# COMPREHENSIVE COMMUNITY $NO_X$ EMISSION REDUCTION METHODOLOGY: OVERVIEW AND RESULTS FROM THE APPLICATION TO A CASE STUDY COMMUNITY

Yong Hoon Sung[1], Jeff Haberl[2]
[1] Research Assistant, Department of Architecture, Energy Systems Laboratory
[2] Professor, Department of Architecture, Energy Systems Laboratory
Texas A&M University, College Station, Texas

## ABSTRACT

This paper reports on the development of a methodology to estimate energy use in a community and its associated effects on air pollution. This methodology would allow decisionmakers to predict the impacts of various energy conservation options and efficiency programs on air pollution reduction, which will help local government and their residents understand how to reduce pollution and manage the information collection needed to accomplish this. This paper presents a broad overview of a community-wide energy use and NOx emissions inventory process and discusses detailed procedures used to calculate the residential sector's energy use and its associated NOx emissions. 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 to demonstrate the application of this methodology.

## INTRODUCTION

Although the United States Environmental Protection Agency (EPA) has established national, state and regional levels of guidance in controlling emission of pollution, limited methods exists that describe how to identify and select cost-effective options for a local community to reduce the air 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. 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 methodology, which is called the Comprehensive Community NOx Emissions Reduction Toolkit (CCNERT). The proposed methodology or toolkit could have a substantial impact on reducing NOx emission by providing decision-makers with a better understanding about the impacts of various energy efficiency programs on emissions reductions (Sung 2004).

## LITERATURE REVIEW

In 1981 the Comprehensive Community Energy Management Planning (CCEMP), developed by Hittman & Associates Inc. (1978), was used to develop a plan 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. From the CCEMP methodology, it was shown that community-wide energy planning is an integration of several approaches, which serves as a basis for the current work (Haberl and Dow 1979).

Tabb and Kreider produced a prototype sustainable community design for a community in southern Japan (Sung 2004). According to Tabb and Kreider, 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 by Tabb and Kreider, their study demonstrated that integrated energy efficiency measures could save significant energy savings and reduce emissions when the the most suitable energy efficiency measures are identified for a given community.

