Jenbacher IQP

The Potential Application of the Jenbacher Engine on the WPI Campus for Energy Independence

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Abstract

This report, prepared for the culmination of our Interactive Qualifying Project, evaluates the potential of using the Jenbacher Engine as a primary means of electrical production for the Worcester Polytechnic Institute Main campus.

Acknowledgements

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Bill Grudzinski

George Hagg

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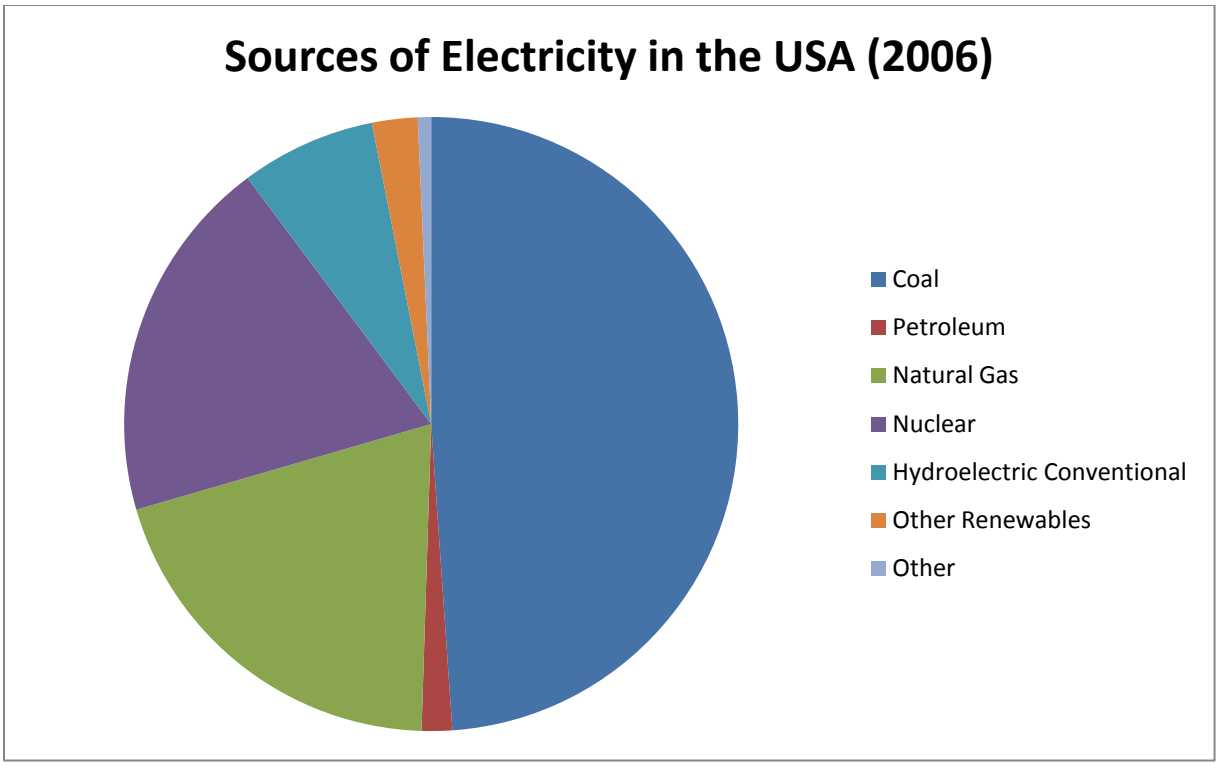
Chapter 1: Introduction

American businessman, Lee R. Raymond, said, "There is hardly an activity that a person can think about that does not intrinsically involve energy, most of which is currently provided by fossil fuels." Modern society as a whole is heavily dependent upon electrical power; there is not a single industry that does not in some way rely on a steady, reliable supply of electricity. On an individual basis, electricity is used for everyday computing, lighting homes, and refrigerating food. Many science fiction writers of the past predicted society's need for power supply would have advanced us to using such innovative ideas as solar power and nuclear fusion. However, unlike the fantastic tales of the 1950's, our modern reality is that power is produced largely in the same way that it has been for nearly 100 years.

