DEVELOPMENT OF A COMPREHENSIVE COMMUNITY NO_x EMISSION REDUCTION TOOLKIT (CCNERT)

A Dissertation

by

YONG HOON SUNG

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2004

Major Subject: Architecture

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Approved as to style and content by:

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August 2004

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ABSTRACT

Development of a Comprehensive Community NOx Emissions Reduction Toolkit (CCNERT).
(August 2004)
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The main objective of this study is to research and develop a simplified tool to estimate energy use in a community and its associated effects on air pollution. This tool is intended to predict the impacts of selected energy conservation options and efficiency programs on emission reduction. It is intended to help local government and their residents understand and manage information collection and the procedures to be used. This study presents a broad overview of the community-wide energy use and NOx emissions inventory process. It also presents various simplified procedures to estimate each sector's energy use.

In an effort to better understand community-wide energy use and its associated NOx emissions, the City of College Station, Texas, was selected as a case study community for this research. While one community might successfully reduce the production of NOx emissions by adopting electricity efficiency programs in its buildings, another community might be equally successful by changing the mix of fuel sources used to generate electricity, which is consumed by the community. In yet a third community low NOx automobiles may be mandated. Unfortunately, the impact and cost of one strategy over another changes over time as major sources of pollution are reduced.

Therefore, this research proposes to help community planners answer these questions and to assist local communities with their NOx emission reduction plans by developing a Comprehensive Community NOx Emissions Reduction Toolkit (CCNERT). The proposed simplified tool could have a substantial impact on reducing NOx emission by providing decision-makers with a preliminary understanding about the impacts of various energy efficiency programs on emissions reductions. To help decision makers, this study has addressed these issues by providing a general framework for examining how a community's non-renewable energy use leads to NOx emissions, by quantifying each end-user's energy usage and its

associated NOx emissions, and by evaluating the environmental benefits of various types of energy saving options.

DEDICATION

To my family
who gave me confidence

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I would like to express my sincere appreciation to the chair of my committee, Dr. Jeff S. Haberl. His profound knowledge and eagerness to research and solve problems was my primary inspiration throughout this study. He always encouraged me especially to discover the essence of this research. His training and instruction in the ways of not only research, but also management nurtured my knowledge and strengthened my confidence in my life.

I wish to express my sincere gratitude and indebtedness to all of the members of my dissertation committee whose support, guidance, and thoughtful comments were so important to the completion of this project. Prof. Larry O. Degelman is respectfully acknowledged here for his enlightenment, encouragement, and thoughtful guidance throughout my studies at Texas A&M University. His profound learning and emotional guidance have kept me on the right track from the genesis to the end of this study. I would like to thank Dr. Phillip E. Tabb for providing valuable information that was very useful to my understanding of the conceptual mechanism of community scale energy analysis. I would also like to extend my sincere thanks to Dr. Charles Culp for not only his technical suggestions, but also his emotional guidance with regards to what a PhD should be.

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I would also like to thank all of the people whom I have met and interacted with in the Energy Systems Laboratory for their help and hospitality. I am also deeply grateful to my parents. Their unfailing confidence in all of my ventures has been an everlasting inspiration for me to do my best. My pleasure in completing this study must also be shared with my wife Younsoo, my daughter Jisoo, and my son Juhyun who have been silently waiting for this moment for a long time.

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CHAPTER I
INTRODUCTION

1.1 BACKGROUND

Community-wide pollution reduction planning is gaining recognition as we become increasingly aware of the environmental problems and other impacts that result from the pollution caused by a community's non-renewable energy use. This growing interest in community emission control raises many questions for local communities:

1) What is community-wide atmospheric emission control?
2) How are emissions reduction calculated by environmental agencies?
3) What kinds of options are available for reducing a community's emissions?
4) How does electrical load diversity among communities influences a community's emissions reduction plan?
5) What methods should be used to collect and analyze community energy use data?
6) What methods should be used to identify each emissions source and to calculate emissions reduction in a community?
7) How can a community determine the most cost-effective options for reducing emissions?

Because of these issues, different communities may come to different conclusions about their emissions reduction options. Therefore, community-wide emissions reduction plans for different communities have different implementations.

1.2 PROBLEM STATEMENT

In 1990, the U.S. Environmental Protection Agency (EPA) classified four areas (Beaumont-Port Arthur, El Paso, Dallas-Ft. Worth, and Houston-Galveston-Brazoria) in Texas

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This dissertation follows the style and format of *ASHRAE Transactions.*

as non-attainment areas based on the EPA's 1-hour ozone standard. Among of them, Houston-Galveston-Brazoria area was classified as a Severe II Non-Attainment Area and must reach attainment by November 15, 2007 (TNRCC 2000). The state of Texas' goal is to demonstrate attainment. In order to do that, significant reductions in NOx emissions are necessary in Texas's non-attainment areas (75% in the Houston/Galveston area, 45% in the Dallas/Fort Worth area, and 40% in the Beaumont/Port Arthur area).

In April 2004, the EPA designated non-attainment areas for the 8-hour ozone standard. The EPA originally issued the 8-hour ozone standard in July 1997, based on information demonstrating that the 1-hour standard was inadequate for protecting public health. Scientific information shows that ozone can affect human health at lower levels, and over longer exposure times than one hour.

In response to this situation, the Texas Natural Resource Conservation Commission (TNRCC)[1] developed a 1994 State Implementation Plan (SIP) to meet the EPA 1-hour ozone standard in the non-attainment areas of Texas. The primary strategy of the 1994 SIP was to reduce the Volatile Organic Compounds (VOCs) from the stationary point sources such as power plants and chemical plants. As a result of the 1994 SIP, VOCs from the stationary point sources were reduced by more than 50 percent in all four areas during the 1990 to 1996 period (TNRCC 2000).

The first plan failed to achieve the EPA's 1-hour ozone standard and thus a second strategy was developed (TNRCC 2002). Since the reduction of VOCs failed to achieve the EPA 1-hour ozone standard, the reduction of nitrogen oxides (NOx) emissions from stationary point sources such as power plants, chemical and petroleum refiners has now been targeted by the TNRCC. Under the Title IV of the Clean Air Act (CAA), the EPA required the state of Texas to apply a similar strategy to major stationary sources for NOx emissions as are applied to major stationary sources of VOCs. Unfortunately, despite increasing NOx emission reductions in stationary sources, increases in power generation and Vehicle Miles Traveled (VMT) are expected to gradually offset the previous improvement. Therefore, the Texas Natural Resource

[1] The TNRCC is now the Texas Commission on Environmental Quality (TCEQ).

Conservation Commission (TNRCC) adopted 1997 VMT Offset SIP to reduce additional NOx emissions resulted from growth in VMT or the number of vehicle trip (TNRCC 2001).

In 2000, the TNRCC published Rule 117 to regulate small combustion sources such as water heaters, small boilers and process heaters by applying specific NOx emission standards to each type of equipment. This is also expected to have an impact of the reduction of NOx emissions.

In 2001, the Texas State Senate passed Senate Bill 5 to further reduce ozone levels by encouraging the reduction of emissions of NOx by sources that are currently not regulated by the TNRCC, including area sources (residential emissions), road mobile sources, and non-road mobile sources (TNRCC 2002). An important part of this legislation is the evaluation of the State's energy efficiency programs, which includes reductions in energy use and demand that are associated with specific utility-based energy conservation measures, and implementation of the International Energy Conservation Code (IECC 2000).

Although the EPA has established regional and multi-state levels of guidance in controlling emissions by using a "top-down approach" (EPA 1999b), limited information exists on how to identify and select cost-effective options for a local community to reduce the pollution caused by the community's energy use. While one community might successfully reduce the production of NOx emissions by adopting electricity efficiency programs in its buildings, another community might be equally successful by changing the mix of fuel sources used to generate electricity, which is consumed by the community. In yet a third community, low-NOx automobiles may need to be mandated. Unfortunately, the impact and cost in one strategy over another changes over time as major sources of pollution are reduced. Therefore, most communities rely on the TNRCC for guidance concerning the selection of NOx reduction measures.

In response to the above-mentioned actions, this research proposes to assist community planners in answering these questions and to assist local communities with NOx emission reduction plans by developing a general framework for a Comprehensive Community NOx Emissions Reduction Tool (CCNERT). The proposed tool should have an impact on reducing

NOx emissions by providing decision makers with a quick estimate of the impacts of various energy efficiency programs on emissions reductions.

1.3 OBJECTIVE AND SCOPE

As previously mentioned, the main objective of this study is to research and develop a general framework to calculate community-based energy use and its associated effects on NOx emissions. The outcome of this study is intended to help decision makers understand the impacts of various energy conservation options and efficiency programs on emission reduction. It may also help local government and their residents understand and manage information collection and procedures to be used. This study presents a broad overview of the community-wide energy use and NOx emissions inventory process. It also presents various simplified procedures to estimate each sector's energy use.

Although a community's environmental quality is degraded by various factors such as energy production from non-renewable fuels (power plants and building energy use), goods production (industry plants), solvent utilization (i.e., surface coating, dry cleaning, degreasing, and graphic arts), transportation, and miscellaneous sources (i.e., unpaved road, BBQ burning and agricultural burning), this research will focus on actions that reduce the environmental effects of air pollution caused by a community's energy use, with a primary emphasis on building energy use. Unfortunately, it is a daunting task to study every possible variable for a community to reduce emissions. Therefore, energy efficiency measures for this study will be limited to several examples.

There are also many constraints in estimating community-wide energy use and its associated emissions. For instance, the emissions audit of a community is a complex process, partly because it is impossible to control every factor involved. In the transportation sector, one difficulty is the estimation of average driver behaviors and trip characteristics, which vary from one community to the next. This is confounded by the fact that there are no uniform performance standards for vehicles. Furthermore, in dealing with all possible variables within all sectors (e.g., transportation, building, and industrial), vast amounts of information are required and therefore collecting the data is labor-intensive and a time-consuming task. Therefore, this study will present an overall outline of the CCNERT methodology and concentrate on applications in the building sector.

1.4 ORGANIZATION OF THE DISSERTATION

This dissertation is divided into seven chapters. Chapter I is the introduction. This chapter provides the background for this research, the problem statement, the objective and scope of this study, and the proposed research. Chapter II is the literature review. This chapter begins by outlining the general characteristics of building energy use and its associated NOx emissions. This involves reviewing the categories of NOx emissions in terms of its general description, regulations, and the characteristics of the various available methodologies for estimating NOx emissions reduction. It goes on to generally discuss how NOx emissions are generated, why NOx emission control is needed, and how these topics related to each other. This chapter also discusses the community-based energy efficiency program in terms of its general characteristics, previously developed methodologies, and its impact on energy reduction. It goes on to generally discuss what work others have previously done to develop community-based energy efficiency methods and outlines procedures for using those methods. Chapter III includes the objective and scope of this study. Chapter IV includes the methodology. This chapter presents the basic concepts and methodology in order to provide a framework for estimating a community-wide energy usage and its associated NOx emissions. Chapter V is the application of this methodology with regard to energy use. This chapter discusses the detailed procedures used to apply this methodology to the case study community of College Station, Texas. This chapter also describes the results obtained regarding estimated energy use using this methodology. Chapter VI applies the methodology to NOx emissions, and provides an overview of the CCNERT effort to date, including the results of the NOx emissions from College Station. This chapter also discusses possible scenarios that could offer energy savings and NOx emissions reductions. Finally, Chapter VII contains a summary and future directions this research could take.

CHAPTER II
LITERATURE REVIEW

2.1 INTRODUCTION

One of the promising options for a local community seeking to reduce their summer ozone pollution is to adopt an energy efficiency plan. This possibility must be evaluated to both identify and quantify on a community-wide basis, the amount and location of energy reduction and the results of any emissions reduction. The related literature includes that which describes understanding community-wide energy efficiency program characteristics, an investigation of end-use energy efficiency measures, and an examination of the development of procedures used to calculate energy savings and NOx emissions reductions that can then reduce ozone pollution.

To obtain a through understanding of the related literature, various sources were reviewed. These sources included publications and reports from ASHRAE, the Journal of Energy and Buildings, the Journal of Solar Energy Engineering, the Proceedings of the Symposium on Improving Building Systems in Hot and Humid Climates, the Proceedings of the American Council for an Energy Efficient Economy (ACEEE), reports from the Environmental Protecting Agency (EPA), the Texas Commission on Environmental Quality (TCEQ), the Public Utility Commission of Texas (PUCT), the Railroad Commission of Texas (RRC), of Brazos County, and of the City of College Station (COCS), as well as documents from the Lawrence Berkeley National Laboratory (LBNL), the Energy Systems Laboratory (ESL) at Texas A&M University, the Oak Ridge National Laboratory (ORNL), the Energy Information Administration (EIA), the U.S. Census Bureau (US Census), and other areas related to this research.

This chapter begins by outlining the general characteristics of building energy use and its associated NOx emissions. This involves a review of the categories of oxides of nitrogen (NOx) emissions in terms of a general description, regulations, and the characteristics of available methodologies for estimating NOx emissions reduction. This chapter includes a general discussion of how NOx emissions are generated, why NOx emission control is needed, and how community-wide energy use and NOx emissions are related. This chapter also discusses community-based energy efficiency programs in terms of their general characteristics, previously developed methodologies, and their impact on energy reduction. It goes on to generally discuss what work others have previously done in developing community-based energy efficiency methods and outlines procedures for using these methods.

2.2 OVERVIEW OF NO_X EMISSIONS

As shown in Table 2-1, nitrogen oxide (NOx) is one of several criteria pollutants that are both complex and pervasive. Once emitted into the environment, NOx travels long distances through atmospheric, terrestrial, and aquatic systems. Accordingly, it causes both direct and indirect impacts on human health and the environment, sometimes hundreds or thousands of miles away from its source (EPA 2002). From 1988 to 1997, large stationary utility and industrial burners accounted for roughly 10.5 to 11 million short tons, or approximately 45 percent of the NOx produced by human activity entering the U.S. atmosphere.

Our daily activities cause directly air pollution through our use of electricity, as well as the combustion of fuels used for heating, and transportation. We also cause air pollution indirectly, when we buy goods and services that use energy in their production and delivery. In the U.S., the conventional production of electricity from power plants that burn fossil fuels cause more air pollution than any other source, and greatly contributes to global warming. In 2000 the United States, with only 4.6 percent (263 million) of the world's population, generated almost 1,571 million metric tons of this carbon equivalent, which equates to about 25 percent of the total world's air pollution (EIA 2001b). The total amount of the world's air pollution is approximately 6,500 million metric tons of carbon equivalent.

The Environmental Protection Agency (EPA's) Acid Rain program, which began in 1990, resulted in a 40 percent reduction in the NOx emission rate of large utility boilers (EPA 2002). The principal goal of the program was to achieve reductions of 10 million tons of sulfur dioxide (SO2) and 2 million tons of nitrogen oxides (NOx), the primary components of acid rain.

Additional reductions due to summertime ozone controls are expected over the next several years. However, increases in electricity generation and peak demands due to population growth are expected to gradually erode the success of these measures, as shown in Figure 2-1.

According to the most recent U.S. Census, the total population in the U.S. increased from 263 million people in 1995 to 291 million people in 2003. With the largest increase in the south and the western regions of the U.S., the demand for air conditioners has significantly increased. In the state of Texas (where air conditioner needs are the highest in the U.S), more than 90% (EIA 2001a) of all households have some type of air conditioning system [Central Air Conditioner (CAC), Heat Pump (HP) or Room Air Conditioner (RAC)]. By increasing the demand for AC, annual and peak electricity demands increased along with NOx emissions.

For instance, according to the Public Utility Commission of Texas (PUCT 2000), the annual electricity generation in Texas has grown considerably in recent years. In addition, peak demands in Texas have also grown significantly in recent years due to sustained economic growth, an increasing population and higher than average peak summertime temperatures. Figure 2-2 shows that the peak demand in the state grew from 56,848 MW in 1995 to 65,469 MW in 1999, which is a compound annual growth rate of 3.6%.

In the Electricity Reliability Council of Texas (ERCOT) service territory, the annual growth rate is an even higher rate of 4.1% per year from 46,668 MW to 54,849 MW. Table 2-2 shows that the annual electricity sales in the state grew from 269,640 GWh in 1994 to 314,260 GWh in 1999, which represents an annual growth rate of 2.0% (PUCT 2000). Among all the sectors (residential, commercial, industrial, and transportation), the residential sector showed the largest annual growth (2.6% from 1994 to 1999). This can be attributed to the increase in population and a corresponding increase in the number of new households and associated equipment.

In addition, an increased demand for more air conditioning, larger houses, and more electricity for an increasing number of consumer electronics (i.e., computers, VCRs, TVs, etc.) has also increased peak demands (EIA 1999). Therefore, electricity savings and peak demand reductions from the building sector are increasingly important for the reduction of NOx emissions.

Table 2-1: Sources and Effects of Common Pollutants.

Pollutant	Anthropogenic Sources	Human Health Effects	Environmental Effects
Ozone (O^3)	Secondary pollutant formed by chemical reaction of VOCs and NOx in the presence of sunlight	Breathing problems, reduced lung function, asthma, irritates eyes, stuffy nose, reduces resistance to colds and infections, premature aging of lung tissue.	Damage crops, forests and other vegetation; damages rubber, fabric, and other materials; smog reduces visibility.
Nitrogen Oxides (NOx)	Burning of gasoline, natural gas, oil (Transportations is major source of NOx)	Lung damage, respiratory illnesses, Ozone (smog) effects.	Ozone (smog) effects; precursor of acid rain which damages trees, lakes, and soil; aerosols can reduce visibility. Acid rain also causes buildings to deteriorate.
Carbon Monoxide (CO)	Burning of gasoline, natural gas, coal, oil	Reduces ability of blood to bring oxygen to body cells and tissues.	
Volatile Organic Compounds (VOCs)	Fuel combustion, solvents, paints	Ozone (smog) effects, cancer and other serious health problems.	Ozone (smog) effects, vegetation damage.
Particulate Matter (PM)	Emitted as particles or formed through chemical reactions; burning of woods, diesel and other fuels; industrial process; agriculture (plowing, field burning) unpaved roads.	Eye, nose, and throat irritation; lung damage; bronchitis; cancer, early death.	Source of haze which reduces visibility. Ashes, smoke, soot and dust can dirty and discolor structures and property, including clothes and furniture.
Sulfur Dioxide (SO2)	Burning of coal and oil, especially high-sulfur coal; industrial process	Respiratory illness, breathing problems, may cause permanent damage to lungs.	Precursor of acid rain, which can damage trees, lakes, and soil; aerosols can reduce visibility.
Lead	Combustion of fossil fuel and lead gasoline; paint; smelters	Brain and nervous system damage, digestive and other problems. Some lead-containing chemicals cause cancer in animals.	Harm to wildlife and livestock.
Mercury	Fossil fuel combustion, waste disposal, industrial process, mining.	Liver, Kidney, and brain damage; neurological and development damage.	Accumulates in food chain. Harm to wildlife.

Source: EPA 1993.

Source: EIA 2002.

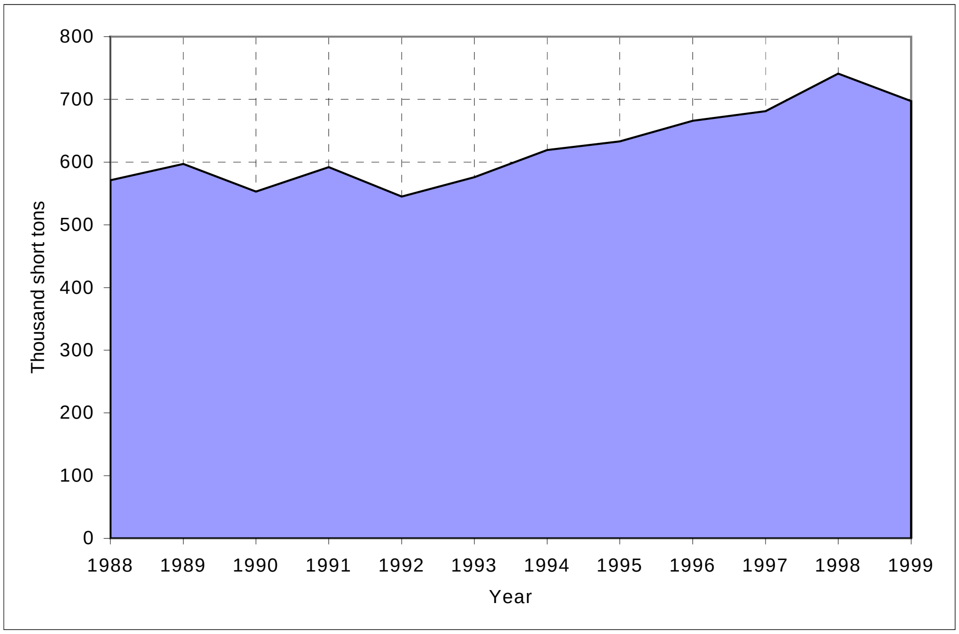


Figure 2-1: Estimated NOx Emissions from the Electric Power Industry in the State of Texas.

Source: PUCT 2000.

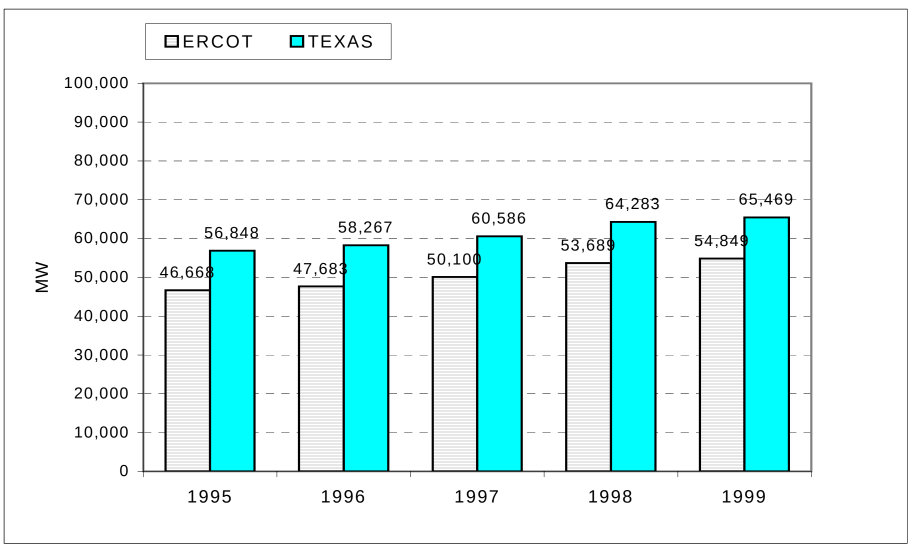


Figure 2-2: Peak Demand (MW) in the State of Texas, 1995-1999.

Table 2-2: Total Annual Electricity Sales by Sector[2].

Year	Residential	Commercial	Industrial	Other	Total	Wholesale	Interruptible	Total Sales
1994	75,674	61,030	81,535	8,889	227,128	37,056	5,457	269,640
1995	78,027	62,804	81,998	9,034	231,864	39,791	4,560	276,215
1996	83,291	64,785	86,883	9,627	244,587	41,774	4,606	290,966
1997	84,469	67,080	89,481	9,726	250,757	42,924	6,452	300,133
1998	91,892	71,128	91,029	10,472	264,522	44,650	7,460	316,632
1999	89,996	73,000	88,757	10,281	262,034	44,569	7,657	314,260
2000	91,986	73,799	88,772	10,687	265,244	42,068	8,134	315,446
2001	94,385	75,157	88,564	10,917	269,023	41,173	8,036	318,232
2002	98,252	77,592	90,203	11,350	277,397	39,702	8,277	325,376
2003	100,835	79,410	91,731	11,560	283,536	40,386	8,365	332,288
2004	103,563	81,301	93,812	11,786	290,462	41,772	8,455	340,690
2005	106,227	83,171	95,978	11,999	297,375	42,551	8,547	348,472
2006	108,949	85,044	98,259	12,204	304,456	43,708	8,639	356,803
2007	111,385	86,830	100,030	12,385	310,629	45,127	8,734	364,490
2008	113,918	88,586	103,087	12,566	318,158	46,616	8,829	373,604
2009	116,606	90,432	105,627	12,760	325,426	48,165	8,926	382,517
AGR	2.6%	2.2%	1.8%	2.2%	2.2%	0.8%	1.5%	2.0%

Source: PUCT 2000.

2.3 EFFORTS MADE TO REDUCE NO_X EMISSIONS

Both the federal and state governments are currently using a number of regulatory programs and activities to reduce NOx emissions from both point and area sources. As shown in Table 2-3, these efforts include programs to reduce NOx emissions from new stationary sources; a program under Title IV of the Clean Air Act (CAA) to reduce NOx from existing coal-fired power plants; regional approaches such as the Ozone Transport Commission's (OTC) trading program; and the "NOx SIP Call" (EPA 2002). In the fall of 1998, the EPA issued a new regulation requiring 22 states and Washington DC to submit to state implementation plans (SIPs) in order to diminish the regional transportation of ground level ozone through a reduction in NOx. These are all "mandatory" programs meant to clean up large polluters and to make mandatory changes to the stock of new automobiles and equipment. Since limited information exists on how to identify and select cost-effective options for local communities selecting to

[2] Data from 1994 to 1999 are actual; data from 2000 to 2009 are projected by PUCT
AGR – the compound annual growth rate from 1999 to 2009.

reduce pollution caused by energy use, these mandatory programs alone will be inadequate to the task of solving regional or community pollution problems. Therefore, community-based programs along with national or state wide mandatory programs are needed for this research. Concurrently, states and local communities are making improvements in their source inventories of their regional modeling efforts (Boone et al. 2002). For instance, the TNRCC is responsible for communicating information concerning area source emission trends.

Table 2-3: Recent National Regulations Affecting NOx Emissions.

Regulation	Compliance Date	Affected Source	Projected NOx Emission Reduction	Inclusion of Emission Cap in Regulation
New Stationary Sources New Source Performance Standards (NSPS) New source Review (NSR)		Major new and reconstructed sources All major new and modified stationary sources apply NOx Best Achievable (BACT) or Lowest Achievable Emission Rate (LAER)	45,650 tons/year (2003)	No Cap
Title IV Acid Rain NOx	Group 1 (phase I): January 1, 1996 Group 1 (phase II) and Group 2: January 1 2000	Group 1: Coal-fired dry bottom wall-fired boilers, tangentially fired boilers Group 2: Wet bottom boilers, cyclones, cell burners, and vertically-fired boilers (nationwide)	2.06 million tons/yr (2000)	No Cap
Ozone Transport Commission (OTC)	Phase 1 (NOx RACT): May 31, 1995 Phase II: May 1999 Phase III: May 1, 2003	Fossil fuel-fired boilers and indirect heat exchangers with a maximum rated heat input capacity of 250 MMBtu/hour or more	320,000 tons/yr	Cap
Section 126	May 1,2003		510,000 tons per ozone season	Cap
NOx SIP Call	State NOx Budget program (and NOx reductions) must be implanted by May 21, 2004: budgets to be achieved by 2007	19 states and the District of Columbia (DC)	880,000 tons per ozone season	Cap

Table 2-3: (Continued).

Regulation	Compliance Date	Affected Source	Projected NOx Emission Reduction	Inclusion of Emission Cap in Regulation
Mobil Source Regulation	Tier I Tailpipe standards	Tier I Tailpipe standards: light duty vehicles and trucks	935,000 tons/yr (2010)	No Cap
	Tier II Gasoline Sulfur Program: 2004 for gasoline sulfur content nationwide; 2004-2009 for tighter NOx Standards for vehicles	Gasoline Nationwide, and cars, light trucks, and SUVs up to 10,000 pounds gross weight sold outside California	4,454 million tons/yr (2030)	
	National Low Emission Vehicle (NLEV) Standards: 1999 in NW ozone transport region; 2001 nationwide	National Low Emission Vehicle (NLEV) standards: Light vehicles and light duty trucks	199,100 tons/yr (2007)	
	Heavy-duty highway diesel standards: 2004	Heavy-duty highway diesel standards	1.1 million tons/yr (2020)	
	Heavy-duty non-road diesel standards: 1999-2006	Heavy-duty non road diesel standards: heavy duty diesel construction, agriculture, industrial engines	1.2 million tons/yr (2010)	
	Small spark-ignition engine standards, phase I: 1997	Small spark-ignition engine standards, small spark fired engines	9,900 tons/yr (2020)	
	Small spark-ignition, non-handheld engine standards, phase II: 2001-2007	Small spark-ignition, non-handheld engine		
	Locomotive engine standards: 2000	Locomotive engine standards: new and rebuilt locomotive engines	493,900 tons/yr (2010)	

Source: EPA 2002.

The Texas Emissions Reduction Plan (TERP) was established in 2001 by the 77th Legislature through the enactment of Senate Bill 5 to ensure that Texas air meets the Federal Clean Air Act requirements (Section 707, Title 42, United States Code), and reduce NOx emissions through mandatory and voluntary programs, including the implementation of energy efficiency and renewable energy programs in non-attainment and affected counties. To achieve the clean air and emissions reduction goals of the TERP, SB 5 created a number of energy efficiency and renewable energy programs for credit in the EPA mandated State Implementation Plan (SIP). As shown in Table 2-4, from the 2001 SIP (Dec 27, 2001), the TNRCC has estimated the emission of VOC and NOx, for area sources in non-attainment areas for selected years. In 2003, the 78th Legislature, through HB 1365 and HB 3235, amended SB 5 to enhance its effectiveness by adding additional energy efficiency initiatives, including: 1) requires the TCEQ to conduct outreach to non-attainment and affected counties on the benefits of implementing energy efficiency measures as a way to meet the air quality goals under the federal Clean Air Act, 2) requires the TCEQ develop a methodology for computing emission.

Unfortunately, since these data mainly deal with a limited area (non attainment and near non attainment areas), this inventory is not sufficient for identifying annual emission trends for all 254 counties in the state of Texas (Bollman et al. 2001). Since the emissions from non-attainment areas are not directly counted, they require a degree of adjustment for regional or local communities not in the current SIPs.

Table 2-4: 1993 Base Case Emissions in the HGA 8-County Area for September 8.

Category	NOx (tpd)		VOC (tpd)	
	Phase 2	Phase 3	Phase 2	Phase 3
On-road mobile sources	416	416	199	199
Area/non-road mobile sources	226	155	318	309
Point sources	695	695	411	411
Biogenic sources	19	18	1608	1294
Total	1356	1284	2536	2213

Source: TNRCC 2001

2.4 REVIEW OF METHODOLOGIES FOR ESTIMATING NO_X EMISSION REDUCTIONS

This section discusses the various methodologies for estimating NOx emissions reductions by adopting energy efficiency measures. Its goes on to generally discuss what work others have previously done to develop methods to estimate energy savings and their associated NOx emissions reductions.

2.4.1 Overview of Existing Methodologies

Estimations of emissions reductions related to energy efficiency measures have historically been developed using several methods and various estimation tools. Although there are several approaches, according to the EPA (1999b) all can be categorized into two main disciplines: 1) the top-down approach and 2) the bottom-up approach. Historically, the EPA has applied a top-down approach. Many state governments have used this approach to estimate their current ozone level and to reduce their non-attainment area ozone levels. Procedures used to develop this information have been fully documented in the state of Texas's SIP (TNRCC 2001). These include installing continuous emissions monitors (CEMs) in power plant stacks, estimating vehicles miles traveled (VMT) from sampling data available from the Texas Department of Transportation (TxDOT), and estimates of aircraft trips from published Federal Aviation Administration (FAA) data. For instance, the TNRCC used this top-down approach to develop useful information, as shown in Figure 2-3. From this information, top-down decision could clearly be made. For instance, in Texas, the Houston-Galveston area is the largest area in the state that has been investigated. In this area, the stationary sources are the most significant sources, followed by on-road mobile sources.

However, grouping sources together has both pros and cons. The pros to this approach are that it works with readily available activity data such as population information, and it gives a generalized answer. The main limitation to this approach is that additional information within a group cannot be further examined without additional details. For example, without knowledge of the building type in a SIP region, one cannot determine if energy conservation in residential or commercial buildings is efficient. Furthermore, most estimates of the amount of energy used for building sectors are derived through statistical analyses of energy consumption data from government sources for the U.S., or sections of the U.S. Unfortunately, these may or may not provide insight into the composition of energy use and its associated emissions production in specific areas as defined by the SIP.

Source: TNRCC 2001.

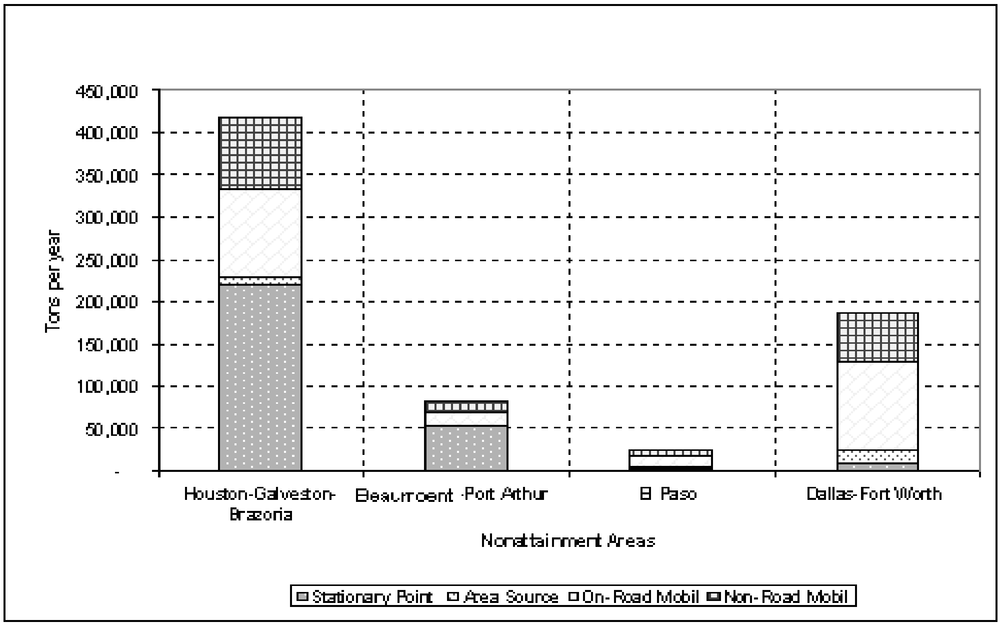


Figure 2-3: Distributions of NOx Emissions from Non-attainment Areas in Texas.

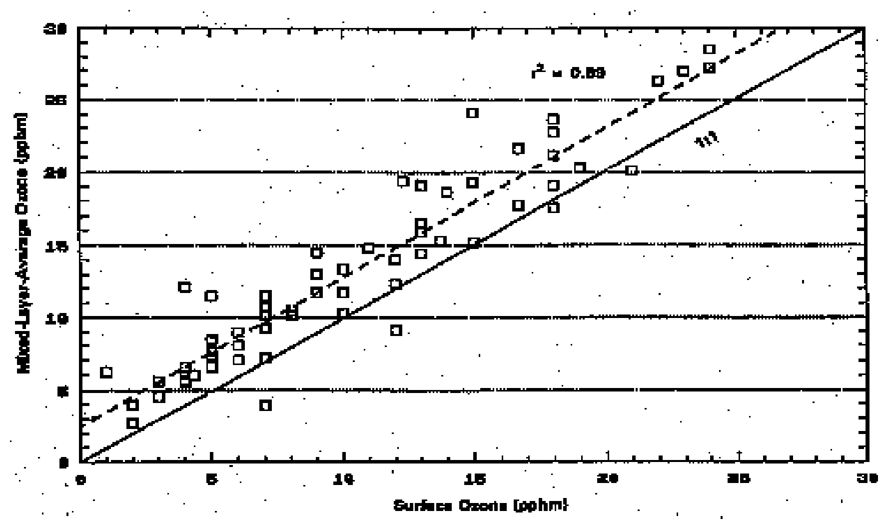
In contrast to the top-down approach, the bottom-up approach is based on the behavior and energy consumption patterns of representative buildings. With such an approach, computer simulations can be used to disaggregate energy use to its individual components (i.e., envelope loads, internal gains, solar, etc.) for a particular building (Huang 2000). However, there are hundreds of building types, and buildings can be categorized in many ways by use, type of construction, HVAC equipment, or thermal characteristics of community-wide energy use. Therefore, using a bottom-up approach only is a daunting task when studying every sector of a community in order to reduce emissions. Fortunately, an integrated, community-wide energy efficiency analysis can be implemented at the regional level for the power generation industry (power plants, distributed generators), transportation, industrial, and for the end-use scale for residential and commercial sectors. Therefore, an integrated “top-down bottom-up approach” is needed to develop the general framework for the Comprehensive Community NOx Emissions Reduction Toolkit (CCNERT) methodology used in this study.

2.4.2 Photochemical Modeling

Emissions of NOx and VOCs from anthropogenic and biogenic sources react with energy from sunlight to form ozone in the lower atmosphere. In response to adverse health effects from exposure to ozone and its precursors, the Clean Air Act Amendment of 1990 established selected comprehensive, three-dimensional (3-D) photochemical air quality simulation models to be used as the required regulatory tools when analyzing the urban and regional problems of high ambient ozone levels across the United States (TNRCC 2001: Chapter 3). These models are applied to study and establish strategies for meeting the National Ambient Air Quality Standard (NAAQS) for ozone non-attainment areas (EPA 1999a). For instance, in the summer of 1993 the Texas Air Quality Board (TACB) conducted an ambitious field study designed to collect data that would allow ozone formation along the Gulf Coast to be better understood and more accurately simulated primarily by utilizing the Urban Airshed Model (UAM) developed by SONOMA Technology Inc. (Kumar and Lurmann 1999). This study was known as the Coastal Oxidant Assessment for Southeast Texas (COAST) study. In this study, the sensitivity of peak ozone concentrations to individual components of the emissions inventory was examined. However, detailed regions or specific emissions controls were not modeled, since only across-the-board reductions were tested. Furthermore, the TNRCC (2001) concluded that the UAM results somehow conflicted with aloft air quality measurements, as shown Figure 2-4.

Later, the TNRCC adopted the Comprehensive Air Model with Extensions (CAMx) developed by the ENVIRON Corporation and used this instead of the UAM to evaluate specific NOx control strategies. CAMx is currently being used by the State of Texas to develop regional and local control strategies, to evaluate attainment plans, and to determine the magnitude of regional transportation of air pollutants (TNRCC 2001).

Source: Roberts et al. 1993.



Comparison of midday and afternoon mixed-layer-average and surface ozone concentrations (linear regression and 1:1 lines shown). (Roberts et al., 1993a)

Figure 2-4: Comparison of UAM Results with Aloft Air Quality Data Based on the South Coast Air Quality Study (SCAQS).

Unfortunately, research has shown that a reduction of ground-level ozone does not always occur when NOx emissions are reduced. Therefore, to fully understand these factors it may be necessary to re-run the hourly photochemical modeling to calculate ozone reductions. However, re-running the CAMx model to simulate the hourly ozone concentrations that were actually measured at each ozone monitor station requires knowledge of the hourly energy use of all energy-consuming sectors. For instance, energy use in buildings is strongly influenced by several factors including climate, building envelope, and internal heat gains. Air pollution, especially the “ground-level ozone,” is also influenced by chemical reactions of VOCs and NOx emissions with strong sunlight. This must then be modeled with concurrent weather data. Therefore, without the photochemical modeling expert’s help, it is very difficult for a decision maker to assess how sensitive ozone concentrations are to changes in various parameters, including pollution emissions, meteorological conditions, and initial and boundary conditions.

In summary, improved procedures for calculating emissions reduction need to be developed to provide greater accuracy when estimating ozone reductions from electricity reduction in buildings. Therefore, this study will provide an outline for developing procedures for calculating community-wide emissions reductions for the primary end-use categories (i.e., residential, commercial, industrial, and transportation), and will provide a detailed example of its application for residential and commercial building energy use. The ultimate goal of such procedures is to allow for the hourly evaluation of all end-use sectors, which can then be translated into the associated pollutants.

2.4.3 Emissions & Generation Resource Integrated Database (eGRID)

Since energy efficiency benefits air quality by decreasing the demand for electricity, and, thereby, decreasing the amount of power plant emissions, determining where or how these kWh are produced and transmitted into the community is critical. However, as shown in Figures 2-5 and 2-6, the electric power service area and power grid in Texas are both highly interconnected due to the variation in capacity and generation mix, transmission capabilities and other physical operation limitations across the various regions (Kerr et al. 2002).

Recently, to overcome this limitation, the EPA contracted with Pechan & Associated Inc. to develop the Emissions and Generation Resource Integrated Database (eGRAD) (TNRCC 2002). eGRID provides emissions and resource mix data for every power plant, electric generation company, state, and region of the U.S power grid. eGRID analyzes how much electricity has been exchanged between each power control area (TNRCC 2002). By using eGRID, the TNRCC has adopted a standard methodology to estimate NOx emissions reductions associated with energy savings. When the annual electricity savings for a selected community or region are inputed into eGRID, NOx reductions can be calculated for each power generator. That information can then be converted into annual or daily reductions. Electric power loss factors resulting from electricity transmissions and distribution processes must be estimated and all values adjusted to obtain the most accurate results. The use of eGRID will be useful to this study because it provides EPA-accepted procedures for calculating NOx emissions reductions from electricity savings.

The eGRID is a comprehensive database of environmental pollution produced by electric power plants. eGRID is based on measured, plant-specific data for all U.S. electricity-generating plants that provide power and report data to the U.S. government. Data reported for each power generator includes its electricity generation (in MWh), the resource mix (i.e., whether renewable or non-renewable), the emissions (in tons for NOx, SO2, and CO2; and in pounds of mercury), the emission rates (in both pounds per megawatt-hour [lbs/MWh] and pounds per million Btu [lbs/MMBtu] for NOx, SO2, and CO2; and in both pounds per gigawatt-hour [lbs/GWh] and pounds per billion Btu [lbs/BBtu] for mercury), the heat input (in MMBtu), and its capacity (in MW). eGRID also reports changes in ownership and industry structure, as well as power flows between states and grid regions.

For this study, with eGRID spreadsheets, several tasks were necessary to convert the community-wide electricity consumption into the companion NOx emissions at the power plants that provided the electricity for a particular community. Original eGRID spreadsheets, which can be obtained from the EPA's website (http://www.epa.gov/cleanenergy/egrid/), were first modified to be readily useful for this study. The original eGRID spreadsheet consisted of four sub spreadsheets:

1) eGRID2002YRyy_plant
2) eGRID2002YRyy_location
3) eGRID2002YRyy_owner
4) eGRID2002YRyy_powerflow

Of these four spreadsheets, the eGRID2002YRyy_plant is a plant data workbook that contains a maximum of eight spreadsheets (plant, boiler, generator, plant biomass adjustment file, and four Note files). The eGRID2002YRyy_location is a location-based data workbook that contains a maximum of 11 location-based spreadsheets (state, electric generation company, parent company, power control area, eGRID sub region, NERC region, U.S. total, four Note files). The eGRID2002YRyy_owner is an owner-based data workbook that contains a maximum of 10 owner-based spreadsheets (electricity generation company, parent company, power control area, eGRID subregion, NERC region, U.S. total, and four Note files).

The eGRID2002YRyy_powerflow consists of 18 time-series spreadsheets (the 1994-2000 state import-export report, one U.S. generation and consumption file for 1994-2000, the 1994-1998 power control area interchange, and the 1994-1998 NERC region interchange files). Of these spreadsheets, eGRID2002yr00_plant.xls (Version 2.01) was directly useful for this study because it provided specific information regarding: 1) the plant name, 2) its location based on PACs, 3) the plant's primary fuel source, 4) its annual net generation (MWh), 5) the plants' annual NOx rate, and 6) the plants' ozone season day NOx rate. However, this table contained information on almost all power plants [4,701 power plants with 155 information (data) columns] in the U.S. The first task was to select the power plants all of, which are located in the state of Texas. Of 155 information columns in the eGRID plant year 2000 data table, seven information columns were selected and regrouped for this study.

Source: PUCT 2002.

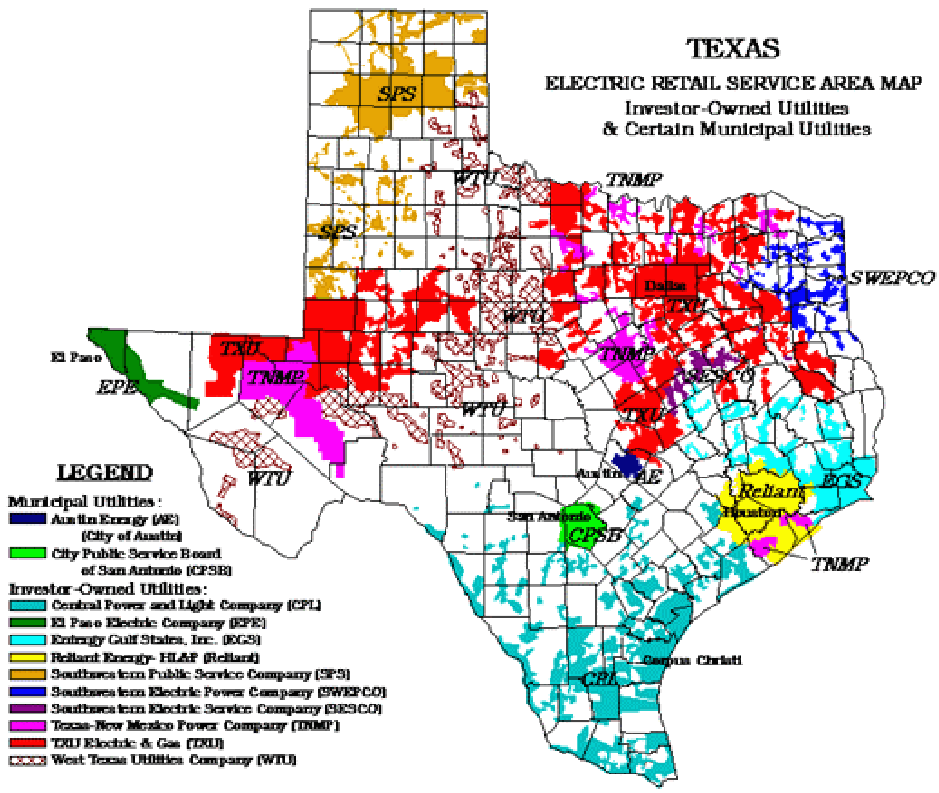


Figure 2-5: Texas Electric Retail Service Area Map.

Source: ERCOT 2002.

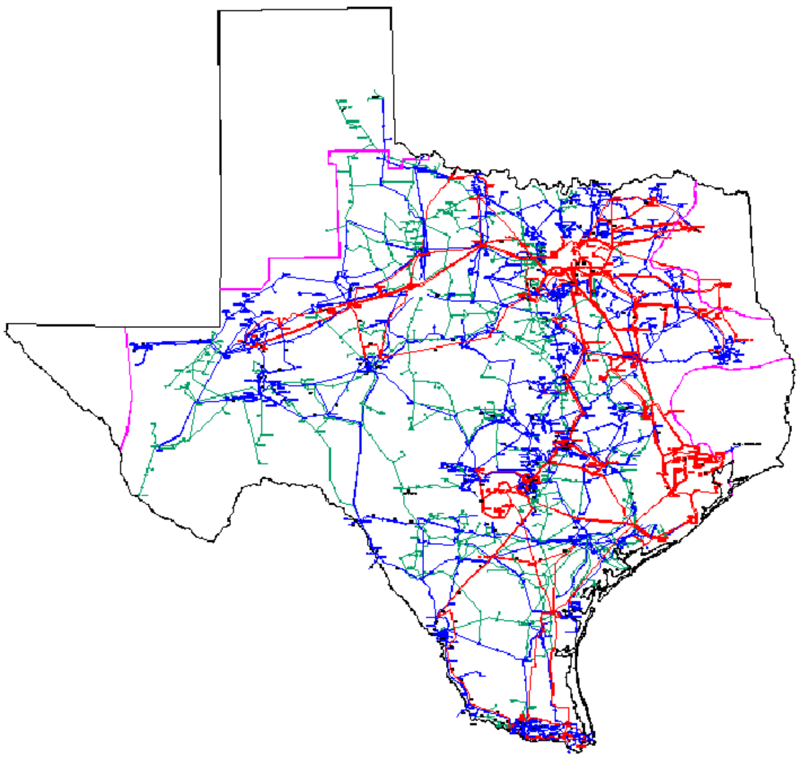


Figure 2-6: Texas Electricity Power Grid Map.

2.5 REVIEW OF COMMUNITY-WIDE ENERGY EFFICIENCY PROGRAMS

To understand the characteristics of community-wide energy efficiency program, previously developed programs and methodologies were reviewed. The programs and methodologies included: the Comprehensive Community Energy Management Planning (CCEMP), and the Community Energy Assessment and Design Support (CEADS).

2.5.1 Comprehensive Community Energy Management Planning (CCEMP)

In 1981 the Comprehensive Community Energy Management Planning (CCEMP), developed by Hittman and Associates Inc. was adopted to reduce energy consumption in the City of Boulder, Colorado. This project was supported by the U.S. Department of Energy (DOE) with the hope of developing and evaluating energy conservation programs for an entire community. The CCEMP was a pioneering effort in the field of community energy planning.

Fortunately, the general concept and description of the CCEMP was thoroughly discussed and summarized by Haberl (1979). This review simply follows his documentation. The CCEMP is a three-volume publication developed by the Hittman & Associates Inc. of Columbia, MD. The CCEMP was intended to measure current community energy usage and to develop energy conservation methods for a total community. Volume I of the CCEMP is a basic procedural manual, which guides the user through energy auditing, the formulation of community objectives, and an evaluation of conservation alternatives and strategies for implementation. Volume II is the support manual for the Volume I and contains default procedures and related necessary information. Volume III is the actual workbook that serves to record energy consumption and also aid the user in an evaluation of alternative and strategies. The general concept of the CCEMP is to classify the total community into different categories: comprehensive energy usage, building type, and energy activity.

A typical description of the CCEMP methodology follows. This methodology provides information concerning the energy usage of a particular group of buildings within the community. Proceeded by the obtaining of values for the square footage of the residential housing units in the community, the information is then recorded on the worksheet, and fuel supply mixes are obtained. One must then multiply (sq.ft) x (% fuel activity) x (% fuel supply mix) x (basic energy factor) to = the energy usage for that specific CCEMP parcel.

Within the community energy audit portion of the CCEMP Volume I, the input data is divided into five basic categories: 1) residential, 2) commercial, 3) industrial, 4) municipal, and 5) transportation. Within each of these different categories, the input information is further reduced to selected parcels. For instance, the residential category is subdivided into five parcels: 1) single-family detached, 2) single-family attached, 3) multi-family low rise, 4) multi-family high-rise, and 5) mobile homes. All necessary energy multipliers are provided in the CCEMP Volume III. If need be, a user can perform a complete community energy audit with only a limited dependence on actual measurements by using the default procedures in the CCEMP Volume III.

The data requirements for the completion of the CCEMP methodology for the five categories are various. In the residential sector, the square footage of all residential units within the community listed both as average per household and average for the grouped units within the residential sector are needed. Energy activity measurements must be taken for each of the residential listings in the CCEMP Volume III. Some typical residential energy activities were given as examples. The input of this type of information breakdown aids in the identification of different energy conservation opportunities. Also needed are the percentages of the different types of fuels used for each of the different energy activities. Future projections are needed for each parcel listed in each of the different CCEMP categories.

In the commercial category, as is similar to the residential category, the square footage for each of the listed parcels is required. Both averages of individual and group values are needed for the computations. Energy usage activity percentages, fuel supply mix percentages and future additions are also required for energy computation through this category.

In the industrial category, data requirements are concerned with the number of industries and the energy intensity (Btu/employee) of each of the different industries listed by the standard industrial code (SIC). The fuel supply mix percentages and future additions are also required.

In the municipal category, the square footage for occupied municipal buildings is required, as well as street lighting information, the capacity of equipment used in water supply and wastewater treatment plants, fuel mix percentages, energy activities, and future for the proper evaluation of this category.

In the transportation category, vehicle miles traveled (VMT) within the city limits listed by vehicle type, as well as future growth comprise the required data input. The sources for this required input data are also described in the CCEMP methodology.

From the CCEMP methodology, it can be found that developing community-wide energy planning is an integration of several approaches. The approaches used in the CCEMP methodology can be summarized and categorized into four generic types, as shown in Figure 2-7. The first task is to determine a community's energy consumption pattern. In preparation for the energy audit, all energy consumers such as buildings, plants, and automobiles in each category must be classified (i.e., type of residence, type of business, type of automobiles, etc.) in order to conform to the methodology's definitions. Next, the number of consumers must be determined. Sources for this information include mail surveys, booth surveys, city tax records, reports from economic development councils, utility company records, census bureau estimates, and information from regional transportation districts. The next step is to determine potential energy problems and to select objectives. The third step is to obtain an impartial and realistic estimate of the maximum energy efficiency potential available for each sector. Lastly, an advisory engineer or energy committee that has been directly or indirectly involved with the development of community-wide energy plans should provide the implementation guidelines.

In this study, a methodology for calculating the NOx emissions reduction from different energy conservation strategies was developed. Fortunately, the previously developed CCEMP methodology included the procedures for calculating community-wide energy consumption. Thus, for this study the CCEMP methodology was carefully reviewed and used as a starting point to develop a framework for examining how community energy use leads NOx emissions. For calculating the total energy derived from the NOx emissions produced by a community's use, the previously developed model "CCEMP" was be modified by adding emissions modules, as shown in Figure 2-8.

2.5.2 Community Energy Assessment and Design Support (CEADS)

In 1993, the Joint Center for Energy Management (JCEM), along with the Vesica Group Architects (VGA), was contracted by Japan Research Institute (JRI) to design and engineer a Soft Energy Community (SEC) based on sustainable concepts and renewable sources. The SEC was later entitled to be the Community Energy Assessment and Design Support (CEADS) for assessing the community form, renewable energy choices, energy conservation measures, transportation modes and configuration of efficiencies. CEADS is a software tool designed to aid in the decision-making process for the planning of sustainable communities or energyresponsive land development projects and is focused on energy conservation and renewable energy resources.

The main CEADS program is complimented by three files: 1) defaults, 2) rules, and 3) weather files. The default file contains the default settings for easy entry of data into CEADS menus for building construction, energy generation and transportation.

Tabb and Kreider (2000) produced a prototype sustainable community design for a real site in southern Japan. This research briefly discussed both the essential conceptual design elements of the prototype-sustainable community design and the basic quantitative mechanism and the function of community scale's energy use. Each and any combination of planning measures and renewable energy choices were also demonstrated. According to Tabb and Kreider (2000), various information sources and procedures were needed for the community scale energy analysis. These procedures included an assessment of the community's size, density, mix of building typologies, building construction thermal properties, integration of solar technologies, transportation modal options, destination efficiencies and infrastructure configurations.

Although the procedures for developing the community scale energy analysis were not fully documented, the previous study is important for this study. This study shows that the impact of integrated energy efficiency measures on energy savings and emissions reductions were magnified when the most suitable energy efficiency measures are identified for the unique characteristics of each community. This study also suggests the most possible scenarios in order to reduce community-based energy savings and emissions reductions. Therefore, not only individual measurements, but also combinations of each measurement should be carefully analyzed in order to find out the most plausible energy savings procedures and emissions reductions for a selected community.

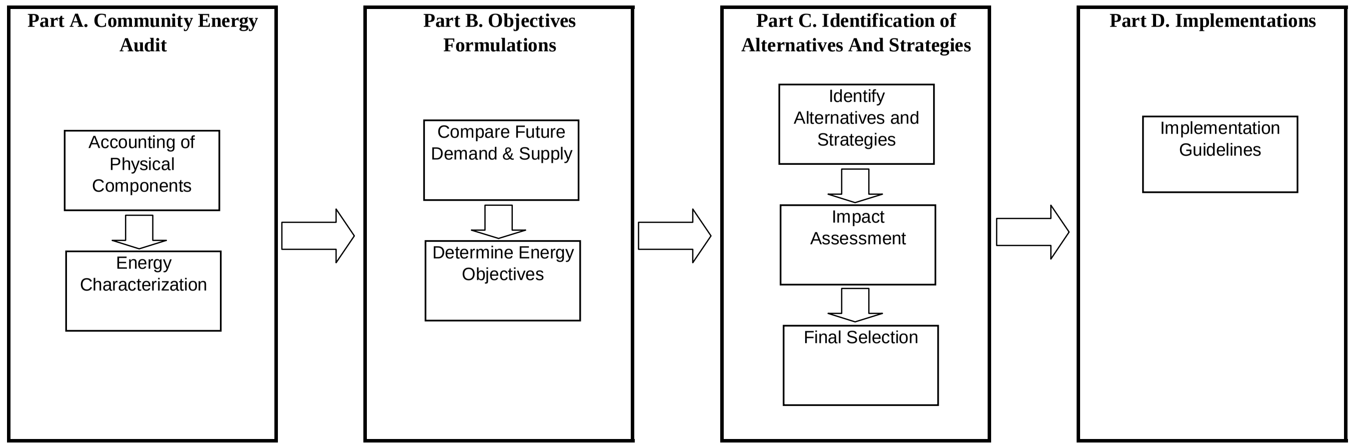
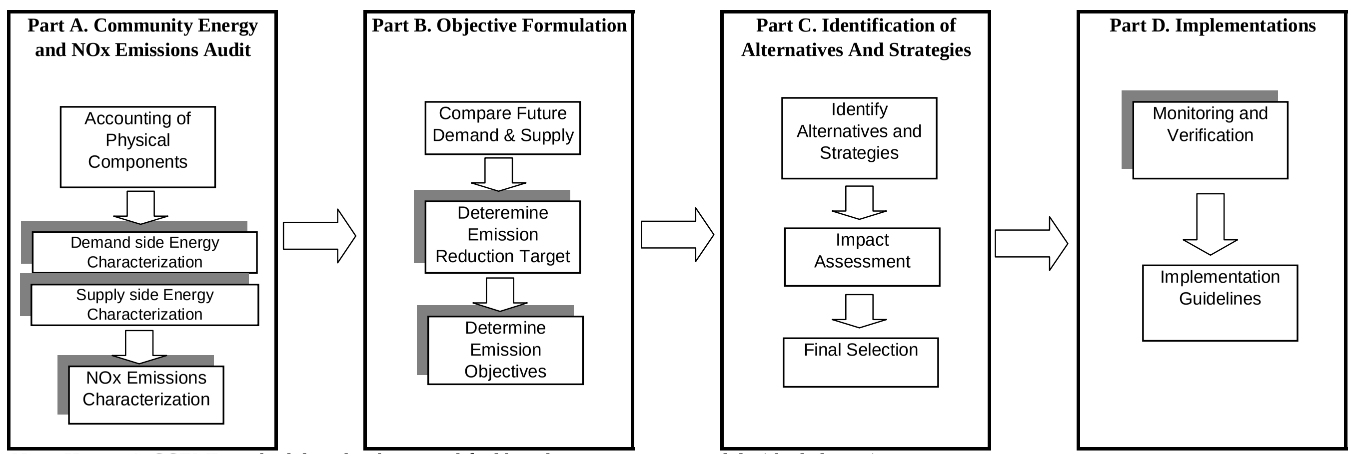


Figure 2-7: General Overview of Comprehensive Community Energy Management Planning.



Note: Hittman's CCEMP methodology has been modified by adopting emission module (shaded parts).

Figure 2-8: Overview of Comprehensive Community NOx Emissions Reduction Methodology.

2.6 REVIEW OF RESIDENTIAL AND COMMERCIAL BUILDING ENERGY BASELINE PROCEDURES

In this section, the most commonly used building energy baseline and prediction models are discussed. These models can be divided into two categories: 1) micro energy models that depict one specific building in detail; and 2) macro energy models that predict the energy behavior of large groups in a community-wide study. There are many micro building energy models [i.e., DOE-2 (LBNL 1989), TRNSYS (SEL 1995), ENER-WIN (Degelman 1995), PRISM (Fels 1986), and ASHRAE's IMT (Kissock et al. 2001)], which are used for individual building energy studies. The most widely used is the DOE-2 program (LBNL 1989).

PRInceton Scorekeeping Method (PRISM) is a variable-based degree-day regression method developed to calculate residential energy savings from energy conservation retrofits (Fels 1986). PRISM was developed in the 1980's to satisfy the need for a reliable scorekeeping method in residential energy conservation programs. PRISM uses monthly utility bills and at least ten years of average daily temperatures from a nearby weather station as data sources. The final product, the Normalized Annual Consumption (NAC) index provides a measure of what the energy consumption would be during the long-term and under average weather conditions. The total energy savings are calculated as the difference between the NAC for the pre- and post-retrofit periods. Many studies about the evaluation of energy conservation retrofits in residential buildings have been performed using PRISM. Although usually there are consistent outdoor temperatures over several years, weather correction is absolutely required in order to obtain reliable estimates of retrofit energy savings.

ASHRAE's Inverse Model Toolkit (IMT) is a FORTRAN 90 application for regression modeling of a building's energy use (Kissock et al. 2001). This toolkit can identify best-fit regression models for measuring retrofit savings in buildings. The IMT includes PRISM's variable-based degree-day algorithms, and utilizes traditional linear, least squares regression models, change-point linear models, multi-linear regression models, and combined models. These models are simpler to use than energy simulation programs such as the DOE-2 but require measured energy consumption data (Haberl et al. 1992). ASHRAE's IMT can also be used to separate the weather dependant from weather-independent loads in a building energy use. Therefore, for this study, the IMT toolkit was used to determine the representative NAC of single-family housing units for the selected community and to compare the normalized energy uses of pre-retrofit and post-retrofit period.

2.7 REVIEW OF INDUSTRIAL SECTOR ENERGY BASELINE PROCEDURES

Energy use characteristics in the industrial sector are very different from the other sectors, because the industrial sector's energy use is significantly dependent upon industrial activity and processes. In general, the industrial sector can be categorized into three major industry categories: 1) energy intensive manufacturing industries, 2) non-energy-intensive manufacturing industries, and 3) non-manufacturing industries. Several previous studies have provided useful information and procedures regarding the industrial sector, including the EIA (2003), the CCEMP methodology (Hittman 1978), and Arthur D. Little Inc. (2001a).

The CCEMP methodology (Hittman 1978) also categorizes industrial activities into 6 industry groups by their similar energy uses per employee. These groups are described in Table 2-5. Group A has the lowest energy intensity factor while group F has the highest energy intensity factor.

In addition, Arthur D. Little, Inc (2001a) has provided an analysis of energy intensity by SIC based on cost of shipment. In 1994 the Energy Information Administration (EIA) designed the Manufacturing Energy Consumption Survey (MECS) in order to provide information on energy consumption by the manufacturing division, as defined by the Standard Industrial Classification (SIC) system. In the 1994 MECS, twenty major manufacturing groups were classified and their energy intensities estimated, as shown in Figure 2-9. These energy intensities vary significantly based on the manufacturing group. The five largest energy consumers are paper and allied products (SIC 26), chemicals and allied products (SIC 28), petroleum and coal products (SIC 29), stone and glass products (SIC 32), and the primary metals industry (SIC 33).

The 20 major groups are subdivided into 139 three-digit industry groups (SIC 201-SIC 399). The further 139 industry groups are then re-subdivided into 459 industry groups (SIC 2011-SIC 3999). Detailed descriptions of the 20 major manufacturing groups are available in Appendix A.

In summary, energy use characteristics in the industrial sector have been analyzed and presented by several sources. In the building sectors such as the residential and commercial sector, energy use is a function of floor space. However, industrial activity or process is the most important factor influencing energy use in the industrial sector. This information is useful for the current study since it allows for an estimation of energy use based on nationally available indices.

Table 2-5: Industry Groups Defined According to CCEMP Methodology.

Group	Industry Name
A	Apparel, Household furniture, Printing and publishing, Footwear and other leather procedures, Office computing and accounting machines, Radio, Television and communication equipment, Miscellaneous manufacturing
B	Ordnance and accessories, Tobacco manufacturing, Miscellaneous fabricated textile products, Wooden containers, Heating, Plumbing, Structural materials, stampings, Screw machine products, Electric industrial equipment and apparatus, Electric components and accessories, Air crafts and parts, Other transportation equipment
C	Broad and narrow fabrics, Yarn and thread mills, Lumber and wood products, Metal containers, Other fabricated metal products, Engines and turbines, Farm machinery and equipment, Construction, Motor vehicles and equipment
D	Food and kindred products, Drugs, Cleaning and toilet preparations, Paints and allied products, Leather tanning and industrial leather products
E	Non-Ferrous metal mining, Stone and clay mining, Paper and allied products, Glass and glass products, Stone and clay products
F	Primary non-ferrous metal manufacturing, Iron and ferroalloy ores mining, Chemical and fertilizer mineral mining, Chemical and selected chemical products, plastics and synthetic materials, Primary iron and steel manufacturing

Source: Hittman 1978.

Source: EIA 1997.

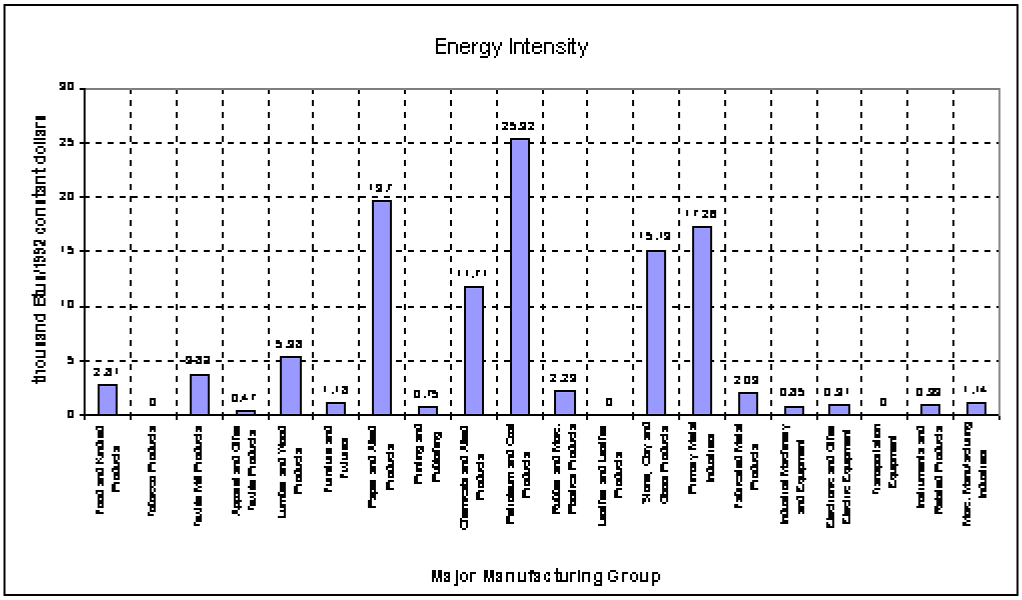


Figure 2-9: Estimated Energy Intensities for Twenty Major Manufacturing Groups.

2.8 REVIEW OF TRANSPORTATION SECTOR ENERGY BASELINE PROCEDURES

Automobile emissions estimates are affected by many factors that vary according to geographic location, and other factors. The most significant factors include average speed, percentage of vehicle miles traveled (VMT) in a given time period, percentage of travel by vehicle type (VMT Mix), and average ambient temperature profile (Cooper and Alley 1994). Vehicles on the road are a mixture of many vehicle types (passenger cars, trucks, vans, etc.), all of which use different fuels (gas, diesel or others). Additionally, the vehicles on a given roadway usually have a wide age distribution. Some cars are the most recent model years, some vehicles are within ten years age, and some are more than 20 years old. All the factors that affect emissions must be taken into account in order to accurately calculate the total vehicle emissions. Therefore, snap-shot checks were conducted for this study in order to determine the vehicle classifications within a community. This snap-shot count consisted of several one-time counts in public parking lots and on major streets.

An emissions factor (EF) is a measure of an average rate of emission of a pollutant for a defined activity rate. For an average vehicle, the EF is the average rate of a particular pollutant when the vehicle is driven according to a specified manner. The EF is usually given in units of grams per mile, per average vehicle. However, many variables influence the numerical value of an EF. According to Cooper and Alley (1994), two variables, vehicle type and vehicle age, affect the numerical value than among others. The same vehicle type, its base emission rates are also various based on the fuel type. Therefore, massive computerized calculations are necessary in order to estimate the correct EF incorporating all variables. For this, the EPA(1995b) has provided an average exhaust emissions factor table for the various ambient conditions, the VMT weighting, and for a range of average speed combinations. Each of the exhaust emissions factor tables (one example is shown in Table 2-6) represents one average speed. Emissions are presented according to seven different speeds: 2.5, 5.0, 10, 19.6, 35, 55, and 65 mph. Each table includes six calendar years: 1990, 1995, 2000, 2005, 2010, and 2020. For each calendar year, 35 emissions factors are provided (five temperatures and seven sets of operating mode fractions). The temperatures are: 0 ^{o}, 25 ^{o}, 50 ^{o}, 75 ^{o}, and 100 ^{o} F. These emissions factors are directly useful to this study.

2.9 REVIEW OF ENERGY EFFICIENCY MEASURES

The review of energy efficiency measures included a broad range of community-wide energy conservation measures, grouped by fuel type per each sector (i.e., residential, commercial, transportation, etc.). Individual energy conservation measures were evaluated and compared based on their relative costs for reducing energy use and its associated NOx emissions. For instance, several types of residential and commercial whole-building efficiency and fuel switching measures such as efficient HVAC systems, lighting and building envelope improvements were reviewed. The most cost-effective, end-use efficiency measures analyzed in the previous studies (LBNL 1995a, ASHRAE 1996, WDNR 1998, IECC 2000 and Arthur D. Little Inc. 2001b) were identified. This study was limited to the best available measures listed in the previous studies, which are available in the current marketplace for residential or commercial buildings.

Table 2-6: Example Emissions Factors.

LOW ALTITUDE
EMISSION FACTORS (GRAMS/MILE)
60-84F DIURNAL, 80F HOT SOAK

Cal.	Pollutant	LDGV						LDGT						HDGV					
Year	By Component	7.0	8.0	9.0	10.0	10.4	11.5	7.0	8.0	9.0	10.0	10.4	11.5	7.0	8.0	9.0	10.0	10.4	11.5
1995	Combined NMHC	2.25	2.44	2.67	3.18	3.42	4.33	3.14	3.36	3.62	4.14	4.39	5.19	7.13	7.93	9.05	10.28	10.85	12.93
1995	Exhaust NMHC	1.68	1.68	1.68	1.83	1.89	2.09	2.43	2.43	2.44	2.59	2.66	2.86	4.73	4.73	4.73	4.77	4.79	4.83
1995	Evaporative HC	0.20	0.24	0.31	0.43	0.49	0.73	0.32	0.36	0.44	0.57	0.65	0.91	1.71	2.11	2.82	3.45	3.76	4.86
1995	Refueling Loss	0.13	0.15	0.17	0.19	0.20	0.23	0.17	0.20	0.23	0.26	0.27	0.31	0.29	0.34	0.39	0.44	0.46	0.51
1995	Running Loss HC	0.18	0.31	0.44	0.67	0.77	1.21	0.16	0.30	0.45	0.65	0.74	1.06	0.29	0.64	1.00	1.51	1.74	2.62
1995	Resting Loss HC	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.10	0.10	0.10	0.10	0.10	0.10
1995	Exhaust CO	21.10	21.10	21.26	25.01	26.77	32.55	28.48	28.48	28.68	32.29	33.96	39.32	95.69	95.69	95.95	97.53	98.22	100.32
1995	Exhaust NOx	1.62	1.63	1.64	1.66	1.67	1.69	1.98	1.99	2.00	2.00	2.01	2.02	5.71	5.61	5.51	5.42	5.38	5.28
2000	Combined NMHC	1.95	2.13	2.34	2.83	3.05	3.89	2.59	2.78	3.02	3.54	3.78	4.59	4.68	5.27	6.05	7.07	7.56	9.35
2000	Exhaust NMHC	1.48	1.48	1.48	1.64	1.71	1.92	2.03	2.03	2.03	2.22	2.31	2.57	2.98	2.98	2.99	3.05	3.08	3.15
2000	Evaporative HC	0.14	0.18	0.24	0.35	0.41	0.63	0.20	0.24	0.31	0.42	0.49	0.71	1.12	1.40	1.86	2.39	2.68	3.68
2000	Refueling Loss	0.13	0.15	0.17	0.19	0.20	0.22	0.17	0.20	0.23	0.26	0.27	0.30	0.28	0.33	0.38	0.43	0.44	0.50
2000	Running Loss HC	0.15	0.27	0.39	0.60	0.68	1.07	0.13	0.27	0.40	0.59	0.67	0.96	0.22	0.48	0.74	1.12	1.28	1.94
2000	Resting Loss HC	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.08	0.08	0.08	0.08	0.08	0.08
2000	Exhaust CO	19.61	19.61	19.75	23.92	25.90	32.44	25.61	25.61	25.80	30.61	32.88	40.33	55.19	55.19	55.59	58.02	59.09	62.33
2000	Exhaust NOx	1.39	1.40	1.42	1.44	1.45	1.47	1.82	1.84	1.86	1.88	1.88	1.91	5.16	5.03	4.89	4.75	4.70	4.56
2005	Combined NMHC	1.79	1.95	2.14	2.57	2.77	3.50	2.33	2.52	2.73	3.24	3.47	4.26	3.49	3.98	4.60	5.50	5.95	7.57
2005	Exhaust NMHC	1.40	1.40	1.41	1.56	1.63	1.85	1.87	1.87	1.88	2.09	2.18	2.46	2.16	2.16	2.17	2.25	2.28	2.37
2005	Evaporative HC	0.12	0.15	0.20	0.29	0.34	0.53	0.14	0.18	0.24	0.33	0.39	0.58	0.82	1.04	1.39	1.86	2.13	3.06
2005	Refueling Loss	0.13	0.15	0.17	0.19	0.20	0.22	0.17	0.20	0.23	0.26	0.27	0.30	0.28	0.32	0.37	0.42	0.44	0.49
2005	Running Loss HC	0.11	0.22	0.33	0.50	0.57	0.87	0.11	0.23	0.36	0.53	0.61	0.88	0.18	0.39	0.61	0.92	1.05	1.59
2005	Resting Loss HC	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.06	0.06	0.06	0.06	0.06	0.06
2005	Exhaust CO	19.39	19.39	19.53	23.88	25.94	32.77	24.44	24.44	24.62	30.01	32.56	41.01	31.97	31.97	32.43	35.19	36.39	40.06
2005	Exhaust NOx	1.28	1.30	1.32	1.34	1.35	1.37	1.70	1.72	1.74	1.77	1.78	1.80	4.60	4.45	4.31	4.17	4.11	3.97

Source: EPA 1995b.

2.9.1 Adoption of Higher SEER Air Conditioning Units in the Residential Sector

According to the most recent U.S. Census, the total population has increased from 263 million people in 1995 to 291 million people in 2003 with the largest increases occurring in three states (California, Texas, and Florida) over the last eight years. Unfortunately, a large portion of the population increase has been in the south and western regions of the U.S. where the demand for air conditioning has significantly increased. In the south, where the air conditioner needs are the largest in the U.S., more than 90% (EIA) of all households have some type of air conditioning system [Central Air Conditioner (CAC), Heat Pump (HP) or Room Air Conditioner (RAC)]. Unfortunately, the increased use of air conditioners has caused electricity utilities in many regions of the U.S. to experience peak-load problems during the cooling season. A variety of studies (Reddy et al. 1992, Lucas 1992) indicates that the residential AC load is a considerable contributor to electric utility peak load. Especially in Texas, 90 % of the residential peak load is contributed by cooling load (Zarnikau 1992). These studies also indicate that residential AC peak loads depend upon three factors: the capacity (size) of the AC unit, the efficiency of the AC unit and the users' operating manner. This is importance to this study because these three factors will be considered when calculating the baseline energy use. From these studies, it can be seen that a high-energy efficiency AC system could be one of the more promising options for a community, especially in the state of Texas looking to achieve energy savings and the associated reductions in NOx emissions.

Recently, many studies have demonstrated the impact of high efficiency HVAC systems on energy savings and peak demand savings in residential houses. These studies include Frontier and Associates (2001), Schiller and Associates (2001), and Park and Shrewin (1996).

Frontier and Associates (2001) demonstrated the impact of highly efficient HVAC systems on annual energy savings (kWh) and demand savings (kW) by using the ESPRI (EPRI Simplified Program for Residential Energy) software. This study compared the energy use of the baseline efficiency (SEER 11) to the energy use of the higher Seasonal Energy Efficiency Ratio (SEER range from 13 to 18) for the various types of AC units: 1) window air conditioners; 2) central air conditioners; and 3) central heat pump systems. Four different weather zones: the South, the Panhandle, the North, and the Valley in Texas and different tonnage ranges from 1.5 to 5.0 tons of energy savings were considered. To identify prototype housing characteristics, various regional information sources were used; these sources include: 1) the South Texas End

Use Study by Central Power and Light; 2) the Entergy 1984 Baseline Study; and 3) the Baseline SPS and AEP utilities efficiency programs.

Table 2-7 shows the results of high efficient central air conditioners on energy savings for the southern climatic zones (Houston, TX). Since the analysis was performed based on regional input data, this study can use the results from Frontier's report to compare annual energy and demand savings from the case study community. Also, the average building characteristics of the average single-family house in Frontier's report can be compared to the average building characteristics in this study.

Schiller and Associates (2001) analyzed and documented the proposed energy savings for the following investor owned utilities: Entergy and Reliant-HL&P. Both the peak demand (kW) and annual savings (kWh) were estimated. Energy savings were determined according to three factors: 1) the equipment size (in tons), 2) the equipment efficiency (SEER), and 3) the operating hours (hrs). Schiller set SEER 11 as the baseline efficiency based on the recent sales of units in the state of Texas as characterized by the AC-distributor program. Schiller used realistic input data of operating hours of the AC units by comparing data from American Refrigerator Institution (ARI) and data from LBNL (1997).

Table 2-7: Proposed Energy Savings by the Highly Efficient CAC (kWh).

Size (tons)	SEER Range					
	13.00-13.49	13.50-13.99	14.00-14.99	15.00-15.99	16.00-16.99	17.00-17.99
1.5	611	695	812	949	1,070	1,177
2	814	927	1,082	1,265	1,426	1,569
2.5	1,018	1,159	1,353	1,582	1,783	1,961
3	1,221	1,391	1,623	1,898	2,139	2,353
3.5	1,425	1,622	1,894	2,214	2,496	2,746
4	1,628	1,854	2,164	2,531	2,853	3,138
4.5	1,832	2,086	2,435	2,847	3,209	3,530
5	2,035	2,318	2,705	3,163	3,566	3,922

Source: Frontier and Associates 2001.

According to Schiller, based on a Lawrence Berkeley National Laboratory (LBNL) conditional load analysis of Texas residential utility data, the ARI's estimated hours for each of Texas' weather zones were reduced by 22% to better represent true consumption pattern. The results show that the average annual energy savings calculated by adopting a SEER 13.5 for the

South (Houston), the Panhandle (Amarillo), the North (Dallas), and the Valley (Corpus Christi) were 347 kWh/ton, 189 kWh/ton, 284 kWh/ton, and 378 kWh/ton, respectively. These results are very similar to Frontier's study. For instance, Frontier's estimated annual savings 611 kWh (see Table 2.7) for the southern weather zone when adopting a 1.5-ton CAC (SEER 13.5); Schiller estimated an annual savings of 347 kWh/ton for Houston when adopting a SEER 13.5. This study emphasized the importance of operating hours to by comparing the ARI to the LBNL data.