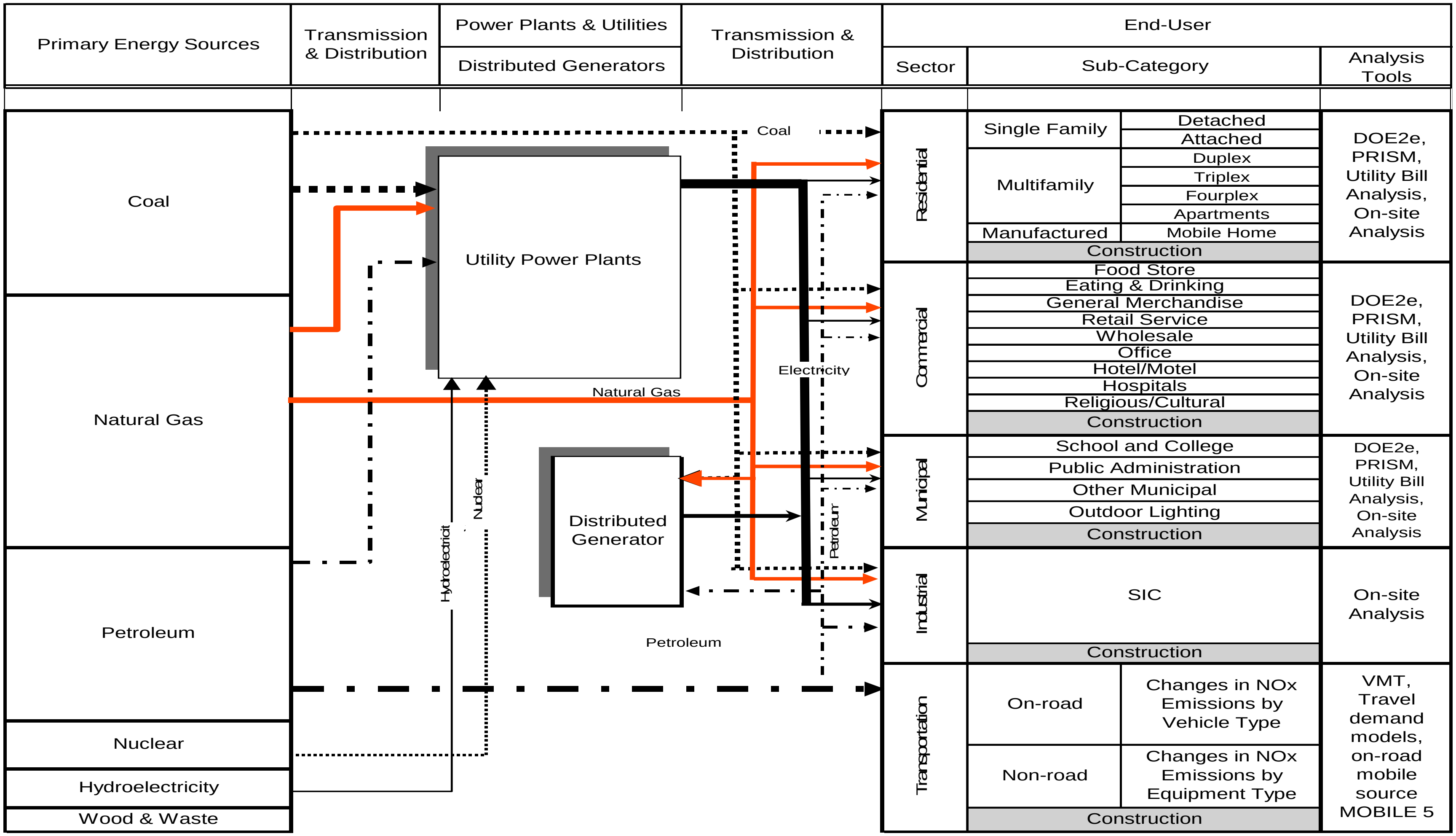



*Figure 1: Simplified diagram of community energy characteristics.*

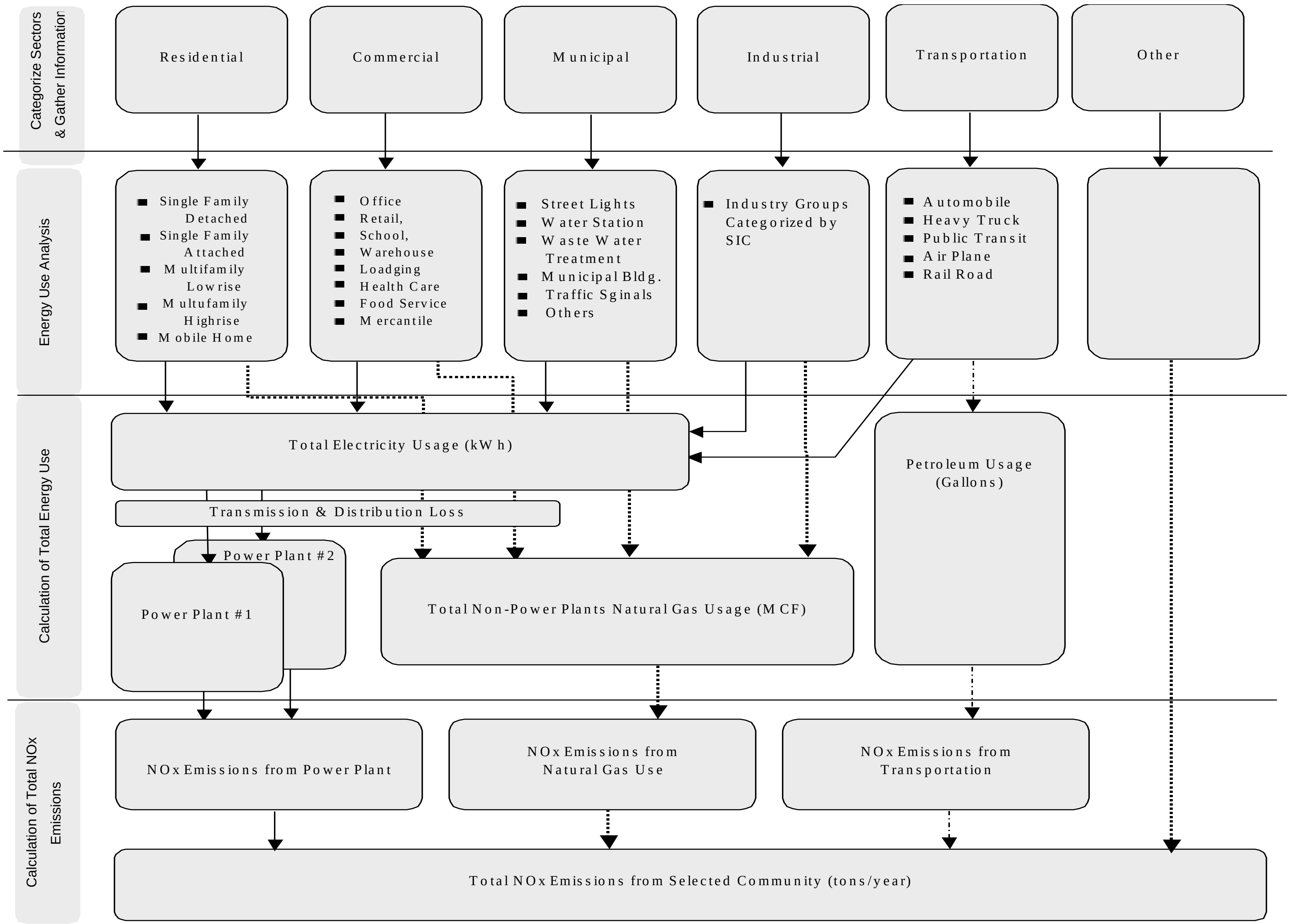



*Figure 2: General diagram of procedures for calculating community-wide energy use and its associated NOx emissions.*