In the United States, approximately 50% of all electricity is produced by the combustion of coal[1].

[1] US Dept. of Energy



Source: *Net Generation by Energy Source by Type of Producer*, (c. 2006), accessed 2009-04-15, Washington: U.S. Dept. of Energy, Energy Information Administration.

Coal is a fossil fuel, a high energy source that is the result of millions of years of compression and heating of organic matter below the surface of the Earth. It is because of the amount of time required to make fossil fuels that they are said to not be sustainable, meaning their rate of depletion exceeds their rate of creation. This could be compared to an energy source such as wood, which is sustainable because new trees can be grown at a rate comparable to the rate at which they are cut down and used as fuel. Since the deposits of fossil fuels on the planet are the result of millions of years of geological process, great care must be taken to insure that the world does not run out.

This project studies the use of energy sources alternative to oil-generated utilities on the WPI main campus. It was theorized that a single school might lead the world by example by

establishing a healthy, efficient power supply no further than its own campus. To demonstrate this, General Electric's Jenbacher Engine series was researched. Other attempts at utilizing the Jenbacher Engine as an alternative means of energy were also researched. Using this research, we constructed a potential application that took into account the Jenbacher Engine's overall cost, reliability, and effectiveness to produce electricity.

Chapter 2: Background

2.1: The Move to Alternative Energy

A minimal amount of electricity in the United States is produced by oil, with the majority of electrical generation resulting from coal power. With 3,971,252 million kilowatt-hours of electricity produced in the United States in 2008, approximately 1,976,174 million kilowatt-hours was produced via coal fired power plants[2]. Although coal is readily found within the United States, limiting the nation's reliance on foreign fuel sources for the production of electricity, it is not without significant drawbacks. Globally, coal is the leading fuel source in energy production; it is also the leading source of carbon dioxide emissions, a poisonous gas that in high concentrations is theorized to contribute to the phenomena of global warming. Additionally, the carbon dioxide created by the combustion of coal is considered to be "old carbon" because it has been locked away within the Earth in a solid state for eons. When it is combusted, this "old carbon" is introduced to the atmosphere which contains a significant amount of carbon dioxide from normal biological processes.

[2] US Dept. of Energy

Despite coal's abundance, its effect on the environment is overwhelming which raises the question of whether or not the price of progress is worth it. As the effects of the most commonly used fossil fuels are felt globally, alternative sources of electrical production have gained increasing popularity.

Whereas many forms of alternative energy have been developed in recent years, including wind power and solar power, the most feasible means of large scale power generation is still via the combustion of hydrocarbons. Coal fired power plants are reliable sources of power because coal burns at a very high temperature for a significant amount of time. A natural gas such as methane similarly yields a large amount of energy when burned but does not produce the same levels of carbon emissions, making it a safer fuel source.

2.2.1: What is Alternative Energy?

Alternative Energy is defined by Random House English Dictionary as "energy, as solar, wind, or nuclear energy, that can replace or supplement traditional fossil-fuel sources, as coal, oil, and natural gas". Colloquially, Alternative Energy is anything that doesn't run on coal or petroleum. Fuel sources such as natural gas, while still fossil fuels, are considered "Green" fuels because they release less carbon into the atmosphere than coal and are less toxic to work with. In terms of toxicity, coal is a known cause of pneumoconiosis[3], a debilitating lung disease caused by excessive exposure to coal dust. It is because of coal's high toxicity and high carbon emissions that the search for Alternative Energy has increased drastically in recent years.

[3] Center for Disease Control

2.3: Sustainable and Green Energy

Many terms are freely used in the discussions of energy consumption and energy resources. It has become easy for companies to claim some superior environmental vigilance without improving their practices. For that reason it is very important to clearly define the popular words like "renewable," "sustainable," and "green." While it may sound good in popular culture, the facts may be far from impressive.

Sustainable energy is an energy derived from a *renewable* resource that keeps up with its rate of use. It should come as no surprise that oil and other fossil fuels are not sustainable energy source. Wood can be a sustainable resource, because it is renewable; trees are planted and grown even as they are cut down and burnt for fuel. No matter how much wood we burn, more will still grow. However, if the rate of tree growth were to lag behind the rate of consumption, the fuel supply-while renewable- would no longer be sustainable.