From these studies, it was recognized that the energy savings were determined according to three factors: the equipment size in tons, the SEER increment between the baseline and retrofitting equipment, and the operating hours. Therefore, for this study, the average AC size for College Station, TX was determined based on the actual average conditioned floor area. The baseline efficiency of the AC unit was determined according to Frontier's study. The operating hours will be determined based on Schiller's study.

2.9.2 Adoption of Energy Efficient Lighting Systems

Lighting is one of the most significant end-users in the commercial sector. It is also a significant use in the residential and municipal sectors (i.e., street lights, traffic signals, etc.). According to the U.S. DOE (2003), at the national level the energy use for lighting accounted for about 18 % of the total U.S. building energy use in 2001. The U.S. residential lighting energy consumption was approximately 202 TWh[3] in 2001.

The total number of households in the U.S. in 2001 was 107 million (EIA 2003). Thus, the annual lighting energy use per household can be assumed to be about 1,887 kWh. Lighting energy use accounted for 12.2% of the total electricity use in U.S. household in 2001 (U.S. DOE 2003). Unfortunately, lighting energy use is expected to continuously increase as a result of the growing number of households, as well as individual increased lighting use per household. Therefore, the adoption of highly efficient lighting systems in building sectors could be one of the more promising opportunities available to reduce community-wide energy use and its associated NOx emissions. Fortunately, many advances have been made to improve lighting efficiency and many studies have demonstrated the effectiveness of advanced lighting systems on building energy use. These studies include: Manclark et al. (1992), Synergic Research Corporation (1992),

[3] A terawatt-hour is 1,000,000 megawatt-hours or 1,000,000,000 kilowatt-hours.

EIA (1996), Tribwell and Lerman (1996), Parker and Sherwin (1996), and Parker and Floyd (1998).

Table 2-8 summarizes the results of the above studies. From these studies, this literature review identified following information: 1) lighting energy use per household, 2) typical lamp and fixture types in houses, 3) hours of use, and lighting efficiency. Determining the appropriate value for the average lighting energy use per house is a very important task for this study because this value can then be used to calculate building sectors' (residential or commercial) baseline lighting energy uses for the selected community. Typical lamps and fixture types used in households were also needed for this study in order to determine how many lamps and fixture could be replaced with highly efficient lighting systems. The information on the average hours of use for a lighting system was needed for this study in order to estimate accurately the actual energy savings. The technical data for highly efficient lighting systems was also needed for this study in order to estimate energy and peak demand savings. For instance, the wattage difference between baseline lighting systems and efficient lighting systems was the peak demand savings. Therefore, a single-family residence in College Station, Texas, was used as a case study for this study in order to determine how substituting energy efficient lamps and fixtures could reduce residential lighting energy use.

2.9.2.1 Residential Lighting Energy Use

As mentioned before, a determination of how much energy is being used for lighting systems in houses was critical for this study. If average annual lighting energy uses per household could be determined, the total residential sector in a selected community could also be calculated. As briefly described in Table 2-8, Manclark et al. (1992) estimated the annual household energy use for lighting based on a survey and metering of 53 homes in Yakima, WA. This showed that the average annual lighting energy use for the selected homes was 2,418 kWh, which was somewhat biased due to the time of year (winter) when the data were taken. Funded by the Bonneville Power Administration and Tacoma Public Utilities, Tribwell and Lerman (1996) showed that the annual lighting energy use per household in 161 monitored sites was approximately 1,818 kWh/yr. That study also found that lighting energy use varied seasonally. Consumption was 30% greater in the winter months than in the summer months, which could be expected from the longer nights in the winter.

Table 2-8: Summary of Previous Studies on Residential Lighting Energy Use and Efficient Lighting Systems.

	Manclark et al. (1992)	Tribwell & Lerman (1996)	Parker & Sherwin (1996)	Parker & Floyd (1998)	Heschong (1997)
Number of Houses	53	161	1	10	697
Type of House	N/A	Single-Family	Single-Family	Single-Family	All Types
Average Floor Area (Ft^2)	N/A	1,750	1,341	1,110	N/A
Average Annual Energy Consumption per House (Electricity)	N/A	N/A	17,763	1,5000	N/A
Total Lighting Load (kW)	N/A	N/A	2.54 kW	0.4 kW to 1.9 kW	N/A
Estimated Annual Lighting Use	2,418 kWh	1,818 kWh	11.1 kWh/day or 4,050 kWh	1,387 kWh to 4,672 kWh	1,313 kWh (2,076 kWh)*
Total Lamps	29 Fixtures/house	17 Fixtures/house	40 Lamps (26 Controls)	6 – 36 Lamps	23 Fixtures/house
Efficiency Measures	Replacing 30% of the incandescent bulbs with CFLs	N/A	CFLs and Dimmer Motion Sensors	7 to 10 fixtures replaced with CFLs	N/A
Average Annual Savings (kWh)	658 kWh	N/A	2,480 kWh	420 kWh	N/A

* Average Estimated Annual Lighting Use for Single Family Home.

2.9.2.2 Typical Lighting Systems in House

Various information sources were reviewed in order to identify the typical lighting systems in various houses. The sources include the Leslie and Conway (1993), the EIA (1996), Park and Floyd (1998), and Vorsatz et al. (1997).

In 1992, the Lighting Research Center at Rennselaer Polytechnic Institute (RPI) conducted a telephone survey of approximately 2,500 homes in Albany, NY, to identify what type of lamps were used in residential homes (Leslie and Conway 1993). The results from this survey clearly indicated that incandescent lamps were most commonly used as the primary fixture for every room type, while fluorescent lamps were more likely to be used in the kitchen than in any other room. About three-quarters of the lamps had wattage of less than 75, and three-quarters of the fixtures had total wattages of less than 150.

Similarly, based on the 2003 Buildings Energy Databook provided by U.S. Department of Energy (U.S. DOE), incandescent lamps accounted for about 90% (standard 87% and halogen

3%) of residential lighting's electricity consumption, while fluorescent lamps account for 10% of residential lighting's electricity consumption in 2001.

From these information sources, it can clearly be recognized that the majority of lamps used in all room types in house are incandescent lamps. For this study, it is reasonably assume that about 80% of lighting lamps used in residential sectors for the selected community are incandescent lamps. In addition, replacing incandescent lamps with highly efficient lighting lamps for this study could be more effective than other types of lamps for residential energy savings.

2.9.2.3 Hours of Using Lighting System in House

For this study, the average hours for using lighting systems needed to be determined to calculate the energy savings. To determine the average hours of a lighting system's use in the house, various source were reviewed.

Manclark et al. (1992) showed that there was an average of 29 fixtures per house, with a median fixture usage of 6 % or 1-1/2 hours per day, based on the study of 53 homes in Yakima, Washington. More recently, Tribwell & Lerman (1996) showed that approximately 23% of household fixtures were used more than three hours per day. Similarly, Moezzi (1996) showed that more than half of both lamps and fixtures were used for less than two hours per day. Only 28% of household lamps are used for more than two hours per day, but these lamps accounted for more than 75% of the lighting energy use. Although less than 4% of lamps were used more than 10 hours per day, these lamps account for 25% of the lighting energy use.

The previous studies suggested that the average daily use is approximately 4 hours of the residential lighting's system. Therefore, an assumption of about 4 hours of lighting use per day can be made for this study.

2.9.2.4 Compact Florescent Lamps (CFLs) Efficiency

Previous studies have demonstrated the savings made possibly by reductions to home lighting energy use. Among them, the following three studies present useful information about the effectiveness of energy efficient lamps in residential lighting energy use.

Manclark et al. (1992) has shown that replacing 30% of the incandescent lamps with CFLs, which saves 23% of the lighting's energy use, can save approximately 658 kWh per home. Parker and Sherwin (1996) have demonstrated that a substitution of CFLs for 7 to 10 incandescent fixtures has shown a 16% reduction in measured miscellaneous electricity consumption equivalent to a 420 kWh/year reduction in lighting energy use.

Parker and Floyd (1998) conducted a case study in order to determine how substituting energy efficient lamps and fixtures could reduce residential lighting's energy use. The total household lighting use estimated by the light loggers was 4,050 kWh/year, or about 23% of a total annual consumption. Metering revealed that outdoor lighting fixtures used the most electricity, followed by lighting in the kitchen, garage and study. Fixtures in these areas accounted for 80% of the total lighting's energy use. The results of this study demonstrated that a 61% reduction in the lighting load was calculated, which is equivalent to an annual savings of 2,480 kWh. Parker and Floyd's research described a detailed calculation method for estimating the energy savings, although only one sample house was used. However, the calculation method can be directly used for this study in order to estimate s community-wide energy savings and a peak demand savings.

From these studies, it was recognized that the household lighting's energy savings from efficient lighting systems varied based on the level of replacement of efficient lighting systems. Therefore, the specific energy use (wattage) of typical incandescent lamps and of CFLs should be identified and compared to each other. For this study, a comparative performance of a 60-watt incandescent lamp to a 15-watt CFL, and a 75-watt incandescent lamp to a 25-watt CFL were identified based on the Central Lighting Wattage Standard provided by Frontier and Associates for the PUCT (Frontier and Associates 2000).

It is important to recognize that the lighting's energy use in a house varies according to the following factors: lamp types, hours of use, housing size, and housing type. In addition, the estimated lighting energy use will vary based on the different methods used in their calculation. For instance, the EIA's analysis was conducted mainly based on surveys, while Parker and Floyd (1998) used detailed bottom-up methods based on the case study. Therefore, actual measured data was needed for this study in order to crosscheck nation-wide available data, and the results were then used to determine the selected community's lighting energy use characteristics. These sources included information from the EIA (1999), data from the LBNL (1997), and data from the case study house.

2.10 SUMMARY OF LITERATURE REVIEW

In summary, previously developed community-wide energy efficient plans can be used as a starting point when developing a Comprehensive Community NOx Emissions Reduction Tool (CCNERT). Previously developed approaches were based on annual energy profiles. However, improved procedures for calculating emissions reduction needs to be developed in order to provide greater accuracy when estimating ozone reductions from electricity reductions in buildings during the summer months. For instance, hourly energy profiles are needed to calculate NOx emissions, which allows for a cross-check of calculated results against actual monitored NOx emissions data from the EPA's emissions monitoring efforts (Haberl et al., 2003a). In addition, hourly photochemical air quality models (i.e., UAM and CAMx, etc.) are being used by the Texas Commission on Environmental Quality (TCEQ) to simulate the photochemical reactions and meteorological conditions that contribute to the formation of ground-level ozone pollution during each hour of the ozone episode. Therefore, the development of a NOx emissions reduction program remains a complex process that requires specialized consultants and interdependent methodologies. It is clearly outside the reach of typical community decision-makers. Hence, there is a need for an integrated procedure for calculating energy savings and their associated environmental benefits especially NOx emissions reductions in a state such as Texas.

The pollution emissions of a community are a function of the dynamic relationship between the level and composition of economic activity, demographic influences, and climatic conditions. These interactions create a complex situation that makes it difficult to appraise the contribution of each factor related to the emissions production without individual metering at each consumption point.

The fundamental concept to be used in this study is that a great variety of building functions, operational procedures, designs and climatic locations result in a broad range of building energy intensities as summarized as by Building Energy Performance Standards (BEPS). Therefore, the use of BEPS by building type can provide a starting point for assessing which categories across the various building types will be the most effective in producing energy savings.

For this study, a community energy audit procedure was the first step in the CCNERT methodology. Its purpose is to evaluate energy use and its associated emissions production within the community. The term "energy audit" has been used in many studies to refer to an analysis of energy use in buildings. According to Hittman (1978), this analysis consists of two parts used to identify energy use patterns in buildings: (1) a definition of various paths of heat loss from, and gain to, the building through its various components (i.e., walls, roof, and windows), and (2) a balance of the losses and gains with the input of energy in the form of fuel (i.e., electricity, gas, coal, etc.). This procedure is usually performed in order to identify the most energy efficient measures for a given building.

In preparation for an energy audit, buildings in each category should be classified (i.e., type of residence, type of business) in order to conform the parcel's definitions. The number of each parcel should then be determined. Within each parcel, energy related data and square footage measurements should then be obtained from electricity utilities, gas utilities, city planning records, and the city assessor's records. These data points consist of five variables: the building's location, the gross square footage of the building's area, the building use type, the electricity and gas energy consumption for the year, and the emissions data from a continuous emissions monitoring system (CEM), if it is available. Based on the building's category type, the energy consumption range of each building can then be examined.

In the industrial sector, the number of establishments should first be determined by using local data. The included establishments should then be classified into similar energy groups based on the SIC. Within each SIC group, ($) the dollar amount of gross sales should first be determined based on data taken from the Texas Comptroller of Public Accounts. The energy intensity should then be determined based on data taken from the EIA (2003a). Based on the energy intensity and the dollar amount of gross sales within each SIC, the total energy consumption in industrial sector can be calculated.

In the municipal sector, the sector should be sub-categorized the seven detailed parcels: 1) city owned municipal buildings, 2) educational buildings owned by the local independent school district, 3) streetlights, 4) traffic lights, 4) the water supply system, 5) the wastewater treatment system, and 7) community parks & recreation facilities. Detailed information for each parcel should then be collected from the selected community. Utility bill information for each parcel will also be needed in order to estimate the municipal sector's energy use.

In the transportation sector, various information sources must be used in order to identify its general characteristics and to calculate its energy use. For instance, one source for the on-road group might include the Texas Department of Transportation (TxDOT) traffic study for the Brazos County and or the vehicle registration data provided by Regional Transportation District (RTD) representatives. Vehicle Miles Traveled (VMT) data might also be needed. Vehicle classifications can be determined by conducting “snap shot-checks” because the average vehicle classification data for specific community might not be available. Instant checks in public parking areas such as shopping centers, and grocery stores, will then be needed in order to determine a representative value of vehicle classification for the selected community.

The total overall impact of energy efficiency measures depends upon the total population of the units eligible for replacement and the existing saturation levels of the individual efficiency measurements within the population. Therefore, various information sources (1997 RECS, 2000 U.S. Census, Building Energy Data Book, etc.) might be reviewed in order to determine the total population of units eligible for replacement and the existing saturation levels.

CHAPTER III
SIGNIFICANCE AND SCOPE OF THE STUDY

3.1 SIGNIFICANCE OF THE STUDY

This research will contribute to the development of a useful tool that can be used to analyze community-wide energy use and its associated NOx emissions. Such a tool could be used to predict the impacts of various energy conservation and efficiency programs on emission reductions. The tool will also help local governments and their residents understand and manage information collection and the procedures to be used to analyze the information. Develop of bottom up and top down approach will contribute to existing body of work. Application to the case study community will be useful in determining its usability.

3.2 SCOPE OF THE STUDY

Although a community's environmental quality is degraded by various factors such as energy production from non-renewable fuels (power plants), goods production (industry plants), and transportation, this research mainly focused on actions that reduce the environmental effects of air pollution caused by a community's energy use, with a primary emphasis on building energy use. Unfortunately, it is a daunting task to study every possible variable for a community to reduce emissions. Therefore, energy efficiency measures for this study were limited to a residential and transportation sectors. In case of the transportation sector, energy efficiency scenario was limited to the improvement of vehicle fuel efficiency. This study did not extend possible energy efficiency measures to other energy users such as industrial and municipal sectors.

There are also many constraints in estimating community-wide energy use and its associated emissions. For instance, the emissions audit of community is a complex process, partly because it is impossible to control every factor involved. In the transportation sector, one difficulty is the estimation of average driver behaviors and trip characteristics, which vary from one community to the next. This is confounded by the fact that there are no uniform performance standards for vehicles. Furthermore, in dealing with all possible variables within all sectors (transportation, building, and industrial), vast amounts of information are required and therefore collecting data is labor-intensive and a time-consuming task. This study used national average or regional average data, when locally derived data are not available. Therefore, this study presented an overall outline of the CCNERT methodology and concentrate on applications in the building sector. This study is limited to actual data from the case study community. This study mainly investigated the community-wide energy savings and its associated NOx emissions reductions, the cost savings or effectiveness from energy efficiency measures however were not investigated.

CHAPTER IV
METHODOLOGY

This chapter presents the methodology for estimating community-wide energy usage and its associated NOx emissions. The goal of this methodology is to create an accurate end-use model to estimate a community's total energy use and its associated NOx emissions. In order to accomplish this goal, several procedures have been developed for calculating the whole-community, base-line energy consumption.

4.1 GENERAL CONCEPTS FOR DEVELOPING THIS METHODOLOGY

Since non-renewable energy use and environmental quality are often inversely related, planning energy efficiency measures is a promising way to improve better air quality. Energy use in buildings is strongly influenced by climate through, the building envelope, as well as weather independent internal heat gains. Air pollution, on the other hand, especially "ground-level ozone" is caused by a photo-chemical reaction of VOCs and NOx emissions that react with strong sunlight. Unfortunately, in hot and humid climates such as in Texas, the maximum electricity use occurs during the most polluted days of the summer ozone season. Even though, there are thousands of different energy users producing NOx emissions in a community, they can be categorized according to end-user (i.e., residential, commercial, industrial, municipal, and transportation) and fuel-type (i.e., oil, natural gas, electricity, etc.). In addition, the average base-level use of the different end-use types can be classified and quantified by using data from various sampling techniques and the existing database.

4.1.1 Community Energy Use Characteristics

In general, community energy characteristics can be organized into three main categories: 1) primary energy sources, 2) energy conversion process, and 3) the demand-side energy use (end-users), as shown in Figure 4-1. Primary energy sources include coal, natural gas, petroleum, and other energy sources. Energy conversion plants include utility power plants and distributed generators. The demand-side energy use includes five main areas: 1) the residential sector, 2) the commercial sector, 3) the municipal sector, 4) the industrial sector, and 5) the transportation sector, as shown in the right side of Figure 4-1. Each of these sectors is further subdivided into numerous sub-sectors. For instance, the residential sector can again be divided into five sub-categories: 1) single-family detached, 2) single-family attached, 3) multi family-low-rise, 4) multi-family high-rise, and 5) mobile homes. A detailed description of each sector will be explained in the following sections. A construction sub-section has also been added to each section to account for the energy use within a community during the construction period. Finally, on the far right of Figure 4-1, the analysis tools are indicated for each end-use sector.

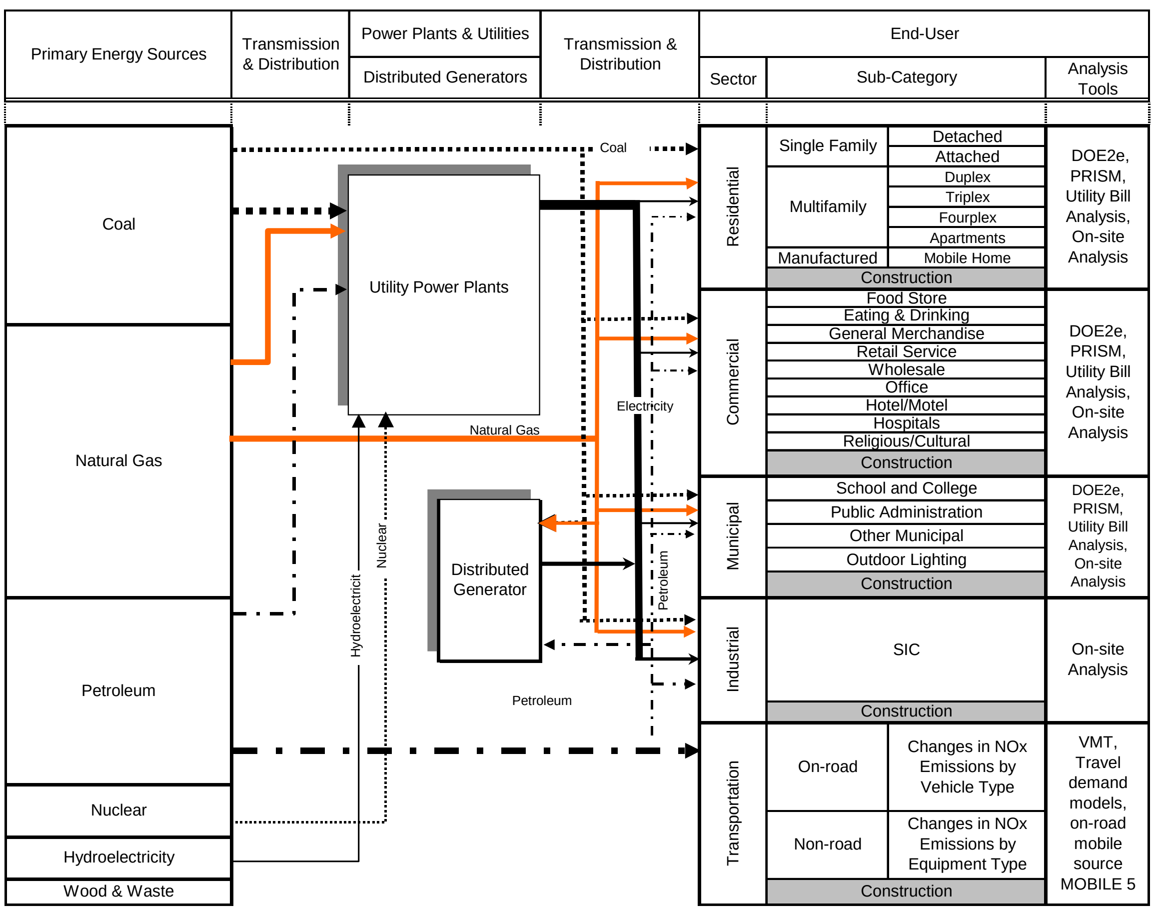


Figure 4-1: Simplified Diagram of Community Energy Characteristics.

4.1.2 Community NOx Emissions Characteristics

From the emissions point of view, a community has two types of NOx emissions: remote-site NOx emissions, and on-site NOx emissions. For instance, in buildings there are two major types of NOx emissions: remote-site NOx emissions from electricity use and on-site NOx emissions from the combustion of natural gas for heating or other purposes. Therefore, energy use within each parcel should be characterized by the type and amount of each fuel used for a specific end-user (i.e., space cooling, space heating, cooking, and other fuel use). These are collectively defined as the fuel mix in this study. Where direct information about a community is not available, fuel mix default values from nation-wide surveys (i.e., 1997 Residential Energy Consumption Surveys (EIA 1999), 1999 CBECS (EIA 2001a), U.S. Census, and other surveys) have been used.

Emissions also vary by the type of fuel burned in the power plant. For instance, if a community's electricity use is provided by renewable resources such as solar, or wind, then the emissions will be less than from a community that uses only fossil fuels. Finally, a major issue addressed in this study is how much detailed data is necessary, how the data can be collected and how that data should be transformed to allow for an accurate estimation of a sector's energy use.

4.2 DEVELOPMENT OF THE FRAMEWORK FOR METHODOLOGY

The methodology used here to develop the general framework for a Comprehensive Community NOx Emission Reduction Tool (CCNERT) builds on the previous CCEMP efforts and more recent procedures developed by the Energy Systems Laboratory for the Texas Emission Reduction Plan (TERP) (Haberl et al. 2003b). Therefore, this study has modified the CCEMP methodology to estimate NOx emissions reductions for a single community. To develop the CCNERT, the following major tasks needed to be performed:

1) A framework was developed to examine how community energy use leads to NOx emissions and the associated environmental pollution such as ozone;
2) Procedures were developed for quantifying end-use energy usage and for the evaluation of associated emissions;

3) The methodology was tested using a case study approach to apply and verify the procedures for residential and commercial buildings.

4.2.1 Developing a Framework for Examining How Community Energy Use Leads to NO_X Emissions

The main purpose of this task was to accurately determine the selected community's level of energy use and its pattern. Figure 4-2 presents an overview of the procedures used for calculating community-wide energy usage and its associated NOx emissions. As shown in Figure 4-2, this procedure consists of four main tasks: 1) the selecting of a community and the determination of its end-use sectors; 2) the determination of the amount of energy use for each sector; 3) the calculation of the total energy use by fuel type; and 4) the calculation of the level of NOx emissions by the various fuel types. These four main tasks consisted of numerous sub-tasks, which are explained later in the following sections. These four main tasks have been similarly applied to estimate each sector's base-line energy consumption and its associated NOx emissions. A detailed description of the steps taken in the individual sectors is explained later in this chapter.

4.2.2 The Selection of the Community

In this research, the City of College Station, Texas, was selected as the case study community. The College Station city limits were used to determine the community's boundary (i.e., the study area). Within the community boundary, the NOx emissions produced by end-use energy usage will be traced to a given point such as the power plants, the transportation or industrial sectors, or building end-use (i.e., residential and commercial heating fuel use).

4.2.3 Determination of the End-User Sectors

Within the community's boundary, there are hundreds of energy users such as buildings, vehicles, streetlights, etc. Building energy users can be categorized in many ways, including by use, type of construction, HVAC system type, or thermal characteristics. In addition, the energy use patterns vary significantly based on community type and activities. To account for these variables, simplified groups of energy users were used.

In this research, the following categories of community energy users are used: 1) residential, 2) commercial, 3) municipal, 4) industrial and 5) transportation. The individual sectors are further subdivided into sub-categories, and detailed information is described in each sector.

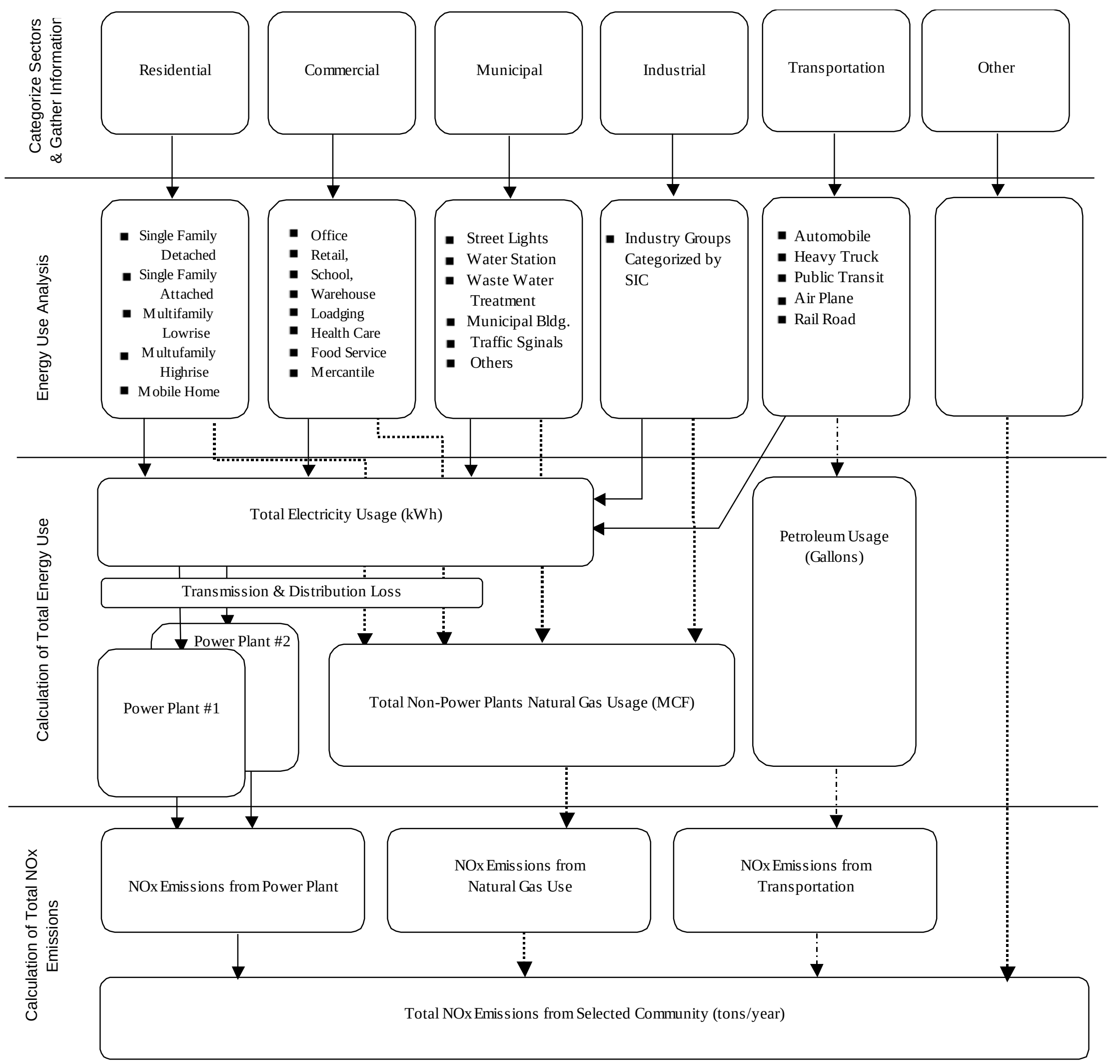


Figure 4-2: General Diagram of Procedures for Calculating Community-Wide Energy Use and Its Associated NOx Emissions.

4.2.4 Gathering of Information for Developing the Community Information System (CIS)

Developing a Community Information System (CIS) is the procedure used to account for land use parcels that represent the energy using components of a community. Figure 4-3 presents the overview of the Community Information System. Energy used in a community is categorized by one of the five sectors, defined by their function in the community. Each of these sectors has specific energy use characteristics that influence the energy use pattern of that sector.

4.2.4.1 Identification of Data Requirements

The next task involved the gathering of information about each sector. Three general categories of data were identified for this task: 1) Information related to the general characteristics of the community (i.e., historical community development, land use plans, population, business patterns, etc.), 2) information related to the energy use characteristics of end-users (i.e., number of houses, number of streetlights, and number of vehicles, etc.), and 3) information related to supply side energy characteristics (i.e., power plant and utilities, etc.).

4.2.4.2 Collection of Information

An integrated data collection approach was developed to collect information identified by the previous task for the selected community, and to verify the data with a secondary source when available. The integrated data collection approach is combined of three main data collection methods: 1) a primary data collection method, 2) a secondary data collection method, and 3) a “rule of thumb” method.

A primary data collection method included local surveys, field measurements, and collection of energy use data. The secondary data collection method obtained the data from existing sources (i.e., land use plans, U.S. Census, and county transportation data). Finally, “rule of thumb” method collected data based on national or state averages for those instances where primary or secondary methods were considered too time consuming, too costly or the data were not available. Detailed descriptions of this procedure are included in the following sections.

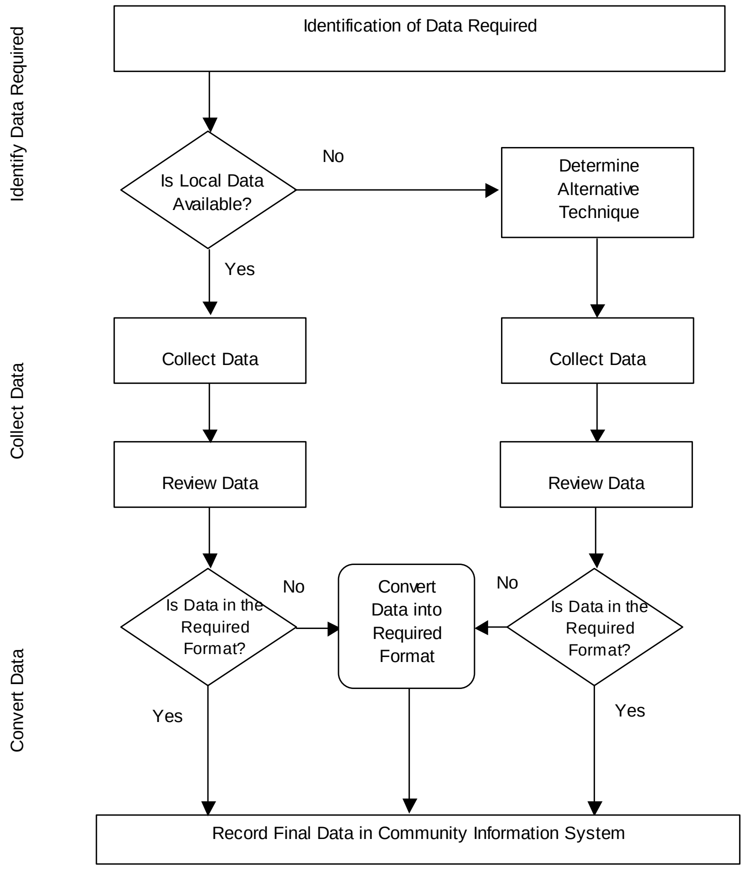


Figure 4-3: Overview of Development of the Community Information System (CIS).

4.2.4.3 Conversion of Information

The main purpose of this task was to establish a uniform format for the various energy users within the community boundary. Different indices were needed for different end-use types, which varied greatly from one sector to another. For instance, the quantification of building energy use as kWh per square foot of conditioned area (kWh/ft^2) is considered to be adequate for most building energy analyses. However, miles per gallon (mpg) are usual index for the performance of vehicles. Unfortunately, odometer readings and fuel purchases are not available for all vehicles in a community. Therefore, most transportation analysis relies on vehicle miles traveled, vehicle mix, and published fuel economy data. In this study, it was discussed that an additional cross-check was available since sales tax data were available for all convenience store that could be approximately sub-divided into fuel and non-fuel sales.

4.2.5 Determination of Energy Use of Each Sector

Estimating community-wide energy use and its associated NOx emissions required accurate energy use analyses for each sector, as defined in the previous section. The main purpose of this task was therefore to determine how and where energy was being consumed within the selected community. This determination could help a community to identify areas of excessive energy use and help to find areas where additional attention could be directed. Finally, the result of this renewed focus could be to realize effective energy conservation efforts (and the resultant NOx reductions) or to implement alternative renewable energy sources for a selected community.

However, developing energy analysis procedures for a community baseline can be a complicated process. Energy use characteristics for these sectors vary significantly based on each sector' activity. For instance, kilowatt-hours (kWh) per square foot of area was deemed adequate to serve as a useful measure, and was selected for application to most building sectors. However, this measurement could not be deemed adequate for use in the transportation and industrial sectors. Therefore, the determination of the energy use for other sectors required different procedures. The different procedures are explained in each of the following energy sectors: 1) the residential sector, 2) the commercial sector, 3) the industrial sector, 4) the municipal sector, and 5) transportation sector.

4.2.6 Determination of Residential Sector Energy Use

The procedures necessary to determine the energy use of the residential sector are explained in this section. The general concepts used to develop the residential sector's baseline model, are discussed first, followed by a detailed discussions of the procedures. Figure 4.4 represents the general basics for developing procedures to determine the residential sector's energy use. The basic procedure includes:

1) Calculating the energy use within each parcel of the residential sector as a function of the total floor areas within each parcel,
2) Calculating the total end-use energy use for the residential sector as a summation of the total end-use of each parcel,

3) Calculating the total end-use energy use of each parcel as the sum of the-end use energy for each activity (i.e. space heating, space cooling, domestic water heating etc.) in that parcel, and
4) Calculating the total end-use energy use for each parcel in that parcel as the sum of the end-use energy use for each fuel type serving that activity.

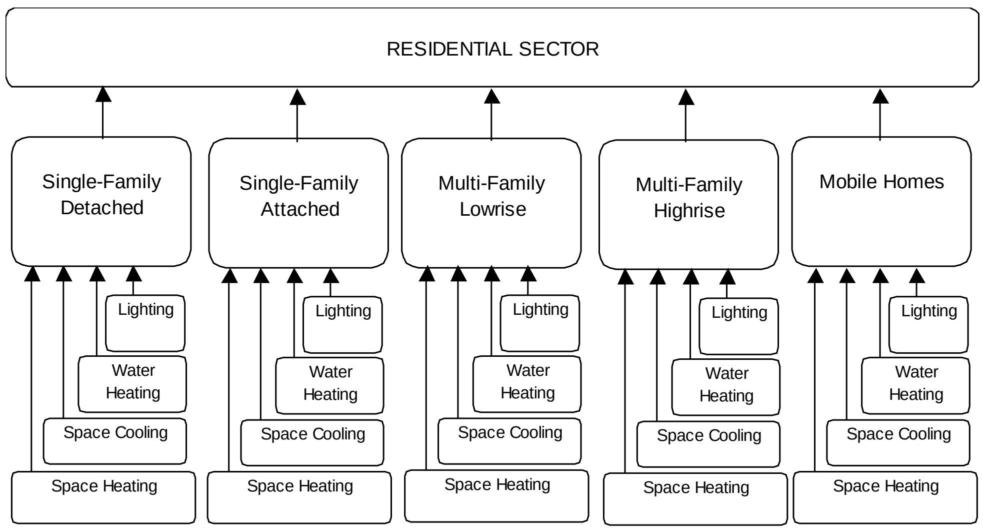


Figure 4-4: Simplified Structure of Energy Use in Residential Sector.

Based on the overall procedure mentioned above, the specific procedures used to estimate the residential sector's energy use were developed. Several sub-tasks were identified, as shown in Figure 4-5:

1) Identification of information related to the general characteristics of the residential sector from the Community Information System (CIS).
2) The selection of a sample of houses.
3) The collection of utility bills from the selected houses to provide a Normalized Annual Consumption (NAC) using ASHRAE's IMT.
4) The development or selection of a representative house based on the previous procedures for the DOE-2 simulation of average house in the Texas Emissions Reduction Plan (TERP) (Haberl et al. 2003c).

5) The preparation of the verified data for the DOE-2 simulation.
6) The comparison of the energy usage predictions and the consumption data from the sample houses.
7) Translating the results obtained from the utility bill analysis and energy simulation for sampling houses to establish values representative of a community, and
8) The calculation of the total energy use and its NOx emissions for the residential sector.

4.2.6.1 Identification of Information Related to the General Characteristics of the Residential Sector

The first necessary procedure was to identify information related to the general characteristics of the existing housing units in the selected community. The energy characteristics varied based on the types of housing. Therefore, the residential sector was sub-divided into several parcels. In this study, the parcels were the same as those in the EIA study conducted for the 1997 RECS (EIA 1999).

In the 1997 RECS the EIA subdivided the residential sector into five parcels: 1) Single-Family Detached (SFD), 2) Single-Family Attached (SFA), 3) Multi-Family Low Rise (MFLR), 4) Multi-Family High-Rise (MFHR), and 5) Mobile Homes (MH). The descriptions of each parcel are shown in Table 4-1.

Each parcel requires a specific type of information to be collected in order to identify housing characteristics, and later compute the total residential sector energy use. The primary types of information needed for this study include: 1) number of housing units in each parcel; 2) housing characteristics (i.e., average square area, no of stories); and 3) thermal characteristics and HVAC system characteristics.

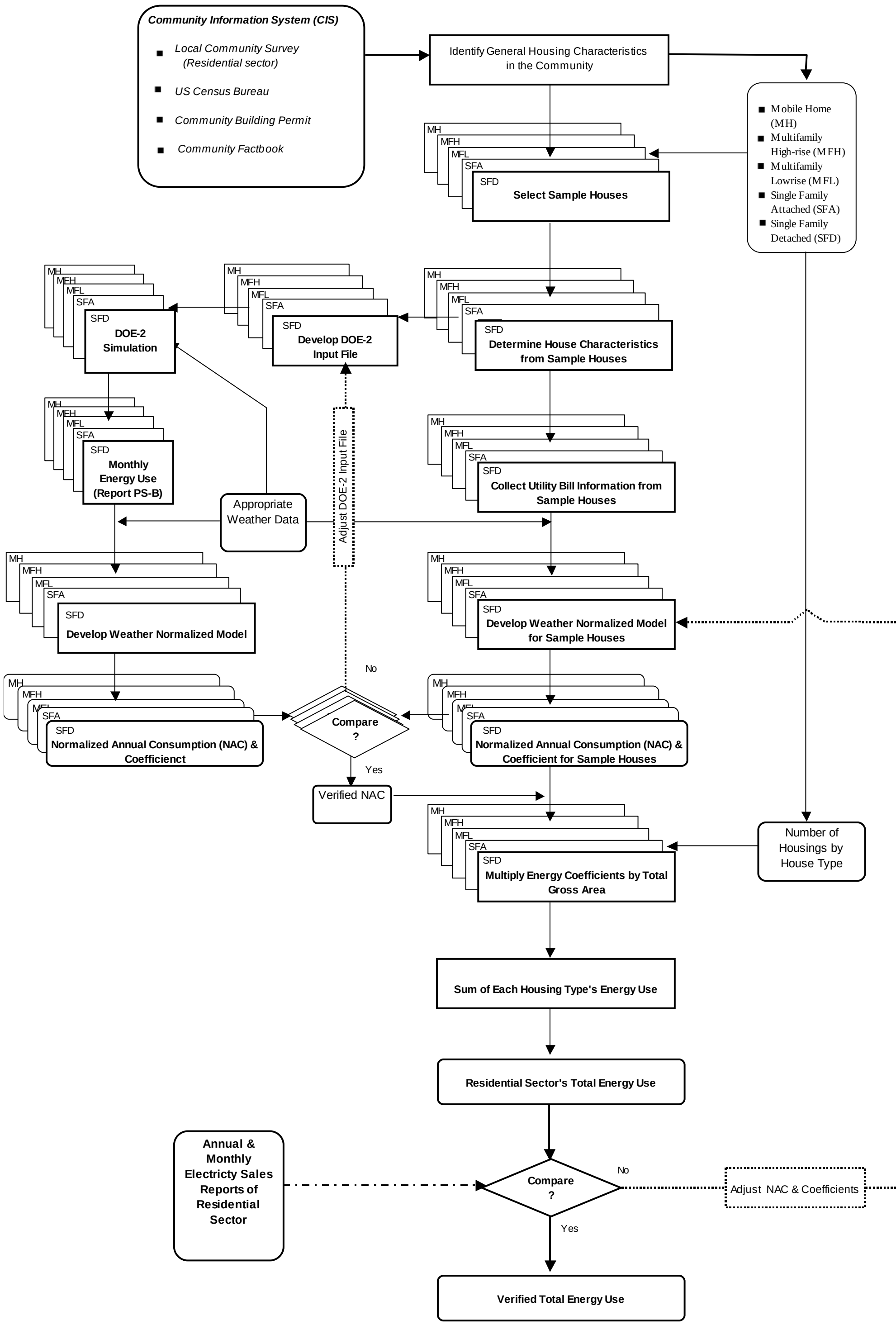


Figure 4-5: Detailed Diagram for Developing Residential Sector's Energy Use Baseline Model.

***Table 4-1: Descriptions of Five Parcels in the Residential Sector*.**

Parcels	Abbreviations	Descriptions
Single Family Detached	SFD	Private, single family residence
Single Family Attached	SFA	Duplex, row houses, town houses
Multifamily Low-Rise	MFLR	Buildings up to and including three stories
Multifamily High-Rise	MFHR	Building with four or more stories
Mobile Homes	MH	Building capable of being towed by a motor vehicle

Source: EIA 1999.

4.2.6.1.1 Determination of the Number of Units and the House Size

To determine the number of housing units and their sizes based for each parcel, the selected building permit reports were required for each housing sector. However, detailed building permit reports were available only for recent years. Therefore, some assumptions needed to be made. For this study, the data taken from the College Station Demographic Report (COCS 2003) was used to determine the number of existing housing stock before 2000. Then the number of building permits between 2001 and 2002 was added to 2000 number of house to determine total number of houses for each parcel. From the reports, detailed building information such as the permit date, street address, permit type, total floor area, and conditioned area were collected. By aggregating the individual building permit reports, total square footage, and conditioned area based on housing type has been determined.

4.2.6.1.2 Determination of Thermal Characteristics and HVAC System Characteristics

The difficulty of collecting accurate and complete information on the thermal characteristics and HVAC system characteristics was resolved by conducting a local survey. While the information related to these characteristics was readily available during the design and construction period, it was very difficult to acquire once the house was completed, since the resident was not usually involved during these periods, and usually knew little about such characteristics.

Therefore, some assumptions needed to be made. For this study, nationwide housing characteristics, and statistical data from several sources were used, including the NAHB's Builder Practices Survey Reports (NAHB 2000), 1997 RECS (EIA 1999), and LBNL (1995a), were reviewed. The detailed data collected is shown in Tables B-1 thru B-5 in Appendix B.

4.2.6.2 Selection of Sample Houses

The second task was to select sample houses and to collect the data necessary to determine normalized housing characteristics. These data were then used to create a representative input file for the DOE-2 simulation. Sample buildings were selected based on the year built to identify its housing characteristics. The relationship between the distribution of the year built and the conditioned area was considered to provide normalized conditioned areas, and then again used to formulate representative values for the selected community.

4.2.6.3 Determination of House Characteristics from the Sample Houses

The third task necessary was to determine common house characteristics from the selected houses using on-site inspection. The building materials, areas, number of stories, and system types were thus determined.

4.2.6.4 Collection of Utility Bill Information from the Sample Houses

The fourth task necessary was to collect utility billing data from the sample houses. The main purpose of this task was to prepare input data to be used in the DOE-2 energy analysis model. Both electric and gas utility companies were contacted in an effort to collect data. In exploring the availability of energy data related to data collected from electric and gas utility companies, it was found that it was difficult to obtain both gas and electric utility for a given house, because in the case-study community the electric utilities do not maintain records for gas utility consumption, and vice versa. Furthermore, the record keeping systems for each utility are different. Therefore, a great deal of manual searching was required to compile data for a sample house. In short order, it became obvious that such an effort was beyond the scope of this study. Therefore, both electric utility billing data and natural gas billing data for one sample house was obtained, while only the electric utility data for other sample houses were obtained by contacting electric utilities.

4.2.6.5 Development of Weather Normalized Model

The main objective of this task is to determine the total energy use by adding five residential energy groups together within a given community. Therefore, a relatively simplified method was developed. The simplified method began with the collection of utility bills from the sample houses, which were then used to create an input file for use with the ASHRAE Inverse Modeling Toolkits (IMT) (Kissock et al. 2001).

The main purpose of using the IMT analysis was to statistically determine the influencing variables for which energy was being used, and how consistent that use was. To provide a Normalized Annual Consumption (NAC), defined as the base-level consumption plus the weather-sensitive consumption (Haberl and Kormor 1990), the whole-building monthly energy use consumption and the average daily temperature for a selected house was obtained.

The first step in providing the NAC was to plot energy use profile in order to determine the general energy consumption patterns. The energy use profile is formulated by plotting the daily average energy usage of each fuel over a billing period within a given year.

The second step was to calculate the average daily temperatures from the hourly weather data obtained from the nearest National Weather Service (NWS) station. Next, the Variable-base Degree-Day (VBDD) model of the IMT was used to calculate the daily average ambient temperature during the individual billing periods. Since the billing periods are usually not one month in length, and the start and end dates are usually not the same as the start and end dates for the previous month, the average ambient temperature during each billing period was needed. Furthermore, to obtain the average ambient temperatures for 12 billing periods, the utility bills for 13 months and then average daily ambient temperatures were required to provide begin and end dates for the 12 billing periods.

Next, IMT was again run using the 3PC and 3PH models. This analysis provided the normalized IMT coefficients, which are the constant term, slope term, and the change point. The typical three-parameter change-point model used to represent the weather normalization is shown below.

$$Y_c = \beta_1 + \beta_2 (X_1 - \beta_3)^+$$

$$Y_h = \beta_1 + \beta_2 (X_1 - \beta_3)^-$$

where β_1 is the constant term, β_2 is the slope term, and β_3 is the change point. The $(\ )^+$ and $(\ )^-$ notations indicate that the values of the parenthetic term should be set to zero when they are negative and positive, respectively.

Although this analysis provides the basic weather-independent and weather-dependent quantities, the end-use energy activities contributed those to the total energy consumption of a given fuel type could not be determined using this method alone. Therefore, a DOE-2 simulation was used to appropriately disaggregate the total energy consumption into end-uses.

4.2.6.6 The DOE-2 Simulation

The characteristics of these sample houses were used to create representative input files for the DOE-2 simulation program. The main purpose of DOE-2 simulation was to estimate the energy use of each activity (i.e., space heating, space cooling, lighting and cooking, etc.) and to provide appropriate hourly profiles. For the analysis of the DOE-2 simulation, detailed information was needed. The collection of data for the selected house identified three general categories of characteristics:

1) information related to the general characteristics of the house (square footage, building envelop materials, type of mechanical systems, etc.),
2) information related to the operating characteristics of the building (operating hours of the HVAC system, how many people in the residence, etc.), and
3) information related to the weather data.

The DOE-2 simulation provides hourly energy consumption data, which can then be used to provide the normalized weekday and weekend usage profiles. To provide the normalized weekday and weekend usage profiles, several tasks were needed.

4.2.6.7 Calculation of Total Residential Energy Use

This section explains how the results obtained from performing the IMT analysis for sample houses can be utilized to establish average values that are representative of a particular community. For this study, the total energy consumption for each parcel was calculated by multiplying the estimated energy intensity factor (Btu/ft^2) for an average house, times the total square footage of each parcel. Finally, the total residential sector energy consumption was calculated by totaling each parcel's energy consumption.

4.2.6.8 Validation of Residential Energy Use Model

For the case study community, the calculated total energy use from the energy use model was validated by cross checking with the utility data available from the College Station Utility. To validate the estimated energy usage predictions from the model, the monthly electric power sold (kWh) for the residential sectors was first converted into monthly average data. Then the daily energy use was calculated by dividing the periodic fuel sold (kWh) with the corresponding days of each month. The total numbers of customers were then divided by the monthly average of the daily value of electricity sold. This then allowed the monthly average of daily electric sold per residential customer to be calculated. If the predicted energy usage was similar to the actual utility data, then the estimated total energy use was considered to be verified.

4.2.6.9 Prediction of Hourly Energy Consumption

The hourly energy consumption was predicted by utilizing the hourly profiles based on operational differences (weekdays and weekends) and seasonal difference (summer, winter, spring and fall seasons). The main purpose of this procedure was to determine the peak daily load for the various seasons, which were then used to estimate the peak-day NOx emissions. to accomplish this, the DOE-2 simulations provided the hourly profiles, which represented the affordable proportions of each hour's energy use.

By applying these hourly profiles (%) to the predicted daily energy, the hourly energy use for the residential sector can be estimated. A simple linear regression model can then be used to find the regression coefficients, which were used to predict the daily energy use by multiplying the appropriate hourly weather data. Finally, a comparison procedure can be used to determine the difference between the residential sector's total energy usage prediction and utility data.

4.2.7 Determination of Energy Use of Commercial Sector

The methodology used to calculate energy consumption for commercial sector is presented in this section. In general, the basic principles used for the residential sector were also used in the commercial sector. This commercial sector analysis assumed that all establishments within a single parcel are considered to have similar energy-sensitive characteristics (i.e., they utilize similar sources and amounts of energy to satisfy similar end-use demands). To obtain more accurate data, multiple models for each sector would need to be developed. This simplification was considered acceptable because this study's goal is to determine the total energy consumption for each sector by finding the sum of each parcel within the given community, rather than calculating the end-use energy use of every individual building.

Based on these basic principles, a simplified structure of the commercial sector's energy use was developed as shown in Figure 4-6. As shown in this figure, the community's commercial buildings were divided into numerous parcels. Within each parcel, various pieces of information (i.e., the number of establishments, the floor area, and other factors affecting energy usage) were required in order to estimate the energy consumption. The commercial buildings within each parcel (type) were then further categorized by equipment and fuel types in order to determine the fuel mix.

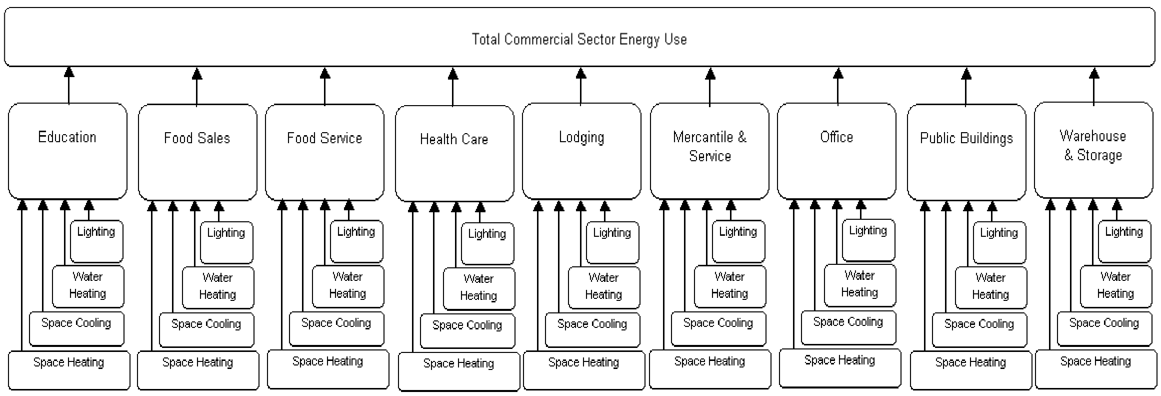


Figure 4-6: Simplified Structure of Energy Use in Commercial Sector.

4.2.7.1 Procedures for Estimating the Commercial Sector Energy Use

Based on the procedures mentioned above, the procedures used to estimate the commercial sector's energy use were developed. To accomplish this, several additional sub-tasks were necessary as shown in Figure 4-7.

4.2.7.2 Identification of Information Related to the General Characteristics of the Commercial Sector

This energy use estimation began with a categorization of the commercial building sector by each building's activities. The first procedure was to identify information related to the general characteristics of the existing commercial buildings in the selected community. The energy characteristics varied based on the building's activity; therefore, the commercial sector was sub-divided into several parcels. In this study, the parcels were determined to be the same as the categories used by EIA (2001a) in the 1999 Commercial Building Energy Consumption Survey (1999 CBECS).

The EIA subdivided commercial sector into eleven parcels, as described in Table 4-2. Each parcel needed a specific type of information collected in order for the building's characteristics to be identified and to later compute total commercial sector's energy use. The primary types of information needed for commercial buildings include: 1) the number of business establishments, 2) the number of employees, 3) the building characteristics (i.e., the average square area, and number of stories), and 4) the HVAC system characteristics.

Table 4-2: Typical Building Activities in the Commercial Sector.

Parcels (Activities)	Descriptions
Education	Buildings used for academic or technical classroom instruction such as elementary, middle or high schools.
Food Sales	Building used for the retail or wholesale of food.
Food Service	Buildings used for the preparation and sale of food and beverages for on-site consumption.
Health Care (Inpatient)	Buildings used as diagnostic and treatment facilities for inpatient care.
Health Care (Outpatient)	Buildings used as diagnostic and treatment facilities for outpatient care.
Lodging	Buildings used to offer multiple accommodations for short term or long-term residents.
Mercantile (Retail other than Mall)	Buildings used for the sale and display of goods other than food.
Mercantile (Mall)	Shopping malls comprised of multiple connected establishments.
Office	Buildings used for general office space.
Public Buildings	Buildings in which people gather for social or recreational activities.
Warehouse/Storage	Buildings used to store goods, manufactured products, or raw materials.

Source: EIA 2001a.

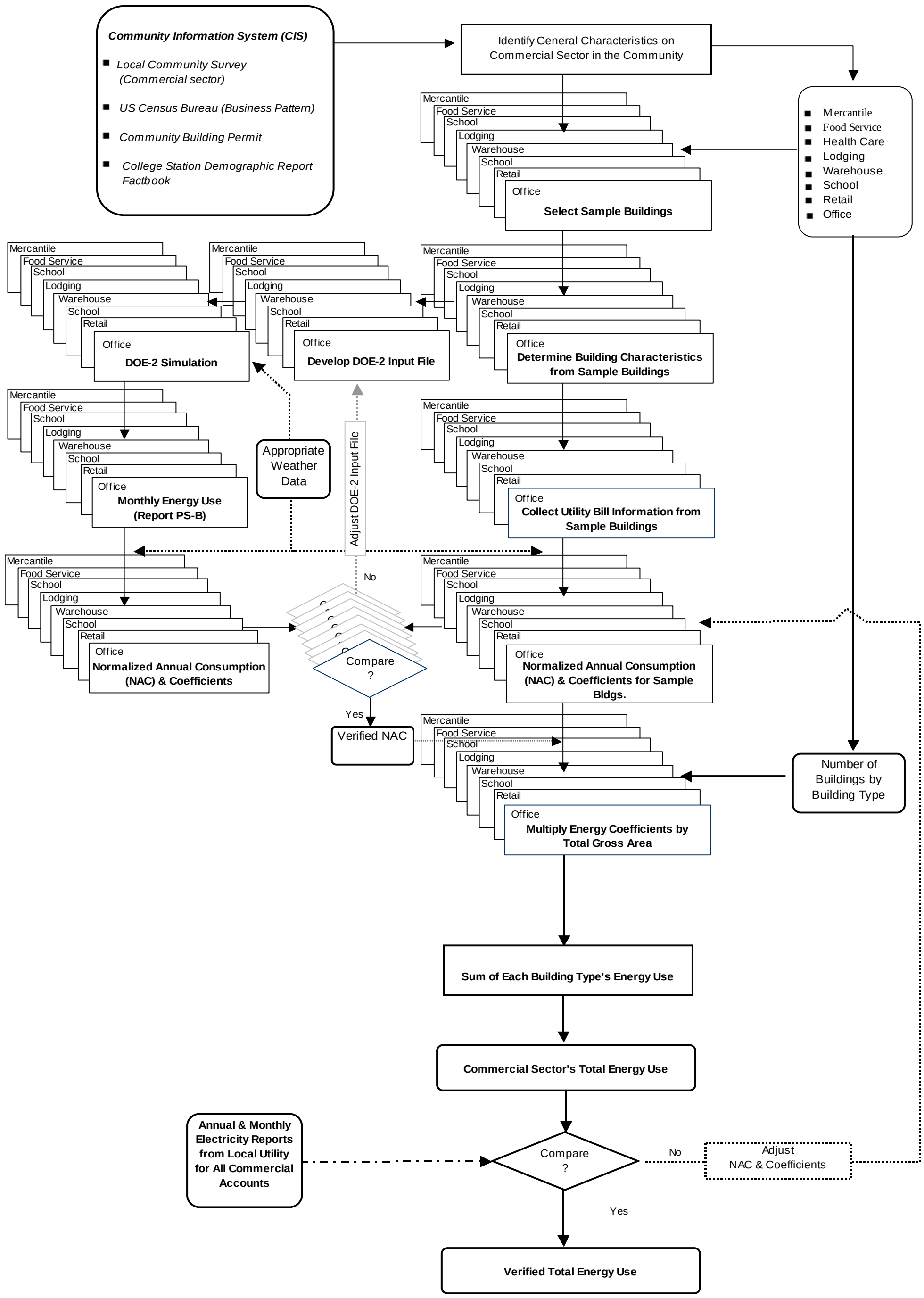


Figure 4-7: Detailed Diagram for Developing the Commercial Sector's Energy Use.

4.2.7.2.1 Determination of the Number of Business (Establishments) Based on the Building's Activity Type

A physical accounting of establishments was accomplished by utilizing data taken from the County Business Pattern provided by U.S. Census Bureaus and by cross-checking that data with the information from local yellow pages. A County Business Pattern provides data on the total number of establishments, mid-March employment, first quarter and annual payrolls, and number of the establishments according to nine employment-size classes, detailed by industry for all counties in the United States.

4.2.7.2.2 Thermal and HVAC System Characteristics

The difficulty of collecting accurate and complete information on thermal HVAC system characteristics was identified by conducting a local survey. While the information related to these characteristics was readily available during the design and construction period, it was very difficult to acquire once the building was completed, since the occupants has not usually involved in these periods. Therefore, the nation-wide building characteristics, statistical results from the 1999 CBECS (EIA 2001a), were reviewed and detailed information are summarized in Tables C1 thru C in Appendix C.

4.2.7.3 Select Sample Business (Buildings)

The second task was to select sample buildings and to collect the data necessary in order to determine the normalized housing characteristics. It is then used to create a representative input file for the DOE-2 simulation. The sample buildings were randomly selected based on the building's activity.

4.2.7.4 Determination of Building Characteristics from the Sample Buildings

The third task was to determine the average building characteristics from the selected buildings by on-site checking. The building's envelope's materials, conditioned areas, number of stories, and HVAC system types were verified through on-site inspection.

4.2.7.5 Collection of Utility Billing Information from Selected Buildings

The fourth task is to collect utility billing information for selected buildings. The main purpose of this task is to help prepare input data file to be used in energy analysis model. Both electric and gas utility companies are contacted in this effort to collect data. Unfortunately, the availability of energy data related to gas utility companies was found to be difficult to obtain for a given buildings. Without first obtaining a utility record release from each building owner. Obtaining utility record for electricity use was less problematic since the City of College Station maintains records for all their electric utility customers in the public domain. Therefore, only electric consumption data of sample buildings was obtained by contacting the College Station electric utilities.

4.2.7.6 Develop Weather Normalized Model

The main objective of this task was to determine the total energy use by adding together the eleven energy groups within the community. To accomplish this a simplified method was developed that begins with the collection of utility bills from selected buildings which are then used to create the input file for use with the ASHRAE Inverse Modeling Toolkits (IMT) (Kissock et al. 2001).

In a similar fashion as the residential sector, the main purpose of using the IMT analysis was to statistically determine the influencing variables for which energy was being used, and how consistent that use was. To provide a Normalized Annual Consumption (NAC), defined as the base-level consumption plus the weather-sensitive consumption (Haberl and Kormor 1990), the whole-building monthly energy use consumption and the average daily temperature for a selected house was obtained.

The first step in providing the NAC was to plot energy use profile in order to determine the general energy consumption patterns. The energy use profile is formulated by plotting the daily average energy usage of each fuel over a billing period within a given year.

The second step was to calculate the average daily temperatures from the hourly weather data obtained from the nearest National Weather Service (NWS) station. Next, the Variable-base Degree-Day (VBDD) model of the IMT was used to calculate the daily average ambient temperature during the individual billing periods. Since the billing periods are usually not one month in length, and the start and end dates are usually not the same as the start and end dates for the previous month, the average ambient temperature during each billing period was needed. Furthermore, to obtain the average ambient temperatures for 12 billing periods, the utility bills for 13 months and then average daily ambient temperatures were required to provide begin and end dates for the 12 billing periods.

Next, IMT was again run using the 3PC and 3PH models. This analysis provided the normalized IMT coefficients, which are the constant term, slope term, and the change point. The typical three-parameter change-point model used to represent the weather normalization is shown below.

$$Y_c = \beta_1 + \beta_2 (X_1 - \beta_3)^+$$
$$Y_h = \beta_1 + \beta_2 (X_1 - \beta_3)^-$$

where β_1 is the constant term, β_2 is the slope term, and β_3 is the change point. The ( )+ and $( )^-$ notations indicate that the values of the parenthetic term should be set to zero when they are negative and positive, respectively.

Although this analysis provides the basic weather-independent and weather-dependent quantities, the end-use energy activities contributed those to the total energy consumption of a given fuel type could not be determined using this method alone. Therefore, a DOE-2 simulation was used to appropriately disaggregate the total energy consumption into end-uses.

4.2.7.7 The DOE-2 Simulation

The characteristics of these sample buildings were used to create representative input files for the DOE-2 simulation program. The main purpose of DOE-2 simulation was to estimate the energy use of each activity (i.e., space heating, space cooling, lighting and cooking, etc.) and to provide appropriate hourly profiles. For the analysis of the DOE-2 simulation, detailed information was needed. The collection of data for the selected house identified three general categories of characteristics:

1) information related to the general characteristics of the buildings (square footage, building envelop materials, type of mechanical systems, etc.),
2) information related to the operating characteristics of the building (operating hours of the HVAC system, how many people in the residence, etc.), and
3) information related to the weather data.

The DOE-2 simulation provides hourly energy consumption data, which can then be used to provide the normalized weekday and weekend usage profiles. To provide the normalized weekday and weekend usage profiles, several tasks were needed.

4.2.7.8 Calculation of Total Commercial Energy Use

This section explains how the results obtained from performing the IMT analysis for sample buildings can be utilized to establish average values that are representative of a particular community. For this study, the total energy consumption for each parcel was calculated by multiplying the estimated energy intensity factor (Btu/ft^2) for an average building, times the total square footage of each parcel. Finally, the total commercial sector energy consumption was calculated by totaling each parcel's energy consumption.

4.2.7.9 Validation of Commercial Energy Use Model

In a similar fashion as the residential sector, the calculated total energy use from the energy use model was validated by cross-checking with the utility data available from the College Station Utility. To validate the estimated energy usage predictions from the model, the monthly electric power sold (kWh) for the commercial sectors was first converted into monthly average data. Then the daily energy use was calculated by dividing the periodic fuel sold (kWh) with the corresponding days of each month. The total numbers of customers were then divided by the monthly average of the daily value of electricity sold. This then allowed the monthly average of daily electric sold per residential customer to be calculated. If the predicted energy usage was similar to the actual utility data, then the estimated total energy use was considered to be verified.

4.2.8 Procedures for Estimating Industrial Sector Energy Use

The simplified procedures to calculate energy use for the industrial sector were developed and are presented in this section. Energy use characteristics in the industrial sector are different from the other sectors. In the building sectors, such as the residential and commercial sectors, energy use is a function of floor space. However, industrial activity or processes are critical factors affecting the energy use in the industrial sector. Therefore, the procedure for estimating energy use for the industrial sector was developed based on the industrial activity or process. The simplified procedure for estimating the energy use of the industrial sector is shown in Figure 4-8.

The main purpose of this procedure is to estimate the industrial sector's energy use by using a simplified procedure. To accomplish this, following tasks were required: 1) determine number of establishment, 2) classify establishments by SIC or NAICS group, 3) determine gross sales in each SIC or NAICS group, 4) calculate energy intensity factor (kBtu/$ sales) in each group, 5) multiply EIF by total number of establishments in each group, as shown in Figure 4.9.

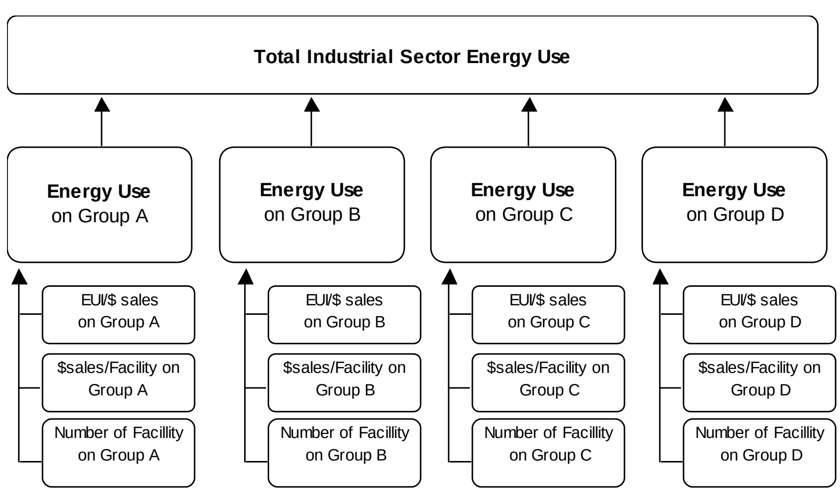


Figure 4-8: Simplified Structure of Energy Use in Industrial Sector.

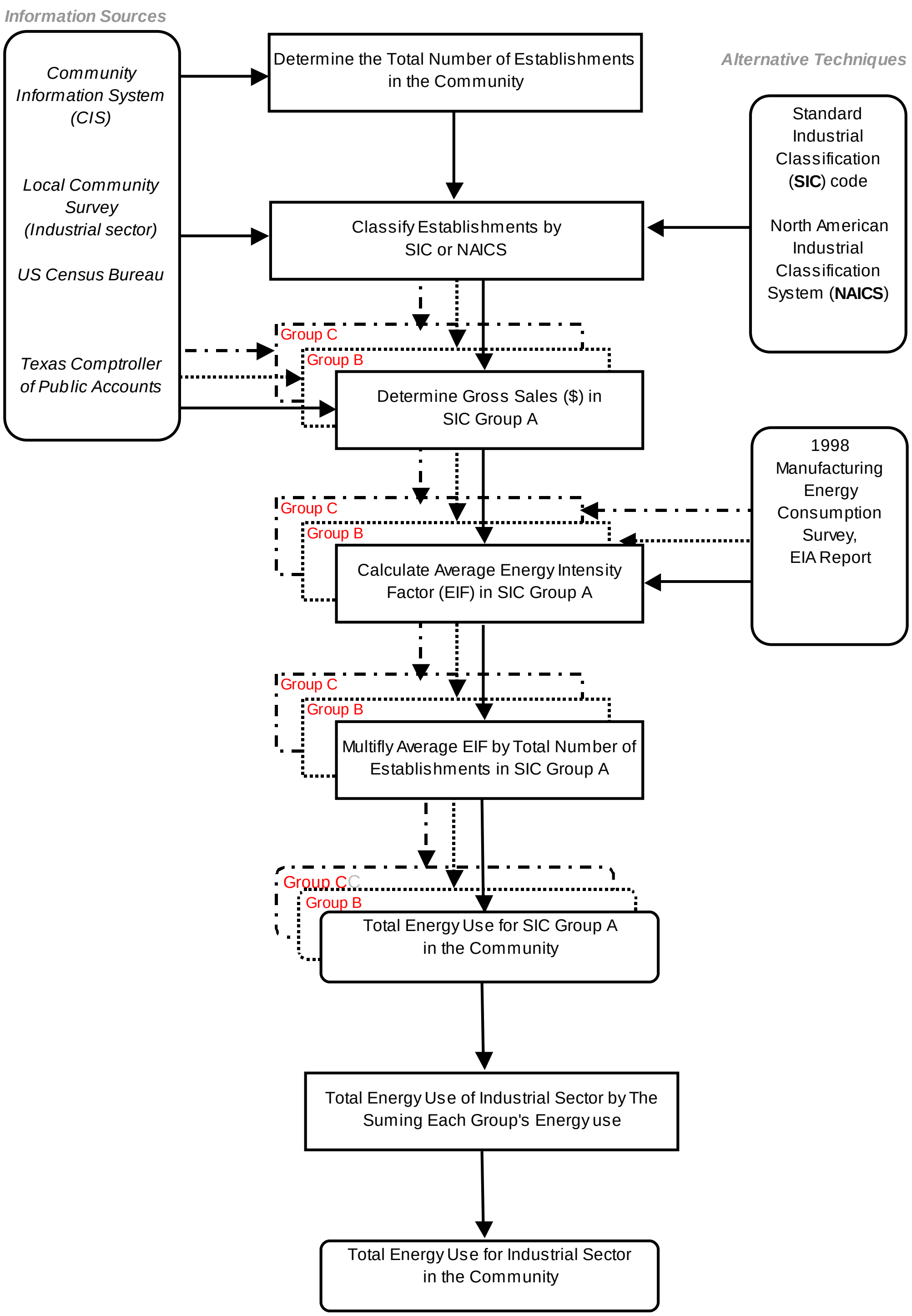


Figure 4-9: Detailed Diagram for Developing Industrial Sector's Energy Use Baseline Model.

4.2.8.1 Determination of Number of Establishments

The first task was to determine the number of establishments and their size based on employment. The main purpose of this task was to identify the general characteristics of the industrial sector in the community. To accomplish this, the following sources were reviewed: the Directory of Business provided by local Chamber of Commerce and the County Business Pattern data provided by the U.S. Census Bureau. From the U.S. Census Bureau's CenStats Databases (see Figure 4-10), information on the total number of establishments and the number of establishments by employment-size classes, detailed by industry for the Bryan-College Station Metropolitan Statistical Areas (MSAs), were obtained and analyzed.

Source: U.S. Census 2003.

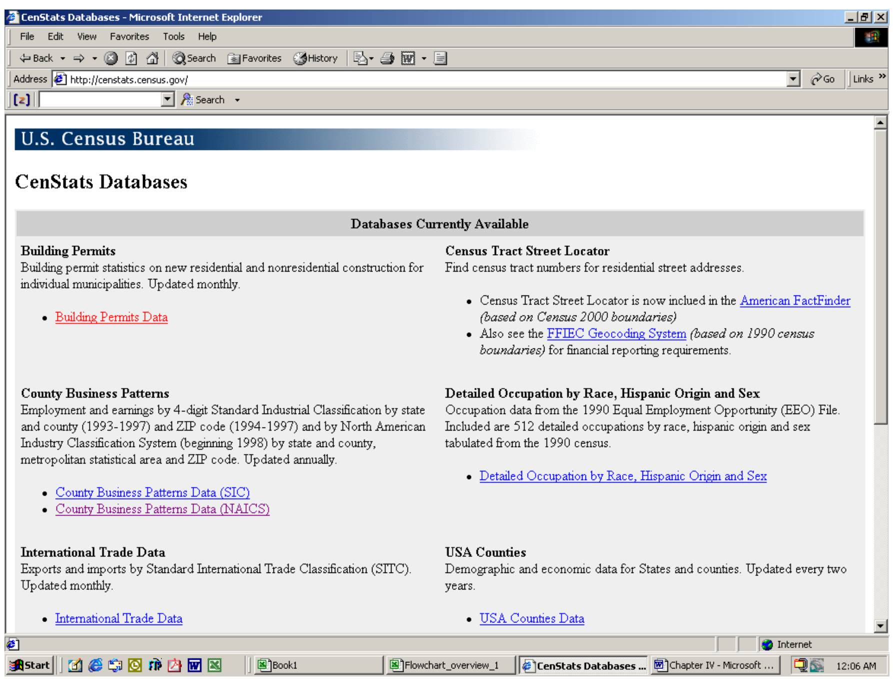


Figure 4-10: U.S. Census Bureau's CenStats Databases.

4.2.8.2 Classification of Establishments by SIC or NAICS Group

The next task was to classify the establishments by similar energy use groups. The main purpose of this task was to distinguish between energy intensive groups and non-energy intensive groups. To accomplish this, the establishments were categorized into industry groups based on the Standard Industrial Classification (SIC) codes or North American Industrial Code Standards (NAICS).

4.2.8.3 Determination of Gross Sales in Each SIC or NAICS Group

The third task was to determine the amount of gross sales in each SIC or NAICS group. The main purpose of this was to provide the level of industrial economic activity, which was then used to calculate the energy use of each group. According to the EIA, energy use in the industrial sector is primarily a function of the level of the industrial economic activity (EIA 2003a). Industrial economic activity in this study was considered to be the value of dollar gross sales (dollar value of shipments) produced by each industry group. The amount of gross sales by SIC groups was determined based on the data taken from the Texas Comptroller of Public Accounts Databases (TCPA 2003), which is available on the website shown in Figures 4-11 thru 4-13. From the database, information on gross sales, amount subject to state tax, and outlet has been provided. The outlets, the number of individual business locations with a sale, were used as the reference value to cross-check the total number of establishment defined previously.

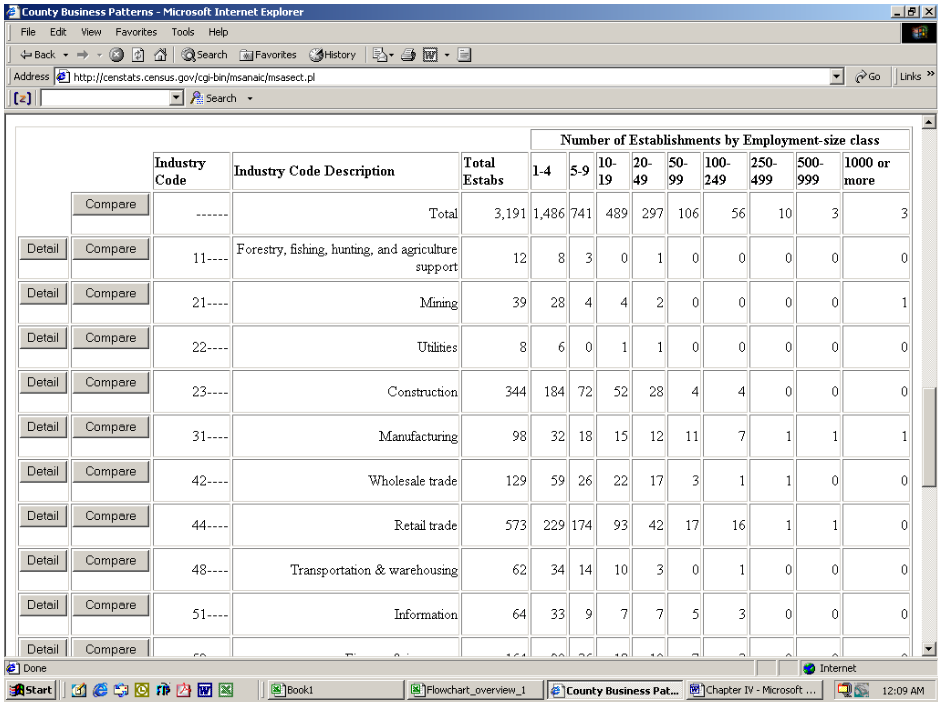
4.2.8.4 Calculation of Energy Intensity in Each SIC Group

The fourth task was to determine the energy intensity in each SIC group in the community. The main purpose of this task was to provide the representative values of energy use for each SIC group, which could then be used to calculate the energy use in each SIC group.

4.2.8.5 Estimation of Total Energy Use of the Industrial Sector

The next task was to calculate the total energy consumption in the industrial sector by finding the sum of each industry group's energy use. Each group's energy use was estimated by multiplying the representative value of the energy intensity by the gross sales (dollar value of shipment).

Source: U.S. Census 2003.



Industry Code	Industry Code Description	Total Estabs	1-4	5-9	10-19	20-49	50-99	100-249	250-499	500-999	1000 or more
------	Total	3,191	1,486	741	489	297	106	56	10	3	3
11----	Forestry, fishing, hunting, and agriculture support	12	8	3	0	1	0	0	0	0	0
21----	Mining	39	28	4	4	2	0	0	0	0	1
22----	Utilities	8	6	0	1	1	0	0	0	0	0
23----	Construction	344	184	72	52	28	4	4	0	0	0
31----	Manufacturing	98	32	18	15	12	11	7	1	1	1
42----	Wholesale trade	129	59	26	22	17	3	1	1	0	0
44----	Retail trade	573	229	174	93	42	17	16	1	1	0
48----	Transportation & warehousing	62	34	14	10	3	0	1	0	0	0
51----	Information	64	33	9	7	7	5	3	0	0	0

Figure 4-11: Output from the U.S. Census Bureau's CenStats Databases.

Source: TCPA 2003.

