COMPREHENSIVE C/I NEW CONSTRUCTION EVALUATION USING DOE MODELING

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Program Overview

This paper presents the results of the evaluation of Northeast Utilities' (NU) **Comprehensive (Design Support) Area** of the **Energy Conscious Construction (ECC) Program** (referred to below as the ECC Comprehensive Area). The ECC Comprehensive Area program is, as the name suggests, NU's most comprehensive program directed at the nonresidential new construction market. The program focuses on larger facilities, i.e., greater than 50,000 square feet, grocery stores with built-up refrigeration systems, chain stores with high electric consumption patterns, air conditioned schools and selected nonresidential buildings between 15,000 and 50,000 square feet. Industrial facilities are also eligible to participate, but incentives are not paid for efficiency improvements in process equipment.

The ECC Comprehensive Area uses a team approach, in which NU staff works directly with owners, developers, architects, and engineers. ECC provides energy information and technical support to the building owner's design team, and financial incentives to cover all or part of the incremental costs of designing and building to more stringent energy efficiency levels. Design support services, especially brainstorming efficiency improvements and model building performance[1], are unique to the ECC Comprehensive Area.

Program Population Demographics

This report summarizes the evaluation work completed during 1995/96 to quantify the demand and net annual energy impacts of measures installed in 1994 as part of the *ECC Comprehensive Area*. During 1994, a total of 56 ECC projects were completed accounting for 31,251 MWh of annual energy savings.

Figure 1 presents a Disaggregation of the 1994 ECC Comprehensive Area energy savings by end-use. In 1994 Other-Refrigeration measures dominated, accounting for over 59% of the total annual energy savings. Next, Lighting measures accounted for just under 32% and Cooling measures accounted for the remaining 9% of total annual energy savings. In 1994, no Heating measures were installed. The large portion of Non-lighting savings, 68% of total savings, is a strong indication of the comprehensive nature of the program. The savings end uses are determined by the end use channels reported by DOE 2 and are sometimes counterintuitive. The end use channels will separate electric cooling from ventilation fans and pumps, which means that a Variable Air Volume HVAC systems would be classified as an Other-Refrigeration measure. The majority of the savings associated with a VAV system are attributable to fan savings which are associated with the delivery of conditioned air. In order to qualify as a Cooling measure the savings would have to be associated with cooling system compressor or condenser work. The installation of energy efficient case lighting would also be classified as Other-Refrigeration savings and not Lighting savings because the majority of the savings are due to a decrease in excess heat in the cases.

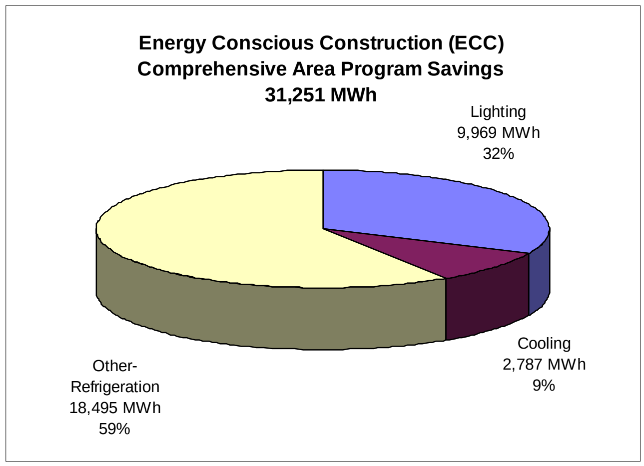

Figure 1 - 1994 Estimated Energy Savings

Table 1 illustrates the distribution of savings across market segments. Although market segment was not utilized as a sector variable for this analysis, it is interesting to note that 66% of the program savings are attributable to the Grocery market segment. The 20,744 MWh of savings includes 9,000 MWh of savings for a refrigerated warehouse that supplies merchandise to many of the grocery stores in the sample.

[1] Interactive hourly software, most frequently DOE-2 version 2.1C, was used on projects in the 1994 program population.