## GENERAL METHODOLOGY

The goal of this work is to create a methodology that is a reasonably accurate end-use model of 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. In general, community energy characteristics can be organized into three main categories: 1) primary energy sources, 2) energy conversion processes, and 3) the demand-side energy use (end-users), as shown in Figure 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 1. Each of these sectors is further subdivided into numerous sub-sectors. From the emissions point of view, a community has two major types of NOx emissions related to buildings: 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). 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 to collect, 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 in a common set of units.

The methodology used in this study consists of a general framework that builds on the previous CCEMP efforts (Hittman & Associates, Inc. 1978) and includes more recent procedures developed by the Energy Systems Laboratory for the Texas Emission Reduction Plan (TERP) (Haberl et al. 2003). Therefore, this study has modified the CCEMP methodology to estimate NOx emissions reductions for a whole community (Sung 2004).

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.

Figure 2 presents an overview of the procedures used for calculating community-wide energy usage and its associated NOx emissions. This procedure consists of four main tasks:

1) the selection 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 have been similarly applied to estimate each sector's base-line energy consumption and its associated NOx emissions. This paper will describe the procedure developed for the residential sector. Detailed descriptions of the procedures for the other sectors can be found in Sung (2004).

## PROCEDURES FOR THE RESIDENTIAL SECTOR'S ENERGY USE ANALYSIS

The procedures developed to estimate the residential sector's energy use consist of several sub-tasks. These tasks include:

1) Identification of information related to the general characteristics of the residential sector from a Community Information System (CIS),

2) The selection of a sample of houses that are representative of the housing stock,

3) The collection of utility bills from the selected houses to provide a Normalized Annual Consumption (NAC) using ASHRAE's Inverse Model Toolkit - IMT (Kissock et al. 2001),

4) The development or selection of a representative house based on the procedures for the simulation of code-traceable and average housing used in the Texas Emissions Reduction Plan (TERP) (Haberl et al. 2003),

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 several sample houses,

7) Translating the results obtained from the utility bill analysis and energy simulation for the sampled 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.

## APPLICATION OF METHODOLOGY

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 study. The city is classified as an "Other Central City Suburban" community type or "mid-size community" according to Bryan College Station Economic Development Cooperation (BCSEDC 2001). The community is also the home of Texas A&M University. However, the university's energy use was not included in this study.

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 (i.e., students, faculty, and staff). The community consists of 40 square miles with a population of 64,743 in the year 2000, which converts to a density of 259 people per square mile – more than three times the average Texas population density of 79.6 persons per square mile.

Table 1 shows that College Station's housing stock mainly consisted of single-family detached houses and various multi-family housing sub-types. The existing housing stock was primarily designed to support the university's large off-campus housing needs. In 2002 there were a total of 28,268 housing units in College Station, of these, 35.5% (10,023 units) were single-family detached, 5.8% (1,650 units) were single-family attached, and 57.0% (16,126 units) were multi-family. Energy use characteristics in each parcel were determined by collecting information from sample housing units and other existing sources of information, including county tax records, etc.

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. College Station's historical land use development was also reviewed to determine what area best represents all areas of the residential housing stock. A total of 65 sample single-family detached (SFD) houses were selected randomly from the four different areas (A, B, C, and D) to determine the general housing characteristics for College Station.

*Table 1: The estimated number of housing units.*

| **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% |

*Source: COCS (2003a,b).*

The average conditioned floor area of a single-family detached housing unit was determined using:

1) the distribution of year built (%);

2) the number of units based on the year built; and

3) the average floor area (sq.ft) based on the sample houses. The results of this analysis are shown in Table 2. From this analysis, the average conditioned floor area of a single-family detached housing unit was determined to be approximately 1,960 ft2.

Table 3 describes the annual average electricity consumption for sample houses based on the year constructed and house size. The annual electricity consumption for Area A ranged from 7,503 kWh to 18,923 kWh. The annual average electricity consumption for Area A was approximately 12,172 kWh, which is an electricity use intensity of approximately 11.3 kWh per square foot of conditioned area. The annual electricity consumption for Area B ranged from 9,328 kWh to 24,931 kWh, which is an annual average electricity consumption of approximately 15,648 kWh, yielding an electricity use intensity of 9.3 kWh per square foot of conditioned area.