"Green energy" is a term coined to describe energy sources that are non-polluting. This category includes geothermal, wind, solar, hydro, and sometimes nuclear power. The benefits of green energy include a reduction in environmental impacts of production and delivery of the energy, and a reduction in the environmental emissions from the energy. ("Buzz")

2.4: GE and the Jenbacher Engine

The Jenbacher engine made by General Electric is a gas-fueled reciprocating engine designed to operate with both conventional and unconventional gaseous fuel sources. Originally developed in the early 1970's by the then Austrian based Jenbacher Company, the Jenbacher Engine was created to meet a turbulent fuel economy head on. Operating on a wide array of fuel

sources, the Jenbacher is one of the few reciprocating engines in the industry that can be considered Green.

The Jenbacher Engine series was designed to produce electrical power through the combustion of gaseous phase sources, the most prominent of which is natural gas. Other fuels for the Jenbacher can include landfill gas, swamp gas, and biogas. (GE Energy) The fuel sources that the Jenbacher Engine series utilizes, however, are significantly less toxic to the environment. Research has concluded that the best fuel source for sustained energy output via the Jenbacher engine is natural gas, a fossil fuel that is considered to be Green due to its relative low carbon output upon combustion.

Currently, General Electric produces five different engine types. The smallest Jenbacher Engine, the Jenbacher Type 2, is an 8 cylinder gas-fueled reciprocating engine that is capable of a sustained output of 250 to 350 kW. (GE Energy) This engine model is the modern version of the same engine developed by Jenbacher in the early 1970's. Although the power output of the Type 2 engine is not substantial enough to power an entire university campus, it is certainly capable of powering a home. The Jenbacher Type 2 Engine is also innovative in that it can operate for 60,000 hours before a main overhaul is necessary.

The other four types of engines produced in the Jenbacher series have increasing power outputs as well as increasing numbers of cylinders. The staple for large scale commercial power production is the Type 6 Jenbacher Engine, which like its smaller cousins can run upwards of 60,000 hours before requiring maintenance. The Type 6 Engine has two primary versions: the 12 cylinder engine and the 16 cylinder engine. The difference in choosing which of these two models comes down mostly to understanding exactly what kind of power production is required;

producing more electricity than necessary with some way to utilize the excess energy is wasteful, whereas not being able to produce enough electricity is a major pitfall economically. The Type 6 Engine is capable of producing power on the scale of 1.8 to 3.0 MW (GE Energy), allowing for significant flexibility of energy consumption versus production. Each J616 Engine is estimated to cost $800,000, not including installation[4].

2.6: Wellesley College

Wellesley College is a women's liberal arts school in Wellesley, Massachusetts. The suburban campus is roughly 800 acres and hosts approximately 2,400 students (2,300 undergraduates) (Wellesley.edu). In 1995, the school faced the problem of reducing operational costs without touching the financial aid budget or changing admissions standards. Their solution was to reduce energy costs with a cogeneration power plant that would serve the campus electricity, steam and chilled water. (Hagg)

Four Jenbacher JMS 616 engines were installed, and then a fifth added later to cover the electricity contractually required by the town of Wellesley. The plant provides 100% of the campus' electricity needs as well as steam and chilled water. (Hagg)

2.5: Cogeneration

Cogeneration is the utilization of normally wasted heat energy produced by a power plant or industrial process. The Jenbacher Engine, like a car engine, gives off a significant amount of thermal energy as a byproduct of the combustion process. As demonstrated by the Wellesley College model, this thermal energy can be successfully captured and used for the heating and

[4] GE Energy – GE Jenbacher

chilling of water. Boasting 81 – 84% total efficiency, Wellesley College is able to produce 250 to 400 tons of chilled water daily.[5] The total efficiency of the system is calculated by combining the percentage of electricity produced by the engines with the estimated amount of equivalent thermal energy utilized by the engines versus the total energy expelled by the combustion of methane. Cogeneration is a viable option to heating and chilling water for a campus, saving Plant Services at Wellesley College an estimated $146,295 annually[6].

