

**A STUDY OF THE ENVIRONMENTAL POLICIES, PROCESSES AND
PRACTICES OF WORCESTER POLYTECHNIC INSTITUTE AND THE
TECHNISCHE UNIVERSITÄT DARMSTADT**

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by

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ABSTRACT

The goal of this research project, which has an environmental focus, is to study and compare the environmental policies, practices and processes of the Technische Universität Darmstadt, Germany, and Worcester Polytechnic Institute, USA, in addition to outside factors that may also have an influence. Specifically, the following points will be examined:

- Electricity Efficiency
- Energy Conservation
- Water and Air Pollution Awareness
- Waste Management and Recycling
- Other factors influencing environmental decisions

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VERSION HISTORY

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1	Initial Revision, reviewed with Professors Dollenmayer and Linke	Oct. 16, 2007
2	Incorporated suggestions from Professor Dollenmayer, added several sections and sources to TUD section following meetings / research	Nov. 5, 2007
3	Expansion of sections on waste management at WPI, reworked statement of purpose to align with current topics	Nov. 20, 2007
4	Sections on resource usage at WPI, specific examples, and background info	Nov. 22, 2007
5	Changed main layout to reflect typical IQP	Nov. 23, 2007
6	Methodology, section on new WPI Residence Hall added, more formatting based on WPI's Projects site for IQPs	Nov. 30, 2007
7	Background on each university, introduction added; methodology expanded	Dec. 2, 2007
8	Environmental policy of the TUD, first appendix, library project added	Dec. 5, 2007
9	TUD resource usage, all comparisons added	Dec. 9, 2007
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INTRODUCTION & BACKGROUND

Worcester Polytechnic Institute

Founded in 1865, Worcester Polytechnic Institute (WPI) is a highly ranked private technical university offering degrees ranging from a Bachelor's to a Doctorate in a variety of disciplines. The university is home to about 4,000 students (3,000 undergraduate, 1,000 graduate) as well as 300 faculty and several hundred additional support staff. Among the undergraduates, nearly 67 percent live on campus in the 11 residence halls. The entire campus comprises 33 major buildings on 80 acres of land. Unlike the Technische Universität Darmstadt (TUD), WPI is a private institution with tuition exceeding \$33,000, and estimated total living expenses for one year (including tuition) exceeding \$45,000 (Worcester Polytechnic Institute, 2007) per student.

WPI, along with some 10 other colleges and universities, is located in Worcester, Massachusetts, which as of 2006 is the second-largest city in New England. For the purposes of this paper, only temperature data regarding Worcester is significant. The weather in Worcester is characteristic of much of Massachusetts and New England, with summer temperatures averaging around 23°C, though often exceeding 30°C, and winter temperatures averaging around 0°C, though often sinking below -8°C. Precipitation throughout the year is uniformly distributed, with the city receiving some 152.4 cm¹ (60 inches) of snow each winter and rain throughout the summer months (Weatherbase, 2007).

¹ Converted at 1 in. = 2.54 cm

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
°C	-4	-3	1	7	13	18	21	20	15	10	4	-2

Figure 1: Average Temperature of Worcester, Massachusetts (Weatherbase, 2007)

Technische Universität Darmstadt

Founded in 1877 as the Technische Hochschule zu Darmstadt, the Technische Universität Darmstadt is one of the leading technical universities in Germany. Considerably larger than WPI, the TUD has a current enrollment of nearly 18,000 students and 3,100 faculty (Wikipedia, 2007). The campus itself consists of 153 buildings on more than 550 acres of land spread across two campuses and several other sites (Schmidt, 2007).² Though a public German university, in 2005 the TUD became the first state-funded university to be given administrative autonomy. The university says that this allows for “self-responsibility and flexibility” leading to “creative freedom and enthusiasm”. The university aims to remain one of the top three technical universities in Germany while being an international leader in technical research (Technische Universität Darmstadt, 2007).

The TUD is located in Darmstadt, Germany, a city known for its strengths in the technological sector. The weather patterns of the city are not terribly different from those in Worcester, though temperatures tend to be milder in Darmstadt. Summer temperatures average around 17°C, though often becoming as warm as 30°C, and winter temperatures average around 3°C, though often becoming as cold as -4°C (euroWeather, 2007).

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
°C	1	2	5	9	14	17	19	18	14	10	4	2

² Source lists 225 hectares, converted at 1 ha = 2.47105 acres

Figure 2: Average Temperatures of Darmstadt, Germany (euroWeather, 2007)

METHODOLOGY

Since the goal of the project was to compare the two universities as objectively as possible, and since research for each university was carried out in a separate country, it was important to establish what points would be important ahead of time. Along with Professor David Dollenmayer, the advisor to this project at WPI, I identified issues that would be important to determine how the two universities were performing environmentally, as well as metrics that could easily be found at each university.

Initially, the focus was going to be on comparisons of raw resource consumption – gas, electricity, etc. – but this has proven less significant as the project progressed. Difficulty obtaining sufficient information from WPI, along with getting a large enough sampling to provide a meaningful statistical analysis have left much to be desired with this metric. Eventually, only the electricity usage had enough data to even attempt a meaningful comparison.

Based on the comments of several people interviewed at the TUD, as well as WPI, it has been prudent instead to focus more on current environmental policy and how that policy is being carried into the future. Each university is currently involved in at least one major building project labelled as being environmentally friendly, and this provides a much more practical way to evaluate the follow-through of each university's respective environmental policy.

Raw Data Collection

Most of the raw data that I received comes from each university's facility management departments. WPI's Department of Facilities provided information regarding their electricity usage and waste tonnage, as well as information such as square footage for various buildings in order to establish average power consumption per square foot, etc. Likewise, the facility management and department of sustainable operations at the TUD provided information regarding their new building projects, as well as various resource usage figures.

