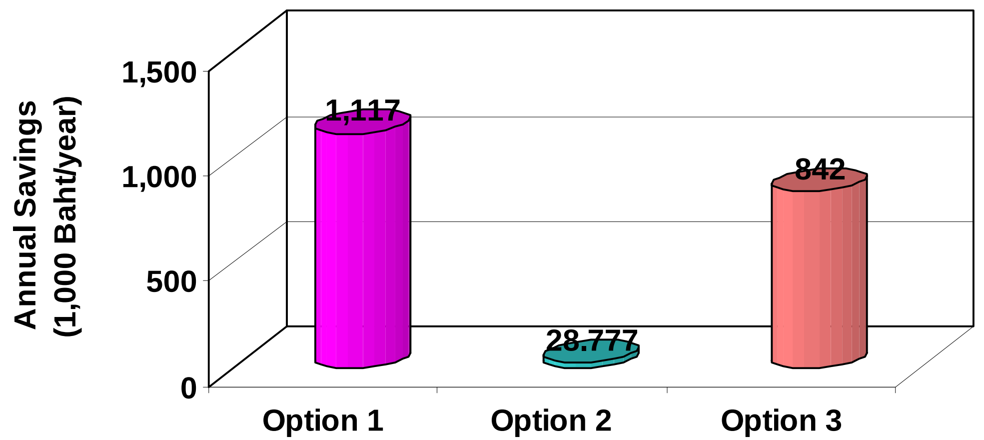
Option	Energy Consumption (kWh/year)		Annual savings	Reduction (%)	Payback (year)
	Before	After			
1	5,605,785	4,948,951	656,834	11	-
2	16,928	0	16,928	100	-
3	759,000	495,000	264,000	34	9
Total	13,495,320	-	937,762	7	-

Remark:

Option 1: Automatic sensor switch

Option 2: Replace the conventional to solar street light

Option 3: Replace the old chiller to the new efficient one



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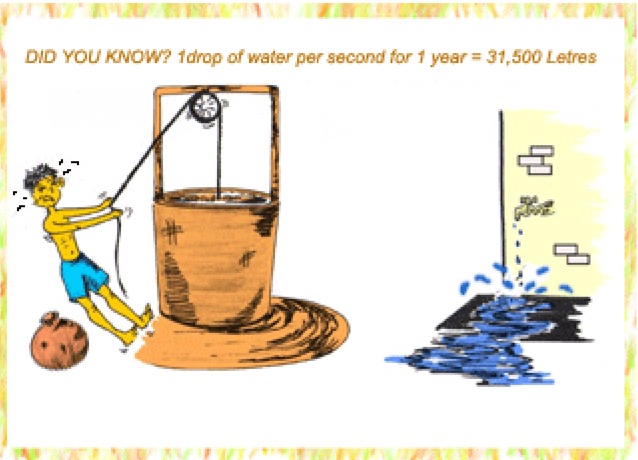
Cleaner Production Options

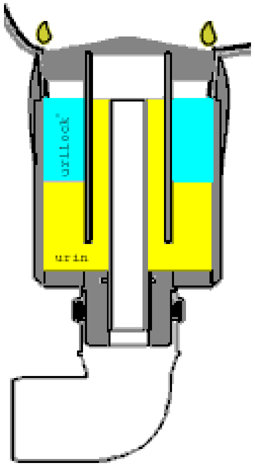
Water conservation

Option 1	Replace old manual faucets to self-closing faucets
Option 2	Replace conventional urinals to non-water urinals
Option 3	Replace high flush toilets to low flush toilets
Option 4	Repair, maintenance and monitor for water leakage
Option 5	Establish water reduction programme

Low flow toilets



Water reduction logo



Uridan Non-water urinal

Cleaner Production Options

Water conservation

Option	Water Consumption (m^3/year)		Annual savings	Reduction (%)	Payback (year)
	Before	After			
1	13,983	1,825	12,158	87	1
2	4,161	0	4,161	100	10
3	72,124	33,288	38,836	54	4
4	49,539	0	49,539	100	-
Total	495,391	-	104,694	21	