Cogeneration is also "Green" because it is a byproduct of another process. Conventionally, water is heated utilizing boilers that burn fuel; because the thermal energy from the Jenbacher Engines is reclaimed via hot exhaust, this intense heat can be in turned used to heat boilers without the need for fuel.

2.7: Worcester Polytechnic Institute

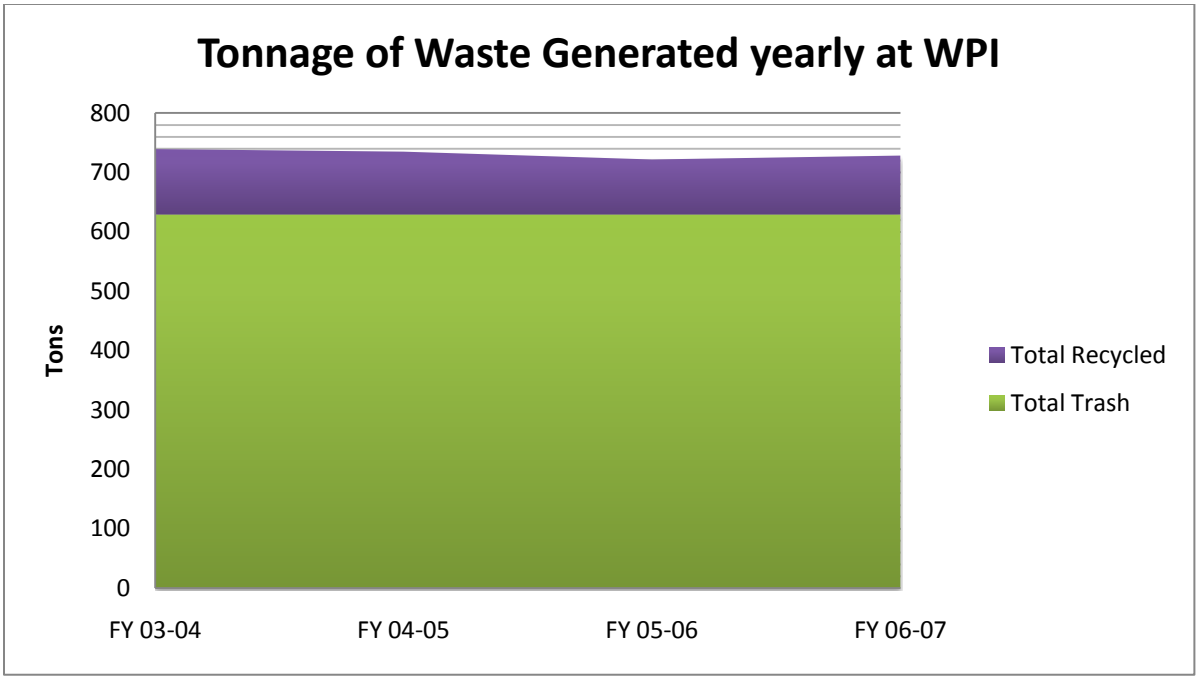
Worcester Polytechnic Institute (WPI) is a private university in Worcester, Massachusetts. The campus is 80 acres (32 ha) within an urban environment. It hosts 33 major buildings for 4,257 graduate and undergraduate students and 333 faculty members[7]. Facilities on campus include a Haas Technical Center, Laser Holography Laboratories, an IBM RS/6000 Supercomputer, and 7 residence halls. The yearly consumption of electricity at WPI since the year 2000 has been roughly 18 gig watt-hours (GW-hrs), at a cost of $2.4 million each year (Carey).

We chose WPI as the grounds for our project discussion for several reasons. Firstly, it's a closed community. It's also relatively small while providing a diverse range of facilities. WPI

[5] Wellesley College
[6] Hagg, George. Personal interview. 1 April, 2009.
[7] WPI

has proven an active interest in reducing the costs of energy consumption and improving the environment through the use of "greener" policies.