Market Segment	Number of Projects	Tracking Savings (kWh)	Percent of Total Savings
Education	4	319,123	1%
Government	7	1,313,987	4%
Grocery	14	20,744,182	66%
Health	5	639,237	2%
Misc Commercial	9	4,160,425	13%
Misc Manufacturing	5	795,796	3%
Office	9	2,204,698	7%
Retail	2	479,084	2%
Utility	1	594,706	2%
Totals	56	31,251,238	100%

Table 1 - Program Savings by Market Segment

Sample Design

The sample design was instituted with reporting requirements that lead to 100% sampling for one of the service territories and also for the five Industrial customers in the other service territory. The Commercial customers for the remaining service territory were stratified and a representative sample was selected. The sample consisted of 27 of the 56 projects or approximately 47% of the population. DOE resimulations were run for 14 of the 27 sample projects sites or approximately 52% of the sample. Table 2 illustrates the results of the hybrid sample design that was utilized for this evaluation. Note that 74% of the Total program savings was contained within the sample and that 66% of the Total savings were evaluated using DOE 2. The Other-Refrigeration savings had the highest level of representation in both the sample and DOE resimulation at 80% and 79% respectively. This was due to the complex nature of the measures contained within this end use, which required the use of a sophisticated analysis tool to accurately evaluate savings. The low percentage of Cooling savings, 32%, that was resimulated was due to the fact that a large percentage of Cooling savings came from "H" sites which were essentially chiller replacement sites with no other installed measures. The "H" sites were not originally evaluated using DOE 2 and the amount of savings attributable to these sites did not warrant the additional effort necessary to create models for the current evaluation.

	Lighting Savings (MWh)	Cooling Savings (MWh)	Other Savings (MWh)	Total Savings (MWh)
Total Sample Savings	6,188	2,063	14,838	23,088
Total Program Savings	9,969	2,787	18,495	31,251
Percent Coverage Sample	**62%**	**74%**	**80%**	**74%**
DOE Resimulation Savings	5,009	904	14,686	20,598
Percent Coverage DOE	**50%**	**32%**	**79%**	**66%**

Table 2 - Sample Savings vs. Program Savings by End Use

Overview of the ECC Evaluation Approach

The impact evaluation began with the development of a sampling plan as previously presented. The next step involved conducting complete file/program documentation reviews on each participant for 1994. The file review was utilized to verify the accuracy of the tracking system, which was maintained at the end use level. In order to develop net and gross program savings a measure level Microsoft ACCESS database was created. The database was used to reconstruct the tracking system from the end use level down to the measure level and was also used to update the NU program savings estimates and assist in detailing and directing the field work. Next, individual measurement plans were developed and documented for each selected sample site. Using the measurement plans as a guide, in-field visits were conducted by the *RLW* Analytics, Inc. (*RLW*) and The Nicholas Group's (TNG) on-site engineering teams. The data gathered during these site visits were used to develop independent estimates of the savings associated with each project. The key elements of the evaluation process were the on-site data collection and the subsequent analysis of savings using either DOE resimulation or spreadsheet analysis.

Site Visits

The primary task of the on-site engineering assessments was to gather information on the actual "as-built" building characteristics, occupancy patterns, schedules, and building control strategies. These findings were used to develop independent "in-field" estimates of savings achieved by the specific Energy Efficient Measures (EEMs) examined at each site. The results of each analysis was an assessment of the actual EEMs installed and their operating characteristics compared to the ECC program's current tracking system estimate of savings. The on-site engineering assessments included a technical process survey that focused on obtaining new, independent information of the actual on-site conditions, identifying and isolating conditions that could affect the energy savings associated with measure installation, verification of the customer's baseline energy efficiency in the absence of the program and obtaining data on future plans as a means of normalizing the impact in future periods. During, or in conjunction with each site visit, personal interviews were conducted with the appropriate facility design decision-maker(s). These interviews were intended to provide detailed information necessary for developing revised gross and net estimates of annual energy (kWh) and peak demand (kW) savings.

One of the key strengths of the on-site engineering assessment approach was the use of in-field measurements to help determine the impacts of the specific EEMs. The techniques employed in the site assessments included standard auditing practices and time-of-use logger monitoring, along with short-term EEM monitoring using MicroData-Loggers.

The DOE-2.1 Re-Simulation Approach

The DOE-2.1 re-simulation and calibration approach is based on the understanding that each "as built" commercial building may have much different characteristics than the building initially modeled for the initial compliance review with "as designed" and "baseline" assumptions and conditions. For four of the WMECo projects, re-simulations were used to develop "improved" in-field engineering estimates of savings based on actual building data. These re-simulations used actual building characteristics and performance data to develop independent DOE-2.1E hourly simulations of each "as built" and "baseline" building's performance. These models were calibrated with monthly billing data; short-term metered data collected during the on-site assessment, and actual weather data.

Several national studies, as well as reports from Northeast Utilities' ECC Comprehensive Area Program, conclude that the re-simulation approach provides appropriate estimates of program savings for large buildings with complex weather dependent measures. Figure 2 illustrates the DOE-2.1 resimulation process that was used.

