Comparison of Electricity and Natural Gas Use of Five Garment Care Technologies

ET 05.01 Final Report

Prepared by:
Peter Sinsheimer
Pollution Prevention Center
Urban and Environmental Policy Institute
Occidental College

Prepared for:

Design & Engineering Services
Customer Service Business Unit
Southern California Edison Company

Emerging Technologies Program
Southern California Gas Company
San Diego Gas & Electric Company

December 10, 2008 (Revised February 19, 2009)

SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL® Company

Southern California Gas Company
A Sempra Energy utility®

SDGE
A Sempra Energy utility®

Acknowledgements

Southern California Edison's (SCE) Design & Engineering Services (D&ES) group and Sempra Utilities/Southern California Gas Company (SoCalGas) and San Diego Gas & Electric (SDG&E) are responsible for this project.

This project was developed as part of SCE's Emerging Technologies program under internal project number ET 05.01. D&ES project manager Paul M. Williams, P.E. conducted this technology evaluation with overall guidance and management from Henry Lau, Ph.D., P.E. For more information on this project, contact *paul.williams*@sce.com.

The SoCalGas project manager was Ed Becker. He can be contacted via email at *EBecker@semprautilities.com*. The SDG&E project manager was Abdullah Y. Ahmed. He can be contacted at *aahmed1@semprautilities.com*.

Technical analysis and reporting was conducted by Peter Sinsheimer, Director of the Pollution Prevention Center (PPC), Urban and Environmental Policy Institute at Occidental College. He can be contacted at (323) 259-1420.

Additional support for this project was provided by Pacific Gas & Electric (PG&E), Los Angeles Department of Water & Power (LADWP), South Coast Air Quality Management District (SCAQMD), the Bay Area Air Quality Management District (BAAQMD), California Air Resources Board (ARB), and the United States Environmental Protection Agency (USEPA).

Specific acknowledgement goes to Peter Sinsheimer at the Pollution Prevention Center (PPC), Urban and Environmental Policy Institute at Occidental College for proposing and conducting the project, and to Cyrus Grout, Angela Namkoong, and Elyse Leon-Reyes at PPC for assisting in project implementation. Assistance from Edward Becker and Jorge Gutierrez at the Southern California Gas Company is acknowledged in the development of methods and test procedures, from Abdullah Y. Ahmed at SDG&E for coordinating research in San Diego, and Robert Davis at PG&E for coordinating research in the San Francisco Bay Area.

Disclaimer

ABBREVIATIONS AND ACRONYMS

BTU	British Thermal Unit
CA	Carbon Adsorber
CO_2	Carbon Dioxide Solvent
D-5	Decamethylepentacycloosiloxane
EPA	U.S. Environmental Protection Agency
FTC	Federal Trade Commission
HCF	Hundred Cubic Feet
HHV	High Heating Value
kW	Kilowatt
kWh	Kilowatt-Hour
LADWP	Los Angeles Department of Water and Power
PCE	Perchloroethylene Solvent
PET	Petroleum or Hydrocarbon Solvent
PG&E	Pacific Gas and Electric
PPC	Pollution Prevention Center
PPM	Parts per Million
SoCalGas	Southern California Gas Company
PSI	Pounds per Square Inch
PWC	Professional Wet Cleaning System
RC	Refrigerator Condenser
SCAQMD	South Coast Air Quality Management District
SDG&E	San Diego Gas and Electric
SIL	Silicone Solvent
Therm	100,000 BTU
VOC	Volatile Organic Compound

CONTENTS

FIGURES

TABLES

EXECUTIVE SUMMARY

This study was designed to evaluate the electricity and natural gas use of five professional garment cleaning technologies: professional wet cleaning (PWC), perchloroethylene dry cleaning, petroleum dry cleaning, silicone dry cleaning, and carbon dioxide dry cleaning.

In the next few years many dry cleaners will have to make a purchase decision for a new garment cleaning system that will last for 15 years. The information presented in this report will help electric and natural gas utilities identify which garment cleaning technology is the most energy efficient. The information will also help governing bodies in future regulations and cleaners to make purchase decisions.

This project was selected because for more than fifty years, the vast majority of the 30,000-plus dry cleaners in the United States have relied on perchloroethylene (PCE) as the solvent used to clean clothes as part of the dry cleaning process. In California, there are currently over 5,000 dry cleaners in operation. In recent years, a wide array of scientific studies and federal, state, and local regulatory actions have focused on the environmental and health risks associated with the use of PCE.

In the 1980s, the United States Environmental Protection Agency, as well as state and regional agencies, began establishing rules to regulate PCE. Solid waste contaminated with PCE must be disposed of as hazardous waste. Discharge of water contaminated with PCE is highly regulated. Soil and groundwater contaminated with PCE are subject to federal superfund designation and clean-up requirements. There are currently twelve states that have created their own superfund program to specifically clean up groundwater and soil contamination from PCE dry cleaning and these programs require dry cleaners to pay annual fees, a solvent tax, and/or a percent of gross receipts. Ten of these state programs also impose fees on other non-PCE solvent used in cleaning garments.

As a consequence of increased regulation of PCE dry cleaning, dry clean machines have become equipped with increasingly complex pollution control devices to capture and reuse solvent vapors and liquid. However, control devices require the consumption of additional electricity and natural gas to operate effectively.

In response to increasingly stringent regulations, a number of alternatives to PCE dry cleaning have emerged. These technologies present the opportunity to reduce environmental risks while maintaining garment cleaning performance standards and financial viability.

The evaluation was conducted at 21 professional garment cleaning facilities, five of which were tested both when they operated with PCE dry cleaning technology and after they switched to professional wet cleaning. A standardized test procedure was developed to compare electricity and natural gas use between different technologies used at different cleaning plants based on kWh/100 lbs and Therms/100 lbs of garments cleaned.

Analysis of the five facilities that switched from PCE dry cleaning to PWC using the standardized test showed consistently lower electricity and natural gas consumption for PWC. Since the only thing to change at these facilities was the cleaning equipment, these cases were able to eliminate the non-process factors that tend to vary from facility to facility including the efficiency of the steam delivery system, the efficiency of air compression system, skill of the pressing staff, and the differences in the size and age of ancillary equipment.

The energy savings is determined by how professional wet cleaning machines deals with solvents at the end of the cleaning process. All non-aqueous cleaning processes have energy-intensive solvent-recovery systems to capture and clean solvent used during cleaning and to remove impurities from solvent during distillation. Like domestic and commercial laundry, professional wet cleaning does not require solvent-recovery and distillation systems. After wash cycles are completed, water, along with cleaning agents and contaminants, are drained directly to the sewer. Garments are then transferred to a dryer that evaporates water vapor directly to the atmosphere.

From the testing results, a projected annual electricity and natural gas savings associated with professional wet cleaning as well as projected savings over the fifteen year life of the equipment was developed.

ELECTRICITY SAVINGS PER CLEANER ASSOCIATED WITH SWITCH TO PROFESSIONAL WET CLEANING

Technology	Electricity Use[1] (kWh/100 lb)	Savings by switching to PWC (kWh/100 lb)	Average Annual Savings Per Cleaner[2] (kWh)	Savings Over 15- Year Life (kWh)
Professional Wet Cleaning	9.3			
Perchloroethylene	26.6	17.3	8,996	134,940
Petroleum	35.5	26.2	13,624	204,360
Silicone	54.2	44.9	23,348	350,220
Carbon Dioxide	30.9	21.6	11,232	168,480

NATURAL GAS SAVINGS WITH SWITCH TO PROFESSIONAL WET CLEANING

TECHNOLOGY	NATURAL GAS USE[3] (THERMS/ 100 LB)	AVERAGE REDUCTION (THERMS/ 100 LB)	AVERAGE ANNUAL SAVINGS PER CLEANER[4] (THERMS)	SAVINGS OVER 15-YEAR LIFE (THERMS)
Professional Wet Cleaning	9.0			
Perchloroethylene	12.0	3.0	1560	23,400
Petroleum	13.1	4.1	2,132	31,980
Silicone	13.4	4.4	2,288	34,320

Professional wet cleaning has the lowest electrical demand. Most cleaners start their cleaning operation early in the morning and complete by noon. Very few cleaners in the test operated the cleaning equipment during the 3 PM to 5 PM weekday time period.

MEDIAN 15 MINUTE PEAK DEMAND FOR FIVE LEADING GARMENT CARE TECHNOLOGIES

TECHNOLOGY	15 MINUTE ELECTRICITY DEMAND (KW)	SAVINGS BY SWITCHING TO PWC (KW)	SAVINGS BY SWITCHING TO PWC %
Professional Wet Cleaning	4.9		
Perchloroethylene	12.9	8.0	62%
Petroleum	10.6	5.7	54%
Silicone	19.3	14.4	75%
Carbon Dioxide	12.3	7.4	60%

While professional wet cleaning has been proven as a viable substitute for dry cleaning, there are a number of significant barriers to its diffusion. These include:

- Cleaners lack of familiarity with professional wet cleaning. Most cleaners are not aware that professional wet cleaning can be used as a substitute for traditional dry cleaning. Of the cleaners that have installed professional wet cleaning equipment, the majority visited at least one cleaner using professional wet cleaning equipment before installing their equipment.
- Existing infrastructure favors petroleum and silicone dry cleaning. Most equipment distributors who previously sold PCE dry cleaning equipment switched to selling petroleum and silicone dry cleaning equipment. While some of these distributors also sell wet cleaning equipment, they make more money selling the more expensive dry cleaning equipment. In addition, while professional wet cleaning requires specialized training, cleaners perceived that petroleum and silicone dry cleaning do not require training, making it easier to pitch the sale of this equipment.
- "Dry clean" care label. Many cleaners fear professional wet cleaning garments that are labeled "dry clean" or "dry clean only." Cleaners believe that if they clean in a method that is different from what is stated on the care label, then they are breaking the law. While it is not against the law to professionally wet clean a garment labeled "dry clean only", the fear that it is, serves as a barrier to the acceptance of professional wet cleaning processing. The Federal Trade Commission (FTC), which regulates garment care labeling, has considered developing a "professional wet clean" care label but decided to wait, in part, because of the lack of prevalence of professional wet cleaners.
- Lack of a tipping point – The total prevalence of professional wet cleaning in California is 3% which includes both mixed and dedicated facilities. The number of dedicated professional wet cleaners in California is approximately 90 cleaners, or 1.6%. Research on technology diffusion suggests that a technology must gain a critical percentage of the market for its diffusion to increase rapidly.

Between 2003 and 2006, of the 5,500 cleaners in California, the percentage switching to petroleum or silicone dry cleaning increased from 10% to 23.6%, while professional wet cleaning increased from 2.7% to 3.5% in the same period. This is a rapid diffusion of petroleum and silicone dry cleaning machines compared to professional wet cleaning new installations.

To encourage customers a switch to energy efficiency technologies, utilities may need to consider developing a rebate program for professional wet cleaning. A rebate could be based on the 15 year energy savings associated with professional wet cleaning compared to the traditional PCE dry cleaning technology or the more energy intensive petroleum and silicone systems.

MACHINE AND INSTALLATION COST COMPARISON

TECHNOLOGY	SIZE	MACHINE / SYSTEM COST	INSTALLATION COST	TOTAL COST	INCREMENTAL COST
Perchloroethylene	45 lb	$50,000	$3,800	$53,800	
Petroleum	50 lb	$68,000	$4,300	$71,800	+$18,500
Silicone	50 lb	$68,000	$4,300	$72,300	+$18,500
Professional Wet Cleaning	50 lb	$51,000	$3,800	$54,800	+$1,000
CO2	60 lb	$143,000	$48,800	$191,800	+$138,000

Finally, financial incentives may overcome a number of the identified barriers by lowering the capital equipment cost, and moving the percentage of cleaners selecting PWC closer to the critical tipping point. As more cleaners switch to professional wet cleaning, other dry cleaners will become more aware and more comfortable with the technology. The greater the prevalence of professional wet cleaning, the more likely equipment distributors will feel comfortable in selling this equipment. As the prevalence of professional wet cleaning grows, it is more likely that the Federal Trade Commission will move forward with developing a “professional wet cleaning” care label.

INTRODUCTION

BACKGROUND

For more than fifty years, the vast majority of the 30,000-plus dry cleaners in the United States have relied on perchloroethylene (PCE) as the solvent used to clean clothes as part of the dry cleaning process. In California, there are currently over 5,000 dry cleaners in operation. In recent years, a wide array of scientific studies along with federal, state, and local regulatory actions have focused on the environmental and health risks associated with the use of PCE.[5]

In the 1980s, the United States Environmental Protection Agency (EPA) as well as state and regional agencies, began establishing rules to regulate PCE as a water, land, and air contaminant.[6] Solid waste contaminated with PCE must be disposed of as hazardous waste. Discharge of water contaminated with PCE is highly regulated. Soil and groundwater contaminated with PCE are subject to federal superfund designation and clean-up requirements. There are currently twelve states that have created their own superfund program to clean up groundwater and soil contamination for dry cleaning and these programs require dry cleaners to pay annual fees, a solvent tax, and/or a percent of gross receipts. Of these state programs, all impose fees on PCE use and ten impose fees on other non-PCE solvent use.[7]

Regulatory oversight of PCE as an air contaminant increased substantially with the passage and subsequent implementation of the 1990 Clean Air Act Amendments. In 1993, in response to requirements in the 1990 Clean Air Act, the EPA implemented regulations to reduce emissions of PCE from dry cleaners. The regulations specified equipment and record keeping requirements designed to reduce emissions and encourage good operating practices among PCE dry cleaners. These regulations have been difficult to comply with and difficult to enforce in an industry dominated by thousands of small shops with a high percentage of ownership by recent immigrants.[8] Increasingly elaborate pollution control equipment has been added to dry cleaning machines to reduce these risks and to comply with regulations, but reducing emissions to ever smaller amounts has proven to be an energy intensive activity.[9]

BACKGROUND OF DRY CLEANING EQUIPMENT

As a consequence of increased regulation of PCE dry cleaning, dry cleaning machines have become equipped with increasingly complex pollution control devices to capture and reuse solvent vapors and used liquid PCE solvent. These solvent-recovery pollution control devices are now standard on all non-aqueous dry cleaning machinery.

While improved pollution control devices have successfully lowered solvent emissions and consumption, their operation appears to be energy intensive. These devices require the consumption of additional electricity and natural gas to operate effectively. The development of these devices and their impact on resource use is discussed below.

DEVELOPMENT OF DRY CLEANING VAPOR RECOVERY EQUIPMENT[10]

FIRST GENERATION: All dry cleaning transfer systems are designated as "First Generation." These dry cleaning machines have separate cylinders for washing and for drying cycles. After the extraction cycle, garments damp with PCE solvent are removed from the washer cylinder and transferred into the dryer cylinder. PCE vapors from the washer cylinder and from the damp garments escape into the shop air during the transfer of garments.

SECOND GENERATION: Second generation dry cleaning machines eliminated the emissions created during the transfer of garments by washing and drying actions in the same cylinder. These machines are referred to as "dry-to-dry" machines, because garments go in and come out dry. Second generation machines use a conventional condenser, cooled by water from a cooling tower or water chiller, to recover some of the PCE vapors during the dry cycle. The air in the dryer is reheated and re-circulated through the cylinder and condenser until most of the PCE vapors are removed, lowering solvent emissions to 25,000 to 75,000 parts per million (ppm).

THIRD GENERATION: Third generation machines operate in essentially the same way as a second generation machine, but use a mechanical refrigeration system to condense the PCE vapor to a liquid state, this condenser system is call a refrigerated condenser (RC) instead of a conventional condenser.[11] A RC is capable of removing higher proportions of PCE vapor from the air (2,000 to 8,600 ppm) during the dry cycle because it generates lower temperatures, increasing the effectiveness of the PCE vapor condensing process.

FOURTH GENERATION: Fourth generation machines add a carbon adsorber (CA) to the RC as a secondary emission control. At the end of the dry cycle cool down period, the air in the cylinder is passed through the CA where PCE vapor is adsorbed by the carbon, and the cleansed air is returned to the cylinder. Some machines use a sensor in the cylinder to monitor PCE concentrations during the adsorption process, and will continue the adsorption process until the desired concentration level is reached (e.g., 300 ppm). Once the CA reaches its capacity, it needs to be desorbed, which is accomplished by passing steam through the CA. The PCE vapors are then vented to a condenser to recover the desorbed PCE.

FIFTH GENERATION: Fifth generation machines have the same primary and secondary controls as fourth generation machines, but also incorporate a door lock that will not allow the cylinder door to be opened until the PCE monitor reports that the PCE concentration in the cylinder has reached the desired level. This guarantees that the door will not be opened before the carbon adsorption cycle has been completed.

DEVELOPMENT OF DRY CLEANER LIQUID RECOVERY EQUIPMENT[12]

In addition to the vapor recovery technology, dry clean machines are also designed to clean and reuse dirty solvent effluent drained during the wash cycle. This liquid recovery process is done through a combination of filters and distillation.

CARTRIDGE FILTERS: Cartridge filters are the most commonly used filters in the United States to collect insoluble particles. Used solvent is pumped through the filter, which contains layers of paper, carbon, and a fine mesh. When the filter becomes full, it is drained and discarded as hazardous waste. Cartridge filters are simple to operate, but do not recover as high a percentage of solvent as other filter types and consequently have higher hazardous waste disposal and filter replacement costs.

SPIN DISK FILTERS: These filters operate in a similar manner to cartridge filters, and sometimes use a powder such as clay to assist in the filtration process. Spin disk filters remove a higher percentage of insoluble particles from solvent, and need to be replaced less often than cartridge filters. A disadvantage is that their daily operation and maintenance is more complex.

DISTILLATION: Distillation is used to remove solvent-soluble impurities from liquid solvent effluent drained during the wash cycle. Contaminated solvent is pumped to a still where it is heated by steam coils and vaporized. Vapors are passed through a condenser, while the impurities are left behind in the still bottom. The vapors are condensed back into a liquid state, and then passed through a water separator, which separates water from the solvent. The water separator uses the differing densities of solvent and water to separate, with the separated solvent pumped back to the solvent storage tank and the contaminated water drained to a wastewater collection drum.

WASTEWATER EVAPORATOR: The wastewater drained off from water separator is still contaminated by PCE and must be disposed of as hazardous waste or evaporated. Given the high costs of hazardous waste disposal, most cleaners opt to evaporate their wastewater. Evaporators may use natural gas, steam, or electrical heat sources to evaporate the wastewater. Some cleaners simply place their wastewater in their boiler room for evaporation.

ALTERNATIVE CLEANING TECHNOLOGIES

A number of alternatives to PCE dry cleaning have emerged since the 1980s in response to increasingly stringent regulations. These technologies present the opportunity to reduce environmental risks while maintaining garment cleaning performance standards and financial viability.

PROFESSIONAL WET CLEANING: Professional wet cleaning (PWC) is a water-based process that uses computer-controlled washers and dryers, specially designed biodegradable detergents to clean sensitive and delicate garments, and specialized tensioning finishing equipment to restore shape and form. Both equipment and operating costs are lower in wet cleaning compared to PCE dry cleaning, and cleaners who have switched to professional wet cleaning have been able to process the same full range garments they had previously dry cleaned.[13] Two other water-based systems have been developed. One is identical to traditional wet cleaning but uses chilled water. The other uses a modified dryer through which a mist of water and detergent are sprayed onto garments. Neither one of these other water-based system were evaluated in this study.[14]

PETROLEUM DRY CLEANING: Petroleum (PET) solvent (also referred to as hydrocarbon) is the most widely used alternative to PCE. Equipment costs are slightly higher than PCE dry cleaning machines. Although petroleum solvents are not currently classified as hazardous air pollutants, they do emit smog and greenhouse gas-producing volatile organic compounds (VOCs) and generate hazardous waste. Government regulations require that petroleum dry clean machines be equipped with solventrecovering pollution control devices similar to those found on PCE dry cleaning machines. Petroleum solvents also face regulations regarding flammability. They are classified as Class III-A solvents, meaning they have a flash point between 140 and 170 degrees Fahrenheit. Fire codes often require an automatic sprinkler system throughout the plant as well as the construction of firewalls between the machine and the rest of the facility.

SILICONE DRY CLEANING: Silicone (SIL) solvent has become increasingly popular over the past few years, and has been aggressively marketed as a non-toxic alternative to PCE by GreenEarth Cleaning, L.L.C. Equipment costs are slightly higher than PCE dry cleaning machines. The Green Earth solvent, also known as D-5 or decamethylepentacyclosiloxane, is similar to the silicone substance formerly used in breast implants (D-6). Silicone dry clean machines are equipped with solvent recovery devices similar to those found on PCE dry cleaning machines, and some machines are designed to handle either petroleum or silicone solvents. Although D-5 has been marketed as non-toxic, toxicity testing has not been completed and a recent inhalation study of rats by Dow Corning has raised questions about its safety.[15] Like petroleum solvents, D-5 is a Class III-A solvent and has a flammability flash point of 170 degrees Fahrenheit. Although it has a higher flash point than petroleum solvents, it is subject to the same fire codes and regulations.

CARBON DIOXIDE DRY CLEANING: Liquid carbon dioxide (CO_2) solvent used in dry cleaning is pressurized carbon dioxide gas, and is non-toxic and non-flammable. Equipment costs of a CO_2 dry cleaning system is substantially higher than a PCE dry clean machine due to the additional steel required to maintain the 700 PSI to 800 PSI pressure inside the cleaning vessel during the wash process.

ENERGY DEMANDS OF CLEANING EQUIPMENT

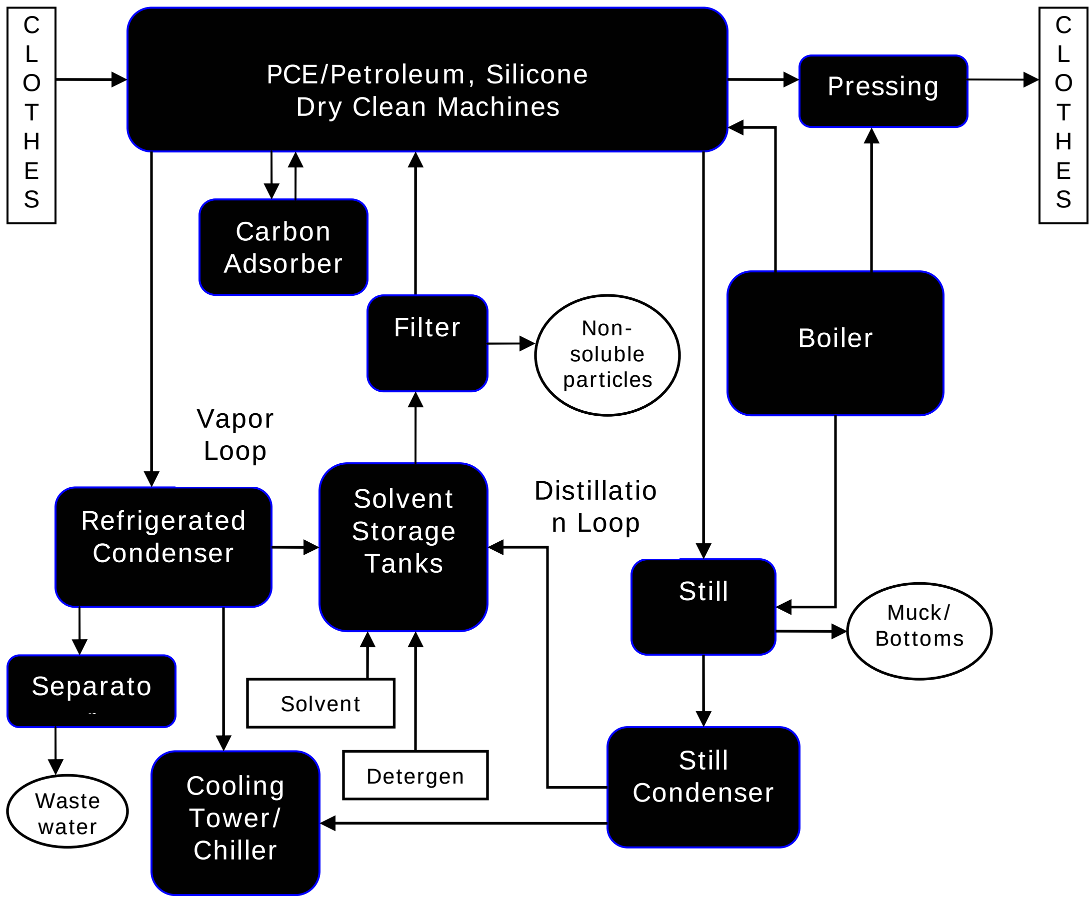
PCE, PETROLEUM, AND SILICONE DRY CLEANING PROCESS

Figure 1 shows the key energy demands associated with advanced PCE, petroleum, and silicone dry cleaning process. The process includes washing, drying, and pressing.

ELECTRICITY: A dry clean machine uses electricity to pump solvent and detergent to the cleaning cylinder, for mechanical action during the wash process, for mechanical refrigeration to cool evaporated solvent during the dry cycle and distillation cycle, and for a pump and fan to operate the cooling tower or chiller, as well as for mechanical action of the pressing equipment.[16]

NATURAL GAS: Dry clean machines are never directly heated by natural gas because of safety hazards associated with the exposure of solvent to open flames. Dry clean machines instead use steam from a boiler as a source of heat.[17] For PCE, petroleum, and silicone dry cleaning, steam heat is used during the dry cycle, distillation, cleaning carbon filters, and pressing.

FIGURE 1. ENERGY PROCESS FLOW DIAGRAM FOR PCE, PETROLEUM, AND SILICONE DRY CLEAN MACHINES[18]



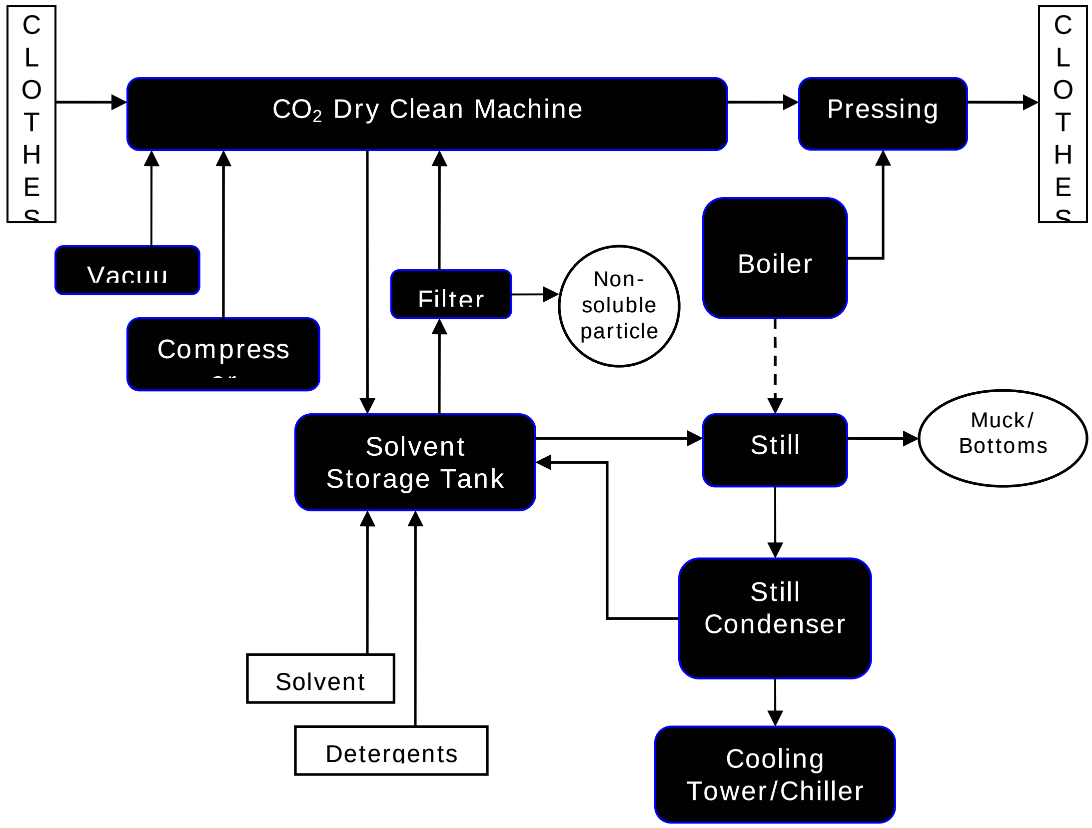
CO_2 DRY CLEAN PROCESS

Figure 2 shows the key energy demands associated with CO_2 Dry Cleaning.

ELECTRICITY: Electricity is used by the CO_2 dry cleaning system for mechanical action and to operate pumps, the vacuum, the computer, sensors, a chiller system, 700 PSI to 800 PSI compressor, and finishing equipment. In addition, some CO_2 machines use electric heating coils to evaporate solvent during distillation.

NATURAL GAS: Unlike the other non-aqueous dry clean systems, CO_2 dry cleaning system does not use steam heat to evaporate solvent during the dry cycle – evaporation takes place as a consequence of a change in pressure. The CO_2 dry clean process uses steam from a boiler for pressing. Some CO_2 dry cleaning machines use steam during distillation while others use electric heating coils.

FIGURE 2. ENERGY PROCESS FLOW DIAGRAM FOR CO_2 DRY CLEAN MACHINE[19]



PROFESSIONAL WET CLEANING PROCESS

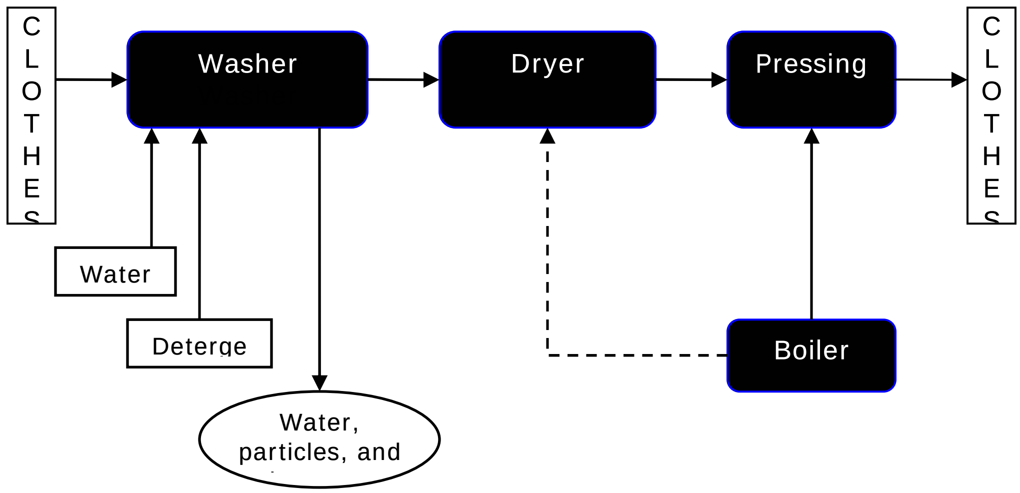
Wet cleaning, a process of hand-laundering delicate garments, has long been practiced by cleaners.[20] *Professional* wet cleaning (PWC) industrializes this practice by using computer-controlled washers and dryers, specially formulated detergents, and specialized finishing equipment to create a cost-effective alternative to dry cleaning. A number of features enhance the efficiency of professional wet clean systems as shown in Figure 3. These features include:

- A horizontally mounted cleaning drum enables the use of low water levels.
- Minimal agitation is used during the wash cycle.
- High-speed turning drum extraction removes moisture from garments and shortens dry times.
- Precision garment-sensitive moisture sensors in the dryer prevent over-drying.
- Tensioning finishing equipment maximizes the use of steam and lowers pressing times.

ELECTRICITY: Professional wet clean washers and dryers use electricity for mechanical action and the operation of computers, sensor systems, and liquid detergent transfer pumps. Tensioning equipment uses electricity to operate fans and computer systems.