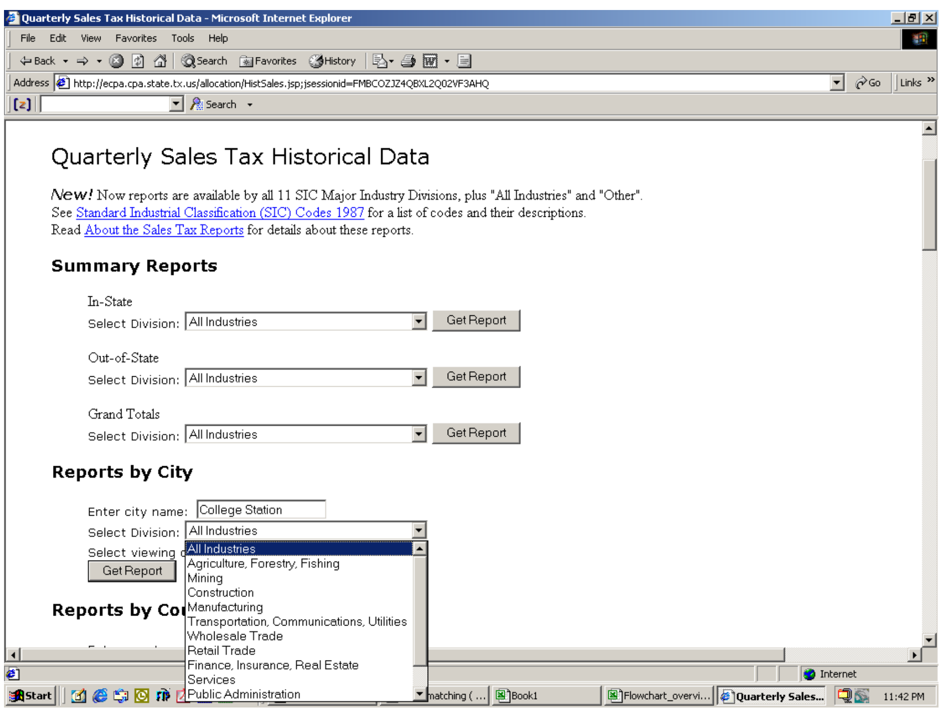
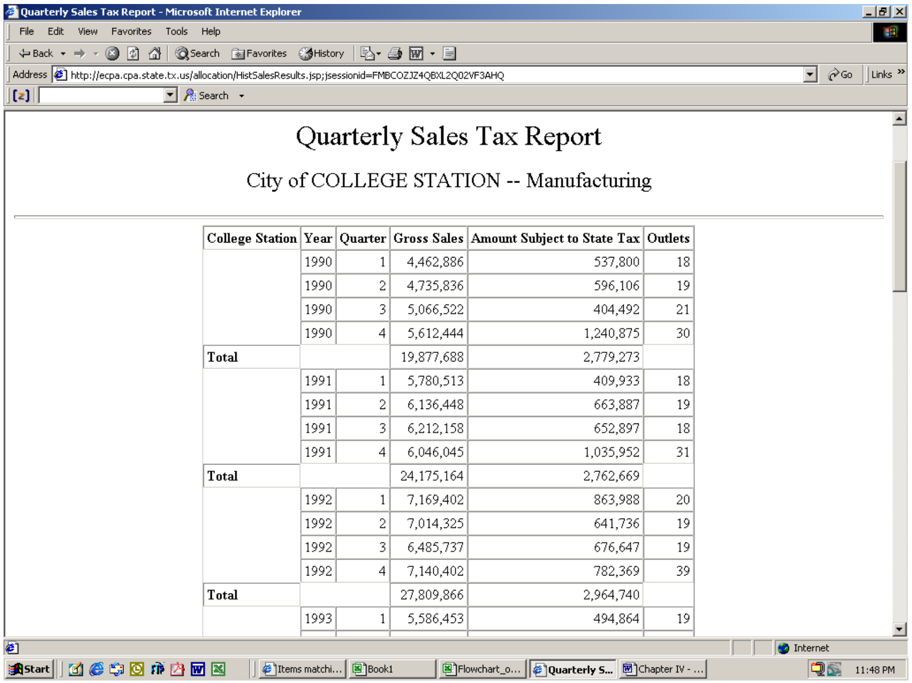


Figure 4-12: Texas Comptroller of Public Accounts Database.

Source: TCPA 2003.



Quarterly Sales Tax Report

City of COLLEGE STATION -- Manufacturing

College Station	Year	Quarter	Gross Sales	Amount Subject to State Tax	Outlets
	1990	1	4,462,886	537,800	18
	1990	2	4,735,836	596,106	19
	1990	3	5,066,522	404,492	21
	1990	4	5,612,444	1,240,875	30
Total			19,877,688	2,779,273	
	1991	1	5,780,513	409,933	18
	1991	2	6,136,448	663,887	19
	1991	3	6,212,158	652,897	18
	1991	4	6,046,045	1,035,952	31
Total			24,175,164	2,762,669	
	1992	1	7,169,402	863,988	20
	1992	2	7,014,325	641,736	19
	1992	3	6,485,737	676,647	19
	1992	4	7,140,402	782,369	39
Total			27,809,866	2,964,740	
	1993	1	5,586,453	494,864	19

Figure 4-13: Output from the Texas Comptroller of Public Accounts Database.

4.2.8.6 Verification of the Energy Use Estimation Model

Figure 4-14 represents the procedure for cross-checking the industrial sector's energy use estimation with its actual energy use. The main objective of this procedure is to show that the energy model works accurately. To accomplish this, two cross-checking procedures were used: 1) an energy use was cross-checked against actual utility bills and other fuel use information for selected business, and 2) an energy use was cross-checked against an integrated modeling analysis of the fiscal year's gross sales information with the energy intensity factors (kBtu/$ of Sales) provided by the EIA (2003a).

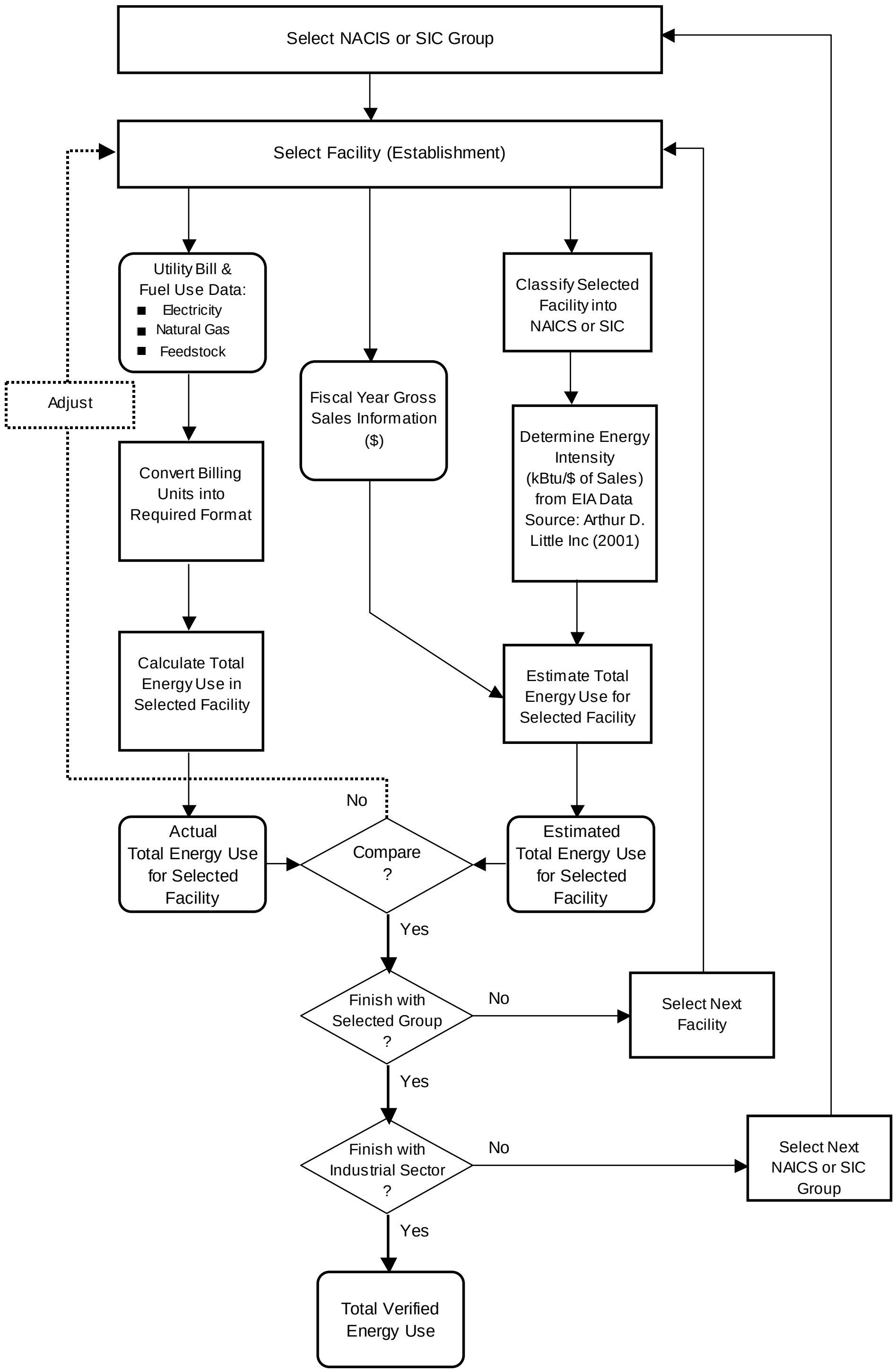


Figure 4-14: Procedure for Cross-Checking the Industrial Sector's Energy Use Estimation with the Actual Energy Use.

For the first step of this procedure, it was necessary to select a sample industry facility. This sample facility was then contacted either personally or by phone to obtain a variety of information (i.e., the type of industrial activity, the number of employees, the annual utility bills, and other fuel use issues). The information is then converted into the required format (MBtus), because this information involves a variety of energy user type and fuel types that are described in unique units. By adding up all the fuel consumption, the total energy use for selected facility was estimated. The second approach began with classifying the selected facility into the NAICS or SIC group. The classification was then used to determine an appropriate energy intensity factor by utilizing the "NEMS Industrial Demand Model Documentation Report 2003" (EIA 2003). Fiscal year gross sales information was obtained by contacting the facility. The total energy use was finally calculated by simply multiplying annual gross sales ($) by the energy intensity factor (kBtu/$ of sales). As a final step in this cross-check, a comparison against utility bills was conducted.

4.2.9 Municipal Sector Energy Analysis

The methodology used to calculate the energy consumption for the municipal sector is presented in this section. The main purpose of this analysis is to estimate how much energy is used for streets lights, traffic signals, and water and wastewater use. The purpose of separating energy use by the municipal sector from that by other sectors is based on two facts. The first fact is that energy use characteristics in the municipal sector are unique. The second fact is that the energy users in this category may directly or indirectly controlled by a local government or a state government. For instance, facilities, owned by local government or local independent school district (ISD), are categorized to the municipal sector.

Five municipal parcels were categorized to help estimate the total energy use in the municipal sector, as shown in Figure 4-15. The five parcels are as follows: 1) public administration buildings; 2) schools and colleges; 3) outdoor lighting; 4) water and waste water treatment; and 5) other municipal factors.

Since the energy characteristics of the first two parcels (schools and college, public administration) are similar to that of other building sectors, the procedures determined on the commercial sector were utilized to provide the baseline energy calculations. However, other parcels such as outdoor lighting and water and wastewater treatment were considered to have different energy use characteristics; for instance, the population, length of street, type of city lights, and size of community are direct factors indicating the amount of energy use. Therefore, only the energy use for outdoor lighting and water and wastewater treatment system are considered in this section. The first procedure was to tabulate the information regarding energy use, i.e., operating energy consumption based on the monthly utility bills obtained from the local utility department or local government for the following parcels:

1) Water supply: an estimate of the operating energy consumption for any pump stations and treatment facilities located in the selected community. If direct information was not available, calculation of the energy use based on the type and length of water supply and distribution pipeline, as well as the gallons of water produced.

2) Wastewater collection: an estimate of the operating energy consumption for any pump stations and treatment facilities, as described above for the water supply. If direct information was not available not available, a calculation of the electricity energy use based on the type of wastewater treatment was necessary, as well as the gallons of sewer served.

3) Streetlights: an estimate of the operating energy consumption according to the number and type of outdoor lighting.

4) Traffic signals: an estimate of the operating energy consumption by the type and number of signal units.

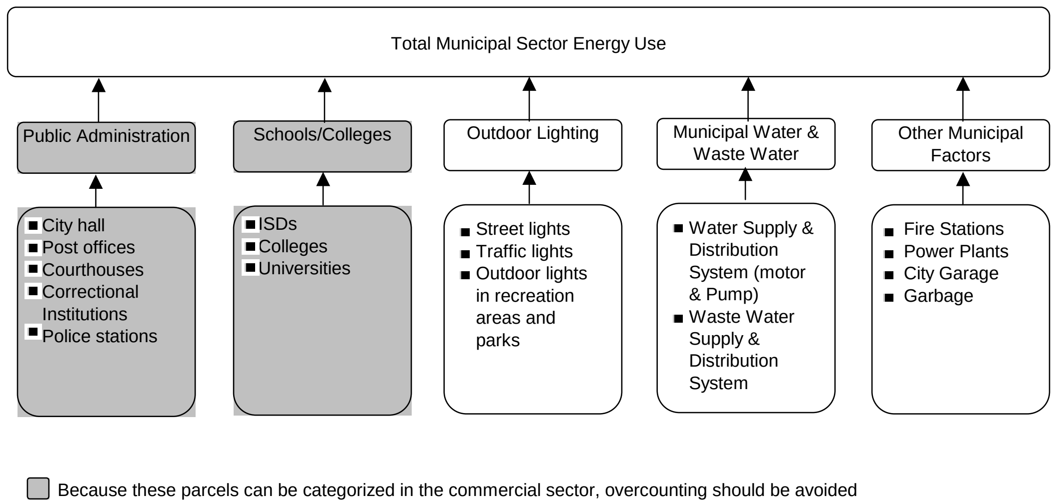


Figure 4-15: Simplified Diagram of the Structure of the Municipal Sector's Energy Use.

4.2.9.1 Calculation of Street Lights' Energy Use

This parcel includes all streetlights on all roads within the community's boundaries (highway, arterials, collectors, and local streets and alleys) as well as other outdoor lighting in park and recreation areas or municipal athletic field lighting.

To complete this energy analysis, the outdoor lighting parcel required the determination of the number of outdoor lights and streetlights as well as the lighting intensity for each type of light. This was due to the fact that the energy uses are related to these factors: 1) the type of lighting used, 2) the lighting levels and 3) the hours of use. The general equation of the lighting energy use calculation in this study is:
Energy Use (Streetlights) = Operation Hours (hours) x Number of Streetlights x Energy Intensity per Street Light (Watt)

The necessary data was available through contact with the local electric utility or local utility department, because the local utility departments control operating schedule and maintenance. If the data were not available, alternative methods were used. Alternative methods included simplified calculations based on typical quantities of lights per mile of different road types and quantities of lights for different types of recreation installation. Detailed information is presented on Tables 4-3 and 4-4.

Table 4-3: Guidelines for the Design of Streetlights.

IES Classification	HPS (high-pressure sodium) Lamp Wattage	Spacing in Feet
Urban Expressway	400 Watt	21 to 35
Expressway Cloverleaf Interchange	400 Watt	60 to 120 per interchange
Arterial	250 Watt	100 to 120
Major Collector	150	120
Minor Collector	100	60
Residential	70	150

Source: IES 1987.

Table 4-4: Guidelines for the Design of Recreational Lighting.

IES Classification	HPS (high-pressure sodium) Lamp Wattage	Number of Lights
Tennis Court	400 Watt	4 - 8
Football Field	400 Watt	40
Softball Field	250 Watt	12 – 18
Football Stadium	400 Watt	80 - 120

Source: IES 1987.

4.2.9.2 Calculation of Water and Wastewater Treatment Energy Use

Community water use includes water for households and businesses, restaurants and public offices, sanitation, landscaping, and fire protection. Water supply and wastewater treatment for a community's domestic water use is commonly performed in activated sludge plants consisting of two biological reactors for the degradation of pollutants, and a settler for the separation of the sludge from the purified water.

To determine the energy use for water supply plants and wastewater treatments, the total motor horsepower for both the water supply and the distribution were needed. The electric motor capacity requirements for the water supply system (collection, purification, and distribution) generally depend upon community water demands and the length of the water supply pipeline. Motor requirements for wastewater treatment systems also depend on the size of the community. Therefore, the water demands were first estimated to determine the motor horsepower. The necessary data may was usually available from contacting the operating manager of each facility, the manager of the public Community Workers Department or by accessing the community annual report. The data needed to calculate the energy consumption are included the: 1) Water Supply and Wastewater treatment plant information, 2) Permitted average daily flow (gpd), 3) Permitted peak 2-hour flow, 4) Existing average daily flow, 5) Existing peak 2-hour flow, 6) Number of pumps, 7) Pump individual rated capacity: (gpm, ft TDH), and 8) Pump motor horsepower.

Table 4-5: Texas Major Community's Water Use (Daily Gallons per Person) in 1990 and 1995.

CITY	1990	1995
Abilene	216	159
Amarillo	234	223
Arlington	101	162
Austin	180	157
Beaumont	158	159
Brownsville	191	184
Corpus Christi	186	140
Dallas	237	230
El Paso	183	179
Fort Worth	210	189
Garland	159	151
Houston	157	126
Irving	188	196
Laredo	254	190
Lubbock	176	189
Mesquite	152	165
Pasadena	129	117
Plano	210	220
San Antonio	159	149
Waco	198	172
State Average	167	158

Source: TWDB 1997.

If necessary information from local utility is not available, simplified methods can be used. The simplified methods were generally developed based on the simple calculation: the total water use for a selected community was calculated by multiplying the appropriate number of per capita use from Table 4-5 by the total population of a community. Table 4-5 presents the Texas major community's water use in 1990 and 1995. Texas average water consumption is about 158 gallons per capita per day (TWDB 1997).

4.2.10 Transportation Sector Energy Use Analysis

The procedure to calculate energy consumption for the transportation sector and its associated NOx emissions is presented in this section. The procedure consists of three main phases: 1) the collection of information, 2) the classification of energy intensity and emissions factors, and 3) the calculation of energy use and its associated NOx emissions. Each phase consists of several sub-tasks, and these are described in later sections.

4.2.10.1 Overview of Procedure

The transportation sector energy use for this study includes two major groups: 1) the on-road vehicles and 2) the non-road group. These two groups were then sub-divided into several energy users, based on EPA classifications. For instance, the on-road group includes eight different vehicle types and the non-road group includes eight different classifications.

An attempt was made to focus this energy analysis on the on-road vehicle use within the community boundary (the city limits). However, it was difficult to figure out how much fuel was consumed by driving within or outside of the community boundary. Therefore, some of the energy use for the transportation results might involve travel outside the community boundary.

In addition, automobile emissions estimates are affected by many factors that vary with geographical locations and estimation conditions. The more significant factors include the average speed, the percentage of vehicle miles traveled (VMT) in a given time period, the percentage of travel by vehicle type (VMT Mix), and the average ambient temperature profile (Cooper and Alley, 1994). Additionally, the vehicles on a given roadway have a wide age distribution. Some cars are recent model years, and a significant proportion of vehicles are within ten years of age but some of them are more than twenty years old. All of the factors that affect emissions should be used to accurately calculate vehicle emissions. Therefore, the calculation of automobile emissions is a very complicated process. However, determining all factors was considered to be too time consuming and therefore outside the scope of this study. Therefore, relatively simplified methods were developed, which are flexible and based on locally available data.

4.2.10.2 Procedures for Calculating the Energy Use in the Transportation Sector

The overall procedure for calculating the energy use in the transportation sector is shown in Figure 4-16. As shown in this figure, this procedure consists of five main tasks: 1) the categorization of the transportation sector, 2) the determination of the number of vehicles or equipments, 3) the determination of the vehicle miles traveled (VMT) and VMT Mix, 4) the determination of energy intensity, and 5) the calculation of the total energy use. These five main tasks consisted of some sub-tasks, which are explained later following sections.

4.2.10.3 Categorization of the Transportation Sector

Estimating energy use in the transportation sector began by categorizing the sector into two main groups (the on-road group and the non-road group) and these were then re-categorized into the detailed classifications. The detailed classifications are described in Table 4-6. The on-road group is comprised of Light Duty Gasoline Vehicle (LDGV), Light Duty Gasoline Truck 1 (LDGT1), Light Duty Gasoline Truck 2 (LDGT2), Heavy Duty Gasoline Vehicle (HDGV), Light Duty Diesel Vehicle (LDDV), Light Duty Diesel Truck (LDDT), Heavy-Duty Diesel Truck (HDDT), and Motorcycles. The non-road group comprises Compression-Ignition Engines (farm, construction, mining, etc.), Small Spark-Ignition Engines (lawn mowers, leaf blowers, chainsaws, etc.), Large Spark-Ignition Engines (forklifts, generators, etc.). Marine Diesel Engines (commercial ships, recreational diesel engines etc.), Marine Spark-Ignition Engines (boats, personal watercraft, etc.), Recreational Vehicles (snowmobiles, dirt bikes, all-terrain vehicles, etc.), Locomotives (Railroads), and Aviation (aircraft, ground support equipment, etc.).

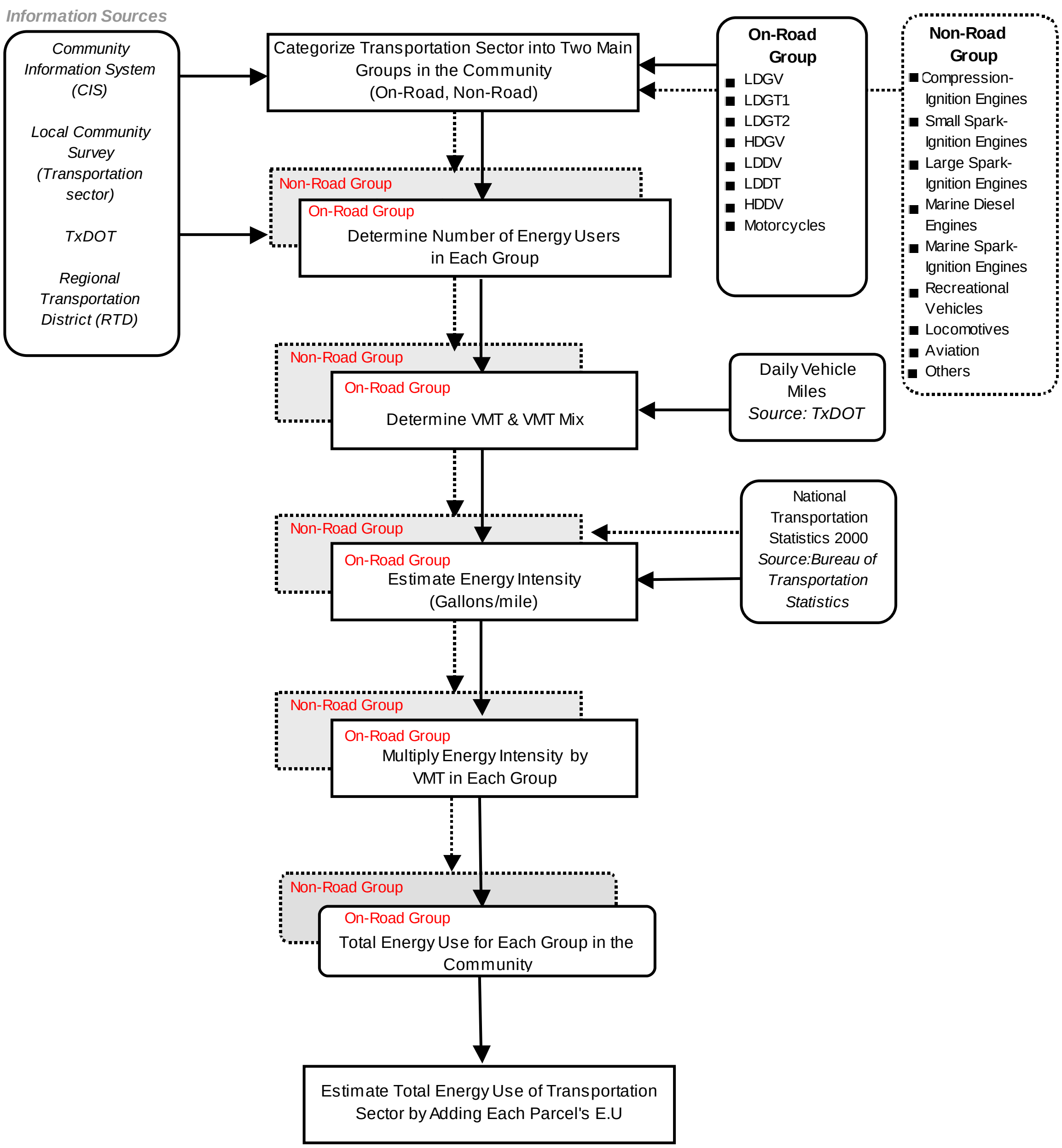


Figure 4-16: Procedures for Developing the Transportation Energy Use and Its Associated NOx Emissions.

Table 4-6: Categorization of Energy Users in Two Main Groups.

Group	Description
On-Road	LDGV (Light duty gasoline vehicle)
	LDGT 1 (Light duty gasoline truck 1)
	LDGT 2 (Light duty gasoline truck 2)
	HDGV (Heavy duty gasoline vehicle)
	LDDV (Light duty diesel vehicle)
	LDDT (Light duty diesel truck)
	HDDV (Heavy duty diesel vehicle)
	MC (Motorcycles)
Non-Road	Compression-Ignition Engines (farm, construction, mining, etc.)
	Small Spark-Ignition Engines (lawn mowers, leaf blowers, chainsaws, etc.)
	Large Spark-Ignition Engines (forklifts, generators, etc.)
	Marine Diesel Engines (commercial ships, recreational diesel etc.)
	Marine Spark-Ignition Engines (boats, personal watercraft, etc.)
	Recreational Vehicles (snowmobiles, dirt bikes, all-terrain vehicles, etc.)
	Locomotives (Railroads)
	Aviation (aircraft, ground support equipment, etc.)

Source: EPA 2003b.

4.2.10.4 Determination of the Number of Fuel Consumers (Vehicles)

To determine the number of fuel consumers in each group, various information sources were required. Sources for the on-road group included the Texas Department of Transportation (TxDOT) traffic study for the Brazos County and vehicle registered data provided by Regional Transportation District (RTD) representatives. For instance, in order to determine a base year's value of vehicle use for College Station, the county values provided by the RTD were interpolated to obtain the total vehicle use in College Station during the year 2002.

4.2.10.5 Determination of Energy Intensity

To determine energy intensity, statistical data provided by the Bureau of Transportation Statistics (BTS) were used (U.S. BTS 2003). This body of statistical data included the average miles per vehicles (miles), average fuel consumed per vehicle (gallons) and average miles traveled per gallon. According to the BTS the average miles per vehicle for U.S during the year 2001 were 11,800 miles. The average fuel consumed per vehicle for U.S during the year 2001 was 693 gallons. The average miles traveled per gallon of passenger cars for U.S during the year 2001 were 21.4 miles per gallon. The detailed information is shown in Table 4-7.

Table 4-7: Average Fuel Efficiency of U.S. Passenger Cars and Light Trucks.

Category		1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Average U.S. passenger car fuel efficiency (mpg) (calendar year)	Passenger car	16.0	17.5	20.3	21.2	21.0	20.6	20.8	21.1	21.2	21.5	21.6	21.4	21.9	22.1
	Other 2-axle 4-tire vehicle	12.2	14.3	16.1	17.0	17.3	17.4	17.3	17.3	17.2	17.2	17.2	17.0	17.4	17.6
New vehicle fuel efficiency (mpg) (model year)	Light-duty vehicle														
	Passenger car	24.3	27.6	28.0	28.4	27.9	28.4	28.3	28.6	28.5	28.7	28.8	28.3	28.5	28.6
	Domestic	22.6	26.3	26.9	27.3	27.0	27.8	27.5	27.7	28.1	27.8	28.6	28.0	28.7	28.8
	Imported	29.6	31.5	29.9	30.1	29.2	29.6	29.7	30.3	29.6	30.1	29.2	29.0	28.3	28.4
	Light truck (<8,500 lbs GVWR)	18.5	20.7	20.8	21.3	20.8	21.0	20.8	20.5	20.8	20.6	21.1	20.9	21.3	20.9
CAFE standards (mpg) (model year)	Passenger car	20.0	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5	27.5
	Light truck	14.0	19.5	20.0	20.2	20.2	20.4	20.5	20.6	20.7	20.7	20.7	20.7	20.7	20.7

Source: U.S. BTS 2003.

4.2.10.6 Determination of the Vehicle Miles Traveled (VMT)

To estimate the vehicle miles traveled (VMT) by vehicle types, locally derived data was required. The data included information on the number of vehicles, vehicle age distribution, average vehicle classification, etc. Because the data varied considerably based on local conditions, efforts to gather information began with contacting the local transportation representatives.

In this study, previously published information was used. The results of the TxDOT traffic study provided expected daily values for Brazos County's vehicle miles traveled in 2001 and 2002. The county's Daily Vehicle Miles (DVM) data were then interpolated to obtain College Station's annual VMT data.

4.2.10.7 Determination of the VMT Mix

To determine the VMT Mix, information on average vehicle classifications was required. However, the average vehicle classification data for College Station was not available. Therefore, statewide (County wide) data provided by TxDOT (2001) was used instead. To validate the VMT Mix, on-site checks were required. For this study, spot-checks in shopping centers and grocery store parking lots were performed to determine the average vehicle classifications for College Station.

4.2.10.8 Calculation of the Total Energy (Fuel) Use

To estimate the total energy (fuel) used by vehicle type (small group), a simple multiplication of the VMT (miles) by the energy intensity (in gallons/mile) was used. To estimate the total energy use of the transportation sector, the total energy use for each vehicle type was determined.

4.3 CALCULATION OF COMMUNITY'S TOTAL ENERGY USE BY FUEL TYPE

Community's total energy use is estimated by adding five sectors (residential, commercial, industrial, municipal, and transportation)' energy use based on fuel type (electricity, natural gas, and vehicle fuels). The main objective of this task was to determine community's total energy use by certain fuel type. Determined each fuel type's total consumption was then converted to uniform format (Million Btus).

4.4 BASELINE NOx EMISSIONS CALCULATION

As the final step in developing the baseline model, the procedures for calculating the NOx emissions are provided in this section. Before describing the detailed procedures used, the general concepts considered for this study in order to develop the NOx emissions calculations are discussed. Then, the detailed procedures are discussed, step-by-step, in the next subsections.

4.4.1 Introduction

In general, NOx emissions provider can be classified as two major types: 1) on-site NOx emissions, and 2) remote-site NOx emissions. On-site NOx emissions are those in which the energy end-user directly combusts the fossil fuels within a given community's boundary. For instance, natural gas is directly combusted inside a gas furnace for space and domestic water heating in a building sector. Another example is that people drive their cars with a direct combustion of fuels when they commute to work. In contrast to the on-site provider, remote-site NOx emissions generally deliver energy within a community's boundary. However, the emissions are generally provided in an area remote from the community. A typical example is a community's electricity use for various purposes (i.e., space conditioning, lighting, and appliances, etc.), which is provided a power plant located at a remote site. Therefore, the procedures for estimating NOx emissions should be individually conducted based on the individual fuel type.

The basic method of calculating NOx emissions for this study is to multiply an appropriate NOx emission rate by the demand for energy use. Emissions rates and energy use have long been fundamental tools for air quality management (EPA 1997). The general equation for an emission estimation in this study is:

$$E = CE \times ER$$

where:
E = emissions,
CE = a community's total energy demand by fuel type, and
ER = the emission rate by fuel type.

CE is the energy use by a given community, organized by fuel type. Since the procedures for calculating community's energy demand were previously discussed in Section 4.3, the procedures for determining the appropriate NO emission rate by fuel type are discussed in this section.

4.4.2 Determination of Appropriate NOx Emissions Rates

The determination of an appropriate emissions rate is an important task for this study. To accomplish this task, a significant amount of information from various sources was reviewed and used in this study. These sources include the EPA's AP-42 (EPA 1995a), the EPA's eGRID (EPA 2003a), the TNRCC (2002), the EPA's Mobile5 (EPA 1994), and the Bureau of Transportation Statistics (U.S. BTS 2003).

The EPA's AP-42 is an emissions rate that is a representative value relating the quantity of a pollutant released into the atmosphere with an activity associated with the release of that pollutant (EPA 1995a). The EPA's AP-42 provides useful information for this study, especially when estimating the NOx emissions from a community's natural gas use. The emissions rates in the EPA's Emissions & Generation Resource Integrated Resource (eGRID) are also very useful for this study, especially when calculating the emissions from electricity use. The emissions rates in the BTS are also useful when calculating the NOx emissions from transportation fuel use. Since a community uses various types of fuel, the procedures for calculating NOx emissions were individually developed and then combined to calculate the community's total NOx emissions. The following procedures are described in the next sub-sections. These procedures include the calculation of NOx emissions from electricity use, natural gas use, and transportation fuel use.

4.4.3 Calculation of NOx Emissions from Electricity Use

The calculation of NOx emissions is often accomplished with a simple method, which is the multiplication of an average emissions rate to calculate the NOx emissions from the electricity use. However, the complexity of the electric utility generation-distribution system made it difficult this study to determine the specific power plant that generated the electricity for the case study community. Texas's electric utility market is a highly integrated collection of ten transmission and generation companies, along with power marketers that are closely related to the wholesale market (PUCT 2000). Electric power is bought and sold in a contract-based wholesale market. Figure 4-17 presents a simplified diagram of a typical investor-owned electric market, which also reflects the electricity market's diversity and decentralization.

Source: Hill 1997.

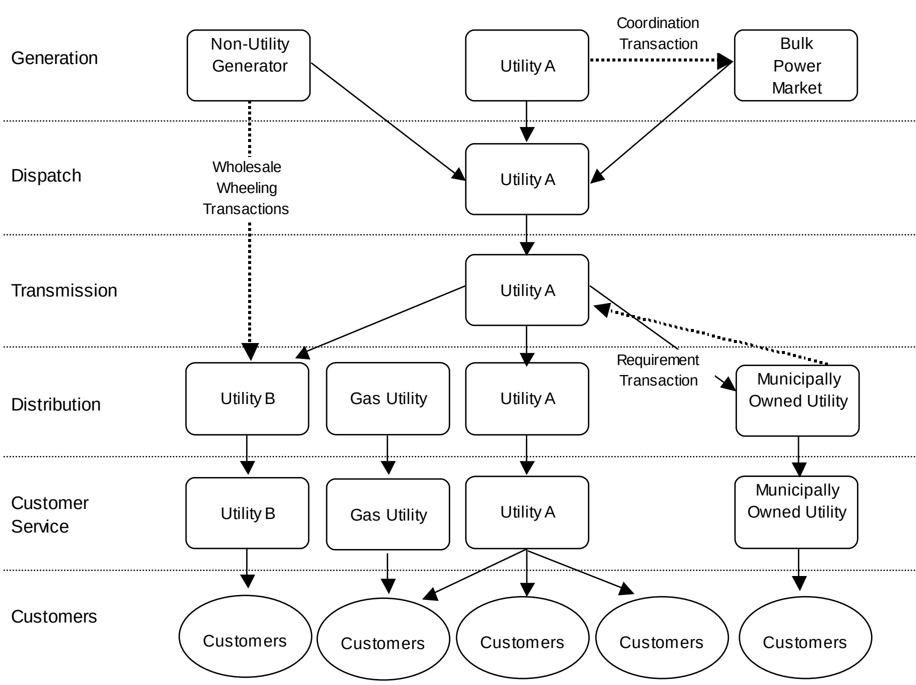


Figure 4-17: A Typical Investor-Owned Electric Utility.

In this figure, a typical investor-owned electric utility's (referred to as utility A) power transactions are presented. The investor-owned utilities generally are vertically integrated, franchise-monopoly electric utilities regulated by state regulatory commissions in return for exclusive franchises in pre-specified geographical areas. In a regulated market, state regulators approve the rates, quality and terms of the electric service in regulator proceedings for the investor-owned utilities. Utility A is partially integrated through five primary utility functions: 1) generation, 2) dispatch, 3) transmission, 4) distribution, and 5) customer service. In the diagram, Utility A engages in three types of market transactions: 1) coordination, 2) requirement, and 3) wholesale wheeling. A coordination transaction means that Utility A buys power in bulk from the power market, under joint contracts. Requirement transactions, on the other hand, are related to the capacity needs of some utilities, such as those that are municipally owned, which do not have their capacity requirements satisfied. Hence, an investor-owned utility could serve all or a portion of the capacity requirements for a municipal utility. Wholesale wheeling transactions are related to power generators other than those of a franchise-monopoly utility (referred as Non-Utility Generators).

For instance, a non-utility generator provides power and sells it to a wholesale power supplier (referred as Utility B) by using the Utility A's transmission lines. In addition, significantly interconnected individual service territories with numerous transmission lines made developing the procedures necessary for this study even more complicated. Therefore, several tasks were needed to convert the community-wide electricity consumption into NOx emissions for the power plants that provided the electricity. To accomplish this, a simplified calculation method was necessary for this study to account for the variables mentioned above. The procedure developed by Haberl et al. (2003c) was simply adopted for this study in order to calculate NOx emissions from a community's electricity use. Figure 4-18 shows the simplified procedure for both the annual and the peak-day NOx emissions calculations (Haberl et al. 2003c). The procedures include the collection of the basic information regarding how the electricity supply traveled from the power plant to where it was used in the community. What types of fuel sources for generating that electricity and emissions rates of that generator were also investigated. Detailed procedures for determining the following factors were also developed: 1) the transmission and distribution loss: 2) the power control areas, 2) the power plant's location and its primary fuel source, 3) the NOx emission rate (both the annual NOx rate and the ozone season day NOx rate), and 4) the calculation of NOx emissions.

Source: Haberl et al. 2003c.

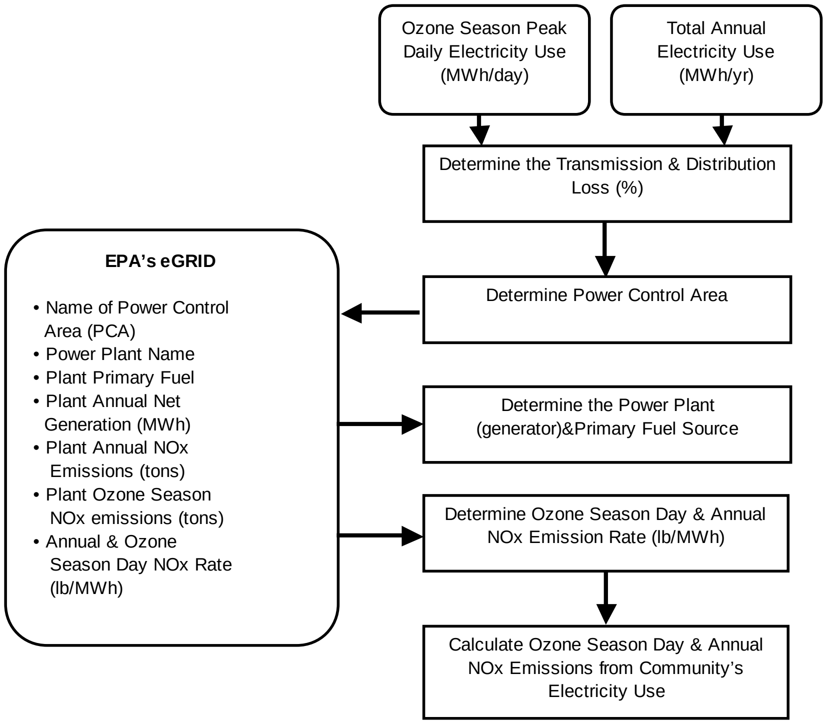


Figure 4-18: Procedures for Calculating NOx Emissions of Electricity.

4.4.3.1 Determination of Transmission & Distribution Loss

The total electricity use was first calculated from the actual electricity consumption with an appropriate fraction added for transmission and distribution loss. For this study, the U.S. average transmission and distribution loss rates were used. Table 4-8 shows the average U.S. electricity systems' losses along the electricity grid. Information in this table was taken from the ORNL (Mulholland, et al. 2000) reports for the U.S. DOE. For the column labeled "stage", the consecutive rows represent each step along a path from generation to end-user sale. Beginning in the upper row the electricity generated in the power plant is increased in voltage to begin the first stage of high-voltage transmission, which represents a 0.32% of energy. Moving down the column, the losses associated with of the different stages of transmission and distributions are listed. Some electricity was sold after high-voltage transmissions to major, direct-service customers (i.e., those with heavy industrial activity). The remainder went through an additional distribution stage before reaching its end-users in the commercial and residential sectors. The total loss of energy delivered from the power plants to the end-users is approximately 7.6% of the energy use. Table 4-8 also presents an instantaneous power loss (10.8%). Therefore, for this study an average use of 10% is used for determining total transmission and distribution loss.

Table 4-8: U.S. Average Electricity System's Loss Along the Electric Grid.

Stage	Percent of Instantaneous Power (%)	Percent of Energy (%)
1. Generation		
2. Transmission		
Step-up transformer	0.32	0.3
Transmission 230 - 500 kV	0.53	0.35
Step-down transformer	0.37	0.38
Transmission 69 - 161 kV	2.94	1.94
Step-down transformer	0.66	0.69
Metering	0.36	0.46
3. Distribution		
Distribution 12 - 25 kV	2.99	1.3
Distribution Transformer	1.77	1.47
Metering	0.9	0.72
Total (%)	10.84	7.61

Source: Mulholland, et al. 2000.

4.4.3.2 Determination of Power Control Area & Power Plant

Next task is to determine the power control area and power plants. According to the PUCT (2000), within the state of Texas there are ten power control areas (PCAs). These PCAs relate to specific service territories and include American Electric Power-West, Austin Energy, Brownsville Public Utility Board, Lower Colorado River Authority, Reliant Energy HL&P, San Antonio Public Service Board, South Texas Electric Coop Inc, Texas Municipal Power Pool, Texas-New Mexico Power Pool, and TXU Electric. Each power control area's annual net generation (MWh) and average NOx emission rate (lbs/MWh) are presented in Table 4-9. The average NOx emissions rate for each power control area varies significantly based on its particular fuel sources. For instance, the two primary electricity providers for College Station and Bryan are quite different, even though the two cities are located close to each other and in the same county (Brazos). The City of College Station currently uses electricity provided by American Electric Power (AEP), while the City of Bryan uses electricity provided by the Texas Municipal Power Agency (TMPA). Therefore, an annual average NOx emissions rate should be determined through direct contact with the local electric provider.

Table 4-9: The Characteristics of Power Control Areas (PCA) in Texas.

Electric Utility	PCA 1998 Annual Net Generation (MWh)	PCA Average Annual NOx Emission Rate(lbs/MWh)
American Electric Power – West	33,028,932	2.9
Austin Energy	3,713	2.56
Brownsville Public Utility	236,180	2.24
Lower Colorado River Authority	12,037,446	3.16
Reliant Energy	104,265,741	2.5
San Antonio Public Service	14,646,928	2.65
South Texas Electric Cooperative	3,239,094	3.28
Texas Municipal Power Pool	8,804,340	3.22
Texas-New Mexico Power Co.	10,258,063	1.59
TXU	105,812,850	3.66
ERCOT Average		2.69

Source: TNRCC 2002.

Table 4-10 shows the electric utility providers for each county in Texas. In Table 4-10 the NOx production for each power plant is provided from the eGRID database, for ten electricity utility suppliers (i.e., AEP, Austin Energy, Brownsville Public Utility, LCRA, Reliant, San Antonio Public Service, South Texas Coop, TMPP, TNMP, and TXU). This table was used for this study to assign the power plant used by electricity provider, which provides electricity to a given county. Once the county had been chosen for a given community, the community to corresponding PCA can be determined using Table 4-10. The first column shows Federal Implementation Plan (FIP) code for each county, and the second column gives the corresponding county in the ERCOT region having electric generators that could be affected by the energy savings. The next ten columns give the NOx production by PCA for one megawatt of electricity produced. In Table 4-10, fifty counties have electric generating plants that would be affected by energy savings based on the application of the methodology in the ERCOT region. Each cell shows the annual average amount of NOx (in pounds) that could be reduced by electric generators in that county if one megaWatt-hour of electricity reduction (i.e., savings) is realized within the PCA for that column. Counties that do not have NOx values do not contain electric power generating plants (in the eGRID database) that would be affected by energy savings realized within the PCAs shown in the column. The total values shown at the bottom of each column represent the total NOx produced to generate by one megaWatt-hour. Once the value of NOx emissions rate had been obtained, a given community's annual NOx emissions can be calculated.

4.4.3.3 Calculation of Annual and Peak-day NOx Emissions

By using the annual NOx emissions rate (lbs/MWh), which is given from Table 4-10, the annual and peak-day NOx emissions can be calculated.

4.4.4 Calculation of NOx Emissions from Natural Gas Use

Natural gas is one of the major fuels used throughout the United States. It is mainly used to generate industrial and utility electric power, to produce industrial steam and heat, and to heat residential and commercial space (EPA 1998).

This calculation procedure was relatively simpler than the procedures necessary to calculate the emissions from electricity use. To accomplish this task, various emissions sources were reviewed. These sources include the EPA's AP-42, Ottinger (1991), and the Leonardo Academy, Inc. (2000). Table 4-12 presents the various NOx emission rates for natural gas combustion in boilers and furnaces. Unfortunately, the NOx emissions rate for natural gas from these sources demonstrates contained significant variation, as shown in Table 4-11. Therefore, for this research, the EPA's AP-42 was chosen for use (EPA 1995a).

Prior to use the EPA's AP-42 data were converted to by multiplying the listed emissions factor by the ratio of the specified heating value (i.e., divided the listed value of lb/10^6 scf by 1,020 to obtain lb/MMBtu).

Table 4-10: eGRID NOx Emissions for Texas Counties in ERCOT Power Control Area.

Cnty_FIP	County	American Electric Power - West (ERCOT)/PCA	Austin Energy/PCA	Brownsville Public Utils Board/PCA	Lower Colorado River Authority/PCA	Reliant Energy HL&P/PCA	San Antonio Public Service Bd/PCA	South Texas Electric Coop Inc/PCA	Texas Municipal Power Pool/PCA	Texas-New Mexico Power Co/PCA	TXU Electric/PCA
48021	BASTROP	0.01	0.20		0.34		0.01				
48029	BEXAR	0.06	0.09	0.04	0.16		2.00	0.08	0.01		
48039	BRAZORIA	0.01	0.01			0.05	0.01				
48041	BRAZOS		0.01		0.01			0.03	0.11		0.01
48057	CALHOUN	0.19		0.14	0.01			0.04	0.01		0.01
48061	CAMERON	0.14		0.20				0.03			0.01
48071	CHAMBERS	0.05	0.06	0.03	0.02	0.35	0.08	0.03	0.02	0.02	0.03
48073	CHEROKEE	0.01	0.01	0.01	0.02			0.02	0.06	0.02	0.10
48081	COKE	0.03		0.02				0.01			
48083	COLEMAN	0.02		0.01							
48085	COLLIN	0.01	0.01		0.02	0.01		0.05	0.19		0.02
48105	CROCKETT	0.14		0.11				0.03			0.01
48113	DALLAS	0.06	0.06	0.04	0.09	0.03	0.01	0.09	0.30	0.09	0.51
48121	DENTON		0.01		0.01			0.04	0.15		0.01
48147	FANNIN	0.02	0.02	0.01	0.03	0.01		0.03	0.09	0.03	0.17
48149	FAYETTE	0.02	0.86	0.02	1.51	0.01	0.04	0.01	0.02		0.02
48157	FORT BEND	0.13	0.17	0.10	0.06	1.01	0.23	0.09	0.06	0.07	0.10
48161	FREESTONE	0.02	0.02	0.02	0.04	0.01		0.03	0.12	0.04	0.22
48163	FRIO	0.05		0.04	0.01			1.15	0.07		
48167	GALVESTON	0.05	0.06	0.04	0.02	0.39	0.09	0.04	0.03	0.42	0.04
48185	GRIMES	0.01	0.01		0.02	0.01		0.06	0.23		0.01
48197	HARDEMAN	0.01		0.01							
48201	HARRIS	0.05	0.07	0.04	0.02	0.41	0.09	0.04	0.02	0.03	0.04
48207	HASKELL	0.16		0.12	0.01			0.03	0.01		0.01

Table 4-10: (Continued).

Cnty_FIP	County	American Electric Power - West (ERCOT)/PCA	Austin Energy/PCA	Brownsville Public Utils Board/PCA	Lower Colorado River Authority/PCA	Reliant Energy HL&P/PCA	San Antonio Public Service Bd/PCA	South Texas Electric Coop Inc/PCA	Texas Municipal Power Pool/PCA	Texas-New Mexico Power Co/PCA	TXU Electric/PCA
48213	HENDERSON				0.01				0.02	0.01	0.03
48215	HIDALGO	0.13		0.10				0.03			
48221	HOOD	0.02	0.02	0.02	0.04	0.01		0.03	0.12	0.04	0.22
48251	JOHNSON								0.01		
48253	JONES	0.14		0.11				0.03			0.01
48277	LAMAR										0.01
48293	LIMESTONE	0.01	0.01			0.05	0.01				
48299	LLANO		0.12		0.21		0.01				
48309	MCLENNAN	0.04	0.04	0.03	0.07	0.02	0.01	0.06	0.22	0.07	0.40
48335	MITCHELL	0.04	0.04	0.03	0.07	0.02	0.01	0.06	0.21	0.07	0.39
48353	NOLAN										0.01
48355	NUECES	0.74	0.01	0.55	0.02	0.01	0.01	0.15	0.02	0.01	0.03
48363	PALO PINTO	0.01	0.02	0.01	0.03	0.01		0.09	0.36		0.02
48367	PARKER							0.01	0.03		
48387	RED RIVER								0.01		0.02
48395	ROBERTSON					0.01				0.40	0.01
48401	RUSK	0.01	0.01	0.01	0.01			0.01	0.04	0.01	0.07
48439	TARRANT	0.04	0.04	0.03	0.06	0.02	0.01	0.05	0.18	0.06	0.33
48441	TAYLOR	0.01									
48449	TITUS	0.01	0.01	0.01	0.02			0.02	0.05	0.02	0.10
48453	TRAVIS		0.46		0.05						
48469	VICTORIA	0.30	0.01	0.22	0.01			0.68	0.05		0.01
48475	WARD	0.06	0.06	0.04	0.09	0.02	0.01	0.08	0.28	0.10	0.51
48479	WEBB	0.06		0.05				0.01			
48481	WHARTON					0.01					
48503	YOUNG	0.02	0.02	0.01	0.03	0.01		0.03	0.09	0.03	0.16
TOTAL		**2.90**	**2.56**	**2.24**	**3.16**	**2.50**	**2.65**	**3.28**	**3.22**	**1.59**	**3.66**

Table 4-11: Emission Factors for Natural Gas.

Source		Combustor Type	NOx Emission Rate		
			lbs/MMBtu	lbs/1000 CF	lbs/Therm
Ottinger (1991)		N/A	0.248	0.253	0.025
EPA AP-42 (1998)	Large Wall Fired Boilers (>100)	Uncontrolled (pre-NSPS)	0.272	0.280	0.028
		Uncontrolled (post-NSPS)	0.184	0.190	0.019
		Controlled-Low NOx burners	0.136	0.140	0.014
		Controlled-Flue gas re-circulation	0.097	0.100	0.010
	Small Boilers (<100)	Uncontrolled	0.097	0.100	0.010
		Controlled-Low NOx burners	0.049	0.050	0.005
		Controlled-Low NOx burners/ Flue gas re-circulation	0.031	0.032	0.003
	Tangential-Fired Boilers (All Sizes)	Uncontrolled	0.165	0.170	0.017
		Controlled-Flue gas re-circulation	0.074	0.076	0.008
	Residential Furnaces (<0.3)	Uncontrolled	0.091	0.094	0.009
Cleaner and Greener Environmental Program (2003)		N/A	0.149	0.153	0.015

Note: ( ) in the first column indicates the MMBtu/hr heat input.

4.4.5 Calculation of NOx Emissions from Transportation Fuel Use

The method for calculating the NOx emissions from the on-road mobile sources is discussed in this section. The procedures consist of steps: 1) the calculation of annual NOx emissions, and 2) the calculation of peak-day NOx emissions. A detailed description for both procedures is discussed in the following sub-sections.

4.4.5.1 Calculation of Annual NOx Emissions from Transportation Fuel Use

This calculation procedure is nearly identical to the procedure used for calculating NOx emissions from natural gas. If the average amount of the NOx emissions rate is known, then a simple method such as the multiplication of an average emission rate by the total transportation fuel use by vehicle type can be used. However, two types of fuel are generally used in transportation (i.e., on-road vehicle). One is gasoline, and the other is diesel. Therefore, a determination of appropriate emissions factors for both fuels was necessary for accurately calculating a baseline NOx emissions production for a community's transportation fuel use. For this research, data taken from the Bureau of Transportation Statistics's (BTS) "National Transportation Statistics 2002" was chosen for use because these data were based on the MOBILE5b, the EPA's latest highway vehicle emissions factor model. MOBILE5b, an integrated set of FORTRAN routines, is widely used in the analysis of the air pollution impact of gasoline-fueled and diesel-powered highway mobile sources.

Table 4-12 shows the information for the estimated national average vehicle NOx emissions rate by vehicle type and fuel (in grams per mile). The emission rates listed on the table are classified by estimation year, vehicle type, and fuel type. Each column presents the NOx emission rates for eleven calendar years. Under each calendar year, the emissions factors are divided by the following factors: four vehicle types for gasoline use, three vehicle types for diesel use, and an average of all vehicles including an average of all fuels. If the specific vehicle classifications were not available, the information in the last row was used to calculate NOx emissions from the vehicle's fuel use.

In a similar fashion as the emission factors for electricity and natural gas, some modifications were needed in order to for the values to be used by this study, since emissions rates are listed in grams per mile. In this case, multiplying the value of grams per mile (gpm) by 453.59 yields the unit value of pounds per mile (lb/mile) allowed for the end result to be added to the emissions for. After determining the appropriate NOx emissions rate (lbs/mile), the previously calculated vehicle miles traveled (in miles) for each vehicle type were then applied in order to estimate annual NOx emissions for each type of vehicle's fuel use.

Table 4-12: Estimated National Average Vehicle NOx Emission Rate by Vehicle Type and Fuel (grams per mile).

Fuel Type	Vehicle Type	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Gasoline	Light-duty vehicles	1.81	1.76	1.72	1.69	1.67	1.61	1.56	1.51	1.45	1.41	1.38
	Light-duty trucks	2.36	2.25	2.16	2.10	2.04	1.97	1.95	1.92	1.87	1.84	1.80
	Heavy-duty vehicles	6.49	6.28	6.05	5.85	5.69	5.48	5.36	5.25	5.05	4.89	4.72
	Motorcycles	0.85	0.85	0.85	0.85	0.85	0.84	0.84	0.84	0.83	0.83	0.83
Diesel	Light-duty vehicles	1.65	1.67	1.68	1.68	1.66	1.64	1.60	1.55	1.48	1.40	1.33
	Light-duty trucks	1.97	2.00	1.99	1.97	1.94	1.90	1.85	1.78	1.67	1.56	1.46
	Heavy-duty vehicles	21.05	19.59	18.14	16.89	15.81	14.79	13.96	13.33	12.66	11.93	11.24
Average of all vehicles, gasoline and diesel		3.09	2.99	2.89	2.80	2.73	2.63	2.56	2.50	2.41	2.34	2.27

Source: U.S. BTS 2003.

4.4.5.2 Determination of Peak-day NOx Emissions

To estimate the peak-day emissions production by the on-road vehicles fuel use, a specific day of study needed to be first determined. For this study, one of ozone days provided by the EPA was used. To calculate peak-day emission the information about average daily NOx emission, day-of-week profile, and hourly profile are required. To determine average daily NOx emission, average daily VMT are used to estimate daily NOx emissions by applying the appropriate emission factor (lbs-NOx/mile). To determine the day-of-week profile, information about the average daily traffic volumes, day-of-week, and season for a selected year is used. These data are obtained from automatic traffic recorders (ATR). To determine the hourly-profile, annual average hourly volumes by day-of-week were used. The ATR data used in this study were from S-177 located in State Highway 6, 1 mile of BS6, College Station for the year 1999. the hourly NOx were then calculated from following equation:

Hourly NOx Emissions (tons) = (NOx tons/day) x (7 days per week) x (day-of-week profile) x (hourly profile)

4.5 SUMMARY

The main purpose of developing the CCNERT methodology was to determine how and where energy was being used and to examine how community energy use might causes NOx emissions within a selected community. To accomplish this, the following procedures were developed: 1) procedures to categorize sectors and to gather information; 2) procedures to calculate each sector's energy use; 3) procedures to calculate the total community wide energy use; and 4) procedures to estimate the total NOx emissions based on previously calculated energy use. These four main tasks have been similarly applied to each sector's base-line energy consumption and its associated NOx emissions.

The City of College Station was selected as the case study community in order to apply and verify the developed procedures for estimating community-based energy use and its associated NOx emissions. Within the community's boundary, there are hundreds of energy users such as buildings, vehicles, streetlights, etc. Furthermore, building energy users could be categorized in many ways, including by use, type of construction, HVAC system types, or thermal characteristics. To account for these variables, simplified groups of energy users were used. In this study, the following categories of community energy users were used: 1) residential, 2) commercial, 3) municipal, 4) industrial, and 5) transportation. The individual sectors were further subdivided into sub-categories.

Since energy use characteristics in these sectors vary significantly based on each sector's activity, different procedures were developed to determine the baseline energy uses of each sector. To determine individual building sector's (residential and commercial) baseline energy use, the following eight steps were developed. The methodology included: 1) the identification of information related to the general characteristics of the building sector, 2) the selection of sample houses or buildings, 3) the collection of utility bill information from sample houses, 4) the development of representative buildings, 5) the preparation of verified data for the ASHRAE IMT analysis and the DOE-2 simulations, 6) the comparison of energy usage predictions to the actual energy consumption data, 7) the translating of results obtained from the baseline energy use analyses to values representative of the selected community, and 8) the calculation of the total energy use.

The municipal sector was sub-categorized into seven detailed parcels: 1) city-owned municipal buildings, 2) educational buildings owned by the local Independent School District (ISD), 3) streetlights, 4) traffic lights, 4) the water supply system, 5) the waste water treatment system, and 7) community parks & recreation facilities. To estimate the total energy consumption, a significant effort was made to collect actual consumption data. One necessary task was to collect utility bill information from College Station Utility Customer Service (CSUCS).

The procedures used to calculate energy use for the industrial sector were developed based on the industrial activity or process examined. The main purpose for this procedure was to estimate the industrial sector's energy use by using a simplified method. To accomplish this goal, the following tasks were determined to be necessary: 1) a determination of the number of establishment, 2) the classification establishments by their SIC or NAICS group, 3) a determination of gross sales in each SIC or NAICS group, 4) a calculation of energy intensity factors for each group, 5) a calculation of energy use for each group. The following information sources were proposed for use: 1) the U.S. census's county business pattern data, 2) the EIA's 1998 Manufacturing Energy Consumption Survey and 3) the Texas Comptroller of Public Accounts.   The procedure for cross-checking the industrial sector's energy use estimations with the actual energy use were also discussed in Chapter IV.

The procedure used to calculate energy consumption for the transportation sector and its NOx emissions was developed and discussed in Chapter IV. The procedure consisted of five main tasks: 1) the categorization of the transportation sector, 2) the determination of the number of vehicles or types of equipment, 3) the determination of vehicle miles traveled (VMT) and the VMT mix, 4) the determination of fuel efficiencies by vehicle type, and 5) the calculation of the total energy use.

As the final step in developing this methodology, the procedures for calculating NOx emissions were discussed in Chapter IV. Since a community uses a variety of types of fuel, the procedures were individually developed and then combined to calculate the community's total NOx emissions. The procedures included the calculation of NOx emissions from electricity use, natural gas use, and transportation fuel use.

4.6 LIMITATIONS OF THIS METHODOLOGY

Although this study used a detailed grid model to calculate by county the NOx emissions reductions, there are several limitations in this calculation method:

1) This calculation method is not as precise as a method based on dispatch or forecasting modeling. Such models provide a more realistic NOx /MWh rate that represents hourly variations in plant operation.
2) For T&D loss, a fixed loss rate was used. In actuality, T&D losses vary according to the path the electricity takes from the power plant to the substation, and by various environmental factors such as temperature, wind, etc.
3) In this study a fixed NOx emission rate was used for transportation. In reality, vehicle NOx emission rates vary according to vehicle speed, ambient temperature, etc.
4) In this study a fixed NOx emission rate was used for all natural gas use. In reality natural gas emission rates vary by the type of system.

CHAPTER V
APPLICATION OF THE METHODOLOGY
(ENERGY USE)

This chapter describes the results of applying the Comprehensive Community NOx Emissions Reduction Tool (CCNERT) methodology to the case study community of College Station, Texas. The CCNERT provided the framework for conducting College Station's energy audit, analyzing the results, and estimating the NOx emissions from the various scenarios. Modifications and assumptions were necessary in some cases to account for local conditions and features unique to College Station. These modifications and assumptions are described in each sector's energy analysis.

This chapter consists of the following four sub-sections: 1) the introduction, 2) the community audit, 3) the energy use in each sector, and 4) the community's total energy use. In the introduction section, a general description of tasks performed for this study is briefly explained. In the community audit section, a detailed description of the development of the Community Information System (CIS) is discussed. In the energy use section, each sector's level of energy use is discussed. In the community total energy use sub-section, College Station's total energy use is determined based on electricity, natural gas, and transportation fuel use.

5.1 INTRODUCTION

This sub-section briefly describes the tasks performed for this study. Certain procedures for estimating energy use that were mentioned in Chapter IV (METHODOLOGY) are not demonstrated in this chapter. Tables 5-1 through 5-5 present the energy user groups that are demonstrated in this study. A detailed energy analyses for all end-users was considered to be beyond the scope of this study. Therefore, some procedures were only demonstrated using a few examples. The application of energy efficiency measurements for the case study was limited to the building sector, with one simple example for the transportation sector.

In this study a community audit was conducted to collect, count, and classify the information necessary for this study to develop the Community Information System (CIS). To accomplish this an integrated data collection approach was used.

In the residential sector, only the single-family detached (SFD) housing type was analyzed to examine the procedures for the residential sector's energy use and its associated NOx emissions. Average values were used for all remaining housing types.

To accomplish this, a total of 65 single-family detached houses were selected. From the sample houses, a representative value of housing characteristics (i.e., the average conditioned area, the distribution of years built, the building materials, and the number of floors) was provided.

The total number of all housing types was estimated by aggregating the data from the City Building Permit Report and the College Station Demographic Report. The total energy consumption for this housing type was determined by multiplying the Normalized Annual Consumption (NAC) by the average floor area (sq.ft).

In the case of single-family attached (SFA) houses, the energy use analysis was mainly based on the results from the previous study (Kim 1998). Other residential land use groups such as multi family residents and mobile homes required the use of the 1997 RECS (EIA 1999) data to determine their energy use.

In the commercial sector, a utility bill analysis was performed only in the three following energy user groups: 1) food service (five restaurants), lodging (four hotels/motels), and food sale (four large grocery stores). Energy use information for other energy groups was obtained from the information provided by the 1999 CBECS (EIA 2001a).

A comparison of the results from the utility bill analysis with the results from a simplified method based on the 1999 CBECS was conducted to determine how the community's energy use differs from the U.S. average.

A significant effort was necessary to collect the information, as well as to classify and count each energy group in the commercial sector. Various information sources were reviewed to understand the general characteristics of the commercial sector, which were then used to determine the commercial sector's energy use pattern. These sources included the College Station Demographic Report provided by the City of College Station (COCS 2003), and the County Business Pattern provided by the U.S. Census Bureau (U.S. Census 2003).

The base year (2002) energy consumption in the municipal sector was determined based on the utility bill information. The sector was sub-categorized into seven parcels: 1) city-owned municipal buildings, 2) educational buildings owned by the local government, 3) streetlights, 4) traffic lights, 5) the water supply system, 6) the wastewater treatment system, and 7) community parks & recreation facilities. Detailed information and utility bill information for each parcel were collected by contacting Mr. Albright from the College Station Utility Customer Service (CSUCS).

Table 5-1: Summary of Procedures (Tasks) Demonstrated in the Residential Sector for This Study.

Sector	Parcel	Tasks	Demonstrated in This Study
Residential	Single Family Detached (SFD)	DOE-2 Simulation	Yes
		Utility Bill Analysis	Yes
		Selection of Samples & Site Visit	Yes
		Determination of Total Number	Yes
		Energy Estimation	Yes
	Single Family Attached (SFA)	DOE-2 Simulation	N/A
		Utility Bill Analysis	N/A
		Selection of Samples & Site Visit	N/A
		Determination of Total Number	Yes
		Energy Estimation	Yes
	Multi-Family Low Rise (MFLR)	DOE-2 Simulation	N/A
		Utility Bill Analysis	N/A
		Selection of Samples & Site Visit	N/A
		Determination of Total Number	Yes
		Energy Estimation	Yes
	Multi-Family High Rise (MFHR)	DOE-2 Simulation	N/A
		Utility Bill Analysis	N/A
		Selection of Samples & Site Visit	N/A
		Determination of Total Number	Yes
		Energy Estimation	Yes
	Mobile Homes (MH)	DOE-2 Simulation	N/A
		Utility Bill Analysis	N/A
		Selection of Samples & Site Visit	N/A
		Determination of Total Number	Yes
		Energy Estimation	Yes

Table 5-2: Summary of Procedures (Tasks) Demonstrated in Commercial Sector for This Study.

Sector	Parcel	Tasks	Demonstrated in This Study
Commercial	Food Store	DOE-2 Simulation	N/A
		Utility Bill Analysis	Yes
		Selection of Samples & Site Visit	N/A
		Determination of Total Number	Yes
		Energy Estimation	Yes
	Eating & Drinking	DOE-2 Simulation	N/A
		Utility Bill Analysis	Yes
		Selection of Samples & Site Visit	Yes
		Determination of Total Number	Yes
		Energy Estimation	Yes
	Hotel/Motel	DOE-2 Simulation	N/A
		Utility Bill Analysis	Yes
		Selection of Samples & Site Visit	Yes
		Determination of Total Number	Yes
		Energy Estimation	Yes
	General Merchandise	DOE-2 Simulation	N/A
		Utility Bill Analysis	N/A
		Selection of Samples & Site Visit	Yes
		Determination of Total Number	Yes
		Energy Estimation	Yes
	Retail Service	DOE-2 Simulation	N/A
		Utility Bill Analysis	N/A
		Selection of Samples & Site Visit	N/A
		Determination of Total Number	Yes
		Energy Estimation	Yes
	Office	DOE-2 Simulation	N/A
		Utility Bill Analysis	N/A
		Selection of Samples & Site Visit	N/A
		Determination of Total Number	Yes
		Energy Estimation	Yes
	Health Care	DOE-2 Simulation	N/A
		Utility Bill Analysis	N/A
		Select Samples & Site Visit	N/A
		Determine Total Number	Yes
		Energy Estimation	Yes
	Religious/Cultural	DOE-2 Simulation	N/A
		Utility Bill Analysis	N/A
		Select Samples & Site Visit	N/A
		Determine Total Number	Yes
		Energy Estimation	Yes

Table 5-3: Summary of Procedures (Tasks) Demonstrated in Municipal Sector for This Study.

Sector	Parcel	Tasks	Demonstrated in This Study
Municipal	School and College	DOE-2 Simulation	N/A
		Utility Bill Analysis	Yes
		Select Samples & Site Visit	N/A
		Determine Total Number	Yes
		Energy Estimation	Yes
	Public Administration	DOE-2 Simulation	N/A
		Utility Bill Analysis	N/A
		Select Samples & Site Visit	N/A
		Determine Total Number	Yes
		Energy Estimation	Yes
	Streetlights	Utility Bill Analysis	Yes
		Select Samples & Site Visit	N/A
		Determine Total Number	Yes
		Energy Estimation	Yes
	Water Supply & Waste Water Treatment Plants	Utility Bill Analysis	Yes
		Select Samples & Site Visit	N/A
		Determine Total Number	Yes
		Energy Estimation	Yes

To determine the industrial sector's energy use, the number of establishments of each North America Industry Classification System (NAICS) group can first be determined. The annual gross sales for each NAICS group can be collected from the Texas Comptroller of Public Accounts Database (TCPA 2003). Energy intensities [kWh/($) of gross sale] of each NAICS group can be determined by the data from the EIA's National Energy Modeling System (NEMS) report for the industrial sector (EIA 2003a).

Table 5-4: Summary of Procedures (Tasks) Demonstrated in the Industrial Sector for This Study.

Sector	Parcel	Tasks	Demonstrated in This Study
Industrial	SIC or NACIS	DOE-2 Simulation	N/A
		Utility Bill Analysis	N/A
		Select Samples & Site Visit	N/A
		Determine Total Number	Yes
		Energy Estimation	Yes

As summarized in Table 4-6, there are two main groups (on-road group and non-road group) of energy users in the transportation sector, however this research mainly focused on the on-road mobile source's energy use and its NOx emissions. The sources of non-road groups, which were not shown in this research, are follows: 1) Compression-Ignition Engines (farm, construction, mining, etc.), 2) Small Spark-Ignition Engines (lawn mowers, leaf blowers, chainsaws, etc.), 3) Large Spark-Ignition Engines (forklifts, generators, etc.). Marine Diesel Engines (commercial ships, recreational diesel engines etc.), 4) Marine Spark-Ignition Engines (boats, personal watercraft, etc.), 5) Recreational Vehicles (snowmobiles, dirt bikes, all-terrain vehicles, etc.), 6) Locomotives (Railroads), and 7) Aviation (aircraft, ground support equipment, etc.).

In an effort to determine the on-road mobile source's energy use, the following information sources were used for this study: 1) the Texas Department of Transportation's (TxDOT) traffic study for the Brazos County (TxDOT 2003) and 2) the number of vehicle registered in the Brazos County provided by personal communication with Mr. Ken Fogle from the City of College Station. The results of the TxDOT traffic study provided the expected daily values for Brazos County's vehicle miles traveled in 2001 and 2002. The county's Daily Vehicle Miles (DVM) data was then interpolated by the population rate (College Station vs. Brazos County) in order to estimate College Station's DVM data.

The vehicle classification was determined by conducting a "snap shot cross-check", because the average vehicle classification data for College Station were not available. One-time counts in public parking lots at shopping centers, grocery stores, the university parking lot, and major streets were performed to obtain the representative values of vehicle classifications for College Station. The energy intensity (fuel efficiency) information was taken from the Transportation Statistics 2002 study provided by the U.S. Bureau of Transportation Statistics (U.S. BTS 2003). A comparison of the on-road mobile group's energy use with the annual gross sales of gas was conducted to verify the on-road mobile group's energy use.

Table 5-5: Summary of Procedures (Tasks) Demonstrated in the Transportation Sector for This Study.

Sector	Parcel	Tasks	Demonstrated in This Study
Transportation	On-Road	DOE-2 Simulation	N/A
		Utility Bill Analysis	N/A
		Selection of Samples & Site Visit	N/A
		Determination of Total Number	Yes
		Energy Estimation	Yes
	Non-Road	DOE-2 Simulation	N/A
		Utility Bill Analysis	N/A
		Selection of Samples & Site Visit	N/A
		Determination of Total Number	N/A
		Energy Estimation	N/A

5.2 COMMUNITY AUDIT

A community audit for the City of College Station was first performed to provide general characteristics, which was then used to evaluate the energy use patterns and the associated NOx emissions. General information regarding the community land use was first collected to account for all physical components within the city boundary. Then, efforts to classify the physical components to similar energy user groups were performed and the results used to determine the community's energy use.

5.2.1 Development of the Community Information System (CIS)

The development of a Community Information System (CIS) was the procedure used to account of land use parcels that represent the energy use components of College Station. The objective of this procedure was to identify and tabulate all possible energy users and their associated NOx emissions within the city limits for a selected year. To accomplish this, a community audit for City of College Station was first performed to provide general characteristics, and then to evaluate energy use patterns and their associated NOx emissions. The community audit included the collection of the general community characteristics (overview of College Station), land use characteristics and utility characteristics, as well as a population profile, housing profile, and a business pattern profile.

5.2.1.1 Overview of College Station

The City of College Station, which adjoins to the City of Bryan, is located in Brazos County in South Central Texas and is about 90 miles northwest of the City of Houston, 180 miles south of the City of Dallas and 104 miles east of the City of Austin as shown in Figure 5-1. The city is classified as an “Other Central City Suburban” community type (TEA 2003) or “mid-size community”(BCSEDC 2001). According to Bryan College Station Economic Development Cooperation (BCSEDC), the community is the home of Texas A&M University. The university significantly influences the community’s life-style. For instance, the university is the community’s major employer. Most community residents work either directly for the University, or for a business that directly supports the university market (students, faculty, and staff). The community consists of 40 square miles with a 2000 population of 64,743, which converts to a density of 259 people per square mile. The average density in Texas is 79.6 persons per square mile.

5.2.1.2 College Station Land Use Characteristics

The City of College Station area covers approximately 42 square miles, including various land uses within the city limits. Table 5-6 details the distribution of land use area within the city limits. Much of the area is currently used either for residential land use (45.8 %) or non-residential land use (29.4%). In the residential land use areas, the medium density land use is the largest portion (22.2%) of the total residential land use, containing exclusively single-family detached residential houses, ranging in density from 3 to 6 dwelling units per acre.

The low-density land use areas contains entirely single-family detached houses that range between ½ to 3 acres/dwelling unit and greater. The residential attached classification contains entirely multifamily residential housing units with densities ranging from 10 to 20 dwelling units per acre. In the non-residential land use areas, the majority of the land is owned by Texas A&M University; the second largest portion of area, about 507.6 acres, is used for public and institutional purposes such as schools, churches, hospitals, and other public entitles. In the City of College Station, a total of 234.4 acres, nearly 1% of total land area is used for office use such as office parks, corporate offices, and office lease space. Table 5-6 indicates that the residential sector is the largest energy consumer in College Station. It also indicates that the industrial sector's energy use would consume a negligible level of actual energy.

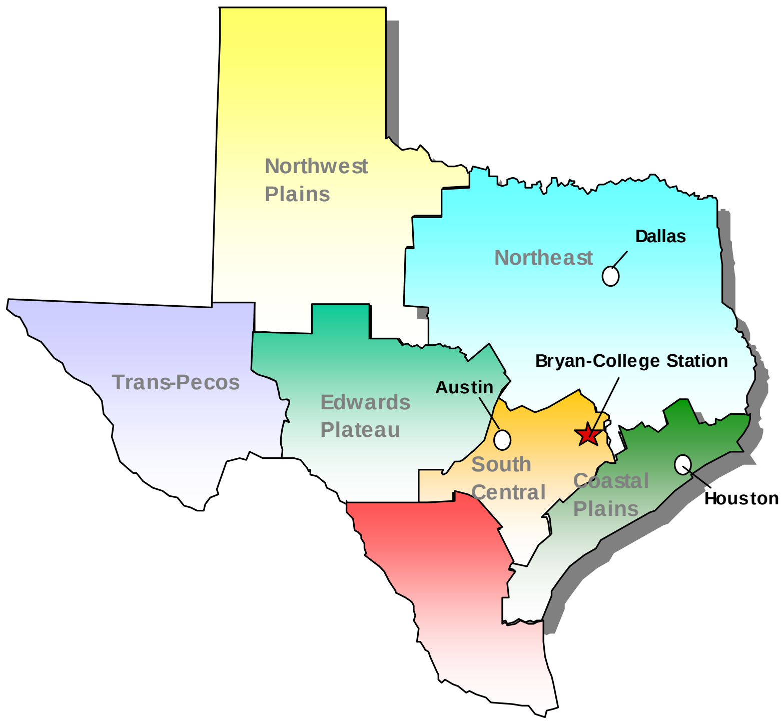


Figure 5-1: Location of City of College Station.

5.2.1.3 Population Profile

According to the U.S. Census Bureau, College Station's population changed by 25 percent from 1990 to 2000. The community's population was 52,400 in 1990 and 64,743 in 2000, an increase of 12,343 residents. In 2000, the median age was 23.6 years, which indicates a city much younger than the statewide average of 32.3 years and the national average of 35.3 years, due presumably to the high concentration of college students in the community. Figure 5-2 clearly shows that the sum of Bryan and College Station's population is nearly 130,000, which is close to the total population of Brazos County (152,415).

Table 5-6: Distribution of Land Use for College Station.

Land Use		Acres	Percent
Residential	Rural Density	976.9	4.20%
	Low Density	2,248.20	9.60%
	Medium Density	5,447.80	23.20%
	High Density	697.1	3.00%
	Residential Attached	1,000.70	4.30%
	Redevelopment	376.5	1.60%
	Total	10747.2 (16.8 sq. mi)	45.80%
Non-Residential	Neighborhood Retail	42	0.20%
	Regional Retail	725	3.10%
	Office	234.3	1.00%
	Light Industrial/R&D	100	0.40%
	Public/Institutional	507.6	2.20%
	Civic Center	50	0.20%
	Texas A & M University	4,669.20	19.90%
	Mixed Use	588.4	2.50%
	Total	6916.5 (10.8 sq. mi)	29.40%
Undeveloped	Park/Open Space	777.9	3.30%
	Floodplains/Greenbelts	2,263.70	9.60%
	Rights-of-Way/Easements	2,785.10	11.90%
	No Development	0	0.00%
	Total	5826.7 (9.2 sq. mi)	24.80%
TOTAL		23490.4 (36.7 sq. mi)	100%

Source: COCS 1997.

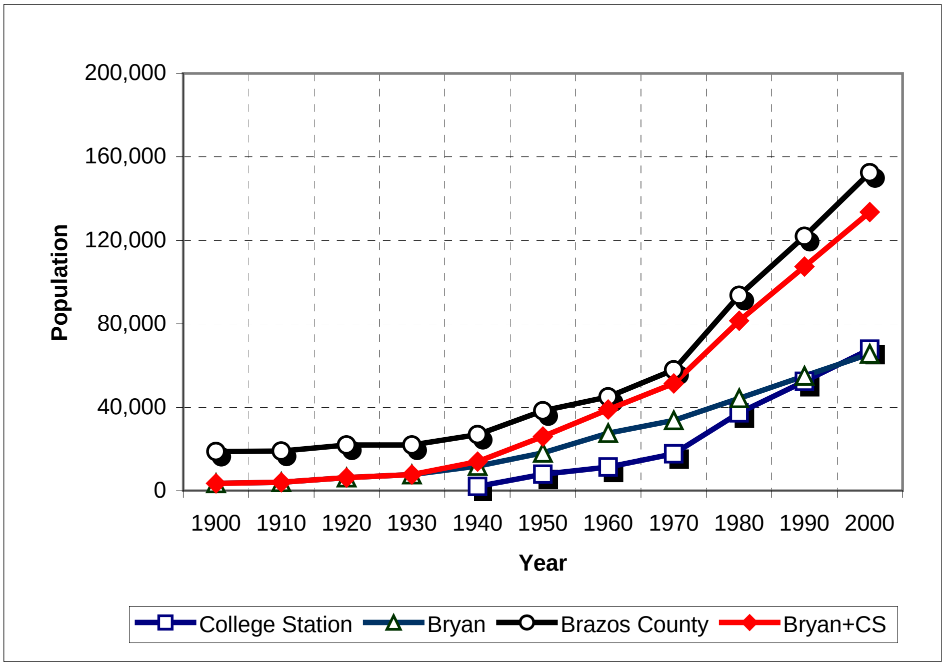


Figure 5-2: Historical Population Growth in the Brazos County Area.

5.2.1.4 Utility Profile

In College Station, there are four different utility providers. The four provider includes 1) electricity provider, 2) natural gas provider, 3) water supply provider, and 4) wastewater treatment system. A general description of each utility provider is discussed in the following sub-sections.

5.2.1.4.1 Electricity Provider

The type of electric utility that serves the city of College Station is a community-owned utility (College Station Utility). The retail electric provider (REP) is American Electric Power (AEP), which currently provides College Station with electricity. According to the City of College Station (COCS 2003), the annual system peak demand is 124 Megawatts (MW) and the annual electricity use was nearly 549,820 Megawatt-hour (MWh) with a service area of 43 square miles. The total length of the transmission lines is 12 miles and the total length of the distribution line is 334 miles.

