FINAL REPORT

The Potential for Gas Energy Efficiency and the Economics of Gas Fuel-Switching for Space Conditioning in the Commercial Sector of the Niagara Mohawk Gas Service Territory

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10 March 1993

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Table of Contents

J. ETO - 10 March 1993

Executive Summary

The Amercian Council for an Energy Efficient Economy (ACEEE), with support from the New York State Energy Research and Development Authority and the New York Gas Group, has recently completed a major study of the potential for gas energy efficiency and fuel-switching in New York state (Nadel, et. al. 1992). This report describes the possible implications that the ACEEE study findings may have for NMGas.

The report was prepared by adapting ACEEE's analysis of the commercial sector of National Fuel Gas to reflect the conditions of NMGas. The adaptations consisted of relying on NMGas commercial forecast data on floorarea, fuel saturations, and EUI. In addition, NMGas future avoided gas costs were used to develop a range of future levelized avoided gas costs ($3.50/DTh and $5.00/DTh) with which to discuss our findings. Six commercial building prototypes (office, retail, hospital, supermarket, restaurant, and warehouse) were examined with a detailed hourly simulation model (DOE-2) to examine (for each building) 10 space heating, 7 water heating, and 5 cooking energy efficiency measures. The economics of 14 fuel-switching space heating and cooling technologies were also examined for these same six building prototypes.

Table EX-1 summarizes the economic potential for commercial sector gas energy efficiency measures for each of the perspectives and sensitivities considered. Three sensitivities were considered to examine the effects of uncertainties in the costs of the energy efficiency technologies. The results suggest that 22 percent and 23 percent of the gas consumed annually by the commercial sector could be saved with energy efficiency measures with levelized costs of less than $3.50/Dth and $5.00/DTh, respectively. Moreover, since these results are generally not greatly affected by the sensitivities considered, controversy over the appropriate cost of conserved gas will have little impact on the magnitude of available cost-effective energy efficiency opportunities.

Table EX-1. Summary of Commercial Sector Economic Savings Potential (%) - NMGas

Perspective	Base Case	Cost -25%	Cost +25%	Cost +50%
Utility - $3.50/DTh	22	23	19	16
Utility - $5.00/DTh	23	24	23	22

From an end-use perspective, the energy efficiency results confirm that space heating accounts for the majority of gas consumption in the commercial sector (61 percent), significant cost-effective savings are achievable from each sensitivity considered, and these savings would have a major impact on commercial gas consumption. Despite the cost-effectiveness of measures directed toward reducing gas hot water heating and cooking energy use, the savings from these end uses account for only a very small portion of total commercial sector gas sales, although the results indicate that the majority of savings for these end uses are highly cost-effective.

From a building type perspective, the greatest source of cost-effective commercial sector gas savings is in the office, retail, and hospital sectors. These sectors account for the largest share of gas consumption (38 percent) and offer significant gas savings, under each sensitivity considered. There are also significant savings available for supermarkets and warehouses, yet the savings in these buildings are modest as a percentage of total commercial sector gas sales.

The energy efficiency measures contributing the most to the cost-effective energy efficiency potential improve the control of HVAC systems, especially the reset of supply-air temperatures for central HVAC systems and set-back of temperatures for both types of HVAC systems in offices. Significant energy savings also result from lowering hot water temperatures. Boiler tune-ups for space heating are highly cost-effective for offices and retail with central HVAC systems. Higher-efficiency equipment for space heating and water heating is generally cost-effective, but sometimes only marginally. Large cost-effective energy savings also result from several measures applied to hospitals including double-pane and then low-e windows, and HVAC heat recovery. Roof insulation is the only other shell measure found to be cost-effective in the other building types.

The economics of fuel-switching were evaluated by comparing the lifecycle costs of owning and operating gas versus electric space conditioning equipment. However, the economics were evaluated from a utility perspective. For example, the value of electricity was measured using NMPC's avoided costs of electricity and cost-effectiveness is described relative to the range of NMGas avoided gas costs, developed for this project ($3.50/DTh and $5.00/DTh).

For the packaged HVAC system analysis, three base electricity technologies were compared to three gas alternatives. For the base electric technology consisting of gas heating and electric cooling, the packaged gas engine cooling/heating system is found to be cost-effective for the office and warehouse, while the dessicant system is never cost-effective. The packaged dessicant system is the most cost-effective system for the office and retail building types compared to both base electric heating systems. To a smaller degree, but more consistently, packaged gas heating systems with electric cooling and packaged gas engine cooling and heating systems are also cost-effective against these same two base electric heating technologies.

For the central HVAC system analysis of heating, a single base electric heating technology was considered, electric boilers. Both the standard and high-efficiency gas alternatives were highly cost-effective compared to this base electric technology.

For the central HVAC system analysis of cooling, a single base electric technology was considered, centrifugal chillers. The gas-fired absorption alternative and the gas engine driven chiller without heat recovery were generally not cost-effective, except for the gas engine chiller in offices. In addition two cogeneration systems, one with and the other without absorption cooling, operated in two modes, were compared to the base technology of centrifugal chillers and gas boilers. Cogeneration systems tracking electric loads were found to be marginally cost-effective for the office and hospital, but not for the retail building; thermal tracking systems were marginally cost-effective only for the hospital.

End use data are the foundation upon which any evaluation of the potential for energy efficiency or the economics of fuel-switching must rest. In the final section of the report, we review the types of uncertainties created by our reliance on these data. Throughout the report we explicitly address uncertainties regarding the cost and performance of the energy efficiency and gas fuel-switching technologies by performing sensitivity analyses on these elements of the analysis. These sensitivities confirm that our findings are, for the most part, quite robust. We also address uncertainties in gas avoided costs in two different ways. First, in discussing cost-effectiveness, we rely on a range of gas avoided costs, developed from NMGas data. Second, in examining gas fuel-switching, we make gas avoided costs a study parameter; all results were expressed relative to a gas breakeven price. While reliance on these procedures greatly increases our confidence in the results, we also believe that there remain important opportunities for improvements to NMGas' end-use data. Specifically, we recommend further refinement of forecast data on the "miscellaneous" building type and end use, data on the existing penetration of energy efficiency and fuel-switching technologies, and survey data for developing commercial building prototypes. We also believe there is a need for more systematic methods to ensure consistency between NMGas end-use data and NMGas gas sales information.

1. Introduction

The Amercian Council for an Energy Efficient Economy (ACEEE), with support from the New York State Energy Research and Development Authority and the New York Gas Group, has recently completed a major study of the potential for gas energy efficiency and fuel-switching in New York state (Nadel, et. al. 1992). The study examined gas energy efficiency and fuel-switching for the residential and commercial sectors in three New York gas utility service territories, Long Island Lighting Company, Brooklyn Union Gas, and National Fuel Gas (NFG).

Niagara Mohawk Gas (NMGas) is currently engaged in gas end-use market planning. Due to important similarities between the gas services territories of NMGas and NFG, which include climate, the likely cost and availability of gas energy efficiency and fuel-switching technologies, and a common electricity supplier (Niagara Mohawk Power Corporation or NMPC), NMGas is interested in possible implications that the ACEEE study findings for NFG might have for NMGas. NMGas has expressed particular interest in the possible implications that the ACEEE findings for the commercial sector might have for NMGas' market planning. NMGas has also expressed interest in the ACEEE study methodology, as it relates to end-use data used by ACEEE and comparable data collected previously for NMGas. These two topics are the subject of this report.

In the first section following this introduction (Section 2), we describe the modifications made to the analysis developed by ACEEE for the commercial sector. An important defining boundary of the current study was that it rely exclusively on the detailed building energy simulation analyses previously developed by ACEEE. This boundary condition means that, while significant modifications, based on data provided by NMGas, are made in order to estimate the potential for commercial sector gas energy efficiency for NMGas, only slight changes are required to estimate the economics of gas fuel-switching for

NMGas commercial buildings.

In the third section of the report, we describe the findings from our analysis of the NMGas commercial sector gas energy efficiency potential. In the fourth section of the report, we describe the findings from our analysis of the economics of gas fuel-switching for space-conditioning end uses (cooling and heating) for the NMGas commercial sector. In discussing cost-effectiveness, both discussions rely on gas avoided costs provided by NMGas.

In the fifth section of the report we comment on the data provided by NMGas for use in "customizing" the ACEEE analysis to be representative of NMGas conditions. These comments are intended to assist NMGas in future end-use data development efforts that, among other objectives, would contribute to the development of commercial building prototypes representative of the buildings in the NMGas service territory.

An appendix reproduces the chapters from the ACEEE study that form the basis of the current report. Extensive reference is made to material presented in these chapters throughout the report.

2. Modifications to the ACEEE Study

Due to important similarities between the NFG commercial sector examined by ACEEE and that of NMGas, such as climate, the likely cost and availability of energy efficiency and gas fuel-switching technologies, and a common electricity supplier (NMPC), the work presented in this report takes ACEEE's analysis of NFG as its starting point. In particular, the present study relies on the building energy simulation analyses carried-out previously by ACEEE for the NFG analysis.

The chapters from the ACEEE report presenting the potential for commercial gas energy efficiency (Chapter 4) and the economics of commercial gas fuel-switching for space heating and cooling (Chapter 5) are reproduced in Appendices A and B, respectively. Both analyses were based on building energy simulations, using DOE-2[1], of six prototypical buildings (Office, Retail, Hospital, Supermarket, Restaurant, and Warehouse), with up to two HVAC systems (Office and Retail were separately examined with both a packaged and a central HVAC system). The potential for gas energy efficiency was developed through an examination of 10 space heating, 7 hot water heating, and 5 cooking measures. The economics of gas fuel-switching were examined for 14 different electric and gas space heating or cooling options. The building simulations for the NFG analysis relied on weather data for Buffalo.

The modifications to ACEEE's analysis differed considerably for the assessment of the potential for gas energy efficiency versus the assessment of the economics of gas fuel-switching due to differences between the two types of analysis and the requirement that this study rely on existing simulation results. On the one hand, estimating the *potential* for gas

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[1] DOE-2 is a well-known building energy analysis tool. It was developed by the Department of Energy and has been extensively verified for its accuracy in modeling energy use in buildings.

energy efficiency requires detailed NMGas-specific information on the size of the commercial sector to which the potential applies. On the other hand, estimating the *economics* of gas fuel-switching requires only a comparison of the relative economic costs of using gas versus electricity for heating or cooling a particular building (albeit, a prototypical one that was designed to be broadly representative of a general class of buildings). In summary, the gas energy efficiency analysis required introduction of significant amounts of NMGas information, while the analysis of gas fuel-switching required only reference to NMGas gas avoided costs.

Table 2.1 summarizes the modifications made to ACEEE's analysis of the potential for NMGas commercial gas energy efficiency. The most important changes reflect the very significant differences in building stock and end-use fuel saturations between the NFG and NMGas commercial sector service territories. While important differences in gas energy use intensities or EUIs were also accounted for, we have some concerns regarding NMGas gas EUIs (as well as floor space) that will be discussed in Section 5 of the report. Finally, and due in part to these and other data concerns, no reconciliation of the total gas sales profile implied by these data to actual NMGas 1991 gas sales was attempted.

Two technical aspects of the modifications made to the ACEEE study in order to estimate the NMGas potential for gas energy efficiency require additional description: 1) use of NMPC CDEMS gas EUIs to estimate the total sectoral potential for energy efficiency savings; 2) extrapolation of findings to building types not represented by the six ACEEE prototypes.

Table 2.1Modifications to ACEEE Study for NMGas Commercial Gas Energy Efficiency

	ACEEE Study - NFG	Niagara Mohawk Gas
Floor Space by Building Type	Developed by NFG from in-house market research	Estimated as residual between NMPC electric service territory total (Edmundson 1993) and NFG gas service territory
Gas End-Use Saturation	Developed by NFG from in-house market research	Developed by HBRS (1992) for NMPC[2]
Gas End-Use EUI	Assumed equal to those developed for NYPP for use in forecasting electricity demands for the NMPC electric service territory	Provided by NMPC from CDEMS forecasting input files (Edmundson 1993)
Energy Efficiency Savings	Relative percentage savings estimated by ACEEE DOE-2 simulations of prototypes	Assumed identical to ACEEE study - NFG
Energy Efficiency Measure Applicability	Estimated from surveys of NMPC electric service territory customer characteristics	Assumed identical to ACEEE study - NFG
Energy Efficiency Measure Costs	Estimated by ACEEE from a variety of sources	Assumed identical to ACEEE study - NFG
Cost-Effectiveness	Results described relative to hypothetical high ($4.00/DTh) and low ($2.50/DTh) avoided gas cost	Results described relative to range of levelized avoided gas cost derived from NMGas data ($5.00/DTh and $3.50/DTh)

[2] We have learned from HBRS that, depending on their final review, the sample weights developed for their analysis of gas fuel saturations may be revised. It was not known, at the time of this writing (10 March 1993), whether this final review had been completed or whether, as a result, the gas fuel saturations have been revised.

Reconciliation/Extrapolation	Factors developed to account for both actual 1991 NFG commercial gas sales and to extrapolate savings for building types not examined directly	Factor developed to extrapolate savings for building types not examined directly - No reconciliation to actual NMGas sale

The ACEEE study relied on EUIs developed for the New York Power Pool to forecast electric and gas demands for the NMPC service territory in its assessment of the gas energy efficiency potential for NFG. These EUIs were the basis for ACEEE's calibration of the upstate DOE-2 building prototypes. The EUIs provided by the NMPC forecasting group differ somewhat from those used in the ACEEE study.Since recalibration of the building prototypes was outside the scope of the present work, we adopted a hybrid approach. The approach consisted of relying on the current NMPC EUIs (i.e., not those developed for the New York Power Pool) to establish the baseline EUIs for the affected gas end-uses (space heating, water heating, and cooking). Gas savings, resulting from the implementation of the energy efficiency measures, were estimated by applying the percentage savings from the ACEEE study to these revised baseline EUIs. In other words, the relative savings quantities calculated by ACEEE were preserved, but applied to a new baseline provided by NMPC.

The six building prototypes selected for the ACEEE study were based on a review of the contribution of these six building types to commercial gas consumption in New York state. Since the fraction of total commercial sector gas consumption represented by these buildings was large, it was deemed reasonable to extrapolate the savings found in these buildings to the remaining building types not examined explicitly (schools, colleges, lodging, and miscellaneous). This extrapolation was also performed for the current NMGas analysis based on the relative gas sales to the six building types explicitly examined and the total NMGas commercial sector (as developed from the sales profile based on CDEMS data inputs). Sections 3 and 5 will discuss some of our reservations regarding the appropriateness of this decision, which was performed solely to ensure consistency between the ACEEE study methodology and the present NMGas analysis.

Finally, all discussions of cost-effectiveness for both the analysis of the potential for NMGas commercial energy efficiency and the economics for NMGas commercial fuel-switching are based on gas avoided costs supplied by NMGas (Hamilton 1993). The costs supplied by NMGas were levelized using a 5 percent real discount rate (which is consistent with the discount rate used throughout the ACEEE study). Considering just the commodity costs, we estimated a high or winter ($5.00/DTh) and low or summer ($3.50/DTh) avoided gas cost. All results will be described in reference to this range.

3. The Potential for NMGas Commercial Sector Gas Energy Efficiency

The potential for NMGas commercial sector gas energy efficiency was developed through an examination of 10 space heating, 7 hot water heating, and 5 cooking measures (see Table 3.1) for 6 building prototypes (office, retail, hospital, supermarket, restaurant, and warehouse). Chapter 4 of the ACEEE report (reproduced as Appendix A) contains detailed descriptions of the prototypes, the energy efficiency measures, their cost, applicability, and existing penetration. The previous section has described additional modifications made in order to apply these results to the NMGas commercial sector.

Table 3.1 Commercial Gas Energy Efficiency Measures

End Use	Measure
Space Heating	Reset HVAC Supply Air Temperature ("Reset SA Temp")
	Boiler Tune-up ("Boiler Tune")
	Time Clocks/Temperature Set-back ("Temp Set Back")
	Higher-Efficiency Boilers ("Hi-Eff Boiler")
	Higher-Efficiency Furnaces ("Hi-Eff Furnace")
	Double-Pane Windows ("Dbl Pane Glass")
	Low-Emissivity Windows ("Low-E Glass")
	Roof Insulation ("Roof Insul")
	HVAC Heat Recovery ("HVAC Heat Rec")
	HVAC System Maintenance ("HVAC Maint")
Water Heating	Lower DHW Temperature ("Lower Temp")
	High-Efficiency Boiler ("Hi-Eff Boiler")
	High-Efficiency Stand Alone Water Heater ("Hi-Eff Stdaln")
	Boiler tune-up ("Boiler Tune")
	Tank Insulation ("Tank Insul")
	Pipe Insulation ("Pipe Insul")
	Auto Temperature Reset ("Auto Reset")
Cooking	Standard to Direct Convection Oven ("Std-Dir Conv")
	Indirect to Direct Convection Oven ("Ind-Dir Conv")
	Catalytic Infrared Fryer ("Cat IR Fry").
	Infrared Griddle ("IR Griddle")
	Power Burner Range ("Pwr Burner")

It is instructive to put some perspective on our findings by first reviewing the NMGas sales profile upon which it is based. That is, since individual savings are calibrated to the EUIs contained in the profile, these EUIs (when combined with floor space and end-use fuel saturations from the profile) define the absolute relationships (in terms of gas sales) between building types, end uses, and the potential for energy efficiency improvements. For example, a measure that saves 50% of an end use, which itself represents only 10% of total gas consumption for a given building type that in turn represents only 5% of NMGas commercial floor space will have only a very small impact on NMGas sales (50%*10%*5%=0.25%) compared to a measure that saves 10% of an end use representing 80% of gas consumption for a building representing 30% of NMGas commercial floor space (10%*80%*30%=2.4%).

Table 3.2 presents the NMGas sales profile developed from a combination of data provided by NMGas (and NMPC) and the previous ACEEE study. As indicated in Table 2.1, NMGas commercial floor space was estimated as the difference between that estimated by NMPC for the total electric service territory for commercial forecasting purposes using the CDEMS model (Edmundson 1993) and that estimated by ACEEE, using NFG data. End-use fuel saturations are taken from either a recent HBRS survey (HBRS 1992) or from NMPC CDEMS inputs. All EUIs are taken from NMPC CDEMS inputs.

The data on Table 3.2 suggest that the six building types examined by ACEEE account for only about 50% of NMGas commercial sector sales. On a building type basis, 13%, 16%, 9%, 3%, 7%, and 1% of total commerical sector gas sales are accounted for by office, retail, health, grocery, restaurant, warehouse, respectively. Total gas consumption by these six buildings, taken together, on an end-use basis is divided 70%, 10%, and 3% for space heating, water heating, and cooking, respectively.[3]

[3] In section 5, we will comment on two particularly disturbing aspects of the sales profile, namely that the miscellaneous building type appears to be by far the largest gas consumer in the NMGas commercial sector (35%, with retail a distant second at 16%) and

Table 3.2 NMGas Sales Profile

	Building Types Considered Explicitly by ACEEE						Building Types Not Considered Explicitly by ACEEE				
	Office	Retail	Health	Supermkt	Restrnt	Warehouse	School	College	Lodging	Misc	
NMGas Service Territory Floor Space (millions sqft)											
1991	131.1	97.9	33.9	19.2	20.0	24.1	63.1	52.3	5.2	217.8	
NMGas Service Territory Gas Fuel Saturation (%)											
sp heat	53.0	76.0	64.0	64.0	72.0	85.0	65.0	45.0	39.0	58.0	
a/c	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
wt heat	42.0	48.0	66.0	58.0	58.0	30.0	71.0	57.0	58.0	37.0	
cooking	8.0	9.0	52.0	40.0	60.0	2.0	34.0	25.0	48.0	9.0	
misc	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
NMGas EUI (kBtu/sqft)											
sp heat	55.5	53.9	116.8	92.0	77.8	14.3	40.0	27.9	67.4	70.2	
a/c	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
wt heat	3.2	2.1	28.8	2.4	83.8	0.2	6.8	6.8	26.7	12.7	
cooking	0.7	1.0	1.4	8.7	44.3	0.1	2.6	2.6	6.0	8.0	
misc	8.5	22.5	4.7	0.0	13.1	0.0	0.0	0.0	0.5	0.7	
Total Forecast NMGas Service Territory Consumption (thousands DTh)											
sp heat	3853	4007	2536	1132	1119	292	1405	694	111	8862	24011
a/c	0	0	0	0	0	0	0	0	0	0	0
wt heat	176	96	645	27	971	1	371	247	41	165	2740
cooking	7	9	25	67	531	0	4	0	11	20	675
misc	1112	2199	160	0	263	0	924	2087	224	4894	11863
total	5147	6312	3366	1226	2884	294	2704	3028	387	13941	39289
Total Gas Consumption (% of Total Commercial Gas Consumption)											
	13	16	9	3	7	1	7	8	1	35	

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that the miscellaneous end use appears to be the second largest end use (30%) after space heating (60%).

The results of our analysis of the potential for energy efficiency are summarized using the cost of conserved gas. The cost of conserved gas is calculated by dividing the levelized cost of the gas energy efficiency measure (using a 5 percent discount rate, per the ACEEE study) by the amount of gas saved annually. The cost of conserved gas, since it is expressed in levelized dollars per DTh saved, can be compared directly to the levelized cost of avoided gas supply.

Table 3.3 summarizes the economic potential for commercial sector gas energy efficiency measures for each of the perspectives and sensitivities considered. The results suggest that 22 percent and 23 percent of the gas consumed annually by the commercial sector could be saved with energy efficiency measures costing less than \$3.50/Dth and \$5.00/DTh, respectively. These results confirm that the cost of conserved gas increases rather steeply over the range of gas avoided costs considered. In other words, controversy over the appropriate cost of conserved gas will have little impact on the magnitude of available cost-effective energy efficiency opportunities.

Table 3.3. Summary of Commercial Sector Economic Savings Potential (%) - NMGas

Perspective	Base Case	Cost -25%	Cost +25%	Cost +50%
Utility - \$3.50/DTh	22	23	19	16
Utility - \$5.00/DTh	23	24	23	22

The analysis appears to be robust with respect to the cost and performance sensitivities considered. For example, if the cost of the energy efficiency measures is 25 percent lower (also corresponding to energy savings 33 percent higher), the cost-effective energy-efficiency potential increase very slightly to 23 percent and 24 percent at the utility cost-effectiveness thresholds of \$3.50/DTh and \$5.00/DTh, respectively. Conversely, if the cost of the energy efficiency measures is 25 percent higher (or energy saving 20 percent lower), the cost-effective energy-efficiency potential decreases slightly more to 19 percent and unchanged at the cost-effectiveness thresholds of $3.50/Dth and $5.00/DTh, respectively. Finally, if the cost of the efficiency measures is 50 percent higher (or energy savings 33 percent lower), the cost-effective energy-efficiency potential decreases to 16 percent and 22 percent for the same range of utility cost-effectiveness thresholds.