NATURAL GAS: Some wet clean washers use natural gas directly to heat the hot water or in the form of steam to heat the hot water used in the wash cycle. Wet clean dryers use natural gas as a direct source of heat or in the form of steam heat from the boiler. Tensioning equipment uses steam from the boiler.

FIGURE 3. PROCESS FLOW DIAGRAM FOR PROFESSIONAL WET CLEAN SYSTEM[21]



PREVIOUS RESEARCH

The only studies to compare energy resource use of different garment care technologies have been conducted by the Pollution Prevention Center at the Urban and Environmental Policy Institute at Occidental College.

In a 1997 evaluation of the first professional wet cleaner established in California, the actual electricity, natural gas, and water used at this cleaner was quantified and compared to an estimate of energy resource use based on machine specifications on advanced PCE dry cleaning equipment.[22] This study estimated that electricity use was 24% lower in professional wet cleaning, natural gas was 23% higher, and water use was 77% higher.

In March 2004, an evaluation of four professional wet cleaning facilities that had switched from PCE dry cleaning was completed.[23] Data was compiled from monthly billing records as well as electrical and natural gas sub meters at three of the facilities. Results showed a systematic reduction in electricity use and natural gas reductions in all but one case. In addition, water used was measured at one facility which switched from PCE dry cleaning to professional wet cleaning and showed a dramatic reduction in water use after the cleaner switched. Part of this reduction was due to the fact that the cooling tower water level float valve was broken and water was continuously flowing into the cooling tower used to cool off dry clean machine. The cooling tower was disconnected after the cleaner switched to wet cleaning. In regards to the equipment energy consumption testing methods used, data from sub metering confirmed observation from monthly billing records, and provided more precise quantification of resource use. In addition, problems with sub metering data collection procedures were noted. During the sub meter data collection period, data was collected on all garments processed at the cleaner; that is, both the professional cleaning operation and the laundry service. First, because both the professional wet clean operation and the laundry services use the same pressing finishing equipment, and because cleaners finish professionally cleaned garments and laundered garments simultaneously, it was difficult to separate out energy resource use associated with the professional cleaning equipment apart from the resource use associated with laundry service. A second problem had to do with the accuracy of the data collected by the cleaners during the sub metering data collection period; cleaners were asked to write down the weight, time, and cleaning program used for every load processed. In some cases the data appeared reliable while in other cases the cleaners did not always remember to write down load weight, load time, or cleaning program used.

In February 2007, research on the first set of cleaners to switch to professional wet cleaning was published in the peer review *Journal of the Air and Waste Management Association.*[24] This study, which is based on utility billing records, showed a reduction in electricity use between 19% and 44% after cleaners switched from PCE dry cleaning to professional wet cleaning. Natural gas use was lower in three of the four cleaners evaluated. For the two cleaners who paid their own water bill, one experienced an increase in water use after switching while the other experienced a decrease in water use.

In January 2008, Pollution Prevention Center completed a study for the US Environmental Protection Agency on the first set of cleaners to convert from PCE dry cleaning to professional wet cleaning in the San Francisco Bay Area and San Diego.[25] The study used utility energy and water billing records as a basis for analysis. Of the five cleaners evaluated in this study, electricity use was reduced from 20% to 41% after the cleaners switched and natural gas was lower for four of the five cases. Water use decreased from 10% to 22% for the three cleaners who had there own separate water billing meters and paid for water.

METHODOLOGY

SCOPE OF INVESTIGATION

The resource use evaluation proposed for this project seeks to provide a stable estimate of the electrical and natural gas energy consumption associated with the use by five garment care technologies:

- Perchloroethylene dry cleaning
- Petroleum dry cleaning
- Silicone dry cleaning
- Carbon Dioxide dry cleaning
- Professional wet cleaning

DATA COLLECTION SITES

In order to maximize the strength of the energy use estimates for each technology, it is desirable to collect data at as many sites as feasible. Data was collected at 26 test sites. Table 1 shows the types and the number of test sites for data collection. Five of the PCE dry cleaning sites and five of the wet clean sites were the same facility before and after they switched from PCE dry cleaning to wet cleaning.

TABLE 1. NUMBER OF GARMENT CARE TEST SITES

TECHNOLOGY	TEST SITES
Professional Wet Cleaning	8
Perchloroethylene Dry Cleaning[26]	9
Petroleum Dry Cleaning	5
Silicone Dry Cleaning	2
Liquid CO_2 Dry Cleaning	2
Total	26

The eight professional wet cleaning sites were all participants in the Pollution Prevention Center's Environmental Garment Care Demonstration Program. Five of these eight cleaners switched to professional wet cleaning from PCE dry cleaning and were also metered as PCE cleaners. This accounted for 13 of the 26 sites. The remaining 13 sites were selected with help from dry clean equipment distributors, other industry association representatives, and regulatory agencies. As an incentive to participate, these remaining cleaners were provided a $1,000 grant. All of the remaining test sites were required to operate a late model cleaning system and a relatively efficient boiler. Only cleaner shops with steam boilers having a minimum combustion efficiency of seventy percent were tested.

DEVELOPMENT OF DATA COLLECTION PROTOCOL

A preliminary evaluation that compares the energy use of cleaners converting from PCE dry cleaning to professional wet cleaning revealed problems with previous data collection procedures. (See section on Previous Research) The first problem was the ability to effectively separate out energy resources used in processing laundry items (e.g. dress shirts, khaki pants, etc.) from resources used in the professional cleaning system that are used for sensitive textiles (e.g. wool, silk, etc). The second problem was associated with lack of accurate record keeping by operators in characterizing each load of garments cleaned during a test period. A new data collection protocol needed to be developed to overcome these problems.

A new data collection protocol was developed in conjunction with engineers from Southern California Edison, Southern California Gas Company, the Los Angeles Department of Water and Power and a member of Occidental College's Environmental Garment Care Demonstration Project Advisory Board who owns both professional wet cleaning facilities and dry cleaning facilities.

The goals for an effective protocol include the following:

- Compare different professional cleaning technologies operated at different cleaning facilities in terms of a standardized measure of electricity and natural gas use.
- Isolate the processing of professionally cleaned garments from start to finish (washing through pressing) from other resource consuming operations (e.g. the laundry service).
- Reflect real-world operating practices of the cleaner (e.g. size of test loads reflecting what the cleaner typically processes).
- Compare comparably sized cleaning systems.
- Minimize the inconvenience to cleaners and minimize interference with daily operations.

NEW DATA COLLECTION PROTOCOL

Key components of the new protocol are as follows:

- Choose test facilities that agree to process (wash, dry, and finish) between two and four loads of garments in their professional cleaning system before operating any other cleaning process (e.g. laundry machines).
- Test facility agrees to conduct test on one to two specified test days.
- Data on load characteristics are to be collected prior to testing. Load characteristics include load weight, number of pieces, garment type (e.g. jacket, pants, etc.), care label instructions, fiber type, and cleaning program used.
- When appropriate, test facility agree to have facility sub metered for electricity and natural gas.

BETA TESTING OF NEW DATA COLLECTION PROTOCOL

Beta testing was carried out at two facilities -- a dedicated professional wet cleaning facility and petroleum dry cleaner. The beta testing was designed to develop specific test procedures that could be used at any professional cleaning facility. Both electricity and natural gas were sub metered and testing was carried out on three days for petroleum dry cleaning and three days for professional wet cleaning.[27]

SPECIFIC TEST PROCEDURES

Based on the results from the beta-tests, the following specific test procedures were developed and implemented at each test facility to create a standard method of data collection.

INSTRUMENTATION SET UP

1. Electricity sub meters and data loggers were installed to monitor overall electricity consumption at the test facility. When possible, sub meters at a dry cleaning facility were installed to provide specific information on the dry clean machine, cooling tower fan and pump, vacuum pump, air compressor, pressing equipment, and boiler. At a wet cleaning facility, were possible, sub

meter data was generated for the wet clean washer, dryer, vacuum pump, air compressor, pressing equipment, and boiler.

2. If the test facility did not have an accurate garment weight scale, a scale was provided during the test period to weigh garments.

DAY OF THE TEST

PRE-TEST

3. Take all initial readings of gas and electric meters, check and monitor equipment.
4. Shut off steam supply valves to equipment that will not be in use during the test.
5. Turn on the boiler and allow it to reach full pressure (e.g. 85 psi)
6. During testing, the cleaner will not operate any equipment that is not associated with the processing of the test garments.

WASHING AND DRYING OF GARMENTS

7. Two to four loads of garments are to be processed in the cleaning machine(s). Specialty loads such as comforters, rugs, or leather will not be included.
8. Before each load is processed, record the garment type (e.g. jacket, pants) on each garment.
9. Record the cleaning control program settings used for each load, including each process step and step time.
10. Record the following information at the start and finish of each load: time, weight, natural gas meter reading, and boiler pressure.

FINISHING OF GARMENTS

11. Finishing of garments will start once the first load has been washed and dried. Pressing will be continuous throughout the test until the last garment of the final load has been pressed. Non-test loads may not be started until the all test garments have been pressed.
12. Any garment considered not clean enough to return to the customer by the facility's staff will be considered not successfully processed and will be considered a redo. Weigh redo garments and subtract their weight from the standard amount of garments cleaned.
13. Testing will conclude once all loads have been cleaned, dried, and pressed. At this point, final readings of gas meter will be recorded and electricity data from data loggers will be downloaded.

FACILITY-BASED DATA ANALYSIS

Once the test data for each facility was complete, a data summary for the facility was developed. The data summary analysis for each facility includes:

1. For each day of testing: total electricity and natural gas used during the test period was compiled.
2. To generate standardized use, total electricity and natural gas used for the test period was divided by the total pounds of garments processed and multiplied by 100 to standardize electricity and natural gas use per 100 pounds cleaned.
3. If a second day of testing was completed, the average of the two days of testing was used as a point estimate for the facility.
4. All non-aqueous cleaning technologies used distillation to clean used solvent. A standardized electricity and natural gas use associated with distillation cycle for each technology was developed. (See below) These standardized distillation energy usages were added to the point estimate for each non-aqueous cleaner to create a final electricity and natural gas use associated with each facility.

DISTILLATION

A protocol was developed to create a standardized estimate of electricity use and natural gas use associated with the distillation process. See Figure 1. Energy Process Flow Diagram for PCE, Petroleum, and Silicone Dry Clean Machiness:

- Each of the non-aqueous cleaning technologies uses a solvent distillation process to clean the solvent by removing impurities from the cleaning fluid after garments have been cleaned. In professional wet cleaning, distillation is not necessary because fresh water from the municipal water supply is used for each wash and rinse cycle and drained directly to the sewer after use.
- Most new dry clean machines are designed to fully distill contaminated solvent immediately after the dirty solvent is drained from the cleaning drum or evaporated during the dry cycle. This distillation process is known as "continuous distillation."
- Equipment manufacturers recommend continuous distillation in order to optimize cleaning quality. If the solvent is not continuously distilled, impurities, such as oils, soils, and dyes, that are removed during the cleaning process will remain with the solvent and can redeposit on garment items the next time the dirty solvent is used.
- Some dry cleaners do not use continuous distillation because of the energy cost associated with the distillation process, and choose to distill once a day or less frequently. Yet, this practice clearly reduces cleaning quality.[28]
- While this study was initially designed to control for cleaning quality, and thus compare professional wet cleaning with dry cleaning using continuous distillation, it was necessary to generalize these results to "typical usage patterns" because not all cleaners do continuous distillation.
- Therefore, this study assumes that the "typical usage pattern" is for PCE, petroleum, silicone, and CO_2 dry cleaners to perform twice-a-week distillation.
- Most PCE, petroleum, and silicone dry cleaning machines have three storage tanks. For cleaners that do not do continuous distillation, one storage tank is used to clean light-colored items, one storage tank is used for dark-colored items, and the third is used to store clean solvent. The idea for creating light and dark colored tanks is that impurities in the solvent would be more visible on lighter items and less visible on darker items.

- The typical twice-a-week distillation practice is to distill the storage tank that was used for dark-colored clothes. During distillation, the cleaned solvent is condensed back to the clean storage tank. After distillation is completed, the solvent in the tanks are rotated: the dark-colored storage tank is refilled with solvent from the light-color storage tank and the light-colored storage tank is refilled with solvent from the clean storage tank.
- The two CO_2 dry cleaning machines tested in this study were not equipped to perform a complete continuous distillation. To completely distill the CO_2 solvent in these machines, these facilities must perform batch distillation, which is done when the cleaning process is not operating.
- To estimate the energy use associated with distillation, separate distillation tests were conducted for perchloroethylene, petroleum, and CO_2.[29] Results for petroleum test were used as a basis for energy associated with distillation for silicone dry cleaning.[30]
- The electricity and natural gas use associated with distillation were then added to each non-aqueous test site.
- The study assumed cleaners processed an average of 200 pounds of garments per day.[31]

A summary of results of the distillation testing is shown in Table 2 for electricity and Table 3 for natural gas.

TABLE 2. ELECTRICITY USED DURING DISTILLATION

TECHNOLOGY	SIZE OF MACHINE TESTED (LBS)	ELECTRICITY USED DURING DISTILLATION TEST (KWH)	ELECTRICITY USED ADJUSTED TO 50 LB MACHINE (KWH)	ELECTRICITY USE ASSOCIATED WITH TWICE-A-WEEK DISTILLATION (KWH / 100 LBS)
PCE	50	8.7	8.7	1.74
Petroleum	30	11.7	19.5	3.90
CO_2 -1	55	19.8	18.0	3.60
CO_2 -2	60	19.3	16.1	3.22

TABLE 3. NATURAL GAS USED DURING DISTILLATION

TECHNOLOGY	SIZE OF MACHINE TESTED (LBS)	NATURAL GAS USED DURING DISTILLATION TEST (HCF)	NATURAL GAS USED DURING DISTILLATION TEST (THERMS)	NATURAL GAS USED ADJUSTED TO 50 LB MACHINE (THERMS)	NATURAL GAS USE ASSOCIATED WITH TWICE-A-WEEK DISTILLATION (THERMS / 100 LBS)
PCE	50	4.3	4.36	4.36	0.87
Petroleum	30	4.0	4.12	6.87	1.37
CO_2 -1	55	2.4	2.47	2.25	0.45
CO_2 - 2	60	N/A			

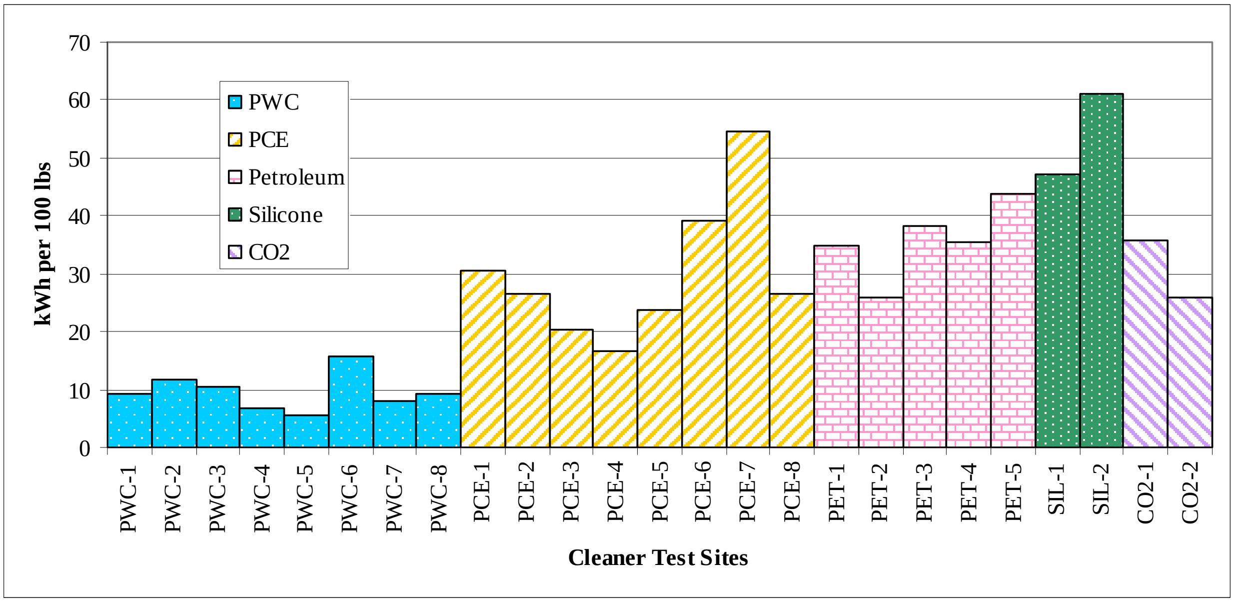
RESULTS

This section compares and analyzes the electricity and natural gas data for the five leading professional garment cleaning technologies.

ELECTRICITY USE PER 100 POUNDS CLEANED

Figure 4 shows the electricity use for each test site standardized per 100 pounds of garments cleaned. Professional wet cleaning used significantly less electricity than any other garment cleaning technology ($p < 0.01$).[32]

FIGURE 4. ELECTRICITY USE FOR FIVE GARMENT CARE TECHNOLOGIES



Within each technology, there was a good deal of variability in the standardized electricity use. For professional wet cleaning, the highest user (PWC-6) used almost three times as much electricity as the lowest user (PWC-5) – 15.8 vs. 5.55 kWh/100 lbs. With perchloroethylene dry cleaning, the highest user (PCE-7)[33] used two and one-half times the electricity as the lowest user (PCE-4) – 54.50 vs. 16.50 kWh/100 lbs. There was less variability among petroleum dry cleaning test sites – the highest user (PET-5) used only 50% more than the lowest (PET- 2) – 43.80 vs. 26 kWh/100 lbs. The two silicone dry cleaning sites varied slightly more – 60.5 kWh/100 lbs. vs. 48.2 kWh/100 lbs, while the two CO_2 dry cleaning sites varied substantially – 35.90 vs. 25.90 kWh/100 lbs.

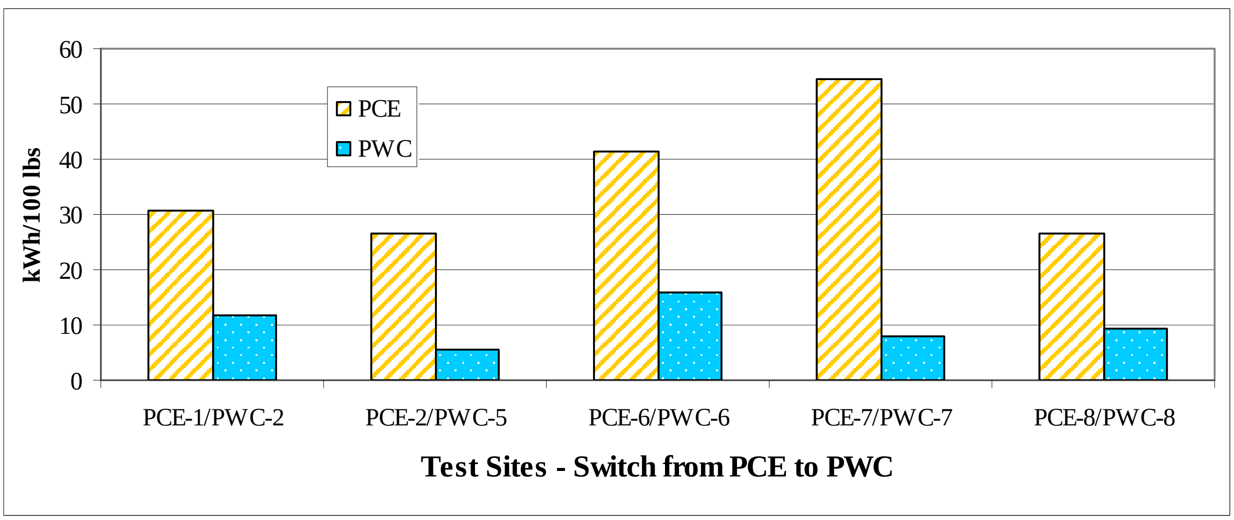
Median electricity use for professional wet cleaning was 9.30 kWh per 100 pounds of garments cleaned. See Table 4 for values from the case studies for the median electricity use by the five leading garment care technologies. The median electrical consumption of the other dry cleaning systems were: PCE (26.60 kWh), petroleum (35.50 kWh), and CO_2 (30.9 kWh) were three times higher, while silicone (54.20 kWh) was over five times higher.

TABLE 4. MEDIAN ELECTRICITY USE FOR FIVE LEADING GARMENT CARE TECHNOLOGIES

TECHNOLOGY	ELECTRICITY USAGE (KWH / 100 LBS)	SAVINGS BY SWITCHING TO PWC (KWH / 100 LBS)	SAVINGS BY SWITCHING TO PWC %
Professional Wet Cleaning	9.3		
Perchloroethylene	26.6	17.3	64%
Petroleum	35.5	26.2	74%
Silicone	54.2	44.9	83%
Carbon Dioxide	30.9	21.6	70%

Isolating the data for the five PCE dry cleaners that switched to professional wet cleaning revealed a substantial reduction in standardized electricity use after the switch. A comparison of electricity use at the test sites that switched from PCE dry cleaning to professional wet cleaning standardized per 100 lbs of garments cleaned is shown in Figure 5.

FIGURE 5. COMPARISON OF ELECTRICITY USE AT TEST SITES SWITCHING FROM PCE DRY CLEANING TO PWC, STANDARDIZED PER 100 LBS CLEANED



The primary explanation for why professional wet cleaning uses significantly less electricity compared to non-aqueous technologies lies in how solvent is processed during the drying cycle and waste is handled. Professional wet clean washers drain liquid waste directly to the sewer and vent dryer exhaust directly to the atmosphere, as does industrial laundry and domestic washer and dryer systems. See Figure 3. Process Flow Diagram for Professional Wet Clean Systems. The non-aqueous technologies all use energy consuming solvent recovery system to capture solvent evaporated during the drying cycle as well as a distillation system to clean drained solvent of impurities, such as oils, soils, dyes, and detergents. See Figure 1 and Figure 2 for diagrams of the energy process flow for PCE, petroleum, silicone, and CO_2 dry clean machines.

The electrical sub meter data suggest that the recovery of solvent in the non-aqueous technologies is a major energy-intensive process. Figure 6 isolates the minute-by-minute electricity demand data for the wash and dry cycles of each of the five technologies. One test site for each technology was used as an example.

FIGURE 6. ONE-MINUTE KW DEMAND DURING WASH AND DRY CYCLE FOR FIVE GARMENT CARE TECHNOLOGIES[34]

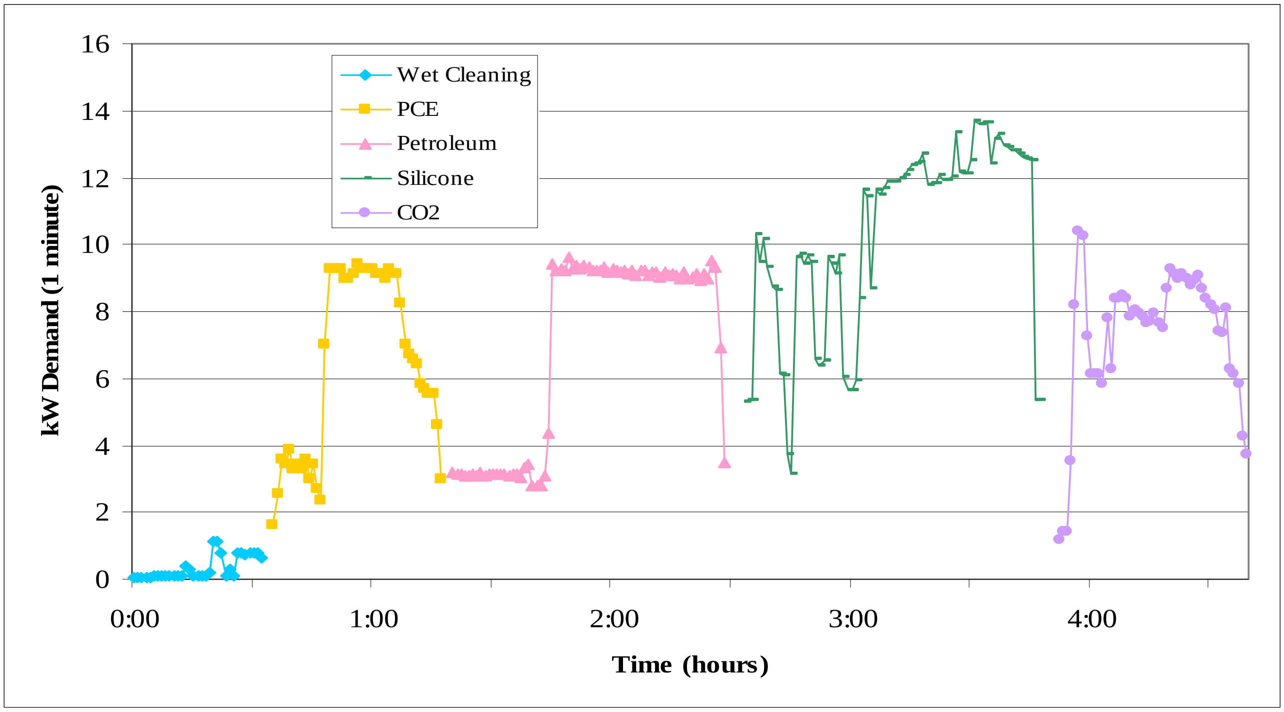


Figure 6 shows the kW demand associated with professional wet cleaning was less than 0.5 kW for the wash cycle, increasing to 1 kW when garments were transferred to the wet clean dryer. For the non-aqueous systems, the patterns for PCE, petroleum, and silicone dry cleaning machines are very similar, with relatively low kW demand during the wash cycle, jumping substantially during the dry cycle when the refrigerated condenser is operating to cool solvent vapors back to a liquid and the cooling tower (or chiller) with the circulation water pump is displacing heat from the refrigerated condenser. For PCE and petroleum, kW demand jumped from 3 kW to over 9 kW. For silicone, kW demand jumped from 7 kW to over 14 kW. The pattern was different for CO_2 dry cleaning. Electricity demand rose quickly at the beginning as the vacuum pump was used to eliminate air and as the machine compressor pump increases CO_2 pressure to compressed CO_2 gas into a liquid for cleaning. Electricity demand then spikes during extraction and vapor recovery. This data does not take into account additional electricity demand if the cleaner was carrying out continuous distillation.

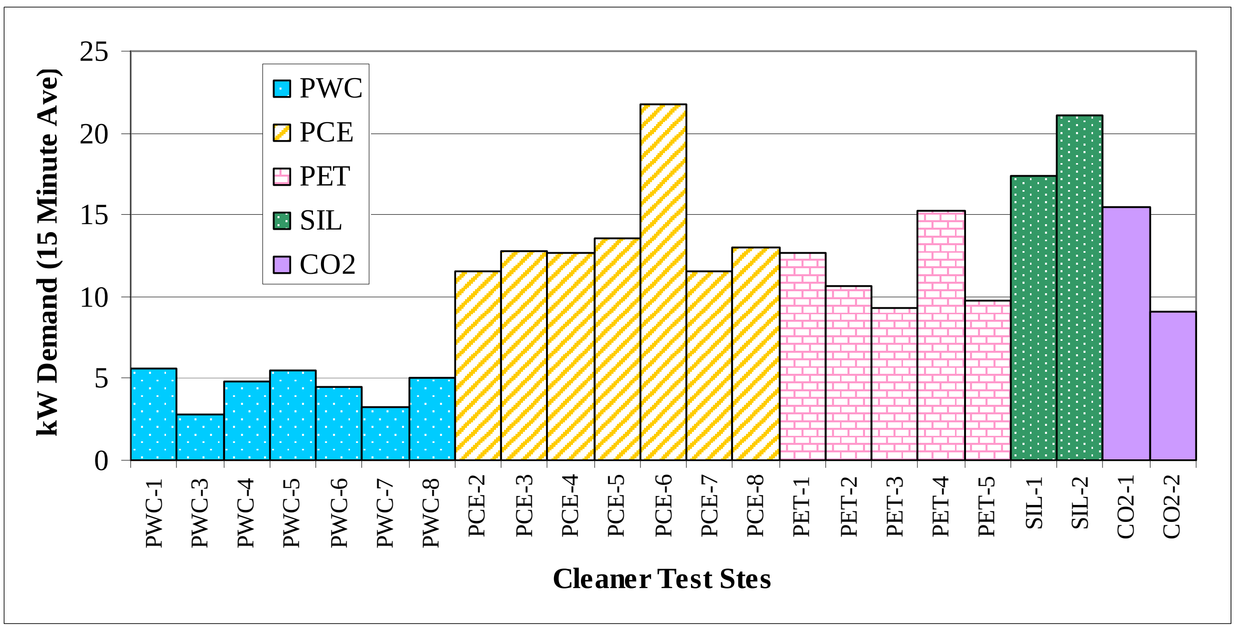
Figure 6 also shows a marked difference in cycle time, with wet cleaning having a cycle of 35 minutes for washing and drying, PCE and CO_2 taking over 45 minutes, and petroleum and silicone over 60 minutes.

This kW demand finding roughly correspond to the electricity name plate rating on the professional wet cleaning equipment compared to the dry cleaning machines. The total demand name plate rating for the wet clean washer and dryer machines was 3.0 kW. The name plate rating for the dry clean equipment tested (including the dry clean machine, cooling tower fan, and cooling tower pump) was over 12 kW.

15-MINUTE PEAK KW DEMAND

Many electric utilities structure billing rates based on the highest average 15 minute demand during a billing period. Figure 7 shows the fifteen-minute peak kW demand for each cleaner taken during the cleaning test, when the cleaning machine and pressing equipment were operating at the same time. Average 15-minute peak demand for professional wet cleaning was significantly lower than the other non-aqueous garment care technologies ($p < 0.001$).

FIGURE 7. 15-MINUTE PEAK KW DEMAND FOR FIVE GARMENT CARE TECHNOLOGIES



Median 15-minute peak demand for professional wet cleaning was 4.9 kW. PCE (12.9 kW), petroleum (10.6 kW), and CO_2 (12.3 kW) were approximately double that of professional wet cleaning, while silicone (19.3 kW) was almost four times that of professional wet cleaning. Table 5 shows the median peak demand for the five leading garment care technologies.