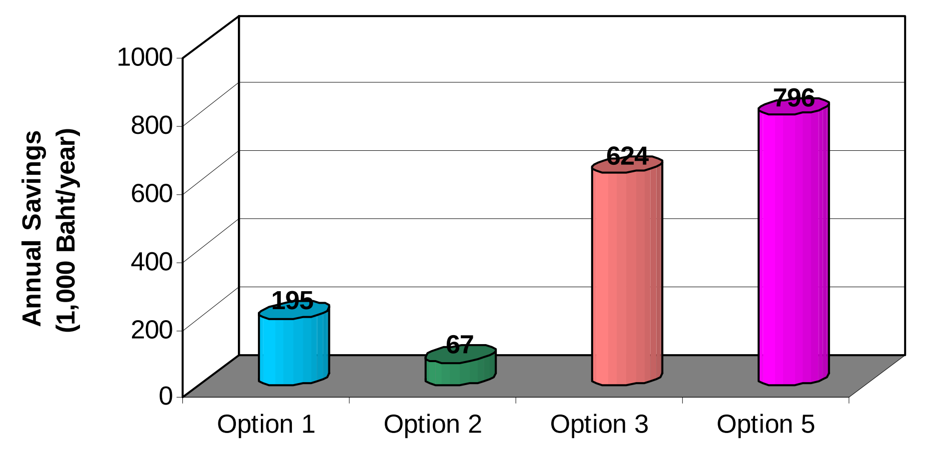
Remark:

Option 1: Replace old manual faucets to self-closing faucets

Option 2: Replace conventional urinals to non-water urinals

Option 3: Replace high flush toilets to low flush toilets

Option 4: Repair, maintenance and monitor for water leakage



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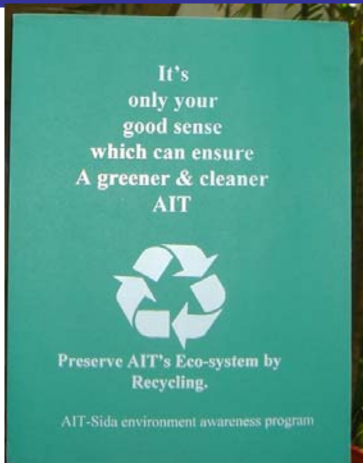
Cleaner Production Options



Solid waste reduction

Option 1

- Promote waste collection center in the AIT campus

Option 2

- Education campaign on campus with 3R concepts (Reduce, Reuse, Recycle)

Option 3

- Promote demonstration projects for waste segregations

Recyclable waste

Future predictions

Energy predictions

✓ If AIT implements these CP options, the estimated trend of energy consumption can be concluded as below:

Performance Indicators	2005 Results	2010 Targets
Daily energy consumption (kWh/person)	9.65	8.06
Cost of daily energy consumption (Baht/person)	16.41	13.69
Net CO_2 emissions (tons/day)	13.87	14.08
Unit price of energy consumption (Baht/kWh)	1.70	-

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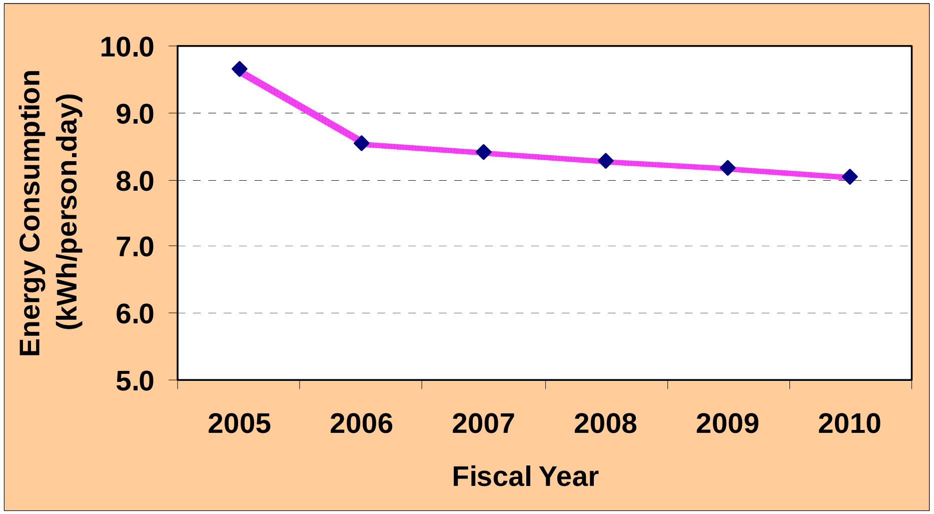