In recent years WPI has worked to embrace the attitude for clean, sustainable energy. The President's Task Force of Sustainability works to provide leadership and coordination in energy conservation and reduction in the harmful environmental impacts of operations across the campus (WPI Sustainability). Initiatives include Recyclemania, a community wide movement towards recycling waste products; a green roof above East Hall, the newest residence hall; and solar powered walkway lights. These efforts are more than hollow claims: East Hall has received a Green Building of America Award. Recyclemania has encouraged and made available recycling across the campus, and WPI now reports a yearly 80 tons of garbage that is recycled. (Carey).

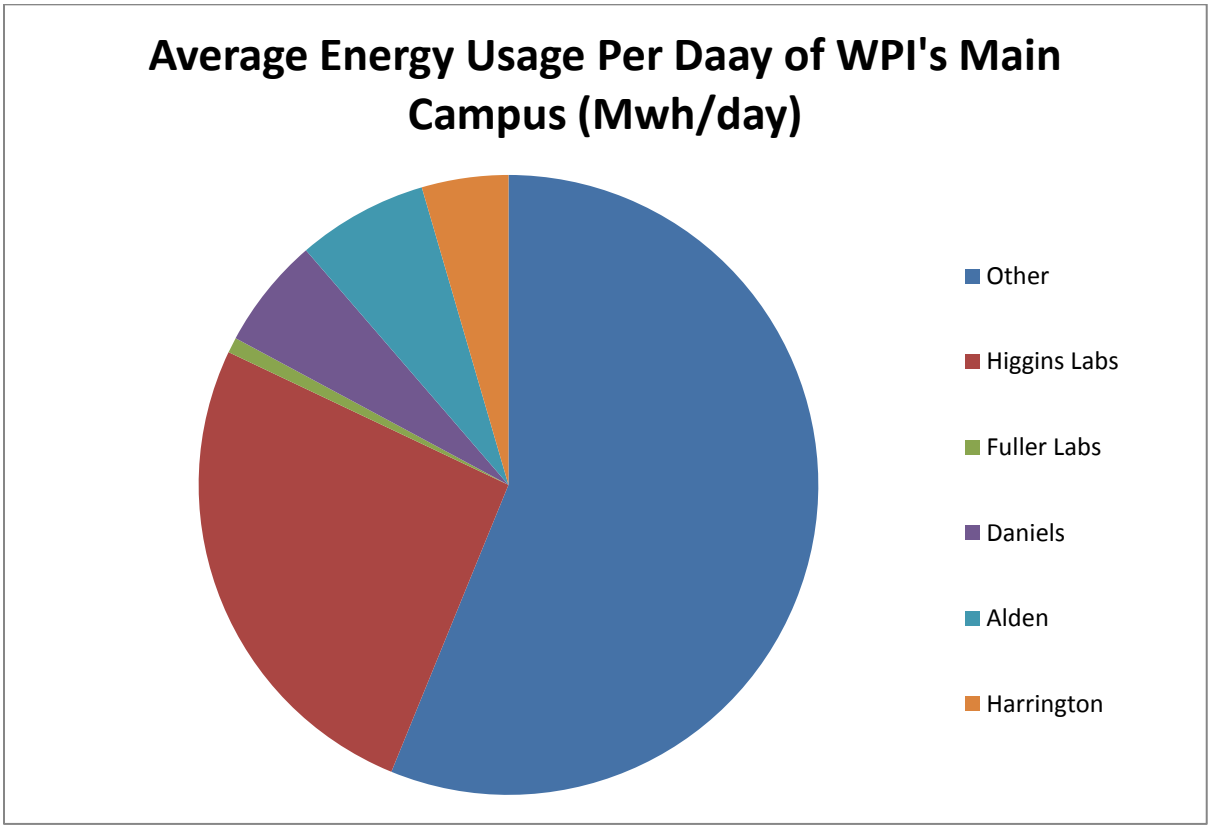


Source: *Recyclemania*, (c. 2006), accessed 2009-04-14, WPI: Sustainability SharePoint.

While providing a convenient target of study, the institute is receptive of new ideas that may further their goals for sustainability. It was natural that we chose WPI as the grounds for our discussion.