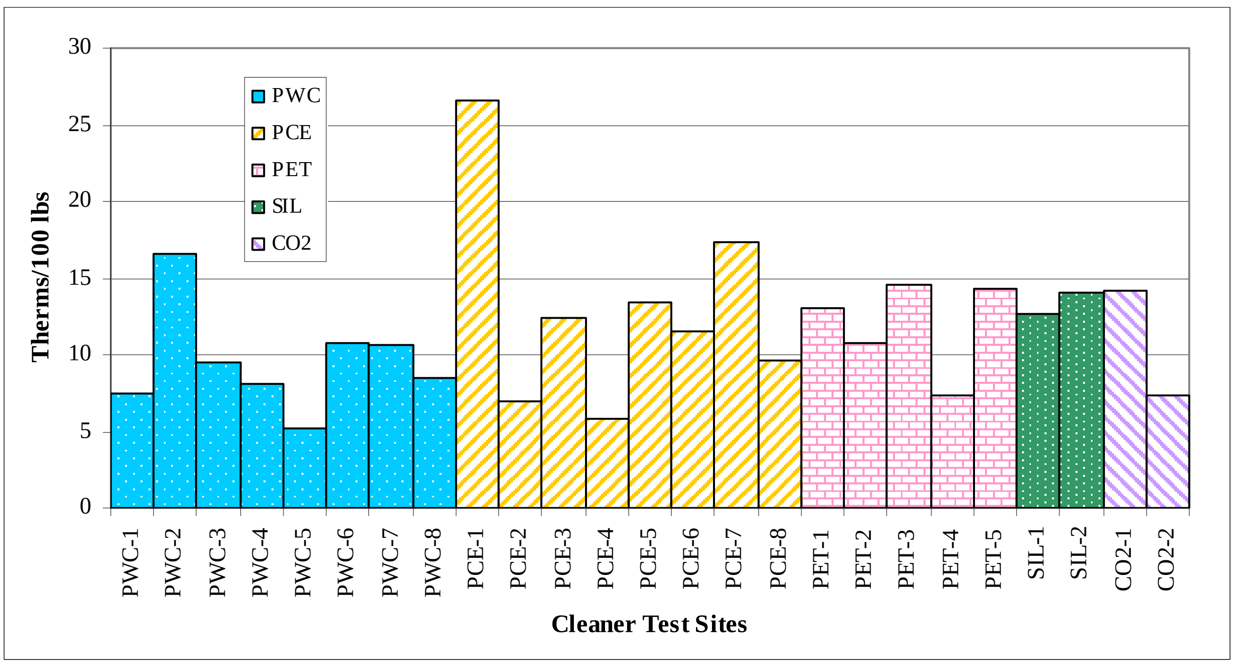
TABLE 5. MEDIAN 15 MINUTE PEAK DEMAND FOR FIVE LEADING GARMENT CARE TECHNOLOGIES

TECHNOLOGY	15 MINUTE ELECTRICITY DEMAND (KW)	SAVINGS BY SWITCHING TO PWC (KW)	SAVINGS BY SWITCHING TO PWC %
Professional Wet Cleaning	4.9		
Perchloroethylene	12.9	8.0	62%
Petroleum	10.6	5.7	54%
Silicone	19.3	14.4	75%
Carbon Dioxide	12.3	7.4	60%

NATURAL GAS CONSUMPTION – SUMMARY ANALYSIS

Figure 8 shows the natural gas use for each test site standardized per 100 pounds of garments cleaned. As with electricity, natural gas use in the professional wet cleaning system was significantly lower than for the other non-aqueous technologies ($p < 0.01$).[35]

FIGURE 8. NATURAL GAS USE FOR FIVE GARMENT CARE TECHNOLOGIES STANDARDIZED PER 100 POUNDS CLEANED

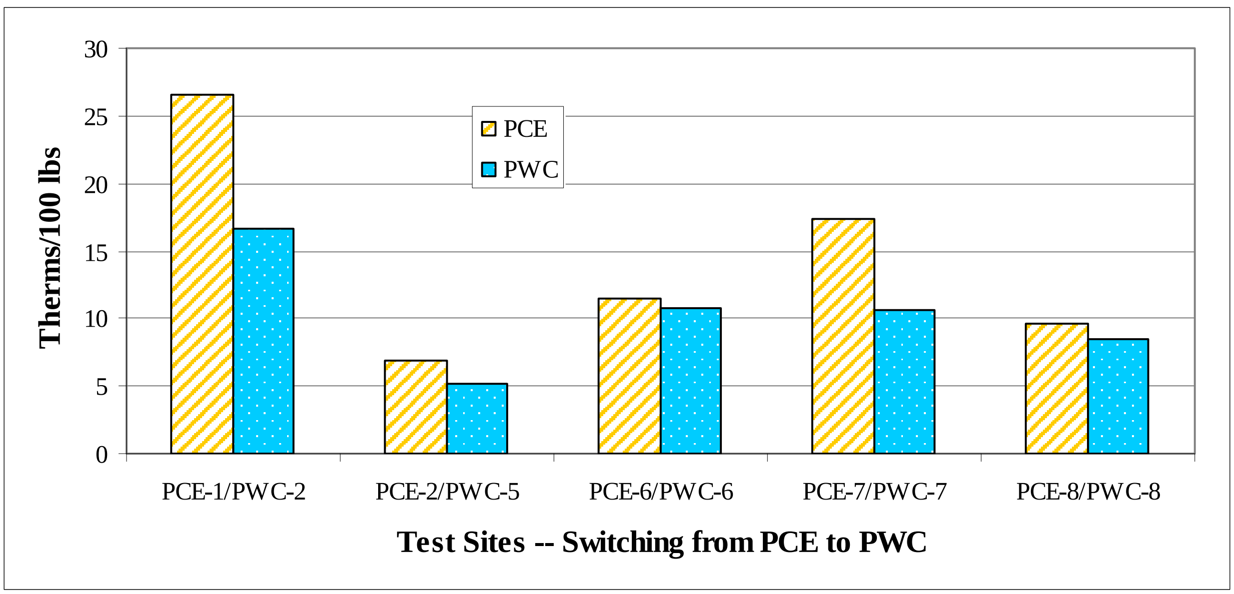


For CO_2 dry cleaning, the differences in distillation methods explained most of the differences in natural gas use for the two CO_2 facilities. The CO_2-1 machine performed a partial distillation at the beginning of each wash load while the CO_2-2 machine was not capable of partial distillation. In addition, the CO_2-1 machine used steam heat to evaporate solvent during distillation, while the CO_2-2 machine uses electric heating coils for solvent evaporation. In fact, the only natural gas use for the CO_2-2 machine was associated with garment steam pressing operation.

Natural gas used for professional wet cleaning was relatively consistent across test sites, except for one site – PWC–2, which was 45% higher than the other professional wet clean sites. This site was a facility that switched to professional wet cleaning from PCE dry cleaning. Among the PCE sites, this cleaner (PCE-1) also tested highest for natural gas use. Observation notes taken during the testing at this facility revealed that there were a number of significant steam leaks from the boiler to the dry cleaning machine and pressing equipment. It is also important to note that at this facility, natural gas use was substantially lower after the cleaner switched from PCE dry cleaning to professional wet cleaning, dropping from 26.6 to 16.6 therms per 100 lbs. Because the wet clean dryer at this facility used natural gas to directly heat, the switch meant that the drying process was no longer dependent on the use of the plant's highly inefficient steam delivery system. The second highest PCE dry cleaning site (PCE-7) was also a facility in which significant steam leaks were observed. This facility as well was one that converted to professional wet cleaning (PWC-7), where it was the third highest natural gas user.

Isolating the data for the five PCE dry cleaners that switched to professional wet cleaning revealed a substantially lower natural gas use in professional wet cleaning compared to PCE use as shown in Figure 9. Of the five cleaners that switched, the biggest reductions in natural gas consumption were for two cleaners that have extremely leaky steam delivery systems – Pair 1 (PCE-1/PWC-2) and Pair 4 (PCE-7/PWC-7). Of the 20 cleaners tested, these were the only two facilities in which steam leaks were observed and noted. This suggests that the efficiency of the steam delivery system contributed to the magnitude of the reduction in natural gas use associated with switching to professional wet cleaning.

FIGURE 9. COMPARISON OF NATURAL GAS USE AT TEST SITES SWITCHING FROM PCE DRY CLEANING TO PWC, STANDARDIZED PER 100 POUNDS CLEANED



Median natural gas use in professional wet cleaning was 9 therms per 100 pounds of garments cleaned, compared to between 12.0 for PCE, 13.1 for petroleum and 13.4 for silicone. For CO_2 dry cleaning sites, the two test sites showed a substantial difference in natural gas used. For the CO_2-#1 site, natural gas use was slightly less than twice that of professional wet cleaning (14.2). For the CO_2-#2 site (7.3), natural gas use was 23% lower than professional wet cleaning and 48% lower than PCE dry cleaning. Table 6 shows the median natural gas use for the five leading garment care technologies.

TABLE 6. MEDIAN NATURAL GAS USE FOR FIVE LEADING GARMENT CARE TECHNOLOGIES

TECHNOLOGY	NATURAL GAS[36] (THERMS / 100 LBS)	SAVINGS BY SWITCHING TO PWC (THERMS / 100LBS)	SAVINGS BY SWITCHING TO PWC %
Professional Wet Cleaning	9.0		
Perchloroethylene	12.0	3.0	25%
Petroleum	13.1	4.1	31%
Silicone	13.4	4.4	33%
Carbon Dioxide	14.2	5.2	37%
Carbon Dioxide	7.3	-1.7	-23%

ANNUAL CLEANER ENERGY ASSUMPTIONS

The calculations for annual cleaner energy consumption were based on:

1. 200 pounds of clothes processed each day per cleaner.
2. 5 days of operation per week per cleaner.
3. 52 weeks of operation per year per cleaner.

The assumptions were based on information collected by the California Air Resources Board.[37]

DISCUSSION

This study was designed to evaluate the electricity and natural gas use of five professional garment cleaning technologies: professional wet cleaning (PWC), perchloroethylene (PCE) dry cleaning, petroleum (PET)dry cleaning, silicone (SIL)dry cleaning, and carbon dioxide (CO_2) dry cleaning. Evaluation was conducted at 21 facilities, 5 of which were tested both when they operated with PCE dry cleaning technology and after they switched to professional wet cleaning. A new standardized test procedure was developed to compare electricity and natural gas use between different technologies used at different cleaning plants.

Results revealed that the professional wet cleaning process used significantly less electricity and natural gas compared with all other technologies. Analysis of the five facilities which switched from PCE dry cleaning to PWC showed consistently lower electricity and natural gas consumption for PWC. Because the only thing to change at these facilities was the cleaning equipment, these cases were able to control for a great deal of non-process factors that tend to vary from facility to facility including the efficiency of the steam delivery system, the efficiency of air compression system, skill of the pressing staff, and the differences in the size and age of ancillary equipment.

The data from this study is consistent with a prior study of cleaners converting from PCE dry cleaning to professional wet cleaning.[38] The prior study used monthly billing records as a basis for comparing electricity and natural gas use.

The difference in energy use is explained by how professional wet cleaning machines deals with cleaning solvents at the end of the cleaning process. All non-aqueous cleaning processes have energy-intensive solvent-recovery systems to capture and clean solvent used during cleaning and to remove impurities from solvent during distillation. Like domestic and commercial laundry, professional wet cleaning does not require solvent-recovery and distillation systems. After wash cycles are completed, water, along with cleaning agents and contaminants, are drained directly to the sewer. At the end of the wash cycle, garments are transferred to dryer that evaporates water vapor directly to the atmosphere.

The efficiency in the steam delivery system appears to contribute to the magnitude of reductions in natural gas use associated with switching to professional wet cleaning. Of the five cleaners who switched, the biggest reductions in natural gas consumption were for two cleaners who have extremely inefficient steam delivery systems.

Data from this evaluation can be used to project annual electricity saving and natural gas saving associated with professional wet cleaning as well as projected savings over the fifteen year life of the equipment.[39] Table 7 shows the electricity savings associated with professional wet cleaning per cleaner over the 15 year life of the equipment ranged from 134,940 kWh in comparison with perchloroethylene dry cleaning to 350,220 kWh in comparison with silicone dry cleaning.

TABLE 7. ELECTRICITY SAVINGS PER CLEANER ASSOCIATED WITH SWITCH TO PROFESSIONAL WET CLEANING

TECHNOLOGY	ELECTRICITY USE[40] (KWH / 100 LB)	SAVINGS BY SWITCHING TO PWC (KWH / 100 LB)	AVERAGE ANNUAL SAVINGS PER CLEANER[41] (KWH)	SAVINGS OVER 15- YEAR LIFE (KWH)
Professional Wet Cleaning	9.3			
Perchloroethylene	26.6	17.3	8,996	134,940
Petroleum	35.5	26.2	13,624	204,360
Silicone	54.2	44.9	23,348	350,220
Carbon Dioxide	30.9	21.6	11,232	168,480

Natural gas savings associated with professional wet cleaning per cleaner over the 15 year life of the equipment ranged from 23,400 therms in comparison to perchloroethylene dry cleaning to 34,320 therms in comparison to silicone dry cleaning. See Table 8 for the natural gas savings with the switch to professional wet cleaning. The carbon dioxide garment cleaning system was not included in this table because, while one test site showed higher natural gas use compared to professional wet cleaning, the other showed slightly lower natural gas use.

TABLE 8. NATURAL GAS SAVINGS WITH SWITCH TO PROFESSIONAL WET CLEANING

TECHNOLOGY	NATURAL GAS USE[42] (THERMS / 100 LB)	AVERAGE REDUCTION (THERMS / 100 LB)	AVERAGE ANNUAL SAVINGS PER CLEANER[43] (THERMS)	SAVINGS OVER 15-YEAR LIFE (THERMS)
Professional Wet Cleaning	9.0			
Perchloroethylene	12.0	3.0	1560	23,400
Petroleum	13.1	4.1	2,132	31,980
Silicone	13.4	4.4	2,288	34,320

Installed cost of professional garment cleaning equipment is summarized in Table 9. These estimates were taken from a 2006 California Air Resource Board Staff Report.[44]

TABLE 9. MACHINE AND INSTALLATION COST COMPARISON

TECHNOLOGY	SIZE	MACHINE / SYSTEM COST	INSTALLATION COST	TOTAL COST	INCREMENTAL COST
Perchloroethylene	45 lb	$50,000	$3,800	$53,800	
Petroleum	50 lb	$68,000	$4,300	$71,800	+$18,500
Silicone	50 lb	$68,000	$4,300	$72,300	+$18,500
Professional Wet Cleaning	50 lb	$51,000	$3,800	$54,800	+$1,000
CO2	60 lb	$143,000	$48,800	$191,800	+$138,000

GRANTS AND REBATES BY OTHERS

Grants and rebates are offered by many utilities, municipals, and state agencies to promote cleaners changing to professional wet cleaning systems. A google search can be helpful to become aware of grants and rebates in different areas of the United States. Because of their funding cycles, grants may or may not be available to cleaners at all times.

A list of a few sources are:

California Air Resource Board Environmental Garment Care Grant -- $10,000 to professional wet cleaning and CO2 dry cleaning:
http://www.arb.ca.gov/toxics/dryclean/dryclean.htm

South Coast Air Quality Management District -- $10,000 to professional wet cleaning and $20,000 to CO2 dry cleaning:
http://www.aqmd.gov/business/drycleaninggrantsNEW.htm

Antelope Valley AQMD -- $5,000 grant to professional wet cleaning: http://www.avaqmd.ca.gov

Utilities that have provided rebates for professional wet cleaning in the past are: Southern California Edison, Pacific Gas & Electric, San Diego Gas & Electric, Los Angeles Department of Water & Power, Sacramento Municipal Utility District, Pasadena Water & Power, and Burbank Water & Power.

Another information resource is the Pollution Prevention Center (PPC), Urban and Environmental Policy Institute at Occidental College: http://departments.oxy.edu/uepi/ppc/projects.htm

CONCLUSION

The professional wet cleaning process uses significantly less electricity than the other non-aqueous dry cleaning technologies and significantly less natural gas compared to PCE, petroleum, and silicone dry cleaning systems.

The estimates for energy use in professional wet cleaning, PCE, petroleum, and silicone cleaning technologies were relatively stable. Natural gas use for CO_2 dry cleaning varied substantially due to differences in the distillation systems of the two machines tested. The leading worldwide manufacturer of CO_2 dry cleaning machines, Electrolux, was not represented in this study because they have not yet begun importing their machines into the United States. Their machine is designed for continuous distillation, which the other CO_2 methods currently in use in the United States are not capable of doing.

Utilities who wish to encourage their customers to switch to energy efficiency technologies should consider developing a rebate program for professional wet cleaning. Such a rebate program could be based on the energy savings associated with professional wet cleaning compared to the traditional PCE dry cleaning technology or the more energy intensive petroleum and silicone systems.

A rebate program for professional wet cleaning is particularly important given the rapid diffusion of petroleum and silicone dry cleaning compared to professional wet cleaning. Between 2003 and 2006, of the 5,500 cleaners in California, the percentage switching to petroleum or silicone dry cleaning increased from 10% to 23.6%, while professional wet cleaning increased from 2.7% to 3.5% in the same period. See Table 10 for the prevalence of non-PCE professional cleaning technologies in California.

TABLE 10. PREVALENCE OF NON-PCE PROFESSIONAL CLEANING TECHNOLOGIES IN CALIFORNIA[45]

Technology	Year			
	2003		2006	
	Number	Percent	Number	Percent
Petroleum	460	8.4%	1110	20.1%
Silicone	90	1.6%	190	3.5%
Professional Wet Cleaning	150	2.7%	175	3.2%
CO_2	3	0.05%	12	0.2%

The rapid increase in petroleum dry cleaning has lead to a significant increase in volatile organic compound (VOC) emissions. VOC emissions create ground-level smog as well as contribute to global warming. The 1,110 petroleum dry cleaners are estimated to add 255,300 pounds to VOC emissions annually.[46]

While professional wet cleaning has been proven as a viable substitute for dry cleaning, there are a number of significant barriers to its diffusion. These include:

- Cleaners lack of familiarity with professional wet cleaning. Most cleaners are not aware that professional wet cleaning can be used as a substitute for traditional dry cleaning. Of the cleaners that have installed professional wet cleaning equipment, the majority visited at least one cleaner before installing their equipment.
- Existing infrastructure favors petroleum and silicone dry cleaning. Most equipment distributors who previously sold PCE dry cleaning equipment switched to selling petroleum and silicone dry cleaning equipment. While some of these distributors also sell wet cleaning equipment, they make more money selling the more expensive dry cleaning equipment. In addition, while professional wet cleaning requires specialized training, cleaners perceived that petroleum and silicone dry cleaning do not require training, making it easier to pitch the sale of this equipment.
- "Dry clean" care label. Many cleaners fear using the professional wet cleaning system to clean garments that are labeled "dry clean" or "dry clean only." Cleaners believe that if they clean in a method that is different from what is stated on the care label, then they are breaking the law. While it is not against the law to professionally wet clean a garment labeled "dry clean only", the fear that it is, serves as a barrier to the acceptance of professional wet cleaning processing. The Federal Trade Commission (FTC), which regulates garment care labeling, has considered developing a "professional wet clean" care label but decided to wait, in part, because of the lack of prevalence of professional wet cleaners.
- Lack of a tipping point – The total prevalence of professional wet cleaning in California is 3% which includes both mixed and dedicated facilities. The number of dedicated professional wet cleaners in California is approximately 90 cleaners, or 1.6%. Research on technology diffusion suggests that a technology must gain a critical percentage of the market for its diffusion to increase rapidly.

Additional financial incentives are likely to overcome a number of these barriers. By lowering the capital equipment cost, more cleaners are likely to switch to professional wet cleaning, moving the percentage of cleaners closer to the critical tipping point. As more cleaners switch to professional wet cleaning, other dry cleaners will become more aware and more comfortable with the technology. The greater the prevalence of professional wet cleaning, the more likely equipment distributors will feel comfortable in selling this equipment. Finally, as the prevalence of professional wet cleaning grows, the more likely the Federal Trade Commission will move forward with developing a "professional wet cleaning" care label.

APPENDICES

Each appendix lists information about the test site, cleaning equipment, energy test data and summary calculations.

Appendix A: PCE 1 Washing Energy Test

Appendix B: PCE 2 Washing Energy Test

Appendix C: PCE 3 Washing Energy Test

Appendix D: PCE 4 Washing Energy Test

Appendix E: PCE 5 Washing Energy Test

Appendix F: PCE 6 Washing Energy Test

Appendix G: PCE 7 Washing Energy Test

Appendix H: PCE 8 Washing Energy Test

Appendix I: PCE 9 Distillation Energy Test

Appendix J: CO_2 1 Washing Energy Test

Appendix K: CO_2 2 Washing Energy Test

Appendix L: SIL 1 Washing Energy Test

Appendix M: SIL 2 Washing Energy Test

Appendix N: PWC 1 Washing Energy Test

Appendix O: PWC 2 Washing Energy Test

Appendix P: PWC 3 Washing Energy Test

Appendix Q: PWC 4 Washing Energy Test

Appendix R: PWC 5 Washing Energy Test

Appendix S: PWC 6 Washing Energy Test

Appendix T: PWC 7 Washing Energy Test

Appendix U: PWC 8 Washing Energy Test

Appendix V: PET 1 Washing Energy Test

Appendix W: PET 2 Washing Energy Test

Appendix X: PET 3 Washing Energy Test

Appendix Y: PET 4 Washing Energy Test

Appendix Z: PET 5 Washing Energy Test

APPENDIX A: PCE 1 WASHING ENERGY TEST

ID PCE 1 **City** Marina Del Rey **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Dry clean machine	Renzacci Serena Sun	1989	55 lbs	14.5 HP	Visibly corroded in places, appears to be in generally poor condition.
Cooling tower fan	Liang Chi Industry, LBC 15		58.5 K	0.75 HP	Float was unattached so water was running constantly, effectively once-through system.
Cooling tower pump	STA-RITE			1 HP	
Air compressor	Kellog American	1964	200 PSI		No spec plate on the motor, probably a 7 HP.
Vacuum pump	No visible nameplate.				Motor was rebuilt in April 2004 after it had a burn-out.
Boiler	Parker	1992		25 HP	Extremely corroded, steam distribution pipes had numerous leaks.
Pressing equipment	Three press stations and one susie. Several pieces had steam leaks and condensate dripping.				

Test # 1 **Date** 5/15/04

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	33	40	12:42	13:25	0:43	
Load	2	Light	39	37	13:26	14:24	0:58	
Pressing			72	77	13:30	15:52	2:22	3:10

	#	kWh 1 St	kWh 1 Fn	kWh 2 St	kWh 2 Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	280.0	285.5	276.0	278.5	8.0	362.2	369.0	6.8
Load	2	285.5	293.2	278.5	281.8	11.0	369.0	374.6	5.6
Pressing			297.5		287.5			382.4	
Total		29.0	Bckgrnd	7.0	Adjusted	22.0		Total	20.2

Test # 2 **Date** 6/25/04

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	30	35	8:03	8:57	0:54	
Load	2	Light	40	41	9:04	10:03	0:59	
Load	3	Dark	36	39	10:04	10:48	0:44	
Pressing			106	115	9:03	11:50	2:47	3:47

	#	kWh 1 St	kWh 1 Fn	kWh 2 St	kWh 2 Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	511.8	517.8	680.0	683.0	9.0	90.0	97.5	7.5
Load	2	517.8	526.1	683.0	686.8	12.1	97.5	103.8	6.3
Load	3	526.1	532.4	686.8	689.8	9.3	103.8	108.0	4.2
Pressing			536.0		692.8			113.8	
Total		37.0	Bckgrnd	8.3	Adjusted	28.7		Total	23.8

Summary Results

	#	kWh	kWh/100 lbs	kWh/100lbs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	22.0	30.6	32.3	20.2	20.6	28.6	29.5
Test	2	28.7	27.1	28.8	23.8	24.3	22.9	23.7
Average		25.4	28.8	30.6	22.0	22.4	25.7	26.6

*HHV=1019

APPENDIX B: PCE 2 WASHING ENERGY TEST

ID PCE 2 **City** Pomona **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Dry clean machine	Realstar RS 323	1998	35 lbs	5.2 kWh per cycle	Strong PCE odors during operation, very strong when door was open.
Cooling tower fan	RSD	1986		0.5 HP	Looked in decent condition, fairly new coils.
Cooling tower pump	STA-RITEJHF-51HLMS2	1986		1.5 HP	
Air compressor	Westinghouse				No faceplate visible. At least 5 yrs old, probably 5 HP.
Vacuum pump	B-System				Faceplate wasn't legible, probably 1 HP
Boiler	Thermosteam				Tested at 77% efficiency. Faceplate not legible, owner thought it was 15 HP.
Pressing equipment	Two pressing stations with press boards and mushrooms, and a susie.				

Test # 1 **Date** 4/20/05

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	27	25	6:25	7:02	0:37	
Load	2	Dark	24	25	7:03	7:35	0:32	
Pressing			51	50	7:05	7:53	0:48	1:28

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			213.8	215.0	1.2
Load	2				215.0	216.0	1.0
Pressing						216.5	
			Total			Total	2.7

Total kWh Use		Bckgrnd		Adjusted	-

Test # 2 **Date** 5/4/05

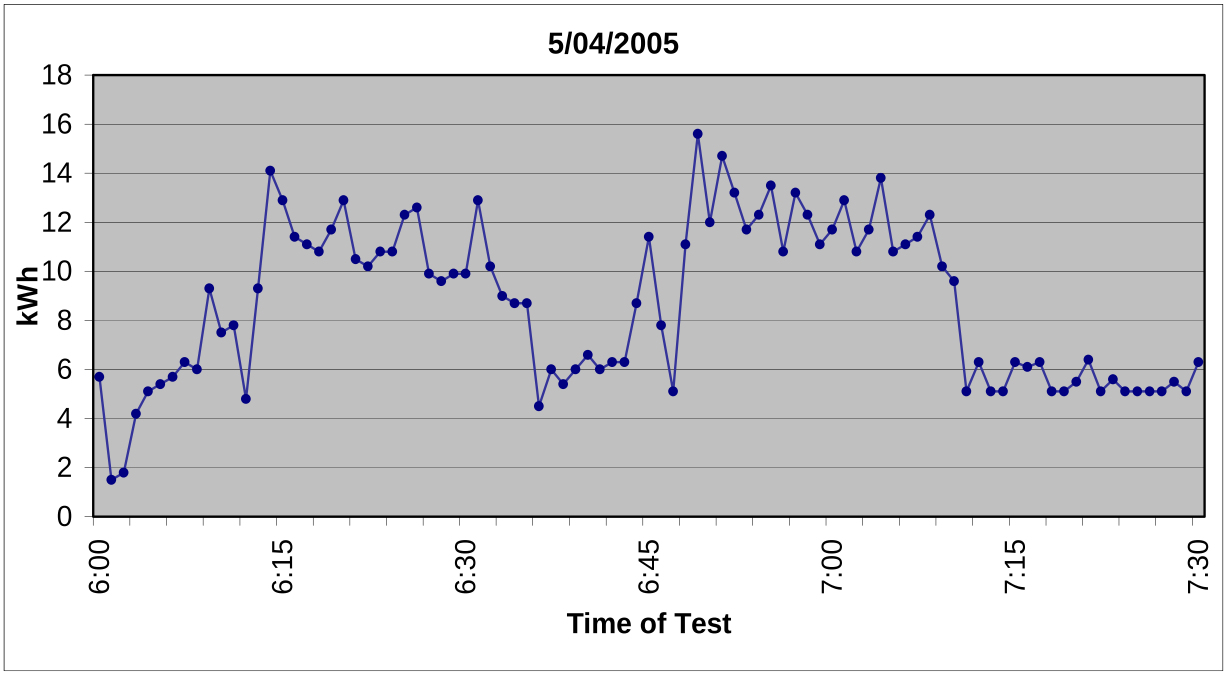
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	24	26	6:02	6:36	0:34	
Load	2	Dark	25	30	6:38	7:10	0:32	
Pressing			49	56	6:40	7:30	0:50	1:28

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			471.2	472.5	1.3
Load	2				472.5	473.8	1.3
Pressing						474.5	
			Total	13.2		Total	3.3

Total kWh Use	13.2	Bckgrnd	1.0	Adjusted	12.2

Summary Results								
	#	kWh	kWh/100 lbs	kWh/100bs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100bs with Distillation
Test	1	-	-	-	2.7	2.8	5.4	6.3
Test	2	12.2	24.9	26.6	3.3	3.4	6.6	7.5
Average		12.2	24.9	26.6	3.0	3.1	6.0	6.9

Comments: During both tests, when the dry clean machine door was opened at the end of each load, the smell of PCE was very strong. The garments felt dry to the touch, but the strong odors suggest that a substantial amount of PCE vapors remained in the cleaning drum. Natural gas and electricity consumption may be understated because of this. The garments processed during the tests were relatively heavy (dark loads), consisting primarily of suit pants and jackets. The boiler was operating at between 50 and 60 psi during both tests (cleaners typcially operate at above 80 psi) which may account for the low gas consumption and explain the strong PCE odors. The installer, Hans Kim, had noted that when the boiler was shut down, the pressure gauge still read 15 psi, suggesting that it was broken. If so, the boiler may have been operating at less than 50 and 60 psi.
*HHV= 1027.3



APPENDIX C: PCE 3 WASHING ENERGY TEST

ID PCE 3 **City** Pasadena **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Dry clean machine	Lindus ML 60	2000	60 lbs	18.5 HP	
Cooling tower fan	RSD TSC 15	2000		0.5 HP	
Cooling tower pump	STA-RITE HF51HL	2000		1.5 HP	
Air compressor	Ingersoll-Rand	2004		5 HP	Had two identical compressors.
Vacuum pump	Rema Dri-Vac			1 HP	
Boiler	Parker	1970	125 psi	9.5 HP	Had two similar boilers, one tested at 73% efficiency, the other at 77%.
Pressing equipment	Two press stations w/ press boards and mushroom heads and one susie. Visible steam leaks from some of the boards and mushrooms.				

Test # 1 **Date** 6/18/05

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark, #5	60	56	7:19	8:10	0:51	
Load	2	Light, #4	60	84	8:39	9:30	0:51	
Pressing			120	140	8:15	10:20	2:05	3:01

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			17.2	20.9	3.7
Load	2				23.9	27.8	3.9
Pressing						32.2	
			Total	23.9		Total	15.0

Total kWh Use	23.9	Bckgrnd		Adjusted	23.9

Test # 2 **Date** 6/25/05

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark, #5	60	57	7:33	8:20	0:47	
Load	2	Light, #4	55	61	8:42	9:33	0:51	
Pressing			115	118	8:40	10:34	1:54	3:01

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			87.5	89.8	2.3
Load	2				91.2	95.2	4.0
Pressing						99.2	
			Total	20.3		Total	11.7

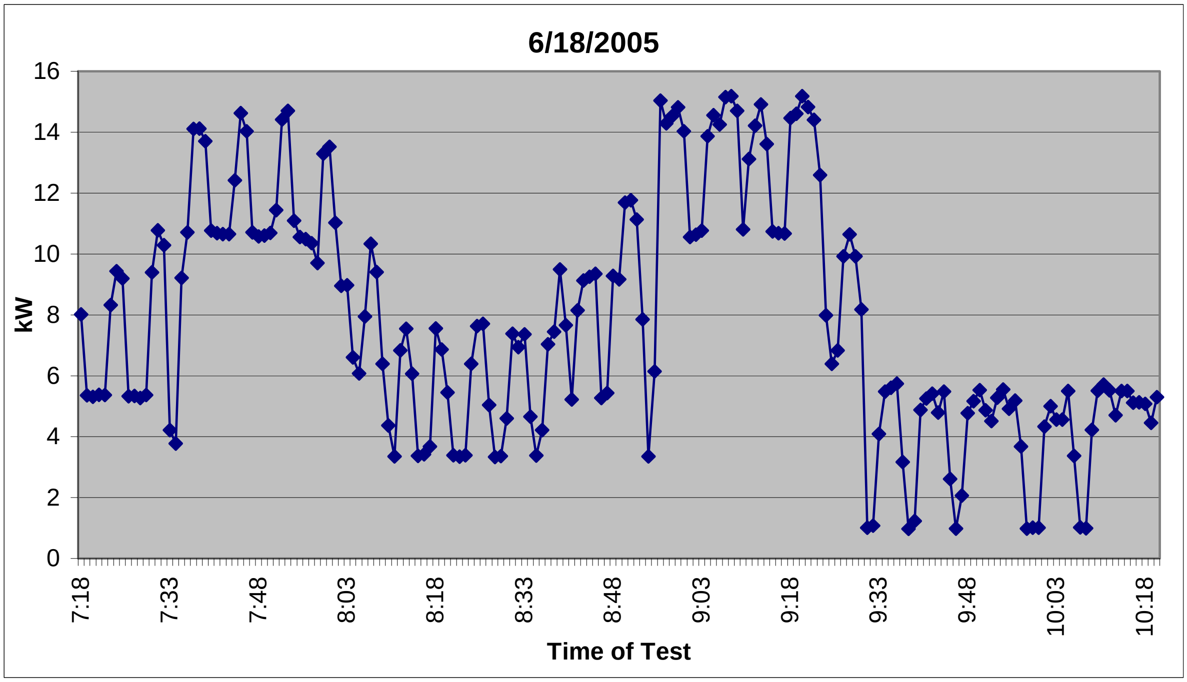
Total kWh Use	20.3	Bckgrnd		Adjusted	20.3

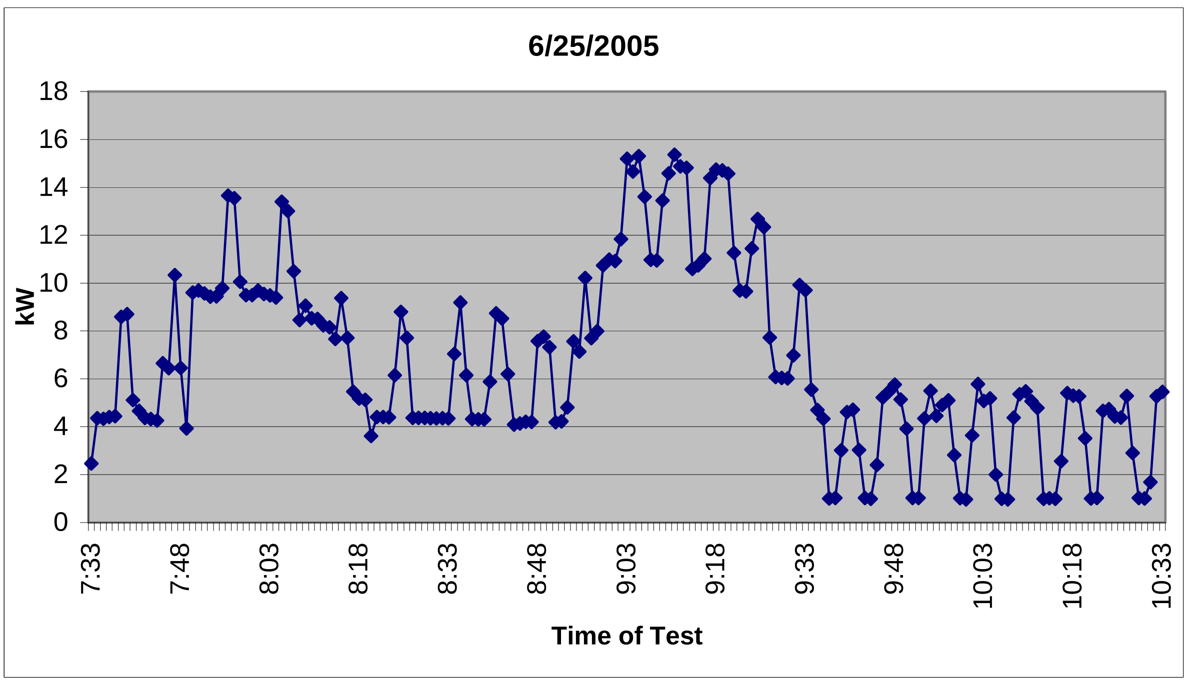
Summary Results								
	#	kWh	kWh/100 lbs	kWh/100 1bs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	23.9	19.9	21.7	15.0	15.2	12.7	13.5
Test	2	20.3	17.7	19.4	11.7	11.9	10.3	11.2
Average		22.1	18.8	20.5	13.4	13.5	11.5	12.4

kWh Submeter Data		
Equipment	Test 1	Test 2
Dry clean machine	8.7	8.6
Cooling tower fan & pump	5.2	4.7
Air compressor	7.1	5.4
Vacuum pump	3.0	1.7
Total	23.9	20.3

*HHV = 1013

Comments: During the first test, the cleaner was operating both boilers. During the second test, the cleaner was asked to use only the more efficient boiler. Sub meter data revealed that the air compressor was running too frequently. An air leak was spotted on the shirt machine, which was not in use during testing. Durin the second test, the supply line the shirt machine was shut down. The air compressor used less energy, but was still running more frequently than it should. The cleaner said he had had problems with air leaks at the connection to the dry clean machine. The vacuum pump used more energy during the first test because it was on for the duration of the test, while during the second test, it wasn't turned on until after the first load. Most cleaners do spotting work during the first load, which often requires the use of the vacuum pump.