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Future predictions

Water consumption predictions

✓ If AIT implements these CP options, the estimated trend of water consumption can be concluded as below:

Performance Indicators	2005 Results	2010 Targets
Daily water consumption (L/person)	354	249
Cost of daily energy consumption (Baht/person)	5.69	3.99
Unit price of energy consumption (Baht/m^3)	16.06	-

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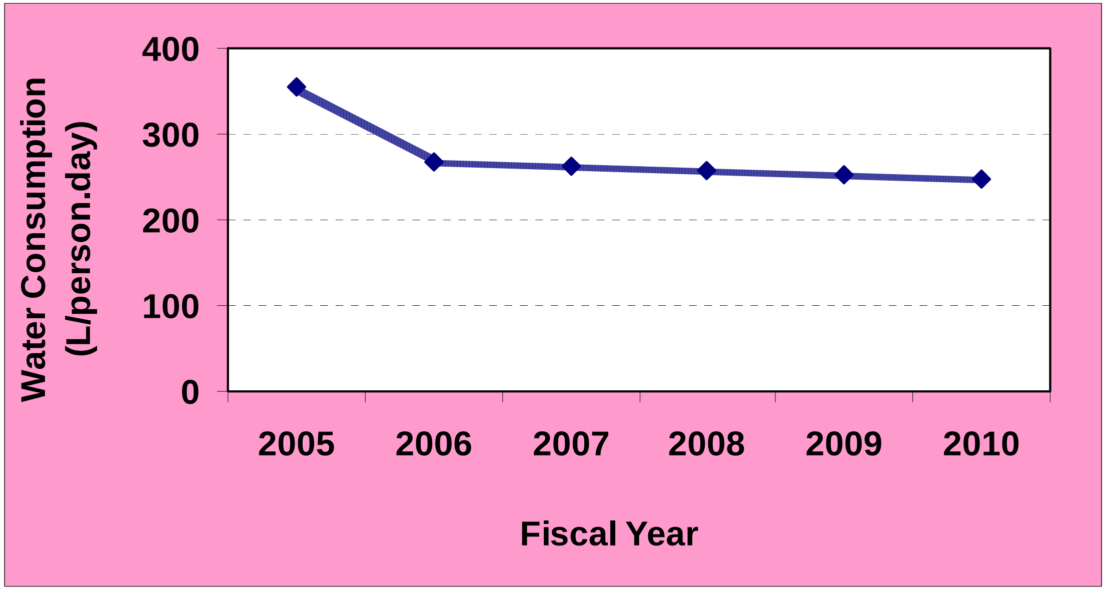

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Future predictions

Solid waste generation predictions

✓ If AIT implements these CP options, the estimated trend of solid waste generation will be as below:

Performance Indicators	2005 Results	2010 Targets
Yearly solid waste generation (tons)	740	666
Daily solid waste generation (kg/person)	0.53	0.42
Yearly recyclable waste (kg)	28,164	31,095
Amount of solid waste transport to the landfill (tons/day)	1.94	0.80
Cost of solid waste disposal	96,000	-