Interviews and Presentations

Initial interviews at WPI were conducted to discover other potential topics for exploration, as well as to gain an overview of WPI's environmental policy. Speaking with Barbara Kolofsky, Head of Dining Services, for instance, served to establish WPI's policy concerning food management. Several additional topics came from this discussion, while others had to be dismissed. Through this interview, I found that it would not make sense to cover food services specifically, since their recycling and waste management was outsourced to other organizations.

Several short interviews followed, serving mostly as sources for other interviews. Fred DiMauro, Assistant Vice President for Facilities, in particular was helpful in setting up other contacts within the Department of Facilities. While he himself was unable to answer any of my questions directly, he was very knowledgeable about who would be able to provide answers. Two people in particular whom he directed me to, Diane Baxter

and Alida Tousignant, both Administrative Assistants for Facilities, were useful in providing raw data, even though I was off-site and unable to interview them.

The first of my German interviews was with Mr. Thorsten Schmidt, the head of facility management for the TUD. He was able to provide a general overview of both TUD campuses, as well as describe several technologies that the TUD employs to be more environmentally friendly, such as recycling rainwater. Additionally, he had a lot of information regarding the TUD's latest building processes as well as the Darmstadtium, a common project of the city of Darmstadt, TUD and the Land Hessen.

The next appointment was with Dr. Andreas Stascheck, the superintendent of the department of sustainable operation and Dr. Michael Linker, the head of the department for environmental protection and disposal. Dr. Stascheck emphasized that while environmental concerns play a role in the operations of the TUD, there are many other factors as well. He was also able to provide some information regarding the recent developments in the TUD, including their switch from being dependent on oil and coal. Lastly, he spoke to the comparisons that are made between the various German universities, and the difficulty in successfully evaluating them.

Next was a short tour of the Brauchwasseranlage (non-drinking water facility) at the Lichtwiese campus. Included were a description of the facility's operation and capacity.

Lastly was an interview with Michael Nitze, the energy coordinator for the TUD. He was able to provide resource usage statistics and building measurements that were comparable to the ones that I found at WPI. Additionally, he provided a comprehensive analysis of many of the buildings at the TUD. Finally, he explained the difficulties that

exist in taking measurements for the statistics that I was asking for. For building areas, he talked about the various measures that exist, and how they split the buildings. For gas usage, he explained that the actual amount of power used has to be adjusted for losses out of building chimneys, and that while it is possible to make a single adjustment for all buildings, this would in fact be inaccurate since many buildings are much less efficient.

RESULTS AND DISCUSSION

This section is broken into three parts: a description of all information found about WPI, followed by a similar section about the TUD, and lastly a section comparing some of the major points that were common to both universities. Since the information found for the two universities did not have a one-to-one correspondence it would be impossible to compare both universities on all points found, but it was important to include nevertheless since it demonstrates the policies and practices of each university.

Worcester Polytechnic Institute

Natural Resource Consumption

WPI's resource usage is managed through the Department of Facilities, specifically Alida Tousignant and Diane Baxter, who handle all bills related to electricity and gas. All energy is provided by NSTAR (<http://www.nstaronline.com>).

Electricity

Unfortunately, WPI doesn't regularly track its electricity usage across every building, and therefore they were unable to provide any figures over a time period of more than a year. However, the most current electricity usages are listed below. A list of the buildings included in this measure, along with their square footages, is given after the usage table.

Period	Usage (Kilowatt-Hours)
10/16/2006 - 11/14/2006	1532900
11/14/2006 - 12/16/2006	1558200
12/16/2006 - 1/17/2007	1312800

1/17/2007 - 2/16/2007	1297300
2/16/2007 - 3/19/2007	998400
3/19/2007 - 4/17/2007	955200
4/17/2007 - 5/16/2007	1053900
5/16/2007 - 6/15/2007	1372800
6/15/2007 - 7/17/2007	1238700
7/17/2007 - 8/15/2007	1567200
8/15/2007 - 9/14/2007	1684800
9/14/2007 - 10/15/2007	1648800
Total	16221000

Figure 3: WPI Electricity Usage for Select Buildings, 10/2006 – 10/2007(Tousignant, 2007)

Though the data is not represented here, WPI acknowledges an increase in electricity usage from the 2006 school year to the 2007 school year. They attribute this to the completion and opening of a new admissions building, as well as the renovation and increased use of several older administrative buildings. Concerning the dip in electricity that occurred from February to May, the Department of Facilities says they are unsure why this would have occurred (Tousignant, 2007).

Building Name	Square Feet	Square Meters³
AJ Knight Field	N/A	N/A
AK	65005	6039.34
Alden	18043.9	1676.38
Alumni Field	N/A	N/A
Alumni Gym	47580.84	4420.53
Boynton Hall (exact figure not available)	42000	3902.04
Football Field	1802	167.42
Fuller	52447.4	4872.66
Goddard	40499	3762.59
Gordon Library	63311	5881.95
Harrington	74089.8	6883.37
Higgins Labs	50000	4645.29
Kaven	34952.3	3247.27
Olin	24706	2295.33
Salisbury	47283	4392.86
Stratton	14174.35	1316.88
Washburn	38919	3615.80
Total	442183.85	41081.41

Figure 4: WPI Buildings and Square Footages(Tousignant, 2007)

³ Converted at 1 square meter = 10.7636 square feet

Based on the data, academic buildings consume on average 394.85 kilowatt-hours per square meter of floor space for electricity.

Waste Management

WPI's waste management is handled primarily by Terrence Pellerin. Trash pickup and disposal is contracted out to Waste Management (<http://www.wm.com/>). For July 1, 2006 through June 30, 2007, WPI's raw waste tonnages are listed below.