6/18/2005
kW
0
2
4
6
8
10
12
14
16
7:18
7:33
7:48
8:03
8:18
8:33
8:48
9:03
9:18
9:33
9:48
10:03
10:18
Time of Test


6/25/2005
kW
0
2
4
6
8
10
12
14
16
18
7:33
7:48
8:03
8:18
8:33
8:48
9:03
9:18
9:33
9:48
10:03
10:18
10:33
Time of Test

APPENDIX D: PCE 4 WASHING ENERGY TEST

ID PCE 4 **City** Santa Ana **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Dry clean machine	Bowe Permac	2002	55lbs	3HP = 60Hz	
Cooling tower fan	RSD 1510	1999	15 gallons	motor 1/2 HP	brown offside
Cooling tower pump	STA-RITE 32080J60002	1999		115/230 volts	
Air compressor	Magnilia electric motor	1987	200 PSI	5HP	
Vacuum pump	Remax DRI_VAC. Model RP-8	about 1994		1.5 HP	
Boiler	Parker Model 103-9.5	1974		9.5	
Pressing equipment					

Test # 1 **Date** 1/30/06

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	50	60	7:13	7:54	0:41	
Load	2	Dark	50	58	7:58	8:37	0:39	
Load	3	Light	50	73	8:42	9:22	0:40	
Pressing			150	191	7:58	10:31	2:33	3:18

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			32.0		(32.0)
Load	2	downloaded from data loggers.			33.2		(33.2)
Load	3				35.2	37.0	1.8
Pressing						39.0	
			Total	21.2		Total	7.0

Total kWh Use	21.2	Bckgrnd	1.5	Adjusted	19.7

Test # 2 **Date** 1/31/06

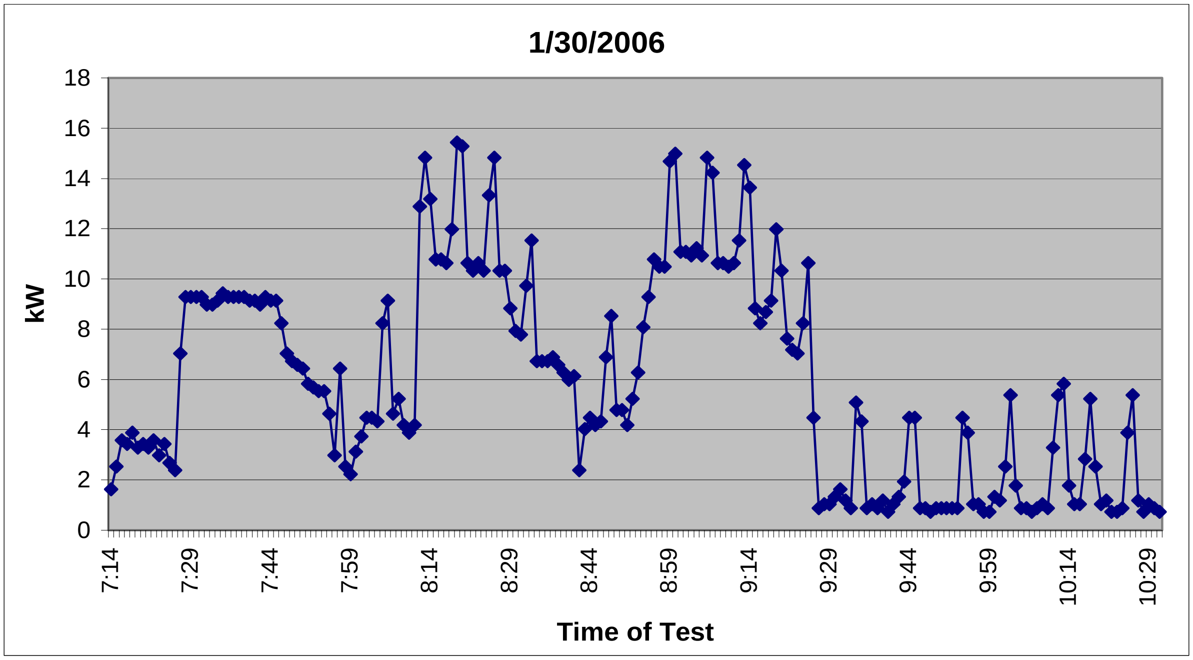
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Clor Bleeder	50	54	7:54	8:06	0:12	
Load	2	Lights	50	79	8:43	8:53	0:10	
Load	3	Lights	50	54	9:32	9:43	0:11	
Pressing			150	187	8:45	11:25	2:40	3:31

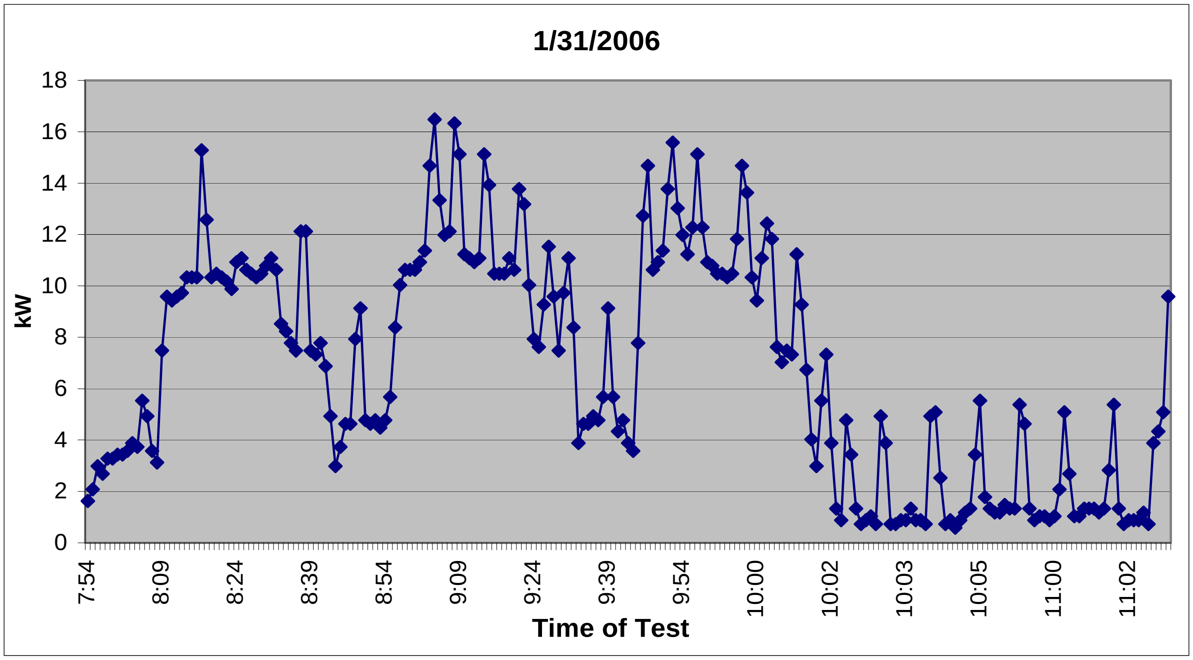
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			53.2	55.1	1.9
Load	2	downloaded from data loggers.			55.1	56.9	1.8
Load	3				56.9	58.4	1.5
Pressing						60.5	
			Total	26.2		Total	7.3

Total kWh Use	26.2	Bckgrnd	1.5	Adjusted	24.7

Summary Results								
	#	kWh	kWh/100 lbs	kWh/100bs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	19.7	13.1	14.8	7.0	7.2	4.8	5.7
Test	2	24.7	16.5	18.2	7.3	7.5	5.0	5.9
Average		22.2	14.8	16.5	7.2	7.3	4.9	5.8

*HHV=1027





APPENDIX E: PCE 5 WASHING ENERGY TEST

ID PCE 5 **City** Sherman Oaks **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Dry clean machine	Union L840-U2000	2002	45lbs	220V	
Cooling tower fan	RSD-10RT	2002.6	10 ton	110v	
Cooling tower pump	Stair-rite	2002.6	1HP	110V	
Air compressor	Falcon	1994	5hp	110v	
Vacuum pump	REMA DRI-VAC	2005 Rebuild	1HP	110v	
Boiler	Thermo Steam	2000	9.5 HP	110v	
Pressing equipment	Cissell 1994 Utility 110V, Cissell 1994 Legger 110V				

Test # 1 **Date** 7/22/06

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	40	35	8:30	9:30	1:00	
Load	2	Dark	40	42	9:40	10:41	1:01	
Load	3	Light	40	40	10:52	11:53	1:01	
Pressing			120	117	11:54	3:25	3:29	5:05

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			55.2	57.5	2.3
Load	2				57.5	59.9	2.4
Load	3				59.9	61.7	1.8
Pressing						67.1	
			Total	34.3		Total	11.9

Total kWh Use	34.3	Bckgrnd	3.8	Adjusted	30.5

Test # 2 **Date** 7/28/06

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	40	32	2:04	3:06	1:02	
Load	2	Dark	42	28	3:13	4:13	1:00	
Load	3	Light	38	36	4:25	5:02	0:37	
Pressing			120	96	8:29	11:05	2:36	9:01

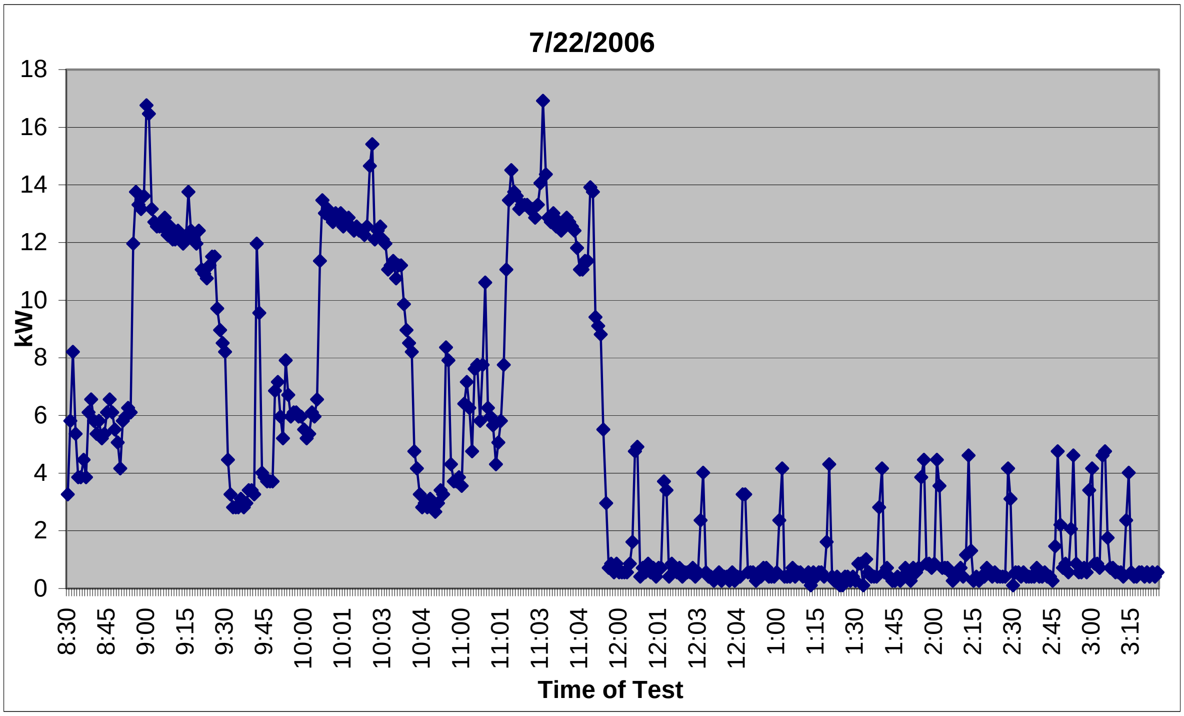
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			49.9	52.2	2.3
Load	2				52.2	54.2	2.0
Load	3				54.2	55.9	1.7
Pressing						67.5	
			Total	25.8		Total	17.6

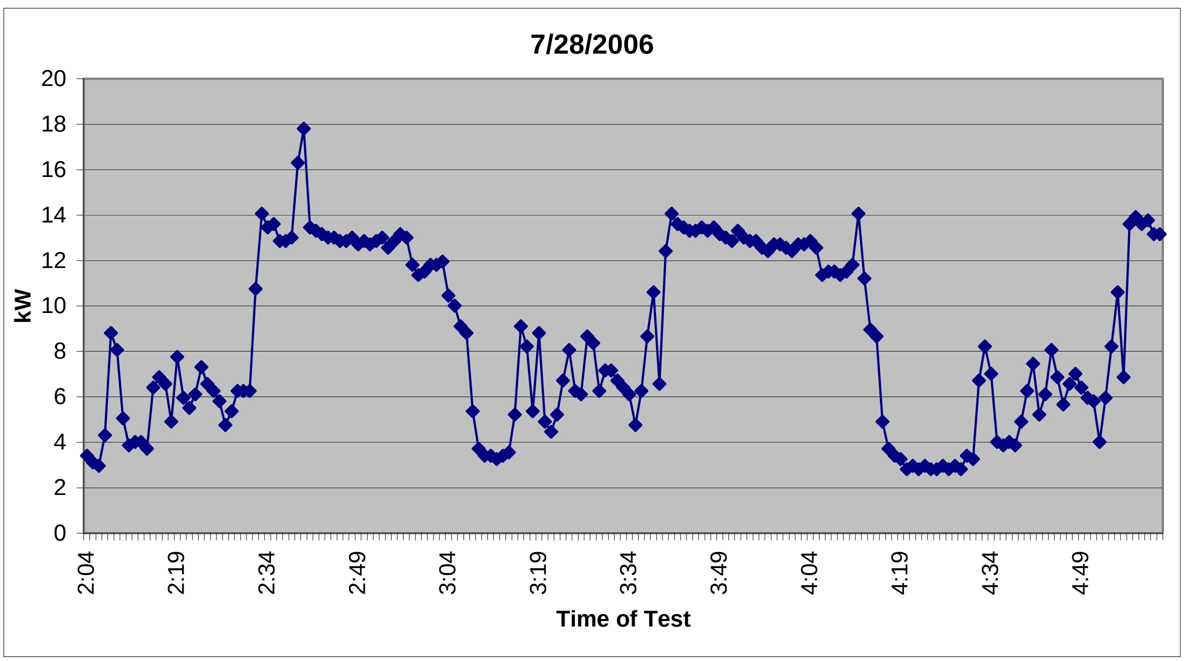
Total kWh Use	25.8	Bckgrnd	3.8	Adjusted	22.0

Summary Results

	#	kWh	kWh/100 lbs	kWh/100lbs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	30.5	25.4	27.2	11.9	12.1	10.1	11.0
Test	2	22.0	18.3	20.1	17.6	18.0	15.0	15.8
Average		26.2	21.9	23.6	14.8	15.0	12.5	13.4

*HHV=1020


7/22/2006
kW
18
16
14
12
10
8
6
4
2
0
8:30
8:45
9:00
9:15
9:30
9:45
10:00
10:01
10:03
10:04
11:00
11:01
11:03
11:04
12:00
12:01
12:03
12:04
1:00
1:15
1:30
1:45
2:00
2:15
2:30
2:45
3:00
3:15
Time of Test


7/28/2006
kW
20
18
16
14
12
10
8
6
4
2
0
2:04
2:19
2:34
2:49
3:04
3:19
3:34
3:49
4:04
4:19
4:34
4:49
Time of Test

APPENDIX F: PCE 6 WASHING ENERGY TEST

ID PCE 6 **City** La Jolla **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Dry clean machine	Bowe P546 Perma	1990	46lbs	208	
Cooling tower fan	KR chiller		5 tons	208	
Cooling tower pump					
Air compressor	Curtis-Toledo	1987	60 gallons	208 5 horsepower	
Vacuum pump	Rema Vacuum			208 1/12 horsepower	
Boiler	Parker	1993	120	9 1/2	
Pressing equipment	6 leggers, 1 form finisher, 1 pants topper				

Test # 1 **Date** 9/12/06

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Light	38	33	6:43	7:31	0:48	
Load	2	Dark	38	38	7:32	7:59	0:27	
Load	3	Light	25	28	8:03	8:39	0:36	
Load	4	Dark	38	40	8:44	9:20	0:36	
Pressing			139	139	7:32	10:32	3:00	3:49

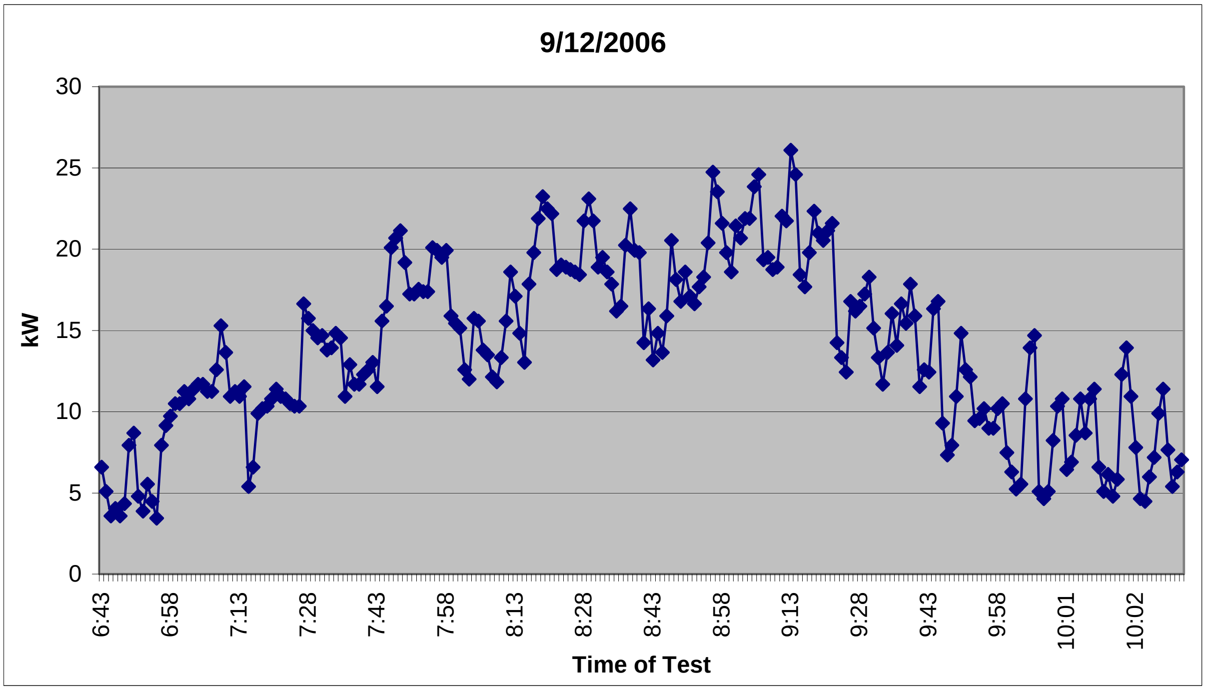
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			296.3	298.9	2.6
Load	2				298.9	300.9	2.0
Load	3				300.9	303.0	2.1
Load	4				303.0	305.2	2.2
Pressing						308.9	
			Total	57.5		Total	14.4

Total kWh Use	57.5	Bckgrnd	2.9	Adjusted	54.6

Summary Results

	#	kWh	kWh/100 lbs	kWh/100bs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	54.6	39.3	41.1	14.4	14.7	10.6	11.5
Average		54.6	39.3	41.1	14.4	14.7	10.6	11.5

*HHV =1023. An adjustment was made for shorting the dryer


9/12/2006
30
25
20
15
10
5
0
kW
6:43
6:58
7:13
7:28
7:43
7:58
8:13
8:28
8:43
8:58
9:13
9:28
9:43
9:58
10:01
10:02
Time of Test

APPENDIX G: PCE 7 WASHING ENERGY TEST

ID PCE 7 **City** Alpine **State** CA

Equipment	**Model**	**Year**	**Capacity**	**Power**	**Comments**
Dry clean machine	Macchine Supreman Premier 903		35lbs	PSI 119, Volt 200	
Cooling tower fan					
Cooling tower pump					
Air compressor	Rand 4000			5HP	
Vacuum pump					
Boiler	Parker 103 9.5	1995	68	9.5HP, 100PSI	Serial # 45583
Pressing equipment					

Test # 1 **Date** 5/4/07

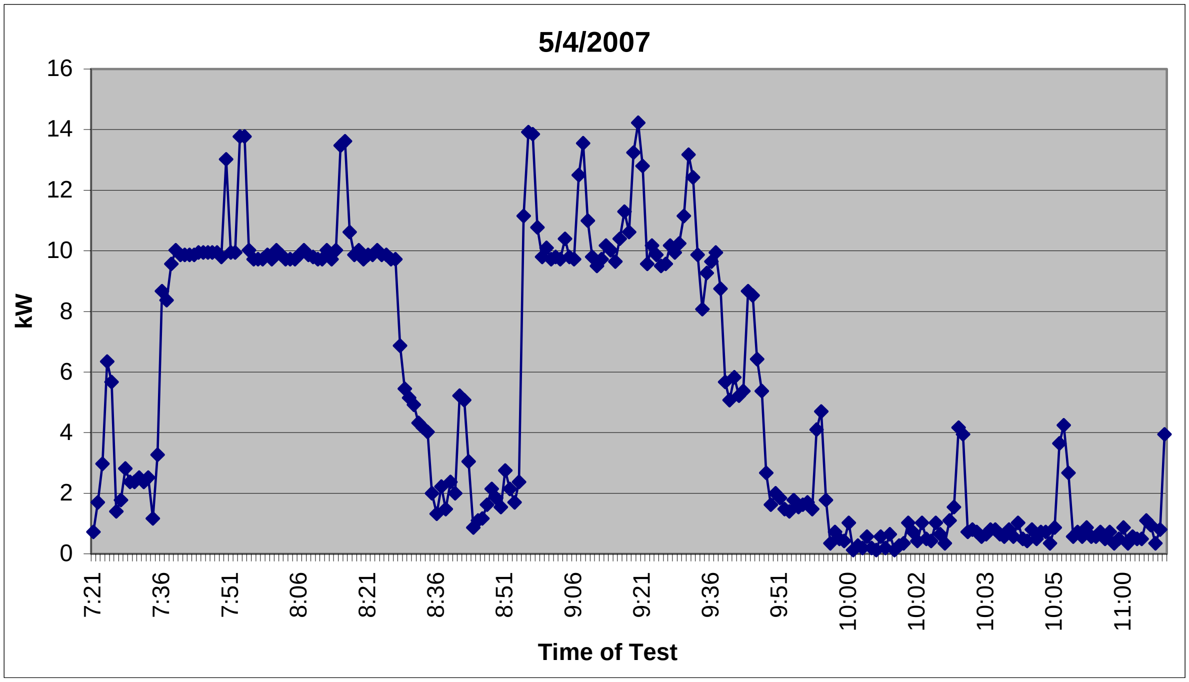
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	20	20	7:21	7:34	0:13	
Load	2	Dark	20	20	8:36	8:52	0:16	
Pressing			40	40	8:35	11:15	2:40	3:54

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			59.5		(59.5)
Load	2				62.0	63.9	1.9
Pressing						66.0	
			Total	22.6		Total	6.5

Total kWh Use	22.6	Bckgrnd	1.5	Adjusted	21.1

Summary Results								
	#	kWh	kWh/100 lbs	kWh/100bs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	21.1	52.8	54.5	6.5	6.6	16.5	17.3
Average		21.1	52.8	54.5	6.5	6.6	16.5	17.3

HHV =1013


5/4/2007
kW
16
14
12
10
8
6
4
2
0
7:21
7:36
7:51
8:06
8:21
8:36
8:51
9:06
9:21
9:36
9:51
10:00
10:02
10:03
10:05
11:00
Time of Test

APPENDIX H: PCE 8 WASHING ENERGY TEST

ID PCE 8 **City** San Lorenzo **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Dry clean machine	VIC Manufacturing M/N 1250F/S07	1996	50lbs	220V / 3p / 60hz / 40A	
Cooling tower fan	Arctic Chill M/N S-5 S/N 0250191205				
Cooling tower pump	Magnetek Century Electric			1-hp DP 230V / 1p / 6.5A	
Air compressor	Speedaire M/N 3Z421B			2-hp Leeson motor 230V / 11A	
Vacuum pump	Rema Dri-Vac			1½-hp Leeson motor 230V / 8.6A	
Boiler	Parker 15 BHP	1988	Input: 645,000 Btu/hr	105 psi	
Pressing equipment					

Test # 1 **Date** 1/23/07

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Light	35	36	7:35	8:37	1:02	
Load	2	Dark	50	46	8:39	9:32	0:53	
Load	3	Dark	50	53	9:33	10:22	0:49	2:47

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			3.0	6.2	3.2
Load	2				6.9	9.3	2.4
Load	3				9.3	14.5	5.2
			Total	35.0			11.5

Total kWh Use	35.0	Bckgrnd	1.4	Adjusted	33.6

Summary Results

	#	kWh	kWh/100 lbs	kWh/100 lbs with Distillation	HCF	Therms*	Therms/ 100 lbs	Therms/100 lbs with Distillation
Test	1	33.6	24.9	26.6	11.5	11.8	8.7	9.6
Average		33.6	24.9	26.6	11.5	11.8	8.7	9.6

*HHV = 1022.91

APPENDIX I: PCE 9 DISTILLATION ENERGY TEST

ID PCE 9 **City** Pasadena **State** CA

Equipment	**Model**	**Year**	**Capacity**	**Power**	**Comments**
Dry clean machine	Multimatic L505	2005	50lb	Volts: 220; Amps: 50	
Cooling tower fan		2005			
Cooling tower pump		2005			
Air compressor					
Vacuum pump					
Boiler					
Pressing equipment	Unipress pants topper and form finisher: 3 leggers, spotter, 2 forenta puffers, 2 presses				

Test # 1 **Date** 10/18/07

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1				3:38	5:24	1:46	
Pressing			-	-	-	-	-	1:46

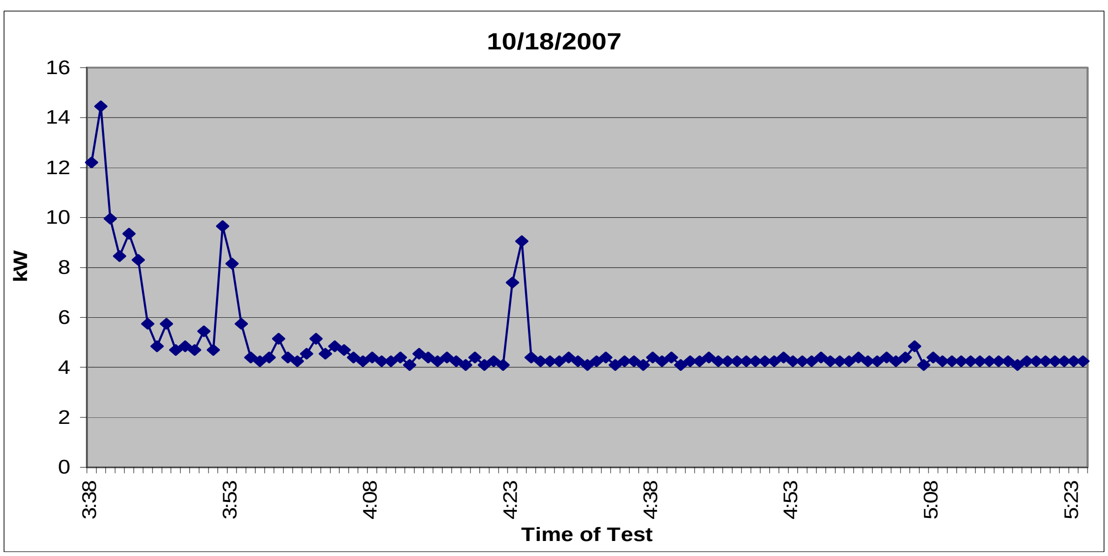
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			52.8	57.1	4.3
Pressing						-	
			Total	12.7		Total	4.3

Total kWh Use	12.7	Bckgrnd	4.0	Adjusted	8.7

Summary Results

	#	kWh	kWh/100bs during Distillation	HCF	Therms*	Therms/100 lbs during Distillation
Test	1	8.7	1.74	4.3	4.36	0.87
Average		8.7	1.74	4.3	4.36	0.87

*HHV =1013



APPENDIX J: CO_2 1 WASHING ENERGY TEST

ID CO2 1 **City** North Hollywood **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Dry clean machine	Chart CO2O L55	2003	55 lbs		Total power was not listed, but a 15 HP CO2 compressor was built in.
Chiller (fan and pump)	York	2003		2.25 HP	Fan - 0.75 HP, Pump - 1.5 HP.
Air compressor				5 HP	
Vacuum pump	Leeson			1 HP	
Boiler	Parker	2003		9.5 HP	Boiler had been having trouble maintaining pressure and was serviced before testing.
Pressing equipment	2 pressing boards, 1 susie, 1 pants topper, electric irons. Appeared to be in good condition.				