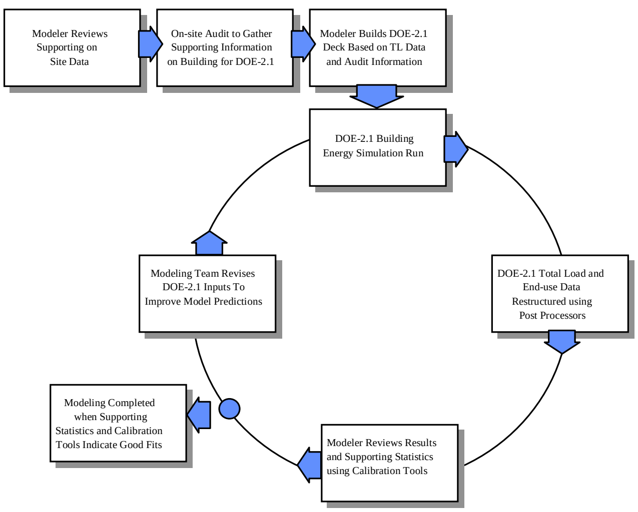

Figure 2 - Overview of Re-Simulation Approach

In this study, the steps in the re-simulation approach included:

Step 1. First, the "as-designed baseline" model was developed using the appropriate building code, program based standards/ASHRAE 90.1 standards for minimal compliance, as described in the project file, and in the initial DOE-2.1 compliance model for the project base-case. Building schedules and occupancy were set at initial program project design levels. These schedules were held constant rather than using the actual conditions found during the on-site survey. This model was run using DOE-2.1E rather than the earlier DOE-2.1C version.

Step 2. Next, DOE-2.1 input file for "as-built-baseline" building was developed using actual schedules and characteristics. This simulation can be thought of as the "tuned-up model." Depending on available information, this model can be based on earlier "as-designed" DOE-2.1 input files, or can be built from scratch, based on existing building input file libraries.

Step 3. The "as-built" model was calibrated using actual weather data for the site, monthly billing data, and any other metered data that were available.

Step 4. The calibrated "as-built" model was re-run using typical meteorological year (TMY) data for the appropriate weather station near the site, in this case, Hartford, CT. The DOE-2.1E output files from this calibrated and tuned up model were then used to define "actual" building performance, providing both annual and monthly energy, annual energy per square foot, and hourly peak demand estimates.

Step 5. Using information from the compliance models, site visits, and the Exhibit A contract for the facility, the "as-built" simulation file was then modified and expanded to reflect each incremental "actual installed" measure. Also, the "as-built" simulation file was enhanced with the actual building characteristics, equipment, building schedules and occupancy conditions gathered during the on-site.

Step 6. The "as-built" models for each incremental measure were run in the same order as the project was initially simulated, using TMY weather data.

Step 7. The gross program energy (kWh) impacts were computed by taking the difference between the "baseline" model results and the "as-built" model results. These impacts were computed at both the measure, and end-use levels and were developed on a monthly and annual basis.

Step 8. Gross program demand impacts were computed between the final "as-built" and "baseline" simulation levels. These estimates were developed for peak and average summer and winter days, using daytype definitions consistent with NU Load Research practice. Demand impacts were computed for each site using the difference between the "baseline" hourly profiles and the "as-built" hourly profiles.

Evaluation of Net Savings

Net program effects are determined by applying a net-to-gross factor to the gross effects developed in the previous section. The net-to-gross factor reflects the impact of free ridership. Participant spillover is accounted for in the gross savings estimates, i.e., if a facility is built more efficient than contracted, the higher efficiency is accounted for in the determination of the gross energy savings estimates. The key approach used in developing a free rider, net-to-gross factor is a survey instrument administered during the in-field visit or through an in-person/telephone interview with the developer, owner, or facility manager.

In the analysis, free ridership was determined by analyzing responses to a number of questions posed to the appropriate facility representatives of the various projects. The survey utilized senior researchers conducting in-person or telephone interviews. The surveys included additional members of the design team when necessary. The survey addressed the free ridership issue by approaching it from two different directions, financial and technical. The survey utilized a battery of questions targeted at determining the ECC Comprehensive Area program's impact on the financial decision made by these individuals relating to the installation of energy efficiency measures. The questions were weighted equally and financial free ridership could range from 0% to 100% for each individual measure.