Category	Tonnage
Mixed Electronics	13.63
Mixed Office Paper	45.06
Cardboard	40.08
Surplus Furniture	16.12
Universal Waste (bulbs, ballasts, batteries)	0.43
Metal	17.14
Trash	629.15

Figure 5: WPI Waste Tonnages for FY06-07(Pellerin, 2007)

Recycling

Formally, WPI only recycles those items in the above table not listed as trash (mixed electronics, mixed office paper, etc.). In fiscal year 2006-2007, this translates to only 17.4% of the gross waste produced by WPI being recycled. Figures provided on WPI's official website show only 15% being recycled(Worcester Polytechnic Institute, 2007), though these figures are "a couple years old"(Pellerin, 2007).

While this list only covers those materials handled specifically by the Department of Facilities at WPI, it is important to note that no official recycling programs exist for any other items. Consumer recyclables, such as glass bottles, aluminum cans, and plastics, are not collected by the university. Some individual efforts exist to collect these goods, primarily within the various dormitories and at the cafeterias. Barbara Kolofsky,

Director of Dining Services at WPI, says that recycling is often a secondary concern when deciding on new items for the cafeterias. Dining Services does however run several small recycling programs, including collection old cell phones and accepting aluminum cans. They also try to limit using Styrofoam usage whenever possible, opting instead for paper and plastics (Kolofsky, 2007). Perhaps the most interesting item that gets recycled by Dining Services is the cooking oil used in the kitchens, which is taken for use in grease car by another employee on campus (see Grease Car below).

New Residence Hall Project

In March 2007, WPI began construction on a new residence hall, focused on serving upperclassmen. The building, to be completed by the fall of 2008 is the latest effort of the school to continue to establish a “lower campus”, following the success of the reconditioning of a neighboring dormitory. Most notably, the building is designed to meet some “green” standards as specified by the Leadership in Energy and Environmental Design (LEED) program.

The LEED Green Building Rating System is, “the nationally accepted benchmark for the design, construction and operation of high-performance buildings” (U.S. Green Building Council, 2007). The rating system for new constructions defines 69 possible points that a building can receive. Depending on the total score, the building can receive an overall rating of Certified (26-32 points), Silver (33-38 points), Gold (39-51 points) or Platinum (52-69 points). Categories for points include sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality and innovation and design process (U.S. Green Building Council, 2005).

While certification does not occur until after completion of the building, WPI plans to achieve a rating of silver with the new residence hall. Below is a breakdown of the various points that WPI and the building design team have identified as achievable, as well as descriptions of each point as it pertains to the project (U.S. Green Building Council, 2005)(Worcester Polytechnic Institute, 2006).

- Sustainable Sites

- Erosion and sedimentation control

This point is meant to “reduce pollution from construction activities by controlling soil erosion, waterway sedimentation and airborne dust generation” (U.S. Green Building Council, 2005) and primarily involves creating a plan before construction for preventing major soil loss during construction.

- Site selection

This requirement defines guidelines for determining if a site is appropriate for a building by listing places where development should not occur. Among sites to avoid are those that are a habitat for endangered species, close to a body of water, or parkland.

- Urban redevelopment

This point requires increased population density of an existing site. In this case, the new residence hall is being built on a location that previously contained several smaller WPI-owned apartment buildings.

- Alternative transportation – Public Transportation

Designed as a pollution reducing measure, this point requires that the

site be located close to several types of public transportation; in Worcester, buses.

- Alternative transportation - parking capacity

To encourage car pooling and reduce emphasis on personal vehicles, this point specifies that parking should be created to meet only minimum zoning requirements for parking places, and that separate parking places be set up for carpools.

- Storm water management

Similar to the preventing erosion during construction, the intent here is to minimize erosion throughout the lifespan of the building due to storm water being channeled by impervious surfaces.

- Landscape design and reduction of heat island

This point provides several options for reducing heat islands, defined as “thermal gradient differences between developed and undeveloped areas” (U.S. Green Building Council, 2005). WPI’s new building implements this with a vegetated roof surface.

- Light pollution reduction

While focusing mainly on exterior lighting guidelines, this point also specifies operation of interior lighting, including mandating sensors to control lights automatically after normal business hours.

- Water Efficiency

- Water efficient landscaping - potable water reduction

This point requires reducing potable water consumption in irrigation

by at least 50% based on normal summer consumption. The point is obtained automatically since WPI has no planned irrigation system for the building.

- Water efficient landscaping - no irrigation

As mentioned above, this point is received by default since the new residence hall has no planned irrigation.

- Water use reduction (30% reduction)

Primarily through the use of high-efficiency fixtures, the new residence hall plans to reduce water consumption by at least 30% compared with the baseline amount set forth in the Energy Policy Act.

- Energy and Atmosphere

- CFC Reduction, Ozone Depletion - non HCFC or Halons

These two points deal with prevention of ozone depletion and global warming by limiting what substances can be used in various building systems. Not only are HVAC systems covered, but fire suppression systems as well.

- Optimize Energy Performance - 20% reduction

The energy optimization point is based on a scale of one to ten depending on the total amount of energy reduction compared to a base level. By using a comprehensive energy model of the building, the designers were able to evaluate and identify possible reductions. One of the larger decisions was the orientation of the building to optimize the use of natural light.

- Materials and Resources

- Storage and collection of Recyclables

Continuing with WPI's current recycling policy (see Recycling), the building will incorporate facilities to collect all currently recycled materials.

- Construction Waste management

The two points available here call for 50% and 75% of construction waste to be diverted from disposal in landfills and incinerators.

Instead, said waste must be either recycled back into the manufacturing process or sent to other sites where it can be used.

Though the highest level called for in the point is 75%, WPI estimates that it will have, at best, 95% recovery of non-hazardous materials.

- Recycled Content

The two points here call for 5% and 10% of all construction materials used in the new building project to be recycled from other buildings, reducing the need for new resources. Among the recycled items WPI plans to use are concrete with blast furnace slag and mineral-fiber insulations.