Test # 1 **Date** 7/31/04

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Light, 1 Bath	22	36	10:01	10:39	0:38	
Load	2	Dark, 1 Bath	40	39	10:55	11:32	0:37	
Pressing			62	75	10:45	14:22	3:37	4:21

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			887.1	888.5	1.4
Load	2	downloaded from data loggers.			888.9	890.2	1.3
Pressing						896.2	
			Total	21.1		Total	9.1

Test # 2 **Date** 8/2/04

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	35	39	7:37	8:12	0:35	
Load	2	Light	30	35	8:37	9:09	0:32	
Pressing			65	74	8:15	12:15	4:38	4:38

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			932.8	934.0	1.2
Load	2	downloaded from data loggers.			934.9	936.1	1.2
Pressing						940.6	
			Total	19.9		Total	7.8

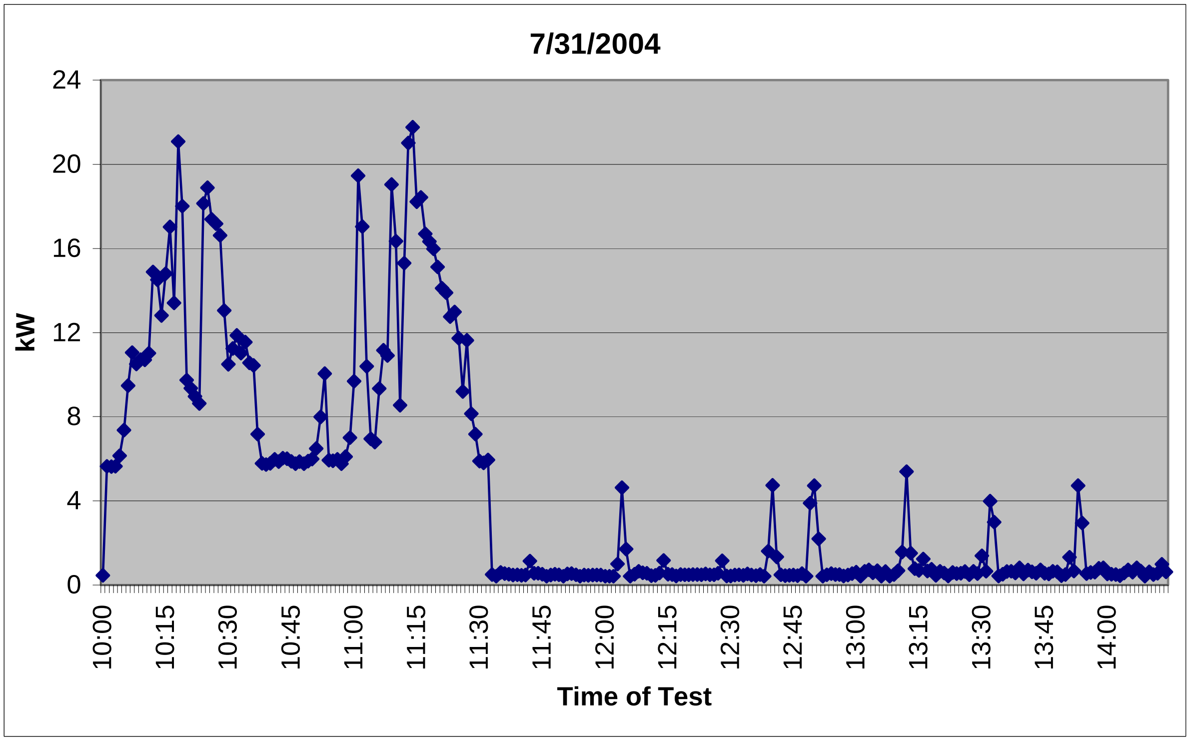
Summary Results

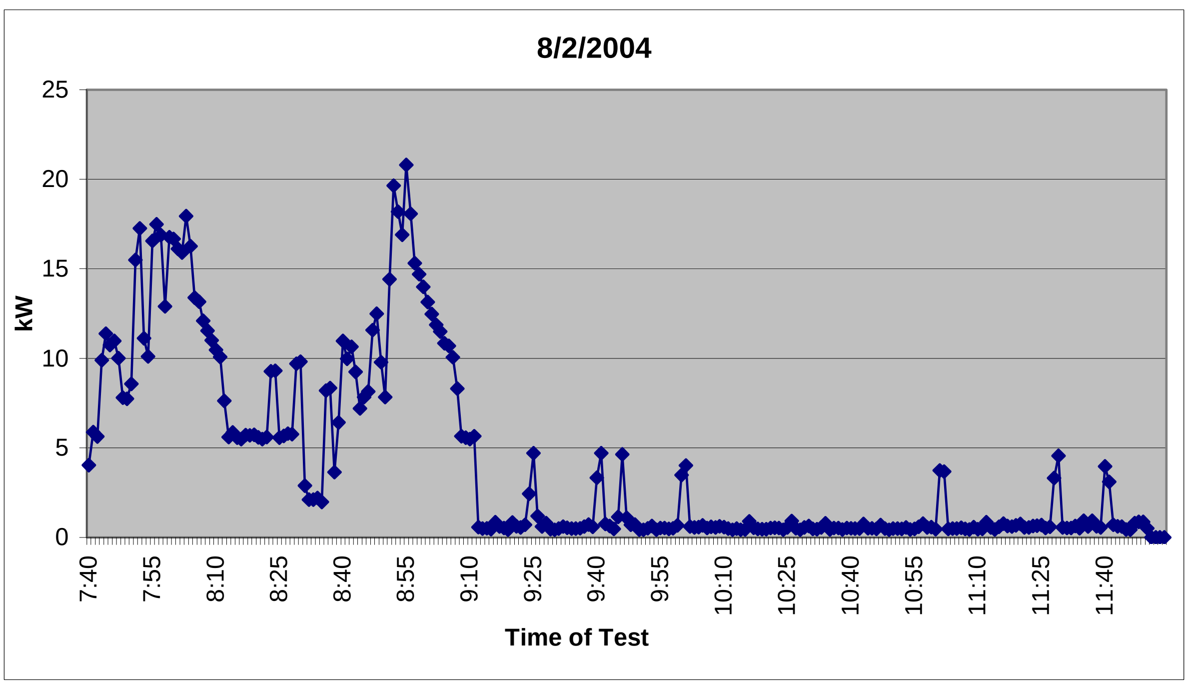
	#	kWh	kWh/100 lbs	kWh/100 lbs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	21.1	34.0	37.6	9.1	9.4	15.1	15.6
Test	2	19.9	30.6	34.2	7.8	8.0	12.4	12.8
Average		20.5	32.3	35.9	8.5	8.7	13.8	14.2

kWh Submeter Data

Equipment	Test 1	Test 2
Dry clean machine	7.9	7.5
Chiller fan	7.7	6.3
Chiller pump	2.4	2.4
Air compressor	0.9	1.5
Vacuum pump	2.3	2.2
Total	21.2	19.9

Comments: The chiller fan and pump accounted for about 40% and 35% of total energy consumption in the two tests. The motors were rated at a total of 2.25 HP or about 1.7 kW, but according to the sub meters they were drawing about 5.2 kW during the time the dry clean machine was operating. If the chiller had been instead drawing 1.7 kW for the 1.5 hours (approx.) the machine was on for each test, total consumption would have been 1.7 kW * 2 hrs = 3.4 kWh. Total consumption was actually 7.7 kWh (test 1) and 6.3 kWh (test 2). That amounts to an increase of 3 to 4 kWh per test, and about 4.7 to 6.3 kWh per 100 lbs. It should also be noted that the loads processed were relatively small and the chiller likely uses the same amount of power regardless of load size. *HHV =1032


7/31/2004
kW
0
4
8
12
16
20
24
10:00
10:15
10:30
10:45
11:00
11:15
11:30
11:45
12:00
12:15
12:30
12:45
13:00
13:15
13:30
13:45
14:00
Time of Test


8/2/2004
kW
0
5
10
15
20
25
7:40
7:55
8:10
8:25
8:40
8:55
9:10
9:25
9:40
9:55
10:10
10:25
10:40
10:55
11:10
11:25
11:40
Time of Test

CO2 -1 DISTILLATION ENERGY TEST

Test # Distillation **Date** 8/3/04

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Distillation	-	-	2:32	4:00	1:28	
Pressing			-	-	-	-	-	1:28

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			5,942.7	5,945.1	2.4
Pressing						-	
			Total	-		Total	2.4

Total kWh Use	-	Bckgrnd	-	Adjusted	-

Summary Results							
	#	kWh	kWh/100bs during Distillation	HCF	Therms*	Electricity used adjusted to 50 lb machine (therms)	Therms/100 lbs during Distillation
Test	1	-	-	2.4	2.47	2.25	0.45
Average		-	-	2.4	2.47	2.25	0.45

** Electricity not measured during distillation. Technical consultant to CO2-1 cleaners stated electricity use during distillation should be comparable to that used during a typical cleaning cycle. Electricity used during average cleaning cleaning = 7.5 kWh/35 minute cycle. Therefore proporation increase = 19.8 kWh/90 minute distillation cycle. *HHV =1030

APPENDIX K: CO2 – 2 WASHING ENERGY TEST

ID CO2 2 **City** Santa Monica **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Dry clean machine	Sailstare CD 60.3	2003	60 lbs	80AMp, 240 VOC	
Cooling tower fan	Carrier Chiller	2003	10 Ton	240	
Cooling tower pump					
Air compressor	Devair #247	203	Sh:184, HD 149; GAL	650 F/MADWP	
Vacuum pump	Rema S5014	2003	15 gallons	220 voltage	
Boiler	Parker 9.5 LA			9.5 HP	80.1% efficiency
Pressing equipment	Hoffman Manuals, 42" length, 1960s. 3 presses. Viet Spotting board, Veit 7406				

Test # 1 **Date** 4/1-4/3/06

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Program #2	49	49	7:30	8:15	0:45	
Load	2	Program #2	33	33	8:22	9:02	0:40	
Pressing			82	82	7:23	10:12	2:49	2:42

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			52.6		(52.6)
Load	2	downloaded from data loggers.			55.8	58.4	2.6
Pressing						58.4	
			Total	24.9		Total	5.8

Total kWh Use	24.9	Bckgrnd	1.6	Adjusted	23.3

Test # 2 **Date** 4/15/06

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Program #2	54	54	7:24	8:12	0:48	
Load	2	Program #2	35	35	8:15	8:57	0:42	
Pressing			89	89	7:17	10:01	2:44	2:37

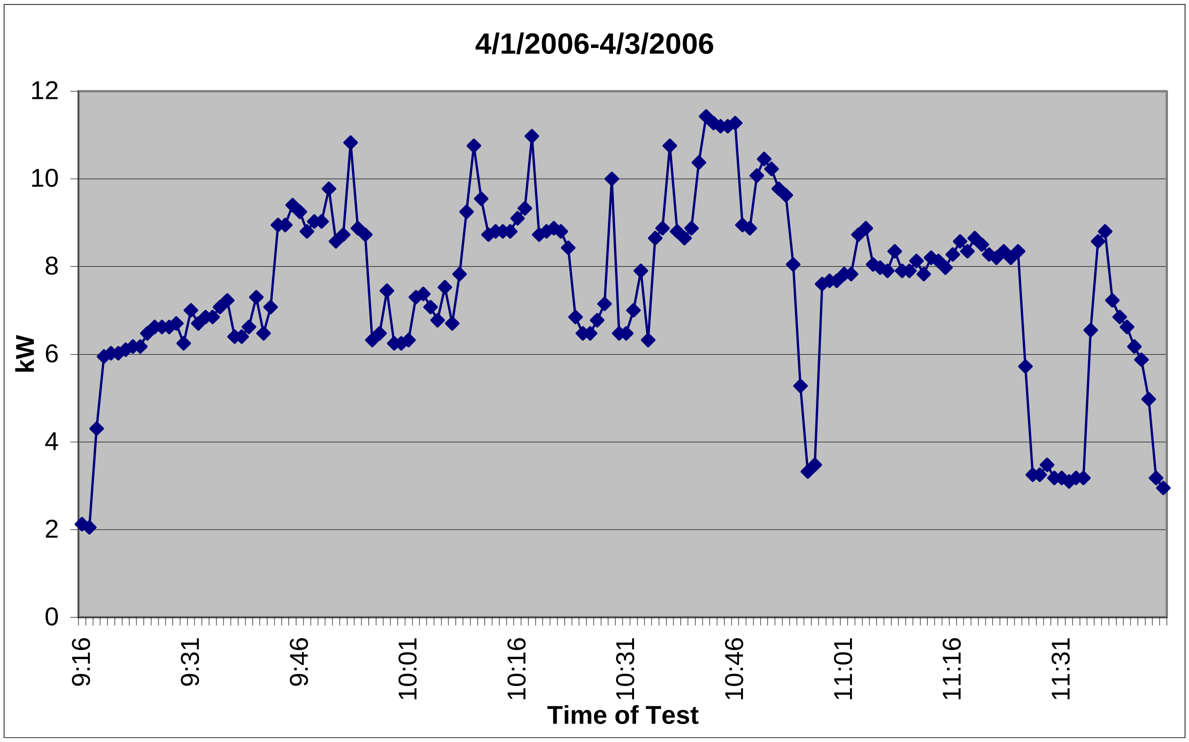
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			597.5		(597.5)
Load	2	downloaded from data loggers.					-
Pressing						603.7	
			Total	16.8		Total	6.2

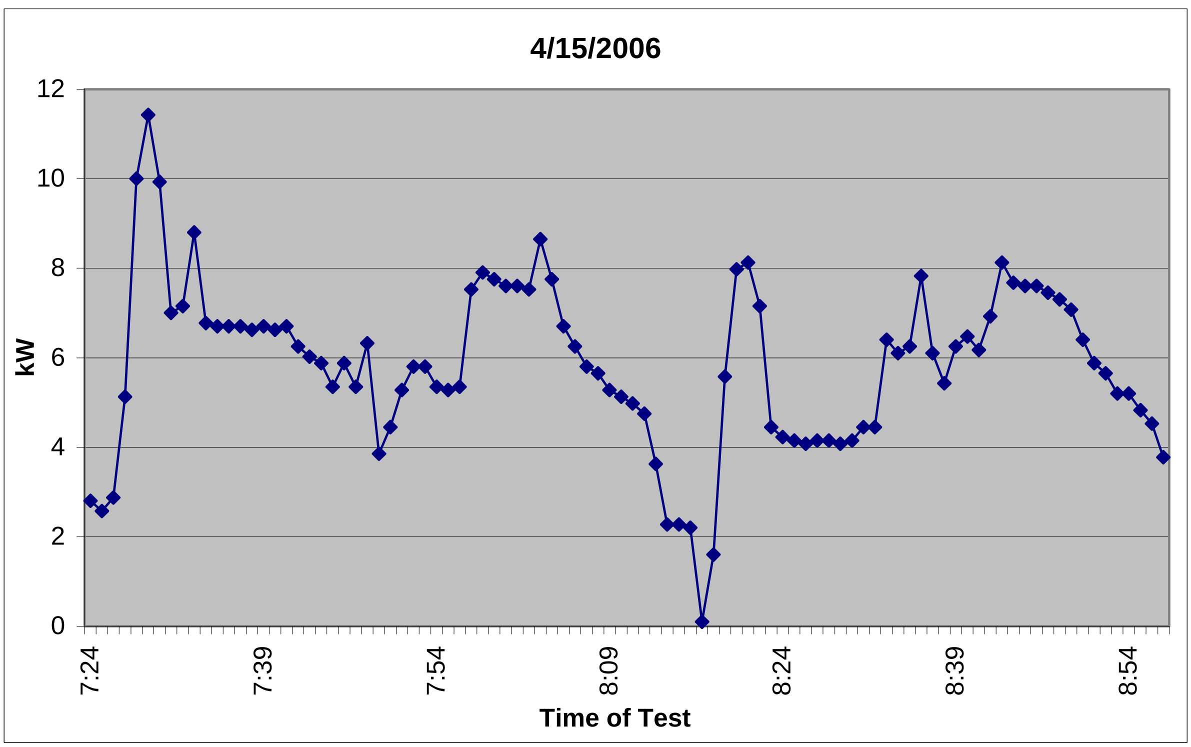
Total kWh Use	16.8	Bckgrnd	1.6	Adjusted	15.1

Summary Results

	#	kWh	kWh/100 lbs	kWh/100 lbs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	23.3	28.4	31.6	5.8	6.0	7.3	n/a
Test	2	15.1	17.0	20.2	6.2	6.4	7.2	n/a
Average		19.2	22.7	25.9	6.0	6.2	7.3	n/a

*HHV =1037


4/1/2006-4/3/2006
12
10
8
6
4
2
0
kW
9:16
9:31
9:46
10:01
10:16
10:31
10:46
11:01
11:16
11:31
Time of Test


4/15/2006
12
10
8
6
4
2
0
kW
7:24
7:39
7:54
8:09
8:24
8:39
8:54
Time of Test

CO_2 - 2 DISTILLATION ENERGY TEST

Test # Distillation **Date** 4/1/06

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Distillation	-	-	9:16	11:45	2:29	
Pressing			-	-	-	-	-	2:29

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			-	-	-
Pressing						-	
			Total	22.85		Total	-

Total kWh Use	22.85	Bckgrnd	3.54	Adjusted	19.31

Summary Results

	#	kWh	Electricity used adjusted to 60 lb machine (kWh)	kWh/100bs during Distillation	HCF	Therms*	Therms/100 lbs during Distillation
Test	1	19.31	16.1	3.22	-	-	-
Average		19.31	16.1	3.22	-	-	-

*No natural gas was used during the distillation for CO2 machine.

APPENDIX L: SIL1 WASHING ENERGY TEST

ID Silicone 1 **City** Los Angeles **State** CA

Equipment	**Model**	**Year**	**Capacity**	**Power**	**Comments**
Dry clean machine	Realstar KM500		60 lbs		
Cooling tower fan	RSD 620			0.5 HP	
Cooling tower pump	STA-RITE JHG-52HL			2 HP	
Air compressor	Rol-Air Systems, Manchester tank	1995	200 PSI	5 HP	Was an air/steam leak on the dry clean machine, compressor was running almost constantly during testing.
Vacuum pump	No visible labels				
Boiler	ThermoSteam	2004	1,000 BTU	15 HP	The boiler was serviced between Tests 1 and 2 b/c it couldn't maintain pressure.
Pressing equipment	Two pressing stations, steam irons, and Hi-Steam tensioning pants topper and form finisher.				

Test # 1 **Date** 8/23/04

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Full dark, #6	55	85	5:53	7:13	1:20	
Load	2	Full light, #2	55	80	7:16	8:26	1:10	
Pressing			110	165	7:17	10:14	2:57	4:21

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			60.0	64.2	4.2
Load	2				64.2	68.0	3.8
Pressing						72.9	
			Total	50.7		Total	12.9

Total kWh Use	50.7	Bckgrnd	1.9	Adjusted	48.9

Test # 2 **Date** 9/14/04

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Full light, #2	58	83	6:02	7:12	1:10	
Load	2	Full dark, #1	55	72	7:19	8:23	1:04	
Load	3	Half light, #4	32	45	8:29	9:37	1:08	
Pressing			145	200	7:14	10:58	3:44	4:56

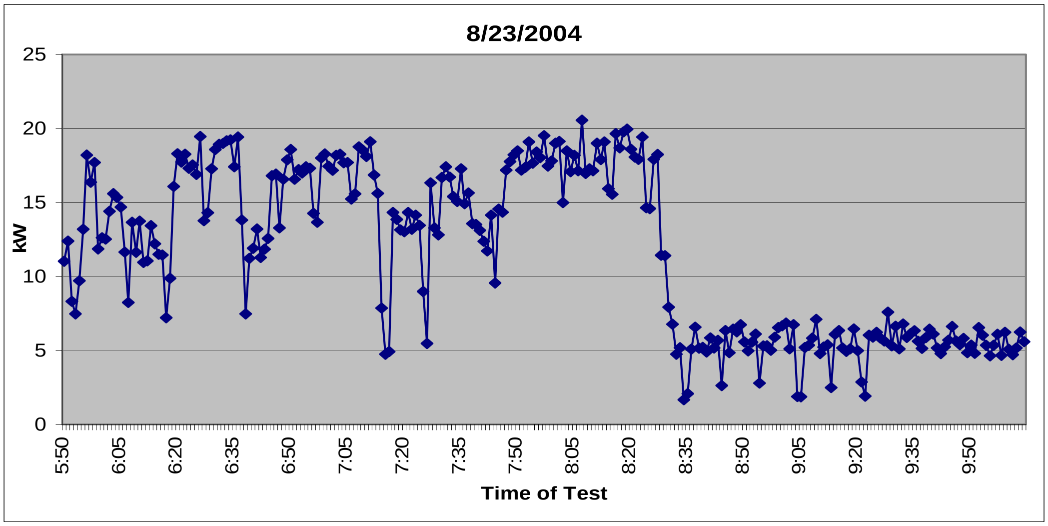
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			99.6	103.5	3.9
Load	2				103.5	107.5	4.0
Load	3				107.5	111.5	4.0
Pressing						114.8	
			Total	63.2		Total	15.2

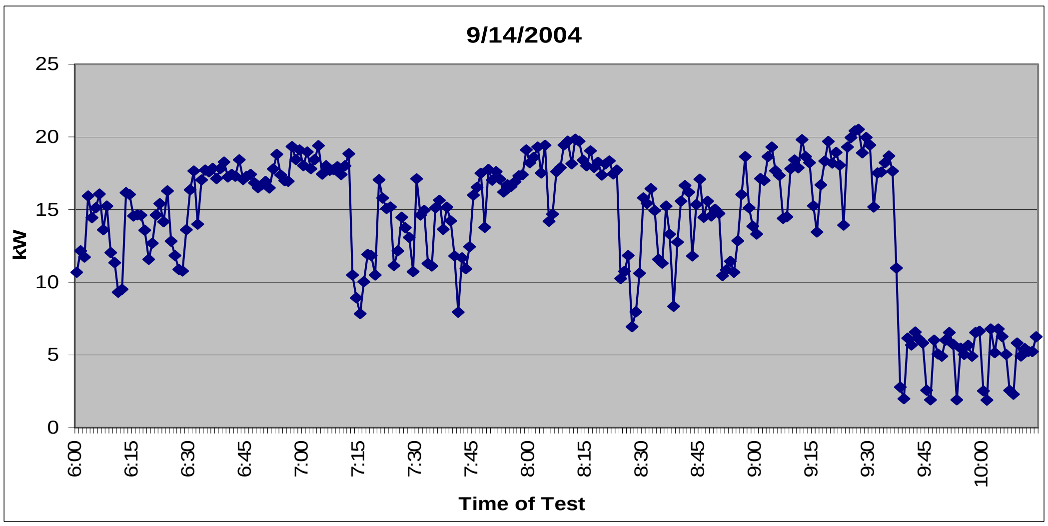
Total kWh Use	63.2	Bckgrnd	1.9	Adjusted	61.4

Summary Results								
	#	kWh	kWh/100 lbs	kWh/100 lbs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	48.9	44.4	48.3	12.9	13.1	11.9	13.3
Test	2	61.4	42.3	46.2	15.2	15.5	10.7	12.0
Average		55.1	43.4	47.3	14.1	14.3	11.3	12.7

kWh Submeter Data		
Equipment	Test 1	Test 2
Dry clean machine	19.6	27.1
Cooling tower fan	1.6	2.2
Cooling tower pump	6.1	8.3
Air compressor	14.5	15.9
Vacuum pump	6.6	7.6
Total	48.5	61.1

Comments: The cooling tower pump was rated at 2 HP (1.5 kW), but it drew about 2.25 kW while in operation. The air compressor ran almost constantly during testing, using about 10 kWh per 100 lbs more than other air compressors tested. An air/steam leak was identified in two places at the back of the dry clean machine after testing had been completed.
*HHV = 1017





APPENDIX M: SIL 2 WASHING ENERGY TEST

ID Silicone 2 **City** Chino Hills **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Dry clean machine	Firbimatic Eco-Green 50	2003	50 lbs	14 kW	
Cooling tower fan	Amcot	2003	80,000 BTU/hr	Not legible	Most cooling tower fans are 0.75 HP
Cooling tower pump	STA-RITE	2003		1.5 HP	
Air compressor	Falcon	2003		7.5 HP	
Vacuum pump	Rema	2003		1.5 HP	
Boiler	Fulton	2003		15 HP	
Pressing equipment					

Test # 1 **Date** 9/9/05

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark, Cycle #13	45	51	7:30	8:46	1:16	
Load	2	Whites, Program #16	40	55	8:51	10:10	1:19	
Pressing			85	106	8:53	11:35	2:42	4:05

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			24.6	28.6	4.0
Load	2	downloaded from data loggers.			28.6	32.4	3.8
Pressing						35.6	
			Total	54.1		Total	11.0

Total kWh Use	54.1	Bckgrnd	2.2	Adjusted	51.9

Test # 2 **Date** 9/16/05

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark, Program #14	47	67	7:28	8:44	1:16	
Load	2	Whites, Program #16	45	68	8:52	10:08	1:16	
Pressing			92	135	8:53	11:51	2:58	4:23

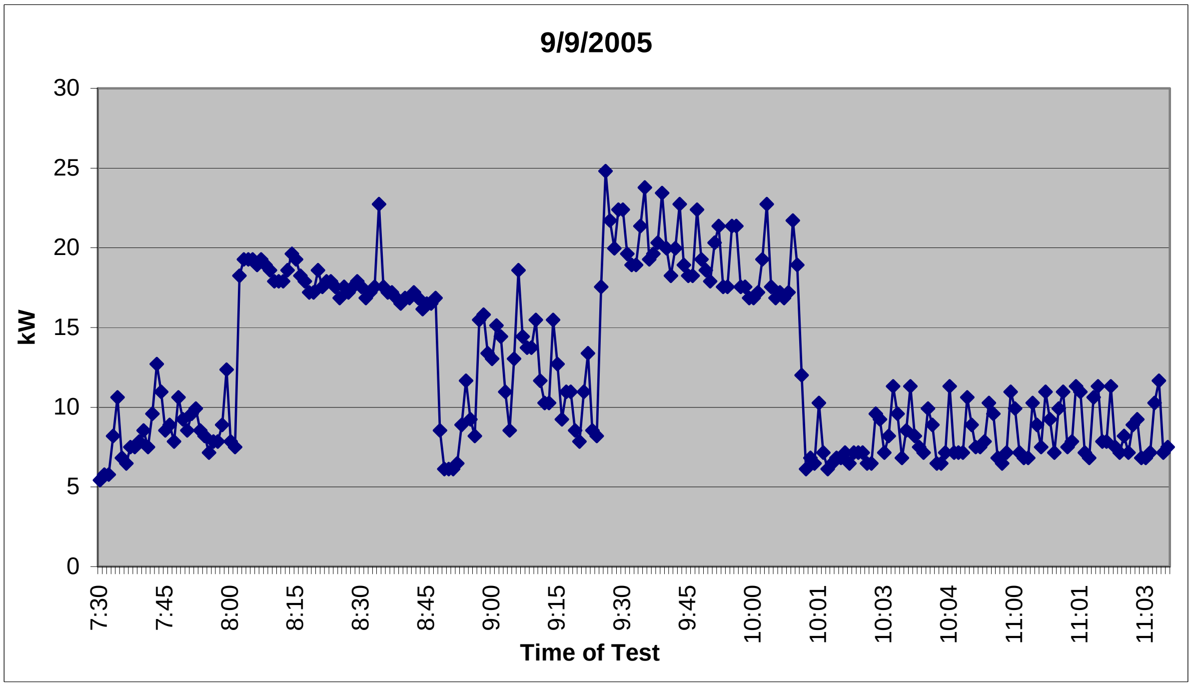
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			56.6	59.8	3.2
Load	2	downloaded from data loggers.			59.8	63.5	3.7
Pressing						67.5	
			Total	51.2		Total	10.9

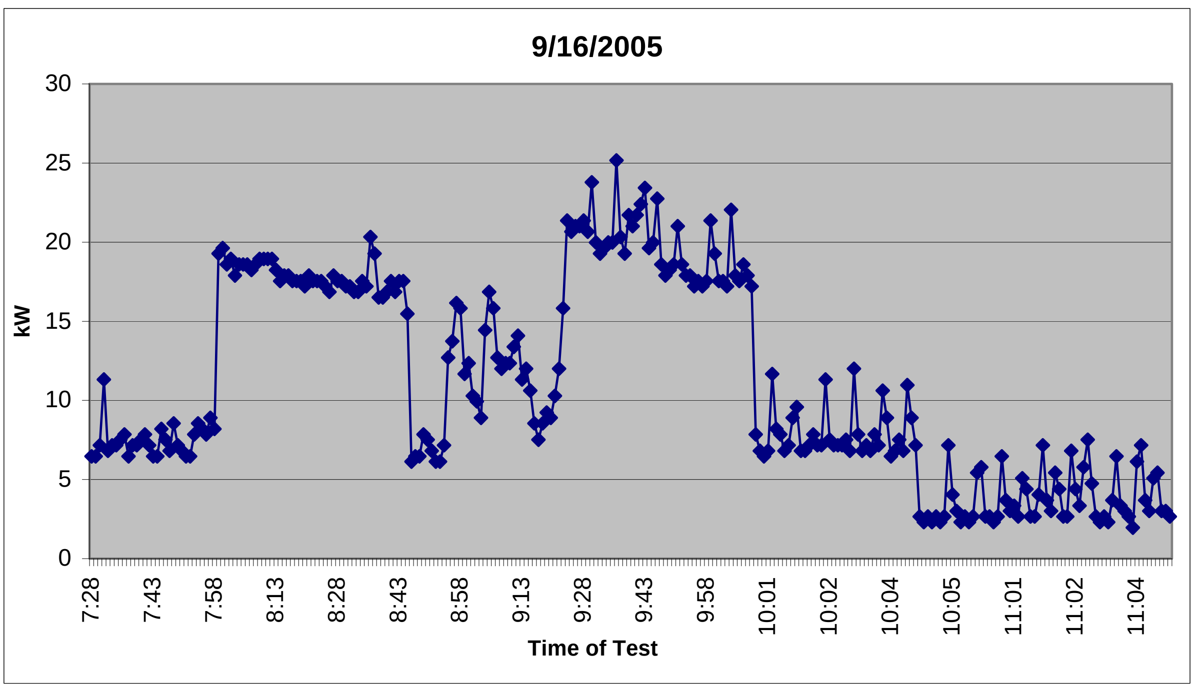
Total kWh Use	51.2	Bckgrnd	2.2	Adjusted	49.0

Summary Results

	#	kWh	kWh/100 lbs	kWh/100 lbs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	51.9	61.1	65.0	11.0	11.2	13.2	14.6
Test	2	49.0	53.2	57.1	10.9	11.1	12.1	13.4
Average		50.4	57.2	61.1	11.0	11.2	12.6	14.0

HHV = 1018.7


9/9/2005
kW
30
25
20
15
10
5
0
7:30
7:45
8:00
8:15
8:30
8:45
9:00
9:15
9:30
9:45
10:00
10:01
10:03
10:04
11:00
11:01
11:03
Time of Test


9/16/2005
kW
30
25
20
15
10
5
0
7:28
7:43
7:58
8:13
8:28
8:43
8:58
9:13
9:28
9:43
9:58
10:01
10:02
10:04
10:05
11:01
11:02
11:04
Time of Test