Table 3.4 summarizes our findings on an end-use basis. Savings are expressed both as percentages of annual gas consumption by the end use, as well as a percentage of total commercial sector gas consumption. The percentage of total sectoral sales accounted for by each end use is also indicated.

Table 3.4. Summary of NMGas Commercial Sector Economic Gas Savings Potential by End Use

Perspective	Space Heat (61%)		Water Heat (7%)		Cooking (2%)	
	% of end use	% of sector	% of end use	% of sector	% of end use	% of sector
Utility - $3.50/DTh	33	20	20	1	25	1
Utility - $5.00/DTh	35	21	20	1	25	1

Table 3.4 highlights the importance of energy efficiency measures to reduce gas used for space heating. Space heating accounts for the majority of gas consumption in the commercial sector (61 percent), significant cost-effective savings are achievable from each sensitivity considered, and these savings would have a major impact on commercial gas consumption. Despite the cost-effectiveness of measures directed toward reducing gas hot water heating and cooking energy use, the savings from these end uses account for only a very small portion of total commercial sector gas sales, although the results indicate that the majority of cost-effective savings for these end uses are highly cost-effective, costing less than the lowest cost-effectiveness threshold considered ($3.50/DTh). For example, all five

cooking measures were found to be cost-effective under any scenario of gas avoided cost or cost/performance sensitivity.

Tables 3.5 summarize our findings separately by building type. The results are expressed both as a percentage of gas consumed by the building type and as a percentage of total commercial sector sales. The percentage of gas consumption accounted for by each building type is also indicated.

Table 3.5. Summary of NMGas Commercial Sector Economic Gas Savings Potential by Building

Perspective	Office (13%)		Retail (16%)		Hospital (9%)	
	% of building	% of sector	% of building	% of sector	% of building	% of sector
Utility - $3.50/DTh	31	4	18	3	29	3
Utility - $5.00/DTh	35	5	18	3	29	3

Perspective	Supermarket (3%)		Restaurant (7%)		Warehouse (1%)	
	% of building	% of sector	% of building	% of sector	% of building	% of sector
Utility - $3.50/DTh	51	2	17	1	41	0
Utility - $5.00/DTh	51	2	17	1	41	0

Table 3.5 indicates that the greatest source of cost-effective commercial sector gas savings is the office, retail, and hospital sectors. These sectors account for the largest share of gas consumption (38 percent) and offer significant gas savings, under each sensitivity considered. There are also significant savings available for supermarkets and warehouses, yet the savings in these buildings are modest as a percentage of total commercial sector gas sales.

Table 3.6 lists all energy efficiency measures in order of increasing cost of conserved gas. Each measure is described with respect to the end use and building type to which it applies. Following the cost of conserved gas (calculated using a 5% real discount rate, per the ACEEE study), the amount of gas that could be saved is indicated in 1000s of DTh.[4] Next, cumulative savings are tabulated, both in 1000s of DTh and as a percentage of the total NMGas commercial sector sales (see Table 3.2). Finally three sensitivities are considered for the cost of conserved gas. The first examines the effects of lower than estimated costs (-25%) for the energy efficiency measures. The second and third sensitivities examine the effects of higher than expected costs (+25% and +50%, respectively).

The energy efficiency measures contributing the most to the cost-effective energy efficiency potential improve the control of HVAC systems, especially the reset of supply-air temperatures for central HVAC systems and set-back of temperatures for both types of HVAC systems in offices. Significant energy savings also result from lowering hot water temperatures. Boiler tune-ups for space heating are highly cost-effective for offices and retail with central HVAC systems. Higher-efficiency equipment for space heating and water heating is generally cost-effective, but sometimes only marginally.

Large cost-effective energy savings also result from several measures applied to hospitals including double-pane and then low-e windows, and HVAC heat recovery. Besides the hospital, roof insulation is the only other shell measure found to be consistently cost-effective in other building types.

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[4] As indicated previously, the total savings for each measure and building type (but not cost-effectiveness) have been adjusted upward to account for savings from implementation of the measures in the building types not examined with unique prototypes.

Table 3.6 The Potential for NMGas Commercial Sector Energy Efficiency

Measure	End Use	Building	CCG ($/DTh)	Savings (1000 DTh)	Cumulative (1000 DTh)	Save (%)	CCG-25%	CCG+25%	CCG+50%
ind-dir conv	cooking	restrnt	0.00	6	6	0.0	0.00	0.00	0.00
ind-dir conv	cooking	hospital	0.00	0	7	0.0	0.00	0.00	0.00
ind-dir conv	cooking	supermkt	0.00	1	7	0.0	0.00	0.00	0.00
ind-dir conv	cooking	office	0.00	0	7	0.0	0.00	0.00	0.00
lower temp	water heat	warehse	0.00	1	8	0.0	0.00	0.00	0.00
ind-dir conv	cooking	retail	0.00	0	8	0.0	0.00	0.00	0.00
lower temp	water heat	retail	0.00	51	59	0.2	0.00	0.00	0.00
ind-dir conv	cooking	warehse	0.00	0	59	0.2	0.00	0.00	0.00
lower temp	water heat	office	0.00	85	144	0.4	0.00	0.00	0.00
lower temp	water heat	supermkt	0.00	18	162	0.4	0.00	0.00	0.00
hi-eff boiler	water heat	hospital	0.08	102	264	0.7	0.06	0.09	0.11
std-dir conv	cooking	hospital	0.16	0	264	0.7	0.12	0.20	0.24
std-dir conv	cooking	restrnt	0.16	9	274	0.7	0.12	0.20	0.24
std-dir conv	cooking	warehse	0.16	0	274	0.7	0.12	0.20	0.24
std-dir conv	cooking	office	0.16	0	274	0.7	0.12	0.20	0.24
std-dir conv	cooking	supermkt	0.16	1	275	0.7	0.12	0.20	0.24
std-dir conv	cooking	retail	0.16	0	275	0.7	0.12	0.20	0.24
cat ir fry	cooking	office	0.19	1	276	0.7	0.14	0.24	0.29
cat ir fry	cooking	hospital	0.19	3	279	0.7	0.14	0.24	0.29
cat ir fry	cooking	supermkt	0.19	8	287	0.7	0.14	0.24	0.29
cat ir fry	cooking	retail	0.19	1	288	0.7	0.14	0.24	0.29
cat ir fry	cooking	warehse	0.19	0	288	0.7	0.14	0.24	0.29
cat ir fry	cooking	restrnt	0.19	61	349	0.9	0.14	0.24	0.29
dbl pane glass	space heat	hospital	0.25	439	788	2.0	0.19	0.32	0.38
reset sa temp	space heat	office cnt	0.30	1476	2264	5.8	0.22	0.37	0.44
pwr burner	cooking	office	0.31	0	2264	5.8	0.23	0.38	0.46
pwr burner	cooking	hospital	0.31	1	2265	5.8	0.23	0.38	0.46
pwr burner	cooking	restrnt	0.31	22	2287	5.8	0.23	0.38	0.46
pwr burner	cooking	retail	0.31	0	2287	5.8	0.23	0.38	0.46
pwr burner	cooking	supermkt	0.31	3	2290	5.8	0.23	0.38	0.46
pwr burner	cooking	warehse	0.31	0	2290	5.8	0.23	0.38	0.46
ir griddle	cooking	retail	0.31	1	2291	5.8	0.23	0.39	0.47
ir griddle	cooking	restrnt	0.31	41	2331	5.9	0.23	0.39	0.47
ir griddle	cooking	warehse	0.31	0	2331	5.9	0.23	0.39	0.47
ir griddle	cooking	supermkt	0.31	5	2336	5.9	0.23	0.39	0.47
ir griddle	cooking	office	0.31	1	2337	5.9	0.23	0.39	0.47

Measure	End Use	Building	CCG ($/DTh)	Savings (1000 DTh)	Cumulative (1000 DTh)	Save (%)	CCG-25%	CCG+25%	CCG+50%
ir griddle	cooking	hospital	0.31	2	2339	6.0	0.23	0.39	0.47
boiler tune	space heat	office cnt	0.45	148	2486	6.3	0.33	0.56	0.67
boiler tune	space heat	retail cnt	0.57	65	2551	6.5	0.43	0.72	0.86
reset sa temp	space heat	retail cnt	0.60	516	3068	7.8	0.45	0.75	0.90
temp set back	space heat	office cnt	0.92	364	3431	8.7	0.69	1.15	1.38
roof insul	space heat	supermkt	0.94	920	4351	11.1	0.71	1.18	1.42
hi-eff boiler	space heat	hospital	1.02	246	4597	11.7	0.77	1.28	1.53
hi-eff stdaln	water heat	office	1.03	50	4647	11.8	0.77	1.28	1.54
low-e glass	space heat	hospital	1.40	373	5019	12.8	1.05	1.74	2.09
hi-eff furnace	space heat	restrnt	1.66	176	5196	13.2	1.24	2.07	2.49
hi-eff stdaln	water heat	restrnt	1.66	247	5442	13.9	1.25	2.08	2.50
hvac heat rec	space heat	hospital	1.78	557	6000	15.3	1.34	2.23	2.67
roof insul	space heat	restrnt	1.90	292	6292	16.0	1.42	2.37	2.85
roof insul	space heat	hospital	1.91	25	6317	16.1	1.43	2.39	2.86
hi-eff furnace	space heat	retail pkg	2.56	398	6715	17.1	1.92	3.20	3.84
hi-eff boiler	space heat	retail cnt	2.59	44	6758	17.2	1.94	3.24	3.89
hi-eff furnace	space heat	supermkt	2.68	143	6901	17.6	2.01	3.35	4.02
temp set back	space heat	office pkg	2.71	255	7156	18.2	2.03	3.39	4.07
hi-eff furnace	space heat	warehse	2.76	101	7258	18.5	2.07	3.45	4.14
hi-eff furnace	space heat	office pkg	2.91	160	7418	18.9	2.18	3.64	4.37
roof insul	space heat	retail pkg	2.94	789	8207	20.9	2.21	3.68	4.41
hi-eff boiler	space heat	office cnt	3.03	73	8279	21.1	2.27	3.79	4.55
dbl pane glass	space heat	office cnt	3.07	92	8371	21.3	2.30	3.84	4.61
roof insul	space heat	retail cnt	3.28	92	8463	21.5	2.46	4.10	4.92
roof insul	space heat	warehse	3.31	109	8573	21.8	2.48	4.13	4.96
roof insul	space heat	office cnt	3.44	138	8710	22.2	2.58	4.30	5.17
roof insul	space heat	office pkg	3.81	257	8967	22.8	2.86	4.76	5.71
dbl pane glass	space heat	office pkg	4.80	122	9089	23.1	3.60	6.00	7.20
hi-eff boiler	water heat	office	4.95	2	9091	23.1	3.71	6.19	7.43
hi-eff boiler	water heat	restrnt	5.35	2	9093	23.1	4.02	6.69	8.03
dbl pane glass	space heat	restrnt	6.14	134	9227	23.5	4.60	7.67	9.21
tank insul	water heat	restrnt	6.20	23	9250	23.5	4.65	7.74	9.29
boiler tune	water heat	office	8.27	1	9251	23.5	6.20	10.34	12.41
tank insul	water heat	supermkt	8.49	4	9254	23.6	6.37	10.61	12.74
hvac maint	space heat	restrnt	8.61	160	9414	24.0	6.46	10.77	12.92
boiler tune	water heat	restrnt	8.94	1	9415	24.0	6.71	11.18	13.42
hvac maint	space heat	supermkt	9.04	121	9536	24.3	6.78	11.30	13.56
dbl pane glass	space heat	retail pkg	9.27	840	10376	26.4	6.95	11.59	13.90
dbl pane glass	space heat	supermkt	9.51	56	10432	26.6	7.13	11.88	14.26

Measure	End Use	Building	CCG ($/DTh)	Savings (1000 DTh)	Cumulative (1000 DTh)	Save (%)	CCG-25%	CCG+25%	CCG+50%
tank insul	water heat	retail	9.55	13	10445	26.6	7.16	11.93	14.32
tank insul	water heat	warehse	9.55	0	10445	26.6	7.16	11.93	14.32
tank insul	water heat	office	9.55	2	10447	26.6	7.16	11.94	14.33
dbl pane glass	space heat	retail cnt	10.39	97	10544	26.8	7.79	12.99	15.58
dbl pane glass	space heat	warehse	10.96	148	10692	27.2	8.22	13.70	16.45
tank insul	water heat	hospital	11.51	1	10694	27.2	8.63	14.38	17.26
pipe insul	water heat	hospital	11.81	4	10698	27.2	8.86	14.77	17.72
pipe insul	water heat	supermkt	13.29	0	10698	27.2	9.97	16.61	19.93
hi-eff stdaln	water heat	supermkt	13.68	4	10702	27.2	10.26	17.10	20.52
hvac heat rec	space heat	office cnt	14.85	91	10793	27.5	11.14	18.56	22.27
hi-eff stdaln	water heat	retail	15.23	23	10817	27.5	11.42	19.04	22.85
pipe insul	water heat	restrnt	16.34	2	10819	27.5	12.25	20.42	24.51
pipe insul	water heat	retail	17.07	2	10820	27.5	12.80	21.34	25.60
pipe insul	water heat	warehse	17.07	0	10820	27.5	12.80	21.34	25.60
pipe insul	water heat	office	17.12	0	10820	27.5	12.84	21.40	25.68
hvac maint	space heat	retail pkg	17.47	330	11150	28.4	13.10	21.83	26.20
low-e glass	space heat	office cnt	18.10	89	11239	28.6	13.58	22.63	27.15
hvac maint	space heat	hospital	19.87	97	11336	28.9	14.90	24.84	29.81
hvac maint	space heat	warehse	21.36	92	11428	29.1	16.02	26.70	32.04
auto reset	water heat	warehse	21.93	0	11428	29.1	16.45	27.41	32.89
auto reset	water heat	retail	21.93	7	11435	29.1	16.45	27.41	32.89
auto reset	water heat	office	21.93	1	11436	29.1	16.45	27.41	32.90
hvac maint	space heat	retail cnt	25.69	58	11494	29.3	19.27	32.11	38.53
hvac maint	space heat	office pkg	27.22	116	11610	29.6	20.42	34.03	40.84
hvac maint	space heat	office cnt	27.46	112	11722	29.8	20.60	34.33	41.19
low-e glass	space heat	office pkg	29.25	113	11835	30.1	21.93	36.56	43.87
auto reset	water heat	restrnt	32.01	6	11841	30.1	24.00	40.01	48.01
hi-eff stdaln	water heat	warehse	43.09	0	11841	30.1	32.32	53.86	64.63
auto reset	water heat	supermkt	43.86	1	11842	30.1	32.90	54.83	65.79
low-e glass	space heat	restrnt	51.09	96	11938	30.4	38.32	63.86	76.64
low-e glass	space heat	supermkt	53.47	43	11980	30.5	40.10	66.84	80.21
low-e glass	space heat	retail pkg	54.11	458	12438	31.7	40.58	67.64	81.17
low-e glass	space heat	warehse	59.14	90	12528	31.9	44.35	73.92	88.71
low-e glass	space heat	retail cnt	59.78	54	12582	32.0	44.84	74.73	89.68

4. The Economics of NMGas Commercial Sector Gas Fuel-Switching

The economics of NMGas commercial sector gas fuel-switching were developed through an examination of 14 gas and electric space heating and cooling technologies for 6 building prototypes (office, retail, hospital, supermarket, restaurant, and warehouse). Chapter 5 of the ACEEE report (reproduced as Appendix A) contains descriptions of the technologies, their costs, and applicability. Table 4.1 summarizes these technologies and the building prototypes for which they were considered as alternatives. The discussion of the calculation of the breakeven gas price and the results from the ACEEE Study are reproduced in this section to enhance readibility. Section 2 previously described additional modifications in order to apply these results to the NMGas commercial sector, namely determination of a levelized gas avoided cost against which to compare results.

The Calculation of a Breakeven Gas Price

Lifecycle costs of electric versus gas space-heating and cooling technologies cannot be calculated without a well-defined avoided cost for gas. However, since the other costs required by such a lifecycle analysis can be specified, for example, the capital and operating cost of both technologies, the real discount rate (5 percent), and the avoided cost of electricity, a breakeven gas price can be calculated by determining the price of gas at which the lifecycle costs of competing electric and gas options are identical. At this price, one would be indifferent (on economic grounds) to the choice of technology. Thus, if the actual avoided cost of gas is lower than the breakeven price, then the gas technology would be more cost-effective than the electric technology and vice versa. To summarize the basic idea: a high breakeven gas price means that the gas technology will be generally cost-effective compared to the electric competitor.

Table 4.1. Applicability of Fuel-Switching Technologies to Commercial Building Prototypes.

Measure	Office Central	Office Pkg	Retail Central	Retail Pkg	Hospital	Super-market	Restau -rant	Warhse
Std. Gas Boiler	X		X		X			
Hi Eff Gas Boil.	X		X		X			
Elect. Boiler	X		X		X			
Pkg. Gas Heat, Elec. Cool		X		X		X	X	X
Pkg. Elec Heat/Cool		X		X		X	X	X
Pkg. Air Source Heat Pump		X		X		X	X	X
Pkg. Gas Eng Heat/Cool		X		X		X	X	X
Pkg Dessicant		X		X		X	X	X
Centrifugal Chiller	X		X		X			
Gas-fired Absor	X		X		X			
Eng. Chlr	X		X		X			
Eng. Chlr w/HR	X		X		X			
Cogeneration	X		X		X			
Cogeneration w/Absorption	X		X		X			

To better understand the concept, it is instructive to review a simplified algebraic derivation of the gas breakeven price. The breakeven gas price is always calculated in reference to the lifecycle cost of an assumed base electric technology compared to a candidate gas alternative. For the total lifecycle costs (TLCC) of the two competing technologies to be equal:

$$\text{TLCC of option 1} = \text{TLCC of option 2} \qquad \text{equation 1}$$

The total lifecycle cost of each option is the sum of the capital and installation costs of each option (CIC), its non-fuel operating and maintenance cost (OMC), its electricity cost (ELC), and its gas cost (GSC). That is:

$$TLCC = CIC + OMC + ELC + GSC \qquad \text{equation 2}$$

The costs of electricity and gas are evaluated using long-run avoided costs (LRACs) for both energy sources and future operating costs are present-valued using an assumed 5 percent real discount rate. However, the GSC is unknown, since it is the product of the quantity of gas consumed (GQ) times the long-run avoided cost for gas (GLRAC) which is unknown. Formally:

$$GSC = GQ * GLRAC \qquad \text{equation 3}$$

The breakeven gas price is based on the concept that, if the two lifecycle costs are equal, simple algebraic manipulation of the terms will allow one to solve for the unknown GLRAC. That is, substituting equation 3 into equation 2, and equation 2 into equation 1, start with the equality:

$$CIC_1 + OMC_1 + ELC_1 + (GQ_1 * GLRAC) = CIC_2 + OMC_2 + ELC_2 + (GQ_2 * GLRAC)$$

Then, solve for GLRAC:

$$GLRAC = [(CIC_2+OMC_2+ELC_2) - (CIC_1+OMC_1+ELC_1)] / (GQ_1 - GQ_2) \quad \text{equation 4}$$

In other words, given that two options have different non-gas lifecycle costs, the price of gas that will make the total lifecycle costs of the two options equivalent is just this difference in non-gas lifecycle costs divided by the difference in gas consumption.

If the likely range of gas avoided costs is less than the gas breakeven price, the gas cooling alternative is more cost-effective than the base electric cooling technology. That is, given the current range of gas avoided costs, the extra capital cost of the gas cooling technology relative to electric cooling technology, despite the increase in gas use, is more than offset by the decrease in electricity use valued at the long-run avoided cost of electricity.

Conversely, if the gas breakeven cost is lower than the likely range of gas avoided costs, the base electric technology would remain more cost-effective than the gas technology. In this case, the added cost of the gas alternative, plus the increase in gas use, is not offset by the reduction in electricity use. Put another way, under this scenario gas must be very cheap for the gas alternative to compete successfully against the assumed electric base technology. If the gas breakeven cost, for example, is negative, then the gas alternative will never be cost-effective at any gas price.

The electric avoided costs used in the calculation of the gas breakeven price are unchanged from those used in the ACEEE study. Thus, as with the NFG analysis, NMPC electric avoided costs are used to evaluate the economics of gas fuel-switching for NMGas. The NMPC electric avoided costs are $0.0364/kWh for energy, $57.8/kW.year for summer peak, and $87.2/kW.year for winter peak (ACEEE 1992).

NMGas Findings

Tables 4.2 through 4.5 present the cost-effectiveness of gas heating and cooling technologies compared to an electric base technology. Table 4.2 presents results from the primary analysis, while tables 4.3, 4.4, and 4.5 present results from sensitivity cases; gas technology cost increased by 25 percent, gas technology cost decreased by 25 percent, and all changes in electricity consumption valued at the on-peak avoided electricity price, respectively.

For the packaged HVAC system analysis, three base electricity technologies were compared to three gas alternatives. In sharp contrast to the ACEEE downstate results for LILCO and BUG, the packaged dessicant system is the most cost-effective system for the office and retail building types compared to both base electric heating systems. To a smaller degree, but more consistently, packaged gas heating systems with electric cooling and packaged gas engine cooling and heating systems are cost-effective against these same two base electric heating technologies.

For the base electric technology consisting of gas heating and electric cooling, however, the packaged gas engine cooling/heating system is cost-effective for only the office and warehouse, while the dessicant system is never cost-effective.

For the central HVAC system analysis of heating, a single base electric heating technology was considered, electric boilers. Both the standard and high-efficiency gas alternatives were highly cost-effective compared to this base electric technology.

For the central HVAC system analysis of cooling, a single base electric technology was considered, centrifugal chillers. The gas-fired absorption alternative and the gas engine driven chiller without heat recovery were generally not cost-effective, except for the gas engine chiller in offices.

In addition two cogeneration systems, one with and the other without absorption cooling, operated in two modes, were compared to the base technology of centrifugal chillers and gas boilers. Overall, the cogeneration systems tracking electric loads were only marginally cost-effective for the office and hospital, although the thermal tracking systems were also marginally cost-effective for the hospital.

The effect of an increase in the cost of the gas alternatives is to reduce the gas breakeven cost and thereby reduce the cost-effectiveness of the alternatives compared to the base case (Table 4.3). Nevertheless, most of the gas technologies that were cost-effective in the base case remained cost-effective compared to the base electric heating technologies. Compared to the packaged gas heat/electric cooling system, however, neither gas cooling alternative, gas engine cooling nor dessicant, remains cost-effective. For the central HVAC system analysis, gas boilers remain highly cost-effective compared to electric boilers, only one gas cooling technology application is even marginally cost-effective, as are only a few of the cogeneration options.