The annual electricity consumption for Area C ranges from 7,784 kWh to 30,304 kWh, which is an annual average electricity consumption of approximately 19,142 kWh, yielding an electricity use intensity of 7.6 kWh per square foot of conditioned area. The

*Table 2: Summary of single-family detached housing units in College Station, TX.*

| 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 |

annual electricity consumption for Area D ranges from 7,751 kWh to 17,603 kWh, which is an annual average electricity consumption of 12,607 kWh, and an electricity use intensity of 5.7 kWh per square foot of conditioned area. Houses in the old housing stock (Area A) use the most electricity per unit of square foot among the four areas. High electricity use intensity appears to be due to inefficient HVAC systems, lower R-values in ceiling, wall, and roof material, and ductwork in the attic. In contrast to the older housing stock, the newer housing stock has lower electricity use intensity.

*Table 3: Summary of electricity use profile in four areas (A ,B, C, and D).*

| Area | Number of Sample House | Average Floor Area (square ft.) | Average Annual Electric Consumption (kWh/yr) | Average EUI (kWh/sq.ft/yr) |
|---|---|---|---|---|
| Area A | 15 | 1,123 | 12,532 | 12.8 |
| Area B | 15 | 1,782 | 15,648 | 9.3 |
| Area C | 20 | 2,488 | 19,142 | 7.6 |
| Area D | 15 | 2,242 | 12,607 | 5.7 |
| Average | | | 14,937 | 8.4 |

The weather-dependent characteristics of electricity consumption for 65 SFD houses in the sample were determined using the ASHRAE IMT analysis (Kissock et al. 2001) to evaluate the relationship between energy consumption and outdoor temperature. The characteristics were identified using a 3-Parameter change-point (3PC) model that provides the values for the cooling dependency (RS), base load (Ycp), and cooling balance temperature (Xcp) varied for those sample houses. The aggregate electricity consumption of the single-family detached (SFD) houses in College Station was then calculated from the coefficients as follows:

$$kWh/day = 26.2 + 2.9 \ x \ \max (Tavg - 67.8)^{+}$$

Additional details concerning the multiple steps in the procedure can be found in Sung (2004).

*Table 4: Aggregated NAC coefficients of SFD in CS, TX.*

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

The energy consumption of single-family attached (SFA) houses was determined by using the annual energy consumption (kWh/house/year) described by a previous study Sung (2004). This previous study provided descriptive statistics of energy consumption over normalized year for 140 sample duplex residences in College Station. 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 2,117 and 2,122 kWh respectively. The base-load consumption was 10,886 kWh/year. Based on previous study, the total energy use of the SFA houses was determined by applying current number of housing units (1,650).

The annual energy use for SFA houses was approximately 24 million kWh. 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. The CSUCS representatives provided the total number of complex and the number of units as well as annual energy consumption. The annual energy consumption per house was approximately 10,031 kWh. Based on this information, the total energy use of the MF houses was determined by applying current number of housing units (16,216). The annual energy use for MF houses was approximately

162,662,696 kWh. The annual energy use for mobile homes (MH) was approximately 6 million kWh.

Using these procedures the 2002 energy consumption for the residential sector was calculated to be 1,636,000 MMBtu/year, as shown in Table 6. The total energy consumption values are represented as electricity (1,169,300 MMBtu/year) and natural gas (466,700 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 units accounted for negligible energy use, as shown in Figure 3.

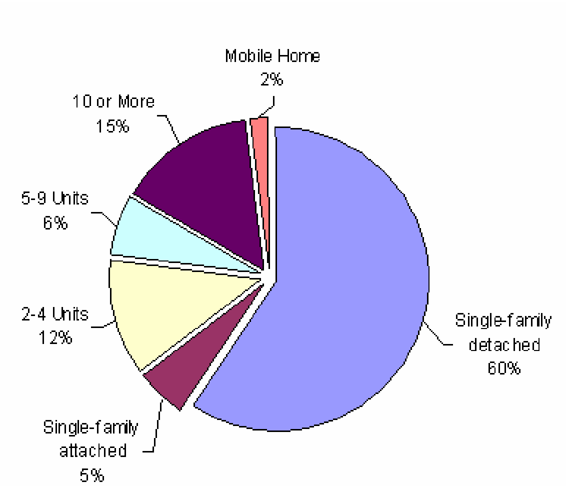



*Figure 3: Distribution of annual energy use by housing type in College Station, TX.*

**Comparison of results of IMT 3PC analysis to the total residential sector electricity use**

In order to demonstrate a procedure to check the accuracy of the calculations for a single-family household a comparison of the estimated energy use was performed against data collected from an actual residence. The objective of this task was to determine if the estimated consumption was reasonably close to the actual energy use for a typical house. To accomplish this, the daily electricity use of a single-family house was first estimated based on two variables: the NAC and the daily average temperature.