- Local/Regional Materials - 20% manufactured locally

The goal of this point is two-fold. First, it intends to help local businesses by encouraging building projects to purchase from local suppliers. More importantly to the environment, however, is that it

reduces overall transportation costs associated with shipping the materials from non-local businesses.

- Certified Wood

This point requires that at least 50% of the wood used in the building project be certified by the Forest Stewardship Council's principles and criteria. The principles outline responsible management of forests used for logging.

- Indoor Environmental Quality

- Low Emitting Materials - adhesives and sealant, paints, carpet and composite wood

These several points put restriction on what types of materials can be used in order to reduce dangerous or irritant contaminants that these materials would otherwise produce.

- Controllability of Systems

While not entirely dedicated to environmental purposes, the controllability of the lighting and thermal systems do serve the purpose of optimizing these systems for whatever use is currently needed. This is especially true in the residence hall's various conference rooms and common areas, where often these systems can be run in low power modes.

- Daylight and View

These points discuss both the amount of daylight that common spaces should receive, and how much common space should have a direct line

of sight to the outdoors. As mentioned previously, WPI ran extensive simulations to establish the criteria for this point. Samples are below (Worcester Polytechnic Institute, 2007).



Figure 6 - Sun Shadow Analysis Model Sample (Worcester Polytechnic Institute, 2007)

Other Examples

Alternative Fuel Vehicles

Alternative fuels continue to be one of the larger environmental topics discussed at an international level. On a very small scale, however, individuals are doing what they can to switch to non-petrol-based fuels. Greasecar Vegetable Fuel Systems (<http://www.greasecar.com>) provides customers the ability to convert cars from only diesel powered into two-fuel diesel and vegetable oil powered. They claim to have sold thousands of systems over the years, and that with their systems installed in vehicles, emissions are drastically reduced, since, “there is no sulfur content in vegetable oil which eliminates the first major carcinogen associated with diesel fuel.” (Greasecar Vegetable Fuel Systems, 2007)

At WPI, Bruce Fiene, Video Systems Specialist at the Academic Technology Center, says he operates two cars that have the Greasecar system installed. “I drive one of our 2 veggie cars to work every day. My wife commutes daily with the other one,” says Fiene (Fiene, 2007). Adding to the environmental impact is the source of the fuel for the cars. All of the vegetable oil that Fiene uses to power his cars comes from WPI’s various cafeterias (Kolofsky, 2007). WPI gives a portion of its used vegetable oil to Fiene, who filters it and is then able to use it in place of gasoline.

Technische Universität Darmstadt

Environmental Policy

The TUD’s practical environmental policy and issues are managed by Department IV: Sustainable Operations⁴. The department’s concerns, however, extend far beyond the environment. The document, “Principles of our Work”⁵ (Technische Universität Darmstadt, 2005) describes how the department aims to balance social, ecological and economic aspects in order to provide the best university environment possible and achieve the goals of sustainability, promoting health and safety, and encouraging research. This is also reflected in the department’s structure and the responsibilities of each sub-department, an abbreviated list of which are listed here (Technische Universität Darmstadt, 2006):

A. Security and Health

- a. Central industrial safety organization and support of representatives
- b. Prevention and measures for the improvement of the industrial safety

⁴ Officially, Dezernat IV: Nachhaltiger Betrieb

⁵ See Appendix A for the original text

- c. Emergency plan and organization of first assistance
 - d. Measures for the protection and promotion of health
 - e. Organization of fire protection and prevention measures
- B. Environmental Protection and Disposal
- a. Management of the waste disposal center
 - b. Waste balances and economical refuse concepts
 - c. Consultation of waste producers
 - d. General environmental protection and ecological report
- C. Service and Technical Management
- a. Security of the power and water supply
 - b. Maintenance, repair and modernization of the operating technology and the central supply systems
 - c. Co-operation with building projects regarding sustainability and enterprise

Sustainability

Sustainability, or being able to maintain a process or activity indefinitely, is one of the main points outlined in the TUD's policies. As it says in the "Principles of our Work" document, "... we have adopted an approach that constitutes the basis of all our actions: sustainability. That means that we prefer solutions that are on a long-term basis most favorable with consideration to social, ecological and economic aspects.

(Technische Universität Darmstadt, 2005)" This is to say that sustainability in this sense refers to more than just the environment. However, when speaking directly about the environmental implications of this policy, Dr. Stascheck, the superintendent of the department, said that most of the new decisions made tend towards improving the

environmental concerns. Historically, he said, the TUD has been dependent on coal and oil for most of its power. However, in the last 10 years there has been a dramatic shift away from this dependence with more emphasis placed on environmentally friendly and efficient energy sources (Stascheck & Linker, 2007).

Cost

Though mostly outside the scope of this paper, it's worth noting that cost does of course play a major role in large decisions for any university, and the TUD is no exception. When considering plans for the new library project, for instance, analysis was done to determine costs associated with installing heat pumps, including upfront and operating costs. In this case, it was found that while installing heat pumps required more than double the initial investment (412,000 € vs. 860,000 €), they also halved the operating costs (66,796 € vs. 123,048 €). From this, a break-even point of 7.8 years was established (Technische Universität Darmstadt, 2007).

Natural Resource Consumption

Michael Nitze, the energy coordinator for the TUD, provided resource data. In order to develop a meaningful comparison to WPI's usage, he also provided the necessary building sizes. He was particularly adamant in making sure that the right measurement was used, since in Germany there are a variety of different sizes listed for the campus. The measurements differ only in the types of surfaces that they take into account. They are:

- Hauptnutzflächen (HNF) – the useful area of a building, including office space, classrooms, etc.

- Nebennutzflächen (NNF) – other area required for a building, including bathrooms, lecture halls, etc. (Wikipedia, 2007)
- Brutto-Grundfläche (BGF) – the gross surface area, including all things in the HNF and NNF(Wikipedia, 2007)

All statistics shown below use the BGF when dealing with surface area. For the TUD, this number is given as 332,211 square meters. For comparison, the HNF is only 245,453 square meters (Nitze, 2007).

