Advanced Energy Production

PeaceHealth St. Joseph Hospital Bellingham

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ESTU 471: Campus Planning Studio

Sustainable Solutions Research Team

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1.0 Introduction

The 2010 Sustainable Solutions Research Team (SSRT) is a collaborative effort between the Office of Sustainability and the Sustainability Institute Initiative to pair students from Bellingham Technical College (BTC), Northwest Indian College (NWIC), Whatcom Community College (WCC) and Western Washington University (WWU) with partners in the Bellingham community looking to adopt sustainable practices. Business, governmental and non-profit organizations are being asked to "green up" their mission and practices by their consumers, employees and board members. Through the Sustainable Solutions Research Team, off-campus partners will benefit from student efforts, students will gain valuable skills and credit for their work, faculty will become more fully involved in their community and each institution will further develop its strategic goal of sustainability.

A grant from Puget Sound Energy Foundation makes this coalition possible. In addition to the work completed during spring 2010, the SSRT is committed to working with St. Joseph Hospital through summer quarter 2010. It is our hope that this research project will result in further work study, and the advent of an important project at St. Joseph Hospital.

1.1 Purpose

PeaceHealth St. Joseph Hospital in Bellingham Washington is proactively managing energy use for operational cost savings, improved comfort and performance, and effective stewardship of resources. Two previous research projects between the WWU Campus Sustainability Planning Studio and PeaceHealth St. Joseph Hospital during 2008 – 2009 included a waste reduction plan and a sustainable landscape plan. Scott Dorough, Resource Conservation Manager for the hospital, developed the following scope of research for the 2010 team.

1.2 Scope

"Determine the life cycle costs of a fully integrated, net metered, roof mounted photovoltaic system (PV) versus a fully integrated combined heat and power (CHP) plant of equal capacity. The CHP can be either: 1) Conventional cogeneration with engine-driven generator, or 2) natural gas-fed fuel cell with heat recovery. The cost of both systems should be captured as completely as possible, and be based on workable designs, including integration with existing electrical infrastructure."

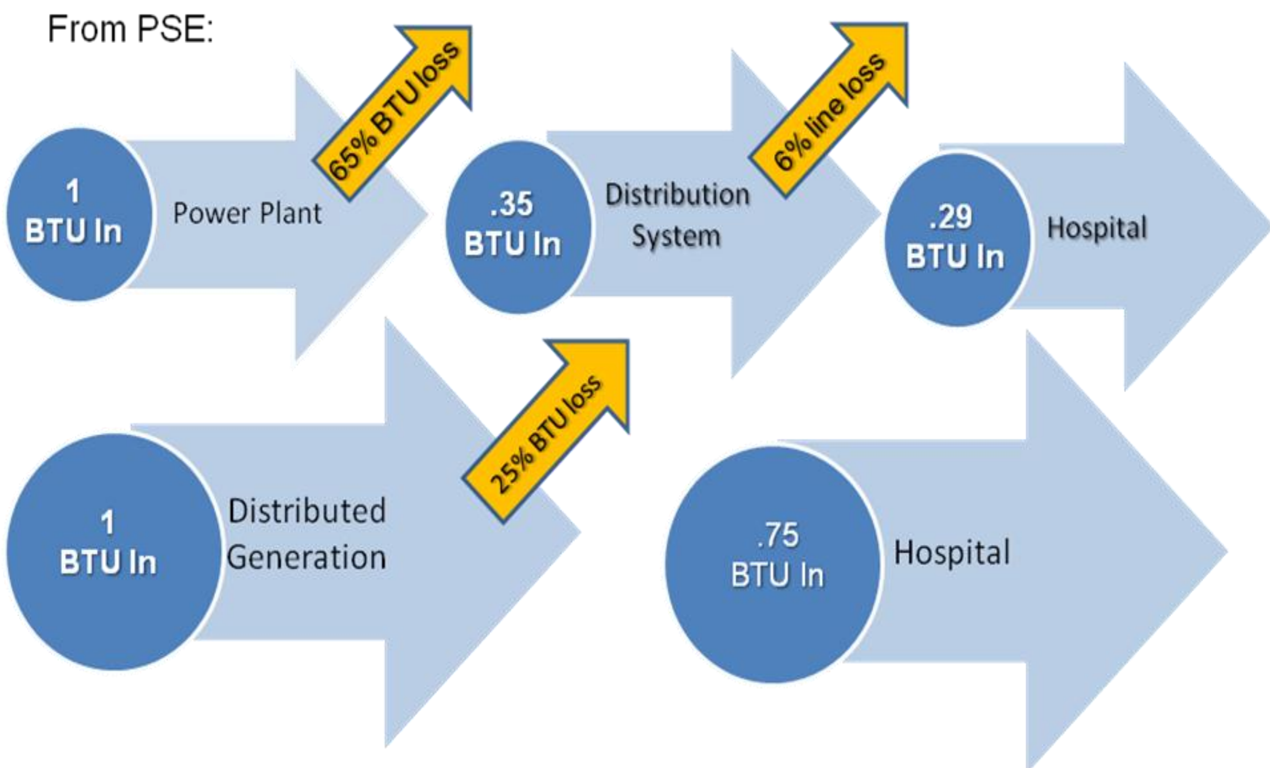
1.3 Benefit to PeaceHealth St. Joseph Hospital