APPENDIX N: PWC 1 WASHING ENERGY TEST

ID Professional Wet Cleaning 1 **City** Rancho Cucamonga **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Wet Clean Washer	Miele WS5191		42 lbs	2.5 kW	
Wet Clean Dryer	Miele T6185/T6551		54 lbs/17lbs	1.05 kW	
Air compressor					
Vacuum pump	Rema				
Boiler	Lattner	2003	150 psi	9.5 HP	Tested at ???? Efficiency
Pants Topper	Veit				
Form Finisher	Veit				
Pressing equipment					

Test # 1 **Date** 4/16/04

Washer and Pressing								
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Wet Cln Dark, #3	29	38	6:19	6:35	0:16	
Load	2	Wet Wsh Light	30	29	6:40	7:19	0:39	
Load	3	Wet Clean Dark	31	33	7:26	7:41	0:15	
Load	4	Wet Clean Dark	26	40	8:09	8:25	0:16	
Pressing			115	140	7:09	10:53	3:44	4:34

Dryer							
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed
Load	1	22%	29	38	6:57	7:23	0:26
Load	2	16%	30	29	7:24	7:44	0:20
Load	3	16%	31	33	7:45	8:13	0:28
Load	4	16%	26	40	8:27	8:55	0:28

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			Data based on submeter data downloaded from data loggers.		
Load	2						
Load	3						
Load	4						
Pressing							
			Total	12.4		Total	10.0

Test # 2 **Date** 4/28/04

Washer and Pressing								
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Wet Clean Dark	30	35	6:37	6:53	0:16	
Load	2	Wet Clean Dark	30	35	6:55	7:10	0:15	
Load	3	Wet Clean Light	25	33	7:13	7:29	0:16	
Load	4	Wet Clean Light	26	32	7:31	7:47	0:16	
Pressing			111	135	7:53	10:10	2:17	3:33

Dryer							
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed
Load	1	3 min	29	39	7:11		0:00
Load	2	3 min	42	42		7:14	7:11
Load	3	5 min	29	51	7:30	7:35	0:05
Load	4	3 min	28	50	7:48	7:52	0:04

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			Data based on submeter data		
Load	2	downloaded from data loggers.			downloaded from data loggers.		
Load	3						
Load	4						
Pressing							
			Total	8.4		Total	7.0

Test # 3 **Date** 5/17/04

Washer and Pressing								
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Wet Cln Dark, #1	29	39	6:26	6:42	0:16	
Load	2	Wet Wsh Dark, #5	42	42	6:56	7:31	0:35	
Load	3	Wet Cln Light, #3	29	51	7:38	7:54	0:16	
Load	4	Wet Cln Light, #3	28	50	8:08	8:24	0:16	
Pressing			128	182	8:28	11:17	2:49	4:51

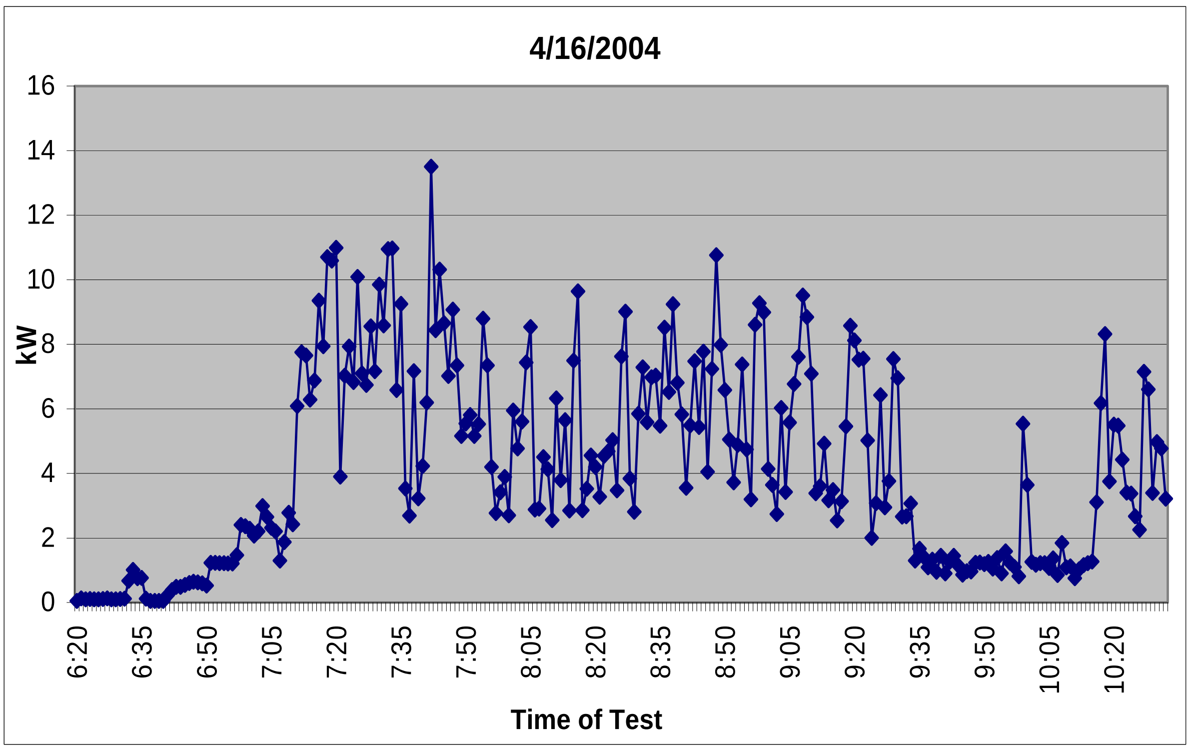
Dryer							
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed
Load	1	3 min	29	39	6:45	6:48	0:03
Load	2	16%	42	42	7:34	7:45	0:11
Load	3	16%	29	51	7:55	8:04	0:09
Load	4	3 min	28	50	8:25	8:33	0:08

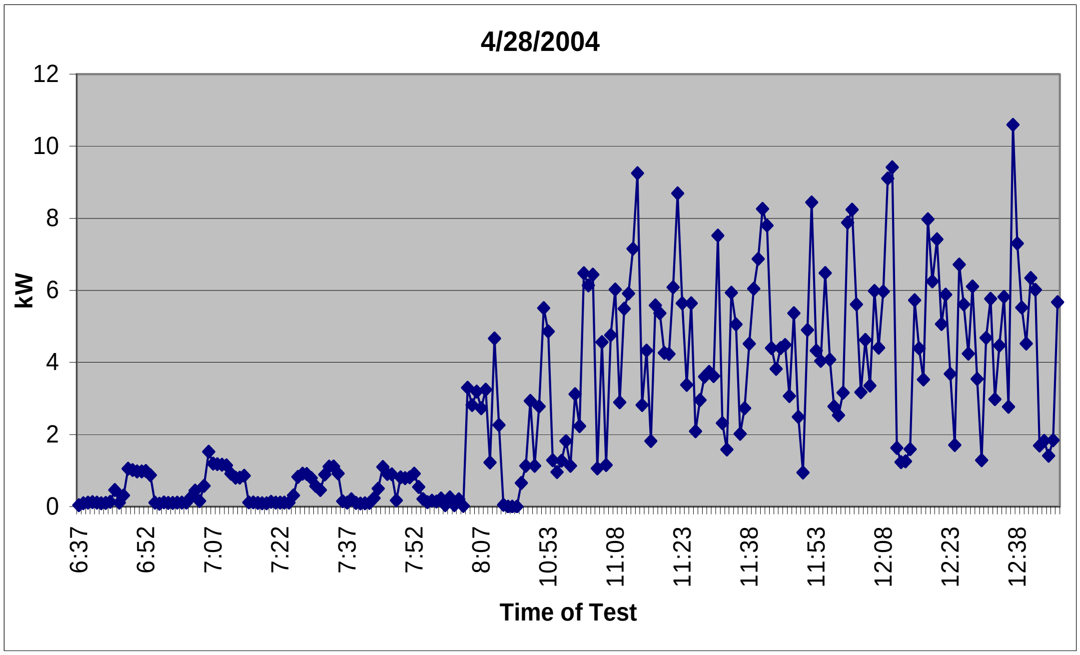
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			Data based on submeter data		
Load	2	downloaded from data loggers.			downloaded from data loggers.		
Load	3						
Load	4						
Pressing							
			Total	12.3		Total	10.0

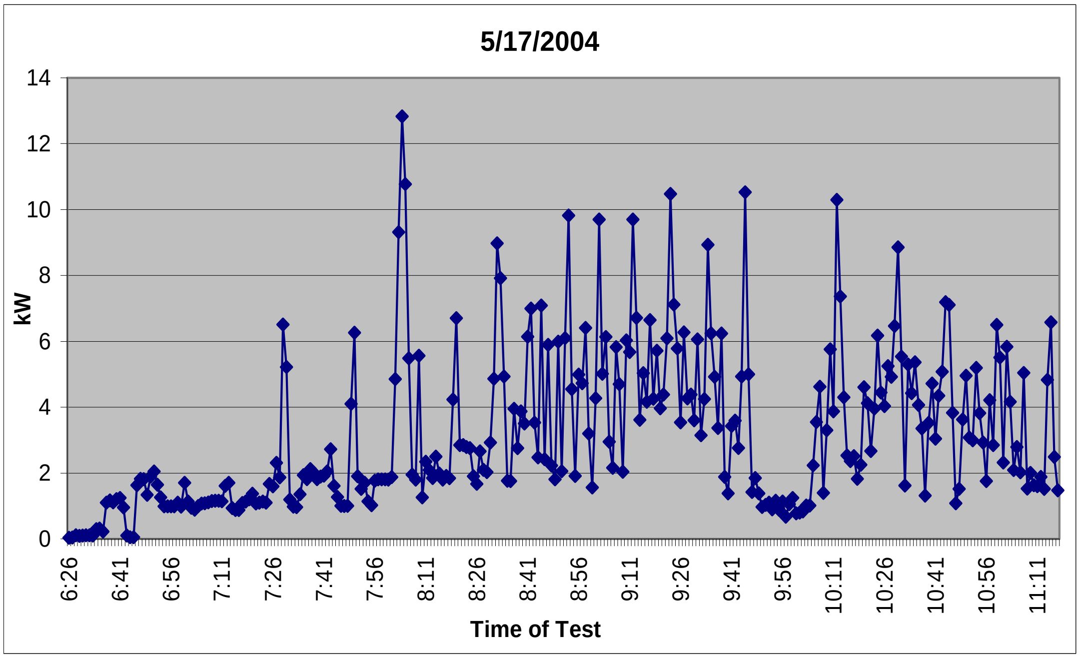
Summary Results						
	#	kWh	kWh/100 lbs	HCF	Therms*	Therms/100 lbs
Test	1	12.4	10.8	9.4	9.5	8.2
Test	2	8.4	7.6	7.0	7.1	6.4
Test	3	12.3	9.6	10.0	10.2	8.0
Average		12.3	9.3	8.8	9.0	7.5

Equipment	Test 1	Test 2	Test 3
Wet clean washer	0.6	0.0	1.1
Wet clean dryer	1.3	0.2	0.8
Air compressor & Vacuum	5.7	3.2	5.5
Tensioning pants topper	4.8	4.9	4.8
Tensioning form finisher	0.0	0.0	0.0
Total	12.4	8.4	12.3

*HHV = 1018.5




4/28/2004
kW
12
10
8
6
4
2
0
6:37
6:52
7:07
7:22
7:37
7:52
8:07
10:53
11:08
11:23
11:38
11:53
12:08
12:23
12:38
Time of Test


5/17/2004
kW
14
12
10
8
6
4
2
0
6:26
6:41
6:56
7:11
7:26
7:41
7:56
8:11
8:26
8:41
8:56
9:11
9:26
9:41
9:56
10:11
10:26
10:41
10:56
11:11
Time of Test

APPENDIX O: PWC 2 WASHING ENERGY TEST

ID Professional Wet Cleaning 2 **City** Marina Del Rey **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Wet clean washer	Wascomat EXSM230	2004	40 lbs	1 kW	Has 65 lbs capacity for laundry.
Wet clean dryer	Wascomat TD75	2004	75 lbs	2 kW	
Air compressor	Kellog American	1964	200 PSI		No spec plate on the motor, probably a 7 HP.
Vacuum pump	No visible nameplate.				Motor was rebuilt in April 2004 after it had a burn-out.
Boiler	Parker	1992		25 HP	Extremely corroded, steam distribution pipes had numerous leaks.
Tensioning pants topper	Hi-Steam PAM510	2004			
Tensioning form finisher	Hi-Steam JAM510	2004			
Pressing equipment	Three press stations and one susie. Several pieces had steam leaks and condensate dripping.				

Test # 1 **Date** 8/7/04

Washer and Pressing

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Lt 1/2 Cotton, #4	15	13	13:38	14:05	0:27	
Load	2	Drk 1/2 Cotton, #6	20	16	14:06	14:34	0:28	
Load	3	Wool Full, #1	40	25	14:39	14:54	0:15	
Pressing			75	54	14:06	16:40	2:34	3:02

Dryer

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed
Load	1	P3 Low	15	13	14:06	14:26	0:20
Load	2	P3 High/Medium	20	16	14:39	15:09	0:30
Load	3	P3 Low	40	25	15:15	15:50	0:35

	#	kWh 1 St	kWh 1 Fn	kWh 2 St	kWh 2 Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	28.0	29.8	18.7	20.5	3.6	40.2	42.2	2.0
Load	2	29.8	32.0	20.5	22.0	3.7	42.2	45.5	3.3
Load	3	32.0	35.0	22.0	24.2	5.2	45.5	49.8	4.3
Pressing			37.8		26.0			53.3	

Total	17.1	Bckgrnd	6.7	Adjusted	10.4	Total	13.1

APPENDIX P: PWC 3 WASHING ENERGY TEST

ID Professional Wet Cleaning 3 **City** Los Angeles **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Wet Clean Washer	Wascomat EXSM 230	2003	40 lbs	1 kW	Wet cleaning capacity is 40 lbs, laundry capacity is 65 lbs.
Wet Clean Dryer	Wascomat TD 75	2003	75 lbs	2 kW	
Air compressor	Falcon tank, Lincoln motor	1989	200 psi	3 HP	
Vacuum pump	Rema			1 HP	
Boiler	Parker	1985	100 psi	9.5 HP	Tested at 73% efficiency.
Pants Topper	Hi-Steam PAM510	2003			
Form Finisher	Hi-Steam JAM510	2003			
Pressing equipment	One pressing station with press board and puff irons.				

Test # 1 **Date** 2/14/05 and 2/15/05

Washer and Pressing

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Wool half, #2	23	24	15:04	15:25	0:21	
Load	2	Wool half, #2	24	22	15:29	15:50	0:21	
Load	3	Cotton half, #4	25	29	16:11	16:50	0:39	
Load	4	Wool half, #2	25	28	17:15	17:50	0:35	
Load	5	Wool half, #2	24	30	9:26	10:03	0:37	
Load	6	Cotton half, #4	25	31	10:07	10:56	0:49	
Pressing			146	164	8:06	15:55	7:49	10:35

Dryer

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed
Load	1	P3 Low	23	24	15:04	15:25	0:21
Load	2	P3 Low	24	22	15:29	15:50	0:21
Load	3	P3 Low	25	29	16:11	16:50	0:39
Load	4	P3 Low	25	28	17:15	17:50	0:35
Load	5	P3 Low	24	30	9:26	10:03	0:37
Load	6	P3 Low	25	31	10:07	10:56	0:49

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			219.5	219.8	0.3
Load	2	downloaded from data loggers.			219.8	220.0	0.2
Load	3				220.0	220.2	0.2
Load	4				220.2	220.5	0.3
Load	5				225.8	227.8	2.0
Load	6				227.8	229.4	1.6
Pressing					222.0	234.5	12.5
			Total	19.6		Total	13.5

Total	19.6	Bckgrnd	4.3	Adjusted	15.3

APPENDIX Q: PWC 4 WASHING ENERGY TEST

ID Professional Wet Cleaning 4 **City** Ontario **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Wet Clean Washer	Miele WS5191	2004	42 lbs	2.5 kW	Capacity is 42 lbs for professional wet cleaning, 65 lbs for laundry.
Wet Clean Dryer	Miele T6551	2004	54 lbs	1.05 kW	
Air compressor	Baldor Motor	1987		3 HP	
Vacuum pump	Rema			1 HP	
Boiler	Lattner	2004	150 psi	15 HP	Tested at 83% efficiency
Pants Topper	Veit 8740	2004		2.2 kW	
Form Finisher	Veit 8362	2004		0.8 kW	
Pressing equipment	Two pressing stations with press boards and puff irons. Not all steam pipes were insulated.				

Test # 1 **Date** 6/7/05

Washer and Pressing

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark, #1	35	30	5:12	5:31	0:19	
Load	2	Dark, #1	34	31	5:32	5:50	0:18	
Load	3	Dark, #1	35	29	5:52	6:12	0:20	
Pressing			104	90	5:56	8:18	2:22	3:06

Dryer

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed
Load	1	16% moisture, #4	35	30	5:32	5:49	0:17
Load	2	16% moisture, #4	34	31	5:52	6:02	0:10
Load	3	16% moisture, #4	35	29	6:14	6:28	0:14

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			37.0	37.8	0.8
Load	2				37.8	38.4	0.6
Load	3				38.4	39.9	1.5
Pressing						45.0	
			Total	9.7		Total	8.0

Total	9.7	Bckgrnd	2.1	Adjusted	7.6

Test # 2 **Date** 6/13/05 and 6/14/05

Washer and Pressing								
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark, #1	35	36	18:13	18:31	0:18	
Load	2	Dark, #1	30	24	18:35	18:54	0:19	
Load	3	Light, #1	35	28	18:57	19:16	0:19	
Pressing			100	88	9:02	11:20	2:18	3:26

Dryer							
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed
Load	1	16% moisture, #4	35	30	18:34	18:41	0:07
Load	2	16% moisture, #4	34	31	18:56	19:01	0:05
Load	3	16% moisture, #4	35	29	19:17	19:21	0:04

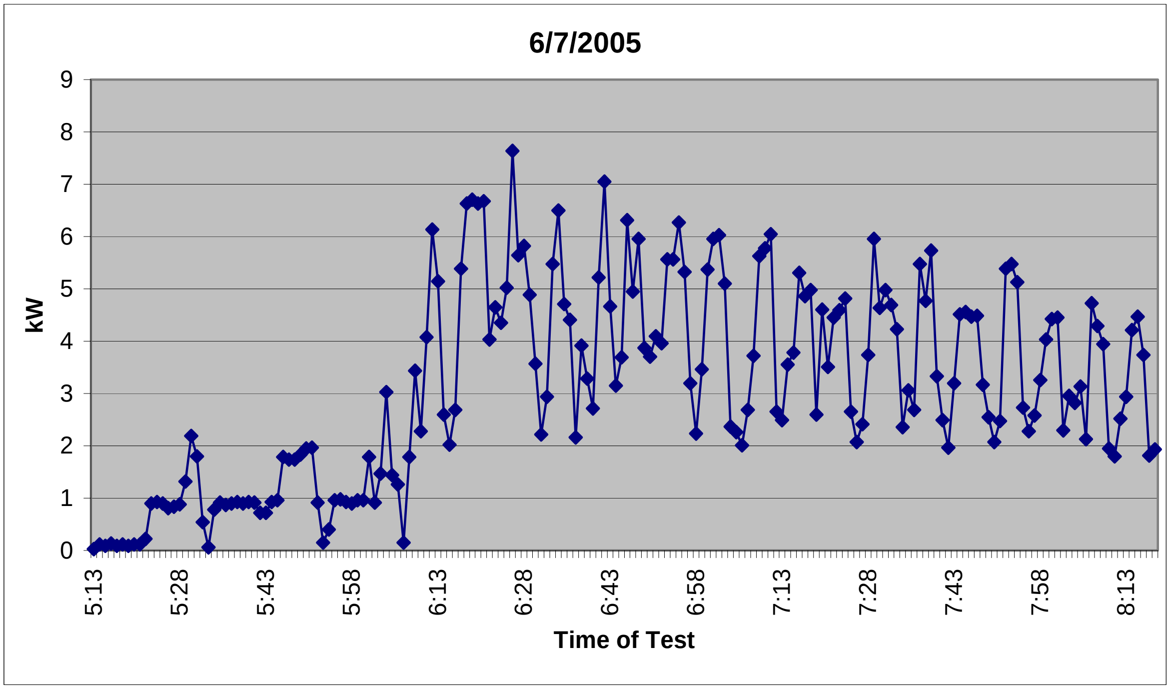
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			69.9	70.9	1.0
Load	2				70.9	72.0	1.1
Load	3				72.0	72.1	0.1
Pressing					82.2	88.0	5.80
			Total	8.5		Total	8.0

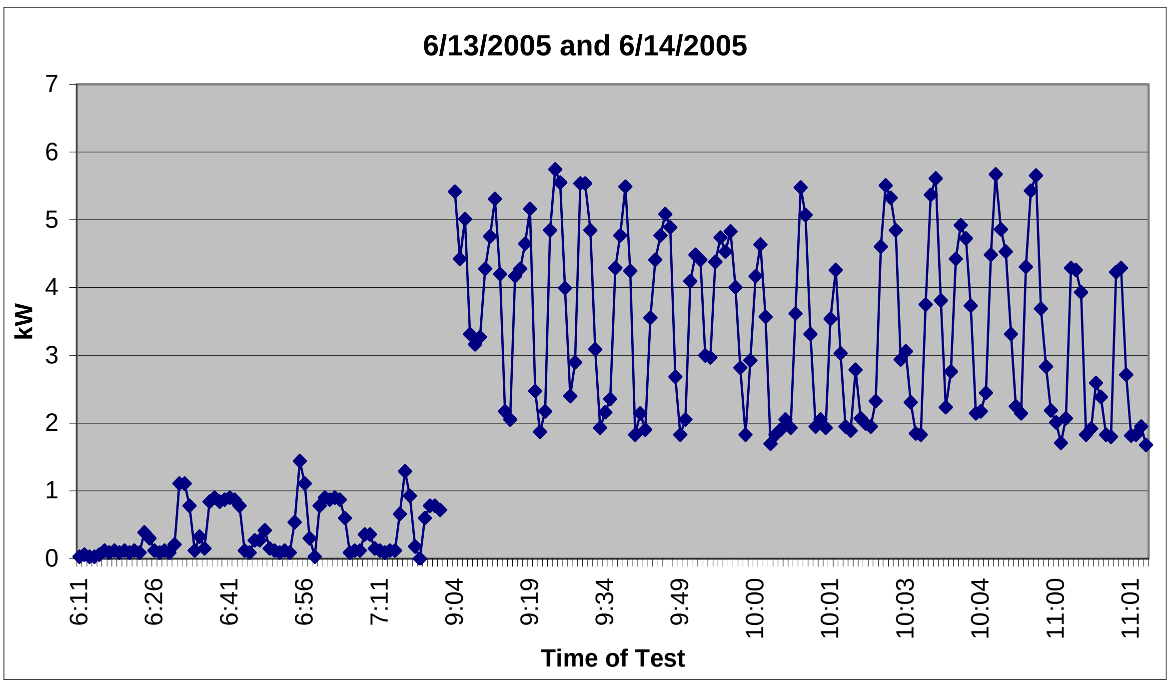
Total	8.5	Bckgrnd	2.1	Adjusted	6.4

Summary Results						
	#	kWh	kWh/100 lbs	HCF	Therms*	Therms/100 lbs
Test	1	7.6	7.3	8.0	8.3	7.9
Test	2	6.4	6.4	8.0	8.3	8.3
Average		7.0	6.8	8.0	8.3	8.1

kWh Submeter Data		
Equipment	Test 1	Test 2
Wet clean washer	0.3	0.3
Wet clean dryer	0.6	0.2
Air compressor	2.5	2.6
Vacuum pump	2.1	2.2
Tensioning pants topper	1.3	0.9
Tensioning form finisher	0.8	0.1
Total	7.6	6.3

Comments: The vacuum sub meter values were adjusted downwards by a factor of 1/2. The sub meter was reading values of about 2 kW during both tests. The vacuum motor was rated at 1 HP, so expected readings were less than 1 kW. The vacuums at other sub metered sites demanded less than 1 kW. The owner commented that he was unhappy with one of his pressers, who he felt was being inefficient.
*HHV = 1033


6/7/2005
kW
0
1
2
3
4
5
6
7
8
9
5:13
5:28
5:43
5:58
6:13
6:28
6:43
6:58
7:13
7:28
7:43
7:58
8:13
Time of Test


6/13/2005 and 6/14/2005
kW
0
1
2
3
4
5
6
7
6:11
6:26
6:41
6:56
7:11
9:04
9:19
9:34
9:49
10:00
10:01
10:03
10:04
11:00
11:01
Time of Test

APPENDIX R: PWC 5 WASHING ENERGY TEST

ID Professional Wet Cleaning 5 **City** Pomona **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Wet Clean Washer	Miele WS5191	2005	42 lbs	2.5 kW	Capacity is 42 lbs for professional wet cleaning, 65 lbs for laundry.
Wet Clean Dryer	Miele T6551	2005	54 lbs	1.05 kW	
Air compressor	Westinghouse				No faceplate visible. At least 5 yrs old, probably 5 HP.
Vacuum pump	B-System				No faceplate visible. Probably 1 HP motor.
Boiler	Thermosteam				Tested at 77% efficiency. Faceplate not legible, owner thought it was 15 HP.
Pants Topper	Veit 8740	2004		2.2 kW	
Form Finisher	Veit 8362	2004		0.8 kW	
Pressing equipment	Two pressing stations with press boards and puff irons.				

Test # 1 **Date** 8/3-8/4/05

Washer and Pressing

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	27	20	2:10	2:29	0:19	
Load	2	Dark	27	28	2:30	2:49	0:19	
Load	3	Light	29	27	2:49	3:10	0:21	
Pressing			83	75			0:00	1:00

Dryer

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed
Load	1	8% moisture	27	20	2:30	2:45	0:15
Load	2	hang dry	27	28			0:00
Load	3	hang dry	27	27			0:00

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			37.5	39.0	1.5
Load	2						-
Load	3				41.2	43.8	2.6
Pressing							
			Total	7.1		Total	4.1

Total	7.1	Bckgrnd	2.0	Adjusted	5.1

Test # 2 **Date** 8/23-8/24/05

Washer and Pressing								
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	27	20	2:24	2:48	0:24	
Load	2	Dark wools	27	23	2:49	3:11	0:22	
Load	3		27	27	3:12	3:31	0:19	
Pressing			81	70	3:05	3:20	0:15	0:56

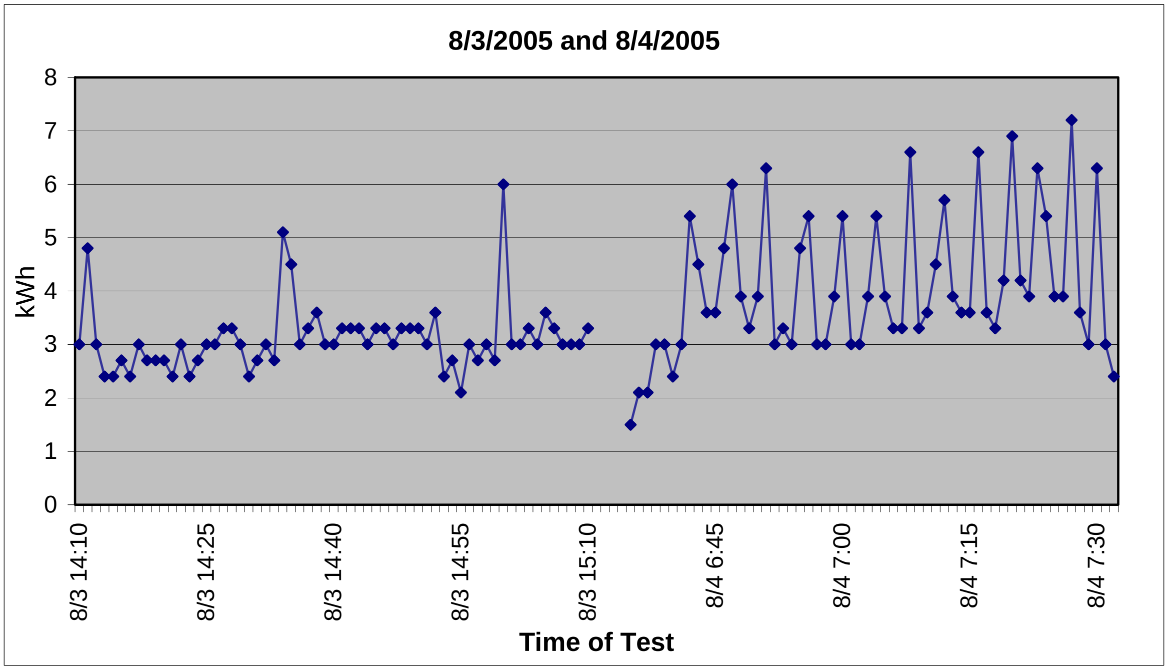
Dryer							
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed
Load	1	A4	27	20	2:48	2:59	0:11
Load	2	A4	27	23	3:10	3:20	0:10
Load	3		27	27			0:00

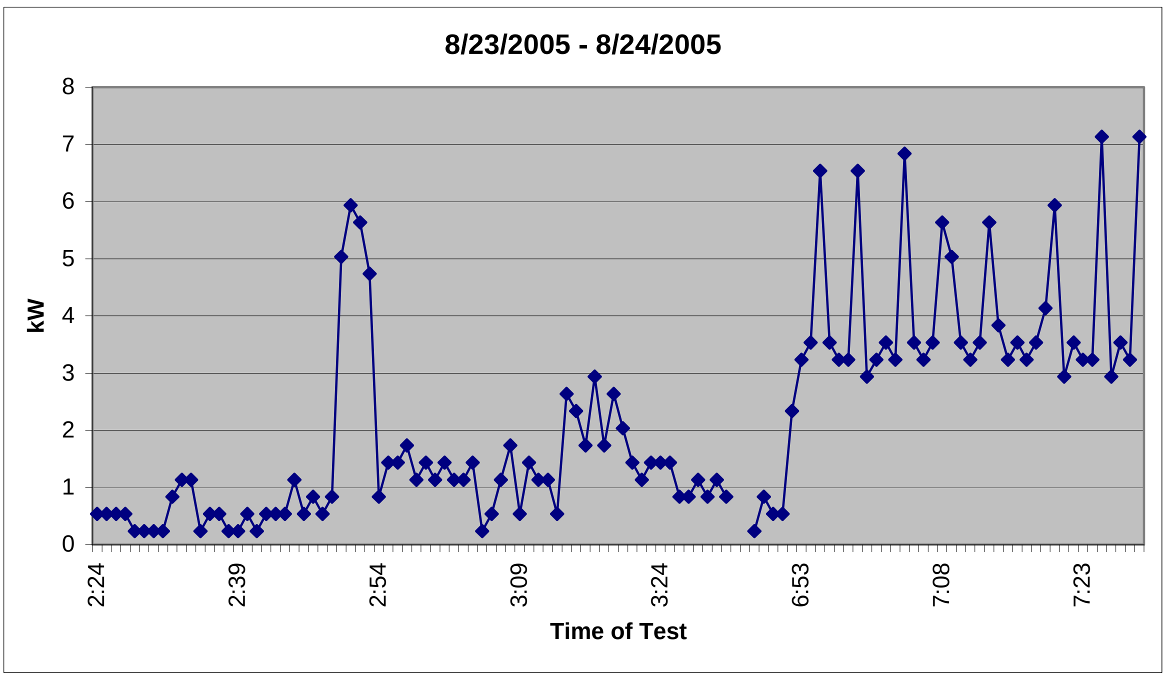
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			31.5	31.7	0.2
Load	2				32.2	32.3	0.1
Load	3				34.2	36.3	2.1
Pressing							-
			Total	5.0		Total	4.8