5.2.1.4.2 Natural Gas Provider

According to the data taken from the Railroad Commission of Texas (RRC 2003), TXU Gas Distribution currently provides College Station with its natural gas. The 2002 annual gas consumption was approximately 823,655 MCF (RRC 2003). Of that, 450,075 MCF were used for domestic usage, and 373,580 MCF were used for small commercial and industrial usage.

5.2.1.4.3 Water Supply and Distribution System

The City of College Station is authorized to produce and supply water to the community. According to the COCS (2003), the total water produced in 2002 was 3.49 billion gallons with one ground storage (Dowling Road Pump Station) and two elevated storage tanks (Park Place and Greens Prairie). The capacity of the Dowling Road Pump Station is 8 million gallons, Park Place's is 3 million gallons, and Greens Prairie's is 2 million gallons. The capacity of the motors used in the water stations are two 10,000 gpm, one 9,000 gpm and one 6,000 gpm. The summer peak demand was 21 million gallons and the average daily demand is 9.69 million gallons. The average daily demand per person is 140 gallons. The total length of the water lines is 294 miles.

5.2.1.4.4 Wastewater Treatment System

The City of College Station operates two wastewater treatment facilities, the Carter's Creek Wastewater Treatment Plant and the Lick Creek Wastewater Treatment Plant, both of which treat wastewater and return clean water back to the receiving streams according to the guidelines of the EPA. The Lick Creek plant was expanded in 2002 from its original 0.5 million gallons per day (MGD) to a 2.0 MGD capacity. Most of College Station's wastewater treatments occur at the Carter's Creek plant.

5.3 DETERMINATION OF EACH SECTOR'S ENERGY USE

The energy use of each sector was determined and will be discussed in this section. Various information sources and procedures were used to determine each sector's energy use. Each sector's energy uses and the procedures used in this study are explained in each of the following energy sectors.

5.3.1 Calculation of the Residential Sector Energy Use

In this study, the residential sector was sub-divided into four parcels: 1) single-family detached (SFD), 2) single-family attached (SFA), 3) multi-family (MF), and 4) mobile homes (MH). The total annual energy use for the residential sector was estimated based on an annual electricity utility sales report provided by the College Station Utility Customer Service (CSUCS) and the annual natural gas consumption data taken from the Railroad Commissioner of Texas (RRC 2003). To proportion the total energy use into four parcels, the number of housing units in each parcel was first determined based on an integrated analysis of the city's building permit data, the residential sector's land use profile (%), information from U.S. Census Bureau, and the College Station Utility Customer Service's (CSCUS)' customer count, because the residential sector in College Station has considerable seasonal variations with regarding to rate of vacancy due to the large number of students.

To determine the single-family detached (SFD) housing characteristics and energy use profile (pattern), 65 sample houses were selected. The sample houses were selected from four different areas with consideration given to the historical land development profile. In the case of single-family attached (SFA) houses, the results of the previous study (Kim 1999) were used to determine the housing characteristics and their energy use. To determine a multi-family house's energy use characteristics, information from the CSUCS's electricity sale in the category of "Master Metered" was used.

The 2002 annual natural gas consumption data for College Station was used to estimate the annual total gas consumption. Since the monthly gas consumption data were not available, annual gas consumption data was interpolated into monthly increments using an appropriate portion of the statewide average (EIA 2003b). To disaggregate the annual consumption into monthly consumption values, the average portion of gas consumed for each month during the last 12 yrs (1990 – 2002) was first obtained. Then an average portion was applied to the annual gas use. The 1999 RECS and information from the NAHB (2000) were used to determine an existing stock of system types and other end user characteristics. More detailed procedures are described in each parcel's energy use analysis.

5.3.1.1 Residential Sector Total Energy Use

The residential sector used the largest portion (49% of the total electricity use and 54% of the total natural gas use) of energy in College Station. In 2002, residential sector used 349 MWh of electricity and 450,075 MCF of natural gas. The energy uses of both electricity and natural gas were converted by multiplying the given factors (3,412 Btu/kWh and 1,030 Btu/CF) to obtain a uniform format (Btu), which allowed comparing each other. Figure 5-3 shows that the energy consumption consisted of space conditioning loads (space heating and cooling) with base loads (lighting, domestic hot water, appliances, etc.). The base loads seem relatively constant throughout the year with relatively constant summertime gas loads, and constant wintertime electricity loads. The space-conditioning loads seem to vary by the individual heating and cooling requirements.

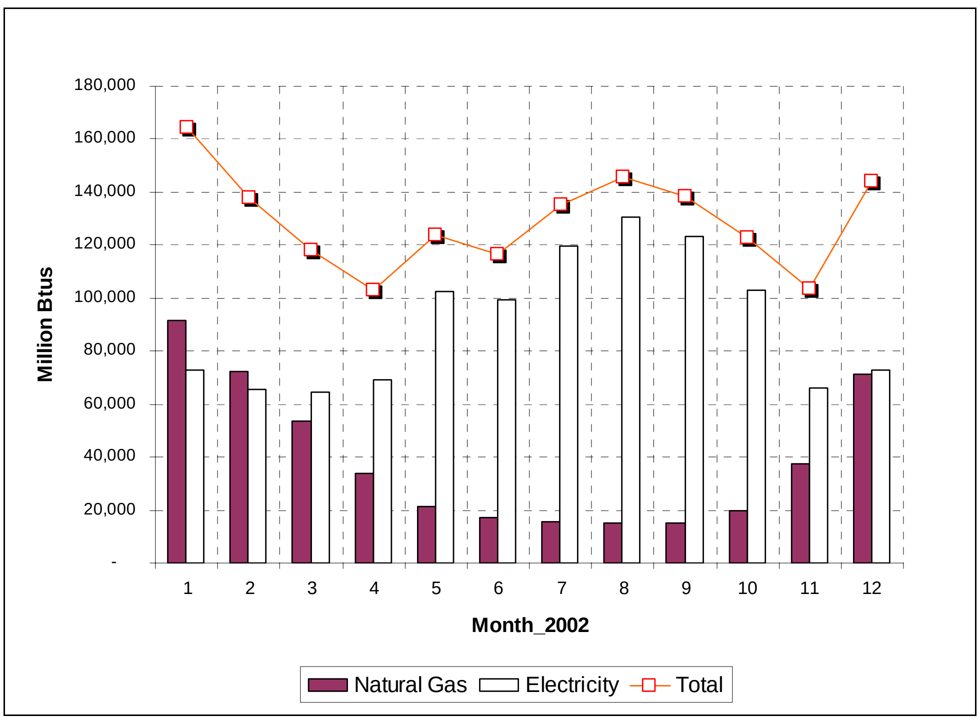


Figure 5-3: Residential Sector Energy Use.

5.3.1.2 Determination of the Number of Housing Units in Each Parcel

The number of housing units in each parcel was determined by the City of College Station (COCS 2003). However, the most recent numbers were not available, leaving information only for 2000. Therefore, the annual number of housing permits in each parcel was added to existing 2000 housing stock to estimate a current number.

Parcel results are shown in Table 5-7. These results show that College Station's housing stock mainly consisted of single-family detached houses and various multi-family housing subtypes. The existing housing stock was primarily designed to support the university's large off-campus housing needs. There were a total of 28,268 housing units in College Station. Of these, 35.5 % (10,023 units) were single-family detached, 5.84 % (1,650 units) were single-family attached, and 57 % (16,126 units) were multi-family.

Finally, a comparison between the total number of housing units and the average number of utility customers was conducted to determine the average occupancy rate. The average total number of utility customers in 2002 was 26,066, this shows that 92% of the households received or paid for utilities, which implies a 92% occupancy rate.

Table 5-7: The Estimated Number of Housing Units in Each Parcel.

Parcel		2000	2001		2002		
		Number of Units	Number of Permits	Permit + previous units	Number of Permits	Permits + previous units	Percent of Total
Single Family Detached		8,706	577	9,283	740	10,023	35.5%
Single Family Attached		1,374	142	1,516	134	1,650	5.84%
Multi Family	2-4 Units	5,694	431	15,800	326	16,126	57%
	5-9 Units	2,899					
	10 or More Units	6,776					
Mobile Home		469	0	469	0	469	1.65%
Total		25,918		27,068		28,268	100%

5.3.1.3 Determination of Energy Use Characteristics

Energy use characteristics in each parcel were determined by collecting information from sample housing units and by deriving results from the existing sources. In the selection of sample housing units, various criteria were considered. First, the housing construction year was considered to determine the relationship between the year constructed, floor area, and energy use. Figure 5-4 shows the distribution by year built and it shows that almost half of the existing housing stock was built between 1970 and 1990.

College Station's historical land use development was also reviewed to determine what area best represents of all eras of built houses. Figure 5-5 indicates that the area of College Station has steadily expanded since 1960. Although College Station has been seven decades of continuous expansion, most of its growth occurred during the period between 1970 and 1980. According to the data from the City of College Station (COCS 1997), the area was nearly 6.34 square miles in 1960, and expanded more than 3.8 times 24.08 square miles by 1980. After the 1980s, the area expansion in College Station has continued primarily on the south side.

Similar to the pattern with College Station's historical land use development, a majority of old housing stock is located adjacent to the university. Newer buildings are generally more remote from the university. Therefore, sample buildings representing the old housing stock were selected from those areas close to the university and buildings representing relatively new housing stock were selected from areas remote from the university.

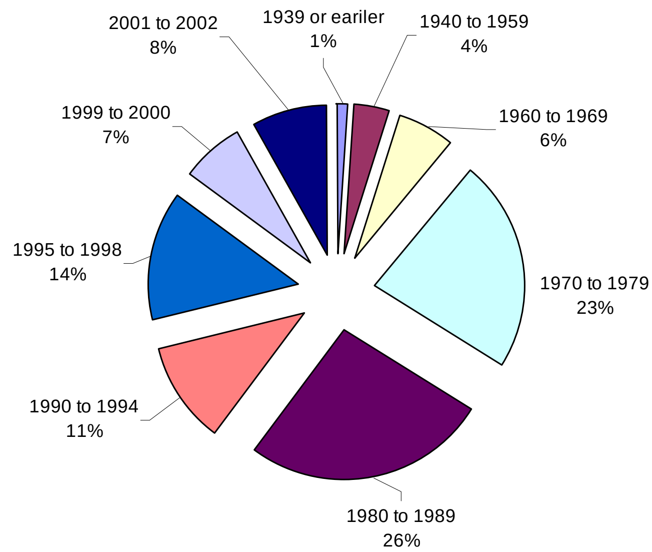


Figure 5-4: The Distribution of Housing Age in City of College Station. (Source: COCS 2003)

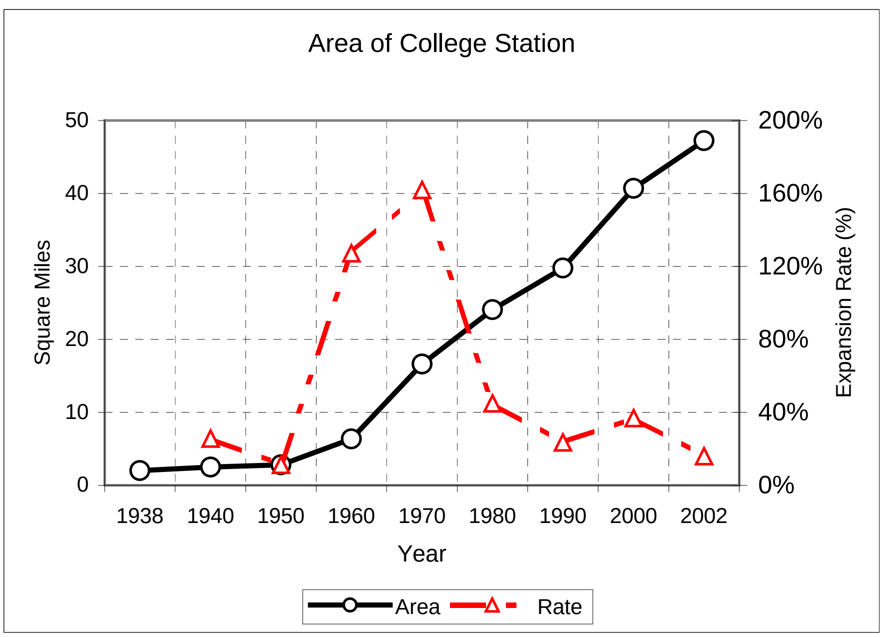


Figure 5-5: Profile of College Station's Area Development and Expansion Rate.

5.3.1.4 Selection of Sample Houses

A total of 65 sample single-family detached (SFD) houses were selected randomly from the four different districts (A, B, C, and D) to determine the general housing characteristics for College Station, as shown in Figure 5-6. The residential districts near the university were assumed to be the oldest districts (District A) in College Station. For this study, 15 sample-housing units along Pairview Street were selected to determine the oldest housing characteristics. The residential districts near Raintree Street were assumed to be the second oldest district (District B). 15 sample houses were selected to determine the general characteristics of the 1980s. The residential district (District C) along Shore Creek Dr. was selected to determine the housing characteristics of the1990s. The residential district (District D) along Woodland Ridge Dr. was selected to represent the recently developed district, and 15 sample houses were selected to determine relatively new housing characteristics. Although newer houses built after year 2002 were available for this study, the houses have been excluded due to the unavailability of 12 months of utility bill information.

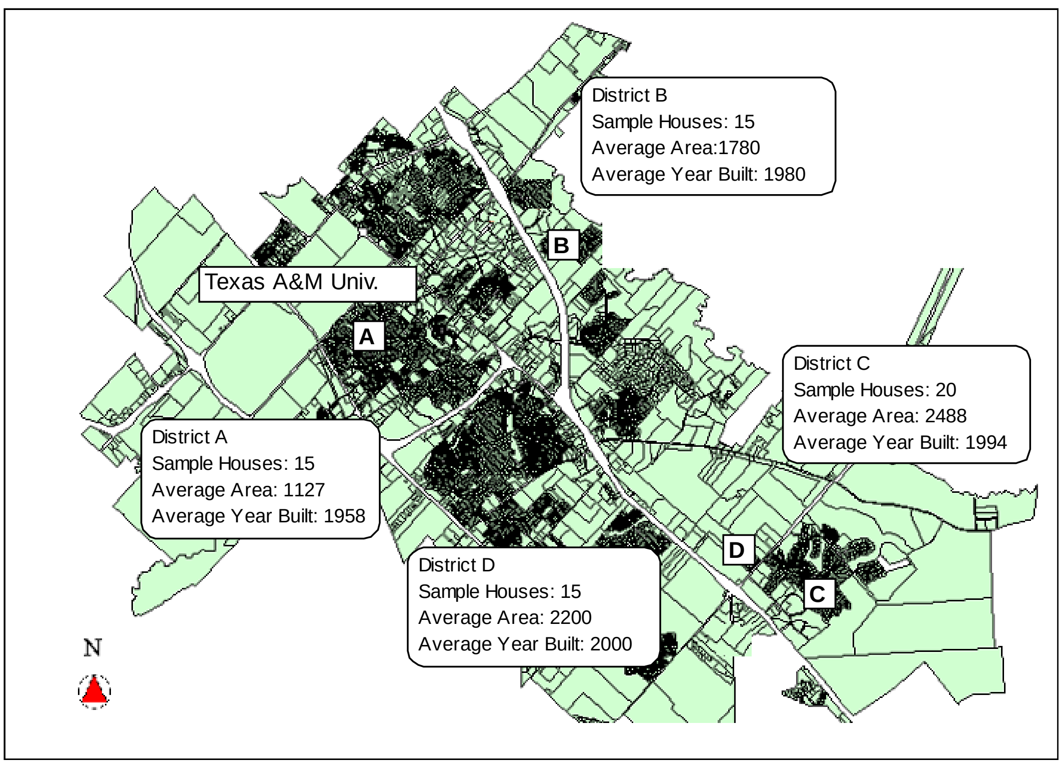


Figure 5-6: Map of Selections for Single Family Detached Housing Units in College Station.

5.3.1.5 Determination of Housing Characteristics from the Sample Houses

From the 65 sample single-family detached houses, the general housing characteristics were determined. The characteristics included floor district, number of stories, wall material, and the fuel source for heating and cooling load requirements. The detailed information from these sample houses is summarized in Table D.1 in Appendix D and Figure 5-7. The average floor area for those sample houses selected from District A was 1,127 square feet. This value is the smallest among the four districts; the average built year of these houses is 1958. The average floor area for the sample houses selected from District B was 1,780 square feet. This value is the second smallest among the four districts; the average built year is 1980. The average floor area of the sample houses selected from District C was 2,488 square feet. This value represents the largest area among the four districts; the average built year is 1994. The average floor area of the sample houses selected from District D was 2,200 square feet. This represents the second largest area among the four districts; the average built year is 2000.

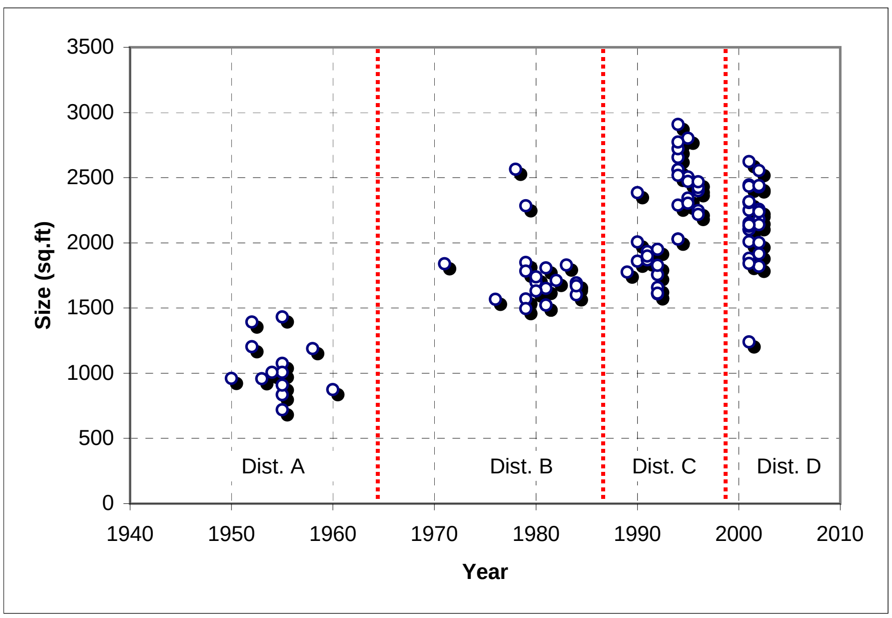


Figure 5-7: A Comparison of Floor Area to Year Built.

Although the number of houses with two stories increases in the new housing stock (Districts C and D), the majority of houses are one-story buildings. In the old housing stock (District A), wood siding provides the majority of wall material; brick provides the majority of wall material for the new housing stock.

In terms of fuel use, all sample houses used electricity for their main cooling energy source, and a majority of sample houses used natural gas as their main heating fuel source. A majority of sample houses had central air conditioning systems. A few houses used room and wall units in the older housing stock.

5.3.1.6 Determination of Average Conditioned Floor Area

The average conditioned floor area of a single-family detached housing unit was determined by using various information: 1) the distribution of year built (%); 2) the number of units based on year built; and 3) the average floor area (sq.ft) based on the sample houses. The results of this analysis are shown in Table 5-8. From this analysis, the average conditioned floor area of a single-family detached housing unit is approximately 1,960 ft^2. The total number of a SFD housing units in the year 2002 was about 10,023. The estimated total number of occupied SFD housing units was approximately 9,501 and the total conditioned area for SFD parcel was estimated to be 19,637,038 ft^2.

Table 5-8: Summary of Single-Family Detached Housing Units in College Station.

Built Year Period	Average Floor Area (sq.ft)	Distribution of Year Built (%)	Number of Units	Total Floor Area (sq.ft)
Before 1970	1,127	11%	1,102	1,241,954
1970-1979	1,781	23%	2,305	4,105,205
1980-1989	1,824	26%	2,606	4,753,344
1990-2000	2,487	25%	2,505	6,229,935
After 2000	2,200	15%	1,503	3,306,600
Total		100%	10,023	19,637,038
Average Area (sq.ft) per SFD House	= Total Floor Area / Number of Units			1,960

5.3.1.7 Collection of Utility Bill Information for Selected Houses

The College Station Utility Customer Service (CSUCS) provided the monthly electricity consumption data for the 65 sample houses (Albright 2003). Some houses were discarded from this analysis due to residents' moving in and out during the course of one year. Table 5-9 describes the annual average electricity consumption for sample houses based on year constructed and house size. Each sample house's annual electricity consumption and electricity intensity (kWh/sq.ft) is shown in Table D-1 in Appendix D.

The annual electricity consumption for District A ranges from 7,503 kWh to 18,923 kWh. The annual average electricity consumption for District A is approximately 12,172 KWh. The electricity use intensity for District A is approximately 11.3 kWh per square foot of conditioned area. The annual electricity consumption for District B ranges from 9,328 kWh to 24,931 kWh. The annual average electricity consumption for District B is approximately 15,648 kWh. The electricity use intensity for District B is approximately 9.3 kWh per square foot of conditioned area.

The annual electricity consumption for District C ranges from 7,784 kWh to 30,304 kWh. The annual average electricity consumption for District C is approximately 19,142 kWh. The electricity use intensity for District C is approximately 7.6 kWh per square foot of conditioned area. The annual electricity consumption for District D ranges from 7,751 kWh to 17,603 kWh. The annual average electricity consumption for District D is approximately 12,607 kWh. The electricity use intensity for District D is approximately 5.7 kWh per square foot of conditioned area.

Houses in the old housing stock (District A) use the most electricity per unit of square foot among the four districts. High electricity use intensity seemed to be due to inefficient HVAC systems and lower R-values in ceiling, wall, and roof material. In contrast to the older housing stock, the newer housing stock has lower electricity use intensity.

Table 5-9: Summary of Electricity Use Profile in Four Districts (A,B,C, and D).

District	Number of Sample House	Average Floor Area (square ft.)	Average Annual Electric Consumption (kWh/yr)	Average EUI (kWh/sq.ft/yr)
District A	15	1,126.70	12,531.69	11.80
District B	15	1,781.60	15,647.86	9.30
District C	20	2,487.90	19,142.15	7.60
District D	15	2,241.80	12,607.45	5.70
Average			14,937.18	8.39

5.3.1.8 Calculation of the Single-Family Detached (SFD) Houses' Total Energy Use

The total electricity used by the single-family detached (SFD) houses was determined by a simple multiplication of the total number of SFD units (Table 5-7) times an average annual electric consumption per house (Table 5-9). Single-family detached houses used 144,274,140 kWh in 2002.

10,023 x 14,937 kWh/house = 144,274,140 kWh/year

5.3.1.9 Calculation of Normalized Annual Consumption (NAC) for SFD

The patterns of electricity consumption for each of the 65 SFD houses in the sample were determined by an ASHRAE IMT analysis to evaluate the relationship between energy consumption and outdoor temperature. The patterns were identified by an IMT 3 Parameter change-point (3PC) model that provides the values for cooling efficiency, base load, and cooling balance temperature. The first step in providing the NAC was to plot the energy use profile, in order to reflect the general energy consumption pattern. In this analysis, the energy use profile was formulated by plotting the daily average usage of electricity over a single billing period against the average temperature for that period. An example is shown in Figure 5-8. The monthly electricity use and daily average electricity use of other sample houses are shown in Figures D.2 through D.67 in Appendix D.

The second step was to prepare the average daily temperature provided by the hourly weather data from the National Weather Service's (NWS) College Station weather station (Easterwood Airport). The Variable-base degree day (VBDD) model in the ASHRAE IMT was used to calculate the average daily ambient temperature (F) during each billing periods.

Residential A-2		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	442.0	14	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28	367.0	13	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30	536.0	18	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30	792.0	26	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32	1006.0	31	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29	1097.0	38	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33	1365.0	41	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30	1272.0	42	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29	945.0	33	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29	659.0	23	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33	556	17	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33	536	16	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29	507.0	17	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28	470.0	17	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29	402.0	14	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30	592.0	20	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32	1144.0	36	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29	1149.0	40	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33	1446.0	44	81.7
8/4/2003	37837	8/4/2003					

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ASHRAE INVERSE MODELING TOOLKIT (1.9)
*********************************************
Output file name = IMT.Out
*********************************************
Input data file name =  A2_3pc.dat
Model type =          3P Cooling
Grouping column No =    0
Value for grouping =    0
Residual mode =        1
# of X(Indep.) Var =    1
Y1 column number =     4
X1 column number =   5
X2 column number =   0 (unused)
X3 column number =   0 (unused)
X4 column number =   0 (unused)
X5 column number =   0 (unused)
X6 column number =   0 (unused)
*********************************************
Regression Results
-------------------------------------
N =    18
-------------------------------------
R2 =    0.967
-------------------------------------
AdjR2 =    0.967
-------------------------------------
RMSE =     2.0511
-------------------------------------
CV-RMSE =    7.600%
-------------------------------------
p =   -0.025
-------------------------------------
DW =    1.783 (p>0)
-------------------------------------
N1 =     7
-------------------------------------
N2 =    11
-------------------------------------
Ycp =    16.0678 (     0.6963)
-------------------------------------
LS =     0.0000 (     0.0000)
-------------------------------------
RS =     1.5183 (     0.0697)
-------------------------------------
Xcp =    65.7700 (     0.6892)
-------------------------------------
--------------------------------
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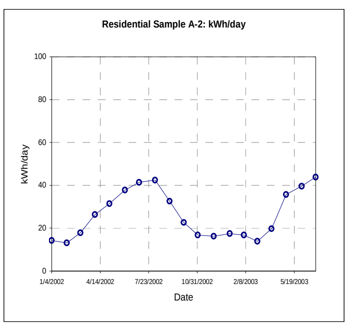


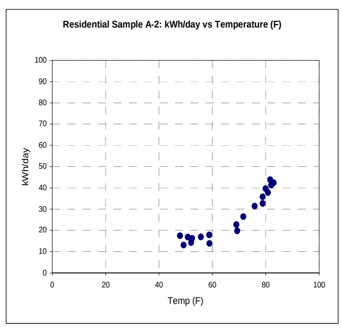


Figure 5-8: Calculated Daily Electricity Use for One Sample House (R-A-2).

Tables 5-10 through 5-13 show the values provided by the IMT 3PC model. The IMT analysis also shows how the values of cooling dependency (RS), base load (Ycp), and cooling balance temperature (Xcp) varied for those sample houses.

Table 5-10: Summary of the ASHRAE IMT 3PC Model Results for Sample Houses in District A.

District A	N	R2	RMSE	Ycp	RS	Xcp
R-A-1	18	0.978	2.5	11.7	2.2	65.8
R-A-2	18	0.967	2.1	16.1	1.5	65.8
R-A-3	18	0.896	5.6	21.5	2.8	69.2
R-A-4	18	0.480	11.7	28.0	3.4	74.7
R-A-5	18	0.955	3.3	27.4	1.7	61.6
R-A-6	18	0.895	7.1	20.5	2.7	65.1
R-A-7	N/A	N/A	N/A	N/A	N/A	N/A
R-A-8	18	0.837	4.7	16.5	1.9	69.9
R-A-9	18	0.964	5.2	31.2	6.4	72.7
R-A-10	18	0.883	3.3	19.2	1.2	65.8
R-A-11	N/A	N/A	N/A	N/A	N/A	N/A
R-A-12	N/A	N/A	N/A	N/A	N/A	N/A
R-A-13	N/A	N/A	N/A	N/A	N/A	N/A
R-A-14	18	0.968	3.1	14.4	2.8	68.5
R-A-15	18	0.963	4.5	20.7	4.7	71.3

Table 5-11: Summary of the ASHRAE IMT 3PC Model Results for Sample Houses in District B.

District B	N	R2	RMSE	Ycp	RS	Xcp
R-B-1	17	0.597	10.1	35.4	1.4	61.9
R-B-2	17	0.865	5.1	17.5	3.3	65.3
R-B-3	17	0.914	4.6	19.8	1.9	72.0
R-B-4	17	0.568	10.7	31.2	1.1	57.8
R-B-5	17	0.910	2.7	14.4	1.3	67.4
R-B-6	N/A	N/A	N/A	N/A	N/A	N/A
R-B-7	17	0.852	4.6	24.1	1.1	59.8
R-B-8	17	0.951	4.2	26.5	2.6	66.0
R-B-9	17	0.960	5.0	29.5	5.0	71.5
R-B-10	17	0.925	6.7	40.8	3.1	65.3
R-B-11	N/A	N/A	N/A	N/A	N/A	N/A
R-B-12	17	0.881	10.7	42.3	3.5	63.3
R-B-13	17	0.592	11.1	30.8	1.7	64.6
R-B-14	17	0.963	3.1	19.6	2.2	66.0
R-B-15	N/A	N/A	N/A	N/A	N/A	N/A

Table 5-12: Summary of the ASHRAE IMT 3PC Model Results for Sample Houses in District C.

District C	N	R2	RMSE	Ycp	RS	Xcp
R-C-1	17	0.850	7.0	23.4	3.0	69.4
R-C-2	N/A	N/A	N/A	N/A	N/A	N/A
R-C-3	17	0.961	5.1	41.1	1.3	66.7
R-C-4	17	0.975	5.3	54.3	5.0	67.4
R-C-5	17	0.618	13.1	41.3	3.4	70.7
R-C-6	17	0.939	5.0	25.4	3.1	68.1
R-C-7	17	0.910	5.5	13.1	3.8	71.4
R-C-8	17	0.971	6.4	47.2	5.4	66.7
R-C-9	17	0.978	3.7	31.0	3.6	66.7
R-C-10	17	0.897	2.8	18.5	1.6	70.7
R-C-11	17	0.942	4.6	31.3	2.2	53.4
R-C-12	17	0.933	5.1	33.7	2.7	66.7
R-C-13	17	0.928	5.3	15.1	4.2	71.4
R-C-14	17	0.848	5.6	23.3	2.4	69.4
R-C-15	17	0.849	5.6	31.3	1.7	65.4
R-C-16	17	0.681	13.4	29.2	2.0	60.7
R-C-17	17	0.949	2.9	9.7	2.5	70.7
R-C-18	17	0.922	4.8	26.5	2.5	67.4
R-C-19	17	0.916	5.2	30.4	2.5	66.7
R-C-20	17	0.951	6.2	30.3	5.3	70.1

Table 5-13: Summary of the ASHRAE IMT 3PC Model Results for Sample Houses in District D.

District D	N	R2	RMSE	Ycp	RS	Xcp
R-D-1	17	0.908	5.0	34.6	2.5	68.3
R-D-2	17	0.904	4.0	19.7	2.6	71.6
R-D-3	N/A	N/A	N/A	N/A	N/A	N/A
R-D-4	17	0.843	5.4	23.8	1.9	67.6
R-D-5	17	0.923	5.6	26.3	3.1	68.3
R-D-6	N/A	N/A	N/A	N/A	N/A	N/A
R-D-7	17	0.914	4.2	22.4	2.3	68.9
R-D-8	17	0.953	2.5	13.1	3.6	74.9
R-D-9	N/A	N/A	N/A	N/A	N/A	N/A
R-D-10	N/A	N/A	N/A	N/A	N/A	N/A
R-D-11	17	0.895	4.0	24.1	2.3	70.9
R-D-12	15	0.934	4.0	27.8	3.0	70.9
R-D-13	17	0.922	3.2	25.8	2.4	71.6
R-D-14	N/A	N/A	N/A	N/A	N/A	N/A
R-D-15	17	0.883	4.9	21.9	2.7	70.9

5.3.1.10 Normalized Annual Consumption (NAC) of SFD for College Station

The normalized annual consumption was estimated using the coefficients from the selected sample houses' ASHRAE IMT 3PC Model results. The equation for the aggregate electricity consumption of the single-family detached (SFD) houses in College Station is as follows:

$$\text{kWh/day} = 26.2 + 2.9 \times \max(T_{avg} - 67.8)^{+}$$

SFD	Ycp	RS	Xcp
Average of Coefficients from Sample Houses	26.2	2.9	67.8

5.3.1.11 Calculation of the Single-Family Attached (SFA) Houses' Energy Use

The energy consumption of SFA houses was determined by using the annual energy consumption (kWh/house/year) described by Kim (1999). Table 5-14 shows the descriptive statistics of energy consumption over normalized year for 140 sample duplex residences in College Station. According to Kim (1999), the mean value of the floor area was 932 square feet. The mean perimeter was 94.4 feet. The annual energy consumption per house was approximately 15,014 kWh. Of that, the mean annual heating and cooling consumption of the 140 sample duplex residences were 2,116.18 and 2,122.16 kWh respectively. The base load consumption was 10,886.36 kWh/year.

Table 5-14: Summary of Single-Family Attached Housing Units in College Station.

Number of Sample Duplex Residents	140
Mean Value of Floor Area	932 square feet
Mean Perimeter	94.42 feet
Number of bedrooms	2
Annual Electricity Use (kWh/yr)	15,014.81
Annual Cooling Consumption (kWh/yr)	2,122.16
Annual Heating Consumption (kWh/yr)	2,116.18
Annual Base Load Consumption (kWh/yr)	10,886.36

Source: Kim 1999.

Based on this information, the total energy use of the SFA houses was determined by applying current number of housing units (Table 5-7). The annual energy use for SFA houses was approximately 24,774,436 kWh.

1,650 x 15,041.81 kWh/house-SFA = 24,774,436 kWh

5.3.1.12 Calculation of the Multi-Family (MF) Houses' Energy Use

To determine the parcel of multi-family (MF) house's energy use, the information from the College Station Utility Customer Service's (CSUCS) electricity sales in the category of "Master Metered" was used. Master Metered is a residential rate for those apartments that do not have individual meters for every apartment. They only have a master meter for the complex and are billed on a residential rate that is comparable to the rate for apartments with individual meters. The CSUCS representatives provided the total number of complex and the number of units as well as annual energy consumption. The results were summarized in Table 5-15.

Table 5-15: Summary of Annual Energy Use in "Master Metered" Apartments.

Number of Complex	Number of Units	2002 Annual Electricity Use (kWh)	Average Electricity Use per Unit (kWh/Unit)
29 (30)[4]	2,799	28,077,169	10,031

Source: Albright 2003.

Based on this information, the total energy use of the MF houses was determined by applying current number of housing units (16,216) from the Table 5-7. The annual energy use for MF houses was approximately 162,662,696 kWh.

16,126 x 10,031 kWh/house-MF = 162,662,696 kWh

[4] The value in ( ) indicates that one complex was added in July 2002.

5.3.1.13 Calculation of the Mobile Home's (MH) Energy Use

ESL's Emission Reduction Calculator 1.0 (ESL 2002) was used to determine the mobile home (MH) parcel's energy use. The Emission Reduction Calculator is simplified simulation program that calculates residential buildings' energy use and its emission production. This program was developed based DOE2 simulation. The base model of the prototype mobile house of the selected community was first determined based on the information from the LBNL (1997). The LBNL developed the building and thermal characteristics of mobile homes based on two regions (north and south) and three different heat types (i.e., electric, Hpump, and fuel). From this report, the foundation type, conditioned floor area, number of stories, roof R-value, wall R-value, glazing layers, infiltration rate (ACH), and foundation insulation for sough region were used as it is. Table 5-16 summarizes the input data for using ESL's Emission Reduction Calculator and the results from the simulation.

Table 5-16: Building Characteristics and Energy Use of Mobile Home (MH) Prototype.

Input Data Description	Prototype
Conditioned Area	961
Wall Height	8
Window Area	148 (15% WWR)
Foundation	Crawl
Wall Insulation	R-value 12
Attic Insulation	R-value 20
Window U-Factor	1.11
Solar Heat Gain Coefficient (SHGC)	0.75
Duct Location	Conditioned Area
Type of Water Heater	Gas
Heating System	Gas Furnace
Gas Heating	80% AFUE
Air-cooled Air Conditioners and Heat Pumps Cooling Mode > 65,000	SEER 10
Electricity Use (kWh/year)	13,712
Natural Gas Use (MCF/year)	20

Source: LBNL 1997.

Based on this information, the total energy use of the MH houses was determined by applying current number of housing units (469) from the Table 5-7. The annual energy use for MF houses was approximately 6,430,928 kWh.

$$469 \text{ x } 13{,}712 \text{ kWh/house-MH} = 6{,}430{,}928 \text{ kWh}$$

Table 5-17: Residential Sector's Total Energy.

Housing Unit Type		Number of Housing Units	Average Conditioned Area (sq.ft)	Electricity Use (kWh) per House	Total Electricity Use (kWh)	Converted to MMBtu	Natural Gas Use (MCF) per House	Total Natural Gas Use (MCF)	Coverted to MMBtu	Total Energy (MMBtu)
Single Family Housing	Single-family detached	10,023	1,960	14,937	149,715,355	510,829	44	443,718	457,030	967,859
	Single-family attached	1,650	932	15,015	24,774,437	84,530				84,530
Multi-Family Housing	2-4 Units	5,966	860	10,031	59,844,946	204,191				204,191
	5-9 Units	3,063	860	10,031	30,724,953	104,834				104,834
	10 or More	7,095	860	10,031	71,169,945	242,832				242,832
Manufactured Home	Mobile Home	469	847	13,712	6,430,928	22,093	20	9,380	9,661	31,754
Total		28,266	1,053	12,124	342,704,650	1,169,308		453,098	466,691	1,635,999

Note: MMBtu indicates million Btu in this study.

The 2002 energy consumption for the residential sector was 1,635,995 MMBtu/year, as shown in Table 5-17. The total energy consumption values are represented as electricity (1,169,308 MMBtu/year) and natural gas (466,691 MMBtu/year). Of these, the single-family housing unit consumption accounted for 64% the use, the multi-family housing unit accounted for 34%, and the mobile home unit accounted for negligible energy use. This value indicated that house in College Station uses significantly less energy use (59 MMBtu/house) as compared to the 1997 RECS Texas average of 98 MMBtu/house, most likely due to the multi-family houses' large portion (57%) of total housing units. According to the 1997 RECS (EIA 1999), the multi-family house in the state of Texas accounted for only 21% of total housing units.

5.3.1.14 Comparison Results of the NAC to the Actual Energy Use

A comparison of the results of the Normalized Annual Consumption (NAC) to the average daily electricity use of the residential sector for base year 2002 was conducted. The main objective of this task was to test method to be used if the developed NAC was close to the actual energy use. To accomplish this, the daily electricity use of a SFD house was first estimated based on two variables: the NAC and the daily average temperature. Figure 5-9 shows the comparison of the actual daily use for the total residential Sector with estimated representative daily use for SFD housing unit.

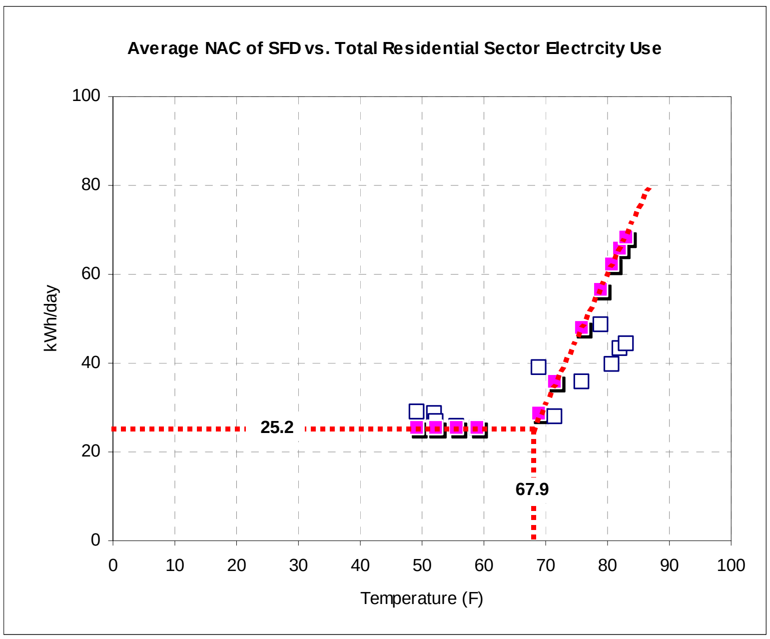


Figure 5-9: Actual Daily Use for the Total Residential Sector vs. the Estimated Daily Use for the SFD House Parcel.

Figure 5-9 indicates that the actual daily energy use is relatively close to the estimate based on the weighted average NAC from the sample houses. However, the difference is larger in both the cooling and heating seasons. From this analysis, two assumptions can be made. The first is that electricity in heating season is mainly dominated by multi-family house's heating load. In College Station, single family houses natural gas as a heating fuel source, while multi-family units used electricity. The second assumption is that the SFD's daily energy use in cooling season is relatively larger than that of multi-family housing units due to the larger size of the larger size of air conditioning units (larger conditioned areas).

5.3.1.15 Comparison of the Actual Energy Use to the Estimated Energy Use From the Model

Table 5-18 gives a comparison of the actual annual electricity sales verse the annual predicted electricity use by the baseline model. According to the CSUCS's 2002 electricity sales report, the annual electricity sales were 347,316,111 MWh/year (Albright 2003), which was well matched by the baseline model that calculated an electricity use of 342,704,650 kWh/year. The comparison shows only a 1.5% variation.

Table 5-18: Comparison of Annual Electric Sales vs. Estimated Electricity Use.

	Electricity Use (kWh/yr)
Annual Electric Sales	347,316,111
Baseline Model	342,704,650

5.3.2 Calculation of the Commercial Sector's Energy Use

Various information sources were reviewed in order to understand the general characteristics of the commercial sector, which were then used to determine the commercial sector's baseline energy use. These sources included the Bryan-College Station Community Fact Book provided by the Bryan-College Station Economic Development Cooperation (BCSEDC 2001), the College Station Demographic Report provided by the City of College Station (COCS 2003), and the County Business Pattern provided by the U.S. Census Bureau (U.S. Census 2003).

To estimate the total floor area of each parcel, either the mean square footage per worker or the mean square footage per parcel of building information (taken from the EIA's 1999 CBECS) was used. To determine the energy intensity (kWh/sq.ft and CF/sq.ft), the electric energy intensity and the natural gas energy intensity (from the EIA's 1999 CBECS) were each used. The annual electric energy use for each parcel was then estimated by multiplying the estimated total floor area for each energy group times the corresponding energy intensity index. A comparison between the actual energy consumption and the estimated energy consumption was conducted, and the difference was noticed.

A detailed energy use analysis for selected parcels (building activity) was conducted to compare College Station's actual energy use to the U.S. average energy use, in order to determine the selected community's unique energy use pattern. The 2002 total electricity sale reports provided by the individually contacting with Mr. Albright from the College Station Utility Customer Service and the 2002 annual natural gas consumption provided by the Railroad Commission of Texas (RRC 2003) were each used to estimate the total commercial sector's actual annual energy use.

5.3.2.1 Determination of the Number of Establishments by Building Activity Type

The number of establishments on each parcel was determined by reviewing the County Business Pattern provided by the U.S. Census Bureau (U.S. Census 2003). This information represented most of College Station's economic activity. Beginning in 1998, data were tabulated by industry type, as defined by the North American Industry Classification System (NAICS). Data for 1997 and earlier were based on the Standard Industrial Classification (SIC) System. For this study, data for 2001, the most recent available information, were used to determine the number of establishments in the commercial sector. Table 5-19 shows the number of establishments as defined by the NAICS for College Station. However, the number cannot be used directly in this study to determine energy use, because information regarding the energy intensity (kWh/sq.ft) from the 1999 CBECS was not available for certain parcels defined by the County Business Pattern (U.S. Census Bureau). For instance, in the NACIS groups the two building activities (lodging and food service) were combined into one category as "accommodation and food service" (NAICS Code # 72). Unfortunately, the energy use patterns for the two building activities are significantly different. Therefore, these functions were first subcategorized into more detailed descriptions, and then compared with the defined parcel functions as specified by the EIA in the 1999 CBECS. Individual establishments were then grouped accordingly. The results were shown in Table 5-20.

Table 5-19: 2001 College Station Business Pattern by NACIS Code and Employment-Size Class.

Industry Code	Industry Code Description	Total Establishments	Number of Establishments by Employment-size class								
			'1-4'	'5-9'	'10-19'	'20-49'	'50-99'	'100-249'	'250-499'	'500-999'	'1000 or more'
11	Forestry, fishing, hunting, and agriculture	7	6	0	0	1	0	0	0	0	0
21	Mining	16	12	2	1	0	0	0	0	0	1
22	Utilities	2	2	0	0	0	0	0	0	0	0
23	Construction	132	73	30	17	9	1	2	0	0	0
31	Manufacturing	22	7	5	1	6	0	3	0	0	0
42	Wholesale trade	25	17	5	1	2	0	0	0	0	0
44	Retail trade	275	92	83	49	30	7	13	1	0	0
48	Transportation & warehousing	14	6	3	3	2	0	0	0	0	0
51	Information	29	18	4	4	2	1	0	0	0	0
52	Finance & insurance	69	34	17	10	6	1	1	0	0	0
53	Real estate, rental & leasing	88	55	21	10	1	1	0	0	0	0
54	Professional, scientific & technical service	168	104	33	18	8	4	1	0	0	0
56	Admin, support, waste mgt & remediation ser	61	26	17	12	3	2	1	0	0	0
61	Educational services	23	11	5	4	2	0	0	1	0	0
62	Health care and social assistance	100	47	30	13	7	1	0	2	0	0
71	Arts, entertainment & recreation	19	6	4	3	5	1	0	0	0	0
72	Accommodation & food services	156	24	17	35	53	20	7	0	0	0
81	Other services (except public administration	120	58	28	25	4	5	0	0	0	0
99	Unclassified establishments	11	8	1	2	0	0	0	0	0	0
Total		1337	606	305	208	141	44	28	4	0	1

Source: U.S. Census 2003.

Note: This table determines the number of establishments in College Station, TX by adding each business pattern from five different ZIP Code areas currently used within College Station's city limits. The five ZIP Code areas include: 77840, 77841, 77842, 77843, and 77845.

Table 5-20: Modification of the U.S. Census Bureau's Industry Code Description into the EIA's Commercial Building Activity Description.

U.S. Census Bureau		EIA
Industry Code Description (NACIS)		Building Activity Description
Mining	Crude petroleum & natural gas extraction	Industrial Sector
	Drilling oil & gas wells	Industrial Sector
	Oil & gas operations support activities	Industrial Sector
Utilities		Office
Construction	Single-family housing construction	Office
	Mfg & industrial building construction	Office
	Commercial & institutional bldg construction	Office
	Plumbing, heating & AC contractor	Office
	Painting & wall covering contractors	Office
	Electrical contractors	Office
	Drywall, acoustical & insulation contractor	Office
	Floor laying & other floor contractors	Office
Manufacturing	Retail bakeries	Industrial Sector
	Other apparel accessories & other apparel mf	Industrial Sector
	All other leather good mfg	Industrial Sector
	Commercial lithographic printing	Industrial Sector
	Electron tube mfg	Industrial Sector
	Watch, clock & part mfg	Industrial Sector
	Other MV electrical & electronic equip mfg	Industrial Sector
Wholesale trade	Brick & related construction material whsle	Mercantile 1
	Other professional equipment & supplies whsle	Mercantile 1
	Metal service centers & offices whsle	Mercantile 1
	Plumbing & heating equipment & supplies whsl	Mercantile 1
	Petroleum bulk stations & terminals	Mercantile 1
	Petroleum prod whsle (bulk station, terminal)	Mercantile 1
Retail trade	New car dealers	Mercantile 1
	Used car dealers	Mercantile 1
	Motorcycle dealers	Mercantile 1
	Automotive parts, accessories & tire store	Mercantile 1
	Tire dealers	Mercantile 1
	Furniture stores	Mercantile 1
	All other home furnishings stores	Mercantile 1
	Household appliance stores	Mercantile 1
	Radio, television & other electronics store	Mercantile 1
	Computer & software stores	Mercantile 1
	Camera & photographic supplies stores	Mercantile 1
	Home centers	Mercantile 2
	Other building material dealers	Mercantile 1
	Grocery (except convenience) stores	Food Sales
	Convenience stores	Food Sales

Table 5-20: (Continued).

U.S. Census Bureau		EIA
Industry Code Description (NACIS)		Building Activity Description
Retail trade	Meat markets	Food Sales
	Confectionery & nut stores	Food Sales
	All other specialty food stores	Food Sales
	Beer, wine & liquor stores	Mercantile 1
	Pharmacies & drug stores	Mercantile 1
	Cosmetics, beauty supplies & perfume store	Mercantile 1
	Optical goods stores	Mercantile 1
	Food (health) supplement stores	Mercantile 1
	All other health & personal care stores	Mercantile 1
	Gasoline stations with convenience stores	Food Sales
	Other gasoline stations	Service
	Men's clothing stores	Mercantile 1
	Women's clothing stores	Mercantile 1
	Children's & infants' clothing stores	Mercantile 1
	Family clothing stores	Mercantile 2
	Clothing accessories stores	Mercantile 1
	Other clothing stores	Mercantile 1
	Shoe stores	Mercantile 1
	Jewelry stores	Mercantile 1
	Sporting goods stores	Mercantile 2
	Hobby, toy & game stores	Mercantile 2
	Sewing, needlework & piece goods stores	Mercantile 1
	Musical instrument & supplies stores	Mercantile 1
	Book stores	Mercantile 1
	Prerecorded tape, CD & record stores	Mercantile 1
	Department stores	Mercantile 2
	Warehouse clubs & superstores	Mercantile 2
	All other general merchandise stores	Mercantile 1
	Florists	Mercantile 1
	Office supplies & stationery stores	Mercantile 1
	Gift, novelty & souvenir stores	Mercantile 1
	Used merchandise stores	Mercantile 1
	Pet & pet supplies stores	Mercantile 1
	Art dealers	Mercantile 1
	All other misc store retailers (exc tobacco)	Mercantile 1
	Electronic shopping & mail-order houses	Mercantile 1
	Vending machine operators	Mercantile 1
	Other direct selling establishments	Mercantile 1
Transportation & warehousing	Scheduled passenger air transportation	Public Assembly
	Used household & office goods moving	Office
	Couriers	Office

Table 5-20: (Continued).

U.S. Census Bureau		EIA
Industry Code Description (NACIS)		Building Activity Description
Transportation & warehousing	Local messengers & local delivery	Office
Information	Book publishers	Office
	Software publishers	Office
	Wired telecommunications carriers	Office
	Paging	Office
	Cellular & other wireless telecommunications	Office
	On-line information services	Office
Finance & insurance	Commercial banking	Office
	Savings institutions	Office
	Credit unions	Office
	Real estate credit	Office
	All other non-depository credit intermediation	Office
	Mortgage & non-mortgage brokers	Office
	Other credit intermediation activities	Office
	Securities brokerage	Office
	Miscellaneous intermediation	Office
	Portfolio management	Office
	Investment advice	Office
	Direct title insurance carriers	Office
	Insurance agencies & brokerages	Office
	Insurance & pension funds, third party adm	Office
Real estate & rental & leasing	Lessors of residential buildings & dwellings	Office
	Lessors of mini-warehouses & self storage uni	Office
	Offices of real estate agents & brokers	Office
	Residential property managers	Office
	Nonresidential property managers	Office
	Offices of real estate appraisers	Office
	Other activities related to real estate	Office
	Passenger car rental	Mercantile 1
	Truck, utility trailer & RV rental & lease	Mercantile 1
	Formal wear & costume rental	Mercantile 1
	Video tape & disc rental	Mercantile 1
	All other consumer goods rental	Mercantile 1
	Const, mining, forestry equip rental & lea	Mercantile 1
	Lessors of other non-financial intangible ass	Mercantile 1
Professional, scientific & technical service	Offices of lawyers	Office
	Offices of certified public accountants	Office
	Tax preparation services	Office
	Payroll services	Office

Table 5-20: (Continued).

U.S. Census Bureau		EIA
Industry Code Description (NACIS)		Building Activity Description
Professional, scientific & technical service	Architectural services	Office
	Other accounting services	Office
	Landscape architectural services	Office
	Engineering services	Office
	Surveying, mapping (exc. geophysical) servi	Office
	Testing laboratories	Office
	Interior design services	Office
	Custom computer programming services	Office
	Computer systems design services	Office
	Other computer related services	Office
	Admin & general management consulting services	Office
	Human resource & exec search consulting services	Office
	Marketing consulting services	Office
	Other management consulting services	Office
	Environmental consulting services	Office
	Other scientific & technical consulting service	Office
	R&D in physical, engineering & life science	Office
	Advertising agencies	Office
	Other services related to advertising	Office
	Photography studios, portrait	Office
	Commercial photography	Office
	Veterinary services	Health Care Out
	All other prof. scientific & technical service	Office
Management of companies & enterprises	Management of companies & enterprises	Office
	Corp, subsidiary & regional managing office	Office
Admin, support, waste mgt, remediation ser	Office administrative services	Office
	Employment placement agencies	Office
	Other business service centers include copy shop	Service
	Travel agencies	Office
	Tour operators	Office
	Convention and visitors bureaus	Office
	Security guards & patrol services	Service
	Security systems services (except locksmiths	Service
	Janitorial services	Service
	Carpet & upholstery cleaning services	Service
	All other support services	Service
Educational services	Elementary & secondary schools	Education
	Colleges, universities & professional school	Education
	Fine arts schools	Education
	Sports & recreation instruction	Education

Table 5-20: (Continued).

U.S. Census Bureau		EIA
Industry Code Description (NACIS)		Building Activity Description
Educational services	Exam preparation & tutoring	Education
	All other miscellaneous schools & instruction	Education
	Educational support services	Education
Health care and social assistance	Offices of physicians (exc mental health)	Health Care Out
	Offices of dentists	Health Care Out
	Offices of chiropractors	Health Care Out
	Offices of optometrists	Health Care Out
	Offices of other mental health practitioners	Health Care Out
	Offices of all other misc health practitione	Health Care Out
	All other outpatient care centers	Health Care Out
	Diagnostic Imaging centers	Health Care Out
	Home health care services	Health Care Out
	Ambulance services	Health Care Out
	Blood & organ banks	Health Care Out
	Other individual & family services	Health Care Out
	Child day care services	Education
Arts, entertainment & recreation	Musical groups & artists	Public Assembly
	Amusement arcades	Public Assembly
	Fitness & recreational sports centers	Public Assembly
	Bowling centers	Public Assembly
	All other amusement & recreation industries	Public Assembly
Accommodation & food services	Hotels (exc. casino hotels) & motels	Lodging
	Rooming & boarding houses	Lodging
	Full-service restaurants	Food Service
	Limited-service restaurants	Food Service
	Snack & nonalcoholic beverage bars	Food Service
	Caterers	Food Service
	Drinking places (alcoholic beverages)	Food Service
Other services (except public administration	General automotive repair	Service
	Automotive glass replacement shops	Service
	Automotive oil change & lubrication shops	Service
	All other automotive R&M	Service
	Computer & office machine R&M	Service
	Commercial equipment (exc auto & elec) R&M	Service
	Appliance repair & maintenance	Service
	Other personal & household goods R&M	Service
	Barber shops	Service
	Beauty salons	Service
	Nail salons	Service
	Diet & weight reducing centers	Service

Table 5-20: (Continued).

U.S. Census Bureau		EIA
Industry Code Description (NACIS)		Building Activity Description
Other services (except public administration)	Other personal care services	Service
	Funeral homes	Public Assembly
	Coin-operated laundries & drycleaners	Service
	Dry-cleaning & laundry services (exc. coin-op)	Service
	Photo finishing laboratories (except one-hour)	Service
	One-hour photo finishing	Service
	Religious organizations	Religious Worship
	Other grant making & giving services	Office
	Human rights organizations	Office
	Civic & social organizations	Office
	Business associations	Office

5.3.2.2 Determination of the Number Employed Based on Building Activity Type

The number of employees was determined by finding the number of establishments by employment-size class provided by the U.S. Census Bureau. To accomplish this, the average number of each employment-size class (see Table 5-18) was first determined. For instance, the average number of the employment-size class '1-4' is 2.5, and that of '250-499' is 375. The total number of the establishments was then multiplied by each building activity in order to determine the total number of employees. Table 5-21 summarizes the total number of those employees and establishments (businesses) by building activity in College Station. The total number of those employed in College Station is approximately 18,862 people. This number agrees with the data taken from the College Station Demographic Report (COCS 2003). The total number of employees in 2000 was approximately 31,439 people (RECenter 2003). Of these, 12,000 people worked at Texas A&M University (COCS 2003). The rest, approximately 20,000 people, worked within the community boundary.

5.3.2.3 Determination of Energy Intensity Factor Based on Building Activity Type

Once the estimated number of employees in each building activity type was established, the square area of each building activity type was estimated by using the mean square footage per worker or the mean square footage per building. The mean square footage per worker and the mean square feet per building were each determined by the data taken from the EIA's 1999 CBECS (See Table B1 in the 1999 CBECS).

Table 5-21: Summary of the Total Number of Employees and Establishments.

Building Type	Building Activity Subcategory	Number of Employees	Number of Establishments
Education	Elementary/Middle/High School (CS ISD)	1,100	15
	Other Education	182	25
	Preschool/Daycare	112	8
	Total	1,394	48
Food Sale	Grocery Store/Food Market	1,307	9
	Other Food Sales or Service (Convenience Store)	245	32
	Total	1,552	41
Food Service	Restaurants	4,245	126
	Total	4,245	126
Health Care	Health Care (Inpatient)	800	2
	Health Care (Outpatient)	1,127	99
	Total	1,927	101
Lodging	Hotel/Inn	645	25
	Total	645	25
Mercantile	Auto Dealership/Showroom	110	8
	Enclosed Mall	N/A	1
	Retail Store	2,948	244
	Strip Shopping Center	N/A	6
	Total	3,058	259
Office	Office	4,227	413
	Total	4,227	413
Public Assembly	Entertainment Venue	76	1
	Recreation	228	10
	Other Public Assembly	55	5
	Total	359	16
Religious Worship	Church & Catholic Church	160	32
	Total	160	32
Public Order and Safety	Courthouse/Probation Office	76	1
	Jail/Prison/Reformatory	228	10
	Total	304	11
Service	Auto Service/Auto Repair	227	26
	Dry Cleaner/Laundromat	38.5	4
	Other Service	725	86
	Total	990.5	116
Total		18,862	1,188

The energy intensity factor (kWh/sq.ft and CF/sq.ft) of each building activity type was determined by reviewing the EIA's 1999 CBECS table. The percentage (%) of natural gas used was also determined in order to calculate the total natural gas use. The information is summarized in Table 5-22.

Table 5-22: Summary of Information Taken from the EIA's 1999 CBECS.

Building Type	Building Activity Sub-category	Mean Square Feet per Worker (MSFW)	Mean Square Feet per Building (sq.ft)	Electricity Energy Intensity (kWh/sq. ft)	Natural Gas Energy Intensity (CF/sq. ft)	% of Natural Gas Use
Education	Elementary/Middle/High School	1,070	71,000	8	35	62%
	Other Education	824	7,000	8	35	62%
	Preschool/Daycare	1,148	3,000	5	25	62%
Food Sale	Grocery Store/Food Market	995	13,000	41	42	63%
	Other Food Sales or Service (Convenience Store)	1,048	3,000	41	42	63%
Food Service	Restaurants	359	5,000	49	217	70%
Health Care	Health Care (Inpatient)	437	229,000	29	120	67%
	Health Care (Outpatient)	529	10,000	18	39	51%
Lodging	Hotel/Inn	1,919	30,000	13	50	57%
Mercantile	Auto Dealership/Showroom	640	7,000	10	50	68%
	Enclosed Mall	1,076	607,000	11	6	63%
	Retail Store	1,166	10,000	13	28	63%
	Strip Shopping Center	766	30,000	13	23	63%
Office	Office	416	3,000	13	29	51%
Public Assembly	Entertainment Venue	822	22,000	11	31	59%
	Recreation	1,808	14,000	14	43	59%
	Other Public Assembly	1,513	30,000	10	29	59%
Religious Worship	Church & Catholic Church	2,059	11,000	13	29	67%
Public Order and Safety	Courthouse/Probation Office	716	75,000	11	31	50%
	Jail/Prison/Reformatory	1,493	47,000	14	43	50%
Service	Auto Service/Auto Repair	777	7,000	9	121	65%
	Dry Cleaner/Laundromat	618	5,000	9	121	65%
	Other Service	799	7,000	14	N/A	65%

Source: EIA 2001a.

5.3.2.4 Determination of the Commercial Sector's Energy Use

In this section the results of the estimation of the 2002 annual energy consumption for the commercial sector in College Station are presented. Table 5-23 represents each parcel's energy use and the commercial sector's total energy use. In the first and second columns, 11 building types and 23 detailed building subcategories are listed. Columns A through M represent the consecutive calculation used to calculate the total sector's energy use. In general, the total energy use for each building's activity was calculated by two processes: 1) the total conditioned floor area was first determined by multiplying the previously estimated total number (Table 5-21) of employees times the mean square feet per worker (MSFW), and 2) the total floor area was multiplied by the energy intensity (kWh/sq.ft or CF/sq.ft). After calculating the total natural gas used for each building activity, the percent (%) of natural gas was applied in order to consider each parcel's share of the heating system. The annual electricity use in 2002 was 288,308 MWh and the annual natural gas use was 514,842 MCF respectively. Each parcel's (building activity) energy use is described in the following sections.

5.3.2.5 Educational Service

The educational service parcel includes those buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses. In College Station, the educational service parcel was compromised of four major groups: 1) Texas A&M University, 2) College Station ISD, 3) preschool and daycare, and 4) other educational services. Texas A&M University was excluded from this energy use calculation because the university generates electricity from its own power plant. College Station Independent School District (CSISD) operates a total of 16 educational buildings and facilities. It includes nine school buildings, the ISD administration buildings, athletic facilities, and the school bus barn. In College Station, there are approximately 8 private preschools and daycares where approximately 112 people work. In other types of education services, there were approximately 25 establishments and 182 people working, respectively.

As represented in Table 5-23, the educational service parcel is about 1.45 million square feet or 7 percent of total commercial building floor area. The estimated total site energy consumption was 69,366 MMBtu or 4 percent of the total site energy consumption for commercial buildings. Among them, electric energy use was 37.9 MMBtu or 5 percent of the

Table 5-23: Commercial Sector Profile and Estimated Energy Use in College Station.

Parcel		A	B	C	D (A x C)	E	F	G (D x F)	H (G x 3,412 Btu/kWh) /1000,000	I	J	K (D x I x J)	L (J x 1,030 Btu/CF) /1000,000	M (H + L)
Building Type	Building Activity Subcategory	Number of Employees	Number of Establishments	Mean Square Feet per Worker (MSFW)	Estimated Total Square Feet based on MSFW	Mean Square Feet per Building (Thousand sq.ft)	Electricity Energy Intensity (kWh/sq. ft)	Total Electricity Use (kWh/yr) by MSFW	Converted to MMBtu	Natural Gas Energy Intensity (CF/sq. ft)	% of Natural Gas Use	Total Natural Gas Consumption (CF)	Converted to MMBtu	Total MMbtu
Education	Elementary/Middle/High School (CS ISD)	1,100	15	1,070	1,177,000	71	7.8	9,180,600	31,324	34.7	0.62	25,321,978	26,082	57,406
	Other Education	182	25	824	149,968	7.3	8.3	1,244,734	4,247	35	0.62	3,254,306	3,352	7,599
	Preschool/Daycare	112	8	1,148	128,576	2.8	5.2	668,595	2,281	25.3	0.62	2,016,843	2,077	4,359
	Total	1,394	48		1,455,544			11,093,930	37,852			30,593,127	31,511	69,363
Food Sale	Grocery Store/Food Market	1,307	9	995	1,300,465	12.6	41.1	53,449,112	182,368	42.1	0.63	34,492,233	35,527	217,895.37
	Other Food Sales or Service	245	32	1,048	256,760	3	41.1	10,552,836	36,006	42.1	0.63	6,810,045	7,014	43,020.62
	Total	1,552	41		1,557,225			64,001,948	218,375			41,302,279	42,541	260,915.99
Food Service	Restaurants	4,245	126	359	1,523,955	5.3	49.1	74,826,191	255,307	216.7	0.7	231,168,734	238,104	493,411
	Total	4,245	126		1,523,955			74,826,191	255,307			231,168,734	238,104	493,411
Health Care	Health Care (Inpatient)	800	2	437	349,600	228.6	28.6	9,998,560	34,115	119.7	0.67	28,037,570	28,879	62,994
	Health Care (Outpatient)	1,127	99	529	596,183	9.5	17.6	10,492,821	35,802	38.6	0.51	11,736,459	12,089	47,890
	Total	1,927	101		945,783			20,491,381	69,917			39,774,029	40,967	110,884
Lodging	Hotel/Inn	645	25	1,919	1,237,755	29.5	12.7	15,719,489	53,635	49.6	0.57	34,993,809	36,044	89,679
	Total	645	25		1,237,755			15,719,489	53,635			34,993,809	36,044	89,679
Mercantile	Auto Dealership/Showroom	110	8	640	70,400	7.4	10.4	732,160	2,498	49.6	0.68	2,374,451	2,446	4,944
	Enclosed Mall	N/A	1	1,076	606,800	606.8	11.0	6,674,800	22,774	5.8	0.63	2,217,247	2,284	25,058
	Retail Store	2,948	244	1,166	3,437,368	10.1	12.6	43,310,837	147,777	27.7	0.63	59,985,509	61,785	209,562
	Strip Shopping Center	N/A	6	766	181,200	30.2	12.6	2,283,120	7,790	23.1	0.63	2,637,004	2,716	10,506
	Total	3,058	259					53,000,917	180,839			67,214,211	69,231	250,070

Table 5-23: (Continued).

Parcel		A	B	C	D (A x C)	E	F	G (D x F)	H (G x 3,412 Btu/kWh) /1000,000	I	J	K (D x I x J)	L (J x 1,030 Btu/CF) /1000,000	M (H + L)
Building Type	Building Activity Subcategory	Number of Employees	Number of Establishments	Mean Square Feet per Worker (MSFW)	Estimated Total Square Feet based on MSFW	Mean Square Feet per Building (Thousand sq.ft)	Electricity Energy Intensity (kWh/sq. ft)	Total Electricity Use (kWh/yr) by MSFW	Converted to MMBtu	Natural Gas Energy Intensity (CF/sq. ft)	% of Natural Gas Use	Total Natural Gas Consumption (CF)	Converted to MMBtu	Total MMbtu
Office	Office	4,227	413	416	1,758,432	2.9	12.7	22,332,086	76,197	29	0.51	26,007,209	26,787	102,985
	Total	4,227	413					22,332,086	76,197			26,007,209	26,787	102,985
Public Assembly	Entertainment Venue	76	1	822	62,472	22.3	11.2	699,686	2,387	31	0.59	1,142,613	1,177	3,564
	Recreation	228	10	1,808	412,224	13.8	14.0	5,771,136	19,691	43	0.59	10,458,123	10,772	
	Other Public Assembly	55	5	1,513	111,500	30.3	9.8	1,092,700	3,728	28.6	0.59	1,881,451	1,938	5,666
	Total	359	16					7,563,522	25,807			13,482,187	13,887	39,693
Religious Worship	Church & Catholic Church	160	32	2,059	329,440	11.1	12.7	4,183,888	14,275	29	0.67	6,401,019	6,593	20,868
	Total	160	32					4,183,888	14,275			6,401,019	6,593	20,868
Public Order and Safety	Courthouse/Probation Office	76	1	716	54,416	74.8	11.2	609,459	2,079	31	0.5	843,448	869	2,948
	Jail/Prison/Reformatory	228	10	1,493	340,404	47	14.0	4,765,656	16,260	43	0.5	7,318,686		
	Total	304	11					5,375,115	18,340			8,162,134	869	19,209
Service	Auto Service/Auto Repair	227	26	777	176,379	6.8	9.2	1,622,687	5,537	121	0.65	13,872,208	14,288	19,825
	Dry Cleaner/Laundromat	38.5	4	618	23,793	5.2	9.2	218,896	747	121	0.65	1,871,319	1,927	2,674
	Other Service	725	86	799	579,275	7	13.6	7,878,140	26,880		0.65	-		
	Total	990.5	116					9,719,722	33,164			15,743,528	16,215.83	49,380
Total		18,862	1,188		14,864,365			288,308,188	983,708			514,842,266	522,749	1,506,457

total commercial building electricity use. Natural gas use was 31.5 MMBtu or 2 percent of the total commercial building natural gas use. Table 5-24 presents the annual electricity consumption for a sample of three educational buildings. The average electricity consumption for these three sample buildings was 12.28 kWh/ft^2- yr. As compared to the U.S. average value of 7.8 kWh/sq.ft/yr, the electricity energy use for those education buildings tended to be larger due to a higher cooling load during the cooling season.

Table 5-24: Summary of the Educational Service Building's Energy Use.

Sample Building	Sector	Category	Main Area (sq. ft)	Year Built	Annual KWh		kWh/sq.ft	MAX kW	Comment
					2,001	2,002			
Sample 1	Commercial	Education	2,763	1984	N/A	N/A	N/A	N/A	Daycare
Sample 2	Commercial	Education	N/A	N/A	29,963	32,312	N/A	N/A	
Sample 3	Commercial	Education	133,588	N/A	2,270,400	1,759,200	17.00	N/A	Junior High
Sample 4	Commercial	Education	74,073	1995	785,200	796,160	10.60	N/A	Elementary

5.3.2.6 Food Sales

The food sales parcel includes buildings or business establishments used for the retail or wholesale distribution of food. In College Station, the food sales parcel is compromised of two major groups: 1) grocery store/food markets and 2) other food sales or services (convenience stores). The majority of food sales are grocery stores. There were approximately 9 grocerie stores and 32 convenience stores in College Station. The food sales parcel contains 1.6 million square feet or 9 percent of the total commercial building floor area. Its total site energy use in this study was 260,241 MMBtu or 21 percent of the total commercial building energy use. Among these, business electric energy use was approximately 218,375 MMBtu or 27 percent of the total commercial sector electricity use. The natural gas use was 41,866 MMbtu or 3.2 percent of the total commercial sector natural gas use. As compared to the educational service parcel, the energy use per conditioned area was much larger due to the refrigerator equipment present.

5.3.2.7 Food Service

The food service parcel includes buildings or businesses where the preparation and the sale of food and beverages for consumption are conducted. In College Station, there are approximately 126 food service businesses. Food service is the fastest-growing type of business in College Station. According to the Texas Comptroller of Public Accounts, gross sales in restaurants throughout College Station were $52 million in the first quarter of 2003. The industry has been growing since the reporting period began in 1996, with an 11.98 percent growth from 1998 to 1999 and an 11 percent increase from 1999 to 2000. Statewide, the growth was 7.4 percent in 1999 and just over 6 percent in 2000.

Food service buildings comprise 0.4 million square feet or 3 percent of the total commercial building's floor area. However, the total site energy use was 141,394 MMBtu or 12.6 percent of the total commercial building energy use. Among these businesses, the electricity use was approximately 60,624 MMBtu or 7.7 percent of the total commercial sector electricity use. Natural gas use was 80,770 MMBtu or 21 percent of the total commercial sector's natural gas use. As compared to other parcels in the commercial sector, the natural gas use per conditioned area was the highest due to frequent cooking activities.

Table 5-25 describes the annual electricity consumption for a sample of five food service buildings. The average food service building studied used 99.7 kWh/sq. ft./yr and a consumption range of 79.9 – 116.8 kWh/sq. ft./yr which is well above the U.S average is 49.1 kWh/sq/ft/yr (EIA 2001a).

Table 5-25: Summary of the Sample Food Service Building's Energy Use.

Sample Building	Sector	Category	Main Area (sq. ft)	Year Built	Annual KWh		kWh/sq.ft	MAX kW	Max kW/sq.ft
					2,001	2,002			
Sample 1	Commercial	Food Service	3,813	1988	445,360	507,440	116.80	98.40	25.8
Sample 2	Commercial	Food Service	3,890	1974	387,920	372,160	99.72	100.00	25.7
Sample 3	Commercial	Food Service	4,954	2000	395,840	391,040	79.90	103.00	20.7
Sample 4	Commercial	Food Service	6,220	1993	548,880	522,840	88.24	265.60	42.7
Sample 5	Commercial	Food Service	5,238	1990	571,280	539,920	109.06	132.80	25.4

Figure 5-10 shows surprisingly similar characteristics across the five sample food service businesses. All five showed roughly 0.15 to 0.30 kWh/ft^2-day at average monthly temperature of 50 ^{o}F. Conversely, the temperature dependency varied across the five businesses from 0.25 to 0.40 kWh/ft^2-day at 80 ^{o}F indicating significantly different loads under summer conditions.

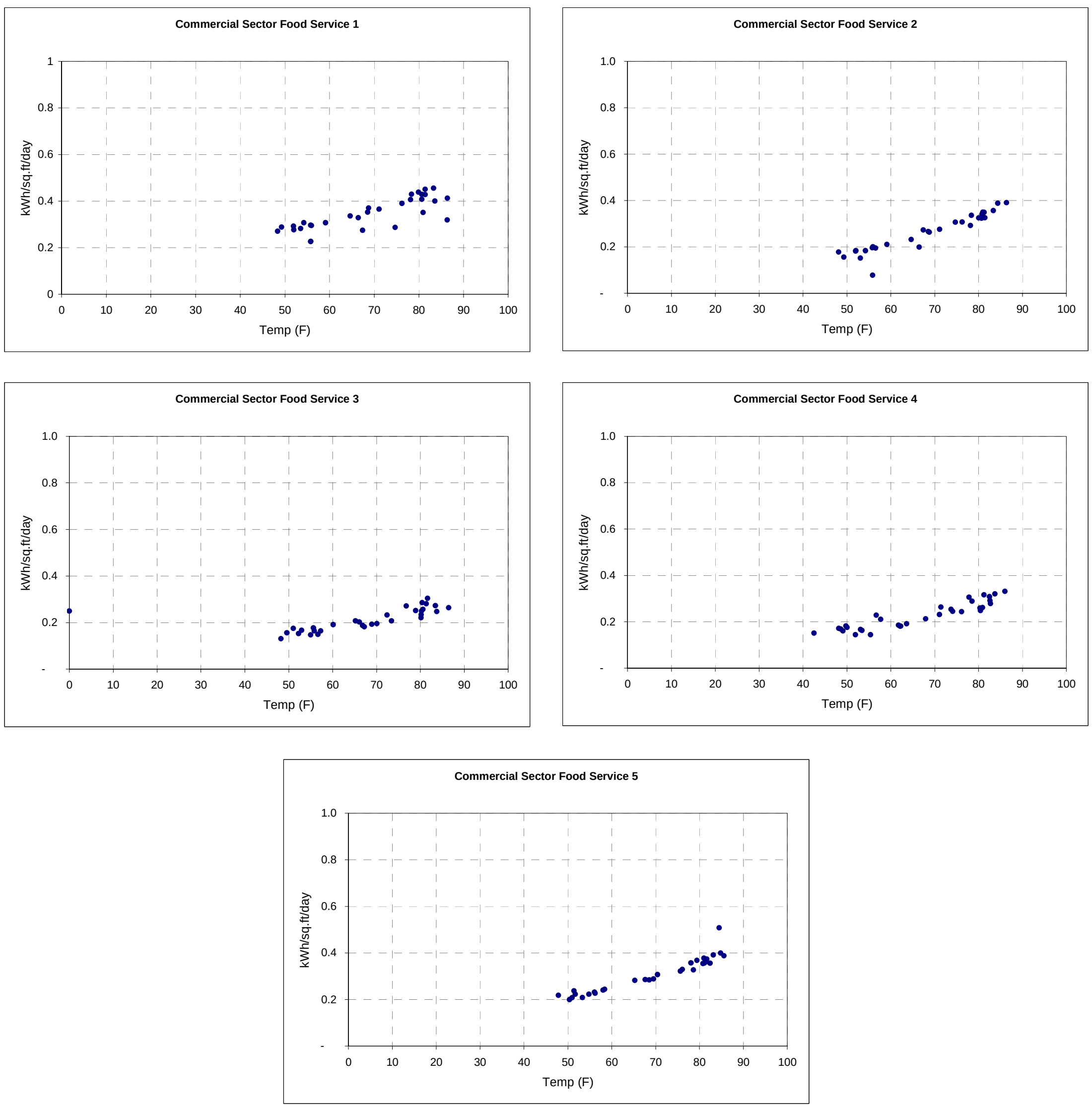


Figure 5-10: Daily Electricity Use Profile (kWh/ft^2-day) for Five Sample Restaurants.

5.3.2.8 Office Building

In College Station, the office parcel is mostly compromised of small office buildings because the majority of businesses are small-scale. In 2002 there were about approximately 296 office buildings. The office parcel comprised 1.6 million square feet or approximately 17 percent of the total commercial building floor area. Its total site energy use in this study was 120,682 MMBtu or 9 percent of the total commercial building energy use. Among these, electricity use was approximately 71,438 MMBtu or 9 percent of the total commercial sector electricity use. Natural gas use was 49,244 MMBtu (47,809 MCF) or 11 percent of the total commercial sector's natural gas use.

5.3.2.9 Retail Trade (Mercantile)

The retail trade parcel is defined in this study as buildings or businesses used for the sale and display of goods other than food. In College Station, retail space has been classified as either neighborhood retail space or regional retail spaces (BCSEDC 2001). Neighborhood retail space is permitted to use small-scale spaces such as small retail centers, commercial services, etc. These uses are generally dependent on easy access to local arterials. The small retail centers in the Northgate and Southside areas are examples of this type of use. Regional retail space is permitted to use regional-scale support. The Post Oak Mall is an example of this use.

Based on the 1999 CBECS (EIA 2001a), the mercantile parcel was categorized into the five building activity categories. These categories include auto dealers, enclosed malls, retail stores, strip shopping centers, and other mercantile. According to the County Business Pattern (U.S. Census 2003), there were eight auto dealers (four new car, three used car, and one motorcycle dear), one enclosed mall, 240 retail stores, and six strip shopping centers in College Station. Other mercantile was not included in the commercial sector's analysis due to the difficulty of classification. The estimated total floor area for the retail trade was 1.2 million square feet with 11 percent of the total commercial floor area. To verify estimated floor area, the Fact Book for Bryan-College Station (BCSEDC 2001) was reviewed. According to the BCSEDC, currently 1.5 million square feet of mercantile space are provided with a 2000 average occupancy rate of 90.35% (BCSEDC 2001). A comparison of these two numbers shows 12 %

difference indicates that the estimation based on the 1999 CBECS (EIA 2001a) is an appropriate method to determine the floor area for the commercial sector.

5.3.2.10 Lodging

Table 5-26 depicts the annual electricity consumption for a sample comprised of four lodging businesses. The average lodging service buildings studied used 15.3 kWh/sq. ft./yr and a consumption range of 8.3 – 24.41 kWh/sq. ft./yr. The U.S average is 15.5 kWh/sq/ft/yr (EIA 2001a). This building type exhibited a large consumption component that varied from month to month in all sample buildings. It appears that outdoor conditions have a significant influence on energy consumption. The energy use pattern is similar to the residential sector's energy use.

To determine building characteristics, the information from twelve sample lodging business was collected and reviewed. An average floor area of twelve sample buildings was 55,810 square feet. In College Station, there were twenty-five lodging businesses. The estimated total floor area of the lodging businesses in College Station was about 1.39 million square feet. This number is close to the value of 1.24 million square feet provided by the 1999 CBECS. The range of each building's floor area was 27,228 to 222,829 square feet. An analysis of selected sample buildings indicates that large lodging businesses tend to be newer than small lodging businesses, with the exception of the one, very large lodging business.