Electricity

Unlike WPI, the TUD keeps detailed records of their electricity consumption. However, accurate measurements are typically only available for a full calendar year. Also different from WPI is the fact that the TUD produces some of its own electricity, rather than purchasing it externally. For 2006, the TUD’s electricity usage is listed below:

Month	Usage (Kilowatt-Hours)
January	3292000
February	3528000
March	3432000
April	3523000
May	3735000
June	3560000
July	3700000
August	3278000
September	3106000
October	3390000
November	3645000
December	3515000
Total	41704000

Figure 7: TUD Electricity Usage, 2006 (Nitze, 2007)

Based on the data, the TUD campus consumes on average 125.53 kilowatt-hours of electricity per square meter of floor space.

Heating

Heating energy at the TUD is measured in terms of effective kilowatt-hours used, rather than gross resource consumption like WPI. The reason for this is that some amount of energy is bound to be lost out of a buildings' chimney when it is being heated. What this means is that the numbers below represent approximately 85% of the energy actually produced to heat the buildings. Mr. Nitze says he arrived at this approximation by attempting to average the relatively efficient buildings with those that have constant airflows outdoors, and therefore are not heated efficiently. For 2005, the TUD's heating energy is listed below:

Month	Usage (Kilowatt-Hours)
January	8934990
February	9904620
March	7401450
April	3808670
May	2137120
June	87910
July	30010
August	50140
September	984660
October	3594010
November	7113770
December	9693640
Total	53741000

Figure 8: TUD Heating Energy, 2005 (Nitze, 2007)

Based on the data, the TUD campus consumes on average 161.76 kilowatt-hours of energy for heat per square meter of floor space.

Also of note is an interesting piece of data that Mr. Nitze mentioned concerning the financial implications of older style heating. He had recently received the cost of refilling one of the last oil tanks on campus that's used for heating a building. After factoring in the energy lost mentioned above, he was able to calculate that the more

modern sources of heating energy for the TUD were actually 36% more cost efficient than using oil (Nitze, 2007).

Water Usage

Similar to electricity, not all of the water used on the TUD campus is purchased externally. In fact, in 2006 more than half the water used on the campus was storm water – that is, water that originates as rain and snow - and other collected groundwater. The exact numbers were 141,306 cubic meters of drinking water and 73,104 cubic meters of storm water (Nitze, 2007). At the Lichtwiese campus, in particular, storm water is gathered at a non-drinking water treatment facility and filtered and processed to near drinking water quality, though its uses will be for bathroom facilities (toilets and irrigation only) and other places where such quality is not required. The Lichtwiese facility has a capacity to treat 25 cubic meters of water per hour, though it doesn't often reach this capacity.

Library Project

Beginning in October of 2007, the TUD began construction on a new university library. At a cost of more than 70 million Euros, the new building will have 30,653 square meters of floor space when completed in late 2010 (Technische Universität Darmstadt, 2007). Various technologies have been considered for the project, both for their environmental and financial impacts. Each environmentally friendly is compared to a comparatively less environmentally friendly and cheaper technology, on a number of points, including investment cost, operational cost and finally carbon dioxide emissions.

The first technology considered is using a heat pump versus a separate cooling facility and long-distance heating station. As mentioned in the section on environmental

policy, the heat pump requires more than double the initial investment, but makes up for it with half the operational costs. More interesting, however, is the amount of carbon dioxide emissions that can be saved using a heat pump. The figures and calculations for the heat pump are below:

CO ₂ emissions for generation of electricity:	0.616 kg CO ₂ / kWh
Necessary heating energy from the heat pump:	1,100,000 kWh per year
Performance factor of the heat pump (heating):	5.3
Necessary electricity for heating:	174,603 kWh per year
Necessary cooling energy from the heat pump:	720,000 kWh per year
Performance factor of the heat pump (cooling):	4.3
Necessary electricity for cooling:	167,442 kWh per year
Total electricity needed (heating + cooling):	342,045 kWh per year
CO ₂ emissions for the heat pump:	210,700 kg CO ₂ per year

By comparison, the figures for a cooling facility and long-distance heating station are below:

CO ₂ emissions for generation of electricity:	0.616 kg CO ₂ / kWh
CO ₂ emissions from natural gas (cogeneration):	0.225 kg CO ₂ / kWh
Necessary heating energy:	1,100,000 kWh per year
CO ₂ emissions for heating (0.225 kg CO ₂ / kWh):	247,500 kg CO ₂ per year
Necessary cooling energy:	720,000 kWh per year
Performance factor of cooling facility:	3.5
Necessary electricity for cooling:	205,714 kWh per year
CO ₂ emissions for cooling (0.616 kg CO ₂ / kWh):	126,700 kg CO ₂ per year

Total CO₂ emissions: 374,200 kg CO₂ per year

In total, the heat pump saves 163,500 kg CO₂ per year versus the alternative method of a cooling facility and long-distance heating station, reducing CO₂ emissions by 43% per year (Technische Universität Darmstadt, 2007).

The next technology considered is using a heat exchanger to provide some of the energy necessary to both heat and cool the library. Like with the heat pump, the alternative method involves using a cooling facility and long-distance heating. Two different scenarios for heat exchangers are presented, and they vary in terms of power and cost. Both cost 508,075 Euros, more than 350,000 Euros more than each of their respective alternatives. Since both exchangers provide energy without significant monetary costs once installed, the variance in the operating costs versus the alternatives is determined by how much power they can deliver. The more powerful of the two saves approximately 37,598 Euros per year, while the weaker saves only 27,600 Euros per year. For carbon dioxide comparisons, only the more powerful exchanger will be considered.