The effect of a decrease in the cost of the gas alternatives is to increase the gas breakeven cost and the cost-effectiveness of the gas alternatives (Table 4.4). For the packaged HVAC system analysis, all gas alternatives become strongly cost-effective compared to the base electric heating systems. Compared to the packaged gas heating/electric cooling system, the dessicant system remains not cost-effective but the packaged gas engine cooling/heating system becomes cost-effective for all building types. For the central HVAC analysis, the most significant changes are found in cooling. The gas engine chillers become moderately cost-effective for the office and retail building type; most of the cogeneration systems become marginally cost-effective, except thermal tracking in retail buildings.

The effect of valuing all changes in electricity use at the on-peak avoided cost of electricity increases the cost-effectiveness of the gas alternatives (Table 4.5). In this case, the effects are less dramatic than those found by decreasing the cost of the gas technologies. In other words, results from the previous sensitivity case examining lower gas technology costs encompasses the results from using a higher avoided electricity cost.

Table 4.2 NMGas Fuel-Switching Results - Base Case

Breakeven Gas Price ($/DTh)

Packaged Rooftop HVAC

	Office	Retail	Supermkt	Restaur	Warehse
reference case = electric resistance heating, electric cooling					
gas heat	9.33	14.23	11.83	12.28	7.13
dessicant	18.97	49.24	7.97	12.52	4.96
gas eng cool	9.20	11.60	10.06	10.32	7.00
reference case = electric air source heat pump					
gas heat	8.12	9.28	8.62	8.07	4.77
dessicant	15.98	23.80	4.83	7.43	-8.70
gas eng cool	8.30	7.59	7.27	6.56	4.95
reference case = gas heating, electric cooling					
dessicant	-6.23	-2.93	-20.68	-15.78	-1.78
gas eng cool	8.82	0.41	-1.63	-6.35	6.14

Central HVAC

HEATING	Office	Retail	Hospital
reference case = electric boiler, electric cooling			
std eff gas boiler	16.96	16.93	16.98
high eff gas boiler	17.76	17.67	17.81

COOLING	Office	Retail	Hospital
reference case = gas boiler, electric cooling			
gas-fired absorption	1.05	0.05	-7.80
gas eng chlr	3.52	2.75	-2.03
gas eng chlr w/hr	3.32	0.57	-12.90
cogen w/o abs - thrml trk	1.02	-2.39	3.56
cogen w/abs - thrml trk	0.81	-1.99	3.41
cogen w/o abs - elect trk	3.52	1.95	3.81
cogen w/abs - elect trk	3.34	2.05	3.67

Table 4.3. NMGas Fuel-Switching Results - Gas Technology Cost +25%

Breakeven Gas Price ($/DTh)

Packaged Rooftop HVAC

	Office	Retail	Supermkt	Restaur	Warehse
reference case = electric resistance heating, electric cooling					
gas heat	7.78	13.09	10.94	11.42	5.82
dessicant	11.03	37.06	6.14	10.37	-10.79
gas eng cool	7.53	10.26	8.93	9.21	5.35
reference case = electric air source heat pump					
gas heat	6.57	8.14	7.72	7.22	3.46
dessicant	8.05	11.62	3.00	5.28	-24.45
gas eng cool	6.63	6.25	6.14	5.45	3.30
reference case = gas heating, electric cooling					
dessicant	-9.64	-5.21	-35.03	-21.84	-4.56
gas eng cool	2.40	-6.63	-10.26	-16.90	-6.26

Central HVAC

HEATING	Office	Retail	Hospital
reference case = electric boiler, electric cooling			
std eff gas boiler	16.81	16.75	16.86
high eff gas boiler	17.55	17.41	17.64

COOLING	Office	Retail	Hospital
reference case = gas boiler, electric cooling			
gas-fired absorption	0.17	-1.59	-17.32
gas eng chlr	2.44	0.78	-5.67
gas eng chlr w/hr	0.77	-4.27	-22.67
cogen w/o abs - thrml trk	-1.06	-6.30	1.78
cogen w/abs - thrml trk	-1.34	-5.77	1.77
cogen w/o abs - elect trk	2.65	0.52	2.81
cogen w/abs - elect trk	2.42	0.61	2.61

Table 4.4. NMGas Fuel-Switching Results - Gas Technology Cost -25%

Breakeven Gas Price ($/DTh)

Packaged Rooftop HVAC

	Office	Retail	Supermkt	Restaur	Warehse
reference case = electric resistance heating, electric cooling					
gas heat	10.88	15.37	12.73	13.13	8.44
dessicant	26.90	61.42	9.80	14.67	20.71
gas eng cool	10.87	12.94	11.20	11.43	8.65
reference case = electric air source heat pump					
gas heat	9.67	10.42	9.52	8.93	6.08
dessicant	23.92	35.98	6.66	9.57	7.05
gas eng cool	9.97	8.93	8.41	7.67	6.60
reference case = gas heating, electric cooling					
dessicant	-2.81	-0.65	-6.32	-9.72	1.01
gas eng cool	15.23	7.46	7.00	4.20	18.53

Central HVAC

HEATING	Office	Retail	Hospital
reference case = electric boiler, electric cooling			
std eff gas boiler	17.11	17.12	17.10
high eff gas boiler	17.97	17.93	17.99

COOLING	Office	Retail	Hospital
reference case = gas boiler, electric cooling			
gas-fired absorption	1.92	1.68	1.71
gas eng chlr	4.60	4.72	1.61
gas eng chlr w/hr	5.86	5.41	-3.14
cogen w/o abs - thrml trk	3.09	1.52	5.34
cogen w/abs - thrml trk	2.96	1.79	5.06
cogen w/o abs - elect trk	4.39	3.39	4.81
cogen w/abs - elect trk	4.27	3.48	4.74

Table 4.5. NMGas Fuel-Switching Results - High Elec Avd Costs

Breakeven Gas Price ($/DTh)

Packaged Rooftop HVAC

	Office	Retail	Supermkt	Restaur	Warehse
reference case = electric resistance heating, electric cooling					
gas heat	11.59	16.15	13.48	13.90	9.24
dessicant	29.59	65.60	10.56	15.74	25.31
gas eng cool	11.50	13.66	11.90	12.18	9.40
reference case = electric air source heat pump					
gas heat	10.23	10.88	10.02	9.39	6.54
dessicant	26.25	38.49	7.17	10.27	9.69
gas eng cool	10.49	9.39	8.90	8.14	7.06
reference case = gas heating, electric cooling					
dessicant	-3.07	-0.58	-5.98	-9.88	1.07
gas eng cool	15.63	7.89	7.43	4.74	18.94

Central HVAC

HEATING	Office	Retail	Hospital
reference case = electric boiler, electric cooling			
std eff gas boiler	18.99	18.99	18.98
high eff gas boiler	19.96	19.92	19.97

COOLING	Office	Retail	Hospital
reference case = gas boiler, electric cooling			
gas-fired absorption	2.16	1.90	2.75
gas eng chlr	5.04	5.13	2.04
gas eng chlr w/hr	6.56	6.10	-2.39
cogen w/o abs - thrml trk	3.88	2.31	6.18
cogen w/abs - thrml trk	3.77	2.60	5.86
cogen w/o abs - elect trk	4.93	3.83	5.39
cogen w/abs - elect trk	4.81	3.93	5.33

5. Evaluation of NMGas End-Use Data

End use data are the foundation upon which any evaluation of the potential for energy efficiency or the economics of fuel-switching must rest. In this section, we review the types of uncertainties that our reliance on these data has created. We also comment directly on the three main sources of Niagara Mohawk data relied on most heavily, the NMPC CDEMS forecasting input files (Edmundson 1993), the HBRS survey (HRBS 1992), and the Xenergy survey (Xenergy 1988).

It is useful to distinguish three types of uncertainties underlying our analysis: 1) the cost and performance of energy efficiency and fuel-switching technologies; 2) the economic measure of the worth of the measures (roughly, gas avoided costs); and 3) the generalizability of the performance of individual technologies to the population of NMGas commercial buildings

With respect to the first type of uncertainty, we have systematically assessed a range of uncertainties in the cost and performance of the energy efficiency and gas fuel-switching technologies as an integral part of our analysis. The assessments took the form of sensitivity analyses of the costs of the technologies (which can also be expressed as sensitivities regarding the performance of the technologies). The sensitivity cases confirmed that our findings were, for the most part, quite robust.

The appropriate measurement and likely trajectory of gas avoided costs is currently one of the most daunting challenges for gas demand-side planning. We have addressed uncertainties in gas avoided costs in two ways. First, in discussing cost-effectiveness, we have relied on a range of gas avoided costs, developed from NMGas data. Second, in examining gas fuel-switching, we made gas avoided costs a study parameter; all results were expressed relative to a gas breakeven price.

The evaluation of energy efficiency potential was based on an extrapolation of individual results to the stock. The extrapolation was based on several types of data drawn from three primary Niagara Mohawk data sources. Before turning to a review of these sources, individually, it is useful to frame our discussion in a larger perspective.

Review of NMGas commercial sales data suggest that there are significant outstanding reconciliation issues. The sales profile presented in Section 3 leads to annual NMGas commercial sector sales of about 40,000 thousand DTh. Yet, sales data provided by NMGas (Hamilton 1993b) suggest that annual sales to the commercial sector are more than twice this figure (81,000 thousand DTh). In light of the significance of these differences, which can not be resolved by simple fixes to the data, we have chosen to present our findings (in Section 3) in an internally consistent fashion. However, it seems to us that there are likely significant, basic definitional differences between the data developed for NMPC for forecasting commercial sector gas loads and that emerging from the NMGas rate department. Review and reconciliation of these differences represents an important first step in aligning NMGas market planning and rate activities.

In what follows, we turn to individual review of the major NMPC data sources used in the study. It appears unlikely that resolution of these data issues would be sufficient to address the more fundamental definitional issues just described.

The CDEMS forecasting input data provided three critical inputs to the current study, floor space, gas fuel saturation (for cooking and miscellaneous), and gas EUI. Of these three, we have specific concerns regarding our derivation of NMGas commercial sector floor space from these data, the size of the miscellaneous sector, and the internal consistency of the gas EUIs across end uses.

NMGas commercial sector floor space was estimated as the difference between NMPC electric service territory floor space and that developed by ACEEE previously for NFG (based on NFG market research). Since the NFG data do not report floor space directly, a derivation was made. For some building types (for example, restaurants and warehouses), we believe the derivations may be in error. This issue, however, belies a more important one regarding the size of the miscellaneous sector.

The CDEMS floor space data indicate that the "miscellaneous" building type is the largest single commercial building type in the NMPC service territory. Our derivation for the NMGas service territory does not alter this finding. When multiplied by gas fuel saturation and gas EUI, this building type becomes the single largest single gas consumer in NMGas service territory, accounting for more sales than office, retail, and restaurant, combined. Since this building type was not examined with a unique prototype, energy efficiency results for this building type were based on extrapolations from the other building types, which were considered explicitly. On the one hand, the extrapolation is probably justified because it is likely, on closer examination, that most buildings classified as miscellaneous are built and operated identically to the building types examined. On the other hand, this conjecture should be confirmed, and, where appropriate, buildings re-classified for future analyses.

We are also concerned about the gas EUIs taken from the CDEMS forecasting input files. In point of fact, the gas EUIs of direct interest to us (space heating, water heating, and cooking) are not at issue since they are reasonably consistent with others developed for New York and the author's own experience with analyses and development of forecasting EUIs. (Although we do believe that continued refinement to and calibration with actual gas sales is warranted for these gas EUIs.) Instead, we are more concerned about the magnitude of the miscellaneous gas EUI for offices and retail. Since, by definition, the saturation of the miscellaneous gas end use is 100 percent, the effect of these EUIs is that 22 and 35 percent of office and retail building gas consumption, respectively, is accounted for by an end use about which we have little or no information. Overall, for all building types taken together, the miscellaneous end use accounts for 30 percent of NMGas sales. As indicated in Section 2, this represents 30 percent of NMGas sales for which no energy efficiency measures were considered. We believe additional research should be devoted to confirming the magnitude of miscellaneous gas use and better characterizing its constituents to determine whether additional opportunities for gas energy efficiency exist.

The saturation of gas space heating and water heating for the NMGas service territory was taken from the HBRS survey. As indicated in Section 2, we understand that these data are currently under review by HBRS and may be modified. In this regard, it should be noted that the NFG gas fuel saturations, the HBRS-developed saturations for NMGas, and the NM CDEMS saturations for the entire electric service territory (which includes both NFG and NMGas) are, to some extent, inconsistent with one another. It is not, however, appropriate to conclude that any one of the three sources is less reliable than the other two without a systematic evaluation of the methods and data used by each source to derive the saturations.

The primary source of information for the development of building prototypes and the determination of the existing penetration of energy efficiency measures was the Xenergy survey. Although we have not reviewed the survey instruments, the scope of and manner of presentation of information in Xenergy survey was much more useful than that of the HBRS survey in providing information that could be readily used to develop prototype building characteristics and to assess the existing penetration of energy efficiency measures. For example, the Xenergy survey allowed one to determine the percent of buildings whose heating was supplied by a particular type of equipment. The HBRS survey, on the other hand, although it asked about the same types of equipment, did not allow us to determine a relative saturation of these types of equipment due to the form in which information was presented. Similarly, the Xenergy survey presented far more detail on structural features of the buildings, HVAC system features, and energy efficiency measures.

Both the HBRS and Xenergy surveys, however, could be improved by gathering additional information. First, it should be possible to design a survey to address some of the floor space and fuel saturation issues identified previously. Second, commercial building energy use is largely driven by building operating schedules. Additional effort should be made to collect more detailed operating information. For example, separate weekday, weekend (and, possibly, seasonal) schedules for occupancy, lighting, and HVAC should be collected. Third, more detailed information on the adoption of energy efficiency measures should be collected. The Xenergy survey was the only source of this information and often required additional clarification and interpretation in order to be usable. For example, no information was collected on the use of high efficiency heating equipment.

6. References

Edmundson, P. 1993. telefax of NMPC CDEMS forecasting input database. Niagara Mohawk Power Corporation, Syracuse, NY. 20 Jan.

Hamilton, W. 1993a. telefax of EMA Gas Marginal Costs for NMGas. Niagara Mohawk Power Corporation, Syracuse, NY. 22 Jan.

Hamilton, W. 1993b. telefax of NMGas commercial sector sales. Niagara Mohawk Power Corporation, Syracuse, NY. 8 Feb.

HBRS. 1992. *Volume 1: Findings from the 1990 Commercial Market Customer Survey for Customers in the Natural Gas Service Area.* HBRS, Madison, WI.

Nadel, S., Eto, J., Kelly, M., and Jordan, J. 1992. *Gas DSM and Fuel-Switching: Opportunities and Experiences.* American Council for an Energy-Efficient Economy, Washington, DC

Xenergy. 1988. *Characterization of Niagara Mohawk Power Corporation's Commercial Class: Equipment Saturations, Conservation Measures, and Decision Making Profile.* Xenergy, Oakland, CA.

Appendix A. **S. Nadel, J. Eto, M. Kelley, J. Jordan. "Gas DSM and Fuel-Switching: Opportunities and Experiences." American Council for an Energy-Efficient Economy. February, 1993**

Chapter 4. The Potential for Commercial Gas Energy Efficiency

and

Chapter 5. The Economics of Commercial Gas Fuel-Switching for Space Heating and Cooling

Chapter 4

THE POTENTIAL FOR COMMERCIAL GAS ENERGY EFFICIENCY

This chapter describes the technical and economic potential for gas space heating, water heating, and cooking energy-efficiency measures in the LILCo, BUG, and NFG commercial sectors. It begins by describing the prototypical buildings used to assess the potential for efficiency improvements in the use of gas for space heating, including calibrating these prototypes with information on end-use energy consumption by commercial buildings in New York State[1]. Next, energy-efficiency measures are described. Following these descriptions, the results of the analysis are presented separately by utility service territory. The presentation of results is followed by a limited review of existing measured data on the energy performance of retrofits in commercial buildings.

METHODOLOGY

A two-part methodology was used to estimate the technical and economic potential for gas energy efficiency in the commercial sector. For those measures affecting space heating energy use, detailed simulations of six prototypical buildings were performed using the DOE-2 building energy-analysis program (the DOE-2 program is the building energy analysis industry's reference hourly energy simulation model). For those measures affecting gas water heating and cooking, two spreadsheet models were developed.

For the DOE-2 analysis of gas space heating energy-efficiency measures, the absence of comparably detailed data on building characteristics and operation for each of the three gas utility service territories led to our developing a common set of prototypical building descriptions. Differences in end-use energy use were estimated by simulating the prototypes

[1] The prototypical buildings developed for analysis of gas space heating energy-efficiency measures are also used to assess the cost-effectiveness of fuel-switching (Chapter 5).

separately for an upstate and downstate climate. The upstate climate was represented using hourly weather data typical for Buffalo; the downstate climate was represented using typical hourly weather data for New York City.

Each prototype was calibrated separately for upstate and downstate conditions using utility-specific end-use data developed for the New York Power Pool (NYPP).

Following calibration, the impacts of gas space heating energy-efficiency measures were estimated using additional simulations. Interactive effects were captured by sequentially simulating the cumulative effects of the energy-efficiency measures. That is, the order of simulation was designed to follow the approximate order of decreasing cost-effectiveness (the most cost-effective measures were simulated first; the least cost-effective measures were simulated last, assuming the presence of the more cost-effective measures). Through this process interactive effects between measures were captured automatically and in the appropriate order. The cost of saved gas for each measure and building type was then calculated using measure cost and lifetime information and the results of the energy simulations. For the remaining building types (i.e., those not represented by six prototypes), we make a simple extrapolation of our results from the detailed analysis of the prototypes.

For the analysis of gas water heating and cooking energy efficiency measures, two spreadsheet models were developed. For these analyses, the energy impacts of the measures were estimated by applying savings fractions from engineering calculations directly to the energy-use estimates developed for the NYPP for each utility service territory. As with the analysis of gas space-heating measures, the cost-effectiveness of the gas water heating and cooking energy-efficiency measures is reported using the cost of saved gas.

Commercial Building Types

The number and types of buildings selected for analysis were intended to ensure that the results could be reliably extrapolated to the population of commercial buildings in each of the gas utility service territories. Based on a review of end-use information developed for the NYPP for forecasting, six commercial building types were selected for detailed analysis: office, retail, hospital, supermarket, restaurant, and warehouse. For the gas space-heating analysis, which involved DOE-2 simulations, two additional prototypes for the office and retail building types were analyzed to capture differences in energy use between buildings with central compared to packaged HVAC equipment. Taken together, the forecasting data imply that the gas consumption of these six building types represents 87, 78, and 63 percent of total commercial sector gas consumption in the LILCo, BUG, and NFG service territories, respectively (see Table 4-1).[2]

The forecasting data used in this analysis (floorspace, end-use fuel saturation, and energy-use intensity), and presented in Table 4-1, were developed primarily by J. Jackson for the NYPP (Jackson 1992a and Jackson 1992b). These data, however, were developed only for New York State *electric* utility service territories. For LILCo, the gas and electric service territories were assumed to be identical. For NFG, the floorspace and fuel saturation estimates were developed in consultation with NFG staff (Pijacki 1992b, Narayannan 1992), but the Energy Use Intensities or EUIs (expressed in kBtu/sqft.yr) of end-uses by fuel type were assumed equal to the NYPP estimate for Niagara Mohawk Power Corporation (NMPC). For BUG, floorspace by building type was derived from information supplied by Consolidated Edison (ConEd) on floorspace by borough (Griffo 1991). BUG saturations were developed by ACEEE, after discussions with New York State Energy Office forecasting staff (Bowman 1992). However, as with NFG, the EUIs of end-uses by fuel type for the BUG service territory were assumed equal to those developed for NYPP for the ConEd service territory.

[2] In reviewing the percentages of total commercial sector gas consumption by the six building types analyzed in this study, it is useful to note that the miscellaneous building category represents 6,14, and 24 percent of total commercial sector gas consumption for LILCo, BUG and NFG, respectively. In other words, with the exception of this extremely heterogeneous building type for which there is little comprehensive information on building or operating characteristics, only 7, 8, and 13 percent of total commercial sector gas consumption is unaddressed by the prototypes for the LILCo, BUG, and NFG service territories, respectively. The unaddressed categories include schools, colleges, and lodging, in addition to the miscellaneous category of commercial customers.

Table 4-1. Commercial Sector Sales Profile

	Office	Retail	Health	Supermkt	Restrnt	Warehse	Source
Fl. Area (mil. sf)							
LILCo	205.4	96.7	28.8	15.2	14.0	25.3	Jackson 1992b
NFG	67.7	22.3	17.8	13.5	2.3	42.3	NFG 1992
BUG	91.5	63.0	32.4	14.6	12.3	60.6	Con Ed 1991, ACEEE
Fuel Saturation %							
LILCo							Jackson
sp heat	45.8	48.7	25.0	42.5	50.3	40.4	1992b
a/c	2.5	0.3	2.9	0.0	0.0	1.1	
wt heat	20.7	34.8	19.0	35.9	54.6	21.3	
cooking	8.1	4.2	12.8	15.0	48.6	0.7	
misc	100.0	100.0	100.0	100.0	100.0	100.0	
NFG							
sp heat	94.0	80.0	94.0	84.0	84.0	78.0	NFG 1992,
a/c	0.0	0.0	0.0	0.0	0.0	0.0	Jackson
wt heat	72.0	62.0	85.0	80.0	80.0	64.0	1992b
cooking	86.0	25.0	48.0	90.0	90.0	100.0	
misc	100.0	100.0	100.0	100.0	100.0	100.0	
BUG							
sp heat	50.0	62.5	40.9	87.8	69.6	62.5	Jackson
a/c	0.9	0.0	17.4	0.0	0.0	0.0	1992b,
wt heat	28.5	76.2	42.0	41.5	65.0	76.2	ACEEE
cooking	8.1	4.2	12.8	15.0	48.6	0.7	
misc	100.0	100.0	100.0	100.0	100.0	100.0	
EUI (kBtu/sf)							
LILCo	59.6	55.6	69.4	104.7	119.4	76.6	Jackson
sp heat	24.0	27.1	62.7	37.0	45.2	26.0	1992a
a/c	6.7	5.9	15.2	14.7	41.0	1.1	
wt heat	9.0	11.9	12.8	58.5	125.3	6.6	
cooking	0.2	2.7	1.1	3.1	3.6	0.7	
misc							
NFG (=NMPC)							
sp heat	77.4	66.7	121.3	116.8	107.3	14.1	Jackson
a/c	0.0	0.0	0.0	0.0	0.0	0.0	1992a
wt heat	6.7	5.9	15.2	14.7	41.0	1.1	
cooking	9.0	11.9	12.8	58.5	125.3	6.6	
misc	0.2	2.7	1.1	3.1	3.6	0.7	
BUG (ConEd)							
sp heat	37.8	50.9	117.7	51.2	70.4	16.8	Jackson
a/c	30.2	15.5	72.7	26.4	36.7	7.8	1992a
wt heat	6.7	5.9	15.2	14.7	41.0	1.1	
cooking	9.0	11.9	12.8	58.5	125.3	6.6	
misc	0.2	2.7	1.1	3.1	3.6	0.7	
Total Gas Consumption (% of Total Commercial Gas Sales)							6 Bldg. types
LILCo	39	20	5	6	13	5	87
NFG	32	8	13	3	3	4	63
BUG	15	19	17	7	13	6	78

Prototype Simulation with DOE-2

For the analysis of gas space heating energy-efficiency measures, detailed prototypical buildings were developed for simulation with the DOE-2 building energy analysis program. The prototypes used in this study were based on earlier prototypes developed by the Lawrence Berkeley Laboratory (LBL). All but the warehouse prototype were originally developed and calibrated to be broadly representative of buildings in the Northeast region, as defined by the Energy Information Administration (EIA) Commercial Buildings Energy Consumption Survey (Huang, et. al. 1991). The warehouse prototype was originally developed for Southern California (Akbari, et. al. 1989). For this present study, the most important features of the prototypes (including the warehouse) were modified using data unique for the specific New York State utility service areas.[3] Finally, the calibration of each of the prototypes (leading to additional re-specification of the building descriptions) was done using end-use energy-use information unique in each service territory.