Table 5-26: Summary of the Sample Lodging Buildings' Energy Use.

Sample Building	Sector	Category	Main Area (sq. ft)	Year Built	Annual KWh		kWh/sq.ft	MAX kW	KW/sq.ft
					2,001	2,002			
Sample 1	Commercial	Lodging	222,829	1984	4,951,200	5,439,300	24.41	1,143	5.1
Sample 2	Commercial	Lodging	52,096	1997	959,400	928,400	17.82	192	3.7
Sample 3	Commercial	Lodging	54,324	1998	455,100	451,800	8.32	162	3.0
Sample 4	Commercial	Lodging	44,744	1999	566,400	477,800	10.68	138	3.0

Figure 5-11 shows the daily electricity use per square foot for four lodging businesses. The range of daily electricity use per square foot was 0.02 to 0.08 kWh/day/sq.ft. One lodging building (CL1, 222,824 sq.ft) constructed in 1984 had the largest electricity use intensity (kWh/day/sq.ft). Older lodging businesses tend to have higher energy intensities than newer businesses.

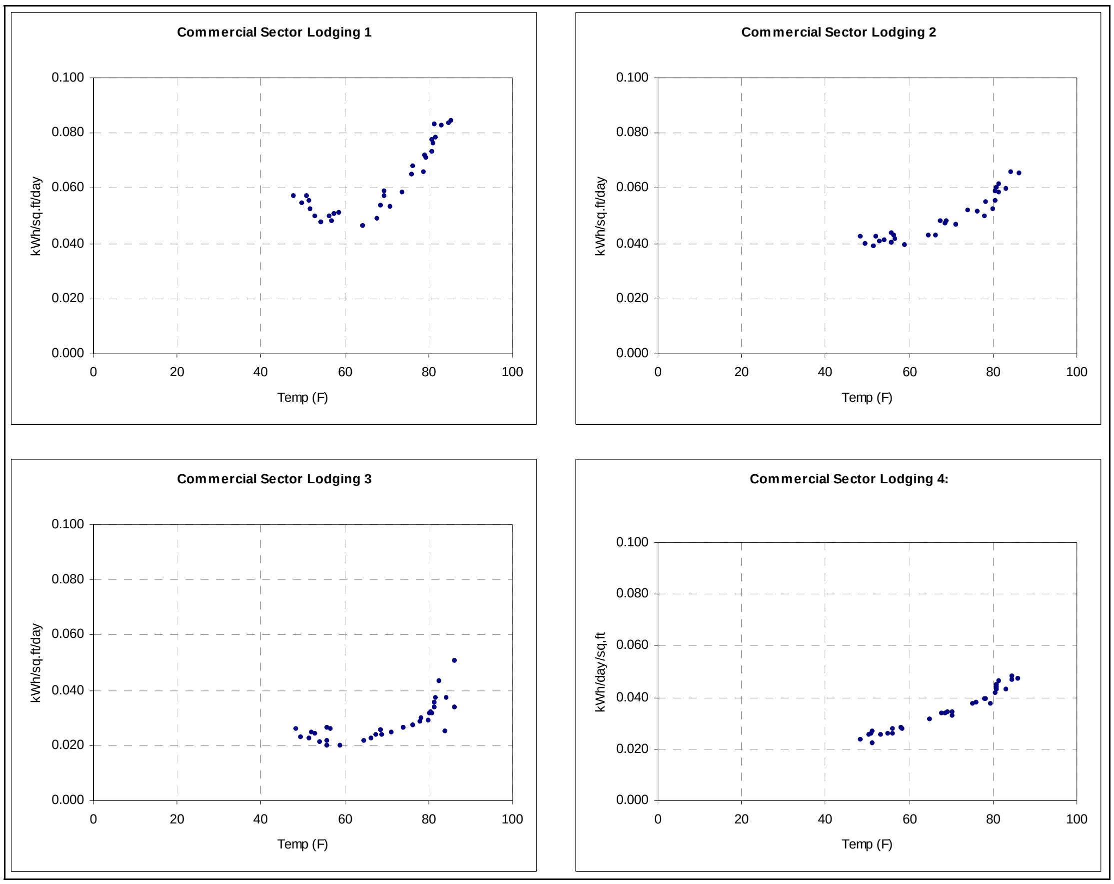


Figure 5-11: Daily Electricity Use Profile (kWh/sq.ft/day) for Four Sample Lodging Buildings.

5.3.2.11 Comparison of the Actual Energy Use to the Estimated Energy Use From the Model

A comparison actual energy use with the results from the baseline model was conducted in order to verify the results of the baseline model. To accomplish this task, the commercial sector's actual energy use data for both electricity and natural gas was first collected. The 2002 annual electricity sales report provided by College Station Utility Customer Service (CSUCS) was used to determine the actual electricity use. The 2002 annual natural gas report (RRC 2003) was used to determine the commercial sector's annual natural gas use.

The annual electricity use of the commercial sector in 2002 was 291,351 MWh and the actual annual natural gas use was 373,580 MCf. These values can be represented as approximately 45% of the total electricity use and 44 % of the total natural gas use in College Station.

Monthly gas consumption was determined based on the average portion of gas consumption for each month during the 12 years (1989 – 2002) of Texas's historical natural gas consumption. Detailed information listed in Table 5-27. Moving down the column, it can be seen that the historical (1989 – 2002) natural gas deliveries to commercial customers are all listed. Each column presents the monthly portion of natural gas consumption for each year. The right column presents the total annual natural gas delivered. Finally, an average monthly portion was determined, as shown in the darkly colored row. It was then used to determine College Station's monthly natural gas consumption by applying the annual gas consumption taken from the RRC. For instance, the annual gas consumption of College Station during the year 2002 was 373,580 MCf. The energy uses of both electricity and natural gas were converted by multiplying the given factors (3,412 Btu/kWh and 1,030 Btu/CF) to obtain a uniform format (Btu), which allowed comparing each other.

In 2002, the total numbers of electricity accounts with a commercial rate was 2,622 (many business have two or more accounts) while the total number of customers who use natural gas under commercial rate was 746 (RRC 2003). The average percentage of natural gas use in Table 5-20 (Column J) agrees with the actual number of natural gas accounts (746) taken from the RRC's annual report. By multiplying the total business establishments (1,188) by the average percentage of natural gas use (61%) the estimated number of natural gas users in commercial sector can be determined to be 725. The difference is approximately 3%.

Figure 5-12 shows an analysis of monthly consumption based on actual utility data. The energy use profile in Figure 5-12 shows that energy consumption comprises of two loads: 1) base load and 2) seasonal load. The base load consists of lighting, water heating, and miscellaneous use, which is relatively constant through year. The seasonal load consists of heating and cooling load, which varies with seasons. For instance, electricity use was largest in July due to cooling season while natural gas use was the largest in January due to heating load. From the Figure 5-12, it was also seen that the summer cooling peak is evident, while the winter heating peak is relatively small, mostly reflecting the decreased heating load of the internal heat gain and the mild winters. Therefore, It appeals that the energy use of the commercial sector has less seasonal variation as compared to that of the residential sector.

Finally, a comparison of the total energy use from the CCNERT methodology with that from actual energy use data was conducted. In Figure 5-13, the annual consumption of both electricity and natural gas is presented for each of two approaches. The results show only a 10% variation of total electricity use, while a 25% variation of total natural gas consumption.

Table 5-27: Estimated Monthly Natural Gas Consumption Based on the Historical Deliveries to Commercial Consumers in Texas (MMCf).

Year	Month												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	21,163	22,930	20,215	15,779	11,310	10,731	12,786	11,350	9,367	10,345	12,823	23,871	182,670
1989	12%	13%	11%	9%	6%	6%	7%	6%	5%	6%	7%	13%	100%
	21,376	16,323	17,118	14,054	12,299	14,204	14,184	11,592	9,448	9,571	12,192	19,981	172,342
1990	12%	9%	10%	8%	7%	8%	8%	7%	5%	6%	7%	12%	100%
	26,377	18,723	16,796	15,181	11,439	10,763	12,769	11,125	8,843	11,156	17,192	20,608	180,972
1991	15%	10%	9%	8%	6%	6%	7%	6%	5%	6%	9%	11%	100%
	22,907	19,049	15,866	14,174	12,557	10,879	13,768	12,966	11,356	11,672	17,386	22,093	184,673
1992	12%	10%	9%	8%	7%	6%	7%	7%	6%	6%	9%	12%	100%
	21,489	18,444	16,162	14,455	12,175	12,943	13,705	12,709	9,660	10,816	14,823	18,605	175,986
1993	12%	10%	9%	8%	7%	7%	8%	7%	5%	6%	8%	11%	100%
	23,042	21,624	18,374	14,889	11,551	13,805	13,712	13,691	9,387	10,563	12,931	16,662	180,231
1994	13%	12%	10%	8%	6%	8%	8%	8%	5%	6%	7%	9%	100%
	23,149	20,308	22,055	18,230	16,425	12,301	16,809	16,588	11,336	13,673	16,279	22,432	209,585
1995	11%	10%	11%	9%	8%	6%	8%	8%	5%	7%	8%	11%	100%
	22,213	17,619	20,685	17,134	14,205	12,257	12,459	12,079	8,830	10,151	12,865	18,053	178,550
1996	12%	10%	12%	10%	8%	7%	7%	7%	5%	6%	7%	10%	100%
	26,687	22,455	20,884	15,194	14,125	13,383	16,419	14,855	14,478	14,188	19,325	24,336	216,329
1997	12%	10%	10%	7%	7%	6%	8%	7%	7%	7%	9%	11%	100%
	21,501	18,456	16,276	11,880	10,425	9,114	13,215	11,729	12,410	10,107	14,533	19,965	169,611
1998	13%	11%	10%	7%	6%	5%	8%	7%	7%	6%	9%	12%	100%
	19,987	21,433	19,281	12,657	9,739	11,721	9,366	11,863	10,192	11,172	13,814	20,488	171,713
1999	12%	13%	11%	7%	6%	7%	6%	7%	6%	7%	8%	12%	101%
	22,018	21,800	16,180	14,521	12,951	11,359	11,720	12,328	11,707	11,451	14,895	24,896	185,826
2000	12%	12%	9%	8%	7%	6%	6%	7%	6%	6%	8%	13%	100%
	28,937	21,287	18,849	13,939	11,492	10,242	10,373	10,282	9,031	10,329	12,487	20,466	177,714
2001	16%	12%	11%	8%	6%	6%	6%	6%	5%	6%	7%	12%	100%
	28,076	22,042	21,054	15,635	12,551	11,431	11,447	12,042	10,586	13,108	NA	22,819	180,791
2002	16%	12%	12%	9%	7%	6%	6%	7%	6%	7%	NA	13%	100%
Monthly Average (1989 - 2002)	12.84%	11.04%	10.14%	8.10%	6.74%	6.46%	7.11%	6.82%	5.71%	6.16%	8.02%	11.52%	1.007
Estimated Monthly Consumption	47,968	41,233	37,874	30,266	25,180	24,115	26,554	25,474	21,335	23,014	29,963	43,036	376,012

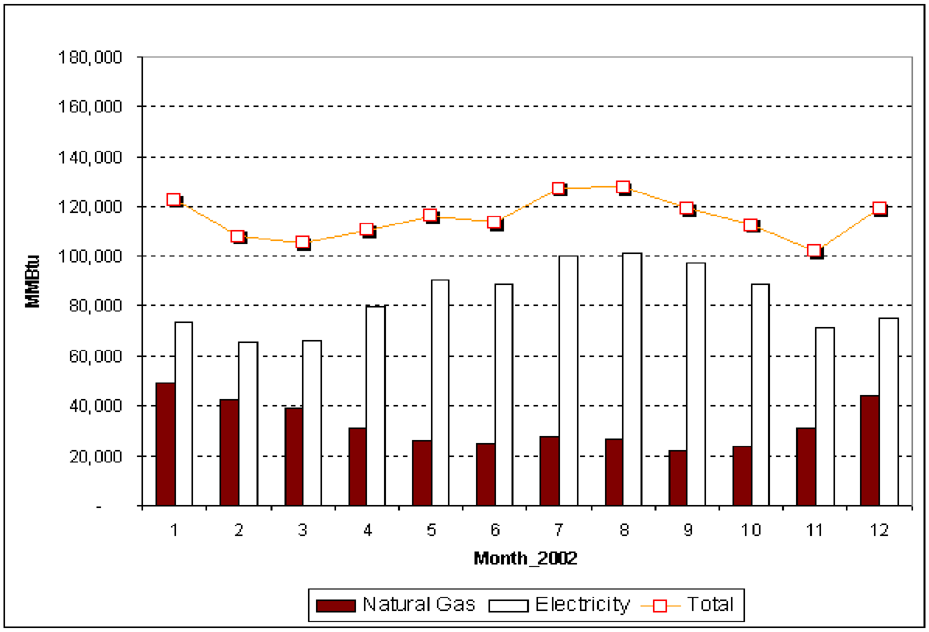


Figure 5-12: The Commercial Sector's Energy Use.

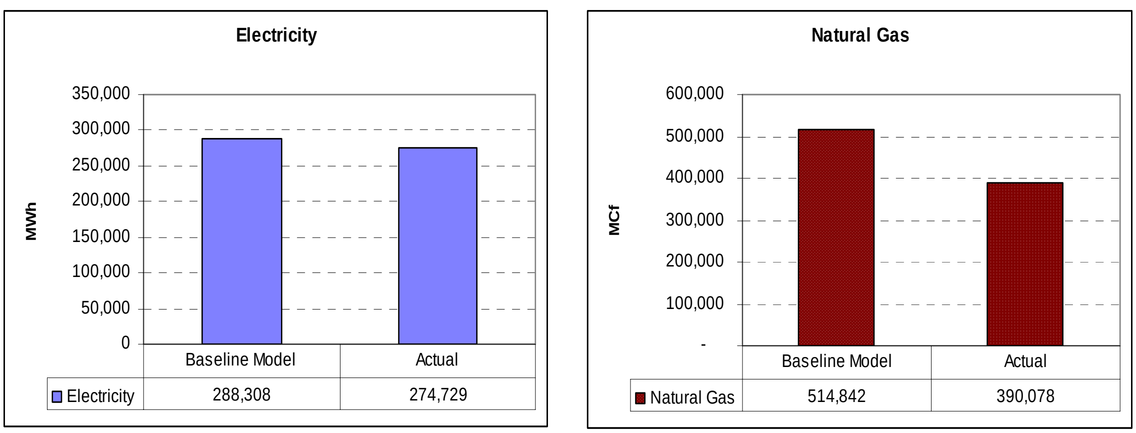


Figure 5-13: Comparison of Baseline Model with Actual Consumption in the Commercial Sector.

5.3.3 Municipal Sector Energy Use Analysis

The base year's (2002) energy use from the municipal sector is discussed in this section. First, the energy consumption from the municipal sector was estimated using several energy estimation methods. As described in Chapter IV, the municipal sector was first sub-categorized into the seven detailed parcels: 1) city-owned municipal buildings, 2) educational buildings owned by the local Independent School District (ISD), 3) streetlights, 4) traffic lights, 4) the water supply system, 5) the waste water treatment system, and 7) community parks & recreation facilities.

To estimate the total energy consumption, a significant effort was made to collect actual consumption data. One necessary task was to collect utility bill information from College Station Utility Customer Service (CSUCS). This body of data was already categorized according to the definitions that were used in this study and was available in electronic form. This is because the CSUCS maintains utility accounts and issues utility bills for each municipal facility. For instance, all city and school accounts are categorized into the rate that applies to their usage, which can be small, medium or large commercial categories depending on the load. Next the total number of buildings or facilities in each parcel was then determined. Then their annual electricity data were collected. Each building's electricity consumption was then summed to estimate the total electricity consumption.

Table 5-28 represents the parcel's electricity use and total electricity use of the municipal sector. The estimated total electricity use of the municipal sector in 2002 was approximately 36 million kWh.

Figure 5-14 shows each parcel's electricity use and its distribution to the municipal sector's total electricity consumption. In the municipal sector, the largest electricity consumer was the educational building parcel (College Station ISD). Its annual electricity consumption was approximately 16 million kWh. This value represents approximately 45 % of the total municipal sector's electricity consumption. The second largest electricity consumer was the wastewater treatment system. Its annual electricity consumption was approximately 5.9 million kWh, which represents 17 % of the total municipal sector's electricity use. The characteristics of each parcel's energy use are described in the following sections.

Table 5-28: Annual Electricity Consumption of the Municipal Sector.

Parcel	2002 Electricity Use			
	Energy Users	Consumption (KWh/yr)	Consumption (MMBtu)	Distribution (%)
Municipal Bldgs.	14 Municipal Buildings	4,637,180	15,822	13%
Streetlights	1,557 Streetlights	2,695,931	9,199	8%
Traffic Signals	50 Traffic Signals	937,754	3,200	3%
Water Supply	3,49 billion gallons of water production in 2002	2,906,610	9,917	8%
Wastewater Treatment	Two Waste-Water Treatment Plants	5,925,200	20,217	17%
Community Parks & Recreation	418.80 acres of parkland	2,120,194	7,234	6%
College Station ISD	9 schools, administration buildings, athletic facilities, bus barn	16,345,113	55,770	46%
Total		35,567,982	121,358	100%

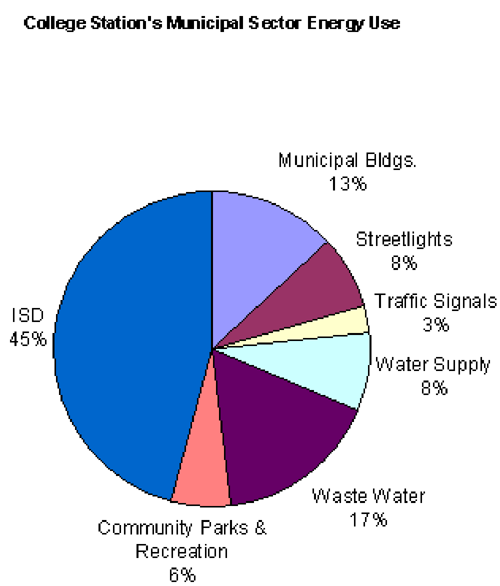


Figure 5-14: Municipal Sector Electricity Use for the City of College Station.

5.3.3.1 Educational Buildings and Facilities Energy Consumption

In 2002, the College Station ISD (CSISD) operated 16 educational buildings and facilities. These included nine school buildings, various administration buildings, athletic facilities, and a school bus barn. The annual electricity consumption in 2002 was approximately 16.3 million kWh, which represents 45 % of the total municipal sector's electricity consumption, the largest electricity end-use in the municipal sector. Figure 5-15 shows the total monthly electricity for College Station ISD. The data indicate that the electricity use during the month of June and July were reduced by the summer breaks.

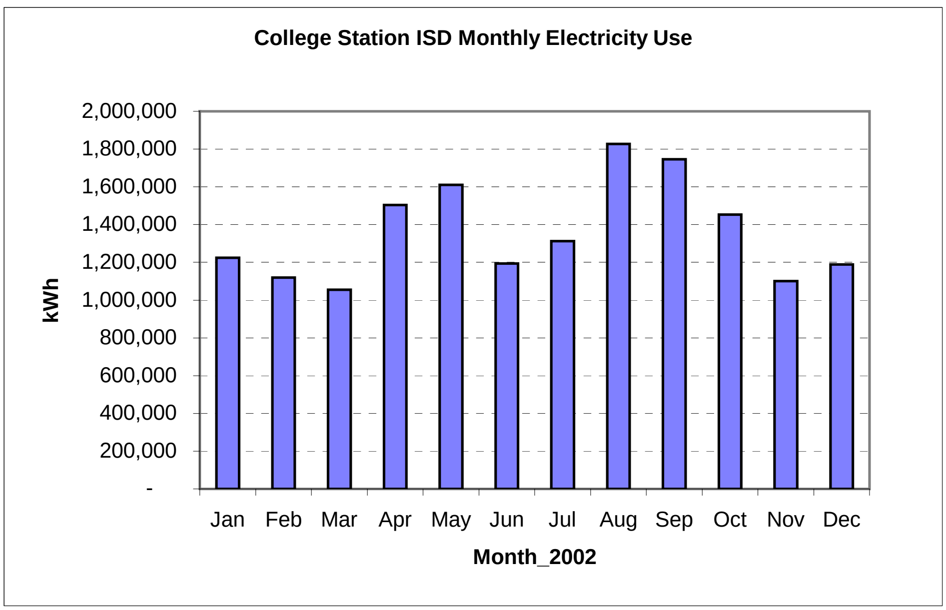


Figure 5-15: College Station ISD Monthly Electricity Use.

5.3.3.2 Municipal Building Energy Consumption

The City of College Station owns and operates 14 public buildings. These include city hall, the courthouse, a police station, fire stations, a public library, a conference center, several buildings used for the utility department, and the public works department. The annual energy electricity use for the municipal buildings was approximately 4.6 million kWh, which presents 13 percent of the total municipal sector's electricity use, the third largest electricity consumption in the municipal sector's energy use.

In Figure 5-16 the monthly electricity use data shows the electricity use peaks during the summer cooling season. However, electricity use during the non-cooling months represents almost 60% of the summertime use.

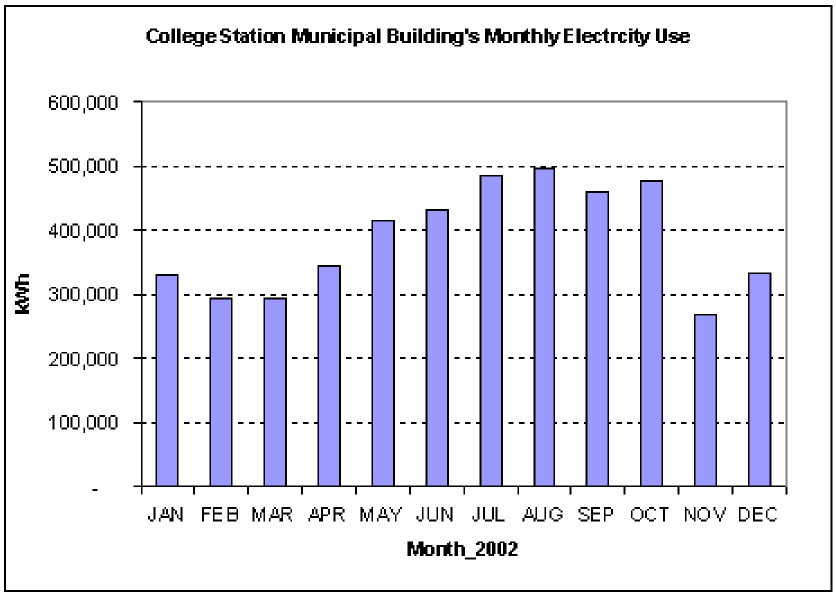


Figure 5-16: Monthly Electricity Use for City of College Station's Municipal Buildings.

5.3.3.3 Streetlight Energy Consumption

Although detailed street lighting calculations and design considerations are beyond the scope of this study, a simple calculation is provided in this section to determine energy use. To analysis this, three tasks were needed. The three tasks are included: 1) determination of number of lights, 2) determination of power density, and 3) determination of operating hours.

According to the information provided by the CSUCS (Albright 2003), the number of fixtures being used increased according to the development of the community area, total number of lights was increased from 2,290 (January 2003) to 2,754 (December 2003). Table 5-29 shows the monthly average number of lighting fixtures being used in College Station at the time of this study. The number of streetlight fixture continually increased with the expanding city limit stretching both roadways and streets. In College Station three different types of lighting fixtures were being used at the time of this study. The lighting fixtures were 400 watt, 250 watt, and 100 watt high-pressure sodium (HPS) lamps.

Table 5-29: Number of Streetlights and Power Density.

Fixtures	100	200	400	Decorative Lights	Total
Power Density (Watt)	101	250	439	250	
Jan	955	668	426	241	2,290
Feb	955	668	447	254	2,324
Mar	952	725	444	356	2,477
Apr	984	728	445	360	2,517
May	984	728	445	360	2,517
Jun	1030	741	446	360	2,577
Jul	1059	738	445	360	2,602
Aug	1080	722	463	360	2,625
Sep	1084	722	463	360	2,629
Oct	1090	756	477	360	2,683
Nov	1138	756	480	360	2,734
Dec	1146	757	480	360	2,743

Operating hours were determined by using actual solar radiation data taken from the Energy Systems Laboratory's database. An hourly global solar radiation was measured on the roof of the Zachry Engineering Building at Texas A&M University in College Station. The hourly solar radiation data was categorized into either day (monthly diurnal period) or night (monthly nocturnal period) to determine operating hours. In the body of data if an hourly data is over "0" it represents daytime, if an hourly data is less than "0" it represent night. The hourly data was then added by the period of each month. Table 5-30 shows the determined monthly daytime hours and night hours of College Station during the year 2002. The estimated monthly operating hours varied depended upon month to month.

Both the estimated monthly electricity consumption and the actual monthly electricity consumption are shown in Figure 5-17. The calculated 2002 annual electricity consumption of streetlights was 2.6 million KWh. This value represents approximately 8 % of the municipal sector's total electricity consumption. The estimated annual electricity use of streetlights agrees with the actual electricity use of 2.7 million kWh. Only 2% of variation was shown in Figure 5-18.

Table 5-30: Estimated Monthly Daytime and Night Hours.

Month	Day	Night	Total	% of Night
Jan	296	448	744	60%
Feb	298	374	672	56%
Mar	343	401	744	54%
Apr	368	352	720	49%
May	401	343	744	46%
Jun	400	320	720	44%
Jul	406	338	744	45%
Aug	385	359	744	48%
Sep	354	366	720	51%
Oct	307	437	744	59%
Nov	304	416	720	58%
Dec	280	464	744	62%
Total	4,142	4,618	8760	53%

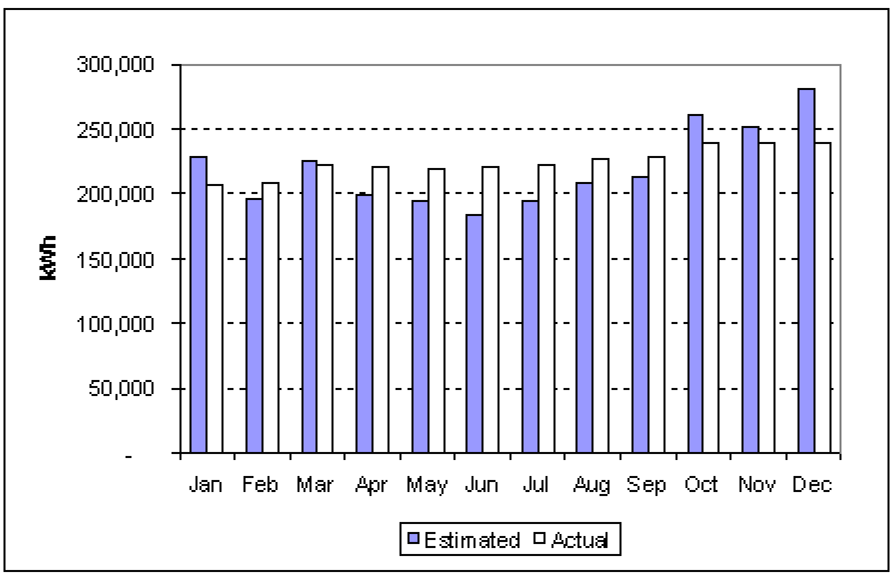


Figure 5-17: Monthly Electricity Consumption by Streetlights in College Station.

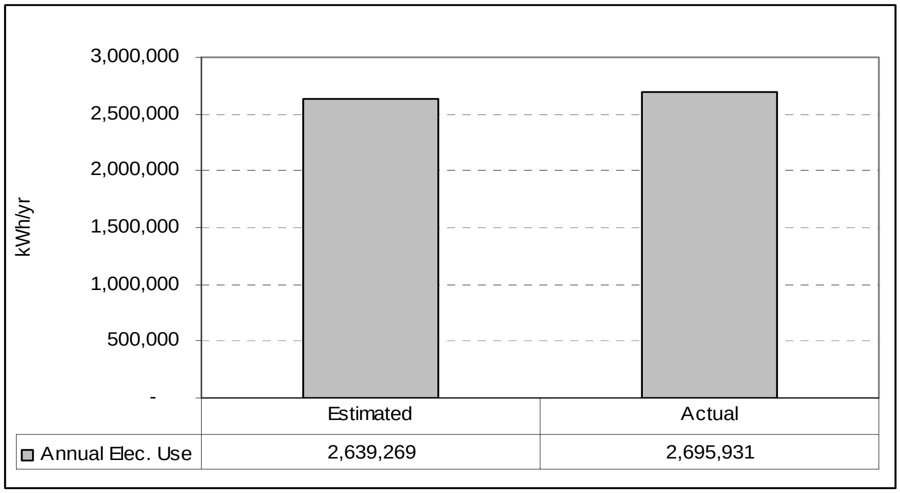


Figure 5-18: Comparison Between Estimated and Actual Electricity Use.

5.3.3.4 Traffic Lights

In the City of College Station, a total of 50 traffic signal fixtures were operated to control traffic in 2002 at the time of this study. The monthly electricity consumption for each traffic signal was constant during the year. However, the consumption for each traffic signal significantly differed because the capacity of each traffic signal varied based on the traffic volume and street type. The traffic lights at busier intersections uses more signal modules than less frequented intersections. The 2002 annual electricity consumptions for traffic lights was 0.9 million kWh. The annual average electricity consumption per intersection was approximately 19,987 kWh, which represents constant 2 kW load of. This represents approximately 3 percent of the total municipal sector's electricity use.

5.3.3.5 Water Supply

In the City of College Station, the total potable water produced in 2002 was 3.49 billion gallons, with one ground storage facility and two elevated storages. The capacity for grounded storage was 8 million gallons. One elevated-storage could hold 3 million gallons, and another elevated storage could hold 2 million gallons. The motors used in the water station were two 10,000 gpm, one 9,000 gpm and one 6,000 gpm. The summer peak demand was 21 million gallons and the average daily demand was 9,69 million gallons.

The annual electricity consumption from July 2002 to June 2003 was approximately 2.9 million kWh. This value represents approximately 15% of the total municipal sector's electricity use. Figure 5-19 shows that the water supply electricity consumption was relatively high during the summer season. The more significant factor for the increase in water consumption and its associated electricity use tend to be the number of customers, as shown in Figure 5-19. In the City of College Station, many residents are university students, who leave during the summer and winter breaks. Therefore, one possible indicator of use in the number of utility customers, in the case of College Station water supply electricity use peak is September, which is often in the ozone episode season.

5.3.3.6 Wastewater Treatment Plants

The City of College Station operates two wastewater treatment facilities, the Carter's Creek Wastewater Treatment Plant and the Lick Creek Wastewater Treatment Plant, that treat wastewater and return clean water back to receiving streams. The Lick Creek Plant was expanded in 2002 from its original 0.5 million gallons per day (MGD) to a 2.0 MGD capacity. The Carter's Creek facility is comprised of four separate running plants that eventually dispose of treated water to the same effluent release. Most of College Station's wastewater operations occur at the Carter's Creek plant. The annual electricity consumption from July 2002 to June 2003 was 5.9 million kWh, which represents approximately 17% of the total municipal sector's electricity use. The electricity consumption of wastewater treatment systems also varies, month to month. Figure 5-19 also shows that the wastewater treatment electricity consumption was relatively high during the month, which has high precipitation rate. For instance, the electricity use of the water supply station was high on May, while the electricity use of the wastewater treatment was lower as compared to that of other month. Therefore, the monthly precipitation rate was plotted in Figure 5-19 to find out what possible factor in affecting an energy use of wastewater treatment plant. The more significant factor for the increase in the capacity of water treatment and its associated electricity use tend to be the precipitation rate. From the comparison, those two plots also shows that the electricity use during the period from April to June, when the precipitation rate relatively smaller than that of other months, has large water supply electricity due to increasing water use to feed residents' and business owners' lawns. Therefore, one of possible options for College Station to reduce community's energy use is a water conservation program.

Figure 5-19: Monthly Electricity Consumption of the City of College Station's Water Supply Stations and Wastewater Treatment Plant.

5.3.3.7 Community Park & Recreation

According to the City of College Station (COCS 2003), a total of 418.80 acres of parkland are provided for residents in College Station (an average of 7.22 acres of parkland and open space per 1,000 population excluding regional parks). College Station is also divided into park zones for the purpose of existing and Future Park planning. Eleven park zones currently exist, with a total of 17 zones being identified for future needs. A total of 32 parks currently exist in College Station with 31 developed and one undeveloped.

The community park and recreation parcel includes shelters, picnic facilities, playgrounds, ponds, the city cemetery, tennis courts, pools, and athletic complexes. The annual electricity use for this parcel in 2002 was 2.1 million kWh. This represents approximately 6% of the total municipal sector's electricity use. Among them, the primary amount of electricity was consumed by the aquatic complex (swimming pool) and the community recreation center.

The energy use characteristics of each facility varied because each facility conducts their own community activities. For instance, athletic complexes typically consume electricity for filed lighting activities such as softball, baseball and soccer.

The pattern of electricity use in swimming pools showed that electricity use during the summer season was much higher than during the winter season. The swimming pool facilities were closed during the winter season. Figure 5-20 shows the monthly electricity use of total of all community parks and recreation facilities.

Figure 5-21 shows the monthly electricity use of the municipal sector by various parcels. The various parcels can be combined into two groups: 1) seasonal-dependant group and 2) yearly constant use group. The seasonal-dependant group includes the parcels of building (CS ISD & municipal building), water supply and wastewater treatment. The yearly constant use group included the parcels of the streetlights and the traffic lights. Figure 5-21 shows that the biggest electricity user was College Station ISD, which would be the best opportunity, if one adopt energy efficiency measure to reduce the municipal sector's energy use. The monthly total use shows that the electricity use peak is August and September, which is often in the ozone episode season.

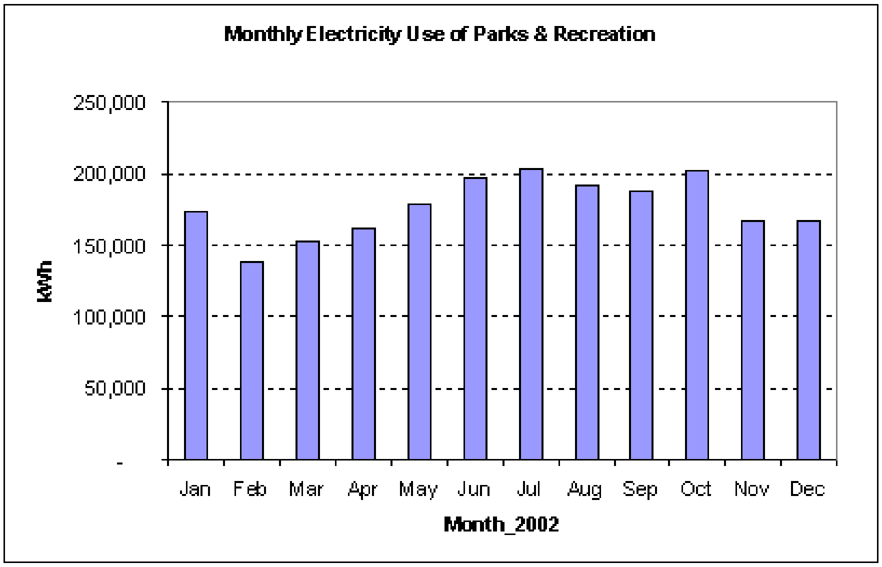


Figure 5-20: Monthly Electricity Use of Community Parks & Recreation.

5.3.4 Calculation of Transportation Sector Energy Use

Various information sources were used to calculate the transportation sector's energy use. Sources for on-road groups included the Texas Department of Transportation (TxDOT) traffic study for the Brazos County (TxDOT 2003) and vehicle registration data provided by contacting the transportation representatives of the City of College Station (COCS 2003).

The total number of vehicles registered in the county 2001 was 109,333. That represents approximately 1.1% of the total Texas registered vehicles (13.8 million) in the state of Texas (TxDOT 2001). From this, the number of vehicles in College Station was assumed by proportioning the total vehicles according to College Station's population. The total population of Brazos County was 152,415, and the population of College Station was 67,890. Therefore, the assumed number of vehicles in College Station was 48,635.

The Daily Vehicle Miles (DVM) data was obtained from the TxDOT (Fogle 2003). Table 5-31 shows the results of the daily values for Brazos County's vehicle miles traveled in 2002.

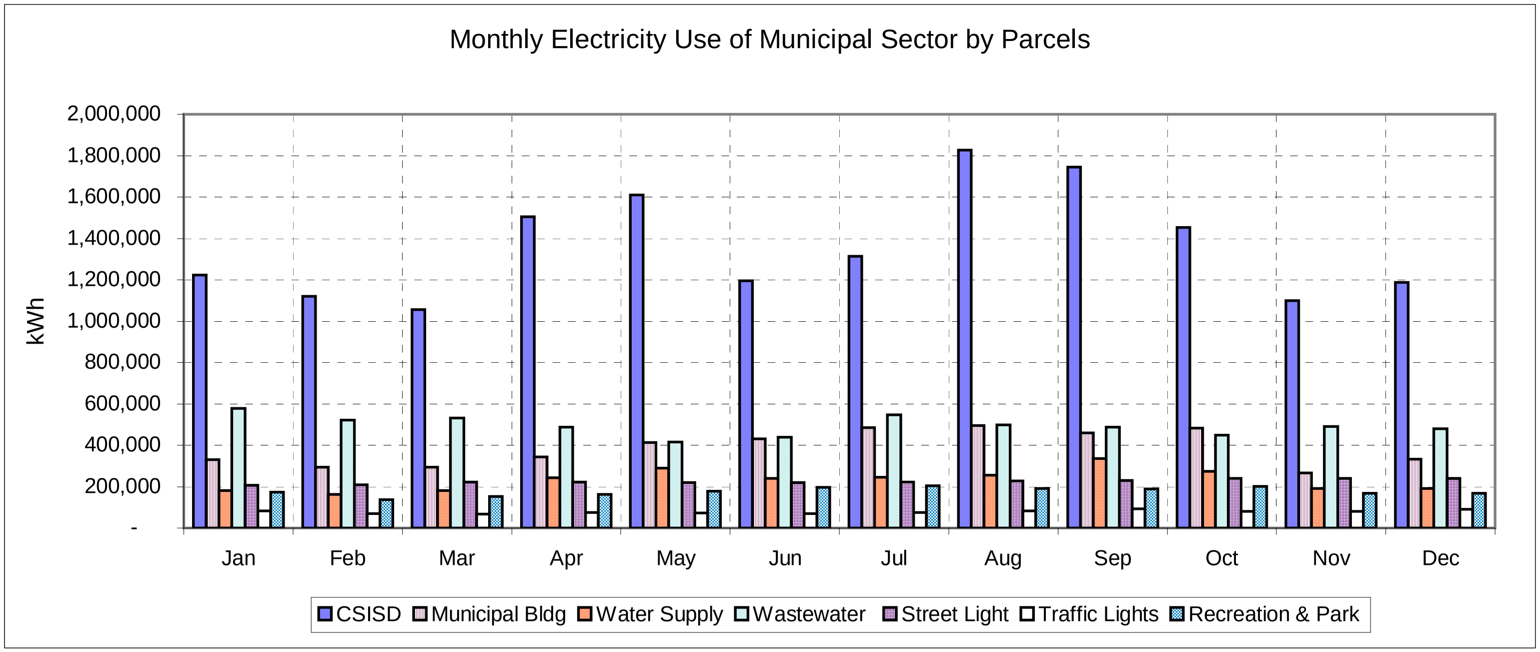


Figure 5-21: Monthly Electricity Use of the Municipal Sector by Parcel.

Table 5-31: Estimated Daily Vehicle Miles (DVM) for the Brazos County, TX.

County		IH	US, UA, UP	SH, SS, SL,BUS RTS	FM, RM, RR	PA, PRK,REC	FRONTAGE ROADS	HIGHWAY SUBTOTAL	DESG LOC MAIN	CITY STREETS	CERTIFIED COUNTY ROADS	OFF-SYS NON-CNTY MAINT	GRAND TOTAL
Brazos	CTR	0	23	99	152	0	38	312	2	586	453	3	1,355
	LAN	0	63	322	365	0	75	825	8	1,196	907	5	2,940
	DVM	0	228,216	1,296,777	897,485	0	70,415	2,492,893	22,105	1,081,280	40,239	207	3,636,724

Note: CTR: Centerline Miles, LAN: Lane Miles, DVM: Daily Vehicle Miles, IH: Interstate Highways, US: US Highways, UA: US Alternate Hwy, UP: US Highway Spur, SH: State Highways, SS: State Hwy Spur, SL: State Hwy Loop, BUS RTS: Business Routes, FM: Farm to Market Roads, RR: Ranch to Market Roads, RR: Ranch Road, PA: Principal Arterial Street System, PRK: Park Roads, REC: Recreation Roads, and DESG LOC MAIN: Designated Local Maintenance.

Source: Fogle 2003: This TxDOT table was obtained through Mr. Ken Fogle (Transportation Planner of COCS).

Unfortunately, direct DVM data for College Station was not available. Only countywide (Brazos County) data was available. Therefore, College Station's DVM was determined by using the same fraction (45%) to estimate vehicle number. From this analysis, the estimated DVM for College Station was 1,619,901. The annual VMT per vehicle was 12,141 miles. A daily vehicle mile per vehicle was approximately 33.2 miles. Table 5-32 represents the results of the estimated VMT for College Station.

Table 5-32: Results of the Estimated VMT for College Station.

Brazos County			College Station				
Population	Registered Vehicle Number	Daily Vehicle Miles (DVM)	Population	Registered Vehicle Number	Daily Vehicle Miles (DVM)	Annual VMT	Annual VMT per Vehicle
152,415	109,333	3,636,724	67,890	48,700	1,619,901	591,263,821	12,141

To determine the number of vehicles by type, vehicle classifications were determined by conducting "snap-shot check," because the average vehicle classification data for College Station was not available at the time of this study. This snap-shop check count consisted of several one-time counts in public parking lots (i.e., shopping centers, grocery stores, and the university) and on major streets; it was conducted in order to determine a representative value of vehicle classifications for College Station. Table 5-33 shows the results of the instant counting of the four public places. Distribution (%) of each vehicle type in the various counting places shows similar results. Light trucks, which included pickups, vans, sports utility vehicles, and other light trucks, made up the largest share (50 %) of the vehicle fleet. It was suggested that the energy use of on-road vehicles in College Station might be large due to significantly lower fuel economy ratings of light trucks versus than passenger cars. Passenger cars made up the second largest share (48 %) of the vehicle fleet.

The VMT mix was determined by a simple multiplication of total registered vehicles (Table 5-32) by vehicle classification (Table 5-33). Table 5-34 shows the resultant VMT mix. The total energy used by on-road vehicles was determined by a simple multiplication of the VMT Mix per each vehicle type (Table 5-34) times the energy intensity (in gallons/mile). Energy intensity (mpg) was determined using data from the 2002 National Transportation Statistics provided by U.S. BTS (2003). The average fuel efficiency of U.S. passenger cars and light trucks was used for this study. Table 5-34 shows the estimated fuel use by vehicle type and total fuel use for both daily and annual values.

On-road vehicles in College Station used approximately 30 million gallons of fuel (gas and diesel). Among them, light trucks account for the largest vehicle fuel use (17 million gallons), 57% of the total fuel use. Passenger cars used nearly 13 million gallons of fuel, 42% of the total fuel use.

Table 5-33: Summary of Vehicle Classifications by "Snap-Shot Check".

Vehicle Type		Vehicle Counting by Place								Total	
		TAMU Parking Lot P 51		Texas AVE		HEB Parking Lot		Post Oak Mall Parking Lot			
		Number	Distribution (%)	Number	Distribution (%)	Number	Distribution (%)	Number	Distribution (%)	Number	Distribution (%)
Passenger Cars		876	50%	213	41%	52	42%	364	48%	1505	48.1%
Light Trucks	Trucks	597	34%	187	36%	42	34%	242	32%	1068	34.1%
	SUV	264	15%	84	16%	26	21%	113	15%	487	15.6%
	Van	5	0%	21	4%	3	2%	32	4%	61	1.9%
Bus		0	0%	5	1%	0	0%	0	0%	5	0.2%
Motorcycle		0	0%	4	1%	0	0%	0	0%	4	0.1%
Total		1742	100%	514	100%	123	100%	751	100%	3130	100.0%

Table 5-34: Result of Estimated VMT Mix and Fuel Use in College Station.

Vehicle Type		Total Registered Vehicle	Number of Vehicle by Type		VMT		Fuel Use	
			Distribution	Number of Vehicles	Total Daily VMT (DVM)	VMT MIX	Fuel Efficiency (mpg) 2001*	Daily Fuel Use (gallons)
Passenger Cars		48,700	48.08%	23,415	1,619,901	778,848	22.1	35,242
Light Trucks	Trucks		34.12%	16,616		552,710	17.6	31,404
	SUV		15.56%	7,578		252,057	17.6	14,321
	VAN		1.95%	950		31,588	17.6	1,795
BUS			0.16%	78		2,592	6.7	387
Motor Cycles			0.13%	63		2,106	50	42
Daily Total				48,700		1,619,901		83,191
Annual Total (Daily Total x 365 days/year)						591,263,865		30,364,763

5.3.4.1 Comparison of Estimated Energy Use with the Results from the Actual Fuel Use

Unfortunately, direct information of vehicle fuel (gas and diesel) consumption in College Station was not available to cross-check the estimated values. Therefore, alternative methods were needed to verify the energy use determined by CCNERT methodology. To accomplish this several methods were utilized specifically, converting the gross sales (dollar amount) of fuel into the appropriate values of energy. To accomplish this task, additional information was necessary. The information included the gross sales of fuel (dollar amount), fuel price (dollars per gallon), and conversion factor (Btu per gallon).

To determine the annual (2002) gross sales of fuel, gas stations located within the community boundary were contacted. However, the data were not available because gas companies did not want to allow their gross sales to be open to the public. Therefore, the U.S. Census's Economic data was used to determine College Station's gross sales for gas stations. Unfortunately, only the 1997 gross sales data for "gas station/convenience stores" located in College Station, TX, were available at this time. Figure 5-22 represents the 1999 gross sales information obtained from the U.S. Census's web site. The 1997 gross sales by gas stations were approximately $45 million dollars (U.S. Census 1999).

Source: U.S. Census 1999.

Table 4. **Summary Statistics for Places: 1997**—Con.

[Includes only establishments with payroll. For meaning of abbreviations and symbols, see introductory text. For explanation of terms, see Appendix A. For information on geographic areas followed by *, see Appendix D]

NAICS code	Geographic area and kind of business	Establishments (number)	Sales ($1,000)	Annual payroll ($1,000)	First-quarter payroll ($1,000)	Paid employees for pay period including March 12 (number)	Percent of sales—	
							From administrative records[1]	Estimated[2]
	COLLEGE STATION, TX—Con.							
44-45	Retail trade—Con.							
447	Gasoline stations	28	45 009	2 912	639	198	9.9	9.4
4471	Gasoline stations	28	45 009	2 912	639	198	9.9	9.4
44711	Gasoline stations with convenience stores	22	D	D	D	c	D	D
447110	Gasoline stations with convenience stores	22	D	D	D	c	D	D
44719	Other gasoline stations	6	D	D	D	b	D	D
447190	Other gasoline stations	6	D	D	D	b	D	D

Figure 5-22: College Station's 1997 Gross Sales of Gas Stations.

One additional assumption needed to be made before converting the cost data to energy unit, because this information was for 1997 instead of 2002. Therefore, College Station's annual population growth rate (3.4%) during the period 1997 and 2002 (COCS 2003) was used to project the data to the current gross sales. This analysis provided that the 2002 gross sales of gas stations would be $54 million dollars. However, this information represented the specific dollar amount for fuel (gasoline and diesel) sales and other sales (i.e., food, goods, and beverages, etc.).

Therefore, informal interviews with several owners and employees in selected gas stations were conducted in order to breakdown the total sales into fuel and other sales. According to the interviews, approximately 70% of the gross sales were from fuel sales, and 30% were other types of sales. It was also determined from the interviews that the fuel sales were approximately 90% were gasoline and 10% were diesel.

The Texas average retail fuel prices for base year (2002) were also determined based on data from the EIA's average gasoline prices in Texas (Table 5-35). Total fuel use was calculated by multiplying the 2002 gross sales from gas stations ($54 million dollars) times the distribution of fuel sales (70%). Average gasoline prices ($1.36 per gallon) were then applied to convert the dollar amount of fuel sales into the fuel consumption (in gallons). From this calculation, the total fuel consumption could be estimated as 27.8 million gallons of fuel, which was further divided into 25 million gallons for gasoline, and 2.8 million gallons for diesel. Finally, the energy conversion factors (125.07 kBtu/gallon of gasoline and 138.69 kBtu/gallon of diesel) were applied to determine the energy use. The total annual energy use of on-road vehicles was 3.4 million MMBtu.

It is interesting to compare the results of both approaches (VMT analysis vs. Gross Sales analysis) to see whether the results are comparable. In Figure 5-23, the total fuel consumption is presented for each of the two approaches. The results show only a 10% variation. It can therefore be concluded that, although the differences between the two approaches cannot be fully explained or quantified, either approach can be used to determine a community's on-road vehicle energy use based on local information availability.

5.4 SUMMARY OF EACH SECTOR'S ENERGY USE

This chapter discussed each sector's energy use estimated using the Comprehensive Community NOx Emissions Reduction Tool (CCNERT) methodology for the case study community of College Station. To estimate each sector's energy use, the community audit was first conducted. The community audit included the collecting of general community characteristics, land use characteristics, utility characteristics, as well as a population profile, housing profile, and a business pattern profile. This chapter also discussed what information should be needed and how to collect, count, and classify them.

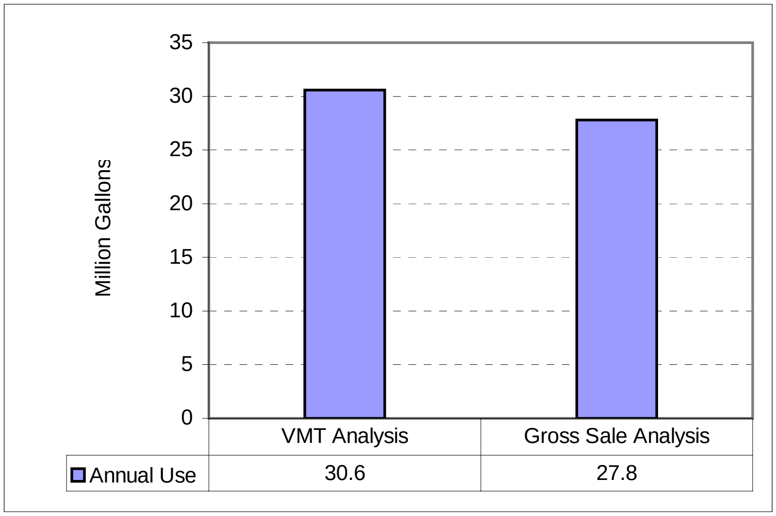


Figure 5-23: Comparison Between VMT Analysis and Gross Sale Analysis.

In the residential sector's energy use, the sector was classified into four different housing types (SFD, SFA, MF, and MH). The procedures to determine the representative value of energy use for each housing type were also demonstrated by using the sampling techniques with IMT Analysis. This procedure included the selection of the sample houses, the determination of housing characteristics as well as average conditioned area. Finally, a comparison of the results of the Normalized Annual Energy Consumption (NAC) to the actual energy use was demonstrated to see the results are reasonable.

In Commercial sector, various information sources were used to estimate the sector's energy use. The U.S. Census's Business Pattern was used to determine the number of employees by building activity types. The EIA's 1999 CBECS (EIA 2001a) was used to determine the each building activity's conditioned floor area (ft^2) and energy intensity (kWh/ ft^2 or MCF/ft^2). The annual electricity and natural gas use for each building activity was then estimated by multiplying the total floor area for each energy group times the corresponding energy intensity index. A utility bill analysis was also conducted to compare the estimated energy use from the CCNERT to that from an actual energy use in selected building activities.

Although the procedure of estimating the industrial sector was developed in the Chapter IV, the procedure was not demonstrated in this chapter due to the selected community's low level of industrial activity.

Municipal sector was sub-categorized into the seven parcels. Individual buildings or facilities were then grouped into one of seven parcels. Utility bill information of individual building and facilities were provided from the CSUCS. One cross-check analysis of streetlights parcel was conducted to see whether the estimated resultant are comparable. The comparison showed that the estimated annual electricity use agrees with the actual electricity use by 2% of variation.

Transportation sector energy use was estimated using the VMT analysis. One-time counts in public parking lots and one major street were performed to determine a representative value of vehicle classifications for selected community. A procedure of converting the gross sales (dollar amount) of fuel into the appropriate values of energy was performed to verify the transportation sector's annual energy use estimated by the CCNERT methodology. The comparison showed 10% of variation.

In the next chapter (Chapter VI), the NOx emissions estimated by applying the CCNERT methodology to the case study community will be described. Next chapter will also demonstrate how the methodology can be used to calculate NOx emissions reductions from several possible scenarios that offer energy savings.

Table 5-35: 2002 Average Gasoline Price of Texas.

Date	Texas Regular Conventional Retail Gasoline Prices ($/gal)	Texas Regular Reformulated Retail Gasoline Prices ($/gal)	Texas Regular All Formulations Retail Gasoline Prices ($/gal)	Texas Mid-grade Conventional Retail Gasoline Prices ($/gal)	Texas Mid-grade Reformulated Retail Gasoline Prices ($/gal)	Texas Mid-grade All Formulations Retail Gasoline Prices ($/gal)	Texas Premium Conventional Retail Gasoline Prices ($/gal)	Texas Premium Reformulated Retail Gasoline Prices ($/gal)	Texas Premium All Formulations Retail Gasoline Prices ($/gal)	Texas All Grades Conventional Retail Gasoline Prices ($/gal)	Texas All Grades Reformulated Retail Gasoline Prices ($/gal)	Texas All Grades All Formulations Retail Gasoline Prices ($/gal)
January	1.05	1.02	1.04	1.15	1.12	1.14	1.24	1.22	1.23	1.09	1.07	1.08
February	1.05	1.03	1.05	1.15	1.14	1.14	1.24	1.23	1.24	1.09	1.08	1.09
March	1.19	1.17	1.18	1.28	1.28	1.28	1.38	1.38	1.38	1.23	1.22	1.22
April	1.33	1.36	1.34	1.42	1.47	1.44	1.52	1.57	1.54	1.37	1.41	1.38
May	1.32	1.35	1.33	1.41	1.45	1.43	1.51	1.56	1.53	1.36	1.39	1.37
June	1.30	1.33	1.31	1.39	1.43	1.41	1.48	1.53	1.50	1.34	1.37	1.35
July	1.29	1.31	1.30	1.39	1.41	1.40	1.49	1.51	1.50	1.34	1.35	1.34
August	1.31	1.32	1.31	1.40	1.42	1.41	1.51	1.51	1.51	1.35	1.36	1.35
September	1.33	1.32	1.32	1.42	1.42	1.42	1.53	1.52	1.53	1.37	1.36	1.37
October	1.40	1.37	1.39	1.50	1.48	1.49	1.60	1.58	1.59	1.44	1.42	1.43
November	1.35	1.35	1.35	1.45	1.46	1.45	1.55	1.56	1.55	1.39	1.40	1.40
December	1.32	1.32	1.32	1.42	1.42	1.42	1.52	1.53	1.52	1.37	1.37	1.37
Annual Average	1.36											

Source: EIA 2004.

CHAPTER VI
APPLICATION OF THE METHODOLOGY
(NO_X EMISSIONS)

6.1 INTRODUCTION

This chapter summarizes the application of the CCNERT methodology to the case study community, and includes the results regarding to NOx emissions from College Station's energy audit for the base year, 2002.

This chapter consists of four sections. This chapter begins with the general discussion of the baseline energy consumption by fuel type. The second section briefly summarizes the NOx emissions. The third section future energy use and its associated NOx emissions of College Station are predicted with "business as usual". Then, possible energy efficiency scenarios were identifies and described according to 2002 baseline and future energy use. This section also demonstrates possible scenarios that offer energy savings and NOx emissions reductions of case study community. Finally, the results from the previous two processes are compared between and within both cases.

6.2 BASELINE ENERGY USE

The findings resulting from the community energy audit of College Station are summarized in this section. Table 6-1 categorizes the total energy use by sectors and fuel type. These values reflect the city's actual energy consumption during the year 2002. Only electricity, natural gas and transportation fuel use (gasoline and diesel) were considered for this study. The 2002 baseline energy consumption level for College Station was 6.4 million MMBtu. The energy consumption values are represented here as residential (1.6 million MMBtu), commercial (1.3 million MMBtu), municipal (0.9 million MMBtu), and transportation (3.4 million MMBtu). Of these, transportation accounted for approximately half (53%) the energy use, the residential sector accounted for 25%, the commercial sector accounted for 21%, and the industrial sector accounted for a negligible level of energy use.

Figure 6-1 shows a comparison of the energy use pattern of College Station against that of the U.S. and of Texas. The energy use distribution for the City of College Station is significantly different than the energy use patterns of the nation and Texas. Transportation consumes over 57% of the total delivered energy used in College Station, whereas it only represents 28% and 22% of the energy use for the US and Texas respectively. Based on a local survey (snap shot counting, shown in Table 5-32), the data indicates that residents in College Station possess a 10% greater share of light trucks (SUVs, minivans, pick up trucks) than Texas average (42%).

The residential sector accounts for the second largest portion of delivered energy use, accounting for nearly 26% of College Station's total energy consumption. The commercial sector accounts for the third largest portion, measuring 20% of College Station's total energy use. The industrial sector consumes only a negligible level of energy use in College Station, significantly less than the sectors' shares for Texas and U.S., reflecting the city's low level of industrial activity.

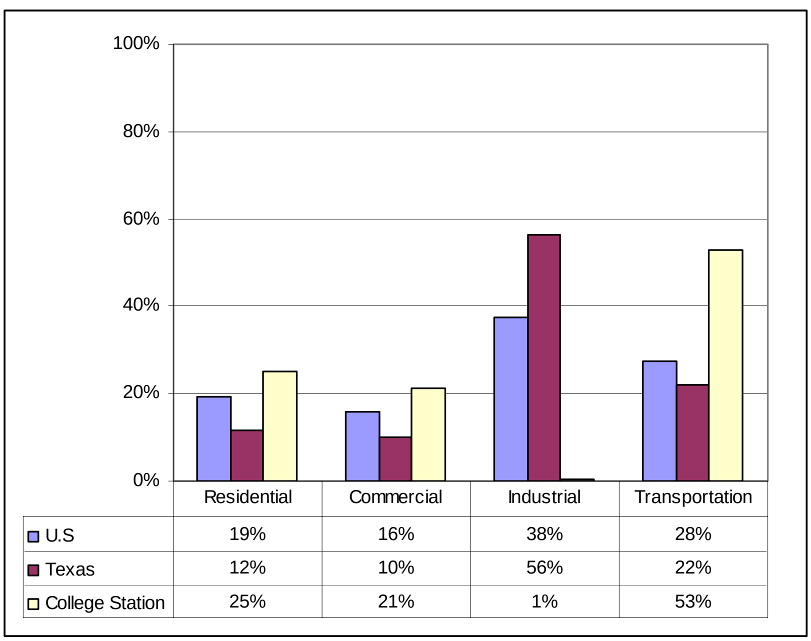


Figure 6-1: Comparison of Energy Use Distributed by Sector.

6.2.1 Electricity Use

The 2002 level of electricity consumption for College Station was 639,476,454 kWh. The energy consumption values are represented as residential (348,118,488 kWh), commercial (255,789,984 kWh), and municipal (35,567,982 kWh). Of these, residential consumption accounted for approximately one half (54%) the use, the commercial sector accounted for 40%, the municipal sector accounted for 6%, and the industrial sector accounted for negligible electricity use.

Table 6-1 shows that the annual electricity consumption per customer (household) in College Station was 13,355 kWh in 2002. This value indicated that house in College Station uses significantly high level of electricity consumption as compared to the 1997 RECS U.S average of 10,140 kWh (34.9 MMBtu), most likely due to the increased air-conditioning load in College Station, when compared to the rest of the U.S.

6.2.2 Natural Gas Use

The 2002 natural gas consumption for College Station was 840,153 MCF. The energy consumption values are represented as residential (450,075 MCF), commercial (373,580 MCF), and municipal (16,498 MCF). Of these, the residential use accounted for approximately one half (54%) the use, the commercial sector use accounted for 44%, and the municipal sector accounted for 2%.

Table 6-1 shows the total annual level of natural gas consumption per customer (household) in 2002 in College Station of 45.6 MCF. This value indicates that houses in College Station used a relatively low amount of natural gas as compared to the 1997 RECS shows that U.S average natural gas consumption per household of 85.3 MCF (EIA 1999), most likely reflecting the decreased heating load of the mild winter (1,866 HDD_{65}).

6.2.3 Gasoline & Diesel Use

The 2002 gasoline & diesel use for College Station was 30 million gallons. Most of that fuel was consumed by the on-road vehicles. Of these, gasoline use accounted for approximately 27 million gallons (90%) and diesel use accounted for 3 million gallons (10%).

Table 6-1: Summary Table of College Station Energy Consumption During 2002.

Sectors	Nat. Gas				Electricity				Gasoline & Diesel			Total	
	Number of Energy Users	Consumption		Distribution (%)	Number of Energy Users	Consumption		Distribution (%)	Total Registered Vehicle	Consumption		Consumption (MMBtu)	Distribution (%)
		MCF	MMBtu			KWh	MMBtu			Gallons	MMBtu		
Residential	10,165	450,075	463,577	54%	28,266	348,118,488	1,187,780	54%				1,651,358	24%
Commercial	746	373,580	384,787	44%	2,622	255,789,984	872,755	40%				1,257,543	18%
Industrial													0%
Municipal		16,498	16,993	2%		35,567,982	121,358	6%				138,351	2%
Transportation									48,700	30,364,763	3,837,195	3,837,195	56%
Total	10,911	840,153	865,358	100%	30,888	639,476,454	2,181,894	100%			3,837,195	6,884,446	100%
Distribution (%)	13%				32%				56%			100%	

Table 6-2: Summary Table of College Station Emissions Production During 2002.

Sectors	Nat. Gas				Electricity				Gasoline & Diesel		Total		
	CO2 117.08 lb/MMBtu	NOx 0.09 lb/MMBtu	VOC 0.00539 lb/MMbtu	SO2 0.00060 lb/MMbtu	CO2 1.493 lb/kWh	NOx 0.00295 lb/kWh	VOC 0.000048 lb/kWh	SO2 0.00396 lb/kWh	CO2	NOx	CO2 (ton)	NOx (ton)	Distribution (%)
Residential	27,138	21	1	0	259,870	565	2	689			287,008	586	29%
Commercial	22,525	17	1	0	190,947	415	1	506			213,473	432	21%
Industrial													0%
Municipal	995	1	0	0	26,551	58	0	70			27,546	58	3%
Transportation									298,975	953	298,975	953	47%
Total	50,658	39	40	0	477,369	1,038	994,115	1,266	298,975	953	827,002	2,030	100%
Distribution (%)		2%				51%				47%			

6.3 BASELINE NO_X EMISSIONS

The estimated total NOx emissions for College Station were calculated, by applying the appropriate emission factors based on the different fuel types, as summarized in Table 6-2. These values represent the estimated NOx emissions during the year 2002. Much of the NOx emissions' characterization in terms of its distribution is identical to that of overall energy consumption. The 2002 baseline NOx emissions for College Station were 2,030 tons per year, which represent residential (586 tons), commercial (432 tons), municipal (58 tons), and transportation (953 tons). Of these, transportation accounted for approximately one half (47%) the annual NOx emissions, residential sector accounted for 29%, the commercial sector for 21%, the municipal sector for 3%, and the industrial sector for a negligible level of NOx emissions.

NOx emissions by fuel type are also estimated in this study. Transportation fuels (gasoline and diesel) produced the largest portion (49%) of total annual NOx emissions in College Station when compared to that used for non-transportation fuel uses (natural gas & electricity). The second largest portion of NOx emissions is from College Station's electricity use, which accounts for 46% of the total NOx emissions. Interestingly, the NOx emissions from electricity use (its generation) were even greater than the NOx emissions from transportation fuel use when transmission and distribution losses (10%) were applied to the estimated electricity use. Furthermore, portion of these emissions occurred in remote counties.

6.4 PREDICTION OF FUTURE ENERGY USE

A simplified method is used to predict NOx emissions forecasts for each year from the base year (2002) through the target year (2007). A NOx emissions forecast is an estimate of the possible NOx emissions from total energy use within a selected community during the base year to the corresponding emissions levels in the target year, which given "business as usual" circumstances. This means that the model assumes that no energy efficiency measures will be implemented to reduce NOx emissions during the selected time periods. Thus energy consumption and its associated NOx emissions are expected to increase due to both population and economic growth. The model then generates the possible reduced level of energy consumption and NOx emissions with the assumption that measures can be implemented to reduce NOx production.

To accomplish this, the target year was first determined and the future energy demand for the selected target year was then calculated. Each sector's activity growth rate was used to calculate the future energy demand from all sectors. This analysis mainly relied on information obtained from historical local community development and the data provided by the EPA's EGAS software. For instance, future energy requirements for residential sectors were calculated based on an integrated relation between the historical population growth and the growth in the number of housing units. Future energy requirements for transportation were calculated based on the VMT growth factor provided by the EPA's EGAS software (Pechan, E.H. 2001).

6.4.1 Determination of Target Year

Generally, an emissions reduction target is a goal established by a community and its local government for reducing greenhouse gas emissions before air pollution level reach unreality levels. The reduction target is usually expressed as the percentage of emissions that will be reduced from the base year's emission total by the time the target year arrives (for example, the emission reduction target of the Texas government calls for a 9 % reduction from the 1990 greenhouse gas emissions by the target year 2007). Therefore, 2007 was selected as the target year for College Station, since Texas is required to meet various reduced emissions level by this date. However, there are cities with emissions reduction targets that simply try to stabilize NOx emissions from the base year to the target year. This effort suggests that there should be no net increases in NOx emissions by the target year, known as "zero emission growth."

6.4.2 Prediction of the Demand Energy Growth and Its Associated NOx Emissions Growth

As energy use in a community is strongly influenced by its population, the local community's activity and the city's historical and current development patterns regarding its population, economy, and housing units were first reviewed. Then, the appropriate growth rates for each energy sector were determined. This analysis was conducted through two approaches:

1) the Economic Growth Analysis System (EGAS) computer model and 2) a simplified method. Countywide (Brazos County) activity growth rate in each sector was predicted by utilizing the EGAS computer model (Pechan E.H. 2001), with the city's growth rate predicted based on various information sources.

6.4.2.1 Population Growth Rate

According to the City of College Station (COCS), the city's population has been steadily increasing. In fact, the city's most prolific decade was 1970-1980, when its annual growth rate was 11.1%, growing from 17,676 persons (1970) to 37,272 persons (1980). The high growth rate of the 1970's continued into the 1980's, with the city experiencing close to a 10% annual growth rate during the first three years of that decade. College Station's proximity to the University and to employment areas in the city of Bryan has had a significant influence on its growth. College Station's growth has continued to increase since the 1990 Census, although more modestly. The 1995 estimated population was approximately 58,000 people with an average annual growth rate of over 2.1% since 1990. Figure 6-2 details the city's population growth from 1900 to 2000.

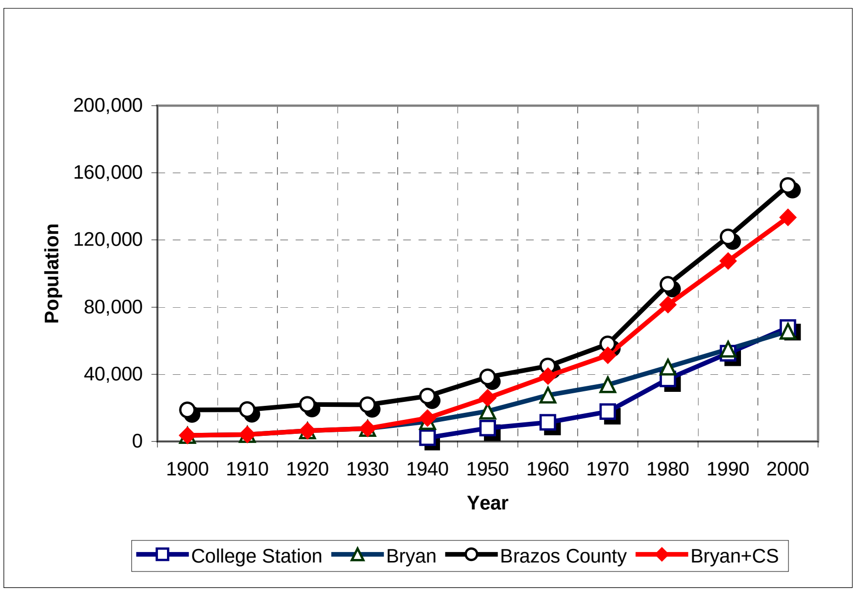


Figure 6-2: Historical Population Growth During the Period 1900-2000.

Table 6-3 projects the City's 20-year population within a more controlled growth environment. College Station's ability to serve all areas with substantial infrastructure and multiple utilities will determine its ability to grow (COCS 2003). Based on the 1989 Comprehensive Plan Update population analysis, a growth rate range of between 2% and 4% was determined to be realistic for the next 20 years in College Station. This growth rate assumption yields a range of 86,200 to 127,000 persons. This population range is used here as the basis for determining the city's future energy demands.

Table 6-3: Projected Population Growth - 1995-2015.

Year	Low	Mid.	High
	(2%)	(3%)	(4%)
1995	58,000	58,000	58,000
2000	64,000	67,200	70,500
2005	70,700	78,000	85,800
2010	78,000	90,400	104,400
2015	86,200	104,700	127,000

Source: COCS 2003

6.4.2.2 College Station Economic Growth Rate

In this study, two assumptions were made: 1) that economic growth could be presented in the form of an increase in employment; and 2) that economic growth could directly influence the commercial sector's energy demand. An employment growth rate (see Figure 6-3) was determined based on the level of employment during the period 1990-2002. A growth rate of 2.6 % was determined to be realistic for the next 20 years in College Station. This growth rate assumption yields 35,715 new jobs by 2007. The estimated level of employment is used here as a basis for determining the future energy demand for both the commercial and the industrial sectors.

6.4.2.3 Housing Units Growth Rate

The 2.7 % annual growth rate of the number of housing units is driven by population, though some variation does occur depending upon housing type as summarized in Table 6-4. The 2000 share of single-family detached units in total housing unit increased, while the 2000 share of multi-family units in total housing unit decreased as compared to that of the 1990.

The growth rate also varied according to different fuel types. According to the NAHB report (NAHB 2000), the single-family houses generally use natural gas as the fuel source for heating while other housing types mainly use electricity as their heating fuel sources in the east of Texas. Therefore, there should be a marked contrast between the electricity growth rate and the natural gas growth rate over the next several years. Furthermore, the type of HVAC system varied according to house type, which is also expected to impact future energy demands. Therefore, the annual growth rate of both electricity and natural gas was predicted by contacting the College Station Utility Customer Service (CSUCS) representatives and historical energy consumption data.

Source: COCS 2003.

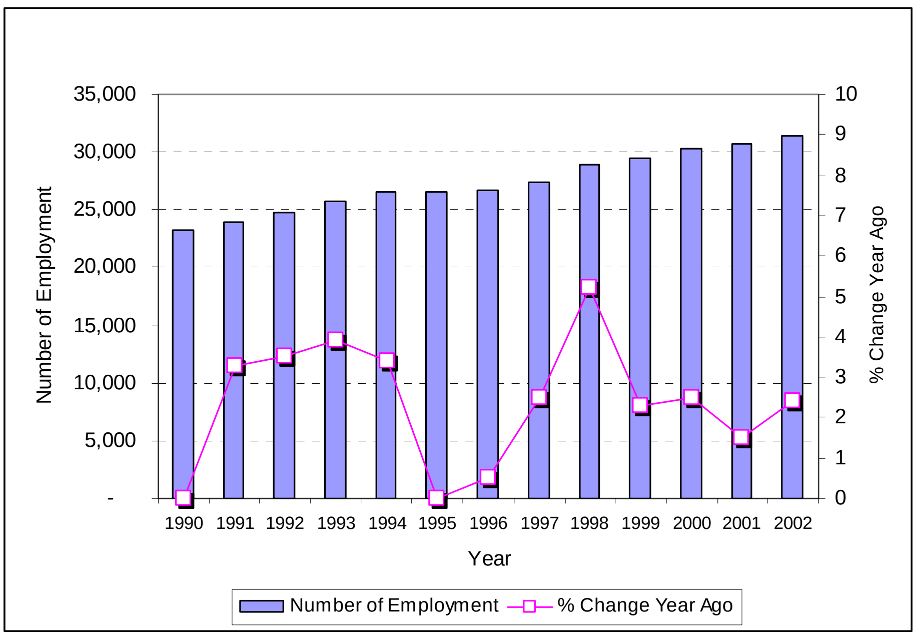


Figure 6-3: Historical Level of Employment and Percent of Change.

Table 6-4: Summary of Various Annual Growth Rates by Housing Type.

Housing Type	1990		2000		Annual Growth Rate
	Number	Percent	Number	Percent	
Single-family detached	5,605	28%	8,706	44%	4%
Single-family attached	1,086	5%	1,374	7%	2%
2-4 units	4,246	21%	5,694	29%	3%
5-9 units	2,508	13%	2,899	15%	1%
10 or more units	5,980	30%	6,776	34%	1%
Mobile Home	419	2%	469	2%	1%
Total Units	19,845		26,008		2.7%

Source: COCS 2003.

6.4.2.4 Electricity Consumption Growth Rate

According to the data taken from the annual electricity sale reports provided by CSUCS, the annual growth rate of electricity consumption is approximately 4%[5], very much like that of the overall population.

6.4.2.5 Natural Gas Consumption Growth Rate

In marked contrast to electricity consumption, according to the data taken from the Texas Railroad Commissions (RRC 2003), College Station has used natural gas for approximately 12% of its annual growth rate (18 % in the residential sector, and 6% in the commercial/industrial sector) during the period 2000-2002, while only exhibiting a growth rate of 4% (CSUCS) for electricity during the same period.

6.4.2.6 Transportation Energy Use Growth Rate

To determine the transportation energy use growth rate, two assumptions were made: 1) that the increase in population could directly influence the transportation sector's fuel use demand; and 2) that the increase of fuel demand could be presented as an increase of VMT. By utilizing the EPA's Economic Growth Analysis System (EGAS), the 2007 VMT projection for

[5] Annual growth rate of electricity was found by contacting the College Station Utility Customer Service (CSUCS) representative at December 2003 and was verified by cross-checking with CSUCS the electricity sale report.

Brazos County was provided with an annual growth rate of approximately 2.3%, as shown in Figure 6-4. However, since EGAS (Pechan E.H. 2001) represents only a countywide analysis, the appropriate adjustments were needed to estimate the appropriate growth factor for College Station. Through a comparison population growth of Brazos County with that of College Station, VMT growth rate of 4% was determined to be realistic for College Station. This growth rate assumption yields an estimated 1,904,539 DVM (Daily Vehicle Miles) for 2007.

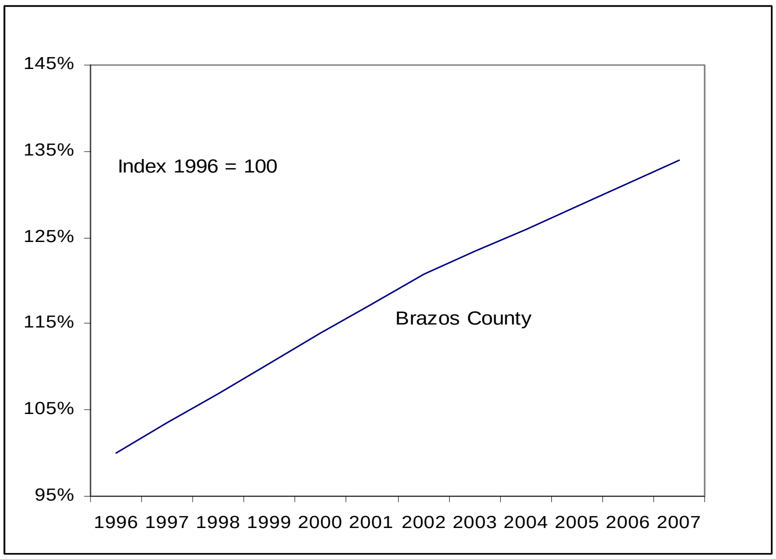


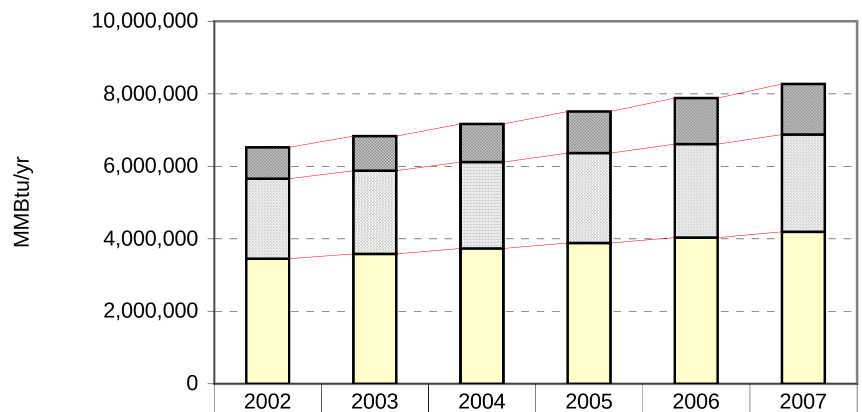
Figure 6-4: Predicted VMT Growth Rate for Brazos County, TX by EGAS.

6.4.2.7 Future Energy Demand Calculation

The future energy demand for the period 2002-2007 was simply calculated by applying the various activity growth rates to the baseline energy use in each energy use. Table 6-5 and Figure 6-5 show that the community-wide energy consumption growth estimates reflect from 2002 to 2007, total energy consumption increases of 27 percent respectively. The annual increases for the community-wide growth rate is 5%. The largest increase in fuel type is natural gas consumption, with a 61% of total increase from the base year. Electricity and transportation fuel use growth estimates reflect a 22% of increase from the base year with 4% annual growth rate.

Table 6-5: Projected Annual Energy Use by Fuel Type (MMBtu/yr).

Fuel Type	2002 (BASE YEAR)	Projected Year					% Increase from (BASE YEAR)
		2003	2004	2005	2006	2007	
Electricity	2,204,715	2,292,904	2,384,620	2,480,005	2,579,205	2,682,373	22%
	Annual GWR	4%	4%	4%	4%	4%	
Natural Gas	865,358	951,894	1,047,083	1,151,791	1,266,971	1,393,668	61%
	Annual GWR	11%	11%	11%	11%	11%	
Transportation Fuel	3,449,424	3,587,401	3,730,897	3,880,133	4,035,338	4,196,752	22%
	Annual GWR	4%	4%	4%	4%	4%	
Total	6,519,497	6,832,198	7,162,600	7,511,929	7,881,514	8,272,792	27%
	Annual GWR	5%	5%	5%	5%	5%	



	2002	2003	2004	2005	2006	2007
Natural Gas	865,358	951,894	1,047,083	1,151,791	1,266,971	1,393,668
Electricity	2,204,715	2,292,904	2,384,620	2,480,005	2,579,205	2,682,373
Transportation Fuel	3,449,424	3,587,401	3,730,897	3,880,133	4,035,338	4,196,752
Total	6,519,497	6,832,198	7,162,600	7,511,929	7,881,514	8,272,792

Figure 6-5: Projected Annual Energy Use by Fuel Type.