CO₂ emissions for generation of electricity: 0.616 kg CO₂ / kWh

CO₂ emissions from natural gas (cogeneration): 0.225 kg CO₂ / kWh

Avoided heating energy from the long-distance

heating: 308,000 kWh per year

CO₂ emissions for heating (0.225 kg CO₂ / kWh): 69,300 kg CO₂ per year

Avoided cooling energy from a cooling facility: 90,000 kWh per year

CO₂ emissions for cooling (0.616 kg CO₂ / kWh): 55,400 kg CO₂ per year

Total CO₂ emissions: 124,700 kg CO₂ per year

In total, the heat exchanger saves 124,700 kg CO₂ per year since it has no carbon dioxide emissions. Between the two technologies, heat pump and heat exchanger, a total of 288,200 kg CO₂ per year are saved (Technische Universität Darmstadt, 2007).

Comparisons

Resource Consumption

The most complete comparison that can be made between the two universities with regards to resource usage is to look at the electricity usage, since data is available for similar time periods. It's easy to see that in terms of raw consumption WPI cannot compare to the TUD. For a campus that's only one eighth the size of the entire TUD, WPI uses more than a third as much electricity as the TUD. This works out to kilowatt hour per square meter per year electricity consumptions of 394.85 and 125.53 for WPI and the TUD, respectively. This means that on a yearly basis, the TUD is apparently three times more efficient than WPI when it comes to electricity.

However, it's also important to look at the individual data points as well as the averages. When considering the entire data set, we see that the standard deviation of WPI's monthly electricity usage is 253,977 kWh, or 18.7% of the monthly average of 1,351,750 kWh. In contrast, the TUD's data only has standard deviation 185,520 kWh, or only 5.3% of its monthly average of 3,475,333 kWh. This could indicate many things, including varied building usage, changing enrollment numbers, or even environmental factors like the temperature at the time. For instance, consider the graphs of electricity usage (Figures 3 and 7) graphed with average temperature for the area where the university is located (Figures 1 and 2).

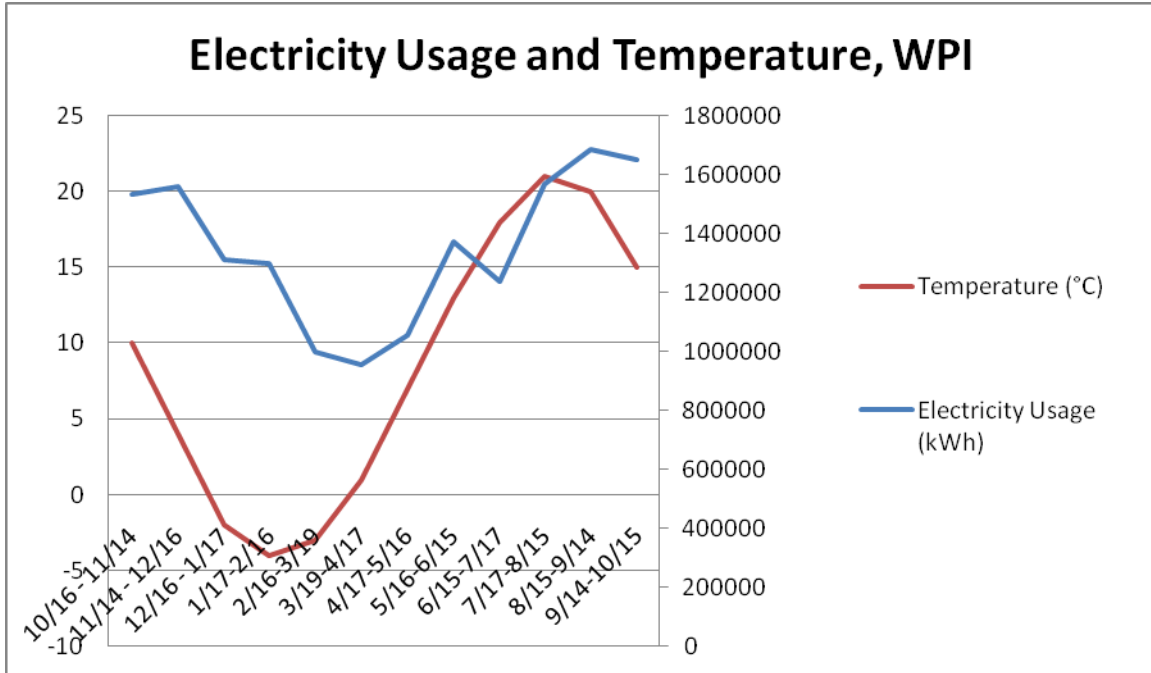


Figure 9: WPI Electricity Usage and Average Temperature

Most notably, there is a significantly larger amount of power being used in late summer and early fall (approximately July – September) followed by a gradual drop-off into the winter. While not a perfect correlation, the electricity consumption graph does seem to follow the average temperature, implying that things like air conditioning have a very large impact on the amount of electricity used on campus. Even anomalies like the dip in June usage seem to support that, since enrollment and activity on campus fall drastically during the annual summer break (normally early May through mid-August).