2.7.1: Energy Consumption and Distribution at WPI

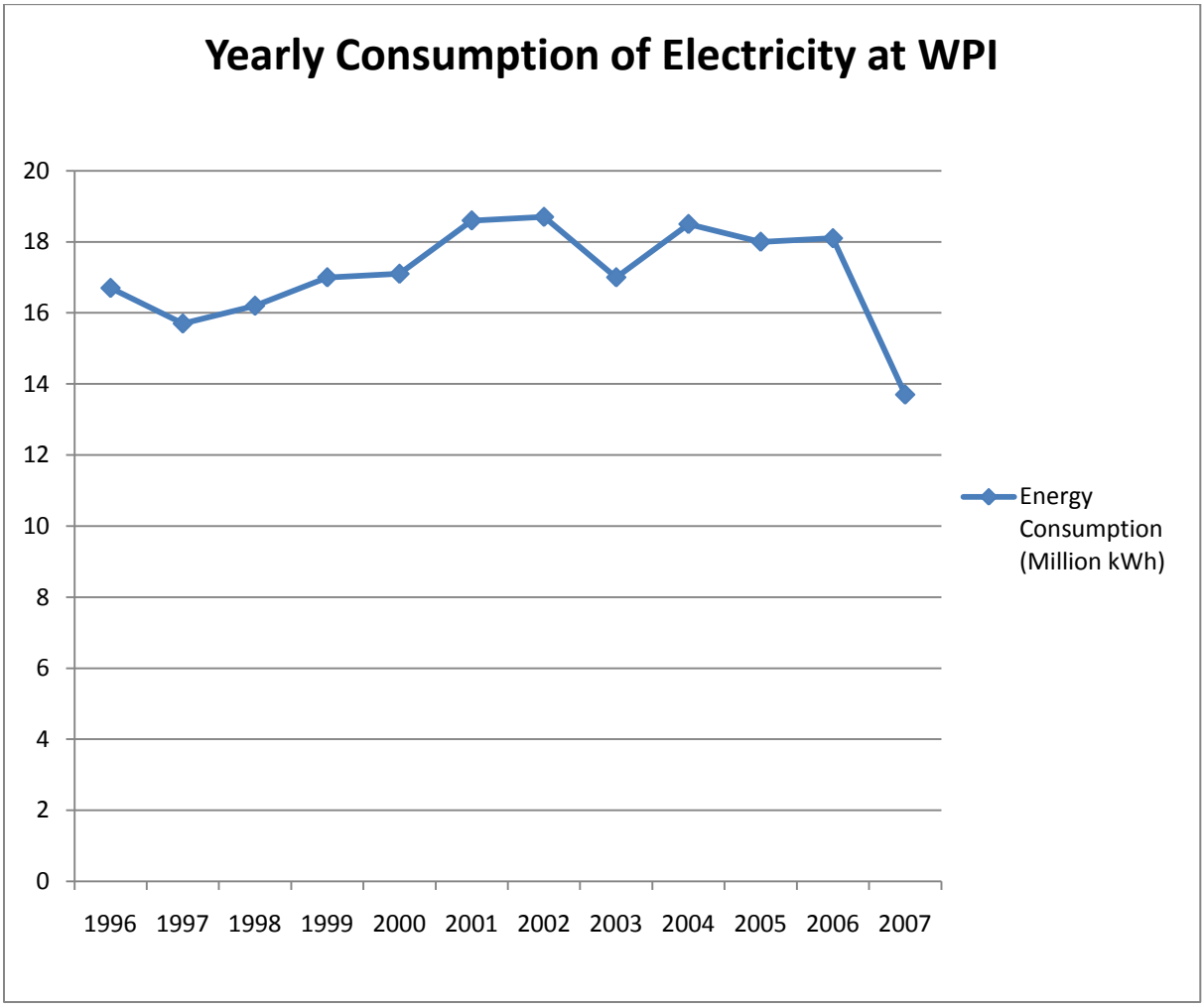
Unfortunately WPI's Plant Services does not have the ability to monitor electrical use by building. An IQP study conducted in 2007 was able to determine the following average distribution of energy over the main campus every day:



Source: O'Hara, Christopher, Maximillian Hobson-Dupont, Max Hurgin, Valerie Thierry. "WPI IQP." *Monitoring Electricity Consumption on the WPI Campus* 05 May 2007 Web.5 May 2009.