Hospital facilities are among the most energy intensive buildings in the United States. Installation of stand-alone, distributed energy generation can minimize risk associated with imported petroleum price volatility. Energy costs, which represent approximately 30% of the total facility operating budget, are the most controllable cost. Energy cost reductions improve operating margins. For example, at Peace Health's operating margin of 3.5%, annual energy savings of $500,000 are equivalent to more than $14M of new gross revenue.

2.0 Methodology

Distributed generation (DG) refers to power generation at the point of consumption. Generating power on-site, rather than centrally, eliminates the cost, complexity, interdependencies, and inefficiencies associated with transmission and distribution. Like distributed computing (i.e. the PC) and distributed telephony (i.e. the mobile phone), distributed generation shifts control to the consumer.

Standard practice and technologies used in this report meet common guidelines for research. In the course of conducting energy studies, the installation of generation will most certainly require the purchase of new equipment. The benefits obtained in the form of reduced energy charges must be sufficient to offset the required investment. This report is designed to inform, estimate, illuminate and illustrate. No particular system is shown special favor. This report is an "early alpha" version that will be refined per St. Joseph directives.

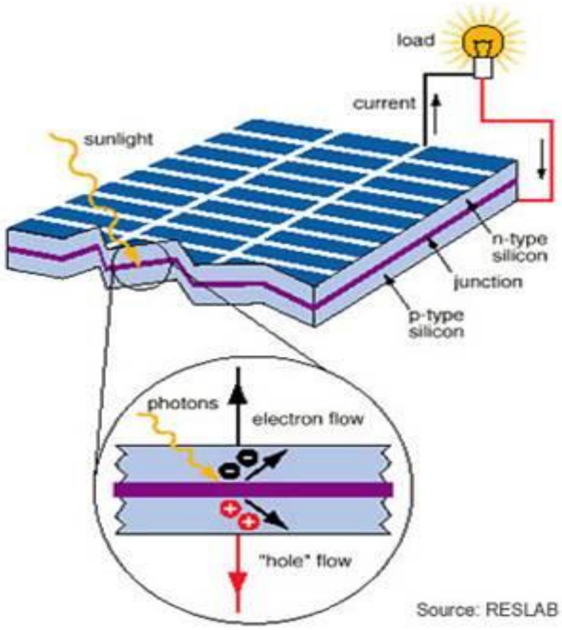


2.1 System Assumptions

Photovoltaic - The baseline system is the photovoltaic (PV) system. The generation capacity of the PV system governs the size of the other systems by token of comparison. The assumed capacity of the PV system is 147 kW. See Research and Analysis (4.0) for details.

PV provides:

- A passive system with no moving parts
- Low maintenance
- No fuel costs to run the system