The prototypes were specified using several modeling conventions that may initially, seem un-natural. These conventions were developed to create an accurate thermodynamic model for prototype energy performance, but may result in building descriptions thar are architecturally unrealistic. For example, the number of distinct HVAC zones was reduced wherever possible. Zone floor areas were expressed as a percentage of the total floor area of the building, as were the numbers of exterior walls, windows, and interior walls adjoining other zones. Instead of developing arbitrary building geometries, average aspect ratios (exterior wall length to width ratios) and surface area-to-volume ratios were defined based on reviewing typical buildings. Wall area was further divided into attached or enclosed exterior and free-standing exterior walls. The total free-standing exterior wall area for each zone was then equally distributed in four directions to avoid directional bias. Finally, envelope thermal integrity features such as roof and

[3] Specific prototype building characteristics will sometimes differ considerably from those now required by New York State building codes or observed in current building practice. The reason is that the prototypes are intended to be broadly representative of the entire stock of New York State buildings, which may consist of buildings that span many generations of building construction and practices. Current building practices and applicable codes affect only the most recent vintages of buildings within the stock.

wall insulation, and window R-values and shading coefficients were modeled calculating a saturation-weighted measure for the entire building component. For example, if 50 percent of a given building type has R-9 roof insulation, the prototype was modeled with the entire roof having an insulation value equivalent to having R-9 insulation for 50 percent of the roof area and R-0 insulation for the remaining area, resulting in an un-insulated roof R-value of 4.

Two main sources of utility-specific data were used to update inputs from the original LBL prototypes. The first was Niagara Mohawk's commercial sector characterization (Xenergy 1988). The second was LILCo's commercial building equipment inventory (Xenergy 1990). Wherever possible, information from these two studies was used to replace inputs from the original LBL prototypes.

The Niagara Mohawk commercial sector characterization reports several important physical and operating characteristics for commercial buildings. The following information from the Niagara Mohawk report replaced characteristics in the original LBL prototypes:

whether the building is free-standing, attached, or enclosed;
number of stories;
presence of ceiling insulation;
presence of wall insulation;
window to wall ratio;
window type (number of panes and if treated);
lighting equipment intensity (W/sqft);
saturation of packaged versus central HVAC equipment (affects only office and retail prototype).

The Niagara Mohawk data often reported categorical features; that is, categories indicating the presence or absence of a feature (e.g., does the building have wall insulation?), but, if present, not the degree (e.g., the amount of insulation). Categorical information was converted by assigning mean values to categories and calculating a weighted average. For example, the percent of buildings reporting wall insulation is multiplied by the minimum wall insulation called for by the New York State energy code (R-9) and a resulting, average R-value is estimated.

The LILCo commercial building equipment inventory provided information on the saturation of packaged versus central HVAC equipment.

Review of both the NMPC and LILCo data confirmed the presence of substantial numbers of packaged and central HVAC systems in office and retail buildings (i.e., central HVAC systems in excess of 15 percent of the stock). Accordingly, two prototypes were developed for these building types, each with identical physical and operating characteristics but with different HVAC systems. A combination of central HVAC systems were modeled for the hospital and packaged HVAC systems were modeled for the remaining building types (supermarket, restaurant, and warehouse).[4]

Two additional sources of information were used to modify the original LBL prototypes. The first was direction from the review committee for the project, which recommended that the office building prototype be a two-story building with a floor area of 75,000 square feet, and that the retail building prototype be a single-story building with 5,000 square feet of floor area.

The second was modifications that arose from calibrating the prototypes to existing EUIs. Lighting and miscellaneous equipment energy-use intensities (i.e., watts per square foot) were adjusted to ensure calibration with existing EUIs.[5] In addition, calibration to existing heating, cooling, and ventilation EUIs resulted in some re-specification of HVAC design and control characteristics from those used in the original LBL prototypes. In general, these characteristics (such as design ventilation rate or temperature control strategy) are rarely reported in any

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[4] Other HVAC systems were also documented in the NMPC and LILCO survey data, but represented a much smaller proportion of the stock than central and packaged HVAC systems. Through our calibrations, we are implicitly assuming that the energy use of these non-explicitly represented systems is captured by the energy performance of the prototypes.

[5] The original values from the Niagara Mohawk data are also specified in Tables 4-2 to 4-7 for comparison.

survey. [6]

The prototype features influencing heating and cooling energy use are summarized in six separate tables, 4-2 to 4-7, one for each prototype. The hospital and supermarket have the most complicated zoning; five distinct building functions were specified and zoned separately. Other building types have multiple zones intended primarily to reflect typical HVAC zoning practices (e.g., core versus perimeter zones) rather than functional differences between zones.

Calibration of Prototypes to End-Use EUIs

The original characteristics of the prototype buildings were modified by extensive calibration efforts to ensure that the analysis of energy-efficiency and fuel-switching measures accurately reflected their potential for New York State. The data used in the calibrations were end-use energy-use intensities or EUIs expressed in kWh/sqft (for electric end uses) or kBtu/sqft (for gas end uses).[7]

As described previously, separate EUIs for each electric service territory in New York were developed by J. Jackson for the NYPP (Jackson 1992a). The EUIs were based on work performed originally by Xenergy, but include additional adjustments, primarily to gas space heat, required for reconciliation with utility records on actual gas sales.

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[6] In the case of minimum outside air ventilation, for example, two issues are being addressed. First, as noted previously, the prototypes are intended to be broadly representative of all generations of New York commercial buildings. Hence, current industry practice (e.g., ASHRAE Std. 62-1989) does not strictly apply. Second, to the extent these practices do apply, actual building occupancies (as specified for the prototypes) are typically lower than those used in design outside air ventilation calculations, resulting in apparently higher outside air ventilation rates on a per person basis than might be recommended in Standards.

[7] Each building is assumed to be heated with natural gas and cooled with electricity. The actual saturations for these fuels, which are required to extrapolate the simulation results to buildings within a given service territory are treated separately.

Table 4-2. Office Prototype Characteristics.

Characteristic	Value	Source/Comment
Size (sqft)	75,000	review comm.
Floors	2	review comm.
No. of Exterior Walls - Height	3.3 - 10 ft	NMPC (Xenergy 1988)
Wall Insulation (R-value)	0.8	NMPC (Xenergy 1988)
Ceiling Insulation (R-value)	2.6	NMPC (Xenergy 1988)
Window/Wall Ratio	0.24	NMPC (Xenergy 1988)
Window Conductance	0.86	NMPC (Xenergy 1988)
Weekday Start/Stop	7 am - 6 pm	Huang 1988
Weekend Start/Stop	8 am - 12 pm	Huang 1988
Occupancy (sqft/person)	420	Huang 1988
Lighting Intensity (watt/sqft)	1.7	calibration (NMPC = 1.8)
Misc. Eqp. Intensity (watt/sqft)	1.1	calibration
Heating Setpoint (F)	72	calibration
Cooling Setpoint (F)	74	calibration
HVAC Zoning	4 perimeter; 1 core	Huang 1988
HVAC System Type	1 Reheat Fan System or 5 Package Single Zones	Huang 1988
Design Air (CFM/sqft)	0.7	calibration
Min. Outside Air (CFM/person)	20/40	calibration
Central Plant	2 Hot-Water Boilers; 2 Hermetic Centrifugal Chillers w/cooling tower	Huang 1988

Table 4-3. Retail Prototype Characteristics.

Chacteristic	Value	Source/Comment
Size (sqft)	5,000	review comm.
Floors	1	review comm.
No. of Exterior Walls - (Height)	3.2 (15 ft)	NMPC (Xenergy 1988)
Wall Insulation (R-value)	0.9	NMPC (Xenergy 1988)
Ceiling Insulation (R-value)	3.2	NMPC (Xenergy 1988)
Window/Wall Ratio	0.16	NMPC (Xenergy 1988)
Window Conductance	1.13	NMPC (Xenergy 1988)
Weekday Start/Stop	9 am - 9 pm	Huang 1988
Weekend Start/Stop	11 am - 6 pm	Huang 1988
Occupancy (sqft/person)	135	Huang 1988
Lighting Intensity (watt/sqft)	1.1	calibration (NMPC = 1.8)
Misc. Eqp. Intensity (watt/sqft)	0.6	calibration
Heating Setpoint (F)	68	calibration
Cooling Setpoint (F)	72	calibration
HVAC Zoning	1 zone	Huang 1988
HVAC System Type	1 Reheat Fan System or 1 Package Single Zone	Huang 1988
Design Air (CFM/sqft)	1.0	calibration
Min. Outside Air (CFM/person)	10	calibration
Central Plant	2 Hot-Water Boilers; 2 Hermetic Centrifugal Chillers w/cooling tower	Huang 1988

Table 4-4. Hospital Prototype Characteristics.

Chacteristic	Value	Source/Comment
Size (sqft)	386,900	Huang 1988
Floors	6	Huang 1988
No. of Exterior Walls - (Height)	3.9 (10 ft)	NMPC (Xenergy 1988)
Wall Insulation (R-value)	0.8	NMPC (Xenergy 1988)
Ceiling Insulation (R-value)	6.1	NMPC (Xenergy 1988)
Window/Wall Ratio	0.27	NMPC (Xenergy 1988)
Window Conductance	0.93	NMPC (Xenergy 1988)
Weekday Start/Stop	24 hour operation	Huang 1988
Weekend Start/Stop	24 hour operation	Huang 1988
Occupancy (sqft/person)	150 - 700	Huang 1988
Lighting Intensity (watt/sqft)	0.4 - 1.0	calibration (NMPC = 1.8)
Misc. Eqp. Intensity (watt/sqft)	0.0 - 4.1	calibration
Heating Setpoint (F)	70	calibration
Cooling Setpoint (F)	74	calibration
HVAC Zoning	Perimeter, Core/Public & Hallway, Kitchen, Clinic	Huang 1988
HVAC System Type (follows order of zones)	Four-pipe fan coil, Reheat fan system, Reheat fan system, Dual-duct system	Huang 1988
Design Air (AC/hr)	2.5 - 9	calibration
Min. Outside Air (%)	50 - 100	calibration
Central Plant	2 Hot-Water Boilers; 2 Hermetic Centrifugal Chillers w/cooling tower	Huang 1988

Table 4-5. Supermarket Prototype Characteristics.

Chacteristic	Value	Source/Comment
Size (sqft)	21,300	Huang 1988
Floors	1	Huang 1988
No. of Exterior Walls - (Height)	2.8 (20 ft)	NMPC (Xenergy 1988)
Wall Insulation (R-value)	0.3	NMPC (Xenergy 1988)
Ceiling Insulation (R-value)	1.0	NMPC (Xenergy 1988)
Window/Wall Ratio	0.14	NMPC (Xenergy 1988)
Window Conductance	0.93	NMPC (Xenergy 1988)
Weekday Start/Stop	6 am - 11 pm	Huang 1988
Weekend Start/Stop	6 am - 11 pm	Huang 1988
Occupancy (sqft/person)	100	Huang 1988
Lighting Intensity (watt/sqft)	1.8	calibration (NMPC = 1.9)
Misc. Eqp. Intensity (watt/sqft)	0.6 - 10.0	calibration
Heating Setpoint (F)	70	calibration
Cooling Setpoint (F)	70	calibration
HVAC Zoning	Office, Bakery, Deli, Dry-storage, Sales	Huang 1988
HVAC System Type	5 package single zone	Huang 1988
Design Air (CFM/sqft)	1.0	calibration
Min. Outside Air (CFM/person)	50	calibration
Central Plant	n/a	

Table 4-6. Restaurant Prototype Characteristics.

Chacteristic	Value	Source/Comment
Size (sqft)	3,084	Huang 1988
Floors	1	Huang 1988
No. of Exterior Walls - (Height)	3.4 (10 ft)	NMPC (Xenergy 1988)
Wall Insulation (R-value)	1.0	NMPC (Xenergy 1988)
Ceiling Insulation (R-value)	2.9	NMPC (Xenergy 1988)
Window/Wall Ratio	0.16	NMPC (Xenergy 1988)
Window Conductance	0.97	NMPC (Xenergy 1988)
Weekday Start/Stop	7 am - 12 am	Huang 1988
Weekend Start/Stop	7 am - 12 am	Huang 1988
Occupancy (sqft/person)	50	Huang 1988
Lighting Intensity (watt/sqft)	0.8	calibration (NMPC = 1.6)
Misc. Eqp. Intensity (watt/sqft)	0.0 - 9.0	calibration
Heating Setpoint (F)	65	calibration
Cooling Setpoint (F)	75	calibration
HVAC Zoning	Kitchen & Dinning	Huang 1988
HVAC System Type	2 package single zone	Huang 1988
Design Air (CFM/sqft)	0.7	calibration
Min. Outside Air (CFM/person)	20	calibration
Central Plant	n/a	

Table 4-7. Warehouse Prototype Characteristics.

Characteristic	Value	Source/Comment
Size (sqft)	25,700	Akbari 1989
Floors	1	Akbari 1989
No. of Exterior Walls - (Height)	3.8 (15 ft)	NMPC (Xenergy 1988)
Wall Insulation (R-value)	0.3	NMPC (Xenergy 1988)
Ceiling Insulation (R-value)	5.3	NMPC (Xenergy 1988)
Window/Wall Ratio	0.21	NMPC (Xenergy 1988)
Window Conductance	1.04	NMPC (Xenergy 1988)
Weekday Start/Stop	9 am - 5 pm	Akbari 1989
Weekend Start/Stop	11 am - 5 pm	Akbari 1989
Occupancy (sqft/person)	1370	Akbari 1989
Lighting Intensity (watt/sqft)	0.7	calibration (NMPC = 1.8)
Misc. Eqp. Intensity (watt/sqft)	0.5	calibration
Heating Setpoint (F)	68	calibration
Cooling Setpoint (F)	70	calibration
HVAC Zoning	1 zone	Akbari 1989
HVAC System Type	1 package single zone	Akbari 1989
Design Air (CFM/sqft)	1.0	calibration
Min. Outside Air (CFM/person)	50	calibration
Central Plant	n/a	

The following assignments of electric service territory EUIs were made in order to calibrate upstate and downstate prototypes. The upstate prototype (used for NFG) is calibrated to the EUIs developed for the NMPC service territory. The downstate prototype (used for LILCo and BUG) is calibrated to the simple average of the EUIs developed for the ConEd and LILCo service territories. See Table 4-1 for the original EUIs.

The results of the calibrations are presented in Table 4-8 which includes information on the calibration to EUIs for electric ventilation, lighting, and miscellaneous (e.g. office information processing equipment), and to gas water heating. Calibration to the EUIs for electric lighting and miscellaneous is important because these end uses contribute to internal gains, that in turn affect space heating and cooling-energy-use. Ventilation is related to space heating and cooling in an even more direct fashion since air is the primary means for transporting mechanical heating and cooling into and out of buildings.

Table 4-8 indicates reasonable overall but imperfect individual calibration to data currently being used by the NYPP. Since calibration for electric lighting and miscellaneous, and gas water heating EUIs result from direct modifications to DOE-2 inputs, excellent calibration results were guaranteed for these end uses. For the space conditioning end uses, except ventilation, acceptable but less precise calibrations were achieved.

The gas space heating EUIs for retail, health, and grocery were within 15 percent of the values used by the NYPP. Both the office EUIs were consistently lower than the NYPP values, i.e., the upstate EUI was higher than the downstate EUI. The restaurant EUIs were within 15 percent; but, in this case, the downstate EUI was lower, while the upstate EUI was higher than the NYPP value. The warehouse EUI was within 15 percent of the downstate NYPP EUI, but significantly higher than the upstate NYPP EUI. Since the upstate NYPP EUI is considerably lower than the downstate NYPP EUI (which is counter to expectations, since upstate New York is colder than downstate), the NYPP EUIs suggest that there are significant structural or operational differences between upstate and downstate warehouses that cannot be captured simply by simulating the same prototype with different weather data.[8]

[8] On the other hand, absent the presence of these differences, it remains an open question, outside the scope of the present study, as to why the NYPP data, themselves, are inconsistent with one another for this end use and building type.

Table 4-8 Calibration Results.

	Downstate			Upstate		
	ACEEE (kBtu/ft2)	**NYPP (kBtu/ft2)**	**(%diff)**	**ACEEE (kBtu/ft2)**	**NYPP (kBtu/ft2)**	**(%diff)**
Office:						
gas heat	44.4	48.7	-9	59.2	77.4	-24
elec cool	9.6	9.9	-3	8.5	9.4	-9
elec vent	11.7	9.2	26	11.8	6.0	98
elec lght	21.4	21.5	-0	21.4	21.5	-0
elec misc	14.9	15.2	-2	15.0	15.2	-1
gas dhw	6.6	6.7	-0	6.6	6.7	-0
Retail:						
gas heat	57.1	53.2	7	73.7	66.7	10
elec cool	9.7	9.1	7	6.4	7.4	-13
elec vent	8.9	5.6	59	8.9	2.7	229
elec lght	16.6	16.6	-0	16.6	16.6	-0
elec misc	7.8	8.0	-3	8.4	8.0	3
gas dhw	5.8	5.9	-1	5.8	5.9	-1
Health:						
gas heat	97.3	93.6	4	131.4	121.3	8
elec cool	14.1	22.1	-36	9.8	5.0	96
elec vent	6.4	11.0	-42	6.5	6.3	3
elec lght	16.1	16.0	1	16.1	16.0	1
elec misc	16.1	16.0	1	15.7	16.0	-2
gas dhw	15.3	15.2	1	15.3	15.2	1

Table 4-8 Calibration Results (continued).

	Downstate			Upstate		
	ACEEE (kBtu/ft2)	**NYPP (kBtu/ft2)**	**(% diff)**	**ACEEE (kBtu/ft2)**	**NYPP (kBtu/ft2)**	**(%diff)**
Grocery:						
gas heat	84.4	78.0	8	134.6	116.8	15
elec cool	11.4	11.7	-3	7.2	9.1	-22
elec vent	19.9	5.6	257	20.4	6.8	201
elec lght	45.1	44.1	2	45.1	44.1	2
elec misc	107.9	113.9	-5	106.9	113.9	-6
gas dhw	14.4	14.7	-2	14.4	14.7	-2
Restaur:						
gas heat	99.0	94.9	4	143.9	107.3	34
elec cool	11.5	14.0	-18	7.1	6.5	9
elec vent	12.1	7.7	57	12.3	2.8	338
elec lght	18.7	19.0	-2	18.7	19.0	-2
elec misc	11.8	11.7	1	11.8	11.7	1
gas dhw	40.5	41.0	-1	40.5	41.0	-1
Warehse:						
gas heat	42.7	46.7	-9	56.7	14.1	304
elec cool	4.5	5.9	-24	2.8	6.2	-54
elec vent	6.1	2.8	122	6.3	1.7	263
elec lght	8.3	8.3	0	8.3	8.3	0
elec misc	6.4	6.2	2	6.4	6.2	2
gas dhw	2.9	2.8	2	2.9	2.8	2

The electric space-cooling EUIs for only office and retail were within 15 percent of the NYPP EUIs. For health and restaurant, due to differences between the upstate and downstate NYPP values (see previous comment regarding warehouse space heating), the prototype EUIs fell in the middle of the range of NYPP EUIs, but in a consistent pattern (i.e., the upstate EUI is higher than the downstate EUI). For the grocery, both upstate and downstate EUIs were lower than the NYPP EUIs, with the upstate EUI significantly lower than the NYPP EUI. For the warehouse, the prototype EUIs were consistently lower than the NYPP EUIs. Since the upstate NYPP EUI for cooling was higher than the downstate EUI, there may be important differences between upstate and downstate warehouses that cannot be captured using only weather data.

The poorest area of calibration was ventilation. For all building types, the prototype EUIs were rarely within 20 percent of the NYPP EUIs. However, concerns regarding the calibration for this end use are mitigated somewhat by two considerations. First, the present study is concerned primarily with the impacts of DSM on gas space heating and of fuel-switching on electric space cooling; ventilation energy use is a secondary concern. Second, conversations with energy analysts confirm that the empirical basis for ventilation EUIs is probably the weakest of all end uses. The end use is often not well-defined and can be difficult to estimate separately from heating and cooling energy use. That is, the poor calibration observed for this end use may be the result of reliance on possibly un-realistically low (and certainly un-verified by, for example, end-use metering) EUIs developed for NYPP.

The cumulative effect of the EUIs developed in the calibration process is summarized in Table 4-9. The Table presents both 1991 commercial sector gas sales for each utility service territory and the gas consumption resulting from the calibrated end-use gas EUIs for the six prototypes, adjusted for saturation, times the floor area represented by each building type (see Table 4-1).

Table 4-9. Reconciliation of Prototype Energy Use to 1991 Commercial Sector Gas Sales.

	1991 Utility Commercial Sector Gas Sales (thousands DTh)	Gas Consumption of Six ACEEE Prototypes (thousands DTh)	Ratio of 1991 Gas Sales to Prototype Gas Consumption
LILCo	14,629	12,068	1.212
BUG	12,208	12,141	1.006
NFG	20,282	12,235	1.658

Total gas consumption by the six prototypes is less than total utility commercial sector gas sales due to several reasons. First and most importantly, gas is consumed in building types other than those for which prototypes were developed (e.g., schools, lodging, and miscellaneous). Second, the calibrated EUIs do not exactly match the EUIs developed for NYPP to forecast gas sales; as mentioned previously, the downstate prototype is calibrated to the simple average of the EUIs developed for LILCo and ConEd.