Figure 4 shows the comparison of the actual daily use of a residence versus the estimated amount for an average household that was used to represent the total residential sector. This figure indicates that the actual daily energy use is relatively close to the estimate based on the weighted-average NAC from the sample houses.

At the aggregate level (not shown) the differences are larger in both the cooling and heating seasons (Sung 2004). In the aggregate analysis, two observations can be made. The first is that the total residential electricity used in the heating season is mainly dominated by multi-family house's heating load. In College Station, the predominate single-family heating fuel source is natural gas, while multi-family units used electricity for heating. The second is that the SFD energy use in cooling season is relatively larger than that of multi-family housing units due to the larger size of the air conditioning units (larger conditioned areas).

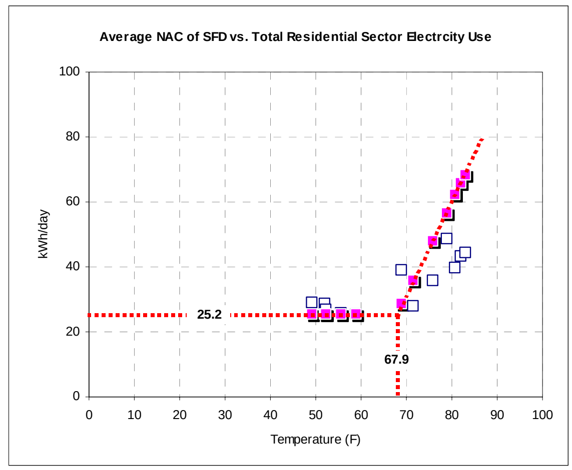



*Figure 4: Actual daily use for the total residential sector (unfilled squares) vs. the estimated daily use for the SFD house parcel (dashed line & filled squares).*

**Calculation of NOx emisions from the residential sector's energy use.**

To calculate NOx emissions from College Station's total residential sector energy use, the total energy use was first categorized by energy (fuel) type (i.e., electricity and natural gas). The NOx emissions factors (lb-NOx/kWh or lb-NOx/MMBtu) were then determined according to various information sources.

The information sources include:

1) The EPA's eGRID table, which was used to determine NOx rate (lb-NOx/kWh) from electricity use (EPA 2003), and

2) The EPA's AP-42, which was used to determine NOx rate (lb-NOx/MMBtu) from natural gas use EPA 1995). In the case of calculating NOx emissions from the electricity use, the transmission and distribution loss (10%) was also added to previously developed total electricity

use. The NOx emissions procedures developed by Haberl et al. (2003) were used in this study.

The estimated total NOx emissions for the residential sector in College Station were calculated by applying the appropriate emission factors based on the different fuel types. Figure 5 values represent the estimated NOx emissions during the year 2002. Much of the NOx emissions' characterization in terms of its distribution is similar to that of overall energy consumption. The 2002 baseline NOx emissions for the residential sector in College Station were 577 tons per year, which represent single-family detached (263 tons), single-family attached (40 tons), multi-family 2-4 units (97 tons), multi-family 5-9 units (50 tons), multi-family 10 or more units (115 tons), and mobile homes (11 tons).

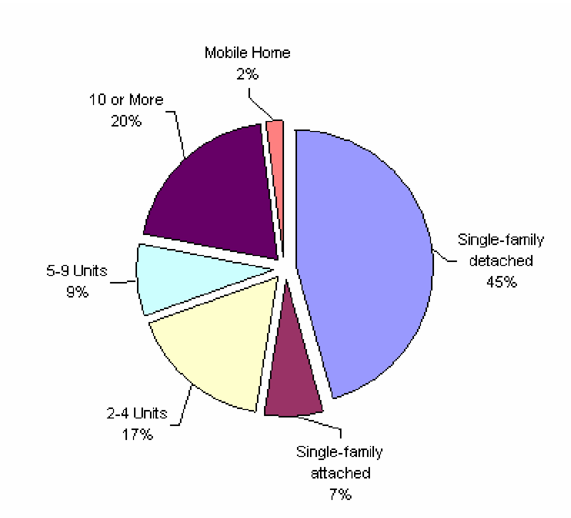



*Figure 5: Distribution of annual NOx emissions by housing type in College Station, TX.*

## Adoption of energy efficiency measures in residential sector

By analyzing the residential sector's baseline energy use, three energy efficiency measures were identified and then proposed in College Station in order to reduce energy consumption, and the resultant NOx emissions. These three scenarios included:

1) the replacement of incandescent lamps with compact fluorescent lamps,
2) the replacement of lower SEER AC units with higher SEER AC units (10 SEER vs 12 SEER), and
3) the elimination of pilot lights in gas furnaces and domestic hot water heaters.