The technical portion of the free ridership survey was designed to identify any necessary adjustments to the baseline assumptions used to calculate program savings. The difficulty in obtaining specific efficiency information i.e. the watts per ft^2 for a base lighting system was overcome by trying to identifying the standard technology utilized i.e. T8 lamps and Electronic Ballasts. If the base case technology was the same as the installed technology then the site was classified as a technical free rider and the baseline was set equal to installed measure efficiency and no net savings were reported for the measure. If the baseline efficiency was determined to be greater than the original baseline efficiency but less than the installed efficiency then the measure was classified as a partial technical free rider, and net savings would be determined after the appropriate adjustment to the baseline.

Participant Spillover

Participant spillover was accounted for during the course of the on site visits. If the facility included higher efficiency measures than contracted, these improvements were included in the calculation of gross energy and demand savings. Similarly, if energy efficiency measures were installed as part of the program process and no incentive was provided, the associated savings were included in the net calculation of energy and demand savings.

1994 Evaluation Results - NU System

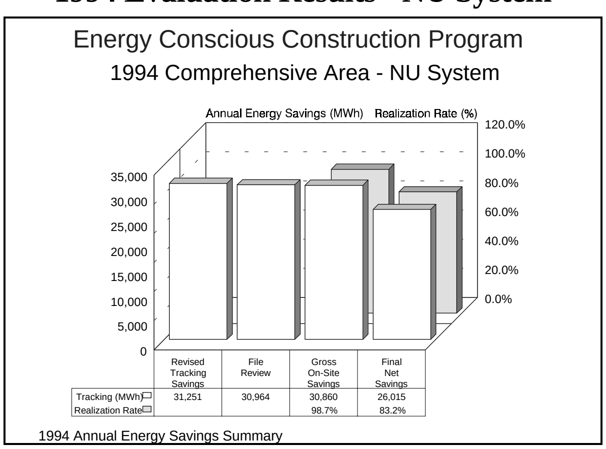

Figure 3 - Summary of Major Findings

Figure 3 presents a summary of the gross and net annual energy savings associated with 1994 measures installation. The figure displays the NU program estimate of savings, termed the revised tracking system estimate, the file review estimate, the gross on-site savings estimate and the final net savings estimate. Also, the figure displays the gross and net realization rates for the program. For the 1994 program year, the ECC Comprehensive Area program included fifty-six program participants with a total estimated energy savings of over 31,251 MWh. File reviews were conducted on the full population of program participants and resulted in a slight write down of tracking system savings to 30,964 MWh. Independent, on-site assessments were conducted on the full population of WMECo program participants with DOE 2.1E resimulations[2] conducted for four of the seven facilities. In addition, on-site assessments were conducted on a stratified sample of nineteen CL&P program participants with DOE 2.1E resimulations conducted for ten of the nineteen facilities. The total estimated annualized savings based on "as built/as occupied" conditions were determined to be approximately 30,860 MWh yielding a gross realization rate of 98.7%[3]. The overall statistical error associated with the 1994 gross savings was calculated to be ±7.5%. Based on the analysis of the participant survey, spillover and free rider adjustments were made to the gross savings estimate. A minimal participant spillover adjustment was made and the free ridership rate was calculated to be approximately 15.8%. Therefore, the net realization rate for 1994 measures is estimated at 83.2% yielding a net annual savings of approximately 26,015 MWh. The relative precision associated with the net savings estimate was calculated to be ±11.9%. This yields a 90% confidence interval for the realization rate from 73.3% to 93.1%.

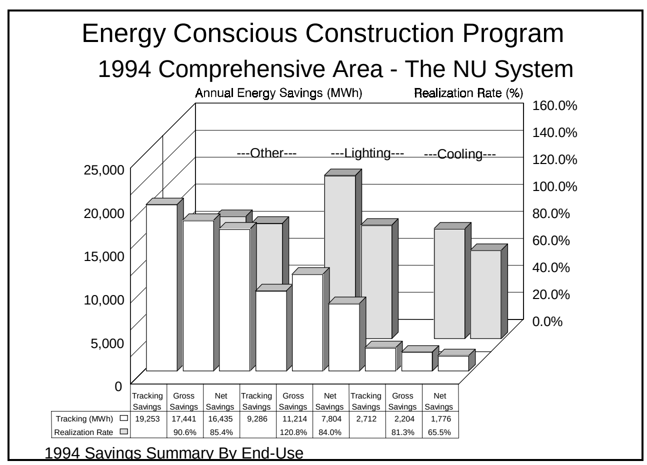

Figure 4 - Summary of Major Findings by End-Use

Figure 4 presents a summary of the major findings for the annual energy savings by end-use. The figure presents the revised tracking system estimate of savings, the gross estimate of annualized savings and the final net estimate of savings. Once again, the gross and net realization

[2] Department of Energy modeling software.