If we correct for the first factor by using the NYPP EUIs to include building types not explicitly considered in this study, the model results are 8 percent higher, 6 percent higher and 10 percent lower than reported 1991 commercial sector sales by LILCo, BUG, and NFG respectively. This comparison suggests our data are quite consistent with actual utility sales. That is, forecast data are intended to represent typical consumption patterns, whereas 1991 gas sales result from the particular economic and climatic conditions influencing gas use in 1991. Since 1991 was a warm year compared to historical averages (Schultz 1992), lower than average gas sales should result (leading to ACEEE over-estimates of gas sales). Indeed, warmer weather in 1991 appears to be a plausible explanation for ACEEE's over-estimates for LILCo and BUG. The under-estimate for NFG, however, cannot be explained by weather. In this case, we believe the under-estimate results from a combination of errors introduced by the floor areas and EUIs assumed in the analysis. Nevertheless, the cumulative effect of these errors is tolerable (only a 10 percent under-estimate), although we believe that this is a worthy area for future research.

The simple ratio of utility 1991 commercial sector gas sales to the gas consumption of the six prototypes is used to scale the energy efficiency results for the six ACEEE prototypes for the building types for which prototypes were not developed and to calibrate energy efficiency results to 1991 utility commercial sector gas sales.

COMMERCIAL SECTOR ENERGY EFFICIENCY MEASURES

To determine the technical and economic potential for improvements to commercial sector gas energy-efficiency, the energy savings and cost-effectiveness of ten gas space heating, seven gas hot water heating, and five gas cooking energy efficiency measures were evaluated. After defining each measure, the cost of measures and the applicability of the measures to the building types considered is discussed.

Ten gas space-heating energy-efficiency measures were analyzed. The energy effects of each measure were simulated using the DOE-2 building energy analysis program for each applicable building prototype. Interactive effects were treated explicitly by simulating the measures cumulatively in the order of cost-effectiveness. That is, the order of simulation was designed to follow the approximate order of decreasing cost-effectiveness (the most cost-effective measures were simulated first; the least cost-effective measures were simulated last, assuming the presence of the more cost-effective measures). Through this process interactive effects between measures were captured automatically and in the appropriate order.[9] The cost of saved gas for each measure and building type was then calculated using measure cost and lifetime

[9] This procedure follows that used in the residential sector analysis (Chapter 2) with one exception. In the analysis of energy efficiency measures for the residential sector, energy savings from the sum of a package of cost-effective measures are re-allocated among individual measures; the effect is to increase the energy savings attributed to the more expensive measures within the group of cost-effective measures and decrease the savings of the less expensive measures. No such reallocation was performed for the analysis of energy efficiency measures in the commercial sector, primarily because of the difficulty of determining the appropriate threshold for cost-effectiveness. Instead, the savings attributable to each measure are taken directly from the simulations as increments assuming the presence of more cost-effective measures. These savings are referred to as "interactive savings" in the example given of this method in Chapter 2.

information and the results of the energy simulations.

The ten space heating measures were:

1. Reset HVAC Supply Air Temperature ("Reset SA Temp") for central HVAC systems (office, retail, and health) re-sets the temperatures in the main supply air ducts hourly to satisfy heating load of the coldest zone. Operation of central HVAC systems without this measure requires manually setting hot deck temperatures to a high temperature (105 degrees F) to ensure the highest expected load will be met during the heating season. Re-setting this temperature lower on an hourly basis to just meet the actual heating load of the coldest zone results in significant gas heating energy savings.[10] This measure is modeled within DOE-2 using an algorithm that compares, each hour, the heating demands of all zones and the minimum hot deck temperature required to satisfy the highest heating load.

2. Boiler Tune-up ("Boiler Tune") refers to general improvements to gas boilers in central HVAC systems (office, retail, health) to improve combustion efficiency by 5 percent (Zoellick 1992). Examples of these improvements include system balancing, duct sealing, thermostat calibration and checking damper operation. The base level of boiler efficiency used in the calibration is 75 percent. This measure is modeled by re-specification of boiler efficiency input to DOE-2.

3. Time Clocks/Temperature Set-back ("Temp Set-Back") are measures to control more precisely the operating hours of the gas heating system in a building. By lowering space temperatures during non-occupied hours, gas energy use for heating is reduced. The measure is modeled by lowering heating temperature set-points to 55 degrees F during non-business hours. This measure is modeled by re-specification of the hourly schedule of temperature set-points input to DOE-2.

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[10] Due to the interaction of this measure with cooling and ventilation energy, electricity consumption may be increased. The cost of saved gas for this measure was calculated with an additional cost-penalty to account for the increase in electricity use. The penalty was calculated by multiplying the increase in electricity use by the avoided cost of electricity (see Table 1-1). No other measure resulted in an increase in electricity use of more than 2%.

4. HVAC Heat Recovery ("HVAC Heat Rec") recovers heat that would normally be exhausted in the return air of a central HVAC system to preheat supply air. It saves gas by reducing the amount of gas that would otherwise be required to preheat supply air. This measure is modeled within DOE-2 using an algorithm that calculates the amount of recoverable heat available in the return air to be exhausted.

5. Higher-Efficiency Boilers ("Hi-Eff Boiler") are forced draft, four pass firetube boilers with rotary damper, characterized fuel valve, and high velocity gas burner for precise fuel to air mixture and high combustion efficiency. These measures increase boiler efficiency to 85 percent (Zoellick 1992). The efficiency of a standard, forced draft, gas fired, watertube boiler is 80 percent. This measure is modeled by re-specifying boiler efficiency input to DOE-2.

6. Higher-Efficiency Furnaces ("Hi-Eff Furnace") rely on similar advanced designs and control techniques to increase furnace efficiency by 6 percent. The efficiency of a standard furnace is 74 percent. This measure is modeled by re-specification of furnace efficiency input to DOE-2.

7. Double-Pane Windows ("Dbl Pane") reduce heating loads by improving the thermal integrity of windows to a center of glass U-value of 0.53, excluding outside air film coefficient and the window frame. This measure is modeled by re-specifying of the window U-value and shading coefficient input to DOE-2.

8. Low-Emissivity Windows ("Low-E Glass") reduce heating loads by improving the thermal integrity of windows to a center of glass U-value of 0.24, excluding outside air film coefficient and the window frame. This measure is modeled by re-specifying the window U-value and shading coefficient input to DOE-2.

9. Roof Insulation ("Roof Ins") reduces heating loads by improving the thermal integrity of the roof. The measure is modeled by increasing the level of insulation input to DOE-2 to R-19, using either rigid board insulation under built-up roofing or fiberglass insulation under the roof deck.

10. HVAC System Maintenance ("HVAC Maint") refers to general improvements to HVAC distribution systems to reduce wasted gas heat by 5 percent (Zoellick 1992). Examples of these improvements include system balancing, duct sealing, thermostat calibration and checking damper operation. This measure is modeled by re-specifying the base level of either the gas boiler or gas furnace efficiency input to DOE-2.

Seven gas water heating energy-efficiency measures were analyzed based on preliminary engineering estimates developed by Xenergy for this study (Zoellick 1992). The preliminary estimates were re-calibrated to NYPP gas water heating EUIs by service territory. The measures included:

1. Lower DHW Temperature ("Lower Temp") reduces gas use through a one-time reduction of hot water temperature from between 130° and 140° F to 120° F. This measure is modeled by reducing the energy required to heat water from an assumed ground water temperature of 60° F to 120° F instead of 130° or 140° F, and by reducing the energy lost through the walls of the tank due to the lower temperature of water.

2. High-Efficiency Boiler ("Hi-Eff Boiler") is based on a 12-hp pulse combustion gas fired boiler that increases efficiency to 85 percent (Zoellick 1992). The efficiency of a standard, forced draft, gas fired, watertube boiler is 80 percent. This measure is modeled by increasing the overall efficiency of gas boiler in meeting hot water loads and maintaining hot water temperatures in the tank.

3. High-Efficiency Stand-Alone Water Heater ("Hi-Eff Stdaln") is a stand-alone water heater that also includes increased insulation, an intermittent ignition device, and a power burner. It increases overall efficiency to 72 percent compared to the efficiency of standard stand-alone, atmospheric, gas fired water heater of 54 percent (Zoellick 1992). This measure is modeled by increasing the overall efficiency of the standalone water heater in meeting hot water loads and maintaining hot water temperatures in the tank.

4. Boiler Tune-up ("Boiler Tune") refers to general improvements to gas boilers to improve

combustion efficiency by about 5 percent.

5. Tank Insulation ("Tank Ins") increases tank insulation from R-5 to R-12 thereby reducing heat losses through the tank walls in proportion to the increase in R-values.

6. Pipe Insulation ("Pipe Ins") adds pipe insulation to exposed pipe runs nearest the hot water heater or boiler. This measure is modeled by reducing heat losses for an assumed exposed bare pipe run of four feet to that for R-3 insulation over the same exposed area.

7. Auto Temperature Reset ("Auto Reset") uses a time-clock to lower hot water temperatures during off-hours. This measure is modeled by calculating the reduction in tank wall heat loss during off-hours resulting from a lower hot water temperature.

Five gas cooking energy-efficiency measures were analyzed. The analysis was performed with a spreadsheet model developed by ACEEE based on data developed by Lobenstein and Hewett (1992) in a study prepared for Minnegasco. A single analysis was performed for all building types and then extrapolated to each building type using building and service territory specific EUIs. The measures are listed below. All savings estimates come from the Minnegasco study.

1. Standard to Direct Convection Oven ("Std-Dir Conv"). Convection ovens use fans located in the rear of the oven compartment to circulate heated air over and around the food being cooked, accelerating heat absorption. Compared to a conventional oven, gas savings average approximately 50 percent.

2. Indirect to Direct Convection Oven ("Ind-Dir Conv"). Convection ovens come in two configurations -- direct and indirect. Indirect convection ovens circulate air heated from the walls of the oven compartment while direct convection ovens circulate hot flue gases. Direct convection ovens are more efficient because the flue gases they circulate are hotter. Compared to indirect ovens, direct ovens reduce gas use by approximately 30 percent.

3. Catalytic Infrared Fryer ("Cat IR Fry"). Infrared fryers use ceramic plate burners to increase combustion temperatures to 1650° F or higher. Increasing temperatures to these levels creates electromagnetic energy which vibrates the atoms in the absorbing object, in this case the frying oil, causing its temperature to rise. In this way heat is delivered directly to the product, without relying on convective or conductive heat transfer. Relative to conventional fryers,y-e energy use is reduced approximately 35 percent. So-called "catalytic" infrared fryers have improved ceramic plates relative to standard infrared fryers, increasing the energy savings compared to conventional fryers to approximately 43 percent.

4. Infrared Griddle ("IR Griddle"). Infrared griddles operate similarly to infrared fryers, except the griddle plate is heated instead of the frying oil. Relative to conventional griddles, infrared griddles reduce gas use by approximately 27 percent.

5. Power Burner Range ("Pwr BurnR"). Power burners fully mix the gas and combustion air in the burner (as opposed to incomplete mixing when secondary combustion air is drawn from around the burner, as in a conventional burner), reducing energy use approximately 24 percent.

The Cost and Life Expectancy of Commercial Sector Gas Energy Efficiency Measures

In addition to energy use, the lifecycle cost of gas energy-efficiency measures depends on two inputs: the capital and operating (not excluding energy) costs[11] of the measures, and their life expectancy. Cost and life expectancy data were developed based on either the most recent estimates available in the literature or information developed specifically for the New York State region.

Generally speaking, costs are developed for retrofit applications of measures. For the

[11] This analysis assumes that the energy-efficiency measures do not increase non-energy operating costs, such as changes in maintenance costs. The issue of increased or decreased operating costs for the gas energy-efficiency measures is treated implicitly through the sensitivity analysis which examines the impact of higher and lower measure costs on the findings.

measures involving equipment up-grades (to higher efficiency or new technologies) for space heating, water heating, and cooking, however, only incremental costs are considered beyond a base technology. Accordingly, these measures would only be considered at time of replacement, while the remaining measures (all retrofits) could be considered at any time.

Three primary sources of information were used to develop measure costs and lifetimes for the gas energy-efficiency measures. The first was an analysis of commercial sector conservation measures performed for the Bonneville Power Administration (UIC 1988). This source was used extensively to develop cost and lifetime information for the gas space heating energy-efficiency measures. The second was data developed by Xenergy specifically for use in this study (Zoellick 1992). These data were used in the analyses of both several gas space heating measures and all the gas water heating energy efficiency measures. The third was Lobenstein and Hewett (1992), which was used for the analysis of all the gas cooking energy-efficiency measures.

The measure cost and lifetime information developed for each measure and its source is summarized in Tables 4-10 through 4-12 for the gas space heating, water heating, and cooking measures, respectively. To facilitate comparisons, the costs presented are normalized to a common metric, such as $/sqft of floor area, $/kBtuh of heating capacity, or $/unit (in the case of cooking), as appropriate. For the analysis of cost-effectiveness, these costs are then scaled by the specific characteristics of the prototypes examined (i.e., by floor area or by peak heating requirements). Measure lives for cooking are capped at 20 years to allow for equipment change-out during remodeling.

The Applicability of Gas Energy-Efficiency Measures

Two steps determine applying gas energy-efficiency measures to commercial buildings in New York State. The first is to map each measure for appropriate commercial building types and, for these buildings, to determine technical feasibility. The second is to estimate how many commercial buildings there are in each of the three service territories, LILCo, BUG, and NFG.

Table 4-10. Summary of Gas Space Heating Energy-Efficiency Measure Costs and Lifetimes.

Measure	Cost	Units ($1991)	Lifetime	Source/Notes
Reset SA Temp	0.03	$/sqft	11	UIC 1988
Boiler Tune	0.30	$/kBtuh	5	Zoellick 1992; lifetime - eng. judgement
Temp Set-back	0.09	$/sqft	10	UIC 1988
HVAC Heat Rec	0.35	$/sqft	14	UIC 1988
Hi-Eff Boiler	2.00	$/kBtuh	15	Zoellick 1992; incr. cost
Hi-Eff Furnace	1.90	$/kBtuh	15	SRC 1990; incr. cost
Dbl Pane	21.00	$/sqft window	20	Reed 1992b
Low-E Glass	24.40	$/sqft window	20	Reed 1992b
Roof Insulation	0.77	$/sqft roof	20	UIC 1988; retrofit
HVAC Maint - central	0.50	$/sqft	5	Zoellick 1992; lifetime - eng. judgement
HVAC Maint - packaged	0.25	$/sqft	5	Zoellick 1992; lifetime - eng. judgement

Table 4-11. Gas Hot Water Energy-Efficiency Measure Cost, Lifetime.

	1991 Cost	$/unit	Lifetime
Lower Temp	0	tank	20
Hi-Eff Boiler	900.00	boiler	15
Hi-Eff Stdaln	166.00	tank	10
Boiler Tune	300.00	boiler	5
Tank Insulation	5.40	sq ft	10
Pipe Insulation	3.74	ft pipe	10
Auto Reset	71.21	tank	10

Source: Zoellick 1992, UIC 1988.

Table 4-12. Gas Cooking Energy-Efficiency Measure Cost, Performance, Lifetime.

Measure	Cost	Avg. (ccf) Saved	Savings	Lifetime
Std-Dir Convection Oven	$1338	720	50%	20
Ind-Dir Convection Oven	0	282	28	20
Catalytic IR Fryer	1253	674	43	15
IR Griddle	1048	292	27	20
Power-Burner Range	870	248	24	20

Source: Lobenstein and Hewett 1992.

The mapping required by the first step is summarized in Tables 4-13 to 4-15 for the gas space heating, water heating, and cooking measures, respectively. Tables 4-13 and 4-14 calculate applicability as a fraction of the building floor area in the service territory where the measure could be applied. The values were derived from the saturation of measures in the NMPC service territory (Xenergy 1988), which, in the absence of more saturation data for each service territory, was assumed to be identical for all three service territories. The NMPC survey data did not report saturations for high-efficiency gas boilers and furnaces and low-E windows; the existing saturation of the high-efficiency measures is assumed to be ten percent and that for low-E windows is assumed to be zero. Table 4-14 separately reports technical feasibility and existing penetration for gas water-heating measures.

Table 4-15 gives the applicability and technical feasibility of gas cooking energy-efficiency measures in a slightly different format. In this table, applicability and existing penetration is expressed on a technology-specific basis with the assumption that the distribution of cooking technologies is constant across all building types, apparently a reasonable assumption without survey information that would permit a more accurate mapping of specific types of cooking equipment for particular buildings.

The second step is to determine how many commercial buildings have gas space heating, water heating, or cooking in each of the three service territories (LILCo, BUG, and NFG). Table 4-1 (in the Methodology sub-section), summarizes floorspace estimates and end-use fuel saturations for gas space heating, water heating, and cooking for each of the three utility service territories.

As described in the Methodology sub-section, two additional prototypes were developed for the office and retail building types to capture important differences in energy use in central and packaged HVAC systems and the large relative saturations of both system types in these buildings. Table 4-16 presents the results of our analysis of LILCo and NMPC survey data (Xenergy 1988 and Xenergy 1990) which were used to develop relative saturations for these system types for downstate and upstate respectively.

Table 4-13. Applicability of Gas Space Heating Energy-Efficiency Measures to Commercial Building Prototypes (%).

Measure	Office Cnt	Office Pkg	Retail Cnt	Retail Pkg	Hospital	Super-market	Restau-rant	Ware-house
Reset SA Temp	95.4		94.7		87.4			
Boiler Tune	74.8		82.1		0.0			
Temp Set-back	69.6	69.6	73.8	73.8	59.0	83.1	85.7	87.7
HVAC Heat Rec	95.6		99.4		73.0			
Hi-Eff Boiler	90.0		90.0		90.0			
Hi-Eff Furnace		90.0		90.0		90.0	90.0	90.0
Double-Pane	21.0	21.0	37.0	37.0	25.0	27.0	20.0	36.0
Low-E Glass	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Roof Insulation	42.0	42.0	36.0	36.0	13.0	71.0	39.0	18.0
HVAC System Maint. - central	66.2		85.6		43.5			
HVAC System Maint. - packaged		66.2		85.6		86.9	93.8	93.7

Source: Xenergy 1988.

Table 4-14. Gas Hot Water Energy-Efficiency Measure Applicability (%).

Technical Feasibility

	Office	Retail	Hospital	Supermkt	Restrnt	Warehse
Lower Temp	100	100	0	100	0	100
Auto Reset	100	100	98	100	98	100
Pipe Ins	100	100	98	100	98	100
Tank Ins	100	100	98	100	98	100
Boiler Tune	8	1	87	0	2	18
Hi-Eff Boiler	8	1	87	0	2	18
Hi-Eff Stdaln	92	98	12	67	96	81

Existing Penetration

	Office	Retail	Hospital	Supermkt	Restrnt	Warehse
Lower Temp	5.3	2.9	17.3	2.4	8.3	0.0
Auto Reset	3.3	4.2	16.1	4.1	1.7	0.0
Pipe Ins	36.7	17.8	71.0	62.9	13.5	11.3
Tank Ins	12.7	18.5	65.0	7.0	17.7	12.4
Boiler Tune	25.2	17.9	100.0	90.3	12.1	5.7
Hi-Eff Boiler	0.0	0.0	0.0	0.0	0.0	0.0
Hi-Eff Stdaln	0.0	0.0	0.0	0.0	0.0	0.0

Source: Xenergy 1988.

Table 4-15. Gas Cooking Energy-Efficiency Measure Applicability (%).

	Equip. Type as % of Total Cooking	Technical Feasibility	Existing Penetration	Applicability Factor
	(a)	(b)	(c)	(d)
Ind-Dir. Conv. Oven	20	50	38	3
Std-Dir. Conv. Oven	20	60	50	2
Catalytic IR Fryer	19	90	10	15
IR Griddle	20	90	10	16
Power Burner Range	26	23	1	9

Applicability factor = [a]*([b]-[c]).
Source: ACEEE estimates based on Lobenstein and Hewett 1991.

Table 4-16. Relative Saturation of Central and Package HVAC for Office and Retail.

	Downstate (LILCo, BUG)	Upstate (NFG)
Office-central HVAC	0.27	0.67
Office-package HVAC	0.73	0.33
Retail-central HVAC	0.23	0.11
Retail-package HVAC	0.77	0.89

Source: Xenergy 1988, Xenergy 1990.

THE COST-EFFECTIVE TECHNICAL POTENTIAL FOR GAS ENERGY-EFFICIENCY

The results of the simulations or spreadsheet analyses, combined with the cost and lifetime of the measures, adjusted for their applicability, the existing penetration of measures, the fuel saturation of the each end use, and a real discount rate of 5 percent, yield a cost of saved gas (in $/DTh) for each energy-efficiency measure in each building type.

The results are discussed from both a gas utility perspective (represented by an avoided cost for gas) and from a commercial gas customer perspective (represented by the average retail price of gas). Since there is no consensus on gas avoided costs, the results from the gas utility perspective are described with reference to a range of possible avoided costs from $2.50 and $4.00/DTh, which is based on the preliminary estimates of avoided costs for year-round and winter-only energy use, as discussed in Chapter 1, and summarized in Table 1-1. The average gas prices used to evaluate technical potential from a commercial gas customer perspective are $6.00/DTh, $8.50/DTh, and $5.00/DTh for LILCo, BUG, and NFG, respectively, which are based on values in Table 1-2, rounded to the nearest half dollar.

Three sensitivity analyses are also presented. The first reports the cost of saved gas assuming that the cost of the energy-efficiency measures is 25 percent higher than that assumed in the analysis. This case also roughly models the impacts of program costs on measure economics assuming the cost to operate a DSM program is equal to 25 percent of measure costs. The second case considers the impacts on the cost of saved gas assuming that the energy-efficiency measures cost 25 percent less than initially assumed. The third considers the impacts on measure economics of measure costs that are 50 percent higher than in the basecase analysis. Since the cost of saved gas is calculated by dividing measure costs by estimated energy savings, these sensitivities for measure cost correspond to sensitivities of plus 33 percent, minus 20 percent, or minus 33 percent respectively, if applied to energy savings. That is, the sensitivity results presented can be used to assess uncertainties in both the measure cost and energy performance of the energy efficiency measures. The third case is included in the analysis to roughly analyze the combined impacts of program costs with either high measure costs or low measure savings.

For each utility service territory, results are first summarized on an aggregated basis, considering both the various cost-effectiveness thresholds and the various sensitivities considered. Next, the results are summarized by end use and building type, considering only the primary cost assumptions. Finally, the results for individual measures are discussed.