As one can see, much of the campus' energy consumption could not be accounted for. This is mainly due to faulty meters and meters placed in inaccessible places. These findings are also too old to include the newer, 'green' certified buildings on campus. It should be apparent however that the buildings on the main campus present a wide range of energy needs.

Yearly electric consumption on campus is trending downward. Since 2004 the president has been installing policies for sustainability and environmental awareness.



Source: Carey

For comparative purposes we have provided the average energy consumption per student at WPI and other major universities. The below chart was constructed by Shawn Carey. We've added Wellesley College to the list, calculating the consumption per student by dividing the campus' yearly energy consumption by student population.

College	kWh per capita per year
WPI	4,300
Middlebury College	6,642
University of Colorado	4,300
University of Canterbury	1,160

Source: Shawn Carey,

2.7.2: The WPI Power Plant

The WPI Power House was constructed in 1895. Since that time it has been renovated and its original purpose – to provide electricity to the campus- abandoned. Today it provides heat and air conditioning to the main campus, excepting the Higgins House.

Renovations took place over the course of two years, completing in 2006. 8 million dollars were spent on the project. It houses boilers with the ability to switch between natural gas and No 2 fuel oil. 85% of the steam is reclaimed and reused. (Caron).

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Chapter 3: Methodology

Our focus of this project was to provide a comprehensive study of the potential of the Jenbacher engine on the WPI campus. The ultimate result we hope to achieve is a decision on whether the Jenbacher should be pursued as an energy source to further WPI's goals for sustainability and reduction in cost of electricity. We also wish to use the WPI campus as tool to assess using the Jenbacher in the wider world. We achieved these goals through the accomplishment of these specific objectives:

1. Research the possible applications of the Jenbacher engine on campus.
2. Evaluate the potential costs and benefits.
3. Represent our findings in a comprehensive way.
4. Recommend or dissuade action regarding the proposal.

3.1: Evolution of the Project

Initially, we started this project to determine whether the Jenbacher engine was worth the reputation it was garnering in the world as the attractive, renewable "solution" to dwindling fossil reserves. ("Expanding") We researched magazine articles, websites, and news reports that almost unanimously called acclaim to the alternative fuel engine. It was being used across the world by many satisfied customers. We also researched other alternative projects that were being used –including wind power, wave power, and solar power. We researched engines produced by other companies to determine why the Jenbacher was unique.

One of the first things we noticed in our research was that many of the cases for alternative energies were impractical. Or they were only applicable in a specific region or a specific scenario. Conversely, the Jenbacher was being used in many countries, by farmers and city-based companies alike. And when it came to similar products by other companies, there

simply was not a competitor that could begin to display the flexibility and the reliability of GE's Jenbacher.

Intrigued by the support behind it, and inspired by rumors of the Jenbacher being used on a college campus not far from WPI, we asked if the Jenbacher engine could not be used to improve energy consumption costs and sustainability in our own city. This led to the main result of our project: a comprehensive study of the Jenbacher Engine's possible application on the WPI campus and informed recommendations.

3.2: Assumptions and Constants

When discussing the WPI campus, this project focuses on the main facilities –bounded by Salisbury St, Park Ave, Institute Rd, and Boynton St. These buildings were chosen because of the availability of usage rates and their similarity to facilities in colleges across the nation. The Higgins House and Garage are not included in this boundary because neither is currently designed to receive heat from the power plant. (Peyser).

We propose using a Jenbacher J616 engine model, bought new. Older models, and previously owned models could be cheaper. Furthermore a contract made with GE to further the ideal of alternative energy on the campus of a widely known engineering school may be made with certain concessions in favor for the buyer. Since the possibilities are numerous and impossible to quantify this early on, we assume the full cost of the engine is paid.

Our proposal includes a team of engineers to run and maintain the engines. Our teams are made up of 8 people working for the salary average of a power plant engineer in Worcester, MA: $88,000. (The average is as predicted by Indeed.com.)