The DOE-2 simulation program was used to calculate the energy savings and its associated NOx emissions reductions for this study. To create savings calculations, two tasks were performed. First, the base-case model of prototype house in a selected community was first determined based on the general housing charcatersitcs from the sample houses (Haberl 2004). Table 5 and Figure 6 summarize the characteristics of the prototype house. Next, the energy efficiency measures were then applied. Finally, the results from the previous two tasks were then compared both between and within the cases.

*Table 5: Summaries of prototype housing characteristics.*

| Input Data Description | Base case |
|---|---|
| Conditioned Area | 2,025 ft2 |
| Wall Height | 8.0 ft |
| Window Area | 219 ft2 |
| Foundation | Slab on Grade |
| Wall Insulation | R-value = 13 |
| Attic Insulation | R-value = 26 |
| Window U-Factor | 1.11 Btu/hr-F-ft2 |
| Solar Heat Gain Coefficient (SHGC) | 0.714 % |
| 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 |

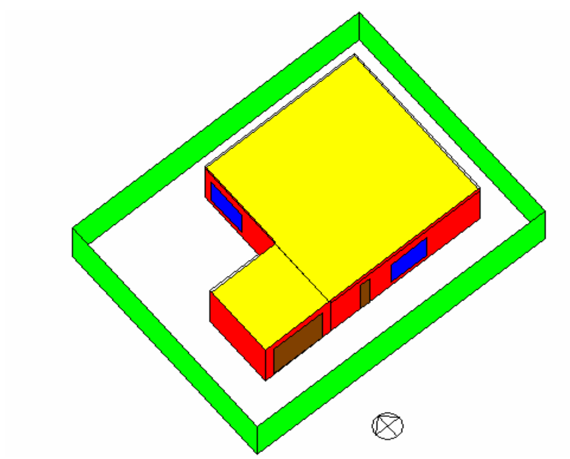


*Figure 6: Architectural rendering of prototypical DOE-2 single-family detached house simulation in College Station, TX.*

## Calculation of energy savings and its NOx emissions reduction

College Station's 2002 total energy use and NOx emissions estimated using the CCNERT methodology is 6.8 million MMBtu and 2,030 tons-NOx. The energy consumption values include residential (1.6 million MMBtu), commercial (1.3 million MMBtu), municipal (0.13 million MMBtu), and transportation (3.8 million MMBtu). The NOx emissions values were calculated to be: residential (586 tons), commercial (432 tons), municipal (58 tons), and transportation (953 tons). Figures 7 and 8 show the distributions of total annual energy use and NOx emissions by sectors.

The projected annual energy savings for each scenario are summarized in Figure 9 for an individual house and in Figure 6 for the community. The first scenario (i.e., CFL) projected a 39.6 million kWh savings in all residential sectors - equivalent to a 12% reduction in the total residential sector electricity use, a 6.4% reduction of total community's electricity consumption and 2.1% of total community energy use. From this electricity savings a total of 63.2 tons of NOx emissions could be reduced annually - equivalent of a 3.3% reduction in community-wide NOx emissions reductions. However, the natural gas consumption actually increased (7% of total natural gas) due to internal heat gain reduction, which required more heating loads during the heating season.

The second scenario (high SEER A/C) projected a 24 million kWh annual savings, and 38.3 tons of NOx emissions reductions. This value represents about 7.25% of the total residential sector's electricity savings and about 1.2% of total energy savings. The third scenario (eliminate all pilot lights) projected approximately 89,049 MMBtu 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 energy use. The projected annual NOx emissions reductions from the elimination of pilot lights is 5 tons. 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 then evaluated in terms of energy savings and NOx emissions reductions. The projected annual energy savings and NOx emissions are summarized in the right side of Table 6. As compared to the individual scenarios, the combination of the four scenarios projected 346,400 MMBtu in annual energy savings, which represented approximately 21% of the total residential sector energy use, 5.4% reductions in the total community's energy use. The projected annual NOx emissions reductions were 134 tons per year, which represented approximately 6.6% in community wide NOx emissions reductions. and results presented for the community's energy use and resultant NOx emissions. Detailed descriptions of the procedures for the other sectors can be found in Sung (2004).

## CONCLUSION

This paper presents a broad overview of a community-wide energy use and NOx emissions inventory process called the Comprehensive Community NOx Emissions Reduction Toolkit (CCNERT). It has also discussed selected aspects of the detailed procedures, which were developed to estimate a community's residential sector energy use with limited information. An example of the CCNERT methodology was applied to a case study community, and the results presented.