6.5 ENERGY EFFICIENCY SCENARIOS

As previously mentioned, the main purpose of the study is to determine how and where energy was being consumed within the selected community. This determination could help a community to identify areas of excessive energy use and help to find out areas where additional attention could be directed. Finally, the result of this renewed focus could be to realize effective energy conservation efforts and the resultant NOx reductions for a selected community. Therefore, this section describes an analysis of possible technology-based scenarios for College Station. The adoption of energy efficient measures would result in both energy savings and the associated NOx emissions reductions. Supply-side technologies were excluded from this study. Only demand-side technologies were considered.

6.5.1 Identification of Energy Reduction Opportunities

By analyzing the baseline energy use and future energy demands, possible energy efficiency measures were identified to reduce energy consumption. These possible scenarios include: 1) Compact Fluorescent Lamps (CFLs) in residential sector, 2) higher SEER Air Conditioning Units in residential Sector, 3) the elimination of pilot lights, and 4) higher fuel efficiency in light duty vehicles. A detailed description of each scenario is explained in the following sub-sections.

6.5.2 Scenario #1: Replacing Incandescent Lamps with Compact Fluorescent Lamps in Residential Sector

The majority of lamps used in the residential sector are incandescent lamps and standard fluorescent lamps. According to the EIA (1996), approximately 87% of household lights in use for more than fifteen minutes per day are incandescent. Similarly, based on the TPU analysis, incandescent lamps account for approximately 78% of lighting hours and consume approximately 86% of household lighting energy, while standard fluorescent lamps account for only 22% of household lighting hours and consume about 13% of household lighting energy (LBNL 1996). Therefore, it is clearly recognized that the majority of lamps used in all room types at house are incandescent lamps. For this study, the assumption that about 80% of lighting lamps used in residential sector for the selected community are incandescent lamps could be reasonable. In addition, replacing incandescent lamps with high efficient lighting lamps for this study could provide more effectiveness than other types of lamps on residential energy savings.

6.5.2.1 Comparative Performance

Compact Fluorescent Lamps (CFLs) of an equivalent lamp illuminance have been shown to save from 20% -75% of per-fixture energy use depending on the incandescent lamp being replaced. For example, if a 60-watt incandescent is replaced with a 15-watt CFL, a savings of 75% is possible. Similarly, the T8/electronic ballast systems can provide up to 30% savings when used to replace the standard T12/magnetic ballast system. HID lamps are the most efficient group of lamps on the market today. They can provide up to 75% savings over a standard outdoor incandescent flood while providing more light. Compact fluorescent lamps are miniaturized fluorescent lamps. They are roughly the same size as incandescent lamps but are three to four times more energy efficient and last 10 times as long. Typically, a 13-watt compact fluorescent lamp equipped with 2-watt ballast is suitable to replace a 60-watt incandescent lamp. Therefore, replacing incandescent lamps with compact fluorescent lamps (CFLs) is one of promising options to reduce the residential sector's energy use. Table 6-6 shows a comparison between the wattage of commonly available incandescent lamps and the wattage of a CFL that will provide similar light levels.

Table 6-6: Comparison of the Wattages between Typical Incandescent Lamps and Comparable CFLs.

Incandescent Lamp (Watt)	Compact Fluorescent Lamp (Watt)
25	5
50	9
60	15
75	20
100	25
120	28
150	39

Source: OEERE 2003.

6.5.2.2 Case Study House

A single-family residence in College Station, Texas, was used as a case study to determine how substituting energy efficient lamps and fixtures could reduce residential lighting energy use. The five-person household was chosen based on its extensive use of interior lighting. A detailed audit conducted by the homeowner revealed 112 lamps (90 incandescent lamps and 22 fluorescent lamps) with a total connected load of 6.1 kW (6,141 W) or 2.56 W/ft2.

The site selected for the case study is a 2,400-ft2 single-family home in College Station, TX. As shown in Figures 6-6 and 6-7, the house contains 4 bedroom, 2.5 baths, 2-car garage, and is built on slab on grade. The site was selected based on the readily available history of 4 years of monthly utility bills. A review of the utility records for this home in 1999-2001 (pre-retrofit) revealed a total average annual energy consumption of 17,606 kWh. Two middle-aged adults and three children occupy the home. The wife is home for a large portion of each weekday, tending to the housework. The husband is a professor at the university. On average, the case study house uses lighting during the early morning and late evening hours. All family members except the wife are typically at school during the daytime on weekdays. All family members are typically home on the weekends.

Figure 6-6: Front View of the Case Study House.

Figure 6-7: Side View of the Case Study House.

The total household lighting use was estimated by the simple calculation to be 4,637 kWh/year or approximately 26% of the annual total consumption as described in Table 6-7. The utility bills for the house were collected from January of 1999, through December of 2001, in a baseline condition. In August of 2002, a total of 90 various compact fluorescent lamps (CFLs) were substituted for the majority of the incandescent lamps in use. The calculated lighting load was dropped from 6.14 kW to 1.59 kW. The total CFLs cost for the retrofit was approximately $450.

The house was audited in its altered condition through August of 2003, with the electric energy specifically compared to that of the pre-retrofit period. The ASHRAE's Inverse Modeling Toolkit (IMT) (Kissock et al. 2001) was conducted to calculate the exact energy savings. To accomplish this, a three-parameter change-point (3p) cooling model was developed using AHRAE IMT. The detailed modeling procedure for this task was described in Chapter IV. The results of 3P cooling model for the pre-retrofit (1999 – 2001) and post-retrofit (2002) were determined. Figure 6-8 shows the output files of 3P cooling model for the pre-retrofit and post-retrofit. The output files shows the IMP coefficients and other information (i.e., adjusted R^2, CV-RMSE, change point (Ycp, Xcp), and slope of model (RS). Using the IMT coefficients (see Table 6-8), the model can be plotted as shown in Figure 6-9.

Table 6-7: Household Lighting Inventory and Energy Savings Calculation.

Room	No. Lamps	Watt/lamp	Day on?	Incand?	Fluor	Watt/fix	Total Incand	Total Fluor	Total Light	Day Incand	Tot CFL	Day CFL	Tot Inc.lamps	Cost $.75	Cost $5
Kitchen	1	75	0	1	0	75	75	0	75	0	11	0	1	$ 0.75	$ 5.00
	4	60	1	1	0	240	315	0	315	240	45	34	5	$ 3.75	$ 25.00
	1	25	0	0	1	25	315	25	340	240	70	34	5	$ 3.75	$ 25.00
	4	45	1	0	1	180	315	205	520	240	250	34	5	$ 3.75	$ 25.00
Liv/Dine	2	150	1	1	0	300	615	205	820	540	293	77	7	$ 5.25	$ 35.00
	1	150	0	1	0	150	765	205	970	540	314	77	8	$ 6.00	$ 40.00
	3	40	0	1	0	120	885	205	1090	540	331	77	11	$ 8.25	$ 55.00
	16	25	0	1	0	400	1285	205	1490	540	389	77	27	$ 20.25	$ 135.00
Outside	4	40	0	1	0	160	1445	205	1650	540	411	77	31	$ 23.25	$ 155.00
	3	40	0	1	0	120	1565	205	1770	540	429	77	34	$ 25.50	$ 170.00
	12	40	0	1	0	480	2045	205	2250	540	497	77	46	$ 34.50	$ 230.00
	2	75	0	1	0	150	2195	205	2400	540	519	77	48	$ 36.00	$ 240.00
	2	75	0	1	0	150	2345	205	2550	540	540	77	50	$ 37.50	$ 250.00
	2	75	0	1	0	150	2495	205	2700	540	561	77	52	$ 39.00	$ 260.00
	6	75	0	1	0	450	2945	205	3150	540	626	77	58	$ 43.50	$ 290.00
Bed Closets	4	35	0	0	1	140	2945	345	3290	540	766	77	58	$ 43.50	$ 290.00
	1	90	0	0	1	90	2945	435	3380	540	856	77	58	$ 43.50	$ 290.00
Garage	5	75	0	1	0	375	3320	435	3755	540	909	77	63	$ 47.25	$ 315.00
M.Bed	5	60	0	1	0	300	3620	435	4055	540	952	77	68	$ 51.00	$ 340.00
	2	100	1	1	0	200	3820	435	4255	740	981	106	70	$ 52.50	$ 350.00
M.Bath	2	40	0	1	0	80	3900	435	4335	740	992	106	72	$ 54.00	$ 360.00
	1	75	0	1	0	75	3975	435	4410	740	1003	106	73	$ 54.75	$ 365.00
	4	45	0	0	1	180	3975	615	4590	740	1183	106	73	$ 54.75	$ 365.00
C.Bed	3	75	0	1	0	225	4200	615	4815	740	1215	106	76	$ 57.00	$ 380.00
B.Bed	3	60	0	1	0	180	4380	615	4995	740	1241	106	79	$ 59.25	$ 395.00
	1	150	0	1	0	150	4530	615	5145	740	1262	106	80	$ 60.00	$ 400.00
	1	75	0	1	0	75	4605	615	5220	740	1273	106	81	$ 60.75	$ 405.00
M.Bed	3	60	0	1	0	180	4785	615	5400	740	1299	106	84	$ 63.00	$ 420.00
	1	150	0	1	0	150	4935	615	5550	740	1320	106	85	$ 63.75	$ 425.00
	1	75	0	1	0	75	5010	615	5625	740	1331	106	86	$ 64.50	$ 430.00
Hall	1	75	0	1	0	75	5085	615	5700	740	1341	106	87	$ 65.25	$ 435.00
K.Bath	4	22	0	0	1	88	5085	703	5788	740	1429	106	87	$ 65.25	$ 435.00
Bath	4	32	0	0	1	128	5085	831	5916	740	1557	106	87	$ 65.25	$ 435.00
	1	75	1	1	0	75	5160	831	5991	815	1568	116	88	$ 66.00	$ 440.00
Attic	2	75	0	1	0	150	5310	831	6141	815	1590	116	90	$ 67.50	$ 450.00

699 =total Watt reduction
86.5% =% of Total
25.9% =% of Total
13.5% =% of Total
14.3% =% of daytime incand.
0.29 =total Watt/ft2 reduction
2.56 =total Watt/ft2
0.05 =total Watt/ft2
0.34 =total Watt/ft2

Case Study House, College Station, TX
2,400 ft2 house
4 bedroom, 2.5 bath, 2 car garage, slab on grade

8.00 =on time
20.00 =off time
12.00 =hours
8.38 =kWh/day
345 =days/yr
2892 =kWh/yr
$ 0.07 =$/kWh
$ 202.45 =savings/yr (no cool)

IMT Result: Pre-Retrofit

```
*************************************************
ASHRAE INVERSE MODELING TOOLKIT (1.9)
*************************************************
Output file name = IMT.Out
*************************************************
Input data file name =  pre.dat
Model type =          3P Cooling
Grouping column No =    0
Value for grouping =    0
Residual mode =         1
# of X(Indep.) Var =    1
Y1 column number =      4
X1 column number =    5
X2 column number =   0 (unused)
X3 column number =   0 (unused)
X4 column number =   0 (unused)
X5 column number =   0 (unused)
X6 column number =   0 (unused)
*************************************************
Regression Results
---------------------------------------
N =     42
---------------------------------------
R2 =     0.848
---------------------------------------
AdjR2 =     0.848
---------------------------------------
RMSE =      8.0176
---------------------------------------
CV-RMSE =    16.791%
---------------------------------------
p =    -0.126
---------------------------------------
DW =     2.175 (p>0)
---------------------------------------
N1 =     18
---------------------------------------
N2 =     24
---------------------------------------
Ycp =     30.1218 (      1.7085)
---------------------------------------
LS =       0.0000 (      0.0000)
---------------------------------------
RS =       2.3098 (      0.1544)
---------------------------------------
Xcp =     64.2068 (      0.8432)
---------------------------------------
```

IMT Result: Post-Retrofit

```
*************************************************
ASHRAE INVERSE MODELING TOOLKIT (1.9)
*************************************************
Output file name = IMT.Out
*************************************************
Input data file name =  post.dat
Model type =          3P Cooling
Grouping column No =    0
Value for grouping =    0
Residual mode =         1
# of X(Indep.) Var =    1
Y1 column number =      4
X1 column number =    5
X2 column number =   0 (unused)
X3 column number =   0 (unused)
X4 column number =   0 (unused)
X5 column number =   0 (unused)
X6 column number =   0 (unused)
*************************************************
Regression Results
---------------------------------------
N =     14
---------------------------------------
R2 =     0.970
---------------------------------------
AdjR2 =     0.970
---------------------------------------
RMSE =      3.0669
---------------------------------------
CV-RMSE =     7.057%
---------------------------------------
p =    -0.616
---------------------------------------
DW =     2.487 (p>0)
---------------------------------------
N1 =      6
---------------------------------------
N2 =      8
---------------------------------------
Ycp =     26.2361 (      1.1977)
---------------------------------------
LS =       0.0000 (      0.0000)
---------------------------------------
RS =       2.2888 (      0.1161)
---------------------------------------
Xcp =     66.8278 (      0.7114)
---------------------------------------
```

Figure 6-8: Three-Parameter Change-point Models for Pre-retrofit and Post-retrofit.

Table 6-8: Summary Table of the IMP Results for the Pre-Retrofit and the Post-Retrofit.

Period	Constant term (Ycp)	Slope term (RS)	Change Point (Xcp)
Pre-Retrofit	30.1218	2.3098	64.206
Post-Retrofit	26.2361	2.2888	66.827

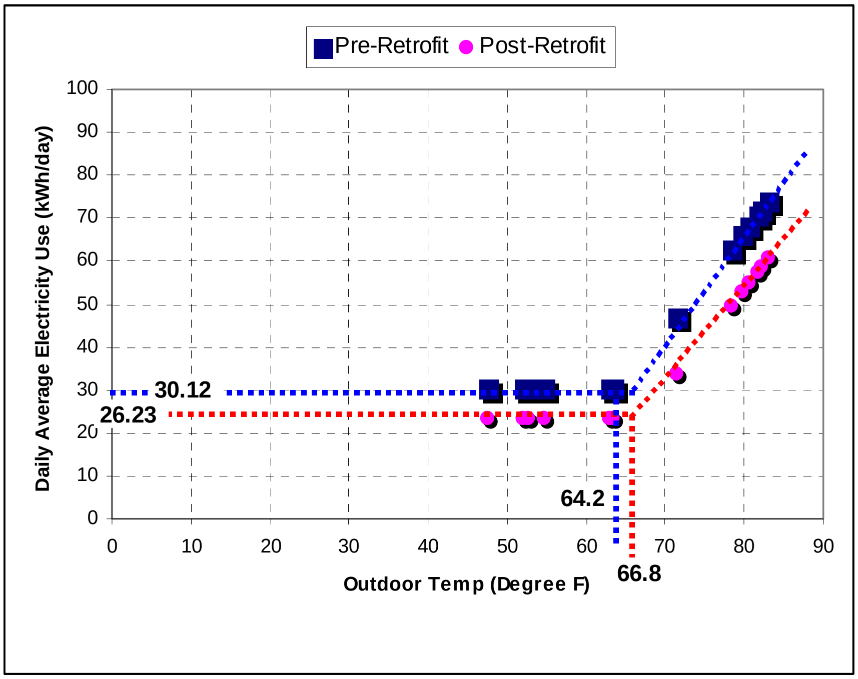


Figure 6-9: The Comparison of Predicted Daily Average Electricity Consumptions from Pre-Retrofit IMT and Post-Retrofit IMT.

The result of 3P cooling model for the pre-retrofit was first used to estimate the baseline energy use for the post-retrofit period (2002) by using the same outdoor temperature used in 3P cooling model for the post-retrofit. From these tasks, the normalized annual energy consumption for both with and without CFLs was then estimated. Table 6-9 shows the results of normalized annual consumption for baseline (17,335 kWh/yr) and predicted energy use (14,765 kWh/yr). Finally, the comparison of two normalized annual energy consumption was conducted to calculate the energy savings.

The actual energy consumption after the retrofit (from August of 2002 to August of 2003) was 14,760 kWh, while the predicted electricity consumption was 17,335 kWh during the same period. The measured savings was approximately 8.38 kWh/day, which equaled a reduction in the total electricity energy consumption of some 15%. Figure 6-10 shows the electricity consumption before and after the retrofit, along with the estimated savings.

Table 6-9: Comparison of Predicted Energy Savings with Actual Energy Savings.

	Annual Electricity Use (kWh/yr)	Savings	% of Savings
Baseline (IMT)	17,335	0	0
Predicted (IMT)	14,765	2,570	14.8 %
Measured (Utility Bills)	14,760	2,585	14.9 %
Calculated	N/A	2,892	16.7 %

The intent of the study was to achieve the maximum lighting energy savings possible, rather than to produce the most economic savings levels. Nevertheless, based on the 15% savings experienced, the reduction has an annual value of $ 202 at current College Station, TX utility prices. The retrofit would pay for itself in between 2 to 3 years, not counting the greater life of the more efficient lighting (CFL lamps typically have a service life of 10,000 hours). The study indicates that an extensive use of more efficient lighting technologies in College Station homes could produce very attractive energy savings for a community-wide energy savings plan.

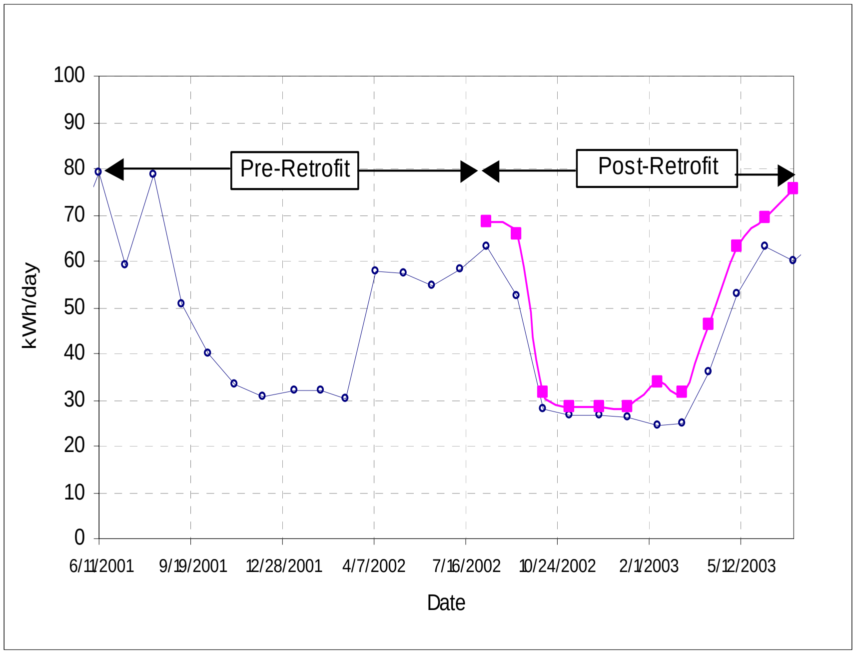


Figure 6-10: Daily Electricity Consumption Before and After Retrofit.

6.5.2.3 Application of CFLs in the Residential Sector

This scenario was assumes all incandescent lamps in each household were replaced with CFL lamps, in order to determine how much community-wide energy and its associated NOx emissions could be reduced. To demonstrate this scenario, two calculation procedures were required: 1) the calculation of energy savings and 2) the calculation of NOx emissions reductions.

To calculate total energy savings, previously determined electricity savings (1.17 kWh/ft^2-yr) from the case study house was simply used. Two parameters were used to calculate the total NOx emissions from single-family detached housing units. The NOx emissions rate (0.00295 lb/kWh)6 was used in this study. Additional 10% of total electricity use was added to consider the transmission and distribution loss, when it was delivered from power generation.

Table 6-10 summarizes the procedures and the impact of adopting a high efficiency lighting system on a community wide energy savings and NOx emissions reduction plan, if one assumes that all of the incandescent lamps in each house were replaced with CFLs in College Station. Each housing type's total conditioned area was first estimated by multiplying the number of housing units (Table 5-7) times an average conditioned floor area by housing type (Table 5-17). An annual energy savings per square foot was then used to estimate annual electricity savings. Therefore, a substitution of CFLs for all incandescent lamps in all housing units (28,268) hypothetically showed a 41,519,355 kWh savings in all residential sector's electricity use – equivalent to a 12% reduction in all residential sector electricity use, a 6.4% reduction in the total community's electricity consumption, and a 2.1% reduction in total community energy use.

A total of 67.4 tons of NOx emissions could be reduced annually – equivalent to a 3.3% reduction in a community wide NOx emissions reduction.

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[6] As reported in E-GRID table, average NOx emission rates within control area name of American Electric Power (AEP) is used in this study.

Table 6-10: Summary Table of CFLs' Impact on Energy Savings & NOx Emissions Reductions.

<table>
<tr><th colspan="2">Housing Unit Type</th><th>Number of Housing Units</th><th>Average Conditioned Floor Area (sq.ft)</th><th>Total Estimated Conditioned Floor Area (sq.ft)</th><th>Annual Electricity Savings per sq.ft</th><th>Annual Energy Savings (kWh/yr)</th><th>T & L Loss</th><th>NOx Emissions Rate (lb/kWh)</th><th>NOx Emissions Savings (ton)</th></tr>
<tr><td rowspan="2">Single Family Housing</td><td>Single-family detached</td><td>10,023</td><td>1,960</td><td>19,645,080</td><td rowspan="6">1.17</td><td>22,984,744</td><td rowspan="6">10%</td><td rowspan="6">0.00295</td><td>37.3</td></tr>
<tr><td>Single-family attached</td><td>1,650</td><td>932</td><td>1,537,800</td><td>1,799,226</td><td>2.9</td></tr>
<tr><td rowspan="3">Multi-Family Housing</td><td>2-4 Units</td><td>5,966</td><td>860</td><td>5,130,760</td><td>6,002,989</td><td>9.7</td></tr>
<tr><td>5-9 Units</td><td>3,063</td><td>860</td><td>2,634,180</td><td>3,081,991</td><td>5.0</td></tr>
<tr><td>10 or More</td><td>7,095</td><td>860</td><td>6,101,700</td><td>7,138,989</td><td>11.6</td></tr>
<tr><td>Manufactured Home</td><td>Mobile Home</td><td>469</td><td>932</td><td>437,108</td><td>511,416</td><td>0.8</td></tr>
<tr><td colspan="2">Total</td><td>28,266</td><td>1,067</td><td>35,486,628</td><td></td><td>41,519,355</td><td></td><td></td><td>67.4</td></tr>
</table>

6.5.3 Scenario #2: Adoption of Higher SEER Residential AC Units in College Station

In this section, the impact of replacing the lower SEER AC units with higher SEER AC units on the residential sector energy consumption and NOx emissions was estimated. The scenario was created from these reasons; the residential sector electricity demand is significantly seasonal (see Figure 5-3) in College Station, and the electric utilities in many parts of the U.S. experience severe peak-load problems during hot summer afternoons. Furthermore, cooling in Texas is said to contribute to 90% of the residential peak. Therefore, replacing the lower SEER AC units with the Higher AC units is one of promising options for College Station to reduce its electricity use and NOx emissions. Since, cooling loads in the houses depend primarily on two factors: the housing thermal characteristics and the efficiency of the AC units, the representative housing characteristics in terms of conditioned area, thermal material R-value, solar heat gain coefficient (SHGC), window-wall ration (WWR), and window U-value were first determined based on the ESL's Texas Emission Reduction Plan (TERP) report (Haberl et al. 2003c). The efficiency (SEER for AC units and AFUE for gas furnace) of HVAC systems was also determined based on the ESL's TERP report. That information was then used to create the DOE-2 input file into the Energy Systems Laboratory's (ESL) Emissions Reduction Calculator for calculating energy savings.

6.5.3.1 Development of the Input File into the ESL's Emissions Reduction Calculator

The average conditioned area of prototype house was determined based on the 65 sample houses. The baseline is considered to be a house with 1,960 sq.ft. Of the building envelope data from NAHB, the wall height, the wall R-Value, the roof/ceiling R-value, the AFUE and SEER were used as it is. However, since the window area, glazing U-factor and SHGC were not provided in NAHB's report, previously developed procedure (Haberl et al. 2003c) was used in order to determine window area, glazing U-factor, and SHGC in this study. The baseline is considered to be a house with wall insulation in the 4" wall cavity with an R-value of 13 taking into account thermal properties of the construction materials that comprise the wall. According to the NAHB (2002), the houses in west Texas have 100% double-pane glass, while that in east Texas have 60% single pane and 40% double pane glass. Based on this information, Haberl et al (2004) developed the U-value and SHGC for east and west Texas. An average window U value (1.11) and an average SHGC (0.714) for east Texas were used for this study.

The baseline efficiency (efficiency of existing housing stock air conditioner) used for the AC-Distributor program characterizes the recent sales of units in the state of Texas (Schiller Associates 2001). 1999 sales of air conditioning units in Texas of less than 5.4 tons (65,000 Btu/hr) show an average SEER rating of approximately 10.75 (U.S. average SEER of 10.98). In this study, SEER 10 was set as baseline efficiency.

The average Annual Fuel Utilization Efficiency (AFUE) of the gas furnaces in College Station was determined based on the shipments of gas furnaces in Texas during 1995-2000 published by the Gas Appliance Manufactures Association (GAMA). According to the GAMA (2003), the vast majority of shipments below 88% AFUE intended for new site-built homes are 80% AFUE. In 1999, therefore, the most common AFUE of gas furnaces for new built house is 80% AFUE (99.1% of total). In this study, 80% AFUE was used as average efficiency value for the gas furnace in the case study community.

6.5.3.2 The Calculation of kWh Savings and NOx Emissions Reductions

ESL's Emission Reduction Calculator 1.0 (ESL 2002) was used to calculate the energy savings and its associated NOx emissions for this study. The Emission Reduction Calculator is simplified simulation program that calculates residential buildings' energy use and its emission production. This program was developed based DOE2 simulation. To create savings by using this program, two tasks were needed. The base model of the prototype house of a selected community was first determined as input data. Energy efficiency measure is then applied. Figure E-1 in Appendix E shows the calculator's input data to estimate the prototype single-family detached house's baseline energy use. Figures E-2 thru E-3 show the results from the baseline energy use and from the adoption of SEER 12 in the prototype house. Finally the results from the previous two tasks were then compared both between and within the cases. Table 6-11 summarizes the characteristics of prototype house.

Table 6-11: Summary of Prototype Housing Characteristics.

Input Data Description	Base case	Higher SEER
Conditioned Area	2025	2025
Wall Height	8.8	8.8
Window Area	218.59	218.59
Foundation	Slab on Grade	Slab on Grade
Wall Insulation	R-value 13	R-value 13
Attic Insulation	R-value 26	R-value 26
Window U-Factor	1.11	1.11
Solar Heat Gain Coefficient (SHGC)	0.714	0.714
Duct Location	Conditioned Area	Conditioned Area
Type of Water Heater	Gas	Gas
Heating System	Gas Furnace	Gas Furnace
Gas Heating	80% AFUE	80% AFUE
Air-cooled Air Conditioners and Heat Pumps Cooling Mode > 65,000	SEER 10	SEER 12

Table 6-12 summarizes the calculation procedures and the results of energy use and its associated NOx emissions. Total annual energy use for single-family detached units in College

Station was about 149,633,367 kWh (14,929 kWh/house). This value presents about 44% of the total residential electricity use. Two parameters were used to calculate the total NOx emissions from single-family detached housing units. The NOx emissions rate (0.00295 lb/kWh)[7] was used in this study. Additional 10% of total electricity use was added to consider the transmission and distribution loss, when it was delivered from power generation. The estimated annual NOx emissions from single-family detached units in College Station were 242.8 tons.

A comparison of the energy use of the baseline efficiency (SEER 10) with that of a higher efficiency (SEER 12) was also made. Annual energy savings of 10,884,886 kWh (1,086 kWh/house) with 17.6 tons of NOx emissions were expected.

Table 6-12: Summary Table of Higher SEER AC Unit's Impact on Energy Savings & NOx Emissions Reductions.

Categories	Base Case (SEER 10)	Higher SEER (SEER 12)
Annual Electricity Use (kWh/house)	15,425 (14,929)	14,307 (13,847)
Electricity Use (kWh/sq.ft)	7.617	7.065
Total Electricity Use	149,633,367	138,788,481
Electricity Savings (kWh)		10,844,886
Transmission & Distribution Loss (%)	10%	10%
NOx Emissions (ton)	242.8	225.2
Total NOx Emissions Reductions (ton)		17.6

Note: Values in ( ) represents the annual electricity use of College Station's single-family detached house. Since the value of 2025 sq.ft was used as conditioned area as the input data in the Emissions Reduction Calculator program. This number was obtained by multiplying an electricity use intensity (7.617 kWh/sq.ft) by an average conditioned area (1,960 ft^2).

This analysis represents the annual electricity saving of 7.25% of each single-family housing unit. The value of 7.25% of electricity savings was also applied in all other housing types (i.e., single-family attached, multi-family, and mobile homes) in order to calculate the annual energy savings and NOx emissions reductions in the residential sector. Tables 6-13 and 6-14 summarize the results of electricity use savings and its associated NOx emissions reductions. Total annual energy use for the residential sector was about 344,220,082 kWh. This

[7] As reported in E-GRID table, average NOx emission rates within control area name of American Electric Power (AEP) is used in this study.

value represents about 48% of total residential sector electricity use, 29% of the total community electricity use, and 9% of the total community energy use.

Finally, a comparison of the energy use of the baseline efficiency (SEER 10) with that of a higher efficiency (SEER 12) was made. Annual energy savings of 24,883,456 with 17.6 tons of NOx emissions were expected. This value represents about 7.25% of total residential sector electricity savings, and about 1.2% of total community energy savings.

Table 6-13: Summary of Higher SEER AC Unit's Impact on Energy Savings.

Sectors		Number of Houses	Base Case (SEER 10)		SEER 12		Savings	
			Consumption (KWh/House)	Total (kWh)	Consumption (kWh/House)	Total (kWh)	Consumption (kWh/House)	Total (kWh)
Residential	Single-Family Detached	10,023	14,930	149,643,390	13,848	138,794,244	1,082	10,849,146
	Single-Family Attached)	1,650	15,015	24,774,750	13,926	22,978,581	1,089	1,796,169
	Multi-Family House	16,126	10,031	161,759,906	9,304	150,032,313	727	11,727,593
	Mobile-Homes	469	15,015	7,042,035	13,926	6,531,487	1,089	510,548
	Total	28,268	343,220,081		318,336,625		24,883,456	

Table 6-14: Summary of Higher SEER AC Unit's Impact on NOx Emissions Reductions.

Sectors		Number of Houses	Base Case (SEER 10)		SEER 12		Savings	
			Total (kWh) + T&D Loss (10%)	NOx Emissions (tons)	Total (kWh) + T&D Loss (10%)	NOx Emissions (tons)	Total Savings at Power Plant (kWh)	NOx Emissions (tons)
Residential	Single-Family Detached	10,023	164,607,729	243	152,673,669	225	11,934,060	18
	Single-Family Attached	1,650	27,252,225	40	25,276,439	37	1,975,786	3
	Multi-Family House	16,126	177,935,897	262	165,035,544	243	12,900,353	19
	Mobile-Homes	469	7,746,239	11	7,184,636	11	561,602	1
	Total	28,268	557		517		40	

6.5.4 Scenario #3: Elimination of Pilot Lights in Domestic Hot Water (DHW)

In Section 6.2, the predicted energy use for the target year shows the biggest increment is from natural gas use. Furthermore, natural gas use in the residential sector has the biggest portion of increase. According to Haberl et al. (2003a), communications several HVAC manufacturers and with GAMA have indicated that most manufacturers of residential furnaces have eliminated the pilot lights in their residential units to achieve the higher AFUE mandated by Federal law. This is estimated to be in the range of 500 to 800 Btuh of open-flame combustion per household. This becomes important when one realizes that about 5 - 10% of all households replace their furnaces in a given year, which can equal or exceed the number of new housing starts in a county. Similar reductions in pilot lights are expected for domestic water heaters and other gas appliances.

Therefore, elimination of pilot lights in residential domestic hot water and gas furnace is selected as energy efficient measure to have natural gas savings and its associated NOx emissions reductions. To accomplish this, two tasks were needed; two tasks include: 1) calculating of energy use for pilot lights in DHW; 2) calculating of NOx emissions from using pilot lights; and 3) calculating of energy savings and its associated NOx emissions reductions.

6.5.4.1 Calculating of Energy Use for Pilot Lights in DHW

First, the existing stock of pilot lights in the residential sector was determined by applying the portion of total natural gas customer by total housing units (total electricity customers). There were two assumptions: 1) the number of gas furnaces (hot water system) can be presented in terms of number of the natural gas customers, and 2) the number of total housing units can be presented in terms of the number of electricity customers. Prior to 2000, gas utility customers usually had at least two pilot lights: one for the domestic hot water system and another for the gas furnace. The pilot light for gas ovens was excluded from this study.

From this analysis, the existing housing stock which used gas-fired DHW and gas furnaces were 39% (10,165) of total housing units in College Station. Furthermore, it was assumed these 10,165 houses units had two pilot lights. Therefore, the total number of pilot lights in the residential sector was estimated to be 20,331 respectively. Finally, an annual operating (burning) hours for pilot light was 8,760 hours per year.

Table 6-15 summarizes the calculation procedures and the results of energy use and its associated NOx emissions. Total annual energy use for pilot light in residential DHW and gas furnace was about 89,049 MBtu respectively. This value represents about 19.2% of total residential natural gas use, 10% of total community natural gas use, and 1.4% of total community energy use.

NOx emissions calculator provided by ESL (2002) was used to calculate the NOx emissions production derived from pilot light's energy use. The NOx emissions factor (0.09 lb/MMBtu) was used in this study. The estimated annual NOx emissions from pilot light were 8,014 lbs (4 tons).

Table 6-15: Calculation of Energy Consumption for Pilot Lights Use in Residential Sector.

1. Determine % of Housing Units With DHW and Gas Furnace		
Number of Housing Units (2002)	SFD	10,023
	SFA	1,650
	MF	16,126
	MH	469
	Total (A)	28,268
Total Number of Electricity Utility Customer		26,066
Total Number of Natural Gas Utility Customer		10,165
Percent of DHW with Pilot Light (B)		39%
Percent Furnace with Pilot Light (C)		39%
2. Calculation of Energy Use for Pilot Light in DHW & Gas Furnace		
Total Number of Pilot Light (D)	(A x B)+ (A x C)	20,331
Energy Use per Pilot Light (E)	Btu/hr	500
Annual Operating Hours (F)	hrs	8,760
Total Energy Use (G) (MMBtu/yr)	D x E x F	89,049
3. Calculation of NOx Emissions for Pilot Light in DHW & Gas Furnace		
NOx Emissions Factor (H)	lb/MMBtu-NG	0.09
NOx Emissions (lbs) (I)	G x H	8,014.5
NOx Emissions (Tons)	(I)/ 2000 lbs/ton	4

6.5.5 Scenario #4: Increase Light Duty Vehicle's Fuel Efficiency by 5 MPG

In this section, the impact of increasing light duty vehicle (passenger cars and light trucks) fuel efficiency on the transportation energy (fuel) consumption and NOx emissions was estimated. The scenario was created for two reasons. First, as previously mentioned in the Section 6.2.1, the transportation sector's fuel use produced the largest portion (one half) of the total annual emissions in College Station when compared to that used for non-transportation fuel uses. Second, College Station's transportation fuel use and NOx emissions are expected to grow over the next few years as shown in Table 6-5. Therefore, improving on-road mobile source's fuel efficiency is one of promising options for College Station to reduce its energy use and NOx emissions.

In general, there are three ways to reduce the transportation sector's energy use, the three ways include: 1) improving vehicle performance, 2) reducing annual vehicle miles by adopting effective land use or urban planning (IWG 2000), and improving NOx/Btu conversion. In this study, the improving vehicle performance was only considered to reduce energy use and NOx emissions. To accomplish this, two tasks were needed in this study. The two tasks included: 1) the determination of possible fuel efficiency improvement, and 2) the conversion of fuel reduction to NOx emissions reduction.

6.5.5.1 Determination of Fuel Efficiency Improvement

The possible fuel efficiency improvement was determined by reviewing the U.S. Bureau of Transportation Statistics (U.S. BTS) data. According to the U.S. BTS (2003), also shown in Table 4-7, the average new passenger vehicle fuel efficiency of model year 2001was 28.6 mpg and the average new light trucks fuel efficiency of model year 2001 was 20.9 mpg. This figure represents an average fuel efficiency improvement of 5-mpg when compared to both the average vehicle efficiency for passenger cars (22.1 mpg) and for light trucks (17.6 mpg) in 2001 (U.S. BTS 2003). Therefore, a 5-mpg improvement was assumed to be a reasonable fuel efficiency increment for this study.

6.5.5.2 Conversion of Fuel Reduction to NOx Emissions Reduction

Since the EPA provided the NOx emissions rate, in grams per mile, the baseline fuel use and NOx emissions in this study were estimated based on the VMT analysis. However, the NOx emissions rate in grams per gallon of fuel type is needed to calculate the NOx emissions reductions when higher fuel efficiency vehicles were adapted to the existing vehicle fleet.

Unfortunately, the NOx emission rate in grams per gallon of fuel type was not available during the period of this analysis. Therefore, a procedure was necessary to convert from the fuel reductions into emission reductions.

To accomplish this, the baseline NOx emissions (in grams) were first divided by fuel use (in gallons). From this task, the value in grams per gallon was determined by vehicle type. The reduced fuel uses (in gallons) by adopting higher fuel efficiency were then applied to calculate new NOx emissions. Finally, the comparison the emissions from the base case over the results from the higher fuel efficiency was performed to determine the NOx emissions reduction.

6.5.5.3 Savings Calculation

Table 6-16 shows the baseline energy use and NOx emissions for the transportation sector. In this table the previously estimated NOx emissions were divided by the fuel use to obtain the NOx emission rate in grams per gallon, shown in the last column of Table 6-12. These values were then used in calculation of NOx emissions when higher fuel efficiency vehicles were adapted to the existing vehicle fleet. The light duty vehicles' (i.e., passenger cars, light trucks, SUV, and vans) fuel efficiency was increased by 5-mpg to determine the energy (fuel) use. Finally, the NOx emission rate (grams per gallon) was multiplied by the fuel use in order to calculate the NOx emissions.

Table 6-17 shows the result of 5-mpg improvement analysis. The expected total annual fuel use was approximately 24 million gallons with 837 tons of NOx emissions. A comparison of the results from the baseline analysis and the results from the 5-mpg analysis was then performed to calculate the savings in terms of energy (fuel) use and NOx emissions. An annual savings of 6 million gallons (20% of the total base case fuel use) with 214 tons of NOx emissions were estimated respectively.

6.5.6 Integration of Four Scenarios

After each scenario was individually evaluated as a comparison to the base case, the scenarios were then combined into one package in order to estimate the most plausible reductions both in energy and in NOx emissions. Each combination of the four scenarios was evaluated in terms of energy savings and NOx emissions reductions. The projected annual energy savings and NOx emissions were summarized in Figure 6-11. As compared to the individual scenario, the combination of four scenarios projected 1.1 million MMBtu in annual energy savings, which represented approximately 15% of total community energy use. The projected annual NOx emissions reductions were 306 tons, which represents 15% of the total community NOx emissions.

6.6 SUMMARY

This study has attempted to demonstrate the impact of energy efficient measures on energy savings and NOx emissions reductions for College Station. The baseline energy consumption has been estimated in order to determine how and where energy is being consumed within the selected community. In College Station, transportation sector uses the largest portion (one half) of the total community's energy. The residential sector accounts for the second largest portion of delivered energy use, accounting for nearly 26% of the total energy consumption. The commercial sector accounts for the third largest portion, measuring 20% of the total energy use. These determinations could help the community in identifying areas of excessive energy use and help to find areas upon which to focus. The effort to identify energy efficiency measures for reducing College Station's energy use and NOx emissions was conducted based on the baseline energy use and future energy demands.

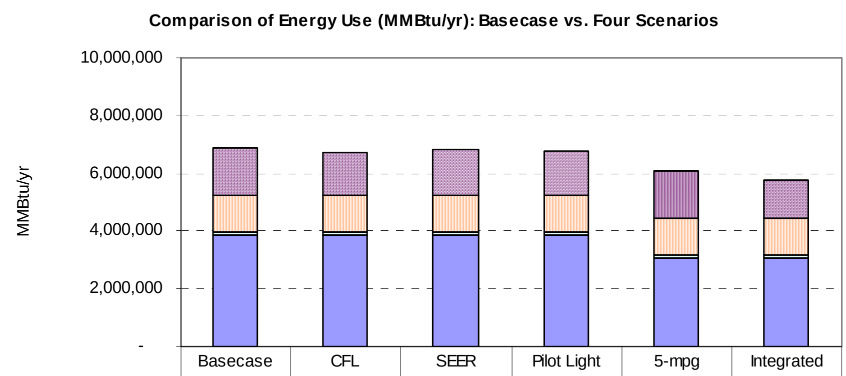
College Station could adopt four possible efficiency technologies: 1) the replacing of incandescent lamps with Compact Fluorescent Lamps (CFLs) in the residential sector; 2) the elimination of pilot lights for DHW and gas furnaces in the residential sector; and 3) the adoption of higher SEER AC units in the residential sector, and 4) the adoption of 5-mpg fuel efficiency improvements in light duty vehicles. The impact of individual uses or combinations of the four scenarios on energy savings and its associated emissions reductions were predicted. As a result, this analysis indicates that an extensive use of more energy efficient technologies in College Station could produce very attractive energy savings and NOx emissions reductions for the community-wide emissions reduction plan.

Table 6-16: Base Case Energy Use and NOx Emissions for the Transportation Sector.

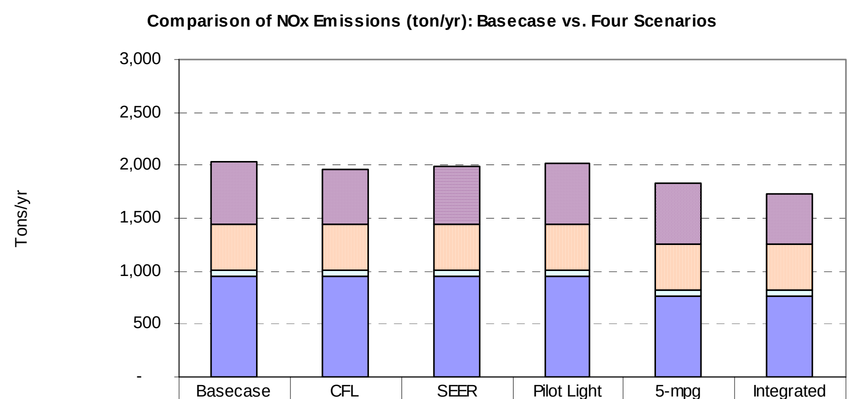
Vehicle Type		Total Registered Vehicle	Number of Vehicle by Type		VMT		Fuel Use		NOx emissions			
			Distribution	Number of Vehicle	Total Daily VMT (DVM)	VMT MIX	Fuel Efficiency (mpg) 2001*	Daily Fuel Use (gallons)	NOx Emission Rate (grams per mile)	NOx Emissions (grams)	NOx Emissions (tons)	Converted to grams per gallons
Passenger Cars		48,700	48.08%	23,415	1,619,901	778,848	22.1	35,242	1.38	1,074,810	1.185	30.50
Light Trucks	Trucks		34.12%	16,616		552,710	17.6	31,404	1.8	994,878	1.097	31.68
	SUV		15.56%	7,578		252,057	17.6	14,321	1.8	453,703	0.500	31.68
	VAN		1.95%	950		31,588	17.6	1,795	1.8	56,858	0.063	31.68
BUS			0.16%	78		2,592	6.7	387	11.24	29,134	0.032	75.31
Motor Cycles			0.13%	63		2,106	50	42	0.83	1,748	0.002	41.50
Daily Total				48,700		1,619,901		83,191		2,611,131	2.88	31.39
Annual Total (Daily Total x 365 days/year)						591,263,865		30,364,763		953,062,925	1,051	

Table 6-17: Light Duty Vehicle's 5-mpg Improvement's Energy Use and NOx Emissions for the Transportation Sector.

Vehicle Type		Total Registered Vehicle	Number of Vehicle by Type		VMT		Fuel Use		NOx emissions			Savings
			Distribution	Number of Vehicle	Total Daily VMT (DVM)	VMT MIX	Fuel Efficiency (mpg) 2001*	Daily Fuel Use (gallons)	Converted to grams per gallons	NOx Emissions (grams)	NOx Emissions (tons)	NOx Emissions (tons)
Passenger Cars		48,700	48.08%	23,415	1,619,901	778,848	27.1	28,740	30.498	876,506	0.966	0.22
Light Trucks	Trucks		34.12%	16,616		552,710	22.6	24,456	31.68	774,772	0.854	0.24
	SUV		15.56%	7,578		252,057	22.6	11,153	31.68	353,326	0.389	0.11
	VAN		1.95%	950		31,588	22.6	1,398	31.68	44,279	0.049	0.01
BUS			0.16%	78		2,592	6.7	387	75.308	29,134	0.032	0
Motor Cycles			0.13%	63		2,106	50	42	41.5	1,748	0.002	0
Daily Total				48,700		1,619,901		66,176	31.387129	2,079,765	2.29	0.59
Annual Total (Daily Total x 365 days/year)						591,263,865		24,154,102		759,114,262	837	214



	Basecase	CFL	SEER	Pilot Light	5-mpg	Integrated
Residential	1,651,358	1,509,693	1,566,455	1,562,309	1,651,358	1,335,742
Commercial	1,257,543	1,257,543	1,257,543	1,257,543	1,257,543	1,257,543
Municipal	138,351	138,351	138,351	138,351	138,351	138,351
Industrial	-	-	-	-	-	
Transportation	3,837,195	3,837,195	3,837,195	3,837,195	3,052,354	3,052,354
Total	6,884,446	6,742,782	6,799,544	6,795,398	6,099,605	5,783,990



	Basecase	CFL	SEER	Pilot Light	5-mpg	Integrated
Residential	586	518	545	582	586	474
Commercial	432	432	432	432	432	432
Municipal	58	58	58	58	58	58
Industrial	-	-	-	-	-	
Transportation	953	953	953	953	759	759
Total	2,030	1,962	1,989	2,026	1,836	1,724

Figure 6-11: Predicted Energy Savings and NOx Emissions Reductions.

CHAPTER VII
SUMMARY AND CONCLUSIONS

7.1 SUMMARY OF STUDY OBJECTIVES

The main objective of this study was to research and develop a general framework for the Comprehensive Community NOx Emissions Reduction Toolkit (CCNERT) in order to calculate a community-based energy use level and its associated NOx emissions. As previously mentioned, one of the intended benefits of the CCNERT is to allow decision-makers to quickly calculate the current energy use and emissions for a whole community, and then to allow for individual measures across the entire community. This cannot be performed with only a top-down approach.

To accomplish this, the general framework of the CCNERT was developed based on an integrated "top-down, bottom-up" approach. To develop a general framework, the related literature was first reviewed in each of the following categories:

1) The general characteristics of NOx emissions,
2) The recent efforts to reduce NOx emissions,
3) The previous related studies used to estimate NOx emissions reductions resulting from energy savings,
4) The community-wide energy efficiency programs,
5) The building sector's energy baseline procedures,
6) The industrial sector's baseline procedures,
7) The transportation sector's energy use baseline procedures, and
8) The community-wide energy efficiency measures.

Based on the findings from the literature review, the various procedures for estimating each sector's energy use and its associated NOx emissions were developed and presented in Chapter IV (Methodology).

7.2 SUMMARY OF METHODOLOGY

The main purpose of developing the CCNERT methodology was to determine how and where energy was being used and to examine how community energy use causes NOx emissions within a selected community. To accomplish this procedures were developed: 1) to categorize sectors and to gather information; 2) to calculate each sector's energy use; 3) to calculate the total community-wide energy use; and 4) to estimate the total NOx emissions based on previously calculated energy use. These four main tasks have been similarly applied to each sector's base-line energy consumption and its associated NOx emissions.

The City of College Station was selected as the case study community in order to apply and verify the developed procedures for estimating community-based energy use and its associated NOx emissions. Within the community's boundary, there are hundreds of energy users such as buildings, vehicles, streetlights, etc. Furthermore, building energy users could be categorized in many ways, including by use, type of construction, HVAC system types, or thermal characteristics. To account for these variables, simplified groups of energy users were used. In this study, the following categories of community energy users were used: 1) residential, 2) commercial, 3) municipal, 4) industrial, and 5) transportation. The individual sectors were further subdivided into sub-categories.

Since energy use characteristics in these sectors vary significantly based on each sector's activity, different procedures were developed to determine the baseline energy uses of each sector. To determine an individual building sector's (residential and commercial) baseline energy use, the following eight steps were developed. The methodology included:

1) The identification of information related to the general characteristics of the building sector,
2) The selection of sample houses or building simulations,
3) The collection of utility billing information from sample houses,
4) The development of representative buildings,
5) The preparation of verified data for the ASHRAE IMT analysis and the DOE-2 simulations,
6) The comparison of energy usage predictions to the actual energy consumption data,

7) The translating of results obtained from the baseline energy use analyses to values representative of the selected community, and
8) The calculation of the total energy use.

The municipal sector was sub-categorized into seven detailed parcels: 1) city-owned municipal buildings, 2) educational buildings owned by the local Independent School District (ISD), 3) streetlights, 4) traffic lights, 4) the water supply system, 5) the waste water treatment system, and 7) community parks & recreation facilities. To estimate the total energy consumption, a significant effort was made to collect actual consumption data. One necessary task was to collect utility bill information from College Station Utility Customer Service (CSUCS).

The procedures used to calculate energy use for the industrial sector were developed based on the industrial activity or process examined. The main purpose for this procedure was to estimate the industrial sector's energy use by using a simplified method. To accomplish this goal, the following tasks were determined to be necessary: 1) a determination of the number of establishment, 2) the classification establishments by their SIC or NAICS group, 3) a determination of gross sales in each SIC or NAICS group, 4) a calculation of energy intensity factors for each group, and 5) a calculation of energy use for each group. The following information sources were proposed for use: 1) the U.S. census's county business pattern data, 2) the EIA's 1998 Manufacturing Energy Consumption Survey, and 3) the Texas Comptroller of Public Accounts. The procedure for cross-checking the industrial sector's energy use estimations with the actual energy use was also discussed in Chapter IV.

The procedure used to calculate energy consumption for the transportation sector and its NOx emissions was developed and discussed in Chapter IV. The procedure consisted of five main tasks: 1) the categorization of the transportation sector, 2) the determination of the number of vehicles or types of equipment, 3) the determination of vehicle miles traveled (VMT) and the VMT mix, 4) the determination of fuel efficiencies by vehicle type, and 5) the calculation of the total energy use.

As the final step in developing this methodology, the procedures for calculating NOx emissions were discussed in Chapter IV. Since a community uses a variety of types of fuel, the procedures were individually developed and then combined to calculate the community's total NOx emissions. The procedures included the calculation of NOx emissions from electricity use, natural gas use, and transportation fuel use.

7.3 SUMMARY OF APPLICATIONS IN THIS METHODOLOGY (ENERGY USE)

The results of the community energy use by applying the CCNERT methodology to the case study community of College Station, Texas, shows that the 2002 baseline energy consumption level for College Station was 6.4 million MMBtu. The energy consumption values are represented here as residential (1.6 million MMBtu), commercial (1.3 million MMBtu), municipal (0.9 million MMBtu), and transportation (3.4 million MMBtu). Of these, transportation accounted for approximately half (53%) the energy use, shown in Figure 7-1. The residential sector accounted for 24%, the commercial sector accounted for 18%, and the industrial sector accounted for only a negligible level of energy use, significantly less than the sectors' shares for Texas and U.S., reflecting the city's low level of industrial activity. As previously mentioned, the energy consumed by Texas A&M University was not included in this analysis.

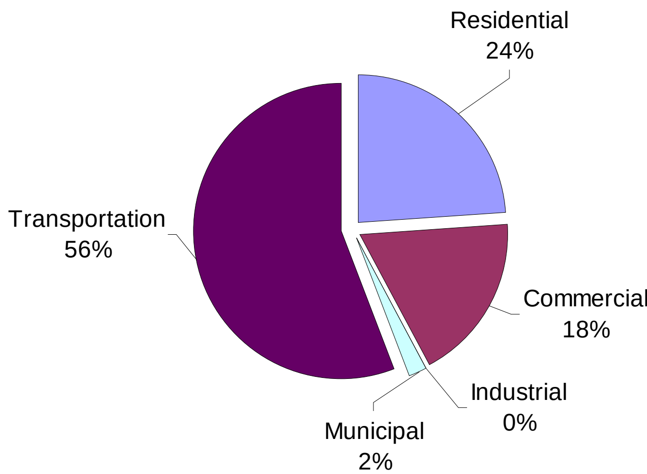


Figure 7-1: Estimated Energy Use by Five Sectors in College Station.

The energy use distribution for the City of College Station is significantly different than the energy use patterns of the nation and Texas. Transportation consumes over 56% of the total delivered energy used in College Station, whereas it only represents 28% and 22% of the energy use for the US and Texas respectively.

7.4 SUMMARY OF APPLICATION OF THE METHODOLOGY (NO_X EMISSIONS)

The results of the community's total NOx emissions through the application of the CCNERT methodology to the case study community of College Station, Texas, shows that the 2002 baseline NOx emissions for College Station were 2,030 tons per year, which represent the residential (586 tons), commercial (432 tons), municipal (58 tons) sectors, and transportation (953 tons). Of these, transportation accounted for approximately one half (47%) the annual NOx emissions, the residential sector accounted for 29%, the commercial sector for 21%, the municipal sector for 3%, and the industrial sector for a negligible level of NOx emissions, shown in Figure 7-2.

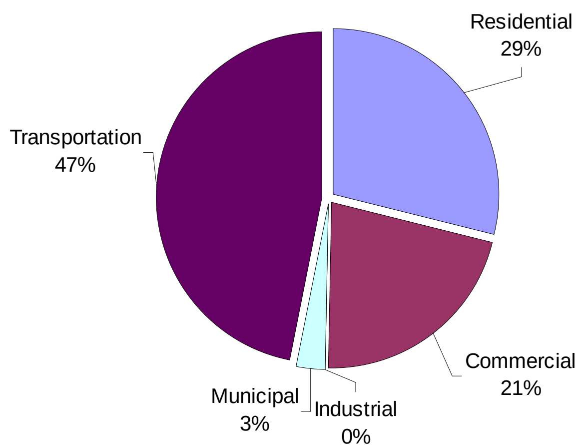


Figure 7-2: Estimated NOx Emissions by Five Sectors in College Station.

NOx emissions by fuel type were also estimated for this study. Transportation fuels (gasoline and diesel) produced the largest portion (47%) of total annual NOx emissions in College Station as compared to those from non-transportation fuel uses (natural gas & electricity). The second largest portion of NOx emissions was from College Station's electricity use, which accounts for 46% of the total NOx emissions. Interestingly, the NOx emissions from electricity use (its generation) were even greater than the NOx emissions from transportation fuel use when transmission and distribution losses (10%) were applied to the estimated electricity use. Furthermore, a portion of these emissions occurred in remote counties.

7.5 SUMMARY OF VALIDATION

The validation of the developed energy analysis model was a major task of this research. The validation was conducted through an empirical validation using the locally derived actual electricity sales data from the local utility (College Station Utility Service) and annual natural gas consumption data from the RRC, compared to the results from the each sector's energy analysis model.

Electricity estimation showed relatively similar results as compared to the natural gas use calculation. There was less than a 10% difference between the results from the building sector's energy use analysis model and the utility analysis model. On-road vehicle fuel uses were also validated by using two simplified methods: 1) a VMT analysis and 2) a gross sales analysis. The results show only a 10% variation. It could therefore be concluded that, although the differences between the two approaches cannot be fully explained or quantified, either approach can be used to determine a community's on-road vehicle energy use based on local information availability.

7.6 SUMMARY OF THE FUTURE ENERGY DEMAND CALCULATIONS

The future energy demands for the period from 2002 to 2007 was simply calculated by applying the various activity growth rates to the baseline energy used by each energy use. The results of the analysis show that the community-wide energy consumption growth estimates reflected from 2002 to 2007 included a total energy consumption increase of 27 percent respectively. The annual increase for the community-wide energy growth rate is 5%. The largest increase in fuel type is natural gas consumption, with a total of a 61% increase from the base year. Electricity and transportation fuel use growth estimates reflect a 22% increase from the base year with 4% annual growth rate.

7.7 SUMMARY OF THE ADOPTION OF ENERGY EFFICIENCY SCENARIOS

As previously mentioned, the main purpose of the study was to determine how and where energy was being consumed within the selected community. This determination could help a community to identify areas of excessive energy use and aid in discovering areas where additional attention can be directed. Finally, the result of this renewed focus could be to realize effective energy conservation efforts and the resultant NOx reductions for a selected community. By analyzing the baseline energy use and future energy demands, four energy efficiency scenarios were identified and then proposed in College Station in order to reduce energy consumption. These four scenarios included:

1) The replacement of incandescent lamps with compact fluorescent lamps in the residential sector,
2) The replacement of lower SEER AC units with higher SEER AC units in the residential sector,
3) The elimination of pilot lights in gas furnaces and domestic hot water heaters, and
4) The improvement of light duty vehicles' fuel efficiency by 5-mpg.

The first scenario projected a 41 million kWh savings in all residential sector's electricity use – equivalent to a 12% reduction in all residential sector's electricity use, a 6.4% reduction in the total community's electricity consumption, and a 2.1% reduction in the total community energy use. A total of 67.4 tons of NOx emissions could be reduced annually – equivalent to a 3.3% reduction in community wide NOx emissions reductions. The second scenario projected a 24 million kWh annual savings; 17.6 tons of NOx emissions are expected. This value represents about 7.25% of the total residential sector's electricity savings, and about 1.2% of total community's energy savings. The third scenario projected approximately 89,049 MBtus in savings. This value represents about 19.2% of the total residential natural gas use, 10% of the total community natural gas use, and 1.4% of the total community energy use. The projected annual NOx emissions reductions were 4 tons. The last scenario projected an annual savings of 6 million gallons (20% of the total base case fuel use) with 214 tons (10% of the total NOx emissions) of projected NOx emissions reductions expected.

After each scenario was individually evaluated as a comparison to the base case, the scenarios were combined into one package in order to estimate the most plausible reductions both in energy and NOx emissions. A combination of the four scenarios projected 1.1 million MBtus of annual energy savings, which represents approximately 15% of the total community's energy use. The projected annual NOx emissions reduction was 306 tons, which represents 15% of the total community's NOx emissions.

In summary, this analysis indicates that the extensive use of more energy efficient technologies in College Station could produce very attractive energy savings and NOx emissions reductions for the community-wide emissions reduction plan.

7.8 CONCLUSIONS

Since a community's energy use and patterns vary significantly by local characteristics such as climate, geography, population, transportation, housing, businesses, and fuel resources available, different communities could come to different conclusions about their energy saving and emissions reduction options. Therefore, community-wide emissions reduction plans for different communities might have different implementations. Furthermore, the energy performance of a community is a function of the dynamic relationship between various factors as mentioned above. These interactions create complex situations in which decision-makers or local governments could have some difficulty when making decisions about energy and emissions reductions. To help decision makers, this study has addressed the issues by providing a general framework for examining how a community's non-renewable energy use leads to NOx emissions, by quantifying each end-user's energy usage and its associated NOx emissions, and by evaluating the environmental benefits of various types of energy saving options.

Although the CCNERT methodology doesn't consider the complexity of the U.S. power market and does not account for an integrated analysis of cost benefits results from the various energy saving options, this methodology does provide a flexible method of quickly estimating community wide energy use and its associated NOx emissions. Estimating community-wide energy use and its associated NOx emissions requires an accurate energy use analysis for each sector. The main purpose of this task was to determine how and where energy is being consumed within a selected community. This determination could help the community to identify areas of excessive energy use and help to find areas upon which a community might focus. However, developing energy analysis procedures for a community base was a very complicated process. Energy use characteristics for these sectors varied significantly based on each sector's activity. Furthermore, the energy calculation procedures also varied depending upon an availability of information. Therefore, estimating energy uses for each sector will always require different procedures, with some degree of flexibility.

7.9 RECOMMENDATIONS FOR FUTURE STUDIES

The application of the CCNERT methodology to the case study community presented many limitations. Three general categories of limitations were identified as follows: 1) difficulties in identifying all energy users, 2) lack of information to reduce uncertainties, and 3) absence of cost-effectiveness analysis. If these limitations were to be further investigated in future studies, it would improve the quality of the analysis. The following discussion identifies these limitations and provides an explanation of each.

As mentioned before, community wide energy use is affected by various factors such as the level and composition of economic activity, demographic influences, climatic conditions, and regulatory efforts to reduce energy consumption. Therefore, the community-wide energy audit is complex process, and it would be impossible in this study to identify and control every factor involved. This situation carried some constraints during the application of the CCNERT methodology to the case study community.

1) The first difficulty for this study was in collecting all the necessary information, locally derived, to estimate current energy use and its pattern. Since, there were thousands of energy users in the case-study community, identifying every end user in intricate detail was a very difficult and time-consuming task. For instance, the exact number of vehicles, traveled within a community boundary (College Station City limits), could not be determined from the currently available information sources such as the TxDOT's county-wide VMT analysis and the

Brazos county's registered vehicles data. One assumption was therefore made for this study to determine the number of vehicle in College Station. Furthermore, in College Station, there could be many vehicles that are not included in the existing county vehicle registration data, because many students buy their vehicle at their hometown and bring it to College Station. Therefore, some portion of the on-road mobile source's energy use should be increased. The portion will be different depending on each community's activity. To overcome this situation, this study provided a simplified cross-check such as a gross fuel sale analysis.

2) As compared to the building sector's energy use characteristics, the transportation sector's energy use, especially on-road mobile source, has some spatial variations. For instance, since the City of College Station adjoins the City of Bryan, there are some possibilities of sharing in vehicle fueling between two communities. For example, College Station's residents may purchase gasoline at a gas station located in Bryan, and the vehicle might mainly travel within the College Station City limits. Therefore, some percentage of purchased gasoline may include purchases outside of the selected community boundary. This was not considered in this study due to difficulty in collecting necessary information. It is felt that a local community survey would be needed to overcome this limitation in a future study.

3) Determination of the number of all energy users in the residential sector was a complicated process due to seasonal variations. For instance, although the numbers of housing units remained constant or increased during the study period, the actual number of houses, using electricity dropped significantly during the university breaks. Second, in the summer even though the number of customers decreased, the total energy consumption had increased. From this fact, it can be assumed that the energy intensity per unit (customer) is much larger during summer season due to the large cooling load requirement. Therefore, if total electricity consumption were divided by a constant number of customers throughout year, the energy intensity during the university breaks would be smaller than the actual electricity use. This impacts the peak day electricity use and its associated NOx emissions. It is strongly felt that the seasonal variation of the number of customers should be considered in future studies.

4) The procedure for determining energy users in the commercial sector was more complicated than the procedure in the residential sector, because it was difficult to categorize various business activities into similar energy user groups and identify separate businesses in the

same building. For instance, if various business activities (i.e., food service, retail, office, and etc.) were conducted within one building with one utility account, the correct proportions of energy usage could not be simply established. In some cases, a space used for food service was renovated for another business activity. In the commercial sector, the energy consumption pattern was significantly different from one business activity to another. For instance, food service business' energy use intensity is much larger than the general office's. With a larger sample it would have been possible to provide more representative building characteristics including building envelope system, HVAC system type, lighting systems, etc., to quantify energy use more accurately.

5) Difficulty with aggregating total energy consumption for the commercial sector into each parcel appeared during the calculation of the commercial sector's energy. Because there were very few similar business activities, it was difficult to have an accurate statistical determination of an energy use index in the various business activities. Therefore, the EIA's CBECS data was combined with US Census's County Business Pattern Data in this study to determine each business activity's energy use. It is felt that this might provide more accurate results if sampling technique is conducted to provide locally derived representative value for each business activity for the commercial building sector.

6) In summary, although some conclusions could be drawn from the limited (nation-wide average information) data used in order to estimate each sector's energy use and NOx emissions, the lack of adequate (i.e., locally derived information) data was the most important limitation in conducting this research. It is strongly felt that a local government and local utility company's significant cooperation in collecting data sources is needed for future studies in order to improve the quality of the analysis.

7) There are also many constraints in estimating community-wide energy use and its associated NOx emissions. The most critical is that every end-user of energy cannot be identified. It is therefore impossible for any study to investigate every possible variable for a community to reduce NOx emissions. Energy efficiency measures for this study were therefore limited to a specific sector. For instance, the number of non-road mobile sources in College Station was not identified using currently available information sources such as TxDOT's

transportation study. Collecting such end-user's energy use would improve the accuracy of community energy use and NOx emissions estimates.

8) Simplified procedures for identifying non-road mobile sources, estimating these identified sources' energy use, and for estimating NOx emissions within selected community, should be developed in future study. One possible suggestion is to use the EPA's Source Classification Codes (SCC) (EPA 1999b).

9) Only certain energy sources such as electricity, natural gas, and transportation fuels were considered in this study. It would be useful in future studies if additional energy sources (i.e., propane, and oil) could be estimated. The procedure to determine possible renewable energy sources for a selected community can also be added in future studies in order to determine how much fossil fuel energy source can be replaced by renewable energy sources.

10) Another constraint of this study is that the energy efficiency measures and NOx emissions reduction options are limited to residential and transportation sectors. This study did not consider measures for other energy user sectors such as municipal and industrial sectors. In general, there are three ways to reduce the transportation sector's energy use, including: 1) improving vehicle fuel efficiency performance, 2) reducing annual vehicle miles by adopting effective land use or urban planning, and 3) improving NOx/Btu conversion. In this study, only the improving of vehicle fuel efficiency was considered to reduce NOx emissions. Other strategies could be used in a future study to determine their impacts on energy savings and NOx emissions reductions in future studies.

11) Although a construction sub-section has been added to each energy user sector to account for the energy use within a community during the construction period, the procedure for estimating construction energy use was not provided in this study. For instance, energy used to build a house should be added to the total residential sector's energy use. Another example is that energy used to build public infrastructure such as bridges and streets should be added to the total community's energy use. These areas would have provided additional energy use for community-wide energy use and NOx emissions if they had been included. The representative values should be determined using several sources of information. For instance, the energy use

can be estimated during the construction process for house or commercial buildings, infrastructures, and then compared against utility accounts assigned to contractor.

12) One possible approach for future studies in order to estimate the energy use for the construction sub-section would be a gross sales analysis. Since the annual gross sales of construction is available form the Texas Comptroller of Public Accounts' web site, the energy use of construction can be determined by converting the gross sales with proper conversion factors (Btu/$). These conversion factors are available from the EIA's NEMS publications (EIA 2003).

13) Another limitation of this study was the absence of a cost-effectiveness analysis. An economic analysis of the benefits of more energy efficiency scenarios should be investigated. Because this research mainly investigated the community-wide energy savings and its associated NOx emissions reductions, it didn't determine the cost savings or effectiveness from end-use energy efficiency measures.

14) Integrated heating, cooling and building envelope improvements in the commercial sector were not considered in this study. If they had been investigated, additional opportunities for increased energy efficiency and NOx emission reductions for a selected community might be revealed.

15) Finally, the CCNERT methodology was tested using only one community to apply and verify the procedures. Expansion of applying the CCNERT methodology to other communities would be necessary to have better verification of the CCNERT methodology.

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APPENDIX A

This appendix contains descriptions of the major manufacturing groups included in the 1994 MECS. The 1987 Standard Industrial Classification Manual (SIC Manual) provides these descriptions, which cover the 20 major groups (2-digit SIC).

Descriptions of Major Manufacturing Groups

SIC 20 - Food and Kindred Products: This major group includes establishments manufacturing foods and beverages for human consumption and certain related products such as manufactured ice, chewing gum, vegetable and animal fats and oils, and prepared feeds for animals and fowls.

SIC 21 - Tobacco Products: This major group includes establishments engaged in manufacturing cigarettes, cigars, smoking and chewing tobacco, snuff, and reconstituted tobacco and in stemming and redrying tobacco.

SIC 22 - Textile Mill Products: This major group includes establishments engaged in performing any of the following operations: (1) preparation of fiber and subsequently manufacturing of yarn, thread, braids, twine, or cordage; (2) manufacturing broad-woven fabrics, narrow woven fabrics, knit fabrics, and carpets and rugs from yarn; (3) dyeing and finishing fiber, yarn, fabrics, and knit apparel; (4) coating, waterproofing, or otherwise treating fabrics; (5) the integrated manufacture of knit apparel and other finished articles from yarn; (6) the manufacture of felt goods, lace goods, non-woven fabrics, and miscellaneous textiles.

SIC 23 - Apparel and Other Textile Products: This major group, known as the cutting-up and needle trades, includes establishments producing clothing and fabricating products by cutting and sewing purchased woven or knit textile fabrics and related materials, such as leather, rubberized fabrics, plastics, and furs.

SIC 24 - Lumber and Wood Products: This major group includes establishments engaged in cutting timber and pulpwood; merchant sawmills, lath mills, and shingle mills, cooperage stock mills, planning mills and plywood and veneer mills engaged in producing lumber and wood basic materials; and establishments engaged in manufacturing finished articles made entirely or mainly of wood or related materials.

SIC 25 - Furniture and Fixtures: This major group includes establishments engaged in manufacturing household, office, public building, and restaurant furniture; and office and store fixtures.

SIC 26 - Paper and Allied Products: This major group includes establishments primarily engaged in the manufacture of pulps from wood and other cellulose fibers, and from rags; the manufacture of paper and paperboard; and the manufacture of paper and paperboard into converted products, such as paper coated off the paper machine, paper bags, paper boxes, and envelopes.

SIC 27 - Printing and Publishing: This major group includes establishments engaged in printing by one or more common process such as letterpress, lithography (including offset), gravure, or screen; and those establishments which perform services for the printing trade, such as bookbinding and plate-making.

SIC 28 - Chemicals and Allied Products: This major group includes establishments producing basic chemicals, and establishments manufacturing products by predominately chemical processes. Establishments classified in this major group manufacture three general classes of products; (1) basic chemicals, such as acids, alkalies, salts, and organic chemicals; (2) chemical products to be used in further manufacture, such as synthetic fibers, plastics materials, dry colors, and pigments; and (3) finished chemical products used for ultimate consumption, such as drugs, cosmetics, and soaps; or to be used as materials or supplies in other industries, such as paints, fertilizers, and explosives.

SIC 29 - Petroleum and Coal Products: This major group includes establishments primarily engaged in petroleum refining, manufacturing paving and roofing materials, and compounding lubricating oils and greases from purchased materials.

SIC 30 - Rubber and Miscellaneous Plastics Products: This major group includes establishments manufacturing products, not elsewhere classified, from plastics resins and from natural, synthetic, or reclaimed rubber, gutta percha, balata, or gutta siak.

SIC 31 - Leather and Leather Products: This major group includes establishments engaged in tanning, currying, and finishing hides and skins, leather converters, and establishments manufacturing finished leather and artificial leather products and some similar products made of other materials.

SIC 32 - Stone, Clay, Glass and Concrete Products: This major group includes establishments manufacturing flat glass and other glass products, cement, structural clay products, pottery, concrete and gypsum products, cut stone, abrasive and asbestos products,and other products from materials taken principally from the earth in the form of stone, clay, and sand.

SIC 33 - Primary Metals Industries: This major group includes establishments engaged in smelting and refining ferrous and nonferrous metals from ore, pig, or scrap; in rolling, drawing, and alloying metals; in manufacturing castings and other basic metal products; and in manufacturing nails, spikes, and insulated wire and cable.

SIC 34 - Fabricated Metal Products: This major group includes establishments engaged in fabricating ferrous and nonferrous metal products such as metal cans, tinware, hand tools, cutlery, and general hardware, nonelectric heating apparatus, fabricated structural metal products, metal forgings, and metal stampings. Ordnance (except vehicles and guided missiles), and a variety of metal and wire products not elsewhere classified.

SIC 35 - Industrial Machinery and Equipment: This major group includes establishments engaged in manufacturing industrial and commercial machinery and equipment, and computers.

SIC 36 - Electronic and Other Electric Equipment: This major group includes establishments engaged in manufacturing machinery, apparatus, and supplies for the generation, storage, transmission, transformation, and use of electrical energy.

SIC 37 - Transportation Equipment: This major group includes establishments engaged in manufacturing equipment for transportation of passengers and cargo by land, air, and water.

SIC 38 - Instruments and Related Products: This major group includes establishments engaged in manufacturing instruments (including professional and scientific) for measuring, testing, analyzing, and controlling, and their associated sensors and accessories; optical instruments and lenses; surveying and drafting instruments; hydrological, hydrographic, meteorological, and geophysical equipment; search, detection, navigation, and guidance systems and equipment; surgical, medical, and dental instruments, equipment and supplies; ophthalmic goods; photographic equipment and supplies; and watches and clocks.

SIC 39 - Miscellaneous Manufacturing Industries: This major group includes establishments primarily engaged in manufacturing products not classified in any other manufacturing major group.

APPENDIX B

This appendix contains summary tables of building and thermal characteristics of single-family, multi-family, and mobile home prototypes in southern regions. These tables were used for this study to characterize the thermal characteristics and HVAC system types of existing housing stock in College Station.

Tables B-1 thru B-3 were originally developed by LBNL (1997) using various information sources. The information sources included: 1) 1987 RECS data, 2) 1987 NAHB Builders Survey data and other studies from LBNL (1997). These tables represent average building conditioned floor area, typical foundation type and number of stories, and average component insulation level. Each table also represents the share (%) of different heating fuel type across shell group (tight or Loose) for the southern region. Tables B-3 thru B-4 were developed by ESL using more resent data for the study of Texas Emissions Reduction Plan (TERP).

The information sources included: 1) the builders practical survey report (NAHB 2000), 2) the Air-Conditioning and Refrigeration Institute (ARI), and 3) Gas Appliance Manufacturers Association (GAMA 1996). These tables therefore represent building and thermal characteristics of relatively newer houses, which were built in 1999. Since there is a broad range of house age in a community, the relationship between house age and building or thermal characteristics should be considered. Therefore, these data were very useful information for this study to understand the relationship and to determine housing characteristics in College Station.

Table B-1: Building and Thermal Characteristics of Single-Family Building Prototypes in Southern Regions.

Heat Type	Shell Group	Regional Population (% of stock)	Foundation Type	Conditioned Floor Area (ft^2)	No. of Story	Roof R-value	Wall R-value	Glazing Layers	ACH
Existing Building									
Electric	Tight	10.30%	Slab	1640	1	19	7	1.4	0.67
Electric	Loose	4.20%	Slab	1170	1	6	2	1.3	0.67
HPump	Tight	11.00%	Slab	1650	1	21	8	1.7	0.7
HPump	Loose	1.80%	Slab	1480	1	6	1	1.2	0.64
Fuel	Tight	32.20%	Crawl	1650	1	20	5	1.5	0.71
Fuel	Loose	40.40%	Crawl	1370	1	5	1	1.2	0.69
New Building									
Electric	All	13%	Slab	1890	1	28	10	1.5	0.62
HPump	All	31%	Slab	1820	1	25	11	1.7	0.63
Fuel	All	56%	Slab	2070	1	25	12	1.7	0.63

Source: LBNL 1997.

Table B-2: Building and Thermal Characteristics of Multi-Family Building Prototypes in Southern Regions.

Heat Type	Shell Group	Regional Population (% of stock)	Foundation Type	Conditioned Floor Area (ft^2)	Roof R-value	Wall R-value	Glazing Layers	ACH
Existing Building								
Electric	Pre-80s	24.40%	Slab	1038	4	1	1	0.49
Electric	1980s	11.40%	Slab	1084	22	13	2	0.37
HPump	Pre-80s	4.80%	Slab	1036	4	1	1	0.5
HPump	1980s	8.80%	Slab	983	22	13	2	0.37
Fuel	Pre-80s	45.70%	Slab	925	2	1	1	0.48
Fuel	1980s	5.10%	Slab	1015	22	13	2	0.37
New Building								
Electric	All	30%	Slab	1084	22	13	2	0.37
HPump	All	35%	Slab	983	22	13	2	0.37
Fuel	All	35%	Slab	1015	22	13	2	0.37

Source: LBNL 1997.

Table B-3: Building and Thermal Characteristics of Manufactured Home Building Prototypes in Southern Regions.

Heat Type	Shell Group	Regional Population (% of stock)	Foundation Type	Conditioned Floor Area (ft^2)	Roof R-value	Wall R-value	Glazing Layers	ACH
Existing Building								
Electric	All	19.80%	Crawl	940	1	11	1	0.53
HPump	All	4.00%	Crawl	1040	1	11	1	0.53
Fuel	All	76.00%	Crawl	847	1	11	1	0.53
New Building								
All	All	100%	Crawl	1195	1	20	2	0.42

Source: LBNL 1997.

Table B-4: Summary Table of Prototype Housing Characteristics for Single-Family House.

	Required Data	NAHB (East Texas)	NAHB (West Texas)
Year		1999	1999
Envelope	Floor Area (ft^2)	2548.01	2426.4264
	Wall Height (ft)	8.8	9.2
	Wall R-value	13.99 (Combined R)	14.18 (Combined R)
	Roof/Ceiling R-value	27.08	26.75
	Window Area (%)	13.8% (16.4 units of windows)	20.6% (24.9 units of windows)
	Glazing U-factor	1.11	0.87
	SHGC	0.714	0.66
Building Mechanical Systems and Equipment	AFUE (Gas-fired or oil-fired furnace < 225,000 Btu/h)	80%	80%
	SEER (Air-cooled air conditioners and heat pumps cooling mode < 65,000 Btu/h cooling capacity)	12	12

Note: This table was developed by the ESL (2003) for the study of Texas Emissions Reduction Plan.

Table B-5: Summary Table of Prototype Housing Characteristics for Multi-Family House.

	Required Data	NAHB (West South Central)
Year		1999
Envelope	Floor Area (ft^2)	1009.3402
	Wall height(ft)	8.441 (1st) 8.342 (2nd)
	Wall R-value	21.414 (Combined R)
	Roof/Ceiling R-value	36.083
	Window area (%)[1]	7.5% (5.326 units)
	Glazing U-factor [2]	0.7535
	SHGC [3]	0.605
Building Mechanical Systems and Equipment	AFUE (Gas-fired or oil-fired furnace < 225,000 Btu/h)	80%
	SEER (Air-cooled air conditioners and heat pumps cooling mode < 65,000 Btu/h cooling capacity)	12

Note: This table was developed by the ESL (2003) for the study of Texas Emissions Reduction Plan.

APPENDIX C

This appendix contains summary tables of commercial building fuel mix and HVAC systems by different building activities. Tables C-1 and C2 was developed using 1999 CBECS data (EIA 2001).

Table C-1: U.S. Commercial Building's Space-Heating Energy Source Used by Building Activity.