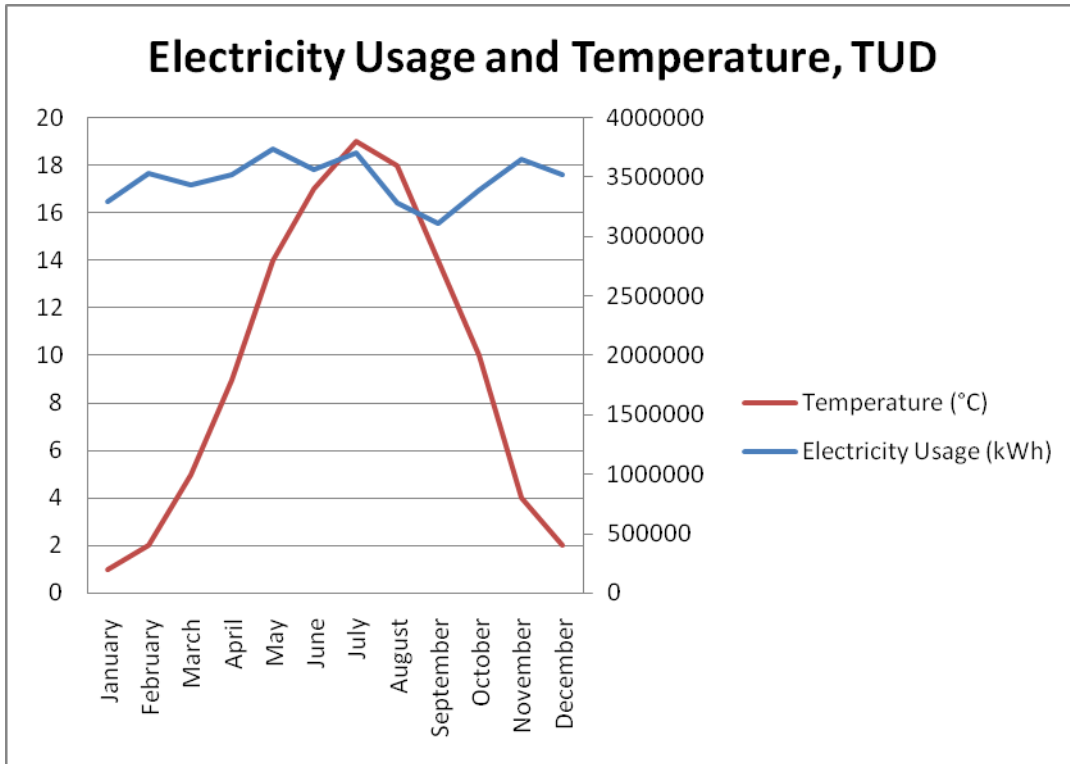


Figure 10: TUD Electricity Usage and Average Temperature

The trends at the TUD are very different from those at WPI. Here we see a slight spike in the early summer months, followed by a noticeable drop into the late summer and early fall, exactly the opposite of WPI. Most significantly, however, is the aforementioned consistency of the data. The numbers lead to a much smaller standard deviation, whatever the temperature at the time. It would seem, then, that other factors than temperature would be the driving force behind whatever variation does exist. This is consistent with comments made by Mr. Nitze, who mentioned that many TUD buildings lack any type of air conditioning, instead relying on their construction to maintain a comfortable temperature in the summer (Nitze, 2007). This is in contrast to WPI, where 13 of the 14 buildings considered make use of air conditioning systems (Tousignant, 2007).

Building Projects

Though only the WPI project is touted as a “green” building, it becomes apparent upon inspection that both projects are very environmentally aware. From the information already discussed, it’s clear that both have a focus on energy reduction and optimization. The TUD library aims to reduce its energy consumption from heating by more than four times by using technologies like heat pumps and exchangers (Technische Universität Darmstadt, 2007). WPI, on the other hand, is planning a comprehensive energy reduction (heating and electricity) of at least 20% versus base values in the area. Instead of employing newer technologies, as the TUD has done, WPI is instead focusing on more efficient fixtures within the building as well as relying on natural lighting and ventilation to alleviate power use. Like the TUD, WPI considered incorporating more environmentally friendly technology, like filtration for storm water and generation of clean energy on site. Several of these technologies exist on the LEED specification that WPI is holding its building to. However, ultimately in the analysis of the various points, these technologies were deemed too costly for the project, and dropped in favor of less expensive and efficient options (Worcester Polytechnic Institute, 2007).

CONCLUSIONS

Though difficult to quantify and state definitively, most of the data gathered supports the idea that the TUD currently surpasses WPI in both policy and practice when it comes to environmental awareness. However, this is not to say that both universities aren't doing the best they can to continue to promote environmentally friendly practices. Both universities have shown that they are at least committed to the idea of developing a sustainable infrastructure in the future; it just happens that the TUD is more advanced on the actual implementation of that idea.

Ultimately, care must be taken when assigning criticism or praise to either institution with respect to the other, since there are so many other factors at play. Since the main goal of each university is ultimately education, this has to be the governing factor in large decisions. Other factors, discussed above, include health and safety issues as well as cost. Together with the environment, all of these together compete for importance in the policies of the schools. Again however, ignoring all outside factors, it becomes apparent that the TUD is the more environmentally aware university.

RECOMMENDATIONS

Based on my experiences compiling the information on this paper and observing firsthand the operation of the TUD, there are a number of things that WPI could do to improve its environmental awareness and policies. The most notable difference that I found between the two universities was that the TUD had specific employees devoted to monitoring and tracking the university's environmental performance. Whereas with WPI the numbers for energy resources were never seen by anyone outside the office who paid them, the TUD had archives going back years describing their usage, and they were able to track it using a number of different methods. At the very least, it seems that WPI should have archives of all of this information so that it can be called upon when needed.

Additionally, it would serve WPI to implement basic conservation policies. As noted, WPI has no formal consumer goods recycling program. They do recycle heavy materials through the waste management company, but unlike at the TUD things like cans and bottles cannot be recycled on campus. Other important programs would aid in the conservation of electricity, since it is apparent that WPI falls below the standards of the TUD.

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Appendix A: Dezernat IV: Grundsätze unserer Arbeit

Original Document (Technische Universität Darmstadt, 2005):

Offen, kommunikativ, eigenverantwortlich, nachhaltig!

Grundsätze unserer Arbeit

1. Unser Selbstverständnis

Als Teil der Universitätsverwaltung verstehen wir uns als Dienstleister, die exzellente Rahmenbedingungen für Forschung und Lehre in den Fachbereichen sowie die ergänzenden Angebote der sonstigen Einrichtungen zur Verfügung stellen wollen.