The presentation of detailed results, by measure, follows a common order: The results for each measure are presented in order of increasing cost; measures with the lowest cost are presented first, while those with the highest cost are presented last. The amount of gas that could be saved annually is presented in thousands of decatherms, which is also equal to thousands of MMBtu. Gas savings from the prototype analyses have been adjusted upwards to extrapolate our results to the building types not examined (schools, hotels, and miscellaneous). We also present the cumulative amount of saved gas, expressed as the fraction of total annual gas sales for the commercial sector of each utility. An arbitrary ceiling of $10/DTh is used to limit the number of measures presented in each table.

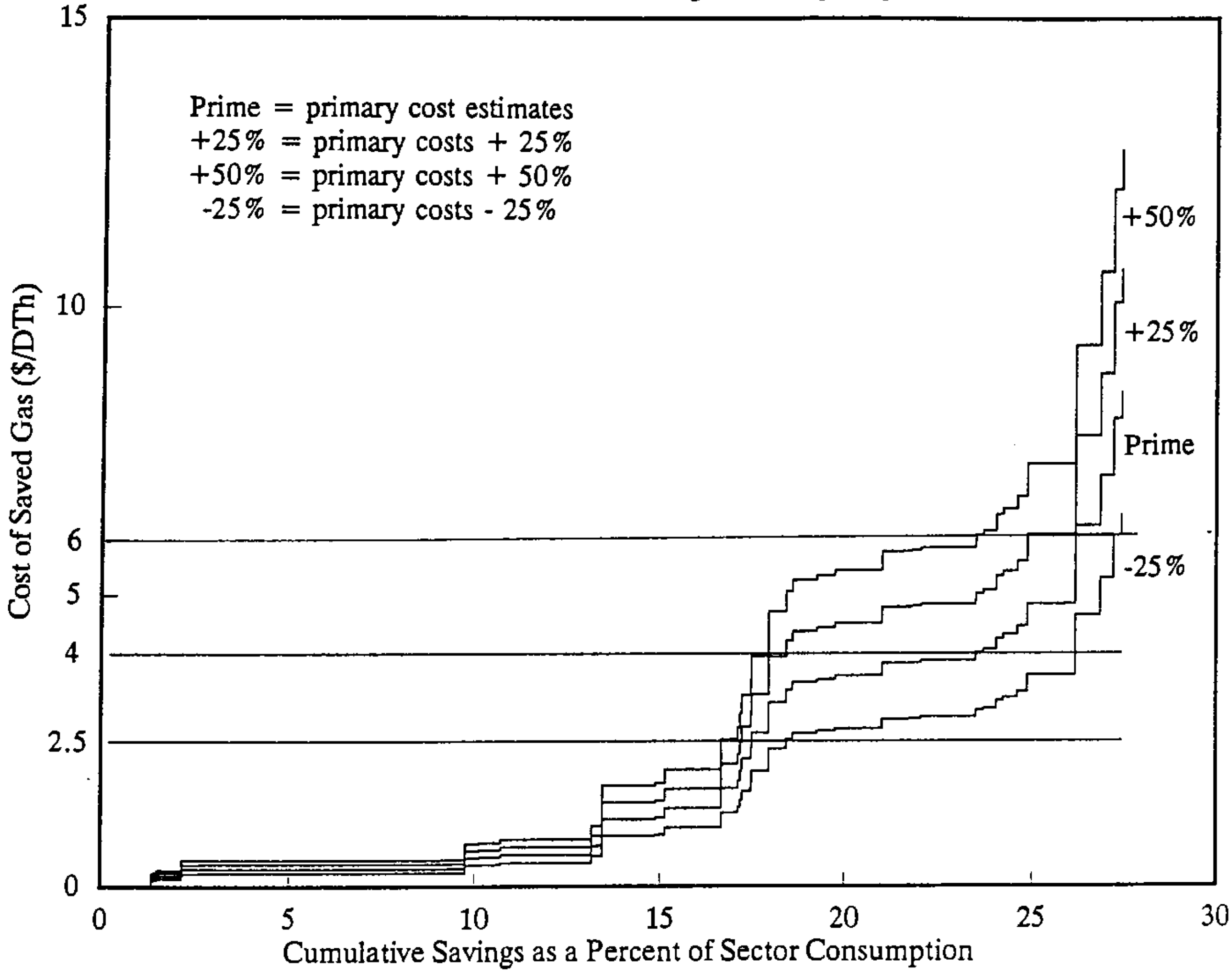
The Potential For Commercial Sector Gas Energy-Efficiency For The LILCo Service Territory

Table 4-17 summarizes the economic potential for commercial sector gas energy efficiency measures for each of the perspectives and sensitivities considered. Figure 4-1 presents these results graphically. The results suggest that 18 percent or 2.7 million DTh to 25 percent or 3.6 million DTh of the gas consumed annually by the commercial sector could be saved with energy efficiency measures costing less than $2.50/Dth and $4.00/DTh, respectively. From the customer perspective ($6.00/DTh), slightly greater savings are cost-effective 28 percent or 4.0 million DTh. Of these savings, replacement measures (typically, higher efficiency equipment) accounted for 14, 21, and 20 percent of the total cost-effective savings potential in each perspective, respectively.

Table 4-17. Summary of Commercial Sector Economic Gas Savings Potential - LILCo.

Perspective	Primary Case	Cost -25%	Cost +25%	Cost +50%
Utility - $2.50/DTh	18	19	18	18
Utility - $4.00/DTh	25	28	19	19
Customer - $6.00/DTh	28	29	26	25

Figure 4–1. Supply Curve of Saved Gas, Long Island Lighting Co., Commercial Sector.



The results appear to be robust with respect to the cost and performance sensitivities considered. Considering only the utility perspective, for example, if the cost of the energy efficiency measures is 25 percent lower (also corresponding to energy savings 33 percent higher), the cost-effective energy-efficiency potential increases slightly to 19 percent and 28 percent at the utility cost-effectiveness thresholds of $2.50/DTh and $4.00/DTh, respectively. Conversely, if the cost of the energy efficiency measures is 25 percent higher (or energy savings 20 percent lower), the cost-effective energy-efficiency potential decreases (to 19 percent) only at the higher cost-effectiveness threshold $4.00/DTh. Similarly, if the cost of the efficiency measures is 50 percent higher (or energy savings 33 percent lower), the cost-effective energy-efficiency potential again only decreases (to 19 percent) only at the higher cost-effectiveness thresholds. Thus, while the cost sensitivities have a greater impact at the higher avoided cost threshold, the most cost-effective savings are resilient.

Table 4-18 summarizes our primary findings on an end use basis. Savings are expressed both as percentages of annual gas consumption by the end use, as well as a percentage of total commercial sector gas consumption. The percentage of total sectoral sales accounted for by each end use is also indicated.

Table 4-18. Summary of Commercial Sector Economic Gas Savings Potential by End Use-LILCo.

Perspective	Space Heat (77%)		Water Heat (8%)		Cooking (10%)	
	% of end use	% of sector	% of end use	% of sector	% of end use	% of sector
Utility - $2.50/DTh	20	15	22	2	15	2
Utility - $4.00/DTh	28	21	28	2	15	2
Customer - $6.00/DTh	32	25	32	3	15	2

Table 4-18 highlights the importance of energy efficiency measures to reduce gas used for space heating. Space heating accounts for the majority of gas consumption in the commercial sector (77 percent); significant cost-effective savings are achievable from each perspective considered, and these savings would have a major impact on commercial gas consumption. Despite the cost-effectiveness of measures directed toward reducing gas water heating and cooking energy use, the savings from these end uses account for only a modest portion of total commercial sector gas sales, although the results indicate that the majority of cost-effective savings for these end uses are highly cost-effective, costing less than the lowest cost-effectiveness threshold considered ($2.50/DTh). For example, all five cooking measures were found to be cost-effective under any scenario of gas avoided cost or cost/performance sensitivity.

Table 4-19 summarizes our primary findings separately by building type. The results are expressed both as a percentage of gas consumed by the building type and as a percentage of total commercial sector sales.

Table 4-19. Summary of Commercial Sector Economic Gas Savings Potential by Building Type - LILCo.

	Perspective					
	Utility-$2.50/DTh		Utility-$4.00/DTh		Customer-$6.00/DTh	
Building Type	% of Bldg	% of Sector	% of Bldg.	% of Sector	% of Bldg.	% of Sector
Office	25	10	13	3	20	1
Retail	31	12	22	6	26	2
Hospital	38	15	24	6	26	2
Grocery	30	2	34	2	34	2
Restuarant	9	1	14	2	14	2
Warehouse	0	0	0	0	10	0

Table 4-19 indicates that the greatest source of cost-effective commercial sector gas savings is the office and retail sectors. Offices and retail account for the largest share of gas consumption (65 percent) and offer significant gas savings, under each perspective considered. There are also significant cost-effective savings available for hospitals and supermarkets, yet the savings in these buildings are modest as a percentage of total commercial sector gas sales.

The changes in cost-effective potential as a function of perspective provides insight into the cost-effectiveness of measures by building type. For example, the majority of savings for the office and supermarket and most of the savings for hospitals are highly cost-effective; only modest additional savings result from considering higher cost-effectiveness thresholds. The majority of (albeit modest) savings for restaurants and warehouses become cost-effective only at the higher thresholds.

Table 4-20 summarizes the individual results for the measures costing less than $10/Dth. The energy-efficiency measures contributing most to the cost-effective energy efficiency potential improve the control of HVAC systems, including the reset of supply air temperatures in central HVAC systems, and the night set-back of temperatures in both central and packaged HVAC systems. Significant energy savings also result from lowering hot water temperatures. Shell measures (double pane windows, low-e glass, and roof insulation) only appear to be cost-effective for some building types, notably hospitals. However, where cost-effective, they offer large energy savings.

Higher-efficiency equipment for space heating and water heating is generally cost-effective, but sometimes only marginally. Boiler tune-ups for space heating are highly cost-effective for offices and retail with central HVAC systems.

The Potential For Commercial Sector Gas Energy Efficiency For The BUG Service Territory

Table 4-21 summarizes the economic potential for commercial sector gas energy efficiency measures for each of the perspectives and sensitivities considered. Figure 4-2 presents these results graphically. The cost-effectiveness results for the BUG service territory parallel those developed for the LILCo service territory since the same prototypes were analyzed using identical cost assumptions. The differences between the findings for the two utilities stem only from the differing amounts of gas consumption affected by the measures, as defined by differences in the population or building type between BUG and LILCo.

Table 4-20. Cost of Saved Gas - LILCO Commercial Sector.

End Use	Measure	Building	CSG $/DTh	Savings M DTh	Cum Save M Dth	Cum as % of Sectr	CSG -25% $/Dth	CSG +25% $/Dth	CSG +50% $/Dth
water heating	Lower temperature	supermarket	0.00	34	34	0.2	0.00	0.00	0.00
water heating	Lower temperature	office	0.00	88	122	0.8	0.00	0.00	0.00
water heating	Lower temperature	retail	0.00	64	186	1.3	0.00	0.00	0.00
water heating	Lower temperature	warehouse	0.00	2	188	1.3	0.00	0.00	0.00
cooking	Ind.-dir. conversion	all buildings	0.00	9	197	1.3	0.00	0.00	0.00
water heating	High-efficiency boiler	hospital	0.15	8	206	1.4	0.11	0.18	0.22
cooking	Std.-dir. conversion	all buildings	0.16	14	220	1.5	0.12	0.20	0.24
cooking	Cat. IR fry	all buildings	0.19	92	312	2.1	0.14	0.24	0.29
space heating	Double pane windows	hospital	0.30	79	391	2.7	0.23	0.38	0.45
cooking	Power burner	all buildings	0.31	33	424	2.9	0.23	0.38	0.46
space heating	Reset ss temperature	off cnt	0.31	941	1365	9.3	0.23	0.38	0.46
cooking	IR griddle	all buildings	0.31	61	1426	9.8	0.23	0.39	0.47
water heating	High-efficiency stand alone unit	office	0.49	52	1479	10.1	0.37	0.61	0.73
space heating	Tune boiler	off cnt	0.50	85	1564	10.7	0.38	0.63	0.75
space heating	Reset ss temperature	ret cnt	0.54	357	1921	13.1	0.41	0.68	0.81
space heating	Tune boiler	ret cnt	0.70	40	1961	13.4	0.52	0.87	1.04
space heating	Temperature set-back	off cnt	1.16	212	2173	14.9	0.87	1.45	1.73
space heating	High-efficiency boiler	hospital	1.18	39	2212	15.1	0.89	1.48	1.78
space heating	Roof Insulation	supermarket	1.34	219	2431	16.6	1.01	1.68	2.01
space heating	Low-E glass	hospital	1.69	66	2497	17.1	1.26	2.11	2.53
water heating	High-efficiency stand alone unit	supermarket	1.82	9	2507	17.1	1.36	2.27	2.73
space heating	Roof Insulation	hospital	1.98	5	2512	17.2	1.49	2.48	2.97
space heating	High-efficiency furnace	restaurant	2.19	38	2550	17.4	1.64	2.74	3.28
water heating	High-efficiency boiler	office	2.35	2	2552	17.4	1.76	2.94	3.53
space heating	Roof Insulation	restaurant	2.64	66	2619	17.9	1.98	3.30	3.96
space heating	HVAC heat recovery	hospital	3.15	68	2686	18.4	2.36	3.94	4.72
space heating	High-efficiency boiler	ret cnt	3.38	25	2711	18.5	2.53	4.22	5.06
space heating	High-efficiency furnace	ret pkg	3.50	102	2813	19.2	2.63	4.38	5.26
space heating	High-efficiency furnace	warehouse	3.55	25	2838	19.4	2.66	4.44	5.33
water heating	High-efficiency stand alone unit	restaurant	3.56	49	2887	19.7	2.67	4.45	5.34
space heating	Temperature set-back	off pkg	3.62	181	3068	21.0	2.71	4.52	5.42
space heating	High-efficiency furnace	off pkg	3.83	114	3182	21.7	2.87	4.79	5.75
space heating	High-efficiency boiler	off cnt	3.85	37	3219	22.0	2.88	4.81	5.77
space heating	Roof Insulation	ret pkg	3.88	214	3433	23.5	2.91	4.85	5.82
water heating	Tune boiler	office	3.93	1	3434	23.5	2.95	4.91	5.89
space heating	High-efficiency furnace	supermarket	4.02	31	3464	23.7	3.02	5.03	6.03
space heating	Double pane windows	off cnt	4.07	51	3515	24.0	3.05	5.09	6.11
space heating	Roof Insulation	warehouse	4.26	27	3543	24.2	3.19	5.32	6.39
space heating	Roof Insulation	ret cnt	4.32	56	3598	24.6	3.24	5.40	6.49
water heating	High-efficiency stand alone unit	retail	4.47	36	3635	24.8	3.35	5.58	6.70
water heating	High-efficiency stand alone unit	warehouse	4.47	1	3636	24.9	3.35	5.58	6.70
space heating	Roof Insulation	off pkg	4.84	191	3827	26.2	3.63	6.05	7.26
water heating	Tank insulation	restaurant	6.20	10	3836	26.2	4.65	7.74	9.29
space heating	Double pane windows	off pkg	6.20	89	3926	26.8	4.65	7.75	9.29
space heating	Roof Insulation	off cnt	7.05	49	3975	27.2	5.29	8.81	10.58
space heating	Double pane windows	restaurant	8.03	32	4007	27.4	6.02	10.04	12.05
water heating	Tank insulation	supermarket	8.49	1	4008	27.4	6.37	10.61	12.74
water heating	Tank insulation	warehouse	9.55	0	4008	27.4	7.16	11.93	14.32
water heating	Tank insulation	retail	9.55	6	4014	27.4	7.16	11.93	14.32
water heating	Tank insulation	office	9.55	1	4015	27.4	7.16	11.94	14.33
water heating	High-efficiency boiler	restaurant	11.45	0	4016	27.5	8.59	14.31	17.18
space heating	Double pane windows	ret pkg	11.48	243	4259	29.1	8.61	14.35	17.22
water heating	Tank insulation	hospital	11.51	0	4259	29.1	8.63	14.38	17.26
water heating	Pipe insulation	hospital	11.81	1	4259	29.1	8.86	14.77	17.72
space heating	Double pane windows	supermarket	12.55	14	4274	29.2	9.41	15.69	18.83
space heating	HVAC maintenance	restaurant	12.57	35	4308	29.5	9.43	15.72	18.86
space heating	Double pane windows	ret cnt	12.72	64	4372	29.9	9.54	15.90	19.08
water heating	Pipe insulation	supermarket	13.29	0	4372	29.9	9.97	16.61	19.93
space heating	Double pane windows	warehouse	13.80	38	4410	30.1	10.35	17.25	20.70
space heating	HVAC maintenance	supermarket	14.62	25	4435	30.3	10.96	18.27	21.93
water heating	Pipe insulation	restaurant	16.34	1	4436	30.3	12.25	20.42	24.51
water heating	Pipe insulation	warehouse	17.07	0	4436	30.3	12.80	21.34	25.60
water heating	Pipe insulation	retail	17.07	1	4437	30.3	12.80	21.34	25.60
water heating	Pipe insulation	office	17.12	0	4437	30.3	12.84	21.40	25.68
water heating	Tune boiler	restaurant	19.13	0	4437	30.3	14.34	23.91	28.69
space heating	HVAC heat recovery	off cnt	19.93	50	4487	30.7	14.95	24.91	29.89
water heating	Auto reset	retail	21.93	3	4490	30.7	16.45	27.41	32.89
water heating	Auto reset	warehouse	21.93	0	4490	30.7	16.45	27.41	32.89
water heating	Auto reset	office	21.93	1	4491	30.7	16.45	27.41	32.90
space heating	HVAC maintenance	ret pkg	24.08	86	4576	31.3	18.06	30.10	36.12
space heating	Low-E glass	off cnt	25.34	46	4623	31.6	19.01	31.68	38.01
space heating	HVAC maintenance	hospital	26.40	16	4638	31.7	19.80	33.00	39.60
space heating	HVAC maintenance	warehouse	28.70	22	4660	31.9	21.52	35.87	43.05
water heating	Auto reset	restaurant	32.01	2	4663	31.9	24.00	40.01	48.01
space heating	HVAC maintenance	ret cnt	33.08	36	4699	32.1	24.81	41.35	49.62
space heating	HVAC maintenance	off cnt	34.88	64	4763	32.6	26.16	43.60	52.32
space heating	HVAC maintenance	off pkg	36.16	83	4846	33.1	27.12	45.20	54.24
space heating	Low-E glass	off pkg	39.29	80	4926	33.7	29.47	49.11	58.94
water heating	High-efficiency boiler	retail	43.10	0	4926	33.7	32.32	53.87	64.65
water heating	High-efficiency boiler	warehouse	43.10	0	4926	33.7	32.33	53.88	64.65
water heating	Auto reset	supermarket	43.86	0	4926	33.7	32.90	54.83	65.79
space heating	Low-E glass	restaurant	70.83	22	4948	33.8	53.12	88.53	106.24
space heating	Low-E glass	ret pkg	71.72	124	5072	34.7	53.79	89.65	107.58
water heating	Tune boiler	retail	71.98	0	5072	34.7	53.99	89.98	107.97
water heating	Tune boiler	warehouse	71.99	0	5072	34.7	53.99	89.98	107.98
space heating	Low-E glass	supermarket	73.40	11	5082	34.7	55.05	91.75	110.09
space heating	Low-E glass	ret cnt	80.80	32	5114	35.0	60.60	100.99	121.19
space heating	Low-E glass	warehouse	82.13	21	5135	35.1	61.60	102.66	123.20

The results suggest that 16 percent or 1.9 million DTh to 22 percent or 2.6 million DTh of the gas consumed annually by the commercial sector could be saved with energy efficiency measures costing less than $2.50/Dth and $4.00/DTh, respectively. From the customer perspective, additional savings are cost-effective (25 percent or 3.1 million DTh) due to the higher retail price of natural gas ($8.50/DTh). Of these savings, replacement measures (typically, higher efficiency equipment) accounted for 16, 23, and 23 percent of the total cost-effective savings potential in each perspective, respectively.

Table 4-21. Summary of Commercial Sector Economic Savings Potential (%) - BUG.

Perspective	Primary Case	Cost -25%	Cost +25%	Cost +50%
Utility - $2.50/DTh	16	17	16	15
Utility - $4.00/DTh	22	24	17	16
Customer - $8.50/DTh	25	25	25	24

The most cost-effective measures appear to be robust with respect to the cost and performance sensitivities considered. Considering only the utility perspective, for example, if the cost of the energy efficiency measures is 25 percent lower (also corresponding to energy savings 33 percent higher), the cost-effective energy-efficiency potential increases only slightly to 17 percent and 22 percent at the utility cost-effectiveness thresholds of $2.50/DTh and $4.00/DTh, respectively. Conversely, if the cost of the energy efficiency measures is 25 percent higher (or energy savings 20 percent lower), the cost-effective energy-efficiency potential decreases to 16 percent and 17 percent at the utility cost-effectiveness thresholds of $2.50/Dth and $4.00/DTh, respectively. Finally, if the cost of the efficiency measures is 50 percent higher (or energy savings 33 percent lower), the cost-effective energy-efficiency potential decreases to 15 percent and 16 percent for the same range of utility cost-effectiveness thresholds.

Table 4-22 summarizes our primary findings on an end use basis. Savings are expressed both as percentages of annual gas consumption by the end use, as well as a percentage of total commercial sector gas consumption. The percentage of total sectoral sales accounted for by each end use is also indicated.

Figure 4–2. Supply Curve of Saved Gas, Brooklyn Union Gas Co., Commercial Sector.