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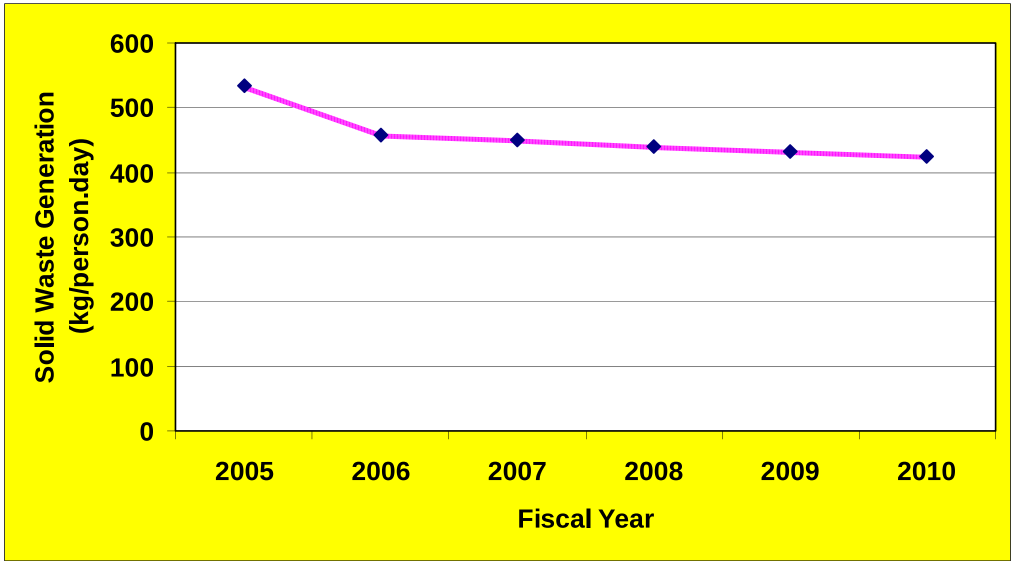

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Conclusions

- AIT consumes more than 13.5 Million watts of energy in each year. About 50% is consumed by academic/ administration blocks.
- AIT consumes about 0.5 Million m^3 of water in each year. Around 50% is consumed by residential areas.
- Water lost accounts to 17% from water consumption to the main sewage pumping station.
- The removal efficiency of BOD at AIT's WWTP is only 70%. Furthermore, the effluent of BOD does not meet the Thai standard.
- AIT generates about 2 tons of solid waste daily, > 95% of total waste is sent to the landfill site.
- Residential areas are the major source of solid waste generation which covers almost 60% of total waste.

Recommendations

- Not only encouraging people how to reduce the consumption but the new technology is also needed.
- The need is to implement all CP options in the campus.
- The installation of automatic switch sensors and replacements of old chillers should be implemented first.
- Replace of the high flush toilet to low flush toilet and leakage detection is prior need for the short term.
- Solid waste collection center, solid waste segregation and education campaign should be immediately conducted in the campus.
- WWTP should be improved, to meet the standard of effluent.
- Organic waste composting should be started in the campus, to reduce large amount of solid waste sent to the landfill.

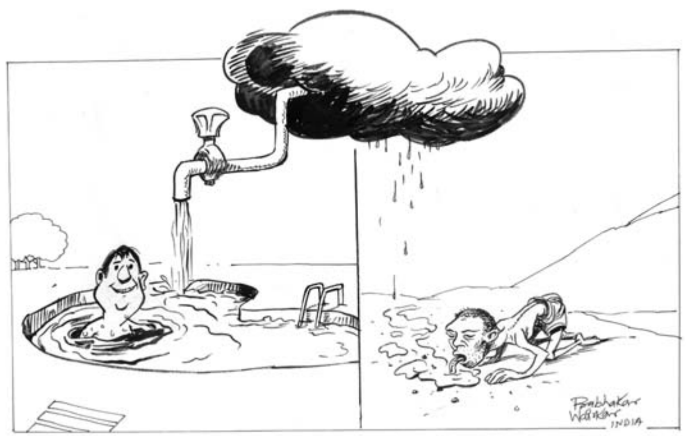
Contribution of this study

✓ These data can be set as the benchmarks for a university in a developing country.

✓ Results of this study shows environmental situation of AIT campus.

✓ This study also suggest how to improve the environmental sustainability in long run and set achievable targets.

✓ AIT's administrators can have better perspectives for improving the campus environment in a sustainable way both in short and long term.



Prabhakar Wairkar, India "ENSURE ENVIRONMENTAL SUSTAINABILITY"


Thank you