Principal Building Activity	All Buildings	All Buildings with Space Heating	Space-Heating Energy Sources Used										
			Electricity		Natural Gas		Fuel Oil		District Heat		Propane		Other
			(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	
Education	8,651	8,612	3,613	0.42	5,317	0.62	1,375	0.16	1,086	0.13	200	0.02	Q
Food Sales	994	880	359	0.41	556	0.63	Q	Q	Q	Q	Q	Q	Q
Food Service	1,851	1,721	836	0.49	1,210	0.70	Q	Q	Q	Q	Q	Q	Q
Health Care	2,918	2,918	1,335	0.46	1,793	0.61	641	0.22	736	0.25	Q	Q	N
Inpatient	1,865	1,865	693	0.37	1,257	0.67	615	0.33	641	0.34	Q	Q	N
Outpatient	1,053	1,053	642	0.61	536	0.51	Q	Q	Q	Q	Q	Q	N
Lodging	4,521	4,424	2,984	0.67	2,503	0.57	Q	Q	527	0.12	Q	Q	Q
Mercantile	10,398	9,848	6,148	0.62	6,423	0.65	649	0.07	Q	Q	332	0.03	Q
Retail (Other Than Mall)	4,766	4,615	2,239	0.49	3,150	0.68	470	0.10	Q	Q	Q	Q	Q
Enclosed and Strip Malls	5,631	5,233	3,909	0.75	3,274	0.63	Q	Q	N	N	Q	Q	N
Office	12,044	11,819	7,221	0.61	6,060	0.51	812	0.07	1,487	0.13	Q	Q	Q
Public Assembly	4,393	4,015	1,848	0.46	2,370	0.59	Q	Q	841	0.21	Q	Q	Q
Public Order and Safety	1,168	1,021	354	0.35	512	0.50	Q	Q	297	0.29	Q	Q	Q
Religious Worship	3,405	3,383	1,534	0.45	2,270	0.67	182	0.05	Q	Q	706	0.21	Q
Service	3,388	3,027	1,145	0.38	1,981	0.65	405	0.13	Q	Q	Q	Q	Q
Warehouse and Storage	10,477	8,104	4,285	0.53	5,719	0.71	576	0.07	Q	Q	483	0.06	Q
Other	1,222	1,086	401	0.37	612	0.56	Q	Q	Q	Q	Q	Q	Q
Vacant	1,908	754	228	0.30	575	0.76	Q	Q	Q	Q	Q	Q	Q

Source: EIA 2001.

Table C-2: U.S. Commercial Building's Space-Heating Equipment Used by Building Activity.

Principal Building Activity	All Buildings	All Buildings with Space Heating	Heating Equipment Used													
			Heat Pump		Furnace		Individual Space Heater		District Heat		Boilers		Packaged Heating Units		Other	
			(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)
Education	8,651	8,612	1,184	0.14	1,040	0.12	1,869	0.22	1,086	0.13	5048	0.59	2710	0.31	Q	Q
Food Sales	994	880	Q	Q	263	0.30	Q	Q	Q	Q	Q	Q	402	0.46	Q	Q
Food Service	1,851	1,721	Q	Q	583	0.34	261	0.15	Q	Q	Q	Q	895	0.52	Q	Q
Health Care	2,918	2,918	648	0.22	368	0.13	676	0.23	736	0.25	1494	0.51	1159	0.40	335	0.11
Inpatient	1,865	1,865	486	0.26	Q	Q	560	0.30	641	0.34	1235	0.66	761	0.41	Q	Q
Outpatient	1,053	1,053	Q	Q	264	0.25	Q	Q	Q	Q	259	0.25	398	0.38	Q	Q
Lodging	4,521	4,424	1,068	0.24	649	0.15	1659	0.38	527	0.12	1814	0.41	1688	0.38	Q	Q
Mercantile	10,398	9,848	1,340	0.14	2,234	0.23	2448	0.25	Q	Q	1291	0.13	6664	0.68	701	0.07
Retail (Other Than Mall)	4,766	4,615	218	0.05	1,620	0.35	1199	0.26	Q	Q	536	0.12	2171	0.47	Q	Q
Enclosed and Strip Malls	5,631	5,233	1,122	0.21	614	0.12	1249	0.24	N	N	755	0.14	4493	0.86	Q	Q
Office	12,044	11,810	1,949	0.17	1,807	0.15	2631	0.22	1,487	0.13	4211	0.36	4304	0.36	1244	0.11
Public Assembly	4,393	4,015	582	0.14	787	0.20	1163	0.29	841	0.21	1409	0.35	1368	0.34	Q	Q
Public Order and Safety	1,168	1,021	Q	Q	Q	Q	232	0.23	297	0.29	541	0.53	251	0.25	Q	Q
Religious Worship	3,405	3,383	327	0.10	1,701	0.50	1021	0.30	Q	Q	1010	0.30	1047	0.31	Q	Q
Service	3,388	3,027	381	0.13	1,129	0.37	1165	0.38	Q	Q	532	0.18	1184	0.39	224	0.07
Warehouse and Storage	10,477	8,104	888	0.11	3,270	0.40	3560	0.44	Q	Q	1369	0.17	3542	0.44	428	0.05
Other	1,222	1,086	Q	Q	309	0.28	257	0.24	Q	Q	247	0.23	383	0.35	Q	Q
Vacant	1,908	754	Q	Q	218	0.29	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q

Source: EIA 2001.

Table C-3: U.S. Commercial Building's Space-Cooling Energy Source Used by Building Activity.

Principal Building Activity	All Buildings	All Buildings with Space Cooling	Space-Cooling Energy Sources Used					
			Electricity		Natural Gas		District Chilled Water	
			(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)
Education	8,651	7,973	7,305	0.92	Q	Q	676	0.08
Food Sales	994	978	947	0.97	Q	Q	N	N
Food Service	1,851	1,760	1687	0.96	Q	Q	Q	Q
Health Care	2,918	2,815	2,537	0.90	Q	Q	433	0.15
Inpatient	1,865	1,762	1554	0.88	Q	Q	356	0.20
Outpatient	1,053	1,053	983	0.93	Q	Q	Q	Q
Lodging	4,521	4,051	3,880	0.96	Q	Q	219	0.05
Mercantile	10,398	10,174	9,914	0.97	462	0.05	Q	Q
Retail (Other Than Mall)	4,766	4,573	4,423	0.97	Q	Q	Q	Q
Enclosed and Strip Malls	5,631	5,601	5,492	0.98	Q	Q	Q	Q
Office	12,044	11,782	11,024	0.94	319	0.03	678	0.06
Public Assembly	4,393	3,859	3,544	0.92	Q	Q	436	0.11
Public Order and Safety	1,168	760	706	0.93	Q	Q	Q	Q
Religious Worship	3,405	2,765	2,763	1.00	Q	Q	Q	Q
Service	3,388	2,481	2,470	1.00	Q	Q	Q	Q
Warehouse and Storage	10,477	7,621	7,520	0.99	Q	Q	Q	Q
Other	1,222	1,087	880	0.81	Q	Q	Q	Q
Vacant	1,908	368	368	1.00	N	N	N	N

Source: EIA 2001.

Table C-4: U.S. Commercial Building's Space-Cooling Equipment Used by Building Activity.

Principal Building Activity	All Buildings	All Buildings with Space Heating	Cooling Equipment Used													
			Residential Type AC		Heat Pump		Individual Space Heater		District Chilled Water		Central Chillers		Packaged AC Units		Residential Type AC	
			(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)	(million ft^2)	Percentage (%)
Education	8,651	7,973	625	0.08	1,220	0.15	2,974	0.37	676	0.08	2108	0.26	4331	0.54	508	0.06
Food Sales	994	978	Q	Q	Q	Q	Q	Q	N	N	Q	Q	610	0.62	Q	Q
Food Service	1,851	1,760	357	0.20	Q	Q	394	0.22	Q	Q	Q	Q	1323	0.75	Q	Q
Health Care	2,918	2,815	572	0.20	684	0.24	696	0.25	433	0.15	1609	0.57	1783	0.63	Q	Q
Inpatient	1,865	1,762	455	0.26	503	0.29	602	0.34	356	0.20	1413	0.80	1109	0.63	Q	Q
Outpatient	1,053	1,053	Q	Q	Q	Q	Q	Q	Q	Q	196	0.19	673	0.64	Q	Q
Lodging	4,521	4,051	736	0.18	1,014	0.25	2075	0.51	219	0.05	980	0.24	1956	0.48	Q	Q
Mercantile	10,398	10,174	1,043	0.10	1,296	0.13	1441	0.14	Q	Q	1278	0.13	8019	0.79	387	0.04
Retail (Other Than Mall)	4,766	4,573	551	0.12	225	0.05	1111	0.24	Q	Q	Q	Q	3003	0.66	Q	Q
Enclosed and Strip Malls	5,631	5,601	492	0.09	1,070	0.19	330	0.06	Q	Q	1115	0.20	5017	0.90	Q	Q
Office	12,044	11,782	1,089	0.09	2,158	0.18	1500	0.13	678	0.06	4559	0.39	6838	0.58	169	0.01
Public Assembly	4,393	3,859	579	0.15	533	0.14	742	0.19	436	0.11	920	0.24	2152	0.56	Q	Q
Public Order and Safety	1,168	760	Q	Q	Q	Q	284	0.37	Q	Q	302	0.40	383	0.50	Q	Q
Religious Worship	3,405	2,765	694	0.25	403	0.15	781	0.28	Q	Q	Q	Q	1630	0.59	Q	Q
Service	3,388	2,481	491	0.20	399	0.16	716	0.29	Q	Q	Q	Q	1575	0.63	Q	Q
Warehouse and Storage	10,477	7,621	1,658	0.22	858	0.11	2155	0.28	Q	Q	349	0.05	5198	0.68	179	0.02
Other	1,222	1,087	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	482	0.44	Q	Q
Vacant	1,908	368	Q	Q	Q	Q	Q	Q	N	N	Q	Q	Q	Q	Q	Q

Source: EIA 2001.

APPENDIX D

This appendix contains summary tables (Tables D-1 thru D-4) of housing characteristics of 65 sample single-family detached houses. The summary tables show wall materials, number of stories, cooling energy source, heating energy source, conditioned floor areas, annual electricity use (kWh/yr), year built, and energy use intensity (kWh/ft^2-year) of each sample house. Figures D-1 thru D-57 show monthly electricity consumption, average daily electricity use profile, and three-parameter change-point electricity models for each sample building. However, some sample houses were discarded from the utility bill analysis due to residents moving in and moving out during the course of one year.

Table D-1: Housing Characteristics and Electricity Use of Sample Houses (District A).

Sample House	Wall Material	Number of Floor	Cooling Source	Heating Source	Area (square ft.)	Year Built	Annual Elec. Consumption	EUI (KWh/sq.ft)	Average EUI
R-A-1	Wood Siding	1	Electricity	Natural Gas	960	1950	10045	10.5	
R-A-2	Wood Siding	1	Electricity	Natural Gas	720	1955	9573	13.3	
R-A-3	Wood Siding	1	Electricity	Natural Gas	1496	1979	12232	8.2	
R-A-4	Wood Siding	1	Electricity	Natural Gas	1075	1955	13256	12.3	
R-A-5	Wood Siding	1	Electricity	Natural Gas	957	1953	16219	16.9	
R-A-6	Wood Siding	1	Electricity	Natural Gas	1008	1955	14352	14.2	
R-A-7	Brick	1	Electricity	Natural Gas	1189	1958	N/A	N/A	
R-A-8	Brick	1	Electricity	Natural Gas	875	1960	8678	9.9	
R-A-9	Wood Siding	1	Electricity	Natural Gas	1840	1971	18923	10.3	
R-A-10	Wood Siding	1	Electricity	Natural Gas	1432	1955	9475	6.6	
R-A-11	Wood Siding	1	Electricity	Natural Gas	836	1955	10902	13.0	
R-A-12	Wood Siding	1	Electricity	Natural Gas	1392	1952	N/A	N/A	
R-A-13	Wood Siding	1	Electricity	Natural Gas	1008	1954	14144	14.0	
R-A-14	Wood Siding	1	Electricity	Natural Gas	910	1955	10379	11.4	
R-A-15	Wood Siding	1	Electricity	Natural Gas	1203	1952	14734	12.2	11.8

Table D-2: Housing Characteristics and Electricity Use of Sample Houses (District B).

Sample House	Wall Material	Number of Floor	Cooling Source	Heating Source	Area (square ft.)	Year Built	Annual Elec. Consumption	EUI (KWh/sq.ft)	Average EUI
R-B-1	Brick	1	Electricity	Natural Gas	1650	1981	19002	11.5	
R-B-2	Brick	1	Electricity	Natural Gas	1523	1981	9328	6.1	
R-B-3	Wood Siding	1	Electricity	Natural Gas	1807	1981	12404	6.9	
R-B-4	Brick	1	Electricity	Natural Gas	1697	1980	14600	8.6	
R-B-5	Wood Siding	1	Electricity	Natural Gas	1630	1981	8024	4.9	
R-B-6	Brick	1	Electricity	Natural Gas	1524	1979	21897	14.4	
R-B-7	Brick	1	Electricity	Natural Gas	1739	1980	13455	7.7	
R-B-8	Brick	1	Electricity	Natural Gas	1712	1982	15922	9.3	
R-B-9	Brick	1	Electricity	Natural Gas	1849	1979	17441	9.4	
R-B-10	Brick	1	Electricity	Natural Gas	1566	1976	22354	14.3	
R-B-11	Brick	1	Electricity	Natural Gas	2283	1979	9386	4.1	
R-B-12	Brick	1	Electricity	Natural Gas	1570	1979	24931	15.9	
R-B-13	Brick	1	Electricity	Natural Gas	1829	1983	17673	9.7	
R-B-14	Brick	1	Electricity	Natural Gas	1782	1979	12653	7.1	
R-B-15	Wood Siding	1	Electricity	Natural Gas	2563	1978	N/A	N/A	9.3

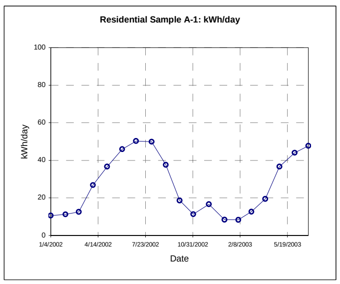
Table D-3: Housing Characteristics and Electricity Use of Sample Houses (District C).

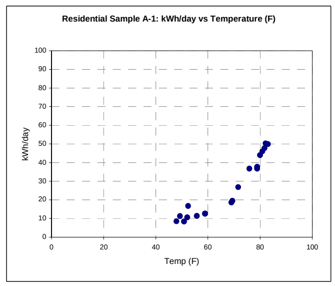
Sample House	Wall Material	Sector	Cooling Source	Heating Source	Area (square ft.)	Year Built	Annual Elec. Consumption	EUI (KWh/sq.ft)	Average EUI
R-C-1	Brick	1	Electricity	Natural Gas	2656	1994	14692	5.5	
R-C-2	Brick	1	Electricity	Natural Gas	2802	1995	52088	18.6	
R-C-3	Brick	1	Electricity	Natural Gas	2721	1994	21772	8.0	
R-C-4	Brick	1	Electricity	Natural Gas	2560	1994	30304	11.8	
R-C-5	Brick	1	Electricity	Natural Gas	2505	1995	21683	8.7	
R-C-6	Brick	1	Electricity	Natural Gas	2773	1994	15213	5.5	
R-C-7	Brick	1	Electricity	Natural Gas	2561	1994	10328	4.0	
R-C-8	Brick	2	Electricity	Natural Gas	2908	1994	28960	10.0	
R-C-9	Brick	1	Electricity	Natural Gas	2562	1994	19664	7.7	
R-C-10	Brick	1	Electricity	Natural Gas	2517	1994	9066	3.6	
R-C-11	Brick	1	Electricity	Natural Gas	2289	1994	18511	8.1	
R-C-12	Brick	1	Electricity	Natural Gas	2344	1995	18363	7.8	
R-C-13	Brick	1	Electricity	Natural Gas	2400	1996	11649	4.9	
R-C-14	Brick	1	Electricity	Natural Gas	2472	1995	13706	5.5	
R-C-15	Brick	1	Electricity	Natural Gas	2247	1996	15900	7.1	
R-C-16	Brick	1	Electricity	Natural Gas	2423	1996	20020	8.3	
R-C-17	Brick	1	Electricity	Natural Gas	2030	1994	7784	3.8	
R-C-18	Brick	1	Electricity	Natural Gas	2468	1996	15479	6.3	
R-C-19	Brick	1	Electricity	Natural Gas	2303	1995	17741	7.7	
R-C-20	Brick	1	Electricity	Natural Gas	2217	1996	19920	9.0	7.6

Table D-4: Housing Characteristics and Electricity Use of Sample Houses (District D).

Sample House	Wall Material	Sector	Cooling Source	Heating Source	Area (square ft.)	Year Built	Annual Elec. Consumption	EUI (KWh/sq.ft)	Average EUI
R-D-1	Brick	1	Electricity	Natural Gas	2151	2001	17603	8.2	
R-D-2	Brick	1	Electricity	Natural Gas	2102	2001	10198	4.9	
R-D-3	Brick	1	Electricity	Natural Gas	2102	2001	N/A	N/A	
R-D-4	Brick	1	Electricity	Natural Gas	2126	2001	12489	5.9	
R-D-5	Brick	1	Electricity	Natural Gas	2010	2001	15526	7.7	
R-D-6	Brick	1	Electricity	Natural Gas	2139	2002	N/A	N/A	
R-D-7	Brick	1	Electricity	Natural Gas	2250	2001	12406	5.5	
R-D-8	Brick	1	Electricity	Natural Gas	2136	2001	7751	3.6	
R-D-9	Brick	1	Electricity	Natural Gas	2002	2002	N/A	N/A	
R-D-10	Brick	1	Electricity	Natural Gas	2237	2002	11624	5.2	
R-D-11	Brick	1	Electricity	Natural Gas	2444	2001	11624	4.8	
R-D-12	Brick	1	Electricity	Natural Gas	2435	2001	14716	6.0	
R-D-13	Brick	2	Electricity	Natural Gas	2316	2001	12652	5.5	
R-D-14	Brick	1	Electricity	Natural Gas	2555	2002	N/A	N/A	
R-D-15	Brick	1	Electricity	Natural Gas	2622	2001	12093	4.6	5.6

Residential A-1		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	327.0	11	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28	315.0	11	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30	378.0	13	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30	804.0	27	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32	1175.0	37	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29	1333.0	46	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33	1660.0	50	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30	1498.0	50	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29	1092.0	38	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29	539.0	19	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33	374	11	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33	550	17	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29	245.0	8	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28	234.0	8	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29	366.0	13	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30	585.0	20	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32	1175.0	37	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29	1277.0	44	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33	1574.0	48	81.7
8/4/2003	37837	8/4/2003					





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Value for grouping = 0
Residual mode = 1
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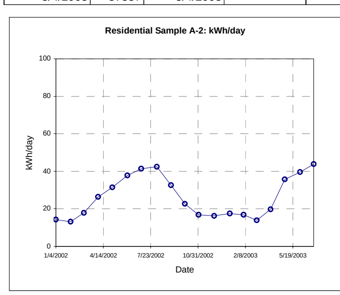
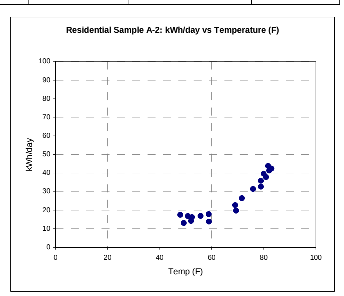
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 18
R2 = 0.978
AdjR2 = 0.978
RMSE = 2.4481
CV-RMSE = 8.898%
p = -0.117
DW = 2.231 (p>0)
N1 = 7
N2 = 11
Ycp = 11.7130 (0.8311)
LS = 0.0000 (0.0000)
RS = 2.1964 (0.0832)
Xcp = 65.7700 (0.6892)

Figure D-1: Summary of Utility Bill Analysis of Sample House A-1.

Residential A-2		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	442.0	14	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28	367.0	13	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30	536.0	18	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30	792.0	26	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32	1006.0	31	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29	1097.0	38	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33	1365.0	41	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30	1272.0	42	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29	945.0	33	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29	659.0	23	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33	556	17	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33	536	16	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29	507.0	17	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28	470.0	17	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29	402.0	14	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30	592.0	20	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32	1144.0	36	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29	1149.0	40	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33	1446.0	44	81.7
8/4/2003	37837	8/4/2003					





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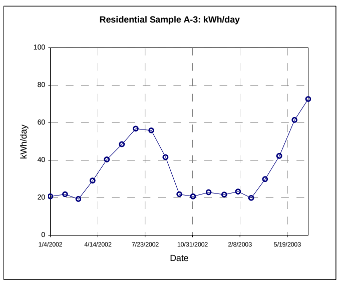
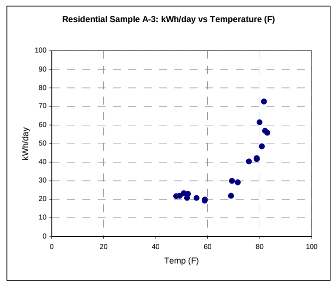
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 18
R2 = 0.967
AdjR2 = 0.967
RMSE = 2.0511
CV-RMSE = 7.600%
p = -0.025
DW = 1.783 (p>0)
N1 = 7
N2 = 11
Ycp = 16.0678 (0.6963)
LS = 0.0000 (0.0000)
RS = 1.5183 (0.0697)
Xcp = 65.7700 (0.6892)

Figure D-2: Summary of Utility Bill Analysis of Sample House A-2.

Residential A-3		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	642.0	21	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28	612.0	22	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30	579.0	19	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30	873.0	29	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32	1293.0	40	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29	1405.0	48	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33	1876.0	57	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30	1675.0	56	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29	1207.0	42	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29	633.0	22	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33	682	21	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33	755	23	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29	628.0	22	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28	652.0	23	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29	576.0	20	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30	896.0	30	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32	1351.0	42	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29	1782.0	61	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33	2397.0	73	81.7
8/4/2003	37837	8/4/2003					



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Residual mode =        1
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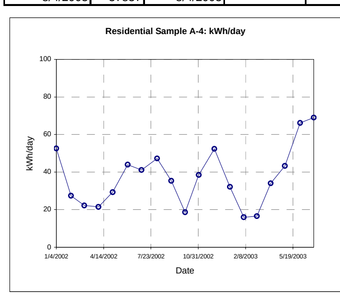
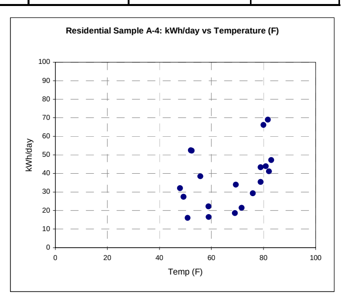
X1 column number =   5
X2 column number =   0 (unused)
X3 column number =   0 (unused)
X4 column number =   0 (unused)
X5 column number =   0 (unused)
X6 column number =   0 (unused)
********************************************
Regression Results
---------------------------------
N =    18
---------------------------------
R2 =    0.896
---------------------------------
AdjR2 =    0.896
---------------------------------
RMSE =     5.6128
---------------------------------
CV-RMSE =    15.548%
---------------------------------
p =    0.155
---------------------------------
DW =    1.251 (p>0)
---------------------------------
N1 =     8
---------------------------------
N2 =    10
---------------------------------
Ycp =    21.4884 (      1.8147)
---------------------------------
LS =     0.0000 (      0.0000)
---------------------------------
RS =     2.8176 (      0.2396)
---------------------------------
Xcp =    69.2160 (      0.6892)
---------------------------------
---------------------------------
```

Figure D-3: Summary of Utility Bill Analysis of Sample House A-3.

Residential A-4		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	1628.0	53	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28	767.0	27	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30	667.0	22	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30	643.0	21	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32	938.0	29	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29	1274.0	44	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33	1358.0	41	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30	1418.0	47	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29	1026.0	35	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29	540.0	19	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33	1270	38	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33	1727	52	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29	931.0	32	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28	448.0	16	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29	480.0	17	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30	1020.0	34	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32	1385.0	43	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29	1919.0	66	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33	2276.0	69	81.7
8/4/2003	37837	8/4/2003					






```
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ASHRAE INVERSE MODELING TOOLKIT (1.9)
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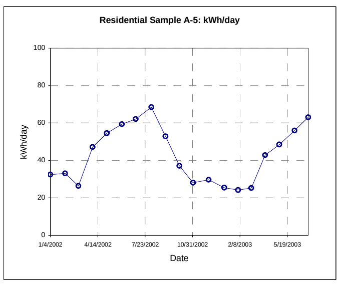
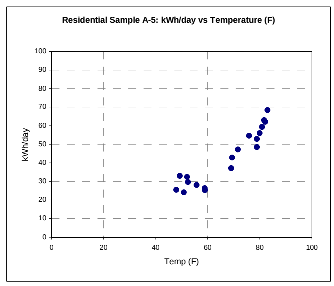
Output file name = IMT.Out
********************************************
Input data file name =  A4_3pc.dat
Model type =          3P Cooling
Grouping column No =   0
Value for grouping =   0
Residual mode =        1
# of X(Indep.) Var =   1
Y1 column number =     4
X1 column number =   5
X2 column number =   0 (unused)
X3 column number =   0 (unused)
X4 column number =   0 (unused)
X5 column number =   0 (unused)
X6 column number =   0 (unused)
********************************************
Regression Results
---------------------------------
N =    18
---------------------------------
R2 =    0.478
---------------------------------
AdjR2 =    0.478
---------------------------------
RMSE =    11.6518
---------------------------------
CV-RMSE =    32.040%
---------------------------------
p =    0.439
---------------------------------
DW =    1.004 (p>0)
---------------------------------
N1 =    10
---------------------------------
N2 =     8
---------------------------------
Ycp =    28.0029 (      3.5107)
---------------------------------
LS =     0.0000 (      0.0000)
---------------------------------
RS =     3.3811 (      0.8841)
---------------------------------
Xcp =    74.7296 (      0.6892)
---------------------------------
---------------------------------
```

Figure D-4: Summary of Utility Bill Analysis of Sample House A-4.

Residential A-5		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	1005.0	32	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28	925.0	33	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30	791.0	26	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30	1416.0	47	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32	1746.0	55	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29	1722.0	59	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33	2049.0	62	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30	2053.0	68	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29	1532.0	53	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29	1076.0	37	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33	925	28	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33	979	30	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29	738.0	25	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28	677.0	24	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29	733.0	25	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30	1284.0	43	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32	1551.0	48	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29	1624.0	56	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33	2079.0	63	81.7
8/4/2003	37837	8/4/2003					

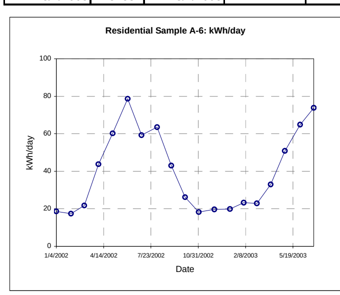


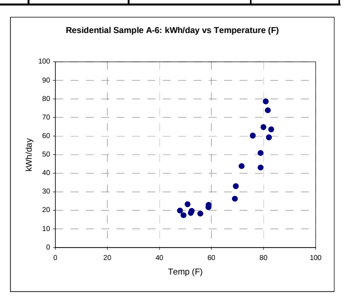


ASHRAE INVERSE MODELING TOOLKIT (1.9)
Output file name = IMT.Out
Input data file name = A5_3pc.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
Regression Results
N = 18
R2 = 0.955
AdjR2 = 0.955
RMSE = 3.3160
CV-RMSE = 7.614%
p = -0.065
DW = 1.911 (p>0)
N1 = 6
N2 = 12
Ycp = 27.3731 (1.1754)
LS = 0.0000 (0.0000)
RS = 1.6621 (0.0902)
Xcp = 61.6348 (0.6892)

Figure D-5: Summary of Utility Bill Analysis of Sample House A-5.

Residential A-6		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	577.0	19	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28	487.0	17	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30	651.0	22	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30	1313.0	44	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32	1926.0	60	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29	2280.0	79	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33	1955.0	59	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30	1906.0	64	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29	1247.0	43	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29	760.0	26	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33	602	18	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33	648	20	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29	576.0	20	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28	652.0	23	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29	663.0	23	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30	990.0	33	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32	1627.0	51	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29	1879.0	65	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33	2436.0	74	81.7
8/4/2003	37837	8/4/2003					

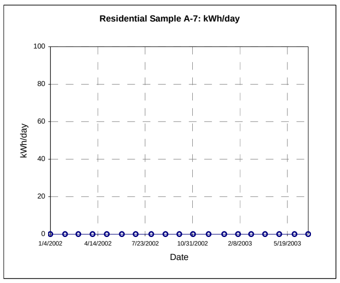




ASHRAE INVERSE MODELING TOOLKIT (1.9)
Output file name = IMT.Out
Input data file name = A6_3pc.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
Regression Results
N = 18
R2 = 0.895
AdjR2 = 0.895
RMSE = 7.0848
CV-RMSE = 17.236%
p = 0.213
DW = 1.500 (p>0)
N1 = 7
N2 = 11
Ycp = 20.5402 (2.4271)
LS = 0.0000 (0.0000)
RS = 2.7010 (0.2313)
Xcp = 65.0808 (0.6892)

Figure D-6: Summary of Utility Bill Analysis of Sample House A-6.

Residential A-7		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31		0	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28		0	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30		0	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30		0	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32		0	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29		0	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33		0	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30		0	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29		0	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29		0	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33		0	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33		0	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29		0	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28		0	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29		0	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30		0	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32		0	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29		0	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33		0	81.7
8/4/2003	37837	8/4/2003					



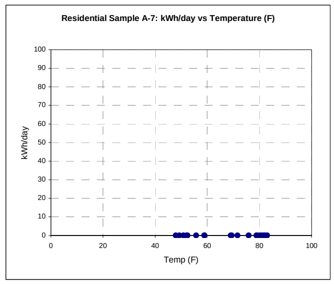
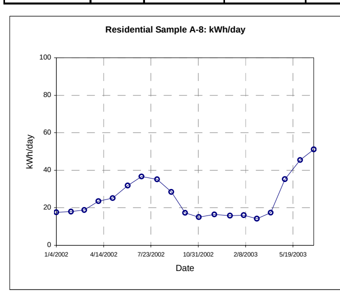
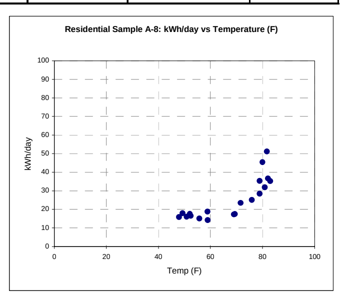


Figure D-7: Summary of Utility Bill Analysis of Sample House A-7.

Residential A-8		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	544.0	18	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28	503.0	18	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30	563.0	19	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30	705.0	24	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32	804.0	25	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29	925.0	32	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33	1210.0	37	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30	1055.0	35	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29	826.0	28	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29	502.0	17	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33	497	15	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33	544	16	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29	459.0	16	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28	450.0	16	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29	411.0	14	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30	523.0	17	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32	1129.0	35	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29	1318.0	45	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33	1687.0	51	81.7
8/4/2003	37837	8/4/2003					






```
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ASHRAE INVERSE MODELING TOOLKIT (1.9)
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Output file name = IMT.Out
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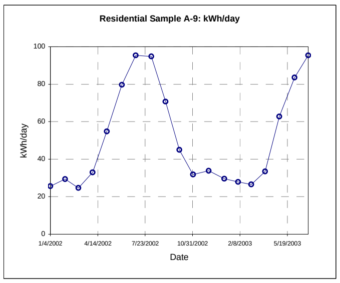
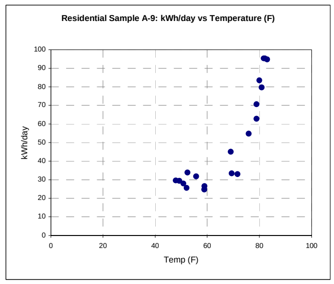
Input data file name =  A8_3pc.dat
Model type =          3P Cooling
Grouping column No =    0
Value for grouping =    0
Residual mode =         1
# of X(Indep.) Var =    1
Y1 column number =      4
X1 column number =   5
X2 column number =   0 (unused)
X3 column number =   0 (unused)
X4 column number =   0 (unused)
X5 column number =   0 (unused)
X6 column number =   0 (unused)
*******************************************
Regression Results
-----------------------------------
N =    18
-----------------------------------
R2 =    0.837
-----------------------------------
AdjR2 =    0.837
-----------------------------------
RMSE =    4.6772
-----------------------------------
CV-RMSE =   18.227%
-----------------------------------
p =    0.595
-----------------------------------
DW =    0.445 (p>0)
-----------------------------------
N1 =    8
-----------------------------------
N2 =    10
-----------------------------------
Ycp =    16.4827 (     1.4957)
-----------------------------------
LS =     0.0000 (     0.0000)
-----------------------------------
RS =     1.9111 (     0.2105)
-----------------------------------
Xcp =    69.9052 (     0.6892)
-----------------------------------
------------------------------
```

Figure D-8: Summary of Utility Bill Analysis of Sample House A-8.

Residential A-9		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	793.0	26	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28	822.0	29	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30	741.0	25	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30	991.0	33	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32	1754.0	55	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29	2310.0	80	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33	3147.0	95	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30	2843.0	95	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29	2049.0	71	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29	1305.0	45	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33	1050	32	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33	1118	34	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29	857.0	30	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28	782.0	28	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29	769.0	27	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30	1003.0	33	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32	2008.0	63	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29	2422.0	84	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33	3146.0	95	81.7
8/4/2003	37837	8/4/2003					





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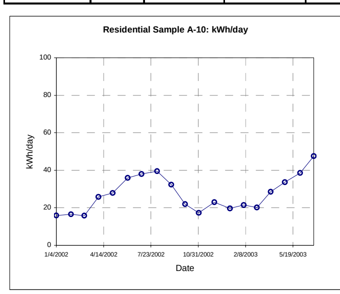
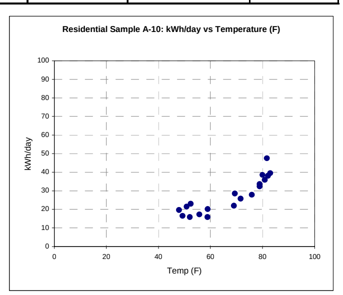
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = A9_3pc.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 18
R2 = 0.964
AdjR2 = 0.964
RMSE = 5.2445
CV-RMSE = 9.914%
p = 0.015
DW = 1.923 (p>0)
N1 = 9
N2 = 9
Ycp = 31.2160 (1.6185)
LS = 0.0000 (0.0000)
RS = 6.3598 (0.3064)

Figure D-9: Summary of Utility Bill Analysis of Sample House A-9.

Residential A-10		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	491.0	16	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28	463.0	17	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30	474.0	16	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30	773.0	26	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32	891.0	28	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29	1041.0	36	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33	1255.0	38	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30	1184.0	39	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29	937.0	32	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29	637.0	22	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33	570	17	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33	759	23	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29	570.0	20	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28	601.0	21	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29	585.0	20	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30	857.0	29	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32	1076.0	34	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29	1118.0	39	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33	1568.0	48	81.7
8/4/2003	37837	8/4/2003					

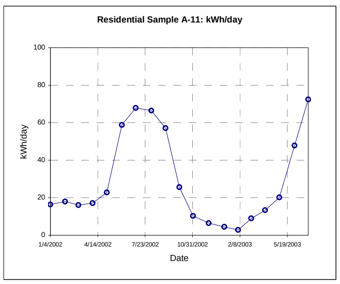


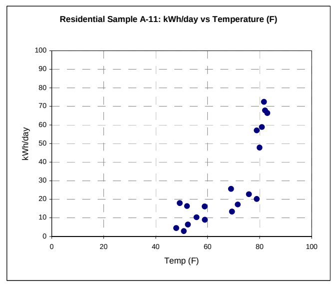


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = A10_3pc.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 18
R2 = 0.883
AdjR2 = 0.883
RMSE = 3.2865
CV-RMSE = 11.747%
p = 0.247
DW = 1.081 (p>0)
N1 = 7
N2 = 11
Ycp = 19.1744 (1.1158)
LS = 0.0000 (0.0000)
RS = 1.2239 (0.1116)
Xcp = 65.7700 (0.6892)

Figure D-10: Summary of Utility Bill Analysis of Sample House A-10.

Residential A-11		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	506.0	16	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28	502.0	18	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30	483.0	16	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30	514.0	17	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32	728.0	23	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29	1706.0	59	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33	2239.0	68	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30	1992.0	66	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29	1656.0	57	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29	742.0	26	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33	340	10	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33	211	6	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29	129.0	4	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28	80.0	3	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29	260.0	9	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30	400.0	13	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32	643.0	20	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29	1387.0	48	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33	2390.0	72	81.7
8/4/2003	37837	8/4/2003					





****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
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Output file name = IMT.Out
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Input data file name = A11.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results

N = 13

R2 = 0.767

AdjR2 = 0.767

RMSE = 375.0128

CV-RMSE = 31.979%
----
p = -0.073

DW = 2.108 (p>0)

N1 = 6

N2 = 7

Ycp = 524.4614 (149.7508)

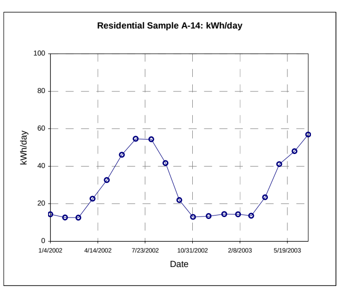
LS = 0.0000 (0.0000)

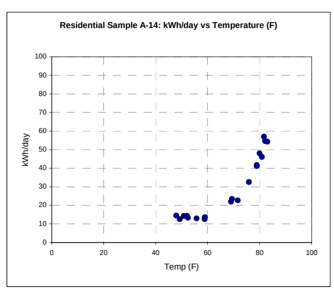
RS = 172.6844 (28.7004)

Xcp = 75.6000 (0.9400)

Figure D-11: Summary of Utility Bill Analysis of Sample House A-11.

Residential A-14		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	444.0	14	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28	354.0	13	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30	377.0	13	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30	680.0	23	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32	1042.0	33	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29	1337.0	46	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33	1802.0	55	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30	1630.0	54	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29	1208.0	42	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29	636.0	22	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33	427	13	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33	442	13	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29	420.0	14	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28	401.0	14	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29	395.0	14	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30	703.0	23	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32	1316.0	41	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29	1393.0	48	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33	1879.0	57	81.7
8/4/2003	37837	8/4/2003					





****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
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Output file name = IMT.Out
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Input data file name = A14_3pc.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results

N = 18

R2 = 0.968

AdjR2 = 0.968

RMSE = 3.1016

CV-RMSE = 10.393%
----
p = 0.026

DW = 1.779 (p>0)

N1 = 8

N2 = 10

Ycp = 14.3547 (1.0123)

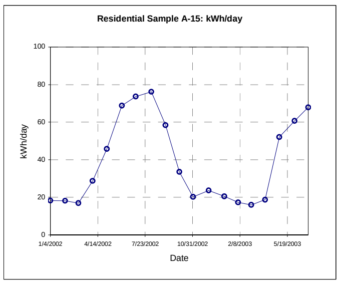
LS = 0.0000 (0.0000)

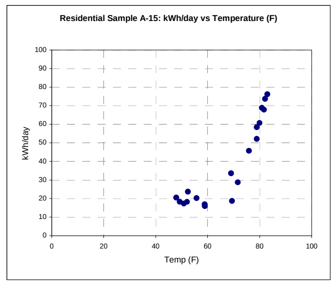
RS = 2.7817 (0.1258)

Xcp = 68.5268 (0.6892)

Figure D-12: Summary of Utility Bill Analysis of Sample House A-14.

Residential A-15		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	566.0	18	52.1
2/4/2002	37291	2/4/2002	3/4/2002	28	509.0	18	49.3
3/4/2002	37319	3/4/2002	4/3/2002	30	507.0	17	58.9
4/3/2002	37349	4/3/2002	5/3/2002	30	862.0	29	71.6
5/3/2002	37379	5/3/2002	6/4/2002	32	1464.0	46	75.9
6/4/2002	37411	6/4/2002	7/3/2002	29	1995.0	69	80.9
7/3/2002	37440	7/3/2002	8/5/2002	33	2430.0	74	82.1
8/5/2002	37473	8/5/2002	9/4/2002	30	2285.0	76	83.0
9/4/2002	37503	9/4/2002	10/3/2002	29	1694.0	58	78.9
10/3/2002	37532	10/3/2002	11/1/2002	29	973.0	34	69.0
11/1/2002	37561	11/1/2002	12/4/2002	33	668	20	55.7
12/4/2002	37594	12/4/2002	1/6/2003	33	781	24	52.4
1/6/2003	37627	1/6/2003	2/4/2003	29	596.0	21	47.9
2/4/2003	37656	2/4/2003	3/4/2003	28	484.0	17	50.8
3/4/2003	37684	3/4/2003	4/2/2003	29	463.0	16	58.9
4/2/2003	37713	4/2/2003	5/2/2003	30	562.0	19	69.4
5/2/2003	37743	5/2/2003	6/3/2003	32	1668.0	52	78.9
6/3/2003	37775	6/3/2003	7/2/2003	29	1761.0	61	80.0
7/2/2003	37804	7/2/2003	8/4/2003	33	2239.0	68	81.7
8/4/2003	37837	8/4/2003					





****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
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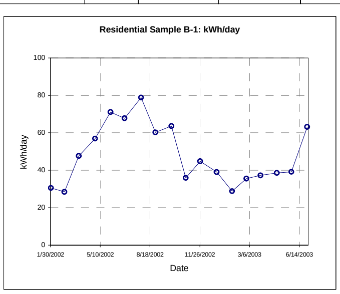
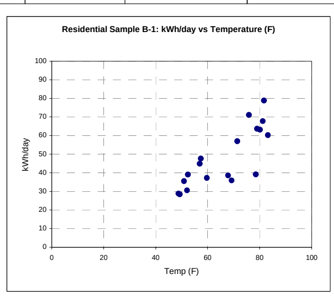
Output file name = IMT.Out
****
Input data file name = A15_3pc.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 18
R2 = 0.963
AdjR2 = 0.963
RMSE = 4.4695
CV-RMSE = 11.216%
p = 0.358
DW = 1.243 (p>0)
N1 = 9
N2 = 9
Ycp = 20.7037 (1.4068)
LS = 0.0000 (0.0000)
RS = 4.6713 (0.2275)
Xcp = 71.2836 (0.6892)

Figure D-13: Summary of Utility Bill Analysis of Sample House A-15.

Residential B-1		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/31/2002	37287	1/31/2002	2/27/2002	27	824.0	31	52.1
2/27/2002	37314	2/27/2002	3/28/2002	29	825.0	28	49.3
3/28/2002	37343	3/28/2002	4/30/2002	33	1571.0	48	57.4
4/30/2002	37376	4/30/2002	5/31/2002	31	1765.0	57	71.4
5/31/2002	37407	5/31/2002	6/28/2002	28	1991.0	71	75.9
6/28/2002	37435	6/28/2002	7/31/2002	33	2237.0	68	81.2
7/31/2002	37468	7/31/2002	8/29/2002	29	2286.0	79	81.7
8/29/2002	37497	8/29/2002	9/30/2002	32	1926.0	60	83.2
9/30/2002	37529	9/30/2002	10/29/2002	29	1846.0	64	79.0
10/29/2002	37558	10/29/2002	11/27/2002	29	1041.0	36	69.2
11/27/2002	37587	11/27/2002	12/30/2002	33	1480	45	57.0
12/30/2002	37620	12/30/2002	1/30/2003	31	1210	39	52.4
1/30/2003	37651	1/30/2003	2/28/2003	29	837.0	29	48.8
2/28/2003	37680	2/28/2003	3/28/2003	28	994.0	36	50.9
3/28/2003	37708	3/28/2003	4/30/2003	33	1229.0	37	59.7
4/30/2003	37741	4/30/2003	5/29/2003	29	1118.0	39	67.9
5/29/2003	37770	5/29/2003	6/30/2003	32	1252.0	39	78.6
6/30/2003	37802	6/30/2003	7/30/2003	30	1894.0	63	80.1
7/30/2003	37832						





****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = B1_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.597
AdjR2 = 0.597
RMSE = 10.1205
CV-RMSE = 20.642%
p = 0.637
DW = 0.734 (p>0)
N1 = 6
N2 = 11
Ycp = 35.3796 (3.7954)
LS = 0.0000 (0.0000)
RS = 1.3731 (0.2912)
Xcp = 61.8792 (0.6868)

Figure D-14: Summary of Utility Bill Analysis of Sample House B-1.

Residential B-2		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/30/2002	37286	1/30/2002	2/27/2002	28	465.0	17	51.0
2/27/2002	37314	2/27/2002	3/28/2002	29	373.0	13	56.2
3/28/2002	37343	3/28/2002	4/30/2002	33	489.0	15	70.3
4/30/2002	37376	4/30/2002	5/30/2002	30	897.0	30	76.1
5/30/2002	37406	5/30/2002	6/28/2002	29	1240.0	43	81.0
6/28/2002	37435	6/28/2002	7/30/2002	32	1191.0	37	81.6
7/30/2002	37467	7/30/2002	8/29/2002	30	1525.0	51	83.2
8/29/2002	37497	8/29/2002	9/27/2002	29	844.0	29	79.3
9/27/2002	37526	9/27/2002	10/29/2002	32	669.0	21	70.4
10/29/2002	37558	10/29/2002	11/27/2002	29	322.0	11	58.2
11/27/2002	37587	11/27/2002	12/31/2002	34	579	17	51.7
12/31/2002	37621	12/31/2002	1/31/2003	31	734	24	47.8
1/31/2003	37652	1/31/2003	2/28/2003	28	470.0	17	51.4
2/28/2003	37680	2/28/2003	3/28/2003	28	591.0	21	58.0
3/28/2003	37708	3/28/2003	4/29/2003	32	607.0	19	78.5
4/29/2003	37740	4/29/2003	5/30/2003	31	947.0	31	79.7
5/30/2003	37771	5/30/2003	6/30/2003	31	1286.0	41	81.5
6/30/2003	37802	6/30/2003	7/31/2003	31	1700.0	55	81.7
7/31/2003	37833						

```
********************************************
ASHRAE INVERSE MODELING TOOLKIT (1.9)
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Output file name = IMT.Out
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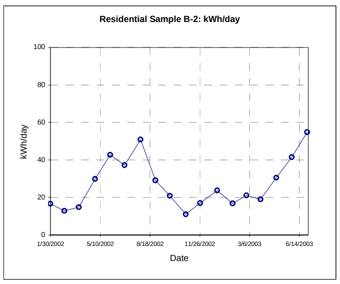
Input data file name =  B2_3PC.dat
Model type =          3P Cooling
Grouping column No =    0
Value for grouping =    0
Residual mode =        1
# of X(Indep.) Var =    1
Y1 column number =     4
X1 column number =   5
X2 column number =   0 (unused)
X3 column number =   0 (unused)
X4 column number =   0 (unused)
X5 column number =   0 (unused)
X6 column number =   0 (unused)
********************************************
Regression Results
---------------------------------
N =     17
---------------------------------
R2 =     0.865
---------------------------------
AdjR2 =     0.865
---------------------------------
RMSE =      5.0772
---------------------------------
CV-RMSE =    18.213%
---------------------------------
p =    -0.144
---------------------------------
DW =     1.937 (p>0)
---------------------------------
N1 =      9
---------------------------------
N2 =      8
---------------------------------
Ycp =     17.4796 (      1.6248)
---------------------------------
LS =      0.0000 (      0.0000)
---------------------------------
RS =      3.3493 (      0.3415)
---------------------------------
Xcp =     73.5548 (      0.6868)
```



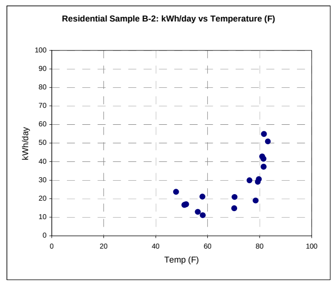


Figure D-15: Summary of Utility Bill Analysis of Sample House B-2.

Residential B-3		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/30/2002	37286	1/30/2002	2/27/2002	28	506.0	18	51.0
2/27/2002	37314	2/27/2002	3/28/2002	29	566.0	20	56.2
3/28/2002	37343	3/28/2002	4/30/2002	33	980.0	30	70.3
4/30/2002	37376	4/30/2002	5/30/2002	30	1375.0	46	76.1
5/30/2002	37406	5/30/2002	6/28/2002	29	1310.0	45	81.0
6/28/2002	37435	6/28/2002	7/30/2002	32	1637.0	51	81.6
7/30/2002	37467	7/30/2002	8/29/2002	30	1758.0	59	83.2
8/29/2002	37497	8/29/2002	9/27/2002	29	1347.0	46	79.3
9/27/2002	37526	9/27/2002	10/29/2002	32	1047.0	33	70.4
10/29/2002	37558	10/29/2002	11/27/2002	29	530.0	18	58.2
11/27/2002	37587	11/27/2002	12/31/2002	34	728	21	51.7
12/31/2002	37621	12/31/2002	1/31/2003	31	620	20	47.8
1/31/2003	37652	1/31/2003	2/28/2003	28	508.0	18	51.4
2/28/2003	37680	2/28/2003	3/28/2003	28	616.0	22	58.0
3/28/2003	37708	3/28/2003	4/29/2003	32	695.0	22	78.5
4/29/2003	37740	4/29/2003	5/30/2003	31	1220.0	39	79.7
5/30/2003	37771	5/30/2003	6/30/2003	31	1380.0	45	81.5
6/30/2003	37802	6/30/2003	7/31/2003	31	1952.0	63	81.7
7/31/2003	37833						

```
********************************************
ASHRAE INVERSE MODELING TOOLKIT (1.9)
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Output file name = IMT.Out
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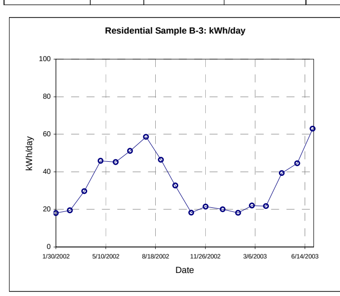
Input data file name =  B3_3PC.dat
Model type =          3P Cooling
Grouping column No =    0
Value for grouping =    0
Residual mode =        1
# of X(Indep.) Var =    1
Y1 column number =     4
X1 column number =   5
X2 column number =   0 (unused)
X3 column number =   0 (unused)
X4 column number =   0 (unused)
X5 column number =   0 (unused)
X6 column number =   0 (unused)
********************************************
Regression Results
---------------------------------
N =     17
---------------------------------
R2 =     0.914
---------------------------------
AdjR2 =     0.914
---------------------------------
RMSE =      4.5834
---------------------------------
CV-RMSE =    13.041%
---------------------------------
p =    -0.199
---------------------------------
DW =     2.025 (p>0)
---------------------------------
N1 =      6
---------------------------------
N2 =     11
---------------------------------
Ycp =     19.7866 (      1.6489)
---------------------------------
LS =      0.0000 (      0.0000)
---------------------------------
RS =      1.9901 (      0.1578)
---------------------------------
Xcp =     65.3132 (      0.6868)
---------------------------------
---------------------------------
```



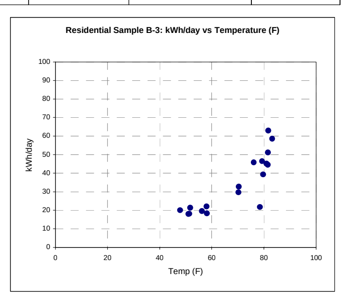
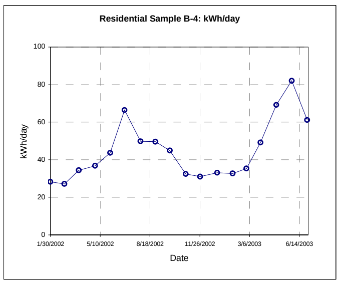
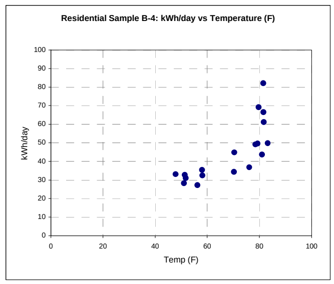


Figure D-16: Summary of Utility Bill Analysis of Sample House B-3.

Residential B-4		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/30/2002	37286	1/30/2002	2/27/2002	28	792.0	28	51.0
2/27/2002	37314	2/27/2002	3/28/2002	29	788.0	27	56.2
3/28/2002	37343	3/28/2002	4/30/2002	33	1135.0	34	70.3
4/30/2002	37376	4/30/2002	5/30/2002	30	1104.0	37	76.1
5/30/2002	37406	5/30/2002	6/28/2002	29	1266.0	44	81.0
6/28/2002	37435	6/28/2002	7/30/2002	32	2127.0	66	81.6
7/30/2002	37467	7/30/2002	8/29/2002	30	1493.0	50	83.2
8/29/2002	37497	8/29/2002	9/27/2002	29	1440.0	50	79.3
9/27/2002	37526	9/27/2002	10/29/2002	32	1436.0	45	70.4
10/29/2002	37558	10/29/2002	11/27/2002	29	940.0	32	58.2
11/27/2002	37587	11/27/2002	12/31/2002	34	1053	31	51.7
12/31/2002	37621	12/31/2002	1/31/2003	31	1026	33	47.8
1/31/2003	37652	1/31/2003	2/28/2003	28	916.0	33	51.4
2/28/2003	37680	2/28/2003	3/28/2003	28	990.0	35	58.0
3/28/2003	37708	3/28/2003	4/29/2003	32	1573.0	49	78.5
4/29/2003	37740	4/29/2003	5/30/2003	31	2144.0	69	79.7
5/30/2003	37771	5/30/2003	6/30/2003	31	2543.0	82	81.5
6/30/2003	37802	6/30/2003	7/31/2003	31	1895.0	61	81.7
7/31/2003	37833						

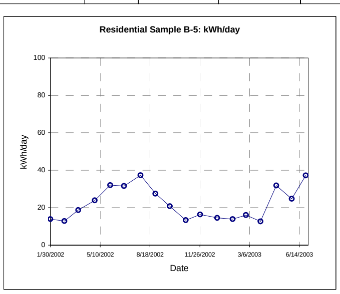


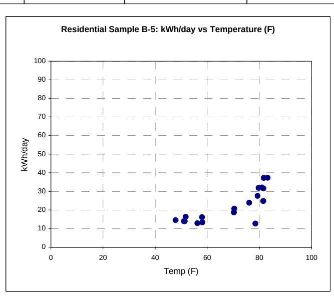


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = B4_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.568
AdjR2 = 0.568
RMSE = 10.6840
CV-RMSE = 23.321%
p = 0.502
DW = 0.992 (p>0)
N1 = 5
N2 = 12
Ycp = 31.2459 (4.1782)
LS = 0.0000 (0.0000)
RS = 1.1451 (0.2576)
Xcp = 57.7584 (0.6868)

Figure D-17: Summary of Utility Bill Analysis of Sample House B-4.

Residential B-5		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/30/2002	37286	1/30/2002	2/27/2002	28	390.0	14	51.0
2/27/2002	37314	2/27/2002	3/27/2002	28	361.0	13	56.2
3/27/2002	37342	3/27/2002	4/29/2002	33	618.0	19	70.3
4/29/2002	37375	4/29/2002	5/30/2002	31	740.0	24	76.1
5/30/2002	37406	5/30/2002	6/27/2002	28	898.0	32	81.0
6/27/2002	37434	6/27/2002	7/30/2002	33	1042.0	32	81.6
7/30/2002	37467	7/30/2002	8/29/2002	30	1120.0	37	83.2
8/29/2002	37497	8/29/2002	9/27/2002	29	799.0	28	79.3
9/27/2002	37526	9/27/2002	10/29/2002	32	664.0	21	70.4
10/29/2002	37558	10/29/2002	11/27/2002	29	387.0	13	58.2
11/27/2002	37587	11/27/2002	12/31/2002	34	555	16	51.7
12/31/2002	37621	12/31/2002	1/31/2003	31	450	15	47.8
1/31/2003	37652	1/31/2003	2/27/2003	27	376.0	14	51.4
2/27/2003	37679	2/27/2003	3/28/2003	29	467.0	16	58.0
3/28/2003	37708	3/28/2003	4/29/2003	32	405.0	13	78.5
4/29/2003	37740	4/29/2003	5/30/2003	31	987.0	32	79.7
5/30/2003	37771	5/30/2003	6/27/2003	28	694.0	25	81.5
6/27/2003	37799	6/27/2003	7/31/2003	34	1266.0	37	81.7
7/31/2003	37833						

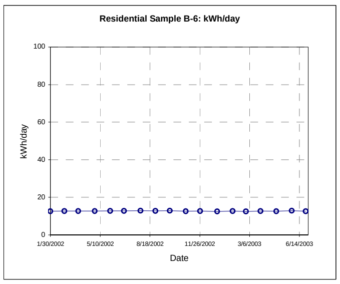


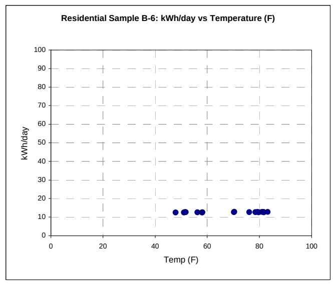


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = B5_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.910
AdjR2 = 0.910
RMSE = 2.7176
CV-RMSE = 11.984%
p = -0.684
DW = 3.147 (p>0)
N1 = 6
N2 = 11
Ycp = 14.3956 (0.9403)
LS = 0.0000 (0.0000)
RS = 1.2969 (0.1050)
Xcp = 67.3736 (0.6868)

Figure D-18: Summary of Utility Bill Analysis of Sample House B-5.

Residential B-6		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/30/2002	37286	1/30/2002	2/27/2002	28	351.0	13	51.0
2/27/2002	37314	2/27/2002	3/27/2002	28	354.0	13	56.2
3/27/2002	37342	3/27/2002	4/29/2002	33	418.0	13	70.3
4/29/2002	37375	4/29/2002	5/30/2002	31	393.0	13	76.1
5/30/2002	37406	5/30/2002	6/27/2002	28	358.0	13	81.0
6/27/2002	37434	6/27/2002	7/30/2002	33	422.0	13	81.6
7/30/2002	37467	7/30/2002	8/29/2002	30	385.0	13	83.2
8/29/2002	37497	8/29/2002	9/27/2002	29	371.0	13	79.3
9/27/2002	37526	9/27/2002	10/29/2002	32	412.0	13	70.4
10/29/2002	37558	10/29/2002	11/27/2002	29	364.0	13	58.2
11/27/2002	37587	11/27/2002	12/31/2002	34	432	13	51.7
12/31/2002	37621	12/31/2002	1/31/2003	31	388	13	47.8
1/31/2003	37652	1/31/2003	2/27/2003	27	343.0	13	51.4
2/27/2003	37679	2/27/2003	3/28/2003	29	363.0	13	58.0
3/28/2003	37708	3/28/2003	4/29/2003	32	406.0	13	78.5
4/29/2003	37740	4/29/2003	5/30/2003	31	390.0	13	79.7
5/30/2003	37771	5/30/2003	6/27/2003	28	359.0	13	81.5
6/27/2003	37799	6/27/2003	7/31/2003	34	428.0	13	81.7
7/31/2003	37833						

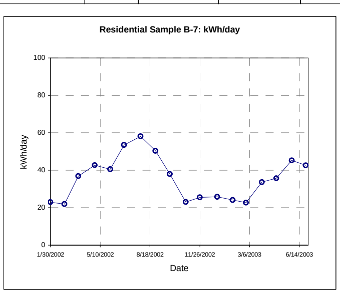


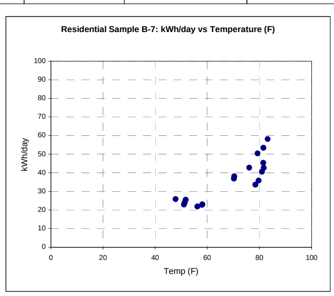



```
********************************************
ASHRAE INVERSE MODELING TOOLKIT (1.9)
********************************************
Output file name = IMT.Out
********************************************
Input data file name =  B6_3PC.dat
Model type =          3P Cooling
Grouping column No =    0
Value for grouping =    0
Residual mode =         1
# of X(Indep.) Var =    1
Y1 column number =      4
X1 column number =   5
X2 column number =   0 (unused)
X3 column number =   0 (unused)
X4 column number =   0 (unused)
X5 column number =   0 (unused)
X6 column number =   0 (unused)
********************************************
Regression Results
--------------------------------------
N =     17
--------------------------------------
R2 =     0.241
--------------------------------------
AdjR2 =     0.241
--------------------------------------
RMSE =     22.3055
--------------------------------------
CV-RMSE =    31.116%
--------------------------------------
p =     0.797
--------------------------------------
DW =     0.321 (p>0)
--------------------------------------
N1 =      9
--------------------------------------
N2 =      8
--------------------------------------
Ycp =    61.5310 (      7.1382)
--------------------------------------
LS =      0.0000 (      0.0000)
--------------------------------------
RS =      3.2711 (      1.5002)
--------------------------------------
Xcp =    73.5548 (      0.6868)
--------------------------------------
--------------------------------
```

Figure D-19: Summary of Utility Bill Analysis of Sample House B-6.

Residential B-7		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/30/2002	37286	1/30/2002	2/27/2002	28	642.0	23	51.0
2/27/2002	37314	2/27/2002	3/27/2002	28	613.0	22	56.2
3/27/2002	37342	3/27/2002	4/29/2002	33	1215.0	37	70.3
4/29/2002	37375	4/29/2002	5/30/2002	31	1325.0	43	76.1
5/30/2002	37406	5/30/2002	6/27/2002	28	1136.0	41	81.0
6/27/2002	37434	6/27/2002	7/30/2002	33	1764.0	53	81.6
7/30/2002	37467	7/30/2002	8/29/2002	30	1743.0	58	83.2
8/29/2002	37497	8/29/2002	9/27/2002	29	1461.0	50	79.3
9/27/2002	37526	9/27/2002	10/29/2002	32	1217.0	38	70.4
10/29/2002	37558	10/29/2002	11/26/2002	28	645.0	23	58.2
11/26/2002	37586	11/26/2002	12/31/2002	35	893	26	51.7
12/31/2002	37621	12/31/2002	1/31/2003	31	801	26	47.8
1/31/2003	37652	1/31/2003	2/27/2003	27	650.0	24	51.4
2/27/2003	37679	2/27/2003	3/31/2003	32	727.0	23	58.0
3/31/2003	37711	3/31/2003	4/29/2003	29	975.0	34	78.5
4/29/2003	37740	4/29/2003	5/30/2003	31	1108.0	36	79.7
5/30/2003	37771	5/30/2003	6/27/2003	28	1268.0	45	81.5
6/27/2003	37799	6/27/2003	7/31/2003	34	1450.0	43	81.7
7/31/2003	37833						

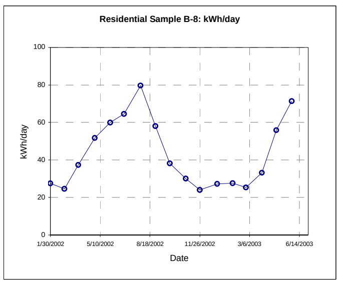


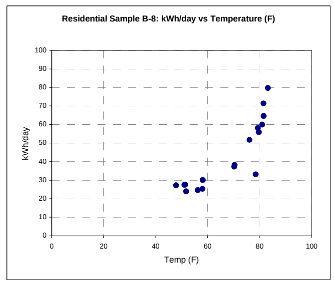



```
********************************************
ASHRAE INVERSE MODELING TOOLKIT (1.9)
********************************************
Output file name = IMT.Out
********************************************
Input data file name =  B7_3PC.dat
Model type =          3P Cooling
Grouping column No =    0
Value for grouping =    0
Residual mode =         1
# of X(Indep.) Var =    1
Y1 column number =      4
X1 column number =   5
X2 column number =   0 (unused)
X3 column number =   0 (unused)
X4 column number =   0 (unused)
X5 column number =   0 (unused)
X6 column number =   0 (unused)
********************************************
Regression Results
--------------------------------------
N =     17
--------------------------------------
R2 =     0.852
--------------------------------------
AdjR2 =     0.852
--------------------------------------
RMSE =     4.5605
--------------------------------------
CV-RMSE =    12.495%
--------------------------------------
p =     0.217
--------------------------------------
DW =     1.462 (p>0)
--------------------------------------
N1 =      6
--------------------------------------
N2 =     11
--------------------------------------
Ycp =    24.0576 (      1.7383)
--------------------------------------
LS =      0.0000 (      0.0000)
--------------------------------------
RS =      1.1035 (      0.1189)
--------------------------------------
Xcp =    59.8188 (      0.6868)
--------------------------------------
--------------------------------
```

Figure D-20: Summary of Utility Bill Analysis of Sample House B-7.

Residential B-8		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/30/2002	37286	1/30/2002	2/27/2002	28	770.0	28	51.0
2/27/2002	37314	2/27/2002	3/27/2002	28	688.0	25	56.2
3/27/2002	37342	3/27/2002	4/29/2002	33	1232.0	37	70.3
4/29/2002	37375	4/29/2002	5/30/2002	31	1604.0	52	76.1
5/30/2002	37406	5/30/2002	6/27/2002	28	1678.0	60	81.0
6/27/2002	37434	6/27/2002	7/30/2002	33	2131.0	65	81.6
7/30/2002	37467	7/30/2002	8/29/2002	30	2390.0	80	83.2
8/29/2002	37497	8/29/2002	9/27/2002	29	1684.0	58	79.3
9/27/2002	37526	9/27/2002	10/29/2002	32	1222.0	38	70.4
10/29/2002	37558	10/29/2002	11/26/2002	28	841.0	30	58.2
11/26/2002	37586	11/26/2002	12/31/2002	35	839	24	51.7
12/31/2002	37621	12/31/2002	1/31/2003	31	843	27	47.8
1/31/2003	37652	1/31/2003	2/27/2003	27	744.0	28	51.4
2/27/2003	37679	2/27/2003	3/31/2003	32	810.0	25	58.0
3/31/2003	37711	3/31/2003	4/29/2003	29	961.0	33	78.5
4/29/2003	37740	4/29/2003	5/30/2003	31	1733.0	56	79.7
5/30/2003	37771	5/30/2003	6/27/2003	28	1998.0	71	81.5
6/27/2003	37799						

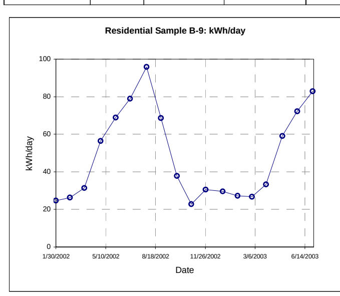


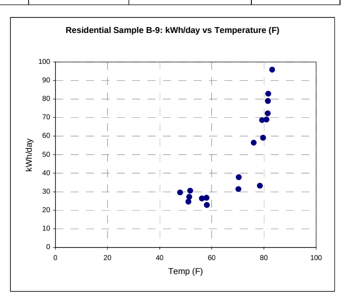


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = B8_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 16
R2 = 0.951
AdjR2 = 0.951
RMSE = 4.2353
CV-RMSE = 9.563%
p = -0.230
DW = 2.198 (p>0)
N1 = 6
N2 = 10
Ycp = 26.4896 (1.5086)
LS = 0.0000 (0.0000)
RS = 2.6350 (0.1591)
Xcp = 66.0000 (0.6868)

Figure D-21: Summary of Utility Bill Analysis of Sample House B-8.

Residential B-9		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/30/2002	37286	1/30/2002	2/27/2002	28	690.0	25	51.0
2/27/2002	37314	2/27/2002	3/28/2002	29	763.0	26	56.2
3/28/2002	37343	3/28/2002	4/30/2002	33	1037.0	31	70.3
4/30/2002	37376	4/30/2002	5/30/2002	30	1692.0	56	76.1
5/30/2002	37406	5/30/2002	6/28/2002	29	1999.0	69	81.0
6/28/2002	37435	6/28/2002	7/31/2002	33	2605.0	79	81.6
7/31/2002	37468	7/31/2002	8/29/2002	29	2779.0	96	83.2
8/29/2002	37497	8/29/2002	9/30/2002	32	2195.0	69	79.3
9/30/2002	37529	9/30/2002	10/29/2002	29	1096.0	38	70.4
10/29/2002	37558	10/29/2002	11/27/2002	29	660.0	23	58.2
11/27/2002	37587	11/27/2002	12/31/2002	34	1037	31	51.7
12/31/2002	37621	12/31/2002	1/30/2003	30	888	30	47.8
1/30/2003	37651	1/30/2003	2/28/2003	29	790.0	27	51.4
2/28/2003	37680	2/28/2003	3/28/2003	28	749.0	27	58.0
3/28/2003	37708	3/28/2003	4/30/2003	33	1097.0	33	78.5
4/30/2003	37741	4/30/2003	5/30/2003	30	1773.0	59	79.7
5/30/2003	37771	5/30/2003	6/30/2003	31	2240.0	72	81.5
6/30/2003	37802	6/30/2003	7/30/2003	30	2486.0	83	81.7
7/30/2003	37832						

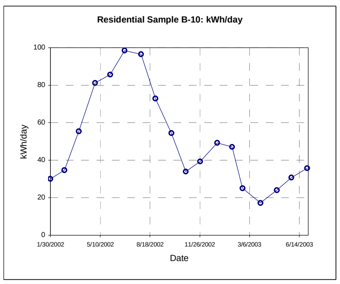


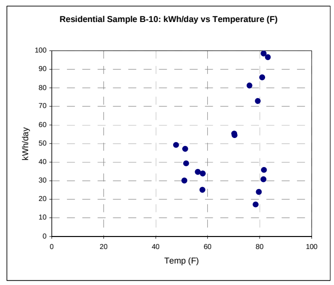


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = B9_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.960
AdjR2 = 0.960
RMSE = 4.9913
CV-RMSE = 10.000%
p = -0.292
DW = 2.519 (p>0)
N1 = 9
N2 = 8
Ycp = 29.4919 (1.6226)
LS = 0.0000 (0.0000)
RS = 5.0125 (0.2652)
Xcp = 71.4944 (0.6868)

Figure D-22: Summary of Utility Bill Analysis of Sample House B-9.

Residential B-10		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/30/2002	37286	1/30/2002	2/27/2002	28	842.0	30	51.0
2/27/2002	37314	2/27/2002	3/28/2002	29	1007.0	35	56.2
3/28/2002	37343	3/28/2002	4/30/2002	33	1827.0	55	70.3
4/30/2002	37376	4/30/2002	5/30/2002	30	2437.0	81	76.1
5/30/2002	37406	5/30/2002	6/28/2002	29	2483.0	86	81.0
6/28/2002	37435	6/28/2002	7/31/2002	33	3250.0	98	81.6
7/31/2002	37468	7/31/2002	8/29/2002	29	2798.0	96	83.2
8/29/2002	37497	8/29/2002	9/30/2002	32	2333.0	73	79.3
9/30/2002	37529	9/30/2002	10/29/2002	29	1579.0	54	70.4
10/29/2002	37558	10/29/2002	11/27/2002	29	983.0	34	58.2
11/27/2002	37587	11/27/2002	12/31/2002	34	1337	39	51.7
12/31/2002	37621	12/31/2002	1/30/2003	30	1478	49	47.8
1/30/2003	37651	1/30/2003	2/20/2003	21	989.0	47	51.4
2/20/2003	37672	2/20/2003	3/28/2003	36	903.0	25	58.0
3/28/2003	37708	3/28/2003	4/30/2003	33	568.0	17	78.5
4/30/2003	37741	4/30/2003	5/29/2003	29	695.0	24	79.7
5/29/2003	37770	5/29/2003	6/30/2003	32	982.0	31	81.5
6/30/2003	37802	6/30/2003	7/30/2003	30	1073.0	36	81.7
7/30/2003							

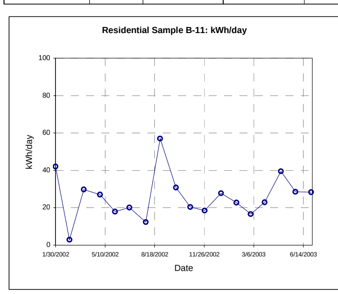


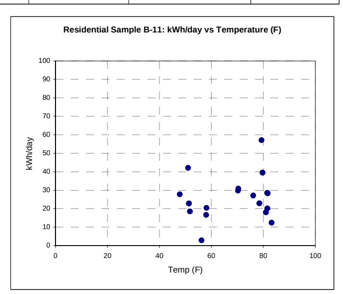



```
********************************************
ASHRAE INVERSE MODELING TOOLKIT (1.9)
********************************************
Output file name = IMT.Out
********************************************
Input data file name = B10_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
********************************************
Regression Results
-----------------------------------
N = 17
-----------------------------------
R2 = 0.369
-----------------------------------
AdjR2 = 0.369
-----------------------------------
RMSE = 21.3471
-----------------------------------
CV-RMSE = 41.164%
-----------------------------------
p = 0.550
-----------------------------------
DW = 0.706 (p>0)
-----------------------------------
N1 = 12
-----------------------------------
N2 = 5
-----------------------------------
Ycp = 43.5545 ( 5.8880)
-----------------------------------
LS = 0.0000 ( 0.0000)
-----------------------------------
RS = 15.5648 ( 5.2557)
-----------------------------------
Xcp = 79.7360 ( 0.6868)
-----------------------------------
-----------------------------------
```

Figure D-23: Summary of Utility Bill Analysis of Sample House B-10.

Residential B-11		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/30/2002	37286	1/30/2002	2/27/2002	28	1179.0	42	51.0
2/27/2002	37314	2/27/2002	3/28/2002	29	84.0	3	56.2
3/28/2002	37343	3/28/2002	4/30/2002	33	983.0	30	70.3
4/30/2002	37376	4/30/2002	5/30/2002	30	812.0	27	76.1
5/30/2002	37406	5/30/2002	6/28/2002	29	522.0	18	81.0
6/28/2002	37435	6/28/2002	7/31/2002	33	665.0	20	81.6
7/31/2002	37468	7/31/2002	8/29/2002	29	360.0	12	83.2
8/29/2002	37497	8/29/2002	9/30/2002	32	1825.0	57	79.3
9/30/2002	37529	9/30/2002	10/29/2002	29	893.0	31	70.4
10/29/2002	37558	10/29/2002	11/27/2002	29	591.0	20	58.2
11/27/2002	37587	11/27/2002	12/30/2002	33	611	19	51.7
12/30/2002	37620	12/30/2002	1/30/2003	31	861	28	47.8
1/30/2003	37651	1/30/2003	2/28/2003	29	660.0	23	51.4
2/28/2003	37680	2/28/2003	3/28/2003	28	466.0	17	58.0
3/28/2003	37708	3/28/2003	4/30/2003	33	757.0	23	78.5
4/30/2003	37741	4/30/2003	5/29/2003	29	1146.0	40	79.7
5/29/2003	37770	5/29/2003	6/30/2003	32	914.0	29	81.5
6/30/2003	37802	6/30/2003	7/30/2003	30	851.0	28	81.7
7/30/2003	37832	7/30/2003					