[3] The gross and net realization rates are provided for use in developing estimates in future program years.

rates are presented on the figure. The net realization rates by end-use are as follows:

- 85.4% Other-Refrigeration,
- 84.0%: Lighting, and
- 65.5%: Cooling.

Figure 5 presents a summary of the energy savings by C/I Class. Clearly, the vast majority of savings were in the commercial market. The commercial and industrial net realization rates were calculated to be 83.3% and 92.3%, respectively.

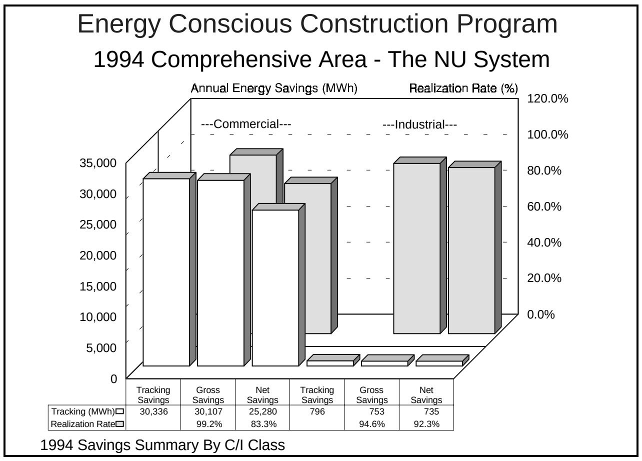

Figure 5 - Energy Savings by C/I Class

Figure 6 presents a summary of the winter peak and summer peak gross and net demand savings. The figure summarizes the peak demand reductions for the system and each service territory. The 1994 ECC Comprehensive Area program resulted in gross winter peak demand savings of approximately 3,028 kW and a net winter peak demand savings of 2,363 kW. For the summer peak, the program's gross demand savings are estimated to be 4,234 kW with a net savings of 3,331 kW.

Figure 7 presents a summary of the NU System winter peak and summer peak gross and net demand savings by end-use. Approximately 68% of the net winter peak demand savings were attained from Other-Refrigeration measures. Lighting accounted for nearly all of the remaining net demand reduction. For the net summer peak demand reduction, Other-Refrigeration measures accounted for 1,972 kW or 59% of the total demand reduction. The Lighting measures contributed 852 kW and the Cooling measures contributed 507 kW to the summer peak demand reduction.

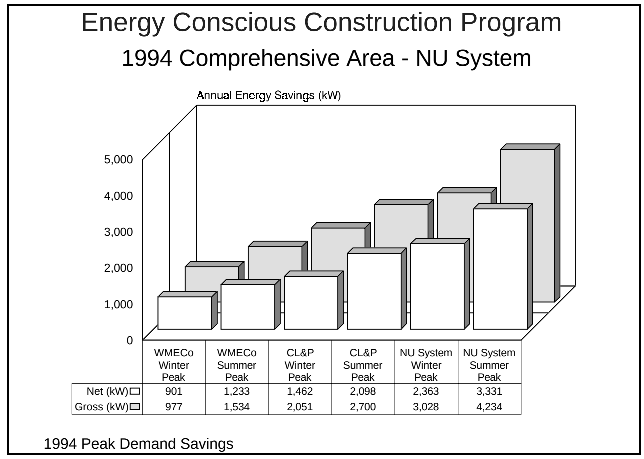

Figure 6 - Summary of Winter and Summer Peak Demand Savings

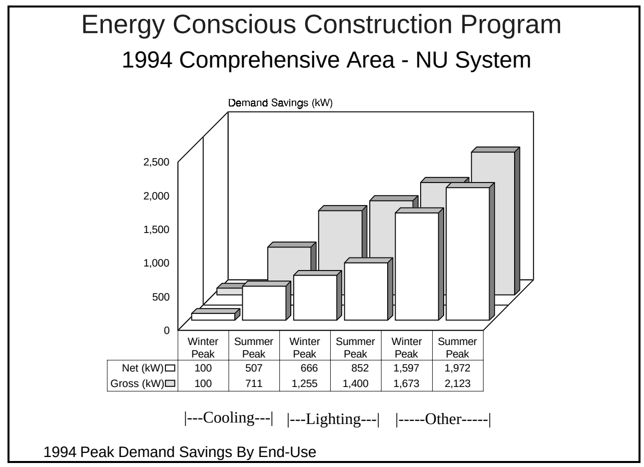

Figure 7- Summary of Peak Demand Savings by End-Use