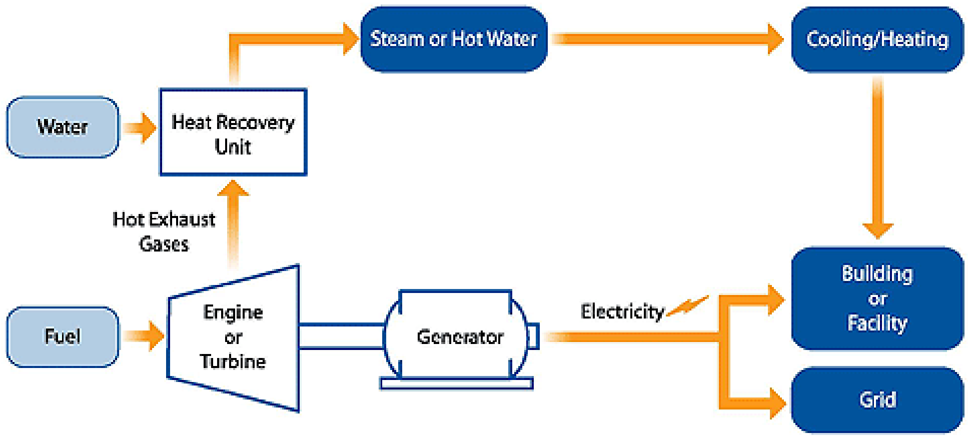
http://wiki.uiowa.edu/display/greenergy/Photovoltaic+Cells+and+Systems

Combined Heat and Power - Combined heat and power is the simultaneous production of electricity and heat from a single fuel source, such as: natural gas, biomass, biogas, coal, waste heat, or oil. CHP is not a single technology, but an integrated energy system that can be modified depending upon the needs of the energy end user.

CHP provides:

- Onsite generation of electrical and/or mechanical power
- Waste-heat recovery for heating, cooling, dehumidification, or process applications
- Seamless system integration for a variety of technologies, thermal applications, and fuel types into existing building infrastructure

Gas Turbine or Engine with Heat Recovery Unit:



Natural gas-fed fuel cell – There are five types of fuel cells. These are: 1) phosphoric acid (PAFC), 2) proton exchange membrane (PEMFC), 3) molten carbonate (MCFC), 4) solid oxide (SOFC), and 5) alkaline (AFC). The electrolyte and operating temperatures distinguish each type. Operating temperatures range from near ambient to 1,800°F, and electrical generating efficiencies range from 30 to over 50 percent HHV (High Heating Value – HHV includes the heat of condensation of the water vapor in the products).

Fuel cells use an electrochemical or battery-like process to convert the chemical energy of hydrogen into water and electricity. They use hydrogen as their fuel, which is derived from hydrocarbon fuel such as natural gas. Fuel cell systems are composed of three primary subsystems:

- The fuel cell stack that generates direct current electricity
- The fuel processor that converts the natural gas into a hydrogen-rich feed stream
- The power conditioner that processes the electric energy into alternating current or regulated direct current

Recently, 300 and 1,200 kW MCFC fuel cells were installed in Combined Heat and Power applications. Fuel cells can achieve overall efficiencies in the 65 to 85 percent range. Waste heat can be used primarily for domestic hot water applications and space heating.

Fuel Cell Energy manufactures a 300 kW system with heat recovery:

FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

DFC300

Key Features
- High Efficiency
- Low Environmental Impact
- Fuel Flexibility
- High Reliability
- Quiet Operation

Advantages
The DFC®300™ stationary fuel cell power plant from FuelCell Energy provides high-quality, Ultra-Clean electrical power with 47% efficiency in a small footprint. Designed for commercial and industrial applications, the system offers 24/7 operation, easy transport, quiet and reliable operation, and easy site planning and regulatory approval.

Performance

Power Output	
Power @ Plant Rating	300 kW
Standard Output AC Voltage	480 V
Standard Frequency	60 Hz
Optional Output AC Voltages	460, 440, 420, 400, 380 V
Optional Output Frequency	50 Hz
Efficiency	
LHV	47 +/- 2 %
Available Heat	
Exhaust Temperature	700 +/- 50 °F
Exhaust Flow	3,950 lb/h
Allowable Backpressure	5 iwc
Heat Energy Available for Recovery (to 250°F)	480,000 Btu/h
(to 120°F)	808,000 Btu/h
Fuel Consumption	
Natural gas (at 930 Btu/ft³)	39 scfm
Heat rate, LHV	7,260 Btu/kWh
Water Consumption	
Average	0.9 gpm
Peak during WTS backflush	10 gpm
Water Discharge	
Average	0.45 gpm
Peak during WTS backflush	10 gpm
Pollutant Emissions	
NOx	0.01 lb/MWh
SOx	0.0001 lb/MWh
PM10	0.00002 lb/MWh
Greenhouse Gas Emissions	
CO_2	980 lb/MWh
CO_2 (with waste heat recovery)	520-680 lb/MWh

2.2 Project Development

In April 2010, Scott Dorough, Resource Conservation Manager for PeaceHealth St. Joseph Hospital in Bellingham, presented a Scope of Work to the SSRT. The three systems were researched by the team (Photovoltaic, Combined Heat and Power, Fuel Cell Combined Heat and Power). Dana Brandt, owner and principal of Ecotech Energy Systems, provided extensive information with regard to photovoltaic. Numerous phone calls with Scott Dorough took place throughout spring quarter of 2010.