Total	5.0	Bckgrnd	1.0	Adjusted	4.0

Summary Results						
	#	kWh	kWh/100 lbs	HCF	Therms*	Therms/100 lbs
Test	1	5.1	6.1	4.1	4.2	5.2
Test	2	4.0	4.9	4.8	4.9	6.1
Average		4.5	5.5	4.1	4.2	5.2

*HHV = 1027.3


8/3/2005 and 8/4/2005
kWh
0
1
2
3
4
5
6
7
8
8/3 14:10
8/3 14:25
8/3 14:40
8/3 14:55
8/3 15:10
8/4 6:45
8/4 7:00
8/4 7:15
8/4 7:30
Time of Test


8/23/2005 - 8/24/2005
kW
0
1
2
3
4
5
6
7
8
2:24
2:39
2:54
3:09
3:24
6:53
7:08
7:23
Time of Test

APPENDIX S: PWC 6 WASHING ENERGY TEST

ID Professional Wet Cleaning 6 **City** La Jolla **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Wet clean washer	Miele PW6161		42 lbs		
Wet clean dryer	Miele PT7401		54 lbs		
Air compressor					
Vacuum pump					
Boiler					
Tensioning pants topper					
Tensioning form finisher					
Pressing equipment					

Test # 1 **Date** 12/18/06

Washer and Pressing								
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark silk	30	30	6:12	6:40	0:28	
Load	2	Dark silk	30	25	6:46	7:10	0:24	
Load	3	Dark silk	36	33	7:18	7:49	0:31	
Pressing			96	88	7:18	10:19	3:01	4:07

Dryer							
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed
Load	1		30	30	6:46	7:12	0:26
Load	2		30	25	7:18	7:41	0:23
Load	3		36	33	7:50	8:12	0:22

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			581.2	582.4	1.2
Load	2				582.4	584.5	2.1
Load	3				584.5	585.8	
Pressing						592.0	
			Total	23.0		Total	10.8

Total	23.0	Bckgrnd	3.0	Adjusted	19.9

Test # 2 **Date** 4/5/07

Washer and Pressing

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark Wool	29	29	6:36	7:06	0:30	
Load	2	Light Silk	25	35	7:14	7:41	0:27	
Load	3	Dark Silk	29	30	7:45	8:12	0:27	
Pressing			83	94	7:29	9:28	1:59	2:52

Dryer

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed
Load	1	Dark Wool	29	29	7:09	7:28	0:19
Load	2	Light Silk	25	35	7:42	8:02	0:20
Load	3	Dark Silk	29	30	8:18	8:38	0:20

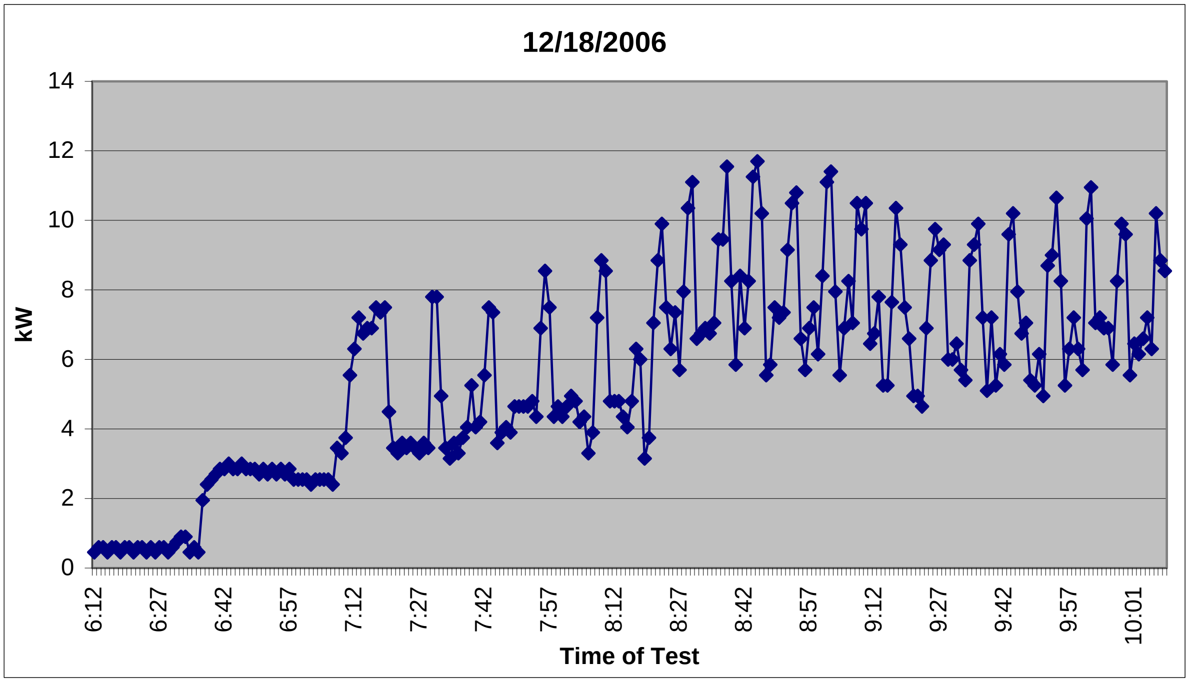
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			907.9	909.4	1.5
Load	2				909.4	910.1	0.7
Load	3				910.1	913.6	3.5
Pressing						915.9	
			Total	11.8		Total	8.0

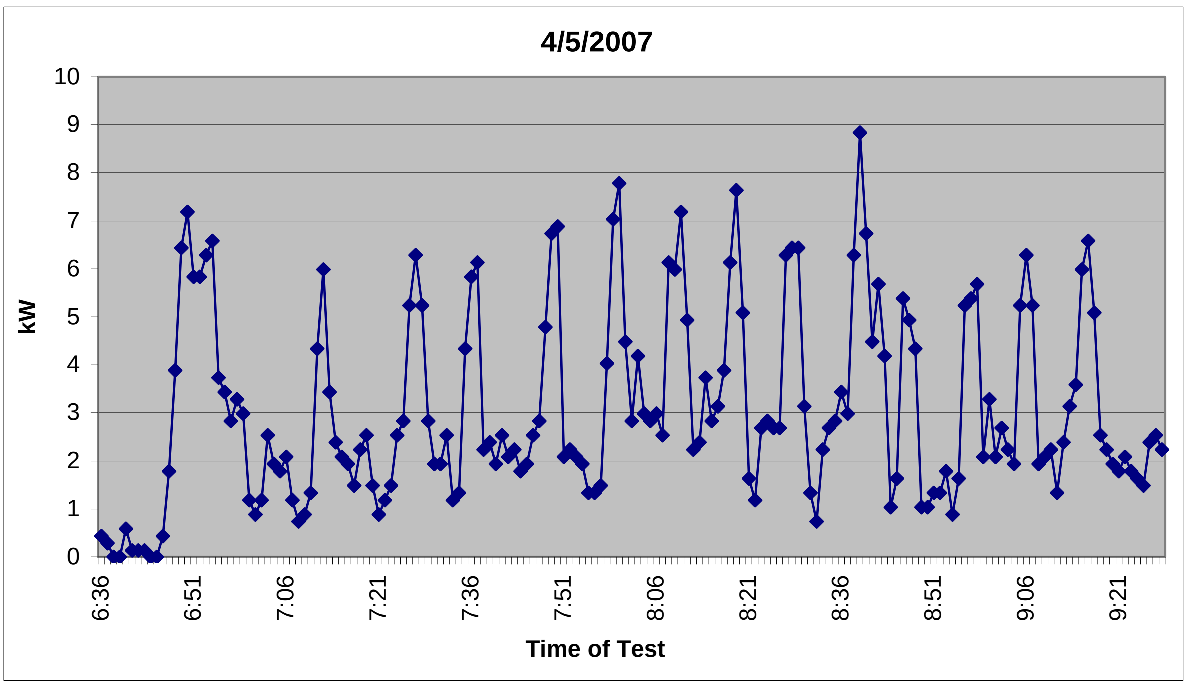
Total	11.8	Bckgrnd	2.9	Adjusted	8.9

Summary Results

	#	kWh	kWh/100 lbs	HCF	Therms*	Therms/100 lbs
Test	1	19.9	20.8	10.8	11.0	11.5
Test	2	8.9	10.7	8.0	8.2	9.9
Average		14.4	15.8	9.4	9.6	10.7

*HHV = 1023


12/18/2006
kW
14
12
10
8
6
4
2
0
6:12
6:27
6:42
6:57
7:12
7:27
7:42
7:57
8:12
8:27
8:42
8:57
9:12
9:27
9:42
9:57
10:01
Time of Test


4/5/2007
kW
10
9
8
7
6
5
4
3
2
1
0
6:36
6:51
7:06
7:21
7:36
7:51
8:06
8:21
8:36
8:51
9:06
9:21
Time of Test

APPENDIX T: PWC 7 WASHING ENERGY TEST

ID Professional Wet Cleaning 7 **City** Pomona **State** CA

Equipment	**Model**	**Year**	**Capacity**	**Power**	**Comments**
Wet clean washer	Maytag Washer NFS50				
Wet clean dryer	Maytag (American Dryer) J-				
Air compressor					
Vacuum pump					
Boiler					
Tensioning pants topper					
Tensioning form finisher					
Pressing equipment					

Test # 1 **Date** 7/9/07

Washer and Pressing								
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark, Program #97	20	20	8:45	9:05	0:20	
Load	2	Dark, Program #98	20	20	9:08	9:29	0:21	
Pressing			40	40	9:29	10:27	0:58	1:42

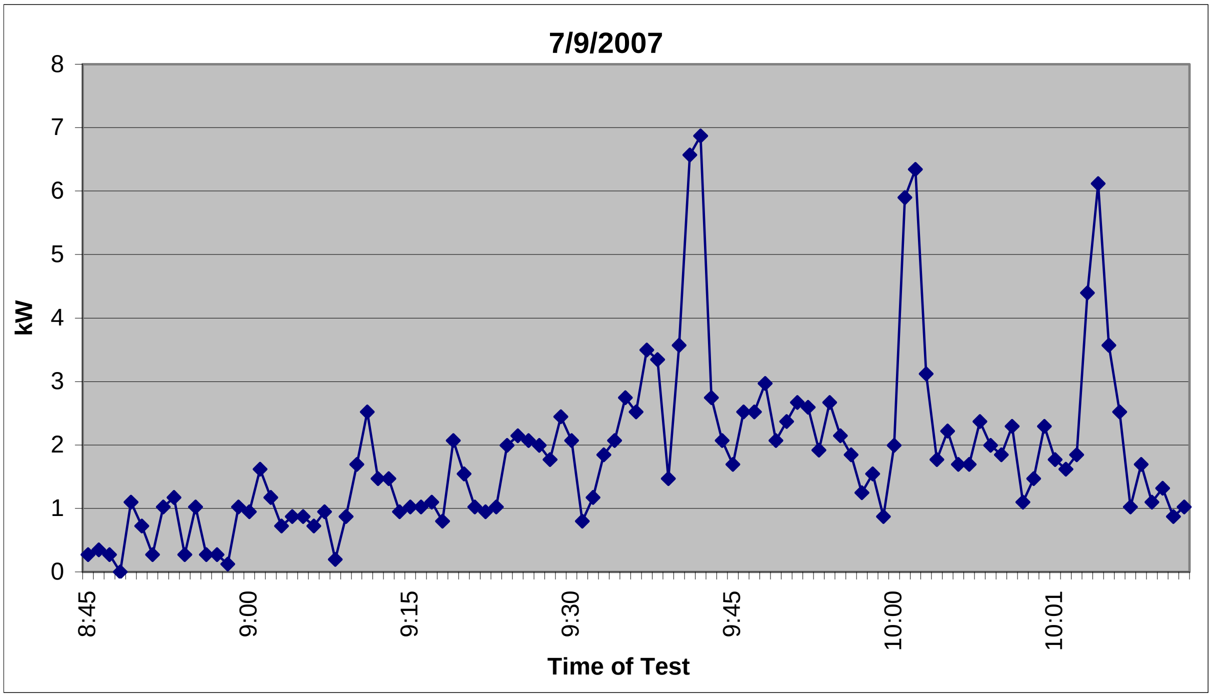
Dryer							
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed
Load	1		20	20	9:07	9:27	0:20
Load	2		20	20	9:29	9:54	0:25

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			497.0		(497.0)
Load	2	downloaded from data loggers.			498.2	500.9	2.7
Pressing						501.2	
			Total	4.6		Total	4.2

Total	4.6	Bckgrnd	1.5	Adjusted	3.1

Summary Results						
	#	kWh	kWh/100 lbs	HCF	Therms*	Therms/100 lbs
Test	1	3.1	7.9	4.2	4.3	10.6
Average		3.1	7.9	4.2	4.3	10.6

*HHV =1013


7/9/2007
kW
0
1
2
3
4
5
6
7
8
8:45
9:00
9:15
9:30
9:45
10:00
10:01
Time of Test

APPENDIX U: PWC 8 WASHING ENERGY TEST

ID Professional Wet Cleaning 8 **City** San Lorenzo **State** CA

Equipment	**Model**	**Year**	**Capacity**	**Power**	**Comments**
Wet clean washer	Miele PW6161	42lb			
Wet clean dryer	Miele PT7401	54lb			
Air compressor					
Vacuum pump					
Boiler					
Tensioning pants topper					
Tensioning form finisher					
Pressing equipment					

Test # 1 **Date** 4/23/07

Washer and Pressing

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	25	25	7:50	8:11	0:21	
Load	2		25	25	8:13	8:34	0:21	
Load	3		25	25	8:37	8:57	0:20	
Load	4	Light	25	25	9:13	9:33	0:20	
Load	5	Light	30	30	10:46	11:25	0:39	
Load	6	Dark	23	23	11:30	11:50	0:20	
Load	7		25	30	11:58	12:39	0:41	
Load	8		25	25	12:42	13:02	0:20	
Load	9		25	25	13:08	13:28	0:20	5:38

Dryer

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed
Load	1		25	25	8:12	8:32	0:20
Load	2		25	25	8:36	8:51	0:15
Load	3		25	25	8:59	9:15	0:16
Load	4		25	25	9:38	9:54	0:16
Load	5		30	30	11:29	11:53	0:24
Load	6		23	23	11:56	12:30	0:34
Load	7		25	30	12:41	13:15	0:34
Load	8		25	25	13:17	13:38	0:21
Load	9		25	25	13:43	14:05	0:22

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			2.8	3.8	1.0
Load	2				5.0	6.1	1.1
Load	3				6.1	7.6	1.5
Load	4				7.6	9.8	2.2
Load	5				13.8	15.4	1.6
Load	6				15.4	16.9	1.5
Load	7				16.9	18.9	2.0
Load	8				18.9	20.1	1.2
Load	9					21.7	21.7
			Total	22.4		Total	18.9

Total	22.4	Bckgrnd	1.3	Adjusted	21.1

Summary Results

	#	kWh	kWh/100 lbs	HCF	Therms*	Therms/100 lbs
Test	1	21.1	9.3	18.9	19.3	8.5
Average		21.1	9.3	18.9	19.3	8.5

APPENDIX V: PET 1 WASHING ENERGY TEST

ID Petroleum 1 **City** Rancho Cucamonga **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Dry clean machine	Bowe K16		35 lbs	21 kW	
Cooling tower fan	Amcot			0.75 HP	
Cooling tower pump	STA-RITE			2 HP	
Air compressor				3 HP	
Vacuum pump				1.5 HP	
Boiler	Parker				
Pressing equipment					

Test # 1 **Date** 4/23/04

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	29	37	5:59	7:01	1:02	
Load	2	Dark	30	39	7:02	8:03	1:01	
Load	3	Light	33	53	8:05	9:05	1:00	
Load	4	Light	32	36	9:06	10:06	1:00	
Pressing			124	165	7:14	10:50	3:36	4:51

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			836.1	839.0	2.9
Load	2	downloaded from data loggers.			839.0	842.5	3.5
Load	3				842.5	845.2	2.7
Load	4				845.2		
Pressing						851.2	
			Total	41.3		Total	15.1

Test # 2 **Date** 4/30/04

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	32	30	5:46	6:48	1:02	
Load	2	Dark	32	38	6:49	7:58	1:09	
Load	3	Light	28	49	7:59	9:05	1:06	
Load	4	Dark	31	49	9:07	10:13	1:06	
Pressing			123	166	7:19	11:16	3:57	5:30

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			992.0	995.0	3.0
Load	2	downloaded from data loggers.			995.0	997.6	2.6
Load	3				997.6	1,001.4	3.8
Load	4				1,001.4		
Pressing						1,006.8	
			Total	42.6		Total	14.8

Test # 3 **Date** 5/14/04

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	32	30	6:16	7:09	0:53	
Load	2	Dark	32	36	7:10	8:02	0:52	
Load	3	Light	32	45	8:05	8:59	0:54	
Load	4	Dark	32	31	9:01	9:53	0:52	
Pressing			128	142	7:28	10:30	3:02	4:14

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			285.0	287.9	2.9
Load	2				287.9	290.0	2.1
Load	3				290.0	293.0	3.0
Load	4				293.0	296.0	3.0
Pressing						297.5	
			Total	32.3		Total	12.5

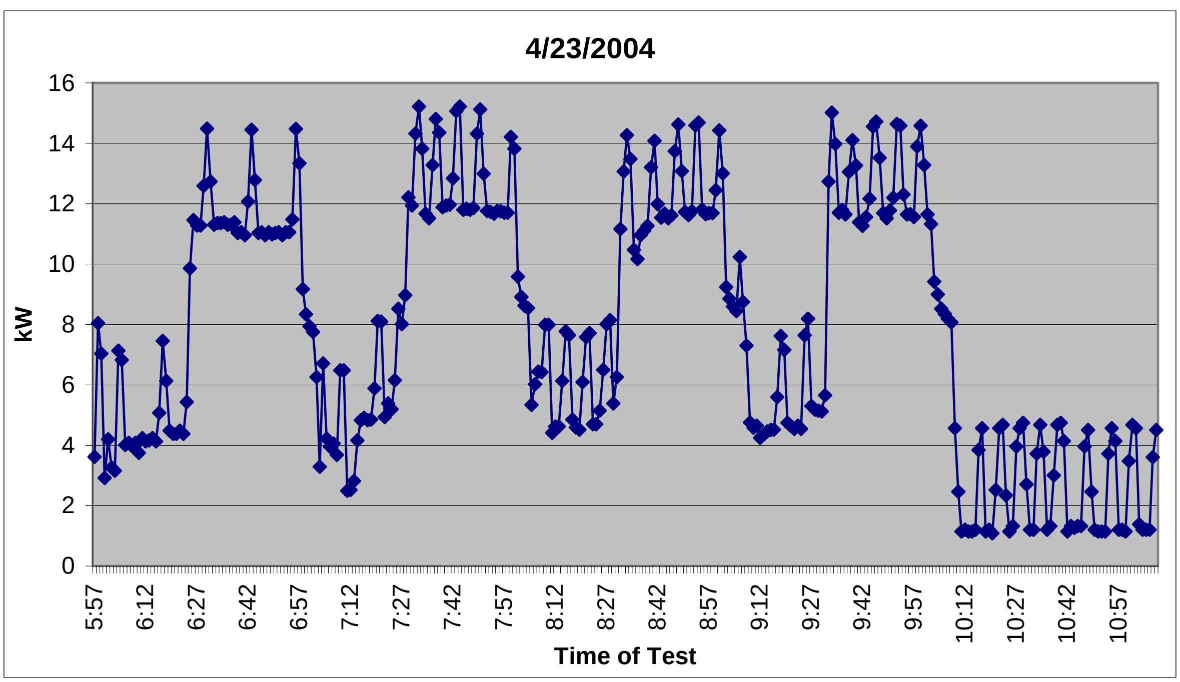
Summary Results

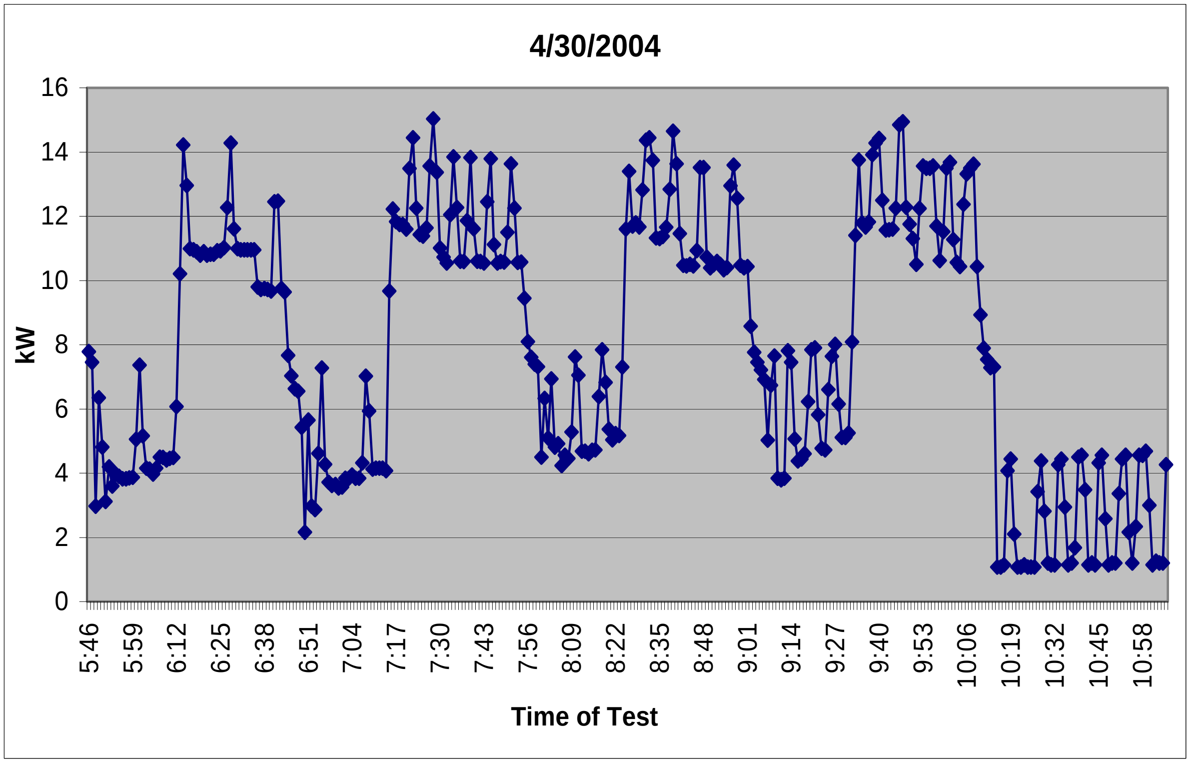
	#	kWh	kWh/100 lbs	kWh/100lbs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	41.3	33.3	37.2	15.1	14.6	11.8	13.2
Test	2	42.6	34.6	38.5	14.8	15.8	12.8	14.2
Test	3	32.3	25.2	29.1	12.5	13.5	10.5	11.9
Average		38.7	31.1	35.0	14.1	14.6	11.7	13.1

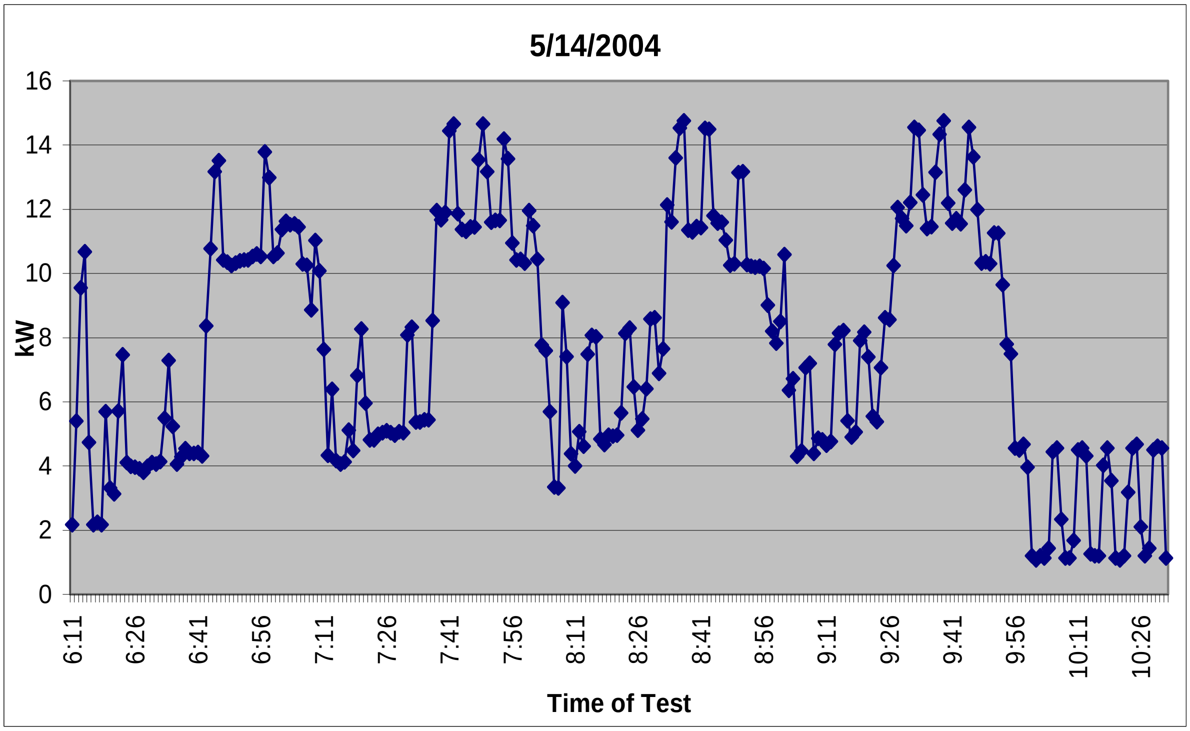
kWh Submeter Data

Equipment	Test 1	Test 2	Test 3
Dry clean machine	24.4	25.0	18.1
Cooling tower fan & pump	8.1	8.7	7.9
Air compressor	4.9	4.9	3.4
Vacuum	3.9	4.0	2.9
Total	41.3	42.6	32.3

Comments: The cooling tower fan and pump are operated by separate motors, but were measured using one sub meter/data logger.
*HHV = 968.9




4/30/2004
kW
Time of Test
16
14
12
10
8
6
4
2
0
5:46
5:59
6:12
6:25
6:38
6:51
7:04
7:17
7:30
7:43
7:56
8:09
8:22
8:35
8:48
9:01
9:14
9:27
9:40
9:53
10:06
10:19
10:32
10:45
10:58


5/14/2004
kW
Time of Test
16
14
12
10
8
6
4
2
0
6:11
6:26
6:41
6:56
7:11
7:26
7:41
7:56
8:11
8:26
8:41
8:56
9:11
9:26
9:41
9:56
10:11
10:26

APPENDIX W: PET 2 WASHING ENERGY TEST

ID Petroleum 2 **City** Northridge **State** CA

Equipment	**Model**	**Year**	**Capacity**	**Power**	**Comments**
Dry clean machine	Lindus PM60	2000	60 lbs	25 HP	
Cooling tower fan	RSD TSC 15	1999		0.5 HP	Sprinkler arms on cooling tower were not rotating.
Cooling tower pump	STA-RITE HF51HL	1999		1.5 HP	
Air compressor	Falcon tank, Lincoln motor			7.5 HP	
Vacuum pump	Rema tank, Leeson motor			1.5 HP	
Boiler	Parker 15L	2000		15 HP	The boiler was serviced immediately before the first test. Measured at 77% efficiency.
Pressing equipment	2 pressing boards, 1 susie, 1 pants topper, electric irons. Appeared to be in good condition.				

Test # 1 **Date** 6/19/04

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark, #8	47	56	6:38	7:45	1:07	
Load	2	Light, #7	45	44	7:48	8:55	1:07	
Load	3	Dark, #8	44	46	8:58	10:05	1:07	
Pressing			136	146	7:50	11:52	4:02	5:14

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			791.0	793.0	2.0
Load	2				793.0	796.5	3.5
Load	3				796.5	799.6	3.1
Pressing						804.0	
			Total	30.8		Total	13.0

Test # 2 **Date** 6/26/04

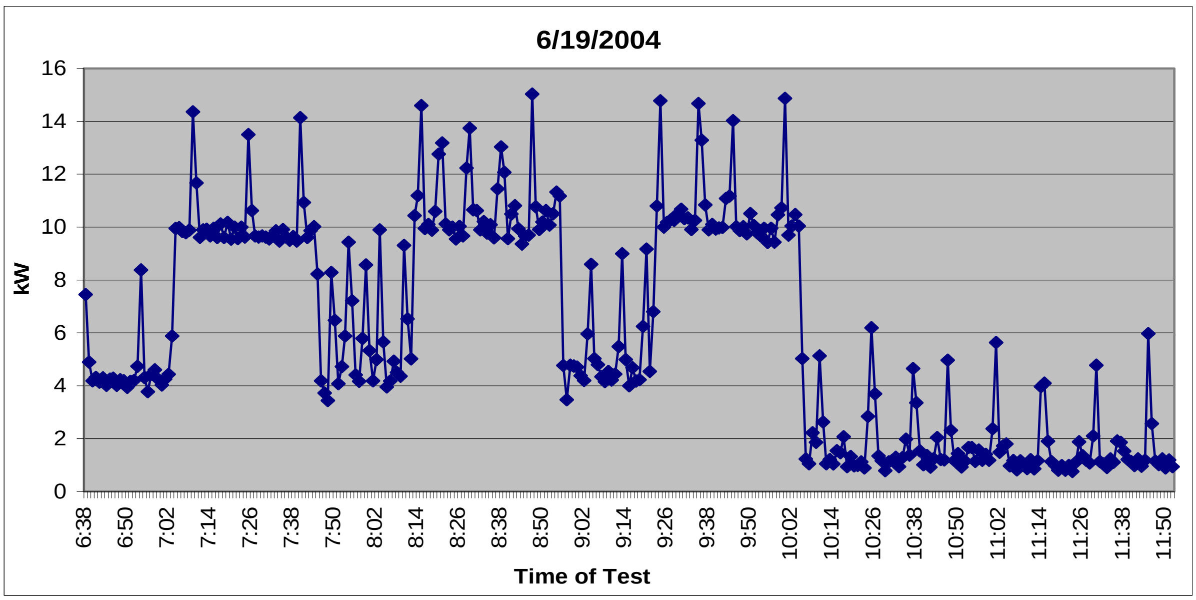
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark, #8	44	52	6:40	7:47	1:07	
Load	2	Light, #7	44	57	7:50	8:57	1:07	
Load	3	Dark, #8	49	51	9:00	10:07	1:07	
Pressing			137	160	7:50	11:44	3:54	5:04

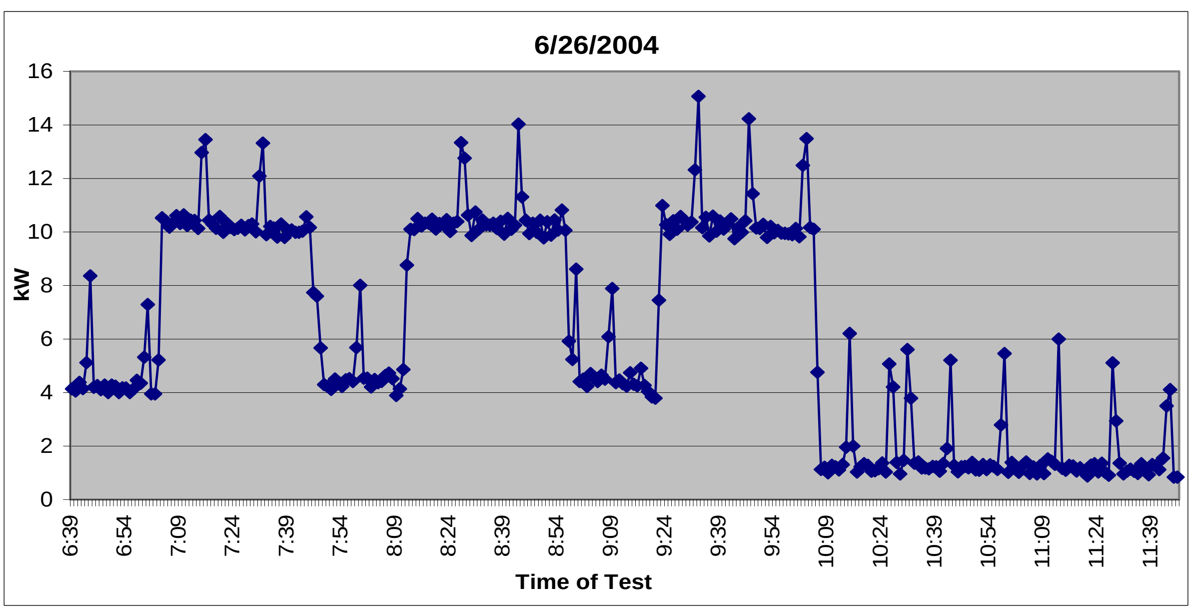
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			986.3	989.0	2.7
Load	2				989.0	992.4	3.4
Load	3				992.4	995.0	2.6
Pressing						998.4	
			Total	29.6		Total	12.1

Summary Results								
	#	kWh	kWh/100 lbs	kWh/100 lbs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	30.8	22.6	26.5	13.0	13.2	9.7	11.1
Test	2	29.6	21.6	25.5	12.1	12.3	9.0	10.3
Average		30.2	22.1	26.0	12.6	12.7	9.3	10.7

kWh Submeter Data		
Equipment	Test 1	Test 2
Dry clean machine	16.9	17.6
Cooling tower fan	4.0	4.0
Cooling tower pump	2.1	2.1
Air compressor	3.0	2.1
Vacuum pump	3.9	3.8
Irons	0.8	0.0
Total	30.8	29.6

Comments: Iron kWh values were doubled because only one of the two irons being used during testing had been sub metered.
*HHV = 1014





APPENDIX X: PET 3 WASHING ENERGY TEST

ID Petroleum 3 **City** San Marino **State** CA

Equipment	Model	Year	Capacity	Power	Comments
Dry clean machine	Lindus PM45 MS	2004	45 lbs	19 HP	
Cooling tower fan	RSD TSC 15	2004		0.5 HP	
Cooling tower pump	STA-RITE HF51HL	2004		1.5 HP	
Air compressor	Teco	1986		5 HP	
Vacuum pump	Rema			1.5 HP	
Boiler	Parker	1987	100 psi	9.5 HP	Boiler tested at 72% efficiency.
Pressing equipment	2 pressing boards, 1 susie, 1 pants topper. Appeared to be in good condition.				