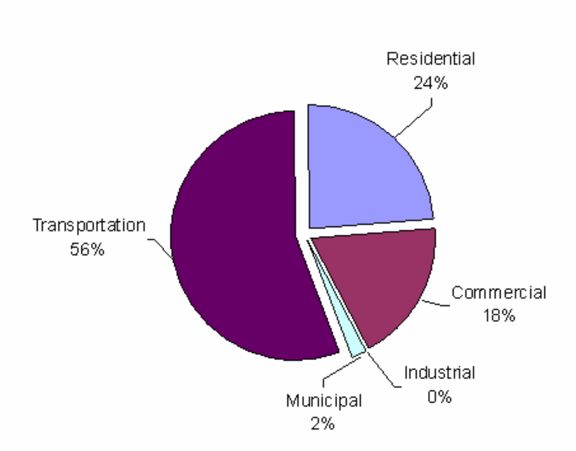



*Figure 7: Distribution of total annual energy use by sectors in College Station, TX.*

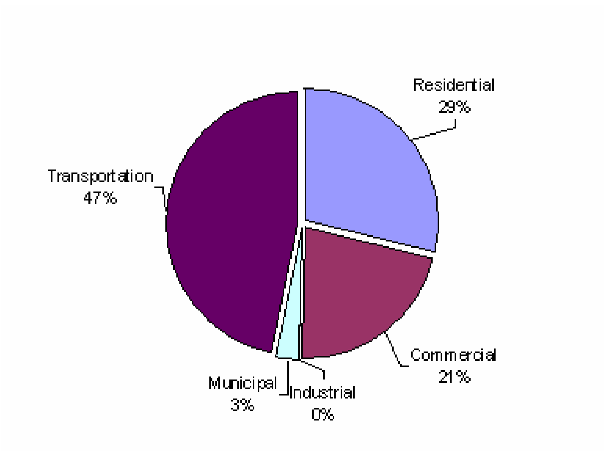
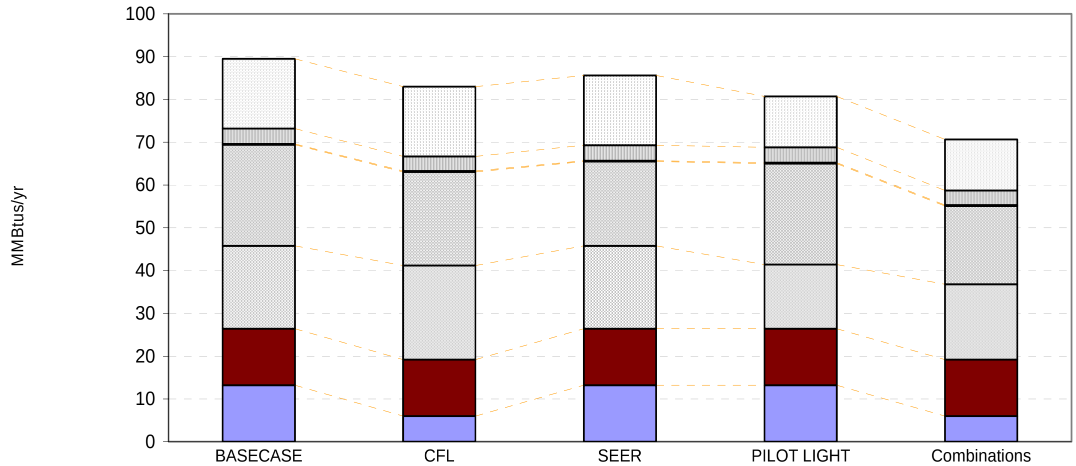



*Figure 8: Distribution of total annual NOx emissions by sectors in College Station, TX.*

**Comparison of Individual Energy Efficient Measure in Single-Family Detached Housing Unit**




| | BASECASE | CFL | SEER | PILOT LIGHT | Combinations |
|---|---|---|---|---|---|
| DOMHOT WATER | 16.3 | 16.3 | 16.3 | 11.92 | 11.92 |
| VENT FANS | 3.6 | 3.4 | 3.6 | 3.6 | 3.4 |
| PUMPS & MISC | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| SPACE COOL | 23.6 | 21.9 | 19.7 | 23.6 | 18.3 |
| SPACE HEAT | 19.4 | 22 | 19.4 | 15.02 | 17.62 |
| MISC EQUIPMT | 13.2 | 13.2 | 13.2 | 13.2 | 13.2 |
| AREA LIGHTS | 13.2 | 6 | 13.2 | 13.2 | 6 |
| Natural Gas Savings (%) | | -7% | 0% | 25% | 17% |
| Electricity Savings (%) | | 17% | 7% | 0% | 24% |
| Total Savings (%) | | 7% | 4% | 10% | 21% |