3.0 Case Studies

3.1 Case Study PV

Loma Linda VA Hospital (California)

On January 24, 2007, President George W. Bush signed an executive order for government agencies to improve their energy efficiency and help reduce greenhouse gas emissions by 3% per year or by 30% by 2015. In order to comply with the executive order, the Department of Veterans Affairs created a department-wide energy plan. After surveying which facilities qualified for photovoltaic systems (PV), they found the Loma Linda Hospital in California as a top applicant. SunWize Power Systems took on the challenging project to install solar panels on the hospital's roof. They completed the project in

September of 2008 and successfully installed a 309-kW DC solar electric system on top of the roof. The cost for this system was $1.85 million and the payback for this system is 31 years. It may seem expensive, but it does not cost anything to run the system and it is virtually maintenance-free.

Loma Linda Hospital, CA

3.2 Case Study CHP

In an effort to reduce operating costs, Resurrection Medical Center (RMC), Chicago installed a Combined Heat and Power plant. The plant generates on-site electrical power and recovers the generated heat to supply heating, hot water and cooling, through an absorption chiller, to the hospital. The system saved the hospital over $400,000 annually in electric costs.

The $2.7 million project was financed in-house; RMC is a not-for-profit organization that finances all purchases internally. They installed (2) 725 kW natural gas engine generators. The estimated cost per kilowatt is $1,200 per. The estimated simple pay-back was 10 years; the actual pay-back was 8 years.

3.3 Case Study Natural Gas-Fed Fuel Cell with CHP

St. Francis Hospital and Medical Center CHP Project

One of the largest hospitals in Connecticut, the St. Francis Hospital and Medical Center affiliated with Mount Sinai Hospital in 1990. In 2003, St. Francis installed a CHP system centered on a fuel cell. The CHP system produces up to 200 kW of electricity and preheats boiler feed water with heat recovered from the fuel cell. By preheating the boiler feed water, St. Francis reduces the amount of fuel consumed by the boiler and reduces operating costs.

With an estimated operating efficiency of nearly 57%, St. Francis' CHP system requires an estimated 25% less fuel than typical onsite thermal generation and purchased electricity. Based on this comparison, the CHP system reduces CO_2 emissions by an estimated 686 tons per year.

In recognition of the outstanding pollution reduction and energy efficiency quality of this project, Environmental Protection Agency (EPA) and Department of Energy (DOE) presented St. Francis Hospital and Medical Center with the 2005 ENERGY STAR CHP Award.

http://www1.eere.energy.gov/industry/distributedenergy/pdfs/past_award_winners.pdf

4.0 Research and Analysis

4.1 Photovoltaic (PV) System Research

The life of a typical solar panel is between 25 to 30 years. Installing PV generates no pollution, has very few moving parts, and is low maintenance. Installation costs are approximately $6,000 per kW. Materials used to make solar panels:

- Silicon (Most popular material used)
- Polycrystalline Thin Films (Reducing material required in solar cells)
- Copper Indium Diselenide (CIS) (improved efficiency of PV device, has high absorptivity, 99% of the light illuminated on CIS will be consumed in the first micrometer of the material).
- Cadmium Telluride (high absorptivity)
- Gallium Arsenide (help absorb sunlight, resistant to damage from radiation)

The East Tower of St. Joseph Hospital is 40,000 square feet. An estimate of 13,200 square feet or about one-third was used to produce a yield of approximately 147 kW. Again, this size was the baseline for our group's research. Even though this system would help power a very small percentage of the hospital's electricity, it could develop into a more extensive project in the future (i.e., solar panels on another tower or a solar panel wall).