Test # 1 **Date** 9/8/05

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	30	64	7:02	8:21	1:19	
Pressing			30	64	8:29	9:24	0:55	2:22

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	2				66.1	68.5	2.4
Pressing						72.6	
			Total	15.1		Total	6.5

Total	15.1	Bckgrnd	1.4	Adjusted	13.7

Test # 2 **Date** 9/15/05

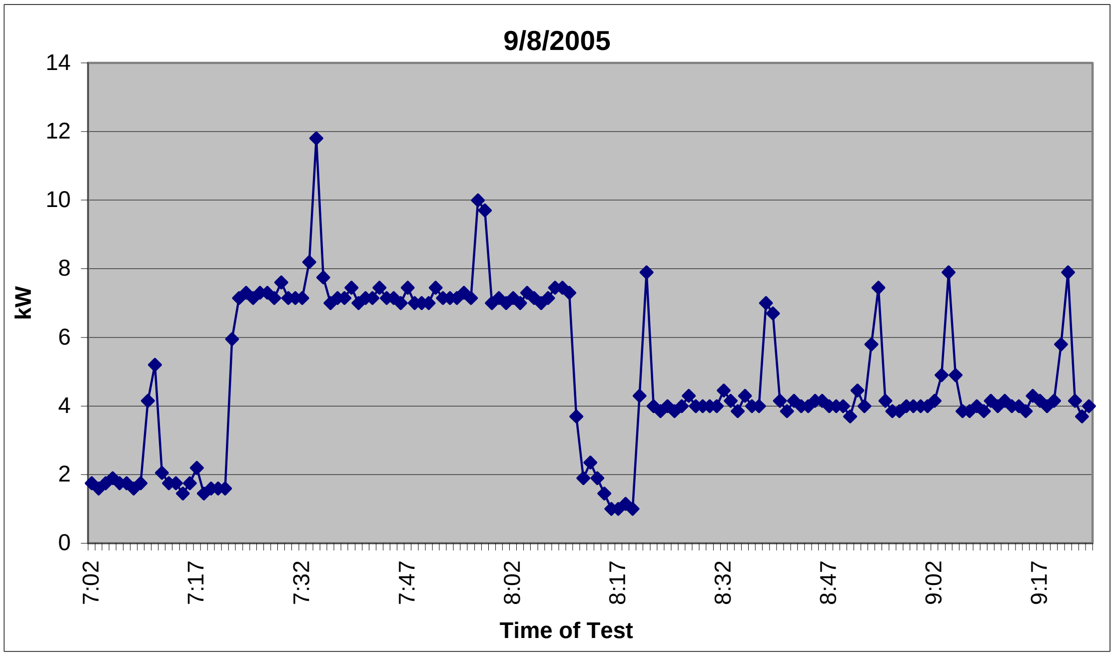
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Light	30	34	6:47	8:35	1:48	
Load	2	Dark	40	39	8:35	9:42	1:07	
Pressing			70	73	8:48	10:17	1:29	3:30

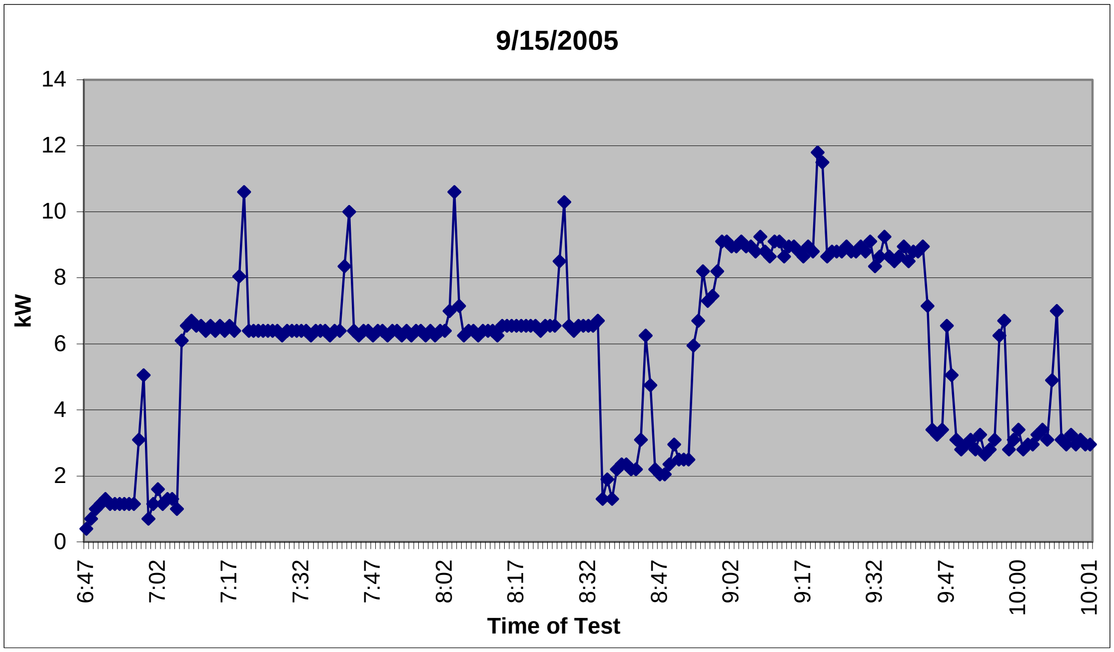
	#	kWh St.	kWh Fn	kWh Use	Therm St.		Therm Use
Load	1	Data based on submeter data			57.1	58.1	1.0
Load	2	downloaded from data loggers.			58.1	61.6	3.5
Pressing						63.2	
			Total	25.3		Total	6.1

Total	25.3	Bckgrnd	1.4	Adjusted	23.9

Summary Results								
	#	kWh	kWh/100 lbs	kWh/100 lbs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	13.7	34.3	38.2	6.5	6.8	17.1	18.4
Test	2	23.9	34.2	38.1	6.1	6.4	9.2	10.5
Average		18.8	34.2	38.1	6.3	6.6	13.1	14.5

*HHV = 1051





APPENDIX Y: PET 4 WASHING ENERGY TEST

ID Petroleum 4 **City** Burbank **State** CA

Equipment	**Model**	**Year**	**Capacity**	**Power**	**Comments**
Dry clean machine	PM 60MS	2005	60lbs	18KW	Strong smell
Cooling tower fan					
Cooling tower pump		2006	60		
Air compressor	Campbell Housefeld	1985		200psi	
Vacuum pump					
Boiler	Parker 352110	2004	68	100psi	
Pressing equipment					

Test # 1 **Date** 2/2/07

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Darks	55	55	6:24	7:57	1:33	
Load	2	Lights	60	61	8:00	9:29	1:29	
Load	3	Darks	60	61	9:30	11:04	1:34	
Load	4	Darks	45	129	11:06	12:23	1:17	
Pressing			220	306	8:07	12:55	4:48	6:31

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			27.5		(27.5)
Load	2				30.3		(30.3)
Load	3				33.2		(33.2)
Load	4				36.5		
Pressing						39.7	
			Total	73.7		Total	12.2

Total	73.7	Bckgrnd	2.7	Adjusted	71.0

Test # 2 **Date** 2/3/07

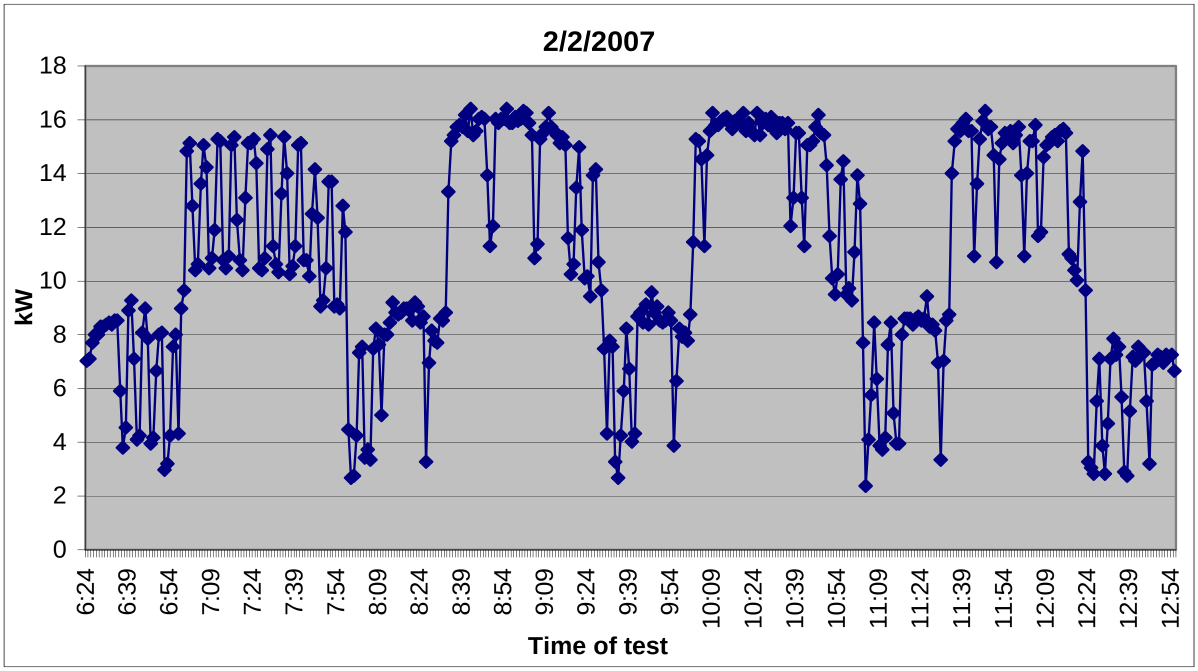
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	60	60	6:40	8:05	1:25	
Load	2	Light	60	60	8:13	9:39	1:26	
Pressing			120	120	8:20	10:42	2:22	4:02

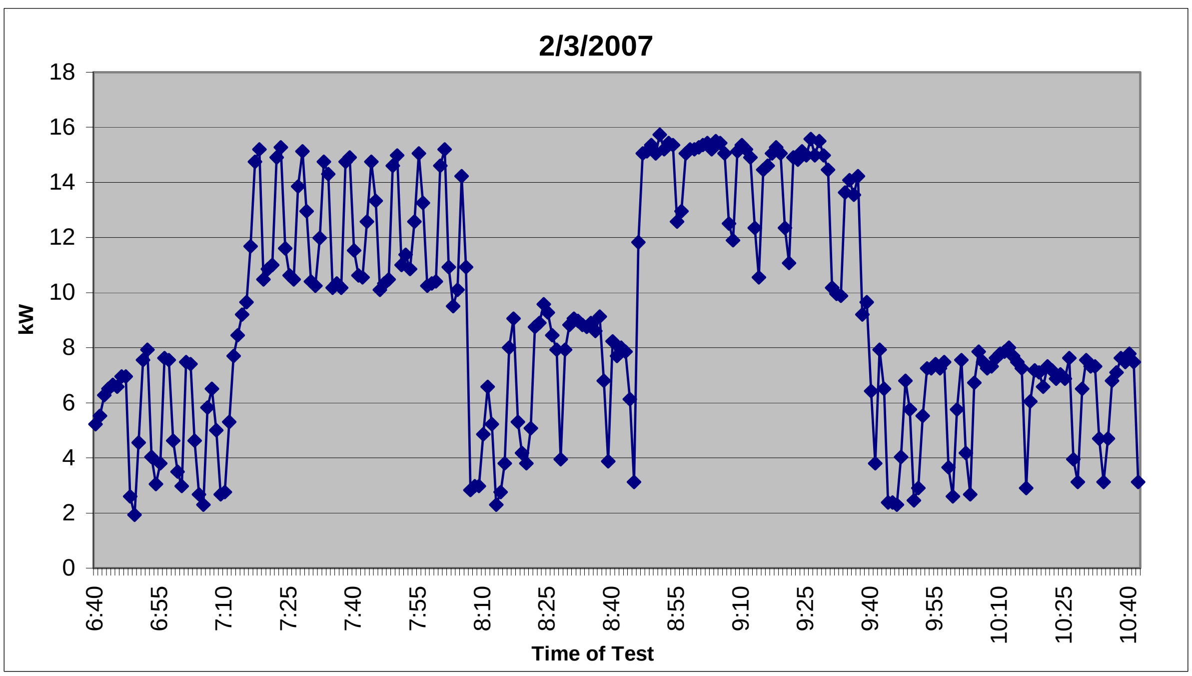
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			40.4		(40.4)
Load	2				43.0	45.6	2.6
Pressing						47.5	
			Total	39.7		Total	7.1

Total	39.7	Bckgrnd	2.7	Adjusted	37.0

Summary Results								
	#	kWh	kWh/100 lbs	kWh/100 lbs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	71.0	32.3	36.2	12.2	12.6	5.7	7.1
Test	2	37.0	30.8	34.7	7.1	7.3	6.1	7.5
Average		54.0	31.6	35.5	9.7	10.0	5.9	7.3

*HHV = 1033





APPENDIX Z: PET 5 WASHING ENERGY TEST

ID Petroleum 5 **City** Burbank **State** CA

Equipment	**Model**	**Year**	**Capacity**	**Power**	**Comments**
Dry clean machine					
Cooling tower fan					
Cooling tower pump					
Air compressor					
Vacuum pump	Remi Dri-Vac				
Boiler	Parker				
Pressing equipment					

Test # 1 **Date** 2/8/07

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Dark	32	32	8:23	9:20	0:57	
Load	2	Dark	25	29	9:27	10:23	0:56	
Load	3	Light	25	35	10:30	11:38	1:08	
Load	4	Light	25	29	11:43	12:53	1:10	
Pressing			107	125	9:23	2:34	6:49	5:49

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			12.2	14.1	1.9
Load	2	downloaded from data loggers.			14.1	16.4	2.3
Load	3				16.4	18.6	2.2
Load	4				18.6	20.9	2.30
Pressing						23.2	
			Total	37.8		Total	11.0

Total	37.8	Bckgrnd	2.1	Adjusted	35.7

Test # 2 **Date** 2/9/07

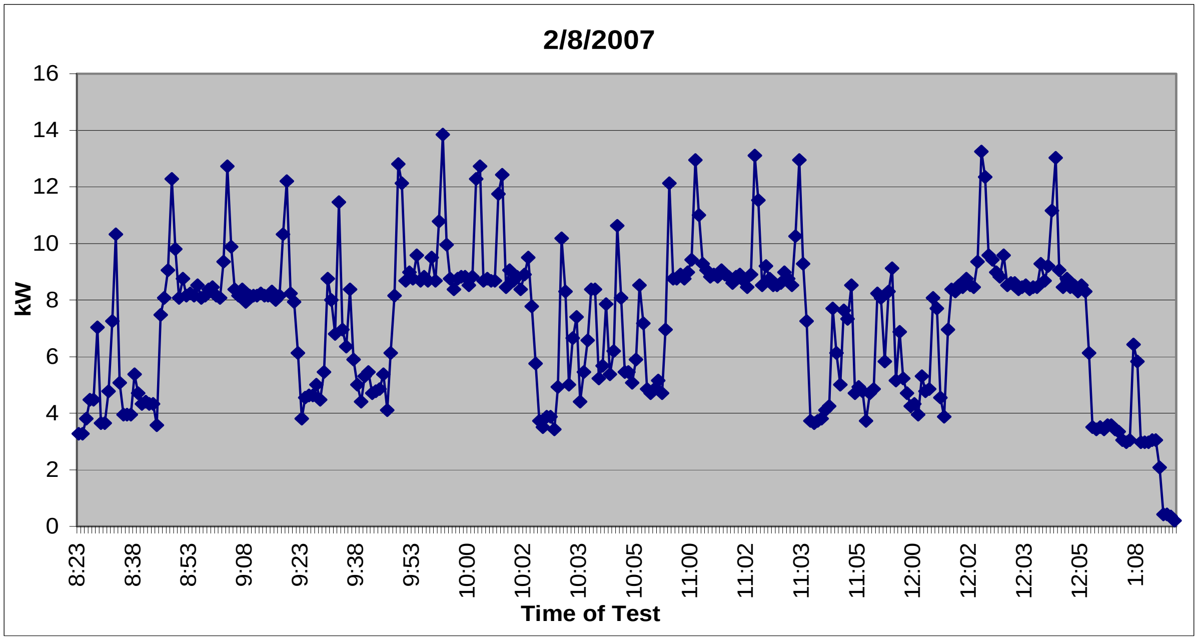
	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Darks	30	35	8:11	9:07	0:56	
Load	2	Light	32	42	9:15	10:22	1:07	
Load	3	Light	25	30	10:36	11:45	1:09	
Pressing			87	107	9:13	12:20	3:07	4:09

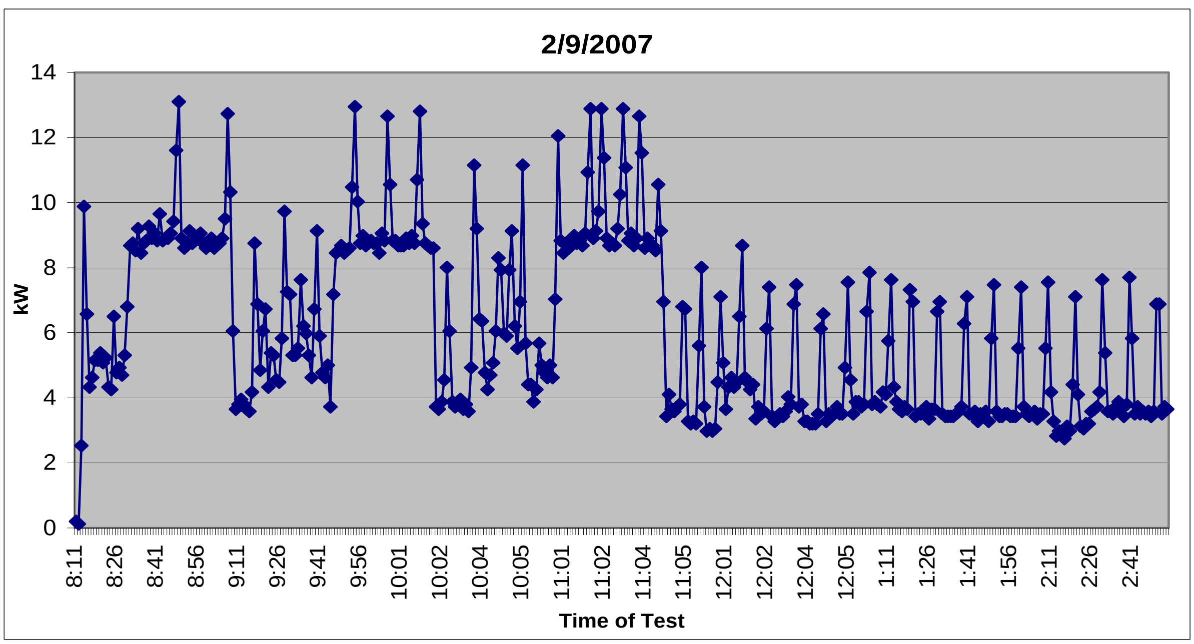
	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data			27.8	29.8	2.0
Load	2	downloaded from data loggers.			29.8	32.2	2.4
Load	3				32.2	33.2	1.0
Pressing						37.9	
			Total	42.6		Total	11.1

Total	42.6	Bckgrnd	2.1	Adjusted	40.5

Summary Results								
	#	kWh	kWh/100 lbs	kWh/100 lbs with Distillation	HCF	Therms*	Therms/100 lbs	Therms/100 lbs with Distillation
Test	1	35.7	33.3	37.2	11.0	11.4	10.6	12.0
Test	2	40.5	46.6	50.5	11.1	11.5	13.2	16.6
Average		38.1	39.9	43.8	11.1	11.4	11.9	14.3

Comments: Machine having problems during recovery process. Wiring for cooling tower is incorrect. Cleaner doesn't know any good maintenance person for his machine. German manufacturer, very limited tech support.
*HHV = 1031





PET 5 Distillation Energy Test

Test # Distillation **Date** 2/9/07

	#	Program Descr.	Lbs	Garments	Time Start	Time End	Elapsed	Total Time
Load	1	Distillation	-	-	12:10	2:44	2:44	
Pressing			-	-	-	-	-	2:44

	#	kWh St.	kWh Fn	kWh Use	Therm St.	Therm Fn.	Therm Use
Load	1	Data based on submeter data downloaded from data loggers.			35.0	39.0	4.0
Pressing						-	
			Total	13.9		Total	4.0

Total kWh Use	13.9	Bckgrnd	2.2	Adjusted	11.7

Summary Results

	#	kWh	Electricity used adjusted to 30 lb machine (kWh)	kWh/100bs during Distillation	HCF	Therms*	Electricity used adjusted to 30 lb machine (therms)	Therms/100 lbs during Distillation
Test	1	11.7	19.5	3.90	4.0	4.12	6.87	1.37
Average		11.7	19.5	3.90	4.0	4.12	6.87	1.37

*HHV =1031

REFERENCES

---

[1] Median value from case studies.

[2] Annual volume based on estimated average annual volume of a cleaner with advanced PCE dry cleaning machine in California was 52,000 pounds. California Air Resource Board, California Dry Cleaning Industry Technical Assessment Report, February 2006, p. IV-23.

[3] Median value from case studies.

[4] Estimated average annual volume of a cleaner with advanced PCE dry cleaning machines in California was 52,000 pounds. California Air Resource Board, California Dry Cleaning Industry Technical Assessment Report, February 2006, p. IV-23.

[5] PCE has been classified as a probable carcinogen by the International Association for Research on Cancer, was listed as a hazardous air pollutant in the 1990 Clean Air Act, and is classified as a toxic air contaminant by the California Air Resources Board. SCAQMD, "Staff Report to Propose Adoption of Rule 1421: Control of Perchloroethylene Emissions from Dry Cleaning Systems and Repeal Rule 1102.1: Perchloroethylene Dry Cleaning Systems" (Diamond Bar, CA, December 1994): 1-4. International Agency for Research on Cancer. Tetrachloroethylene. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Vol. 63, Dry Cleaning, Some Chlorinated Solvents and other Industrial Chemicals.

[6] Cleaner Technologies Substitutes Assessment for Professional Fabricare Processes, EPA 744-B-98-001; United States Environmental Protection Agency, Design for the Environment, 1998.

[2](www.drycleancoalition.org/survey.pdf). Updated December 8, 2007.

[8]For example, recent enforcement activity at the SCAQMD has revealed that 70% of dry cleaners inspected were not in compliance with Rule 1421. Edwin Pupka, SCAQMD, Senior Manager, Engineering & Compliance Administration, January 14, 2000. This figure was based on 1160 inspections of dry cleaners between March 1999 through January 1, 2000.

[9] USEPA. Cleaner Technology Substitutes Assessment, EPA 744-B-98-001, June 1998, p.7-19.

[10] USEPA. Cleaner Technology Substitutes Assessment, EPA 744-B-98-001, June 1998, p. 2-2.

[11] The operation of a cooling tower is still needed in order to dissipate the heat absorbed by the refrigerator during the condensation process.

[12] USEPA. Cleaner Technology Substitutes Assessment, EPA 744-B-98-001, June 1998, p.2-5.

[13] Sinsheimer, PJ; Grout, C; Namkoong, A; Gottlieb, R; Latif, A. (2007) The Viability of Professional Wet Cleaning as a Pollution Prevention Alternative to Perchloroethylene Dry Cleaning Journal of the Air & Waste Management Association 57:172–178.

[14] The prevalence of the chilled water system was considered too low to evaluate. As for the mist system, questions have been raised about the cleaning quality associated with this system. For example, while the South Coast Air Quality Management District has provided incentive funds for non-PCE technologies, it chose to exclude the mist system due to issues related to cleaning quality.

[15] Dow Corning. OPPT Public Docket #42071-A, February 4, 2003

[16] Some petroleum and silicone dry cleaning machines also use a vacuum pump to eliminate oxygen from the cleaning system as a fire protection process.

[17] Models that use an electrical heat source are also available, but are less common.

[18] Adopted from USEPA. Cleaner Technology Substitutes Assessment, EPA 744-B-98-001, June 1998, p. 2-4.

[19] Adopted from USEPA. Cleaner Technology Substitutes Assessment, EPA 744-B-98-001, June 1998, p. 2-4.

[20] Encyclopedia Americana, 1970, Vol. 9.

[21] Adopted from USEPA. Cleaner Technology Substitutes Assessment, EPA 744-B-98-001, June 1998, p.2-5.

[22] Pollution Prevention in the Garment Care Industry: Assessing the Viability of Professional Wet Cleaning, Occidental College, Pollution Prevention Education and Research Center, 1997.

[23] Resource Use in Professional Wet Cleaning vs. Perchloroethylene Dry Cleaning, Occidental College, Pollution Prevention Education and Research Center, March 31, 2004.

[24] Sinsheimer, PJ; Grout, C; Namkoong, A; Gottlieb, R; Latif, A. (2007) The Viability of Professional Wet Cleaning as a Pollution Prevention Alternative to Perchloroethylene Dry Cleaning Journal of the Air & Waste Management Association 57:172–178.

[25] Commercialization of Environmental Technologies in the Garment Care Industry. Pollution Prevention Center (PPC), Occidental College, January 31, 2008.

[26] Testing at PCE 9 was done only for distillation.

[27] Beta testing at the professional wet clean facility was held 4/16/04, 4/28/04, and 5/17/04. Beta testing at the petroleum cleaner was held 4/23/04, 4/30/04, and 5/14/04.

[28] Another method to reduce the cost of distillation has been developed in which solvent extracted after cleaning is drained through a clay filter to remove impurities. Cleaning detergents, which are used to remove water-soluble stains, are not used in this process because they clog the clay filter. While this method eliminates the use of distillation, the lack of cleaning detergents compromises the quality of cleaning. Because the currently study was based on comparable cleaning quality, and because of a lack of an independent evaluation of the relative cleaning quality of the clay filtration method, this method was not evaluated.

[29] Results for the distillation tests are provided as follows: Perchloroethylene (PCE) – Appendix I; Petroleum(PET) – Appendix Z; Carbon Dioxide (CO2)-1 – Appendix J; and Carbon Dioxide (CO2)-2 – Appendix K.

---

[30] Petroleum and silicone machines are virtually identical and many manufacturers advertise that their machines can be used for either solvent. Cleaning cycles are comparable.

[31] California Air Resources Board. California Dry Cleaning Industry, Technical Assessment Report. February 2006. This study estimated the typical volume for a cleaner with older PCE machines was 52,000 pounds per year. Assuming that the dry clean machines operate five days a week, average daily volume amounts to 200 pounds.

[32] Use Mann-Whitney Rank Sum Test – comparing professional wet cleaning with all other non-aqueous groups.

[33] Excludes PCE 9 because the site was used only for a distillation test.

[34] The graph in Figure 3.2 represents the following sub meter data: Wet Cleaning – 1st load at test site PWC-4 (6/15/05); PCE – 1st load at test site PCE-4 (1/30/06); Petroleum – 1st load at test site PET-2, 6/26/04; Silicone – 1st load at test site SIL-1, 9/14/04; CO2 – 1st load test site CO2-2, 4-15-06.

[35] Use Mann-Whitney Rank Sum Test – combining all other groups.

[36] Median value from professional wet cleaning, perchloroethylene, petroleum, and silicone.

[37] California Air Resources Board. California Dry Cleaning Industry, Technical Assessment Report. February 2006.

[38] Sinsheimer, PJ; Grout, C; Namkoong, A; Gottlieb, R; Latif, A. (2007) The Viability of Professional Wet Cleaning as a Pollution Prevention Alternative to Perchloroethylene Dry Cleaning Journal of the Air & Waste Management Association 57:172–178.

[39] California Air Resources Board. California Dry Cleaning Industry, Technical Assessment Report. February 2006. This study estimated the typical volume for a cleaner with older PCE machines was 52,000 pounds per year.

[40] Median value from case studies.

[41] Annual volume based on estimated average annual volume of a cleaner with advanced PCE dry cleaning machine in California was 52,000 pounds. California Air Resource Board, California Dry Cleaning Industry Technical Assessment Report, February 2006, p. IV-23.

[42] Median value from case studies.

[43] Estimated average annual volume of a cleaner with advanced PCE dry cleaning machines in California was 52,000 pounds. California Air Resource Board, California Dry Cleaning Industry Technical Assessment Report, February 2006, p. IV-23.

[44] Staff Report: Initial Statement of Reasons for the Proposed Amendments to the Control Measure for Perchloroethylene Dry Cleaning Operations and Adoption of Requirements for Manufacturers and Distributors of Perchloroethylene." December 8, 2006, State of California, Air Resources Board. Stationary Source Division Emissions Assessment Branch.

[45] Derived from Staff Report: Initial Statement of Reasons for the Proposed Amendments to the Control Measure for Perchloroethylene Dry Cleaning Operations and Adoption of Requirements for Manufacturers and Distributors of Perchloroethylene." December 8, 2006, State of California, Air Resources Board. Stationary Source Division Emissions Assessment Branch, p. VII-5.

[46] California Dry Cleaning Industry Technical Assessment Report. February 2006, State of California, Air Resources Board. Stationary Source Division Emissions Assessment Branch. See: Table IV-18. Emissions Comparison. Emissions from petroleum were estimated to be 230 pounds per cleaner per year.