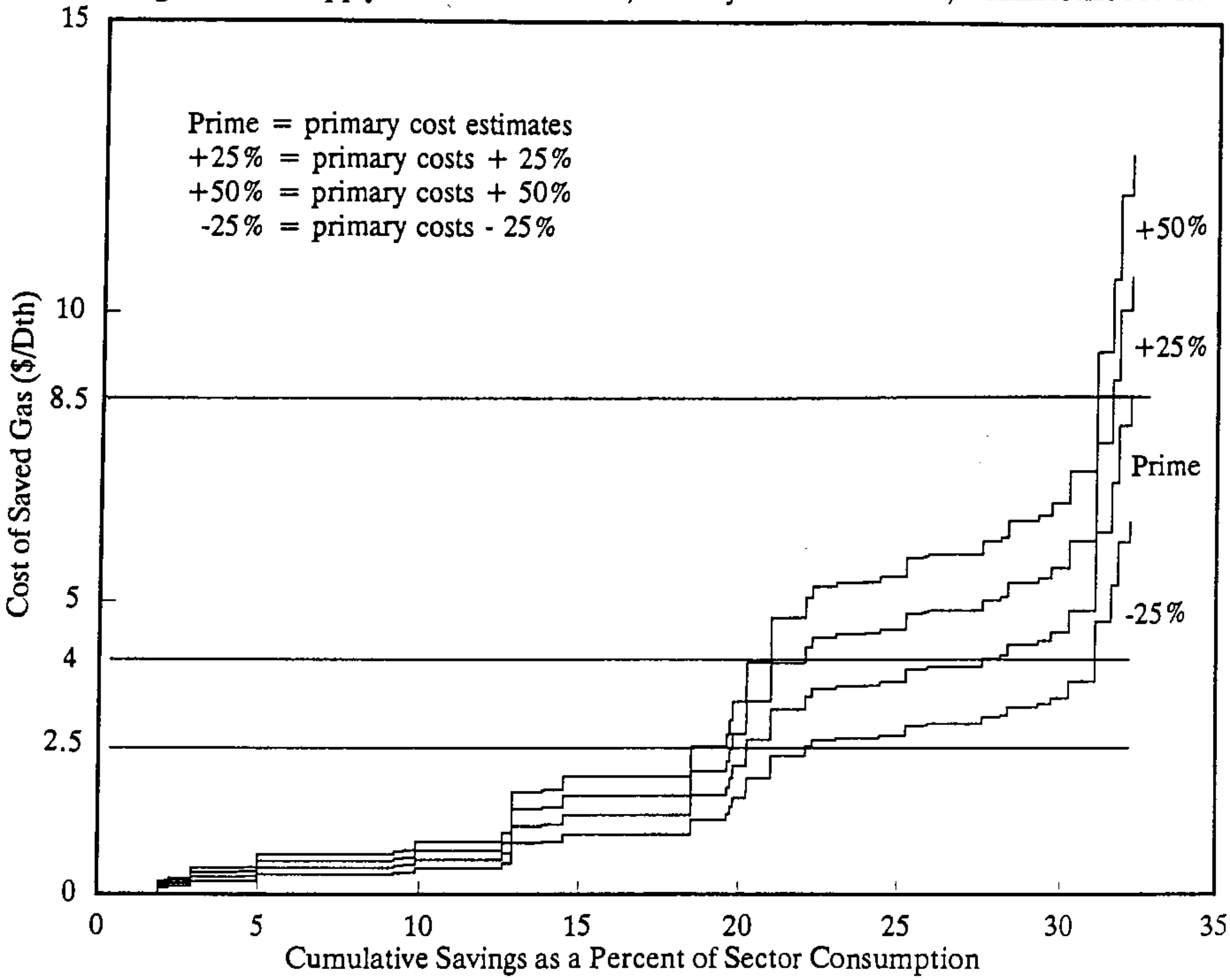


Table 4-22. Summary of Commercial Sector Economic Gas Savings Potential by End Use - BUG.

Perspective	Space Heat (75%)		Water Heat (10%)		Cooking (9%)	
	% of end use	% of sector	% of end use	% of sector	% of end use	% of sector
Utility - $2.50/DTh	17	13	19	2	15	1
Utility - $4.00/DTh	25	19	23	2	15	1
Customer - $8.50/DTh	28	21	28	3	15	1

Table 4-22 highlights the importance of energy efficiency measures to reduce gas used for space heating. As was found for LILCO, space heating accounts for the majority of gas consumption in the commercial sector (75%); significant cost-effective savings are achievable from each perspective considered, and these savings would have a major impact on commercial gas consumption. Despite the cost-effectiveness of measures directed toward reducing gas water heating and cooking energy use, the savings from these end uses account for only a modest portion of total commercial sector gas sales, although the results indicate that the majority of cost-effective savings for these end uses are highly cost-effective, costing less than the lowest cost-effectiveness threshold considered ($2.50/DTh). For example, all five cooking measures were found to be cost-effective under any scenario of gas avoided cost or cost/performance sensitivity.

Table 4-23 summarizes our primary findings separately by building type. The results are expressed both as a percentage of gas consumed by the building type and as a percentage of total commercial sector sales. The percentage of gas consumption accounted for by each building type is also indicated.

Table 4-23 indicates that, unlike LILCO, the sources of cost-effective commercial sector gas savings are spread among several building types, primarily offices, retail, hospital and supermarket. There are significant savings available for restaurants and warehouses, but the savings in these buildings are modest as a percentage of total commercial sector gas sales.

Table 4-23. Summary of Commercial Sector Economic Gas Savigns Potential by Building Type - BUG.

	Perspective					
	Utility- $2.50/DTh		Utility- $4.00/DTh		Customer- $6.00/DTh	
Building Type	% of Bldg	% of Sector	% of Bldg.	% of Sector	% of Bldg.	% of Sector
Office	26	5	32	6	39	7
Retail	14	3	23	5	33	7
Hospital	17	3	23	4	23	4
Grocery	33	4	37	4	37	4
Restaurant	8	1	14	2	16	3
Warehouse	1	0	5	1	11	2

The changes in cost-effective potential as a function of perspective provides insight into the cost-effectiveness of measures by building type. For example, the majority of savings for the office and supermarket and, to a lesser degree, for retail and hospital are highly cost-effective; only modest additional savings result from considering higher cost-effectiveness thresholds. The majority of (albeit modest) savings for restaurants and warehouses again become cost-effective only at the higher thresholds.

Table 4-24 summarizes the individual results for the measures costing less than $10/Dth. The energy-efficiency measures contributing most to the cost-effective energy efficiency potential improve the control of HVAC systems, including the reset of supply air temperatures in central HVAC systems, and the night set-back of temperatures in both central and packaged HVAC systems. Significant energy savings also result from lowering hot water temperatures. Shell measures (double pane windows, low-e glass, and roof insulation) only appear to be cost-effective for some building types, notably hospitals. However, where cost-effective, they offer large energy savings.

Table 4-24. Cost of Saved Gas - BUG Commercial Sector.

End Use	Measure	Building	CSG $/DTh	Savings M DTh	Cum Saving M Dth	Cum as % of Sector	CSG -25% $/Dth	CSG +25% $/Dth	CSG +50% $/Dth
water heating	Lower temperature	supermarket	0.00	42	42	0.3	0.00	0.00	0.00
water heating	Lower temperature	warehouse	0.00	20	62	0.5	0.00	0.00	0.00
water heating	Lower temperature	office	0.00	60	122	1.0	0.00	0.00	0.00
cooking	Ind.-dir. conv.	all buildings	0.00	9	131	1.1	0.00	0.00	0.00
water heating	Lower temperature	retail	0.00	102	234	1.9	0.00	0.00	0.00
water heating	High efficiency boiler	hospital	0.15	23	257	2.1	0.11	0.19	0.22
cooking	Std.-dir. conv.	all buildings	0.16	13	270	2.2	0.12	0.20	0.24
cooking	Cat IR fry	all buildings	0.19	87	357	2.9	0.14	0.24	0.29
space heating	Double pane windows	hospital	0.30	164	520	4.3	0.23	0.38	0.45
cooking	Power burner	all buildings	0.31	31	551	4.5	0.23	0.38	0.46
cooking	IR griddle	all buildings	0.31	57	608	5.0	0.23	0.39	0.47
space heating	Reset ss temperature	off cnt	0.45	513	1121	9.2	0.34	0.57	0.68
water heating	High-efficiency stand-alone u	office	0.49	36	1157	9.5	0.37	0.61	0.73
space heating	Tune boiler	off cnt	0.50	46	1203	9.9	0.38	0.63	0.75
space heating	Reset ss temperature	ret cnt	0.59	336	1539	12.6	0.44	0.74	0.89
space heating	Tune boiler	ret cnt	0.70	37	1576	12.9	0.52	0.87	1.04
space heating	Temperature set-back	off cnt	1.16	115	1691	13.9	0.87	1.45	1.73
space heating	Hgh-efficiency boiler	hospital	1.18	81	1772	14.5	0.89	1.48	1.78
space heating	Roof insulation	supermarket	1.34	487	2259	18.5	1.01	1.68	2.01
space heating	Low-E glass	hospital	1.69	136	2395	19.6	1.26	2.11	2.53
water heating	High-efficiency stand-alone u	supermarket	1.82	12	2407	19.7	1.36	2.27	2.73
space heating	Roof insulation	hospital	1.98	11	2417	19.8	1.49	2.48	2.97
space heating	High-efficiency furnace	restaurant	2.19	52	2470	20.2	1.64	2.74	3.28
water heating	High efficiency boiler	office	2.35	1	2471	20.2	1.76	2.94	3.53
space heating	Roof insulation	restaurant	2.64	91	2562	21.0	1.98	3.30	3.96
space heating	HVAC heat recovery	hospital	3.15	139	2701	22.1	2.36	3.94	4.72
space heating	High efficiency boiler	ret cnt	3.38	24	2724	22.3	2.53	4.22	5.06
space heating	High-efficiency furnace	ret pkg	3.50	96	2820	23.1	2.63	4.38	5.26
space heating	High-efficiency furnace	warehouse	3.55	103	2923	23.9	2.66	4.44	5.33
water heating	High-efficiency stand-alone u	restaurant	3.56	58	2981	24.4	2.67	4.45	5.34
space heating	Temperature set-back	off pkg	3.62	99	3079	25.2	2.71	4.52	5.42
space heating	High-efficiency furnace	off pkg	3.83	62	3142	25.7	2.87	4.79	5.75
space heating	High efficiency boiler	off cnt	3.85	20	3162	25.9	2.88	4.81	5.77
space heating	Roof insulation	ret pkg	3.88	201	3362	27.5	2.91	4.85	5.82
water heating	Tune boiler	office	3.93	0	3363	27.5	2.95	4.91	5.89
space heating	High-efficiency furnace	supermarket	4.02	68	3431	28.1	3.02	5.03	6.03
space heating	Double pane windows	off cnt	4.07	28	3459	28.3	3.05	5.09	6.11
space heating	Roof insulation	warehouse	4.26	113	3572	29.3	3.19	5.32	6.39
space heating	Roof insulation	ret cnt	4.32	52	3624	29.7	3.24	5.40	6.49
water heating	High-efficiency stand-alone u	retail	4.47	58	3682	30.2	3.35	5.58	6.70
water heating	High-efficiency stand-alone u	warehouse	4.47	9	3691	30.2	3.35	5.58	6.70
space heating	Roof insulation	off pkg	4.84	104	3795	31.1	3.63	6.05	7.26
water heating	Tank insulation	restaurant	6.20	12	3807	31.2	4.65	7.74	9.29
space heating	Double pane windows	off pkg	6.20	49	3856	31.6	4.65	7.75	9.29
space heating	Roof insulation	off cnt	7.05	27	3882	31.8	5.29	8.81	10.58
space heating	Double pane windows	restaurant	8.03	44	3926	32.2	6.02	10.04	12.05
water heating	Tank insulation	supermarket	8.49	1	3928	32.2	6.37	10.61	12.74
water heating	Tank insulation	warehouse	9.55	2	3930	32.2	7.16	11.93	14.32
water heating	Tank insulation	retail	9.55	9	3939	32.3	7.16	11.93	14.32
water heating	Tank insulation	office	9.55	1	3940	32.3	7.16	11.94	14.33
water heating	High efficiency boiler	restaurant	11.45	1	3940	32.3	8.59	14.31	17.18
space heating	Double pane windows	ret pkg	11.48	227	4168	34.1	8.61	14.35	17.22
water heating	Tank insulation	hospital	11.51	1	4168	34.1	8.63	14.38	17.26
water heating	Pipe insulation	hospital	11.81	2	4170	34.2	8.86	14.77	17.72
space heating	Double pane windows	supermarket	12.55	32	4202	34.4	9.41	15.69	18.83
space heating	HVAC maintenance	restaurant	12.57	47	4249	34.8	9.43	15.72	18.86
space heating	Double pane windows	ret cnt	12.72	60	4309	35.3	9.54	15.90	19.08
water heating	Pipe insulation	supermarket	13.29	0	4309	35.3	9.97	16.61	19.93
space heating	Double pane windows	warehouse	13.80	157	4466	36.6	10.35	17.25	20.70
space heating	HVAC maintenance	supermarket	14.62	56	4522	37.0	10.96	18.27	21.93
water heating	Pipe insulation	restaurant	16.34	1	4523	37.1	12.25	20.42	24.51
water heating	Pipe insulation	warehouse	17.07	0	4524	37.1	12.80	21.34	25.60
water heating	Pipe insulation	retail	17.07	1	4525	37.1	12.80	21.34	25.60
water heating	Pipe insulation	office	17.12	0	4525	37.1	12.84	21.40	25.68
water heating	Tune boiler	restaurant	19.13	0	4525	37.1	14.34	23.91	28.69
space heating	HVAC heat recovery	off cnt	19.93	27	4552	37.3	14.95	24.91	29.89
water heating	Auto reset	retail	21.93	5	4557	37.3	16.45	27.41	32.89
water heating	Auto reset	warehouse	21.93	1	4558	37.3	16.45	27.41	32.89
water heating	Auto reset	office	21.93	0	4559	37.3	16.45	27.41	32.90
space heating	HVAC maintenance	ret pkg	24.08	80	4639	38.0	18.06	30.10	36.12
space heating	Low-E glass	off cnt	25.34	25	4664	38.2	19.01	31.68	38.01
space heating	HVAC maintenance	hospital	26.40	32	4696	38.5	19.80	33.00	39.60
space heating	HVAC maintenance	warehouse	28.70	91	4788	39.2	21.52	35.87	43.05
water heating	Auto reset	restaurant	32.01	3	4790	39.2	24.00	40.01	48.01
space heating	HVAC maintenance	ret cnt	33.08	34	4824	39.5	24.81	41.35	49.62
space heating	HVAC maintenance	off cnt	34.88	36	4859	39.8	26.16	43.60	52.32
space heating	HVAC maintenance	off pkg	36.16	45	4904	40.2	27.12	45.20	54.24
space heating	Low-E glass	off pkg	39.29	43	4948	40.5	29.47	49.11	58.94
water heating	High efficiency boiler	retail	43.10	0	4948	40.5	32.32	53.87	64.65
water heating	High efficiency boiler	warehouse	43.10	1	4948	40.5	32.33	53.88	64.65
water heating	Auto reset	supermarket	43.86	0	4948	40.5	32.90	54.83	65.79
space heating	Low-E glass	restaurant	70.83	30	4979	40.8	53.12	88.53	106.24
space heating	Low-E glass	ret pkg	71.72	116	5095	41.7	53.79	89.65	107.58
water heating	Tune boiler	retail	71.98	0	5095	41.7	53.99	89.98	107.97
water heating	Tune boiler	warehouse	71.99	0	5096	41.7	53.99	89.98	107.98
space heating	Low-E glass	supermarket	73.40	24	5119	41.9	55.05	91.75	110.09
space heating	Low-E glass	ret cnt	80.80	30	5149	42.2	60.60	100.99	121.19
space heating	Low-E glass	warehouse	82.13	86	5235	42.9	61.60	102.66	123.20

Higher-efficiency equipment for space heating and water heating is generally cost-effective, but sometimes only marginally. Boiler tune-ups for space heating are highly cost-effective for offices and retail with central HVAC systems.

The Potential For Commercial Sector Gas Energy Efficiency For The NFG Service Territory

Table 4-25 summarizes the economic potential for commercial sector gas energy efficiency measures for each of the perspectives and sensitivities considered. Figure 4-3 presents these results graphically. The results suggest that 20 percent or 4.0 million DTh to 27 percent or 5.5 million DTh of the gas consumed annually by the commercial sector could be saved with energy efficiency measures costing less than $2.50/Dth and $4.00/DTh, respectively. From the customer perspective, slightly greater savings are cost-effective (28 percent or 5.5 million DTh). Of these savings, replacement measures (typically, higher efficiency equipment) accounted for 17, 22, and 22 percent of the total cost-effective savings potential in each perspective, respectively.

Table 4-25. Summary of Commercial Sector Economic Savings Potential (%) - NFG.

Perspective	Primary Case	Cost -25%	Cost +25%	Cost +50%
Utility - $2.50/DTh	20	25	19	17
Utility - $4.00/DTh	27	28	24	20
Customer - $5.00/DTh	28	28	27	25

The analysis appears to be robust with respect to the cost and performance sensitivities considered. Considering only the utility perspective, for example, if the cost of the energy efficiency measures is 25 percent lower (also corresponding to energy savings 33 percent higher), the cost-effective energy-efficiency potential increases somewhat to 25 percent and 28 percent at the utility cost-effectiveness thresholds of $2.50/DTh and $4.00/DTh, respectively. Conversely, if the cost of the energy efficiency measures is 25 percent higher (or energy saving 20 percent lower), the cost-effective energy-efficiency potential decreases very slightly to 19 percent and 24 percent at the utility cost-effectiveness thresholds of $2.50/Dth and $4.00/DTh, respectively. Finally, if the cost of the efficiency measures is 50 percent higher (or energy savings 33 percent lower), the cost-effective energy-efficiency potential decreases to 17 percent and 20 percent for the same range of utility cost-effectiveness thresholds.

Table 4-26 summarizes our primary findings on an end use basis. Savings are expressed both as percentages of annual gas consumption by the end use, as well as a percentage of total commercial sector gas consumption. The percentage of total sectoral sales accounted for by each end use is also indicated.

Table 4-26. Summary of Commercial Sector Economic Gas Savings Potential by End Use - NFG.

Perspective	Space Heat (80%)		Water Heat (7%)		Cooking (12%)	
	% of end use	% of sector	% of end use	% of sector	% of end use	% of sector
Utility - $2.50/DTh	20	16	26	2	15	2
Utility - $4.00/DTh	29	23	27	2	15	2
Customer - $5.00/DTh	30	24	29	2	15	2

Table 4-26 highlights, as was found for both LILCO and BUG, the importance of energy efficiency measures to reduce gas used for space heating. Space heating accounts for the majority of gas consumption in the commercial sector (80 percent), significant cost-effective savings are achievable from each perspective considered, and these savings would have a major impact on commercial gas consumption. Despite the cost-effectiveness of measures directed toward reducing gas water heating and cooking energy use, the savings from these end uses account for only a modest portion of total commercial sector gas sales, although the results indicate that the majority of cost-effective savings for these end uses are highly cost-effective, costing less than the lowest cost-effectiveness threshold considered ($2.50/DTh). For example, all five cooking measures were found to be cost-effective under any scenario of gas avoided cost or cost/performance sensitivity.

Figure 4–3. Supply Curve of Saved Gas, National Fuel Gas Co., Commercial Sector.

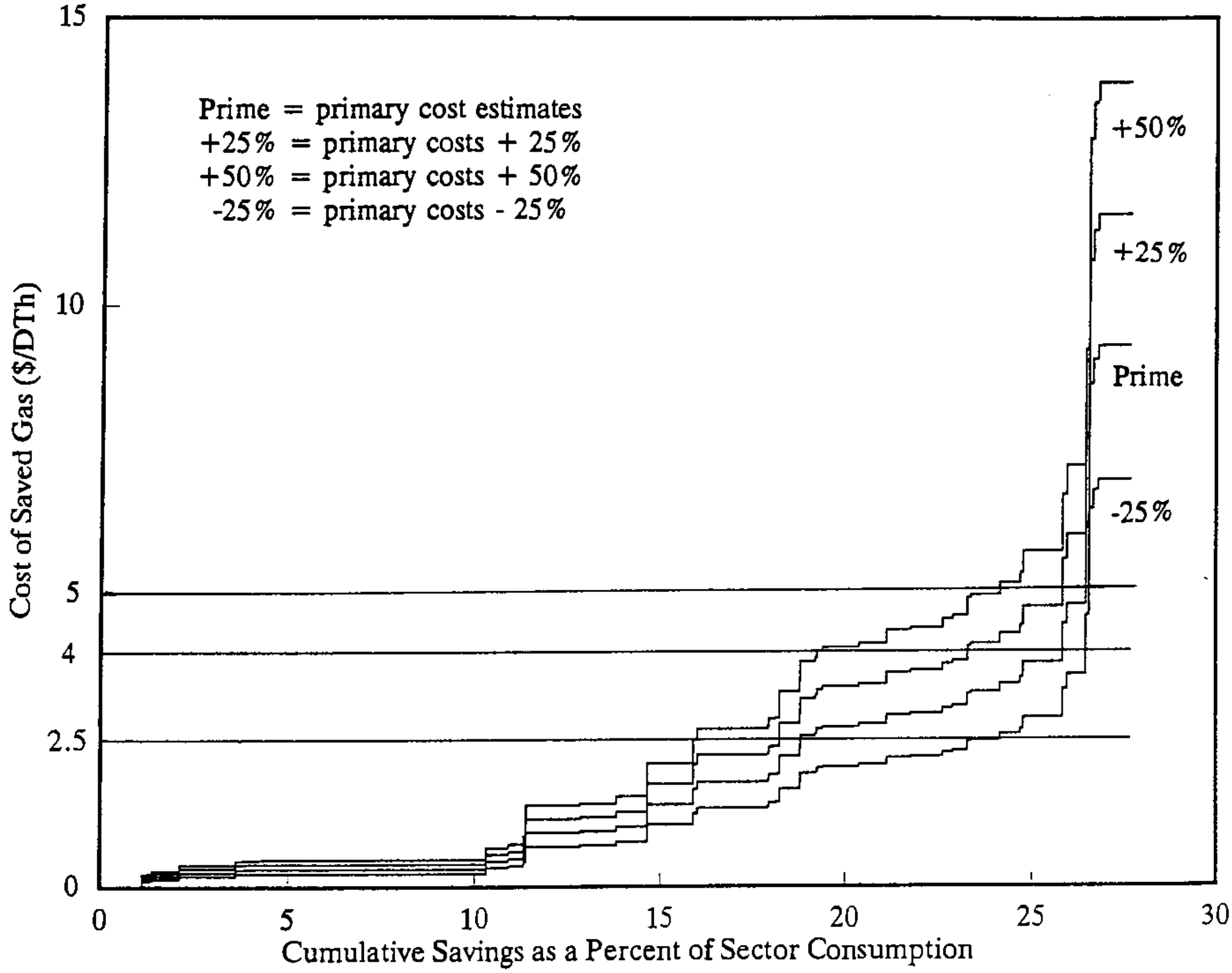


Table 4-27 summarizes our primary findings separately by building type. The results are expressed both as a percentage of gas consumed by the building type and as a percentage of total commercial sector sales. The percentage of gas consumption accounted for by each building type is also indicated.

Table 4-27. Summary of Commercial Sector Economic Gas Savings Potential by Building Type - NFG.

	Perspective					
	Utility-$2.50/DTh		Utility-$4.00/DTh		Customer-$6.00/DTh	
Building Type	% of Bldg	% of Sector	% of Bldg.	% of Sector	% of Bldg.	% of Sector
Office	27	10	38	14	40	15
Retail	8	1	19	2	19	2
Hospital	30	6	30	6	30	6
Grocery	27	1	13	1	30	2
Restaurant	12	1	13	1	13	1
Warehouse	2	0	11	2	11	2

Table 4-27 indicates that, like LILCo, the greatest source of cost-effective commercial sector gas savings is the office sector. Offices and hospitals account for the largest share of gas consumption (59 percent) and offer significant gas savings, under each perspective considered. There are also significant savings available for retail and supermarkets, yet the savings in these buildings are modest as a percentage of total commercial sector gas sales.