4.2 Combined Heat and Power (CHP) Research

CHP technologies are conventional power generation systems with the means to make use of energy remaining in exhaust gases, cooling systems, and other energy waste streams. Combined Heat and Power operation is a simple (as opposed to "combined") cycle gas turbine with a heat recovery heat exchanger. The heat exchanger recovers the heat in turbine exhaust and converts it into useful thermal energy. This is usually in the form of steam and hot water and a combined cycle operation. In this system, high-pressure steam is generated from recovered exhaust heat and used to create additional power using a steam turbine. Some combined cycles extract steam at an intermediate pressure for use in industrial processes and are combined cycle CHP systems.

Some of the features that make CHP popular are:

- Distributed generation is anticipated to provide fewer sags and surges. Conversion from primary power to grid backup is measured in "cycles" rather than "seconds".
- More Back up Power - Both Grid back-ups supply 100% of the Hospital's needs; not just Life Safety requirements: imagine no chillers or HVAC in August.
- More Reliable Back-up Power - Probability of failure of the traditional hospital "grid plus back-up " is 67% (Primen Perspective's RX for Health Care Power Failures DE-PP- 24, 11/2003 (epa.gov))

- "Island Power" - In the event of a grid failure due to natural, technical or terrorist causes, this strategic community asset will remain in operation when needed it most.
- Reliable Normal Power – When a hospital converts to fully digital medical records, RFID/ Bar Code Scan drug delivery, Computerized Physician Order Entry etc, *health care delivery will stop if the lights go out* (epa.gov)

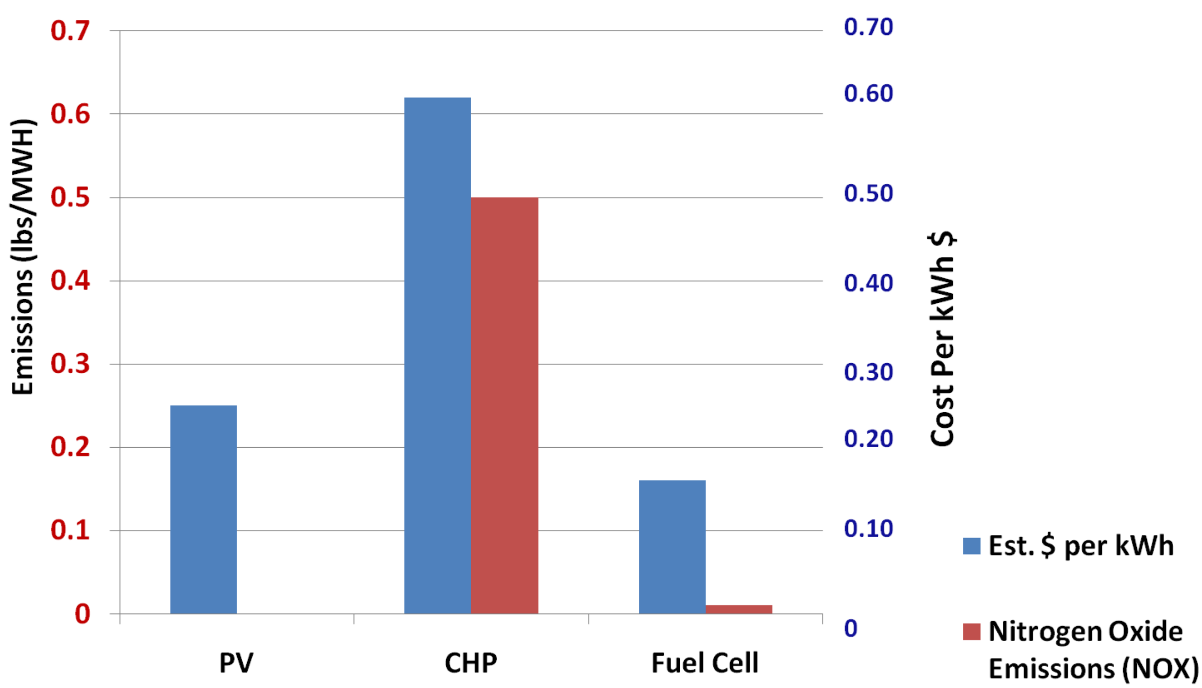
4.3 Natural Gas Fed Fuel Cell Research

Fuel cell systems employ an entirely different approach to the production of electricity. Fuel cells are similar to batteries in that both produce a direct current (DC) through an electrochemical process without direct combustion of a fuel source. However, whereas a battery delivers power from a finite amount of stored energy, fuel cells can operate indefinitely provided the availability of a continuous fuel source. Two electrodes, (a cathode and anode) pass charged ions in an electrolyte to generate electricity and heat. A catalyst enhances the process.