The space for the engines will be provided by either building a power plant in Higgins's garden, or by remodeling the existing power plant. The cost of those projects is not included in our assessment of the proposal.

Chapter 4: Application on WPI

4.1: The Jenbacher Engine and Natural Gas

The proposed engine model is the Jenbacher J616, a 16 cylinder gas fueled reciprocating engine. It is also proposed the engine be fueled with natural gas, a fossil fuel that is currently considered a "green" fuel. Running on natural gas, the Jenbacher J616 is capable of serving the 1.8 to 3.0 MW power range[8]. Natural gas, unlike other alternative gaseous fuel sources, does not require on-site storage. Due to the abundance of natural gas as a conventional home heating source, a pipeline from the WPI main campus to the East coast pipeline could be used. The benefit of not having natural gas stored on the WPI campus is that the risk of tank leakage is entirely removed. Natural gas is also dangerous when stored in holding tanks because of it high volatility; removing holding tanks from the equation drastically reduces the likelihood of an explosive accident.

A school the size of Wellesley College requires 4 fully functioning Jenbacher J616 engines to meet all of the electrical needs of the campus, with a 5th engine in reserve in the event

[8] GE Energy – GE Jenbacher

one of the 4 operating engines fails. These 4 engines are capable of producing 24 million kWh (Hagg). With only 13.7 million kWh used by WPI during the 2007 academic year, a system of 4 Jenbacher Engines will supply adequate power to the campus. Additionally, it is proposed that the Jenbacher Engine facility run parallel to the existing power grid. In the event of a system failure, electrical power would be provided by the existing grid. This simple crossover would enable the campus to operate normally while the problem is repaired.

4.2: Considerations

For a practical discussion of our proposal, we considered the various effects of a cogeneration plant on the WPI campus without limiting ourselves to financial issues. The following list includes those topics we considered in no particular order.

- Noise
- Space
- Electrical interconnectivity requirements
- Diverse electric usage over the seasons and over the day
- Air quality
- Need for hot water

The initial reservations we had over introducing an energy productive power plant on campus were allayed by George Hagg's model on the Wellesley College campus. As the Assistant Director of Utilities he was also forced to confront the issues of noise and air pollution. Sound proof walls and the "green" emissions from the Jenbacher engine were enough to make those concerns negligible. While separated from the running engines by only a window, we

were able to hold a comfortable conversation, devoid of noise intrusions. Outside the plant was mute.

Electrical interconnectivity requirements are limiting on the WPI campus without further construction at an unknown cost to the school. However the main campus –excepting those buildings stated in 3.2 of this paper- is currently connected to the existing power plant.

Cogeneration is able to supply hot water to the campus, just as the plant currently does.

Having multiple engines and an alert engineering staff could make the diversity of electrical consumptions over the year –and over the day- favorable to the school's budget. Shutting down engines when they aren't needed, and starting them up when they are, is simple (Hagg). Doing so allows production costs to be minimized.

The space is prepared in the WPI power plant. Conversely, it is possible to include space for a new building in Higgins garden.

Conclusions and Recommendations

The research conducted for this Interactive Qualifying Project supports the proposal that an alternative energy fueled power plant utilizing the Jenbacher reciprocating engine is possible. In reference to the Wellesley College model, the entire renovation of the college's Utilities House cost approximately $7.5 million. In the 16 years of its operation, the cogeneration facility

has saved the school approximately $936,826 annually for a total close to $16 million in savings. (Hagg).

The recommended fuel source for a facility utilizing Jenbacher Engines is natural gas for several reasons. First of all, usage of natural gas as a fuel source will allow the WPI Power House to apply for "Green" status. Although natural gas is a fossil fuel, it is currently on the list of accepted "Green" fuel sources[9]. Additionally, the cost of natural gas is a relatively stable market. Given the rapid fluctuation of other fuel sources such as oil in the recent past, having a stable market will enable more accurate budgeting for each year. Natural gas is also a readily available fuel source that does not need to be stored on the WPI campus. This fuel source can easily be piped in from the main gas line that runs along the East Coast from its source in Louisiana. Other gaseous fuel sources would need to be stored in holding tanks on the WPI campus or close by, adding additional costs to both construction and upkeep.

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