```
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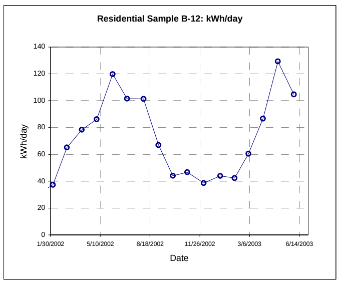
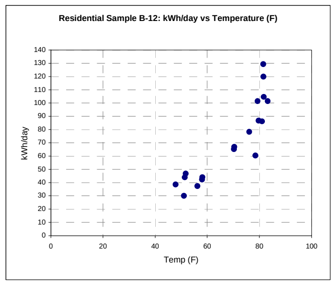
ASHRAE INVERSE MODELING TOOLKIT (1.9)
********************************************
Output file name = IMT.Out
********************************************
Input data file name = B11_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
********************************************
Regression Results
-----------------------------------
N = 16
-----------------------------------
R2 = 0.168
-----------------------------------
AdjR2 = 0.168
-----------------------------------
RMSE = 9.9800
-----------------------------------
CV-RMSE = 37.956%
-----------------------------------
p = 0.150
-----------------------------------
DW = 1.668 (p>0)
-----------------------------------
N1 = 12
-----------------------------------
N2 = 4
-----------------------------------
Ycp = 28.3921 ( 2.7897)
-----------------------------------
LS = 0.0000 ( 0.0000)
-----------------------------------
RS = -5.6247 ( 3.3455)
-----------------------------------
Xcp = 80.4228 ( 0.6868)
-----------------------------------
-----------------------------------
```

Figure D-24: Summary of Utility Bill Analysis of Sample House B-11.

Residential B-12		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	931.0	30	51.0
2/4/2002	37291	2/4/2002	3/4/2002	28	1046.0	37	56.2
3/4/2002	37319	3/4/2002	4/3/2002	30	1954.0	65	70.3
4/3/2002	37349	4/3/2002	5/3/2002	30	2349.0	78	76.1
5/3/2002	37379	5/3/2002	6/4/2002	32	2756.0	86	81.0
6/4/2002	37411	6/4/2002	7/3/2002	29	3474.0	120	81.6
7/3/2002	37440	7/3/2002	8/5/2002	33	3348.0	101	83.2
8/5/2002	37473	8/5/2002	9/4/2002	30	3041.0	101	79.3
9/4/2002	37503	9/4/2002	10/3/2002	29	1940.0	67	70.4
10/3/2002	37532	10/3/2002	11/1/2002	29	1278.0	44	58.2
11/1/2002	37561	11/1/2002	12/4/2002	33	1541	47	51.7
12/4/2002	37594	12/4/2002	1/6/2003	33	1273	39	47.8
1/6/2003	37627	1/6/2003	2/4/2003	29	1274.0	44	51.4
2/4/2003	37656	2/4/2003	3/4/2003	28	1187.0	42	58.0
3/4/2003	37684	3/4/2003	4/2/2003	29	1752.0	60	78.5
4/2/2003	37713	4/2/2003	5/2/2003	30	2600.0	87	79.7
5/2/2003	37743	5/2/2003	6/3/2003	32	4137.0	129	81.5
6/3/2003	37775	6/3/2003	7/2/2003	29	3035.0	105	81.7
7/2/2003	37804	7/2/2003					

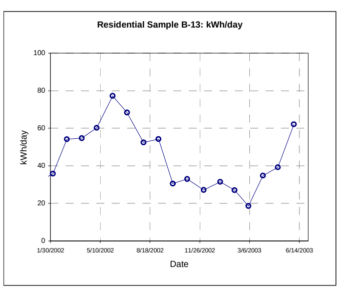


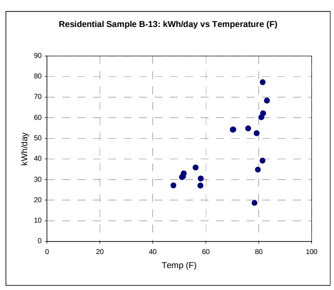


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = B12_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.881
AdjR2 = 0.881
RMSE = 10.6805
CV-RMSE = 14.489%
p = -0.303
DW = 2.583 (p>0)
N1 = 6
N2 = 11
Ycp = 42.2951 (3.9498)
LS = 0.0000 (0.0000)
RS = 3.4709 (0.3294)
Xcp = 63.2528 (0.6868)

Figure D-25: Summary of Utility Bill Analysis of Sample House B-12.

Residential B-13		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/4/2002	37260	1/4/2002	2/4/2002	31	966.0	31	51.0
2/4/2002	37291	2/4/2002	3/4/2002	28	1003.0	36	56.2
3/4/2002	37319	3/4/2002	4/3/2002	30	1625.0	54	70.3
4/3/2002	37349	4/3/2002	5/3/2002	30	1643.0	55	76.1
5/3/2002	37379	5/3/2002	6/4/2002	32	1927.0	60	81.0
6/4/2002	37411	6/4/2002	7/3/2002	29	2240.0	77	81.6
7/3/2002	37440	7/3/2002	8/5/2002	33	2254.0	68	83.2
8/5/2002	37473	8/5/2002	9/4/2002	30	1573.0	52	79.3
9/4/2002	37503	9/4/2002	10/3/2002	29	1574.0	54	70.4
10/3/2002	37532	10/3/2002	11/1/2002	29	885.0	31	58.2
11/1/2002	37561	11/1/2002	12/4/2002	33	1088	33	51.7
12/4/2002	37594	12/4/2002	1/6/2003	33	895	27	47.8
1/6/2003	37627	1/6/2003	2/4/2003	29	912.0	31	51.4
2/4/2003	37656	2/4/2003	3/4/2003	28	758.0	27	58.0
3/4/2003	37684	3/4/2003	4/2/2003	29	540.0	19	78.5
4/2/2003	37713	4/2/2003	5/2/2003	30	1044.0	35	79.7
5/2/2003	37743	5/2/2003	6/3/2003	32	1254.0	39	81.5
6/3/2003	37775	6/3/2003	7/2/2003	29	1800.0	62	81.7
7/2/2003	37804	7/2/2003					

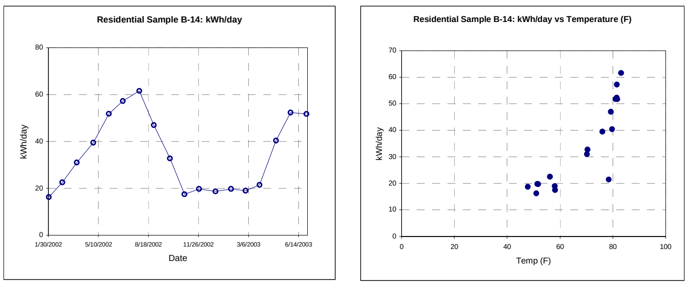




****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = B13_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.592
AdjR2 = 0.592
RMSE = 11.0884
CV-RMSE = 24.770%
p = 0.488
DW = 1.021 (p>0)
N1 = 6
N2 = 11
Ycp = 30.7532 (4.0302)
LS = 0.0000 (0.0000)
RS = 1.7165 (0.3677)
Xcp = 64.6264 (0.6868)

Figure D-26: Summary of Utility Bill Analysis of Sample House B-13.

Residential B-14		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/31/2002	37287	1/31/2002	2/27/2002	27	438.0	16	51.0
2/27/2002	37314	2/27/2002	3/28/2002	29	653.0	23	56.2
3/28/2002	37343	3/28/2002	4/30/2002	33	1023.0	31	70.3
4/30/2002	37376	4/30/2002	5/31/2002	31	1224.0	39	76.1
5/31/2002	37407	5/31/2002	6/28/2002	28	1450.0	52	81.0
6/28/2002	37435	6/28/2002	7/31/2002	33	1889.0	57	81.6
7/31/2002	37468	7/31/2002	8/29/2002	29	1785.0	62	83.2
8/29/2002	37497	8/29/2002	9/30/2002	32	1503.0	47	79.3
9/30/2002	37529	9/30/2002	10/29/2002	29	950.0	33	70.4
10/29/2002	37558	10/29/2002	11/27/2002	29	507.0	17	58.2
11/27/2002	37587	11/27/2002	12/30/2002	33	651	20	51.7
12/30/2002	37620	12/30/2002	1/30/2003	31	580	19	47.8
1/30/2003	37651	1/30/2003	2/28/2003	29	573.0	20	51.4
2/28/2003	37680	2/28/2003	3/28/2003	28	532.0	19	58.0
3/28/2003	37708	3/28/2003	4/30/2003	33	708.0	21	78.5
4/30/2003	37741	4/30/2003	5/29/2003	29	1171.0	40	79.7
5/29/2003	37770	5/29/2003	6/30/2003	32	1674.0	52	81.5
6/30/2003	37802	6/30/2003	7/30/2003	30	1551.0	52	81.7
7/30/2003	37832	7/30/2003					



****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
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Input data file name = B14_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results

N = 17

R2 = 0.963

AdjR2 = 0.963

RMSE = 3.1084

CV-RMSE = 8.749%
----
p = -0.103

DW = 2.106 (p>0)

N1 = 6

N2 = 11

Ycp = 19.5866 (1.1054)

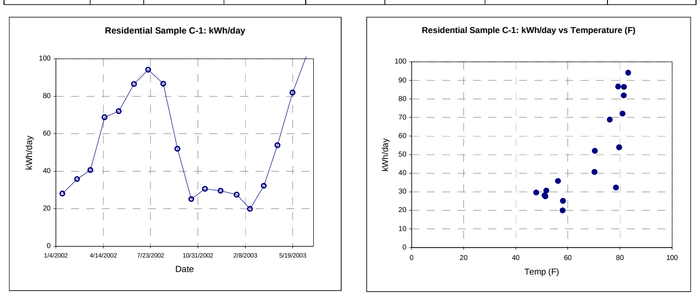
LS = 0.0000 (0.0000)

RS = 2.1917 (0.1111)

Xcp = 66.0000 (0.6868)

Figure D-27: Summary of Utility Bill Analysis of Sample House B-14.

Residential C-1		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	871.0	28	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	1003.0	36	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	1220.0	41	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	2065.0	69	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	2305.0	72	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	2594.0	86	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	3012.0	94	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	2599.0	87	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	1507.0	52	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	729.0	25	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	1010	31	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	1005	30	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	771.0	28	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	579.0	20	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	934.0	32	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	1725.0	54	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	2457.0	82	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	3372.0	102	81.7
7/21/2003	37823	7/21/2003					



****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = C1_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results

N = 17

R2 = 0.850

AdjR2 = 0.850

RMSE = 6.9853

CV-RMSE = 18.128%
----
p = 0.366

DW = 1.267 (p>0)

N1 = 8

N2 = 9

Ycp = 23.3999 (2.3596)

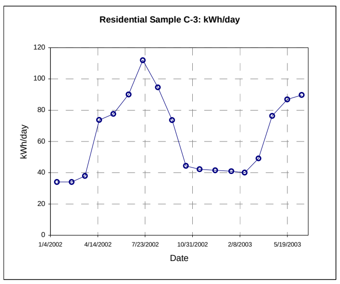
LS = 0.0000 (0.0000)

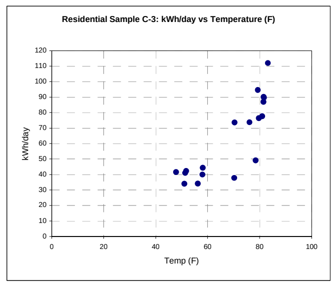
RS = 2.9869 (0.3242)

Xcp = 69.4038 (0.6722)

Figure D-28: Summary of Utility Bill Analysis of Sample House C-1.

Residential C-3		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	1054.0	34	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	954.0	34	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	1135.0	38	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	2211.0	74	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	2484.0	78	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	2702.0	90	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	3583.0	112	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	2837.0	95	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	2134.0	74	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	1285.0	44	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	1393	42	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	1412	42	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	1148.0	41	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	1160.0	40	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	1425.0	49	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	2443.0	76	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	2608.0	87	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	2959.0	90	81.7
7/21/2003	37823						

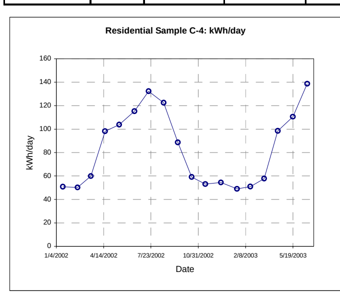


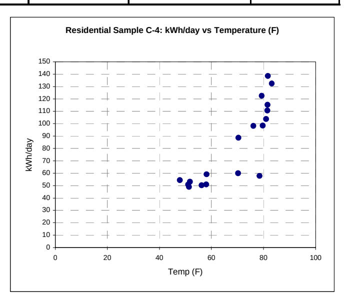


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = C3_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.961
AdjR2 = 0.961
RMSE = 5.0842
CV-RMSE = 7.825%
p = 0.270
DW = 1.323 (p>0)
N1 = 8
N2 = 9
Ycp = 41.2898 (1.7458)
LS = 0.0000 (0.0000)
RS = 3.6495 (0.1904)
Xcp = 66.7150 (0.6722)

Figure D-29: Summary of Utility Bill Analysis of Sample House C-3.

Residential C-4		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	1575.0	51	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	1407.0	50	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	1798.0	60	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	2946.0	98	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	3319.0	104	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	3456.0	115	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	4236.0	132	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	3676.0	123	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	2570.0	89	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	1716.0	59	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	1754	53	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	1851	54	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	1370.0	49	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	1479.0	51	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	1676.0	58	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	3151.0	98	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	3318.0	111	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	4574.0	139	81.7
7/21/2003	37823						

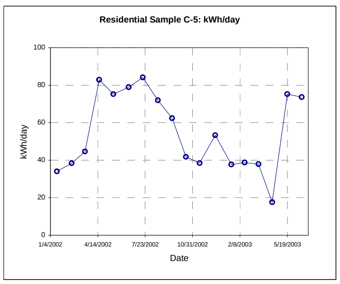


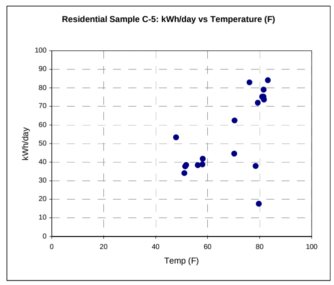


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = C4_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.975
AdjR2 = 0.975
RMSE = 5.2839
CV-RMSE = 6.225%
p = -0.023
DW = 1.530 (p>0)
N1 = 8
N2 = 9
Ycp = 54.2929 (1.8086)
LS = 0.0000 (0.0000)
RS = 4.9870 (0.2081)
Xcp = 67.3872 (0.6722)

Figure D-30: Summary of Utility Bill Analysis of Sample House C-4.

Residential C-5		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	1056.0	34	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	1075.0	38	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	1338.0	45	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	2487.0	83	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	2407.0	75	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	2369.0	79	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	2691.0	84	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	2157.0	72	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	1810.0	62	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	1212.0	42	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	1268	38	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	1813	53	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	1055.0	38	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	1124.0	39	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	1098.0	38	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	562.0	18	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	2257.0	75	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	2430.0	74	81.7
7/21/2003	37823						

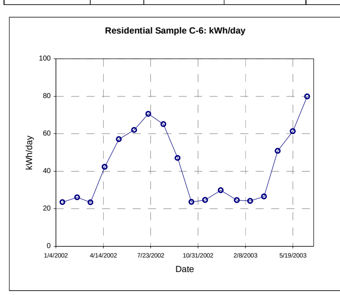


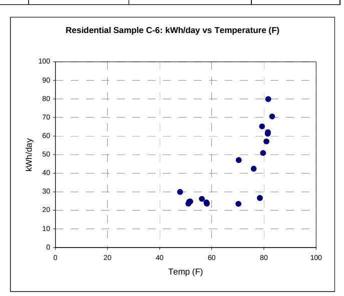


ASHRAE INVERSE MODELING TOOLKIT (1.9)
Output file name = IMT.Out
Input data file name = C5_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
Regression Results
N = 17
R2 = 0.618
AdjR2 = 0.618
RMSE = 13.1299
CV-RMSE = 23.427%
p = -0.002
DW = 1.994 (p>0)
N1 = 8
N2 = 9
Ycp = 41.2544 (4.3758)
LS = 0.0000 (0.0000)
RS = 3.3971 (0.6892)
Xcp = 70.7482 (0.6722)

Figure D-31: Summary of Utility Bill Analysis of Sample House C-5.

Residential C-6		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	730.0	24	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	731.0	26	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	703.0	23	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	1271.0	42	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	1827.0	57	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	1861.0	62	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	2258.0	71	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	1955.0	65	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	1364.0	47	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	684.0	24	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	815	25	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	1014	30	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	689.0	25	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	703.0	24	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	771.0	27	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	1628.0	51	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	1839.0	61	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	2635.0	80	81.7
7/21/2003	37823						

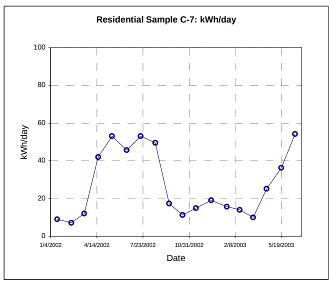


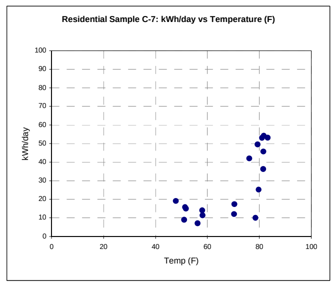


ASHRAE INVERSE MODELING TOOLKIT (1.9)
Output file name = IMT.Out
Input data file name = C6_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
Regression Results
N = 17
R2 = 0.939
AdjR2 = 0.939
RMSE = 4.9956
CV-RMSE = 11.487%
p = 0.110
DW = 1.368 (p>0)
N1 = 8
N2 = 9
Ycp = 25.3568 (1.7036)
LS = 0.0000 (0.0000)
RS = 3.1380 (0.2073)
Xcp = 68.0594 (0.6722)

Figure D-32: Summary of Utility Bill Analysis of Sample House C-6.

Residential C 7		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	279.0	9	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	199.0	7	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	360.0	12	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	1260.0	42	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	1699.0	53	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	1371.0	46	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	1700.0	53	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	1485.0	50	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	505.0	17	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	328.0	11	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	494	15	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	648	19	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	440.0	16	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	407.0	14	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	290.0	10	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	806.0	25	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	1087.0	36	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	1789.0	54	81.7
7/21/2003	37823						

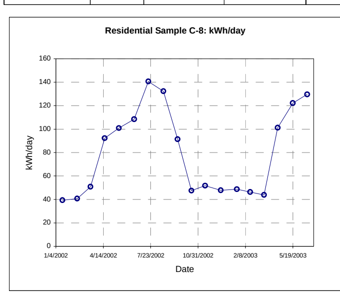


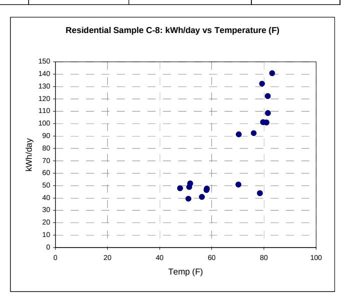


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = C7_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.910
AdjR2 = 0.910
RMSE = 5.4603
CV-RMSE = 19.315%
p = 0.400
DW = 1.163 (p>0)
N1 = 8
N2 = 9
Ycp = 13.1488 (1.8036)
LS = 0.0000 (0.0000)
RS = 3.7818 (0.3062)
Xcp = 71.4204 (0.6722)

Figure D-33: Summary of Utility Bill Analysis of Sample House C-7.

Residential C-8		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	1219.0	39	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	1141.0	41	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	1523.0	51	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	2769.0	92	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	3228.0	101	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	3255.0	109	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	4501.0	141	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	3968.0	132	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	2649.0	91	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	1376.0	47	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	1706	52	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	1625	48	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	1365.0	49	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	1344.0	46	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	1271.0	44	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	3236.0	101	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	3668.0	122	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	4278.0	130	
7/21/2003	37823	7/21/2003					

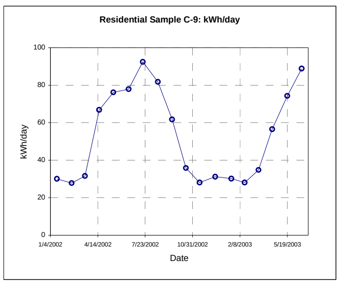


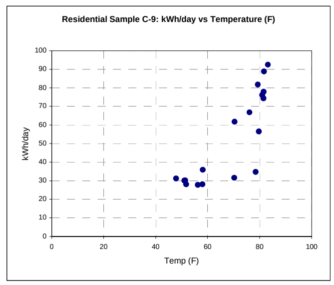


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = C8_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.971
AdjR2 = 0.971
RMSE = 6.4405
CV-RMSE = 7.841%
p = 0.361
DW = 1.246 (p>0)
N1 = 8
N2 = 9
Ycp = 47.2103 (2.2115)
LS = 0.0000 (0.0000)
RS = 5.3825 (0.2412)
Xcp = 66.7150 (0.6722)

Figure D-34: Summary of Utility Bill Analysis of Sample House C-8.

Residential C-9		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	931.0	30	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	777.0	28	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	948.0	32	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	2005.0	67	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	2438.0	76	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	2337.0	78	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	2958.0	92	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	2452.0	82	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	1789.0	62	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	1040.0	36	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	927	28	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	1062	31	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	845.0	30	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	813.0	28	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	1008.0	35	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	1808.0	57	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	2229.0	74	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	2931.0	89	81.7
7/21/2003	37823						





ASHRAE INVERSE MODELING TOOLKIT (1.9)

Output file name = IMT.Out

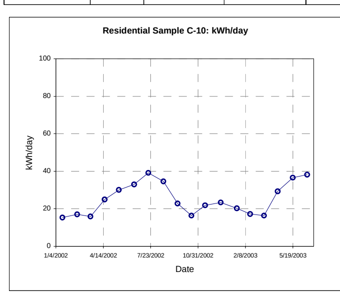
Input data file name = C9_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)

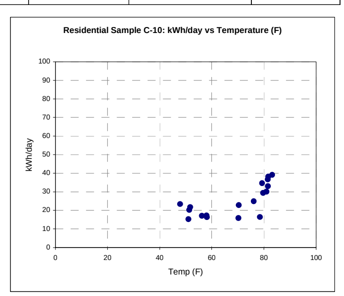
Regression Results

N = 17
R2 = 0.978
AdjR2 = 0.978
RMSE = 3.7347
CV-RMSE = 6.872%
p = -0.300
DW = 2.419 (p>0)
N1 = 8
N2 = 9
Ycp = 30.9507 (1.2824)
LS = 0.0000 (0.0000)
RS = 3.6051 (0.1399)
Xcp = 66.7150 (0.6722)

Figure D-35: Summary of Utility Bill Analysis of Sample House C-9.

Residential C-10		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	474.0	15	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	477.0	17	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	475.0	16	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	748.0	25	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	962.0	30	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	991.0	33	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	1253.0	39	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	1038.0	35	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	661.0	23	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	474.0	16	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	719	22	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	794	23	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	566.0	20	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	500.0	17	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	475.0	16	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	939.0	29	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	1098.0	37	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	1260.0	38	81.7
7/21/2003							





ASHRAE INVERSE MODELING TOOLKIT (1.9)

Output file name = IMT.Out

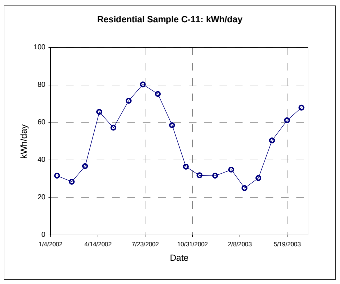
Input data file name = C10_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)

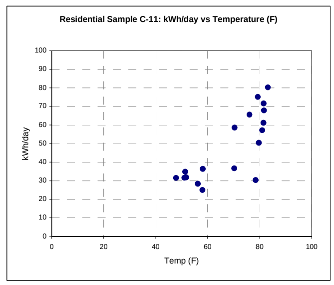
Regression Results

N = 17
R2 = 0.897
AdjR2 = 0.897
RMSE = 2.7536
CV-RMSE = 10.715%
p = 0.506
DW = 0.953 (p>0)
N1 = 8
N2 = 9
Ycp = 18.5222 (0.9177)
LS = 0.0000 (0.0000)
RS = 1.6480 (0.1445)
Xcp = 70.7482 (0.6722)

Figure D-36: Summary of Utility Bill Analysis of Sample House C-10.

Residential C-11		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	980.0	32	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	794.0	28	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	1099.0	37	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	1968.0	66	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	1829.0	57	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	2147.0	72	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	2567.0	80	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	2254.0	75	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	1698.0	59	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	1054.0	36	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	1049	32	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	1072	32	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	974.0	35	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	725.0	25	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	880.0	30	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	1612.0	50	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	1835.0	61	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	2239.0	68	81.7
7/21/2003	37823	7/21/2003					





ASHRAE INVERSE MODELING TOOLKIT (1.9)

Output file name = IMT.Out

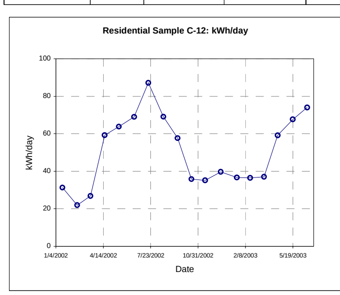
Input data file name = C11_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)

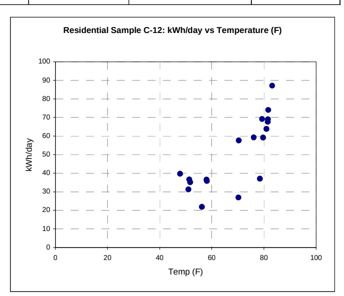
Regression Results

N = 17
R2 = 0.942
AdjR2 = 0.942
RMSE = 4.6436
CV-RMSE = 9.371%
p = 0.232
DW = 1.492 (p>0)
N1 = 7
N2 = 10
Ycp = 31.2503 (1.6265)
LS = 0.0000 (0.0000)
RS = 2.1935 (0.1406)
Xcp = 63.3540 (0.6722)

Figure D-37: Summary of Utility Bill Analysis of Sample House C-11.

Residential C-12		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	970.0	31	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	613.0	22	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	806.0	27	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	1779.0	59	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	2043.0	64	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	2070.0	69	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	2788.0	87	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	2074.0	69	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	1671.0	58	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	1038.0	36	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	1160	35	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	1351	40	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	1026.0	37	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	1059.0	37	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	1075.0	37	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	1892.0	59	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	2029.0	68	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	2442.0	74	81.7
7/21/2003	37823	7/21/2003					





ASHRAE INVERSE MODELING TOOLKIT (1.9)

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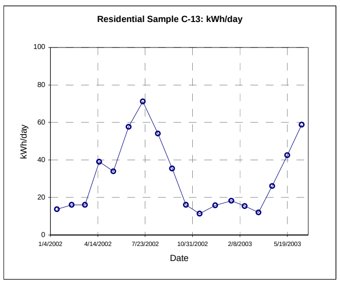
Input data file name = C12_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)

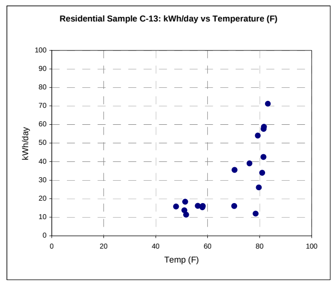
Regression Results

N = 17
R2 = 0.933
AdjR2 = 0.933
RMSE = 5.0577
CV-RMSE = 9.810%
p = 0.390
DW = 1.139 (p>0)
N1 = 8
N2 = 9
Ycp = 33.7481 (1.7367)
LS = 0.0000 (0.0000)
RS = 2.7440 (0.1894)
Xcp = 66.7150 (0.6722)

Figure D-38: Summary of Utility Bill Analysis of Sample House C-12.

Residential C-13		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	425.0	14	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	451.0	16	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	482.0	16	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	1170.0	39	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	1086.0	34	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	1730.0	58	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	2279.0	71	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	1621.0	54	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	1029.0	35	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	466.0	16	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	374	11	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	536	16	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	512.0	18	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	446.0	15	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	347.0	12	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	834.0	26	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	1275.0	43	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	1941.0	59	81.7
7/21/2003	37823	7/21/2003					





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ASHRAE INVERSE MODELING TOOLKIT (1.9)
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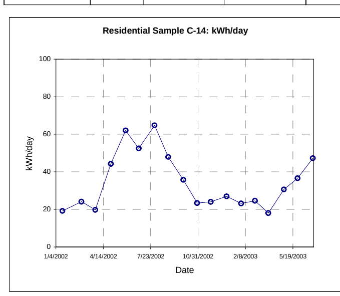
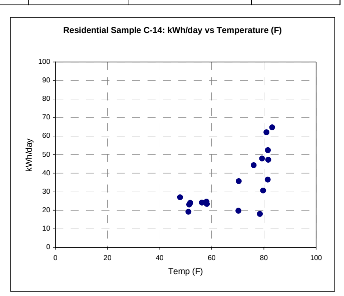
Input data file name = C13_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.928
AdjR2 = 0.928
RMSE = 5.3405
CV-RMSE = 16.822%
p = -0.064
DW = 2.117 (p>0)
N1 = 8
N2 = 9
Ycp = 15.1185 (1.7640)
LS = 0.0000 (0.0000)
RS = 4.1586 (0.2995)
Xcp = 71.4204 (0.6722)

Figure D-39: Summary of Utility Bill Analysis of Sample House C-13.

Residential C-14		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/27/2002	40	766.0	19	51.0
2/27/2002	37314	2/27/2002	3/28/2002	29	699.0	24	56.2
3/28/2002	37343	3/28/2002	4/30/2002	33	652.0	20	70.3
4/30/2002	37376	4/30/2002	5/31/2002	31	1372.0	44	76.1
5/31/2002	37407	5/31/2002	6/28/2002	28	1736.0	62	81.0
6/28/2002	37435	6/28/2002	7/31/2002	33	1730.0	52	81.6
7/31/2002	37468	7/31/2002	8/29/2002	29	1877.0	65	83.2
8/29/2002	37497	8/29/2002	9/30/2002	32	1534.0	48	79.3
9/30/2002	37529	9/30/2002	10/29/2002	29	1036.0	36	70.4
10/29/2002	37558	10/29/2002	11/27/2002	29	677.0	23	58.2
11/27/2002	37587	11/27/2002	12/30/2002	33	791	24	51.7
12/30/2002	37620	12/30/2002	1/30/2003	31	836	27	47.8
1/30/2003	37651	1/30/2003	2/28/2003	29	671.0	23	51.4
2/28/2003	37680	2/28/2003	3/28/2003	28	689.0	25	58.0
3/28/2003	37708	3/28/2003	4/30/2003	33	595.0	18	78.5
4/30/2003	37741	4/30/2003	5/29/2003	29	887.0	31	79.7
5/29/2003	37770	5/29/2003	6/30/2003	32	1170.0	37	81.5
6/30/2003	37802	6/30/2003	7/30/2003	30	1418.0	47	81.7
7/30/2003	37832	7/30/2003					





****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
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Output file name = IMT.Out
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Input data file name = C14_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.848
AdjR2 = 0.848
RMSE = 5.5704
CV-RMSE = 15.791%
p = 0.644
DW = 0.547 (p>0)
N1 = 8
N2 = 9
Ycp = 23.3168 (1.8817)
LS = 0.0000 (0.0000)
RS = 2.3604 (0.2585)
Xcp = 69.4038 (0.6722)

Figure D-40: Summary of Utility Bill Analysis of Sample House C-14.

Residential C-15		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	867.0	28	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	647.0	23	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	757.0	25	70.3
4/17/2002	37363	4/17/2002	5/29/2002	42	1921.0	46	76.1
5/29/2002	37405	5/29/2002	6/18/2002	20	1230.0	62	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	1617.0	54	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	2302.0	72	83.2
8/19/2002	37487	8/19/2002	9/19/2002	31	1786.0	58	79.3
9/19/2002	37518	9/19/2002	10/17/2002	28	1437.0	51	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	977.0	34	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	1118	34	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	1241	37	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	998.0	36	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	942.0	32	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	875.0	30	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	1582.0	49	79.7
5/19/2003	37760	5/19/2003	6/19/2003	31	1453.0	47	81.5
6/19/2003	37791	6/19/2003	7/21/2003	32	1807.0	56	81.7
7/21/2003	37823	7/21/2003					

```
*******************************************
ASHRAE INVERSE MODELING TOOLKIT (1.9)
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Output file name = IMT.Out
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Model type =          3P Cooling
Grouping column No =   0
Value for grouping =   0
Residual mode =        1
# of X(Indep.) Var =   1
Y1 column number =     4
X1 column number =   5
X2 column number =   0 (unused)
X3 column number =   0 (unused)
X4 column number =   0 (unused)
X5 column number =   0 (unused)
X6 column number =   0 (unused)
*******************************************
Regression Results
-----------------------------------
N =    17
-----------------------------------
R2 =    0.849
-----------------------------------
AdjR2 =    0.849
-----------------------------------
RMSE =    5.5646
-----------------------------------
CV-RMSE =   12.689%
-----------------------------------
p =    0.111
-----------------------------------
DW =    1.648 (p>0)
-----------------------------------
N1 =     8
-----------------------------------
N2 =     9
-----------------------------------
Ycp =    31.3247 (     1.9205)
-----------------------------------
LS =     0.0000 (     0.0000)
-----------------------------------
RS =     1.7396 (     0.1897)
-----------------------------------
Xcp =    65.3706 (     0.6722)
-----------------------------------
-----------------------------------
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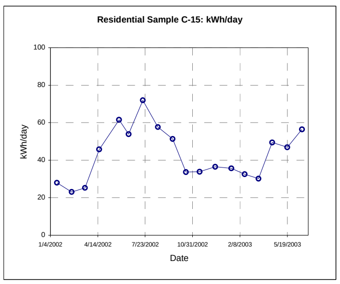

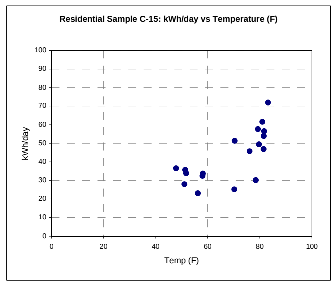

Figure D-41: Summary of Utility Bill Analysis of Sample House C-15.

Residential C-16		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	1622.0	52	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	1552.0	55	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	1689.0	56	70.3
4/17/2002	37363	4/17/2002	5/23/2002	36	2956.0	82	76.1
5/23/2002	37399	5/23/2002	6/18/2002	26	1512.0	58	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	2084.0	69	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	2639.0	82	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	2424.0	81	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	1685.0	58	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	880.0	30	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	460	14	51.7
12/18/2002	37608	12/18/2002	1/16/2003	29	517	18	47.8
1/16/2003	37637	1/16/2003	2/18/2003	33	1093.0	33	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	732.0	25	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	718.0	25	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	1214.0	38	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	1710.0	57	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	2248.0	68	81.7
7/21/2003	37823	7/21/2003					

```
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Value for grouping =   0
Residual mode =        1
# of X(Indep.) Var =   1
Y1 column number =     4
X1 column number =   5
X2 column number =   0 (unused)
X3 column number =   0 (unused)
X4 column number =   0 (unused)
X5 column number =   0 (unused)
X6 column number =   0 (unused)
*******************************************
Regression Results
-----------------------------------
N =    17
-----------------------------------
R2 =    0.681
-----------------------------------
AdjR2 =    0.681
-----------------------------------
RMSE =    13.3511
-----------------------------------
CV-RMSE =   26.667%
-----------------------------------
p =    0.725
-----------------------------------
DW =    0.660 (p>0)
-----------------------------------
N1 =     5
-----------------------------------
N2 =    12
-----------------------------------
Ycp =    29.2340 (     4.8999)
-----------------------------------
LS =     0.0000 (     0.0000)
-----------------------------------
RS =     2.0496 (     0.3618)
-----------------------------------
Xcp =    60.6652 (     0.6722)
-----------------------------------
-----------------------------------
```
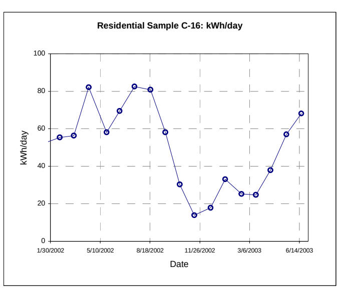



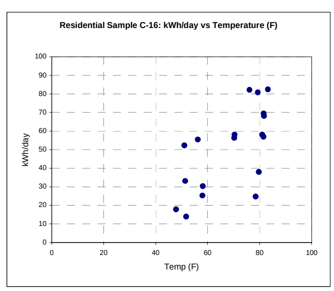
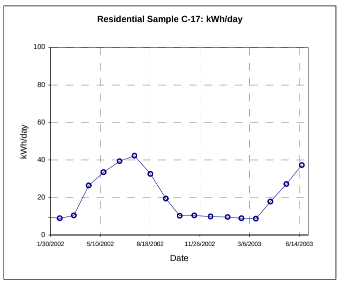
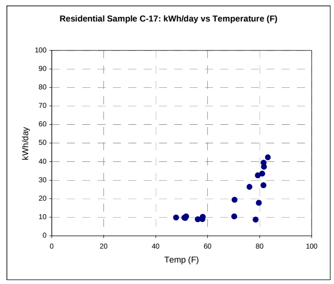


Figure D-42: Summary of Utility Bill Analysis of Sample House C-16.

Residential C-17		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	302.0	10	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	248.0	9	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	313.0	10	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	790.0	26	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	1072.0	34	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	1181.0	39	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	1352.0	42	83.2
8/19/2002	37487	8/19/2002	9/19/2002	31	1009.0	33	79.3
9/19/2002	37518	9/19/2002	10/17/2002	28	542.0	19	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	296.0	10	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	344	10	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	335	10	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	268.0	10	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	259.0	9	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	251.0	9	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	569.0	18	79.7
5/19/2003	37760	5/19/2003	6/19/2003	31	842.0	27	81.5
6/19/2003	37791	6/19/2003	7/21/2003	32	1192.0	37	81.7
7/21/2003	37823	7/21/2003					





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ASHRAE INVERSE MODELING TOOLKIT (1.9)
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Output file name = IMT.Out
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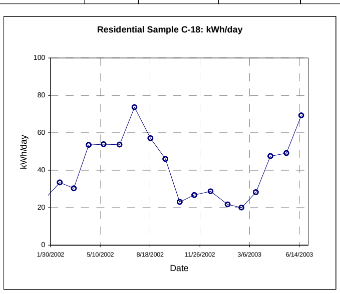
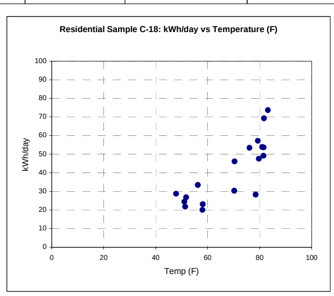
Input data file name = C17_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.949
AdjR2 = 0.949
RMSE = 2.8974
CV-RMSE = 13.974%
p = 0.304
DW = 1.388 (p>0)
N1 = 8
N2 = 9
Ycp = 9.6881 (0.9656)
LS = 0.0000 (0.0000)
RS = 2.5367 (0.1521)
Xcp = 70.7482 (0.6722)

Figure D-43: Summary of Utility Bill Analysis of Sample House C-17.

Residential C-18		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	757.0	24	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	936.0	33	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	910.0	30	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	1604.0	53	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	1723.0	54	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	1610.0	54	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	2357.0	74	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	1714.0	57	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	1336.0	46	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	670.0	23	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	884	27	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	978	29	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	608.0	22	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	580.0	20	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	820.0	28	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	1520.0	48	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	1475.0	49	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	2286.0	69	81.7
7/21/2003	37823	7/21/2003					

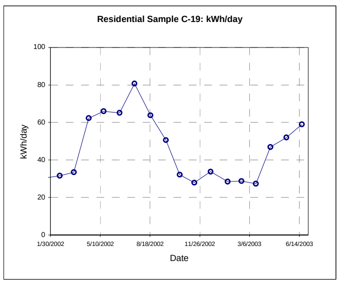


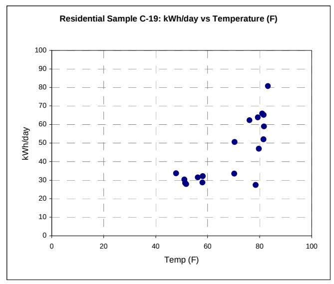


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = C18_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.922
AdjR2 = 0.922
RMSE = 4.8462
CV-RMSE = 11.503%
p = -0.327
DW = 2.294 (p>0)
N1 = 8
N2 = 9
Ycp = 26.5016 (1.6588)
LS = 0.0000 (0.0000)
RS = 2.5476 (0.1908)
Xcp = 67.3872 (0.6722)

Figure D-44: Summary of Utility Bill Analysis of Sample House C-18.

Residential C-19		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	942.0	30	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	883.0	32	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	1004.0	33	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	1870.0	62	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	2110.0	66	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	1955.0	65	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	2584.0	81	83.2
8/19/2002	37487	8/19/2002	9/19/2002	31	1979.0	64	79.3
9/19/2002	37518	9/19/2002	10/17/2002	28	1415.0	51	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	933.0	32	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	920	28	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	1146	34	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	796.0	28	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	833.0	29	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	793.0	27	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	1501.0	47	79.7
5/19/2003	37760	5/19/2003	6/19/2003	31	1611.0	52	81.5
6/19/2003	37791	6/19/2003	7/21/2003	32	1886.0	59	81.7
7/21/2003	37823	7/21/2003					

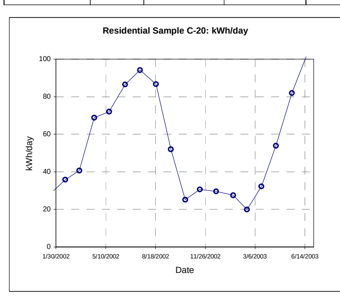


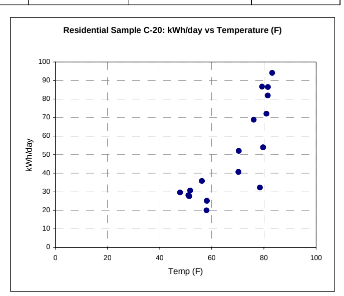


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
Output file name = IMT.Out
Input data file name = C19_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
Regression Results
N = 17
R2 = 0.951
AdjR2 = 0.951
RMSE = 6.2924
CV-RMSE = 11.386%
p = 0.085
DW = 1.563 (p>0)
N1 = 8
N2 = 9
Ycp = 30.2888 (2.1126)
LS = 0.0000 (0.0000)
RS = 5.3023 (0.3101)
Xcp = 70.0760 (0.6722)

Figure D-45: Summary of Utility Bill Analysis of Sample House C-19.

Residential C-20		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/18/2002	37274	1/18/2002	2/18/2002	31	871.0	28	51.0
2/18/2002	37305	2/18/2002	3/18/2002	28	1003.0	36	56.2
3/18/2002	37333	3/18/2002	4/17/2002	30	1220.0	41	70.3
4/17/2002	37363	4/17/2002	5/17/2002	30	2065.0	69	76.1
5/17/2002	37393	5/17/2002	6/18/2002	32	2305.0	72	81.0
6/18/2002	37425	6/18/2002	7/18/2002	30	2594.0	86	81.6
7/18/2002	37455	7/18/2002	8/19/2002	32	3012.0	94	83.2
8/19/2002	37487	8/19/2002	9/18/2002	30	2599.0	87	79.3
9/18/2002	37517	9/18/2002	10/17/2002	29	1507.0	52	70.4
10/17/2002	37546	10/17/2002	11/15/2002	29	729.0	25	58.2
11/15/2002	37575	11/15/2002	12/18/2002	33	1010	31	51.7
12/18/2002	37608	12/18/2002	1/21/2003	34	1005	30	47.8
1/21/2003	37642	1/21/2003	2/18/2003	28	771.0	28	51.4
2/18/2003	37670	2/18/2003	3/19/2003	29	579.0	20	58.0
3/19/2003	37699	3/19/2003	4/17/2003	29	934.0	32	78.5
4/17/2003	37728	4/17/2003	5/19/2003	32	1725.0	54	79.7
5/19/2003	37760	5/19/2003	6/18/2003	30	2457.0	82	81.5
6/18/2003	37790	6/18/2003	7/21/2003	33	3372.0	102	81.7
7/21/2003	37823	7/21/2003					

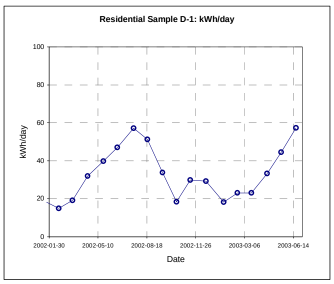


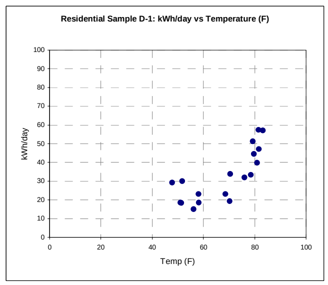


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
Output file name = IMT.Out
Input data file name = C20_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
Regression Results
N = 17
R2 = 0.951
AdjR2 = 0.951
RMSE = 6.2809
CV-RMSE = 11.364%
p = 0.086
DW = 1.561 (p>0)
N1 = 8
N2 = 9
Ycp = 30.2894 (2.1087)
LS = 0.0000 (0.0000)
RS = 5.3031 (0.3096)
Xcp = 70.0760 (0.6722)

Figure D-46: Summary of Utility Bill Analysis of Sample House C-20.

Residential D-1		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
2002-01-22	37278	2002-01-22	2002-02-19	28	519.0	19	51.0
2002-02-19	37306	2002-02-19	2002-03-19	28	419.0	15	56.2
2002-03-19	37334	2002-03-19	2002-04-19	31	596.0	19	70.3
2002-04-19	37365	2002-04-19	2002-05-21	32	1021.0	32	76.1
2002-05-21	37397	2002-05-21	2002-06-19	29	1154.0	40	81.0
2002-06-19	37426	2002-06-19	2002-07-22	33	1554.0	47	81.6
2002-07-22	37459	2002-07-22	2002-08-19	28	1599.0	57	83.2
2002-08-19	37487	2002-08-19	2002-09-19	31	1588.0	51	79.3
2002-09-19	37518	2002-09-19	2002-10-18	29	981.0	34	70.4
2002-10-18	37547	2002-10-18	2002-11-15	28	517.0	18	58.2
2002-11-15	37575	2002-11-15	2002-12-17	32	957	30	51.7
2002-12-17	37607	2002-12-17	2003-01-22	36	1051	29	47.8
2003-01-22	37643	2003-01-22	2003-02-19	28	512.0	18	51.4
2003-02-19	37671	2003-02-19	2003-03-20	29	668.0	23	58.0
2003-03-20	37700	2003-03-20	2003-04-21	32	739.0	23	68.6
2003-04-21	37732	2003-04-21	2003-05-20	29	968.0	33	78.5
2003-05-20	37761	2003-05-20	2003-06-19	30	1334.0	44	79.7
2003-06-19	37791	2003-06-19	2003-07-21	32	1833.0	57	81.5
2003-07-21	37823	2003-07-21					

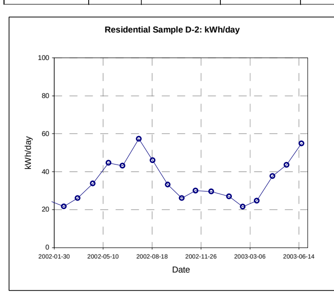


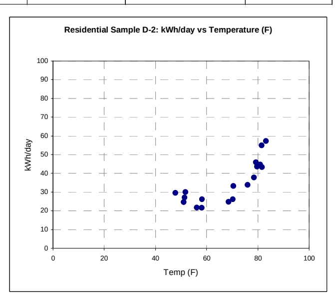


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = D1_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.908
AdjR2 = 0.908
RMSE = 5.0304
CV-RMSE = 10.227%
p = -0.215
DW = 2.295 (p>0)
N1 = 8
N2 = 9
Ycp = 34.6115 (1.7110)
LS = 0.0000 (0.0000)
RS = 2.5429 (0.2093)
Xcp = 68.2832 (0.6616)

Figure D-47: Summary of Utility Bill Analysis of Sample House D-1.

Residential D-2		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
2002-01-22	37278	2002-01-22	2002-02-19	28	689.0	25	51.0
2002-02-19	37306	2002-02-19	2002-03-19	28	608.0	22	56.2
2002-03-19	37334	2002-03-19	2002-04-19	31	809.0	26	70.3
2002-04-19	37365	2002-04-19	2002-05-21	32	1082.0	34	76.1
2002-05-21	37397	2002-05-21	2002-06-19	29	1295.0	45	81.0
2002-06-19	37426	2002-06-19	2002-07-22	33	1426.0	43	81.6
2002-07-22	37459	2002-07-22	2002-08-19	28	1603.0	57	83.2
2002-08-19	37487	2002-08-19	2002-09-19	31	1424.0	46	79.3
2002-09-19	37518	2002-09-19	2002-10-18	29	962.0	33	70.4
2002-10-18	37547	2002-10-18	2002-11-15	28	732.0	26	58.2
2002-11-15	37575	2002-11-15	2002-12-17	32	959	30	51.7
2002-12-17	37607	2002-12-17	2003-01-22	36	1063	30	47.8
2003-01-22	37643	2003-01-22	2003-02-19	28	758.0	27	51.4
2003-02-19	37671	2003-02-19	2003-03-20	29	624.0	22	58.0
2003-03-20	37700	2003-03-20	2003-04-21	32	791.0	25	68.6
2003-04-21	37732	2003-04-21	2003-05-20	29	1095.0	38	78.5
2003-05-20	37761	2003-05-20	2003-06-19	30	1307.0	44	79.7
2003-06-19	37791	2003-06-19	2003-07-21	32	1755.0	55	81.5
2003-07-21	37823	2003-07-21					

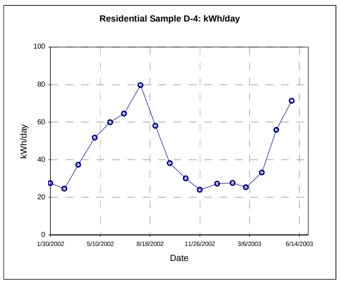


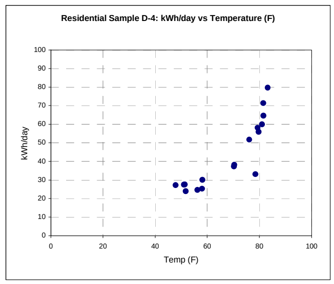


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = D2_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.900
AdjR2 = 0.900
RMSE = 4.0037
CV-RMSE = 13.303%
p = 0.086
DW = 1.507 (p>0)
N1 = 8
N2 = 9
Ycp = 19.7491 (1.3171)
LS = 0.0000 (0.0000)
RS = 2.5988 (0.2235)
Xcp = 71.5912 (0.6616)

Figure D-48: Summary of Utility Bill Analysis of Sample House D-2.

Residential D-4		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/30/2002	37286	1/30/2002	2/27/2002	28	770.0	28	51.0
2/27/2002	37314	2/27/2002	3/27/2002	28	688.0	25	56.2
3/27/2002	37342	3/27/2002	4/29/2002	33	1232.0	37	70.3
4/29/2002	37375	4/29/2002	5/30/2002	31	1604.0	52	76.1
5/30/2002	37406	5/30/2002	6/27/2002	28	1678.0	60	81.0
6/27/2002	37434	6/27/2002	7/30/2002	33	2131.0	65	81.6
7/30/2002	37467	7/30/2002	8/29/2002	30	2390.0	80	83.2
8/29/2002	37497	8/29/2002	9/27/2002	29	1684.0	58	79.3
9/27/2002	37526	9/27/2002	10/29/2002	32	1222.0	38	70.4
10/29/2002	37558	10/29/2002	11/26/2002	28	841.0	30	58.2
11/26/2002	37586	11/26/2002	12/31/2002	35	839	24	51.7
12/31/2002	37621	12/31/2002	1/31/2003	31	843	27	47.8
1/31/2003	37652	1/31/2003	2/27/2003	27	744.0	28	51.4
2/27/2003	37679	2/27/2003	3/31/2003	32	810.0	25	58.0
3/31/2003	37711	3/31/2003	4/29/2003	29	961.0	33	78.5
4/29/2003	37740	4/29/2003	5/30/2003	31	1733.0	56	79.7
5/30/2003	37771	5/30/2003	6/27/2003	28	1998.0	71	81.5
6/27/2003	37799						

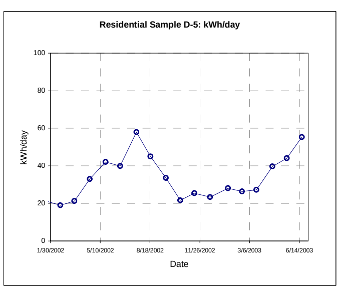


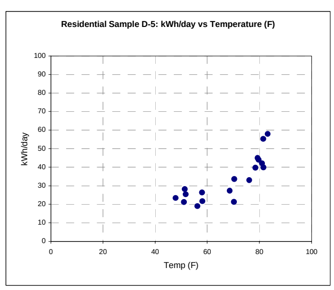


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = B8_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 16
R2 = 0.951
AdjR2 = 0.951
RMSE = 4.2353
CV-RMSE = 9.563%
p = -0.230
DW = 2.198 (p>0)
N1 = 6
N2 = 10
Ycp = 26.4896 (1.5086)
LS = 0.0000 (0.0000)
RS = 2.6350 (0.1591)
Xcp = 66.0000 (0.6868)

Figure D-49: Summary of Utility Bill Analysis of Sample House D-4.

Residential D-5		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/22/2002	37278	1/22/2002	2/19/2002	28	594.0	21	51.0
2/19/2002	37306	2/19/2002	3/19/2002	28	531.0	19	56.2
3/19/2002	37334	3/19/2002	4/19/2002	31	660.0	21	70.3
4/19/2002	37365	4/19/2002	5/21/2002	32	1055.0	33	76.1
5/21/2002	37397	5/21/2002	6/19/2002	29	1219.0	42	81.0
6/19/2002	37426	6/19/2002	7/22/2002	33	1315.0	40	81.6
7/22/2002	37459	7/22/2002	8/19/2002	28	1621.0	58	83.2
8/19/2002	37487	8/19/2002	9/19/2002	31	1394.0	45	79.3
9/19/2002	37518	9/19/2002	10/18/2002	29	974.0	34	70.4
10/18/2002	37547	10/18/2002	11/15/2002	28	606.0	22	58.2
11/15/2002	37575	11/15/2002	12/17/2002	32	813	25	51.7
12/17/2002	37607	12/17/2002	1/22/2003	36	842	23	47.8
1/22/2003	37643	1/22/2003	2/19/2003	28	787.0	28	51.4
2/19/2003	37671	2/19/2003	3/20/2003	29	764.0	26	58.0
3/20/2003	37700	3/20/2003	4/21/2003	32	872.0	27	68.6
4/21/2003	37732	4/21/2003	5/20/2003	29	1150.0	40	78.5
5/20/2003	37761	5/20/2003	6/19/2003	30	1321.0	44	79.7
6/19/2003	37791	6/19/2003	7/21/2003	32	1769.0	55	81.5
7/21/2003	37823	7/21/2003					

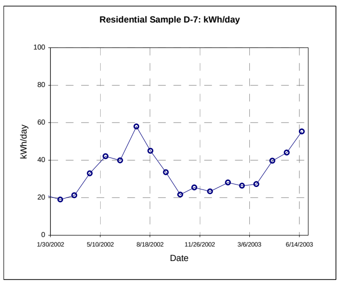


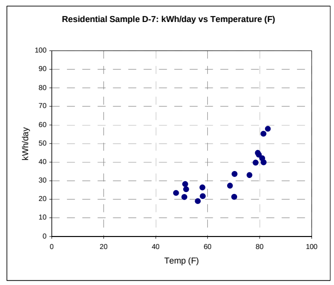


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = D5_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.923
AdjR2 = 0.923
RMSE = 5.5747
CV-RMSE = 12.625%
p = -0.371
DW = 2.561 (p>0)
N1 = 8
N2 = 9
Ycp = 26.3140 (1.8961)
LS = 0.0000 (0.0000)
RS = 3.1121 (0.2319)
Xcp = 68.2832 (0.6616)

Figure D-50: Summary of Utility Bill Analysis of Sample House D-5.

Residential D-7		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/22/2002	37278	1/22/2002	2/19/2002	28	594.0	21	51.0
2/19/2002	37306	2/19/2002	3/19/2002	28	531.0	19	56.2
3/19/2002	37334	3/19/2002	4/19/2002	31	660.0	21	70.3
4/19/2002	37365	4/19/2002	5/21/2002	32	1055.0	33	76.1
5/21/2002	37397	5/21/2002	6/19/2002	29	1219.0	42	81.0
6/19/2002	37426	6/19/2002	7/22/2002	33	1315.0	40	81.6
7/22/2002	37459	7/22/2002	8/19/2002	28	1621.0	58	83.2
8/19/2002	37487	8/19/2002	9/19/2002	31	1394.0	45	79.3
9/19/2002	37518	9/19/2002	10/18/2002	29	974.0	34	70.4
10/18/2002	37547	10/18/2002	11/15/2002	28	606.0	22	58.2
11/15/2002	37575	11/15/2002	12/17/2002	32	813	25	51.7
12/17/2002	37607	12/17/2002	1/22/2003	36	842	23	47.8
1/22/2003	37643	1/22/2003	2/19/2003	28	787.0	28	51.4
2/19/2003	37671	2/19/2003	3/20/2003	29	764.0	26	58.0
3/20/2003	37700	3/20/2003	4/21/2003	32	872.0	27	68.6
4/21/2003	37732	4/21/2003	5/20/2003	29	1150.0	40	78.5
5/20/2003	37761	5/20/2003	6/19/2003	30	1321.0	44	79.7
6/19/2003	37791	6/19/2003	7/21/2003	32	1769.0	55	81.5
7/21/2003	37823	7/21/2003					





****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = D7_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results

N = 17

R2 = 0.914

AdjR2 = 0.914

RMSE = 4.1580

CV-RMSE = 11.959%
----
p = -0.102

DW = 2.155 (p>0)

N1 = 8

N2 = 9

Ycp = 22.3570 (1.4078)

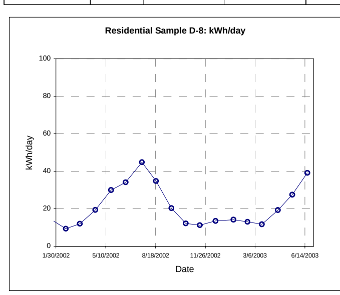
LS = 0.0000 (0.0000)

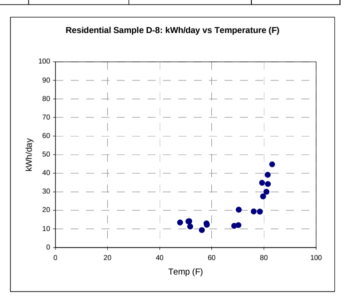
RS = 2.3059 (0.1825)

Xcp = 68.9448 (0.6616)

Figure D-51: Summary of Utility Bill Analysis of Sample House D-7.

Residential D-8		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/22/2002	37278	1/22/2002	2/19/2002	28	392.0	14	51.0
2/19/2002	37306	2/19/2002	3/19/2002	28	263.0	9	56.2
3/19/2002	37334	3/19/2002	4/19/2002	31	373.0	12	70.3
4/19/2002	37365	4/19/2002	5/21/2002	32	621.0	19	76.1
5/21/2002	37397	5/21/2002	6/19/2002	29	869.0	30	81.0
6/19/2002	37426	6/19/2002	7/22/2002	33	1126.0	34	81.6
7/22/2002	37459	7/22/2002	8/19/2002	28	1254.0	45	83.2
8/19/2002	37487	8/19/2002	9/19/2002	31	1079.0	35	79.3
9/19/2002	37518	9/19/2002	10/18/2002	29	589.0	20	70.4
10/18/2002	37547	10/18/2002	11/15/2002	28	341.0	12	58.2
11/15/2002	37575	11/15/2002	12/17/2002	32	359	11	51.7
12/17/2002	37607	12/17/2002	1/22/2003	36	485	13	47.8
1/22/2003	37643	1/22/2003	2/19/2003	28	396.0	14	51.4
2/19/2003	37671	2/19/2003	3/20/2003	29	377.0	13	58.0
3/20/2003	37700	3/20/2003	4/21/2003	32	374.0	12	68.6
4/21/2003	37732	4/21/2003	5/20/2003	29	560.0	19	78.5
5/20/2003	37761	5/20/2003	6/19/2003	30	824.0	27	79.7
6/19/2003	37791	6/19/2003	7/21/2003	32	1251.0	39	81.5
7/21/2003	37823	7/21/2003					





****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = D8_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results

N = 17

R2 = 0.953

AdjR2 = 0.953

RMSE = 2.5117

CV-RMSE = 11.654%
----
p = -0.361

DW = 2.407 (p>0)

N1 = 9

N2 = 8

Ycp = 13.1447 (0.7762)

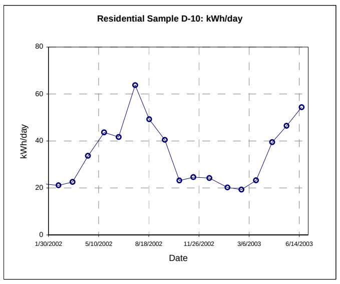
LS = 0.0000 (0.0000)

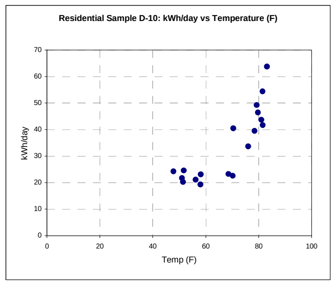
RS = 3.6218 (0.2072)

Xcp = 74.8992 (0.6616)

Figure D-52: Summary of Utility Bill Analysis of Sample House D-8.

Residential D-10		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/22/2002	37278	1/22/2002	2/19/2002	28	608.0	22	51.0
2/19/2002	37306	2/19/2002	3/19/2002	28	591.0	21	56.2
3/19/2002	37334	3/19/2002	4/19/2002	31	699.0	23	70.3
4/19/2002	37365	4/19/2002	5/21/2002	32	1077.0	34	76.1
5/21/2002	37397	5/21/2002	6/19/2002	29	1266.0	44	81.0
6/19/2002	37426	6/19/2002	7/22/2002	33	1375.0	42	81.6
7/22/2002	37459	7/22/2002	8/19/2002	28	1784.0	64	83.2
8/19/2002	37487	8/19/2002	9/19/2002	31	1526.0	49	79.3
9/19/2002	37518	9/19/2002	10/18/2002	29	1173.0	40	70.4
10/18/2002	37547	10/18/2002	11/15/2002	28	648.0	23	58.2
11/15/2002	37575	11/15/2002	12/17/2002	32	787	25	51.7
12/17/2002	37607	12/17/2002	1/22/2003	36	872	24	47.8
1/22/2003	37643	1/22/2003	2/19/2003	28	566.0	20	51.4
2/19/2003	37671	2/19/2003	3/20/2003	29	560.0	19	58.0
3/20/2003	37700	3/20/2003	4/21/2003	32	744.0	23	68.6
4/21/2003	37732	4/21/2003	5/20/2003	29	1145.0	39	78.5
5/20/2003	37761	5/20/2003	6/19/2003	30	1393.0	46	79.7
6/19/2003	37791	6/19/2003	7/21/2003	32	1740.0	54	81.5
7/21/2003	37823	7/21/2003					

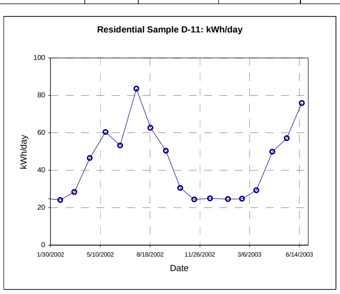


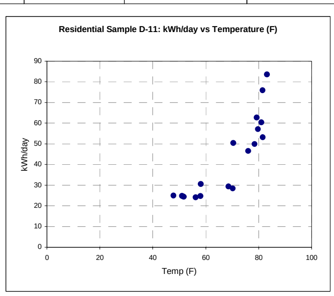


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = D10_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.895
AdjR2 = 0.895
RMSE = 3.9603
CV-RMSE = 11.555%
p = 0.039
DW = 1.634 (p>0)
N1 = 8
N2 = 9
Ycp = 24.1183 (1.3149)
LS = 0.0000 (0.0000)
RS = 2.3447 (0.2073)
Xcp = 70.9296 (0.6616)

Figure D-53: Summary of Utility Bill Analysis of Sample House D-10.

Residential D-11		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/22/2002	37278	1/22/2002	2/19/2002	28	696.0	25	51.0
2/19/2002	37306	2/19/2002	3/19/2002	28	676.0	24	56.2
3/19/2002	37334	3/19/2002	4/19/2002	31	880.0	28	70.3
4/19/2002	37365	4/19/2002	5/21/2002	32	1489.0	47	76.1
5/21/2002	37397	5/21/2002	6/19/2002	29	1751.0	60	81.0
6/19/2002	37426	6/19/2002	7/22/2002	33	1755.0	53	81.6
7/22/2002	37459	7/22/2002	8/19/2002	28	2339.0	84	83.2
8/19/2002	37487	8/19/2002	9/19/2002	31	1943.0	63	79.3
9/19/2002	37518	9/19/2002	10/18/2002	29	1461.0	50	70.4
10/18/2002	37547	10/18/2002	11/15/2002	28	856.0	31	58.2
11/15/2002	37575	11/15/2002	12/17/2002	32	780	24	51.7
12/17/2002	37607	12/17/2002	1/22/2003	36	900	25	47.8
1/22/2003	37643	1/22/2003	2/19/2003	28	687.0	25	51.4
2/19/2003	37671	2/19/2003	3/20/2003	29	717.0	25	58.0
3/20/2003	37700	3/20/2003	4/21/2003	32	939.0	29	68.6
4/21/2003	37732	4/21/2003	5/20/2003	29	1447.0	50	78.5
5/20/2003	37761	5/20/2003	6/19/2003	30	1712.0	57	79.7
6/19/2003	37791	6/19/2003	7/21/2003	32	2428.0	76	81.5
7/21/2003	37823	7/21/2003					

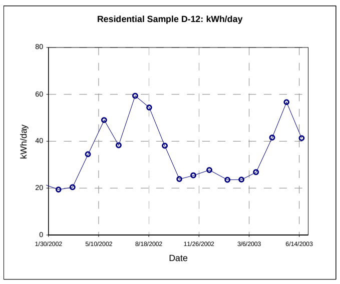


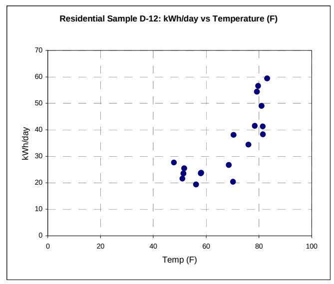


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = D11_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
\# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.895
AdjR2 = 0.895
RMSE = 3.9603
CV-RMSE = 11.555%
p = 0.039
DW = 1.634 (p>0)
N1 = 8
N2 = 9
Ycp = 24.1183 (1.3149)
LS = 0.0000 (0.0000)
RS = 2.3447 (0.2073)
Xcp = 70.9296 (0.6616)

Figure D-54: Summary of Utility Bill Analysis of Sample House D-11.

Residential D-12		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/22/2002	37278	1/22/2002	2/19/2002	28	604.0	22	51.0
2/19/2002	37306	2/19/2002	3/19/2002	28	542.0	19	56.2
3/19/2002	37334	3/19/2002	4/19/2002	31	631.0	20	70.3
4/19/2002	37365	4/19/2002	5/21/2002	32	1101.0	34	76.1
5/21/2002	37397	5/21/2002	6/19/2002	29	1422.0	49	81.0
6/19/2002	37426	6/19/2002	7/22/2002	33	1262.0	38	81.6
7/22/2002	37459	7/22/2002	8/19/2002	28	1662.0	59	83.2
8/19/2002	37487	8/19/2002	9/19/2002	31	1686.0	54	79.3
9/19/2002	37518	9/19/2002	10/18/2002	29	1104.0	38	70.4
10/18/2002	37547	10/18/2002	11/15/2002	28	666.0	24	58.2
11/15/2002	37575	11/15/2002	12/17/2002	32	814	25	51.7
12/17/2002	37607	12/17/2002	1/22/2003	36	995	28	47.8
1/22/2003	37643	1/22/2003	2/19/2003	28	659.0	24	51.4
2/19/2003	37671	2/19/2003	3/20/2003	29	684.0	24	58.0
3/20/2003	37700	3/20/2003	4/21/2003	32	856.0	27	68.6
4/21/2003	37732	4/21/2003	5/20/2003	29	1203.0	41	78.5
5/20/2003	37761	5/20/2003	6/19/2003	30	1698.0	57	79.7
6/19/2003	37791	6/19/2003	7/21/2003	32	1320.0	41	81.5
7/21/2003	37823	7/21/2003					

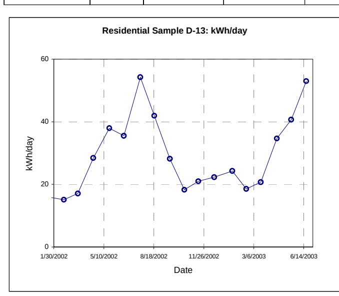


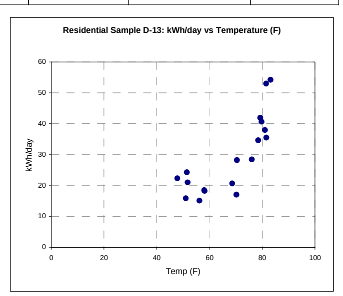


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = D12_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.934
AdjR2 = 0.934
RMSE = 3.9719
CV-RMSE = 9.339%
p = -0.276
DW = 1.961 (p>0)
N1 = 6
N2 = 9
Ycp = 27.8074 (1.4937)
LS = 0.0000 (0.0000)
RS = 2.9994 (0.2212)
Xcp = 70.9296 (0.6616)

Figure D-55: Summary of Utility Bill Analysis of Sample House D-12.

Residential D-13		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/22/2002	37278	1/22/2002	2/19/2002	28	444.0	16	51.0
2/19/2002	37306	2/19/2002	3/19/2002	28	423.0	15	56.2
3/19/2002	37334	3/19/2002	4/19/2002	31	529.0	17	70.3
4/19/2002	37365	4/19/2002	5/21/2002	32	910.0	28	76.1
5/21/2002	37397	5/21/2002	6/19/2002	29	1100.0	38	81.0
6/19/2002	37426	6/19/2002	7/22/2002	33	1171.0	35	81.6
7/22/2002	37459	7/22/2002	8/19/2002	28	1518.0	54	83.2
8/19/2002	37487	8/19/2002	9/19/2002	31	1299.0	42	79.3
9/19/2002	37518	9/19/2002	10/18/2002	29	818.0	28	70.4
10/18/2002	37547	10/18/2002	11/15/2002	28	511.0	18	58.2
11/15/2002	37575	11/15/2002	12/17/2002	32	672	21	51.7
12/17/2002	37607	12/17/2002	1/22/2003	36	803	22	47.8
1/22/2003	37643	1/22/2003	2/19/2003	28	679.0	24	51.4
2/19/2003	37671	2/19/2003	3/20/2003	29	537.0	19	58.0
3/20/2003	37700	3/20/2003	4/21/2003	32	662.0	21	68.6
4/21/2003	37732	4/21/2003	5/20/2003	29	1005.0	35	78.5
5/20/2003	37761	5/20/2003	6/19/2003	30	1219.0	41	79.7
6/19/2003	37791	6/19/2003	7/21/2003	32	1695.0	53	81.5
7/21/2003	37823	7/21/2003					

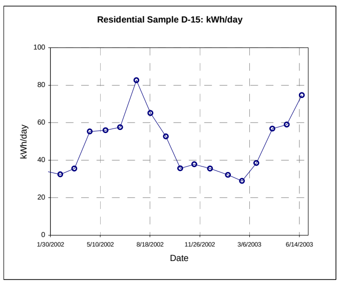


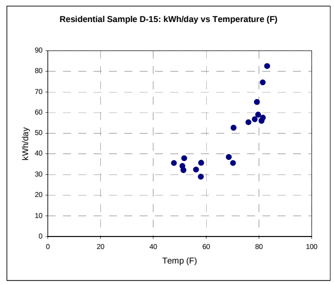


****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = D13_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results
N = 17
R2 = 0.922
AdjR2 = 0.922
RMSE = 3.2173
CV-RMSE = 9.101%
p = -0.058
DW = 1.799 (p>0)
N1 = 8
N2 = 9
Ycp = 25.8240 (1.0584)
LS = 0.0000 (0.0000)
RS = 2.3931 (0.1796)
Xcp = 71.5912 (0.6616)

Figure D-56: Summary of Utility Bill Analysis of Sample House D-13.

Residential D-15		Date Begin	Date End	# of Days	kWh Consumption per Period	Use per Day	Avg Temp(F)
1/22/2002	37278	1/22/2002	2/19/2002	28	954.0	34	51.0
2/19/2002	37306	2/19/2002	3/19/2002	28	907.0	32	56.2
3/19/2002	37334	3/19/2002	4/19/2002	31	1103.0	36	70.3
4/19/2002	37365	4/19/2002	5/21/2002	32	1769.0	55	76.1
5/21/2002	37397	5/21/2002	6/19/2002	29	1624.0	56	81.0
6/19/2002	37426	6/19/2002	7/22/2002	33	1900.0	58	81.6
7/22/2002	37459	7/22/2002	8/19/2002	28	2312.0	83	83.2
8/19/2002	37487	8/19/2002	9/19/2002	31	2019.0	65	79.3
9/19/2002	37518	9/19/2002	10/18/2002	29	1527.0	53	70.4
10/18/2002	37547	10/18/2002	11/15/2002	28	998.0	36	58.2
11/15/2002	37575	11/15/2002	12/17/2002	32	1211	38	51.7
12/17/2002	37607	12/17/2002	1/22/2003	36	1279	36	47.8
1/22/2003	37643	1/22/2003	2/19/2003	28	900.0	32	51.4
2/19/2003	37671	2/19/2003	3/20/2003	29	840.0	29	58.0
3/20/2003	37700	3/20/2003	4/21/2003	32	1231.0	38	68.6
4/21/2003	37732	4/21/2003	5/20/2003	29	1647.0	57	78.5
5/20/2003	37761	5/20/2003	6/19/2003	30	1770.0	59	79.7
6/19/2003	37791	6/19/2003	7/21/2003	32	2388.0	75	81.5
7/21/2003	37823	7/21/2003					





****
ASHRAE INVERSE MODELING TOOLKIT (1.9)
****
Output file name = IMT.Out
****
Input data file name = D15_3PC.dat
Model type = 3P Cooling
Grouping column No = 0
Value for grouping = 0
Residual mode = 1
# of X(Indep.) Var = 1
Y1 column number = 4
X1 column number = 5
X2 column number = 0 (unused)
X3 column number = 0 (unused)
X4 column number = 0 (unused)
X5 column number = 0 (unused)
X6 column number = 0 (unused)
****
Regression Results

N = 17

R2 = 0.883

AdjR2 = 0.883

RMSE = 4.8624

CV-RMSE = 14.445%
----
p = 0.138

DW = 1.489 (p>0)

N1 = 8

N2 = 9

Ycp = 21.9141 (1.6145)

LS = 0.0000 (0.0000)

RS = 2.7122 (0.2546)

Xcp = 70.9296 (0.6616)

Figure D-57: Summary of Utility Bill Analysis of Sample House D-15.

APPENDIX E

Figure E-1 shows the calculator's input data page to estimate the prototype single-family detached house's baseline energy use. This input data page includes information that the use can enter, including: the window area, window U-factor, solar heat gain coefficient, the house's floor type, information about the house's floor information, solar energy contributions (a place holder for future functions), the R-value of the wall insulation, R-value of the attic insulation, duct location, type of water heater, heating system type, efficiency of the heating system, cooling system type, efficiency of the cooling system, and cost information for electricity and natural gas.

In Figures E-2 thru E-3 shows the results from the baseline energy use and from the adoption of SEER 12 in the prototype house. These results include information about the total energy use, electricity use and natural gas use, with each of the categories including cost, energy, NOx, SO2, and CO2 values.

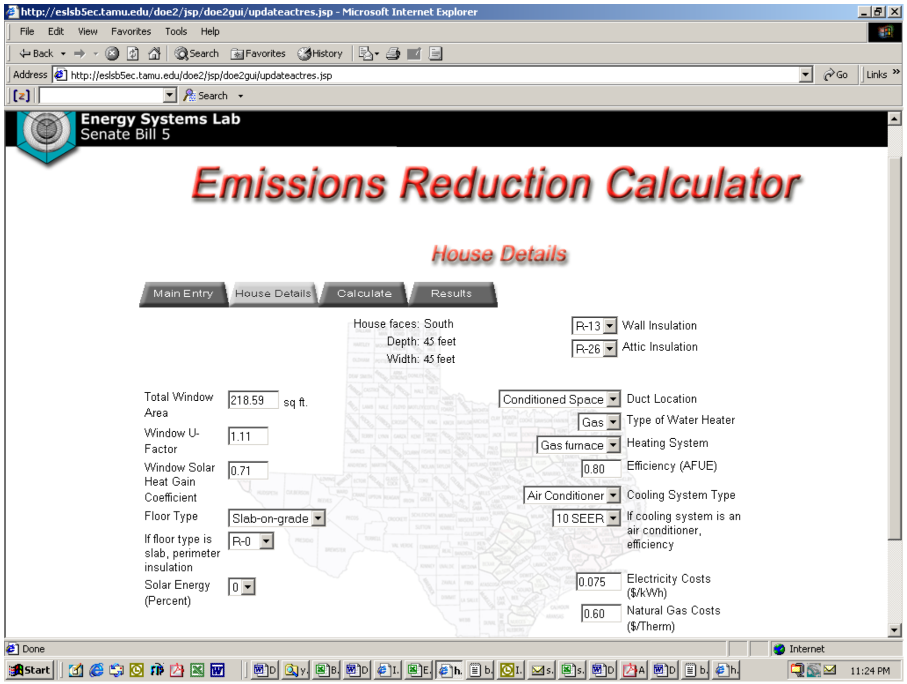


Figure E-1: Input of Prototype Single-Family Detached House.

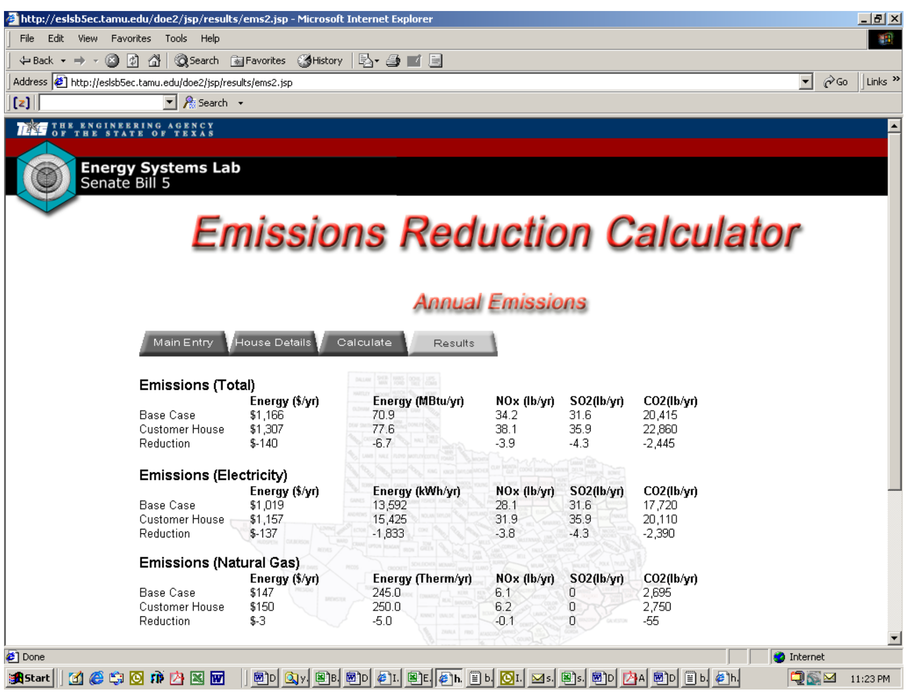
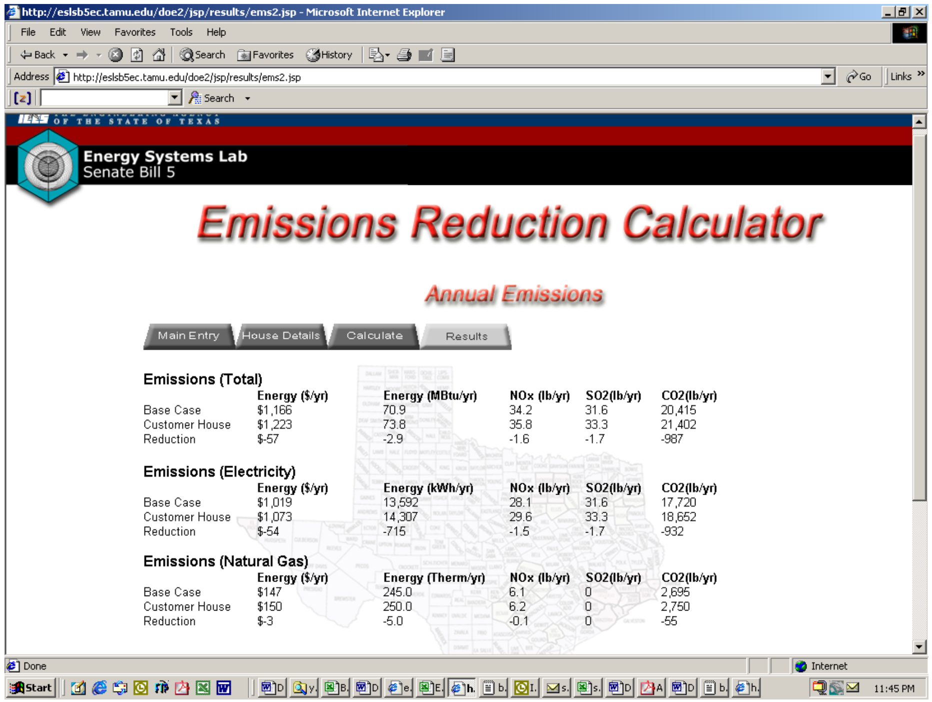


Figure E-2: Output of Prototype Single-Family Detached Housing (SEER 10).



Energy Systems Lab
Senate Bill 5

Emissions Reduction Calculator

Annual Emissions

Main Entry | House Details | Calculate | Results

Emissions (Total)

	Energy ($/yr)	Energy (MBtu/yr)	NOx (lb/yr)	SO2(lb/yr)	CO2(lb/yr)
Base Case	$1,166	70.9	34.2	31.6	20,415
Customer House	$1,223	73.8	35.8	33.3	21,402
Reduction	$-57	-2.9	-1.6	-1.7	-987

Emissions (Electricity)

	Energy ($/yr)	Energy (kWh/yr)	NOx (lb/yr)	SO2(lb/yr)	CO2(lb/yr)
Base Case	$1,019	13,592	28.1	31.6	17,720
Customer House	$1,073	14,307	29.6	33.3	18,652
Reduction	$-54	-715	-1.5	-1.7	-932

Emissions (Natural Gas)

	Energy ($/yr)	Energy (Therm/yr)	NOx (lb/yr)	SO2(lb/yr)	CO2(lb/yr)
Base Case	$147	245.0	6.1	0	2,695
Customer House	$150	250.0	6.2	0	2,750
Reduction	$-3	-5.0	-0.1	0	-55

Figure E-3: Output of Adopting SEER 12 in Single-Family Detached Housing Unit.

VITA

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