Fuel cells offer the potential for clean, quiet, and efficient power generation. Because the fuel is not combusted, but instead reacts electrochemically, there is virtually not air pollution associated with its use. Fuel cells have been under development for over 35 years as the power source of the future. There are now systems available for commercial use.

5.0 Conclusion

5.1 Costs and Emissions



This graph illustrates the cost per kilowatt hour and the nitrogen oxide emissions of the three systems. The system costs per kilowatt hour can be found on the right side of the graph. The emissions of Nitrogen Oxide for each System can be found on the left. Each system weighs in differently.

Our project purpose is not to recommend a certain system, but to compare these systems to each other. Affordability can outweigh emissions, and operating cost can be more important than fuel cost.

The project requires further study, which will take place during summer 2010.

5.2 Systems Summary

System	Cost per kWh	Installed Cost per kW	Operating Cost per kWh	Generation Capacity on site	Electrical Efficiency	Thermal Utilization	Natural Gas Fuel Cost	Nitrogen Oxide Emissions
PV	$0.25	$6,000	$0	147 kW	100%	0%	$0	No emissions
CHP	$0.62	$1,200	$0.09	150 kW	32%	95%	$5.30 per MMBtu	0.50 lbs/ MW hr.
Fuel Cell	$0.16	$7,000	$0.06	200 kW	47%	87%	$5.30 per MMBtu	0.10 lbs/MW hr.

This table contains some of the important factors used in our comparison. It is a snapshot of each system, and a brief summary of all three.

6.0 Future Works

During Summer Quarter 2010, we will provide more in-depth research for St. Joseph Hospital energy production. The research SSRT provides will be based on the direction of St. Joseph Hospital staff. We will research all systems more thoroughly, or focus on one system, or a blend of systems. The focus will be based on what direction St. Joseph Hospital provides to the team.

7.0 References

Photovoltaic Systems:

Email from Dana Bryant:

-*Why 25 year warranty and not more?*
- It's a business decision and a really good warranty for a business. He said there really isn't anything else out there for businesses like this that has a long warranty.

-*Life cycle costs*
- The install cost is about $6 per Watt.
- No maintenance cost (we knew that) and only investment cost. PV panels are selling for about $3 per Watt.
- He gave me the example of installing a 200 Watt system. On the day the PV panels are bought, it is guaranteed to produce 200 W of electricity. After 10 years, the panels should be producing no less than 80 W. Between 10-25 years, they should be producing no less than 40 W. This ensures a company that they will be getting some power out of the panels for up to 25 years.

-*A few important pts to make in our presentation*
- Stress no maintenance again to our stakeholders
- Good PR
- All fixed costs for the system (no surprises)
- The entire life cycle cost is calculated ahead of time, so businesses have a good estimate on how much they will be paying.

http://www.sunwize.com/government/VAhospitals.php

http://www.pe.com/localnews/healthcare/stories/PE_News_Local_N_solar15.48d7ce2.html

http://www1.eere.energy.gov/solar/solar_cell_structures.html (DOE)

http://www.azooptics.com/details.asp?ArticleID=147

CHP:

Northeast CHP Application Center
www.northeastchp.org/nac/CHP/basics.htm
Smith_College.php
www.rentechboilers.com/casestudies/
Search Bar information: Case Studies 500 kW Natural Gas CHP System
www.epa.gov/chp/documents/meeting_10029_mardiat_heidt.pdf

Fuel Cell:

http://www.epa.gov/chp/documents/wbnr112008_schwass.pdf

Emerging Technologies and Research, Commercial – Micro CHP Using Fuel Cells and Microturbines, ACEEE 2004

Technology Characterization: Fuel Cells, EPA Combined Heat and Power Partnership Program, December 2008

Fuel Cell Energy, Inc., www.fuelcellenergy.com

General:

Implementing Strategic Energy Management Plan for Health Care, PeaceHealth Facilities, May 2008 (PDF).

Energy Management Handbook, Wayne Turner, 1993.

Contacts:

Dorough, Scott (PeaceHealth St. Joseph Hospital, Resource Conservation Manager). Numerous conversations and meetings held during April and May 2010.

Brandt, Dana (Principal, Ecotech). Numerous conversations and meetings held during April and May 2010.