2. Unsere Ziele

Übergeordnetes Ziel unserer Arbeit ist es, allen Beschäftigten, Studierenden und Gästen eine exzellente Infrastruktur entsprechend ihren Bedürfnissen zur Verfügung stellen zu können sowie den täglichen Betrieb der Universität möglichst ausfallfrei und unfallfrei sicherzustellen. Alle Aufgaben müssen unter Wahrung der gesetzlichen Auflagen und Pflichten, insbesondere hinsichtlich Arbeitssicherheit und Umweltschutz sowie im Rahmen unserer finanziellen Möglichkeiten erledigt werden. Dabei ist eine enge Zusammenarbeit bzw. Abstimmung z. B. mit der Stadt Darmstadt, dem Land Hessen und unseren Aufsichtsbehörden (Regierungspräsidien, Unfallkasse Hessen, etc.) oder auch anderen Universitäten sinnvoll und unverzichtbar.

3. Unser Leitbild

Die Erledigung unserer Aufgaben ist auf vielfältige Weise möglich. Damit unsere täglichen Entscheidungen aber nicht personenabhängig und damit in gewisser Weise beliebig sind, haben wir uns ein Leitbild gegeben, das Grundlage aller unserer Handlungen ist: Nachhaltigkeit. Das bedeutet, dass wir Lösungen bevorzugen, die unter Berücksichtigung sozialer, ökologischer und wirtschaftlicher Aspekte langfristig am günstigsten sind. Ressourcen schonen heißt, dass wir die Gesundheit der bei uns tätigen Menschen in besonderer Weise schützen und fördern, in unsere Umwelt nicht mehr als unbedingt nötig eingreifen und unsere finanziellen Mittel so sparsam und effizient wie möglich einsetzen wollen.

4. Unsere Arbeitsweise

Durch offene Kommunikation, flache Hierarchien, Projektorganisation und Teambildung über Organisationsgrenzen hinweg wollen wir die hohe Kompetenz der bei uns tätigen Menschen optimal nutzen. Wir fördern und fordern eine hohe Eigenverantwortung jedes Einzelnen, denn sie ermöglicht schnelle, unbürokratische Entscheidungen und kurze Ausführungszeiten. Durch externe Kontakte, Erfahrungsaustausche und Benchmarking-Projekte mit den verschiedensten Partnern können wir vorhandenes Wissen für uns nutzen und gleichzeitig unsere Ideen mit kompetenten Partnern zu praktikablen Lösungen weiterentwickeln.

5. Anforderungen an uns als Mitarbeiter

Loyalität zur TU Darmstadt und ihren Zielen, ein konstruktiver Umgang mit Kritik, die Bereitschaft zur Übernahme von Verantwortung und Offenheit zur Aus- und

Weiterbildung bilden die Grundlage für eine kooperative Zusammenarbeit. Eine positive Lebenseinstellung bildet die Grundlage für Spaß und Freude bei der Arbeit und beim Dienst an unseren "Kunden".

6. Unser Anspruch

Wir sind immer auf der Suche nach Verbesserungen und neuen Ideen. Wir begreifen Kritik als Chance zur Weiterentwicklung. Wir denken vorausschauend und überprüfen ständig unser eigenes Handeln und die Qualität unserer Arbeit. Unsere Lösungen sollen auch neue wissenschaftliche Erkenntnisse berücksichtigen und moderne Techniken nutzen. Wir ruhen uns nicht auf unseren Erfolgen aus, denn wir wollen besser werden, um gut zu sein.

English Translation:

Open, communicative, personally responsible, sustainable!

Principles of our Work

1. Our Mission

As part of the university administration we understand ourselves to be service providers, who want to make available excellent conditions for research and teaching in the academic departments as well as making available the other supplementary services.

2. Our Aims/Goals

A main goal of our work is to make available to all employees, students and guests an excellent infrastructure corresponding to their needs, as well as to guarantee that the daily operations of the university are as smooth and accident free as possible. All tasks must be accomplished keeping with legal requirements and obligations, in particular regarding

workplace safety and environmental protection as well as in the context of our financial availabilities. Close cooperation and/or agreement with other entities is important and indispensable, for example, with the city of Darmstadt, the State of Hessen, and our regulatory agencies (district administrators, Hessen State Workman's Compensation, etc.) and also with other universities.

3. Our Overall Approach

The completion of our tasks is possible in various ways. So that our daily decisions are however not dependent on individuals and thus in a certain way arbitrary, we have adopted an approach that constitutes the basis of all our actions: sustainability. That means that we prefer solutions that are on a long-term basis most favorable with consideration to social, ecological and economic aspects. Conserving resources means that we protect and promote the health of our employees in a special way, do not disrupt our environment any more than necessary, and use our financial means as economically and efficiently as possible.

4. Our Working Methods

By open communication, flat hierarchies, project organization and team formation across organizational borders, we aim to use the high competence of our employees optimally. We promote and demand high personal responsibility of every individual because that allows fast, non-bureaucratic decisions and short performance times. By external contacts, experience exchange and benchmarking projects with the most diverse partners we can use existing knowledge for ourselves and at the same time develop our ideas further with competent partners into practicable solutions.

5. Our Obligations as Coworkers

Loyalty to the TU Darmstadt and its goals, giving and receiving constructive criticism, readiness to assume responsibility, and openness to training and continuing education form the basis of cooperative collaboration. A positive life attitude forms the basis for fun and joy at work and in the service of our "customers".

6. Our Standards

We are always on the search for improvements and new ideas. We understand criticism as a chance for advancement. We think with regard to the future and constantly examine our own actions and the quality of our work. Our solutions also take into account new scientific advancements and use modern techniques. We do not rest on our successes because we want to become better, in order to be good.