*Figure 9: Comparison of individual scenario and combination of three scenarios in the prototype house.*

*Table 6: Summary Table of Energy savings and its associated NOx emissions reductions.*

| **Housing Unit Type** | | **Base Case** | | **CFL** | | **SEER** | | **Pilot light** | | **Combinations** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Electricity Use (MWh)** | **Natural Gas Use (MMBtu)** | **Electricity Use (MWh)** | **Natural Gas Use (MMBtu)** | **Electricity Use (MWh)** | **Natural Gas Use (MMBtu)** | **Electricity Use (MWh)** | **Natural Gas Use (MMBtu)** | **Electricity Use (MWh)** | **Natural Gas Use (MMBtu)** |
| **Single Family Housing** | **Single-family detached** | 149,715 | 443,700 | 124,264 | 474,800 | 139,235 | 443,700 | 149,715 | 332,800 | 113,784 | 379,300 |
| | **Single-family attached** | 24,774 | - | 23,040 | - | 23,040 | - | 24,774 | - | 18,829 | - |
| **Multi-Family Housing** | **2-4 Units** | 59,845 | - | 55,656 | - | 55,656 | - | 59,845 | - | 45,482 | - |
| | **5-9 Units** | 30,725 | - | 28,574 | - | 28,574 | - | 30,725 | - | 23,351 | - |
| | **10 or More** | 71,170 | - | 66,188 | - | 66,188 | - | 71,170 | - | 54,089 | - |
| **Manufactured Home** | **Mobile Home** | 6,475 | 9,400 | 5,374 | 10,000 | 6,022 | 9,400 | 6,475 | 7,000 | 4,921 | 8,000 |
| **Residential Total** | | 342,705 | 453,100 | 303,096 | 484,800 | 318,715 | 453,100 | 342,705 | 339,900 | 260,456 | 387,400 |
| **Savings** | | - | - | 39,608 | (31,700) | 23,989 | - | - | 113,300 | 82,249 | 65,800 |
| **Savings (%)** | | | | 12% | -7% | 7% | 0% | 0% | 25% | 24% | 15% |
| **T&D Loss** | | | | 43,569 | | 26,388 | | - | | 90,474 | |
| **NOx Emissions Reduction (tons)** | | | | 63.2 | (1.4) | 38.3 | - | - | 5.1 | 131.2 | 3.0 |

## REFERENCES


BCSEDC 2001. Fact Book for Bryan-College Station, Bryan-College Station Economic Development Cooperation (BCSEDC). 2001. TX. January

COCS 2003a. Building Permit Report (NOTE: The number of building permit of 2001 and 2002 was obtained from the COCS website), City of College Station, College Station, Texas (COCS).

COCS 2003b. College Station Demographic Report: Embracing the Past, Exploring the Future, City of College Station (COCS), College Station, Texas.

EPA 1995. Compilation of Air Pollutant Emission Factors, AP-42. Volume I: Stationary Point and Area Source. Fifth Edition. U.S. Environmental Protection Agency (EPA).

EPA 2003. Users Manual Emissions & Generation Resource Integrated Resource (eGRID). Prepared by E.H. Pechan & Associates, Inc. U.S. Environmental Protection Agency (EPA).

Haberl, J., Dow, J. 1979. "Application of the Hittman methodology", Energy Auditing, Association of Energy Engineers, Association of Energy Engineers, Atlanta, GA.

Haberl, J. S. and C. Culp, B. Yazdani, T. Fitzpatrick, J. Bryant, and D. Turner. 2003. Energy Efficiency/Renewable Energy Impact in the Texas Emissions Reduction Plan (TERP): Volume II-Technical Report. ESL-TR-03/12-04. College Station, TX.

Haberl, J., Im, P., Culp, C. 2004. “Methodology to Calculate NOx Emissions Reductions From Implementation of the 2000 IECC/IRC Conservation Code in Texas”, Proceedings of the Fourteenth Symposium on Improving Building Systems in Hot and Humid Climates, Texas A&M University, Richardson, Texas, accepted for publication (Feb.), pp. 113-125.

Hittman and Associates, Inc. 1978. Comprehensive Community Energy Planning. Final Report HIT-703-3 Prepared under U.S. Department of Energy. Hittman Associates, INC. Columbia, MD.

Kissock, K., Haberl, J., and D. Claridge. 2001. Development of a toolkit for calculating linear, change-point linear and multiple-linear inverse building energy analysis models: Final report for ASHRAE research project 1050-RP, Energy Systems Laboratory, Texas A&M University, College Station, TX.

Sung, Y. 2004. Development of a comprehensive Community NOx Emissions Reduction Tool Kit (CCNERT). Ph D’s Thesis, Department of Architecture, Texas A&M University, in preparation (August).