The changes in cost-effective potential as a function of perspective provides insight into the cost-effectiveness of measures by building type. For example, the majority of savings for the office, supermarket, restaurant and all of the savings for the hospital are highly cost-effective; only modest additional savings result from considering higher cost-effectiveness thresholds. The majority of (albeit modest) savings for warehouse and, to a lesser extent, retail become cost-effective only at the higher thresholds.

Table 4-28 presents the individual results for the measures costing less than $10/Dth. The energy-efficiency measures contributing the most to the cost-effective energy efficiency potential improve the control of HVAC systems, especially the reset of supply-air temperatures for central HVAC systems and set-back of temperatures for both types of HVAC systems in offices. Significant energy savings also result from lowering hot water temperatures. Large cost-effective energy savings also result from several measures applied to hospitals including double-pane and then low-e windows, and HVAC heat recovery.

Roof insulation is the only shell measure found to be consistently cost-effective across building types.

Higher-efficiency equipment for space heating and water heating is generally cost-effective, but sometimes only marginally. Boiler tune-ups for space heating are highly cost-effective for offices and retail with central HVAC systems.

MEASURED PERFORMANCE OF COMMERCIAL SECTOR ENERGY EFFICIENCY MEASURES

The use of measured data to evaluate the in-field performance of energy efficiency measures in commercial buildings is rare. The most comprehensive source of these data is Lawrence Berkeley Laboratory's Buildings Energy Use Compilation and Analysis (BECA) project, which has collected measured performance data on almost 500 retrofit projects in nearly 1,800 commercial buildings (Greely, et al. 1990).

The BECA data provide a wealth of information regarding several aspects of the current study, including the measured performance of window modifications, HVAC controls, and improved maintenance practices. In addition, some of the data collected provide insight into the relationship between measured and predicted savings. Finally, a significant fraction of the data were collected from buildings and projects in the Northeastern region of the US, which is particularly relevant for our study.

Table 4-28. Cost of Saved Gas - NFG Commercial Sector.

End Use	Measure	Building	CSG $/DTh	Savings M DTh	Cum Saving M Dth	Cum as % of Sector	CSG -25% $/Dth	CSG +25% $/Dth	CSG +50% $/Dth
water heating	Lower temperature	warehouse	0.00	14	14	0.1	0.00	0.00	0.00
water heating	Lower temperature	office	0.00	139	153	0.8	0.00	0.00	0.00
water heating	Lower temperature	retail	0.00	36	190	0.9	0.00	0.00	0.00
water heating	Lower temperature	supermarket	0.00	24	214	1.1	0.00	0.00	0.00
cooking	Ind.-dir. conv.	all buildings	0.00	15	229	1.1	0.00	0.00	0.00
water heating	High-efficiency boiler	hospital	0.15	32	261	1.3	0.11	0.18	0.22
cooking	Std.-dir. conv.	all buildings	0.16	23	283	1.4	0.12	0.20	0.24
cooking	Cat. IR fry	all buildings	0.19	148	431	2.1	0.14	0.24	0.29
space heating	Double pane windows	hospital	0.25	301	733	3.6	0.19	0.32	0.38
cooking	Power burner	all buildings	0.31	52	785	3.9	0.23	0.38	0.46
cooking	IR griddle	all buildings	0.31	98	883	4.4	0.23	0.39	0.47
space heating	Reset sa temperature	off cnt	0.32	1208	2090	10.3	0.24	0.39	0.47
space heating	Tune boiler	off cnt	0.45	121	2211	10.9	0.33	0.56	0.67
water heating	High efficiency stand-alone u	office	0.49	83	2294	11.3	0.37	0.61	0.73
space heating	Tune boiler	ret cnt	0.57	14	2308	11.4	0.43	0.72	0.86
space heating	Temperature set-back	off cnt	0.92	298	2606	12.8	0.69	1.15	1.38
space heating	Roof insulation	supermarket	0.94	194	2800	13.8	0.71	1.18	1.42
space heating	High-efficiency boiler	hospital	1.02	169	2968	14.6	0.77	1.28	1.53
space heating	Low-E glass	hospital	1.40	256	3224	15.9	1.05	1.74	2.09
space heating	High efficiency furnace	restaurant	1.66	22	3246	16.0	1.24	2.07	2.49
space heating	HVAC heat recovery	hospital	1.78	383	3629	17.9	1.34	2.23	2.67
water heating	High efficiency stand-alone u	supermarket	1.82	7	3635	17.9	1.36	2.27	2.73
space heating	Roof insulation	restaurant	1.90	37	3672	18.1	1.42	2.37	2.85
space heating	Roof insulation	hospital	1.91	17	3689	18.2	1.43	2.39	2.86
space heating	Reset sa temperature	ret cnt	2.21	111	3800	18.7	1.66	2.77	3.32
water heating	High-efficiency boiler	office	2.35	3	3803	18.8	1.76	2.94	3.53
space heating	High efficiency furnace	ret pkg	2.56	85	3889	19.2	1.92	3.20	3.84
space heating	High-efficiency boiler	ret cnt	2.59	9	3898	19.2	1.94	3.24	3.89
space heating	High efficiency furnace	supermarket	2.68	30	3928	19.4	2.01	3.35	4.02
space heating	Temperature set-back	off pkg	2.71	209	4137	20.4	2.03	3.39	4.07
space heating	High efficiency furnace	warehouse	2.76	145	4282	21.1	2.07	3.45	4.14
space heating	High efficiency furnace	off pkg	2.91	131	4413	21.8	2.18	3.64	4.37
space heating	Roof insulation	ret pkg	2.94	169	4583	22.6	2.21	3.68	4.41
space heating	High-efficiency boiler	off cnt	3.03	59	4642	22.9	2.27	3.79	4.55
space heating	Double pane windows	off cnt	3.07	75	4717	23.3	2.30	3.84	4.61
space heating	Roof insulation	ret cnt	3.28	20	4737	23.4	2.46	4.10	4.92
space heating	Roof insulation	warehouse	3.31	157	4894	24.1	2.48	4.13	4.96
space heating	Roof insulation	off cnt	3.44	113	5007	24.7	2.58	4.30	5.17
water heating	High efficiency stand-alone u	restaurant	3.56	17	5024	24.8	2.67	4.45	5.34
space heating	Roof insulation	off pkg	3.81	210	5234	25.8	2.86	4.76	5.71
water heating	Tune boiler	office	3.93	1	5235	25.8	2.95	4.91	5.89
water heating	High efficiency stand-alone u	retail	4.47	21	5256	25.9	3.35	5.58	6.70
water heating	High efficiency stand-alone u	warehouse	4.47	7	5262	25.9	3.35	5.58	6.70
space heating	Double pane windows	off pkg	4.80	100	5362	26.4	3.60	6.00	7.20
space heating	Double pane windows	restaurant	6.14	17	5379	26.5	4.60	7.67	9.21
water heating	Tank insulation	restaurant	6.20	3	5382	26.5	4.65	7.74	9.29
water heating	Tank insulation	supermarket	8.49	1	5383	26.5	6.37	10.61	12.74
space heating	HVAC maintenance	restaurant	8.61	20	5403	26.6	6.46	10.77	12.92
space heating	HVAC maintenance	supermarket	9.04	25	5429	26.8	6.78	11.30	13.56
space heating	Double pane windows	ret pkg	9.27	180	5609	27.7	6.95	11.59	13.90
space heating	Double pane windows	supermarket	9.51	12	5621	27.7	7.13	11.88	14.26
water heating	Tank insulation	warehouse	9.55	1	5622	27.7	7.16	11.93	14.32
water heating	Tank insulation	retail	9.55	3	5626	27.7	7.16	11.93	14.32
water heating	Tank insulation	office	9.55	2	5627	27.7	7.16	11.94	14.33
space heating	Double pane windows	ret cnt	10.39	21	5648	27.8	7.79	12.99	15.58
space heating	Double pane windows	warehouse	10.96	212	5860	28.9	8.22	13.70	16.45
water heating	High-efficiency boiler	restaurant	11.45	0	5861	28.9	8.59	14.31	17.18
water heating	Tank insulation	hospital	11.51	1	5861	28.9	8.63	14.38	17.26
water heating	Pipe insulation	hospital	11.81	3	5864	28.9	8.86	14.77	17.72
water heating	Pipe insulation	supermarket	13.29	0	5864	28.9	9.97	16.61	19.93
space heating	HVAC heat recovery	off cnt	14.85	75	5939	29.3	11.14	18.56	22.27
water heating	Pipe insulation	restaurant	16.34	0	5939	29.3	12.25	20.42	24.51
water heating	Pipe insulation	warehouse	17.07	0	5939	29.3	12.80	21.34	25.60
water heating	Pipe insulation	retail	17.07	0	5940	29.3	12.80	21.34	25.60
water heating	Pipe insulation	office	17.12	0	5940	29.3	12.84	21.40	25.68
space heating	HVAC maintenance	ret pkg	17.47	71	6010	29.6	13.10	21.83	26.20
space heating	Low-E glass	off cnt	18.10	73	6083	30.0	13.58	22.63	27.15
water heating	Tune boiler	restaurant	19.13	0	6083	30.0	14.34	23.91	28.69
space heating	HVAC maintenance	hospital	19.87	67	6150	30.3	14.90	24.84	29.81
space heating	HVAC maintenance	warehouse	21.36	132	6282	31.0	16.02	26.70	32.04
water heating	Auto reset	retail	21.93	2	6284	31.0	16.45	27.41	32.89
water heating	Auto reset	warehouse	21.93	1	6284	31.0	16.45	27.41	32.89
water heating	Auto reset	office	21.93	1	6285	31.0	16.45	27.41	32.90
space heating	HVAC maintenance	ret cnt	25.69	13	6298	31.0	19.27	32.11	38.53
space heating	HVAC maintenance	off pkg	27.22	95	6393	31.5	20.42	34.03	40.84
space heating	HVAC maintenance	off cnt	27.46	91	6484	32.0	20.60	34.33	41.19
space heating	Low-E glass	off pkg	29.25	93	6577	32.4	21.93	36.56	43.87
water heating	Auto reset	restaurant	32.01	1	6578	32.4	24.00	40.01	48.01
water heating	High-efficiency boiler	retail	43.10	0	6578	32.4	32.32	53.87	64.65
water heating	High-efficiency boiler	warehouse	43.10	1	6579	32.4	32.33	53.88	64.65
water heating	Auto reset	supermarket	43.86	0	6579	32.4	32.90	54.83	65.79
space heating	Low-E glass	restaurant	51.09	12	6591	32.5	38.32	63.86	76.64
space heating	Low-E glass	supermarket	53.47	9	6600	32.5	40.10	66.84	80.21
space heating	Low-E glass	ret pkg	54.11	98	6698	33.0	40.58	67.64	81.17
space heating	Low-E glass	warehouse	59.14	129	6827	33.7	44.35	73.92	88.71
space heating	Low-E glass	ret cnt	59.78	12	6838	33.7	44.84	74.73	89.68
water heating	Tune boiler	retail	71.98	0	6838	33.7	53.99	89.98	107.97
water heating	Tune boiler	warehouse	71.99	0	6839	33.7	53.99	89.98	107.98
space heating	Temperature set-back	supermarket	374.92	0	6839	33.7	281.19	468.64	562.37
space heating	HVAC heat recovery	ret cnt	562.13	0	6839	33.7	421.60	702.66	843.19

Use of the BECA data, however, must be cautioned by the following considerations: (1) the projects included in the database were selected based on the completeness of data available -- the resulting findings, while indicative of actual performance, are not necessarily statistically representative; (2) all results are presented in common units of changes in site energy intensity, sometimes making it difficult to isolate separate gas and electricity savings; and (3) packages of measures are typically installed, making it difficult to identify the savings due to individual measures.

At the most aggregate level, the BECA data suggest that fuel savings were an important factor in the cost-effectiveness of the retrofits examined. For health and education buildings, fuel savings accounted for nearly all savings. For health (29 projects), fuel savings averaged 15% (total savings were slightly more than 15%) of pre-retrofit total site energy use, with an average payback time of just under 6 years. For education (207 projects), fuel savings averaged nearly 16% (total savings averaged slightly more than 16%) of pre-retrofit total site energy use, with an average payback time of a little more than 5 years. For offices (74 projects), fuel savings averaged 5% (total savings averaged 23%) of pre-retrofit total site energy use, with an average payback time of 2.6 years. For retail (101 projects), fuel savings also averaged 5% (total savings averaged 21%) of pre-retrofit total site energy use, with an average payback time of only 1 year.

Typically, more than one type of retrofit was considered in a project. The BECA data report savings for classes of retrofits (e.g., shell, HVAC, lights, etc.). For the 18 projects implementing shell measures alone (windows, insulation, infiltration reduction, singly or in combination), the site energy savings averaged 14%, with the majority of these savings being attributable to fuel use reductions. HVAC measures alone (115 projects) saved an average of 18%. HVAC measures in combination with shell measures (30 projects) saved an average of 24%. These savings are in line with our savings potential estimates at $4.00/DTh.

For a small number of projects, only a single retrofit was performed. While there remains the problem of separating energy savings between electricity and fuel, these measures are the only BECA data that allow for direct comparison to our study results. In general, the results are quite comparable.

Local HVAC controls (mostly, timeclocks) saved an average of 8% of total site energy use. Our simulations of timeclocks led to natural gas savings of between 8% and 13% (or about half these percentage amounts on a total site energy basis).

Improved maintenance (88 projects), often performed with in-house labor, saved an average of 12% of total site energy use. Our simulations of boiler tune-ups led to natural gas savings of between 2% and 5%. Our simulations of HVAC system maintenance measures led to natural gas savings of between 3% and 5%.

Window modifications (5 projects) saved an average of 6% of total site energy use. The simulations of double-pane windows led to natural gas savings ranging from just under 2% to nearly 10%. The simulations of low-e glass windows led to additional savings ranging from somewhat more than 1% to over 6%. For both measures, the savings are based on simulations that already include the effects of more cost-effective measures.

The BECA data also include information on the relationship between predicted and measured performance for nearly 30% of the projects. While the researchers found significant differences between the predicted and measured savings, they also note that there is "a fairly even split between underestimates and overestimates of savings."

Thus, the limited field data available tend to support the validity of the savings estimates presented in this chapter.

Chapter 5

THE ECONOMICS OF COMMERCIAL GAS FUEL-SWITCHING FOR SPACE HEATING AND COOLING

The six prototypical buildings used to assess the economic potential for commercial sector gas space-heating energy-efficiency measures in Chapter 4 were also used to examine the economics of fuel-switching from electricity to gas for space heating and cooling. The economic perspective is a comparison of the lifecycle costs of owning and operating electric compared to gas space heating or cooling equipment.[1] Lifecycle costs are compared from a total resource perspective, meaning that electricity and gas consumption are valued at their marginal (avoided) cost, and not the retail cost to consumers. Because consensus over the value of gas avoided costs does not exist, the economics of fuel-switching have been analyzed using a "breakeven" gas price.

The economics of using electricity compared to gas for water heating and cooking were not studied.

THE CALCULATION OF A BREAKEVEN GAS PRICE

Lifecycle costs of electric versus gas space-heating and cooling technologies cannot be calculated without a well-defined avoided cost for gas. However, since the other costs required

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[1] This perspective differs from that used in the analysis of residential fuel-switching presented in Chapter 3. The residential analysis considered replacement of existing electricity using equipment with gas-fired appliances. In that case, the energy cost savings from switching to gas had to off-set the *entire* capital cost of the new gas appliance in order to be cost-effective. In this Chapter, we consider the choice of equipment at the time of replacement. In this case, only the *difference* in capital costs between new gas and new electric equipment must be off-set by the energy cost savings for the gas equipment to be cost-effective. The approach for the residential and commercial sectors differ because commercial equipment is generally larger and more expensive, which means that commercial fuel-switching will usually be cost-effective only at the time existing equipment is being replaced. Residential fuel-switching will often be cost-effective on a retrofit basis.

by such a lifecycle analysis can be specified, for example, the capital and operating cost of both technologies, the real discount rate (5 percent), and the avoided cost of electricity, a breakeven gas price can be calculated by determining the price of gas at which the lifecycle costs of competing electric and gas options are identical. At this price, one would be indifferent (on economic grounds) to the choice of technology. Thus, if the actual avoided cost of gas is lower than the breakeven price, then the gas technology would be more cost-effective than the electric technology and vice versa. To summarize the basic idea: a high breakeven gas price means that the gas technology will be generally cost-effective compared to the electric competitor. A detailed explanation of the calculations involved can be found in Appendix B.

Electric avoided costs were developed from a recent New York Public Service Commission order for long-run avoided costs for LILCo, ConEd for the BUG analysis, and NMPC for the NFG analysis. Table 1-1 gives these values for an annual average \$/kWh[2], and a winter and summer \$kW-yr. Sales of electricity to the utility for the cogeneration options were evaluated using the same avoided costs. While generalized avoided distribution costs are included in these avoided costs, site-specific avoided distribution costs, which may differ significantly from the reported service territory-wide averages and which may include distribution cost savings on the customer's side of the meter, are not included due to their highly site-specific nature.

The winter and summer capacity values of the technologies were estimated by averaging electricity demand over the peak demand-period hours (8 am to 8 pm) for weekdays in January, and over the peak demand period hours (12 pm to 6 pm) for weekdays in August, respectively. Consideration of only the change in building electricity demand during the single hour of the building's peak demand in each season, for example, would tend to overstate the capacity impacts of the technologies to the electric utility due to the lack of coincidence between the

[2] The avoided energy cost represents an annual weighted average of peak and off-peak avoided costs for summer and winter. Later in this Chapter, a sensitivity analysis is performed on the avoided costs used in the analysis to examine the reasonableness of the weighting procedure used.

timing of a particular building's peak demand and that of the utility system.[3] Similarly, consideration of the building's peak demand only at the time of utility system peak places undue importance on a single hour's contribution. That is, peak demand periods and system peak capacity values are defined not in terms of a single hour of system peak, but on the basis of the likely times of system peak, because the time, day or even month of system peak is rarely identical from year to year. An average over the entire peak demand period, separately for the peak heating and cooling months, is a more conservative estimate of the capacity impacts of the technologies on the utility system in absence of building-specific coincidence factors.[4]

The energy performance of the gas and electric space-heating and cooling technologies was calculated using DOE-2 simulations of the same prototypes used in the analysis of gas space heating energy-efficiency measures. However, reliance on the same prototypes used to evaluate energy-efficiency potential has important consequences for the fuel-switching analysis. That is, the prototypes were calibrated to mean or average end-use EUIs to generalize results for a broad population of buildings within a service territory. This decision, essential for determining a service territory-wide energy-efficiency potential, may under- or over-state the cost-effectiveness

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[3] Class load research, for example, suggests that commercial customer class electricity coincidence factors of less 60 percent are not uncommon, especially for smaller customers (SCE 1986). A coincidence factor is defined as the ratio of a customer's demand at the time of system peak demand to the customer's actual peak demand.

[4] Not surprisingly, different approaches to estimate the coincidence between building loads and utility system peak demands can yield the same basic result. Consider, for example, the retail building with a central HVAC system with centrifugal chillers compared to the central system with a gas engine-driven chiller; the simulations of the gas engine-driven chiller for the central HVAC system were also used to estimate the performance of the packaged gas engine cooling/heating system. For a single hour: At 4 pm on the hottest day in August, which can be assumed to be the system peak hour and day, the difference in electric loads between the two simulations leads to percentage reductions in electrical peak demand of 42 percent and 30 percent for the downstate and upstate locations, respectively. Consider four hours: At 4 pm on the four hottest days in August (for a broader measure of system peak demand), the average percentage reductions in electrical peak demand are 40 percent and 31 percent for the downstate and upstate locations respectively. Consider finally, 132 hours: (i.e., application of the technique used in the current study) the differences in loads are averaged over the 6 on-peak period hours, 12 to 6 PM, of all 22 weekdays in August, leading to peak demand reductions of 37 percent and 33 percent for the downstate and upstate locations respectively. In other words, for these examples, all three methods yield approximately the same result and no one method appears uniquely biased with respect to the others.

of gas fuel-switching because the most attractive gas fuel-switching markets are likely to be found in the "tails" of the distribution of EUIs. Depending on which tail of the distribution a building happens to fall, there will be fuel-switching opportunities that are both more and less cost-effective than that indicated by the analysis. Thus, the analysis reported here is not intended to substitute for site specific analysis of promising fuel switching opportunities.

COMMERCIAL GAS AND ELECTRIC SPACE HEATING AND COOLING TECHNOLOGIES

Separate analyses were performed for gas and electric heating and cooling technologies, within both central and packaged HVAC systems. Table 5-1 lists these technologies and the building type/HVAC system configurations for which they were considered.[5]

The base technology was always assumed to be electric. For packaged HVAC systems, three base systems were considered: a packaged HVAC system with electric resistance heating and compressive cooling; a packaged HVAC system with an air source heat pump for heating and cooling; and a packaged HVAC system with gas heating and electric compressive cooling. Using these three base system configurations, up to three gas heating and cooling options were considered: packaged HVAC with standard efficiency gas heating and electric cooling ("gas heat"); a packaged HVAC with desiccant gas heating and cooling ("desiccant"); and (3) a packaged HVAC with gas engine cooling and gas-fired heating ("gas eng cool").

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[5] Baseboard electric resistance heat was not studied as part of this analysis. Baseboard heat is found in some small commercial buildings. A rough indication of the cost-effectiveness of switching from electric baseboard heat to gas heat can be found by reviewing the analysis of residential fuel switching in Chapter 3.

Table 5-1. Applicability of Fuel-Switching Technologies to Commercial Building Prototypes.

Measure	Office Central	Office Pkg	Retail Central	Retail Pkg	Hospital	Super-market	Restau-rant	Warhse
Std. Gas Boiler	X		X		X			
Hi Eff Gas Boil.	X		X		X			
Elect. Boiler	X		X		X			
Pkg. Gas Heat, Elec. Cool		X		X		X	X	X
Pkg. Elec Heat/Cool		X		X		X	X	X
Pkg. Air Source Heat Pump		X		X		X	X	X
Pkg. Gas Eng Heat/Cool		X		X		X	X	X
Pkg Desiccant		X		X		X	X	X
Centrifugal Chiller	X		X		X			
Gas-fired Absor	X		X		X			
Eng. Chlr	X		X		X			
Eng. Chlr w/HR	X		X		X			
Cogeneration	X		X		X			
Cogeneration w/Absorption	X		X		X			

For central HVAC systems, separate comparisons were made for heating and cooling. For heating, the base HVAC system was an electric boiler with electric compressive cooling. The alternatives considered include: standard; and high-efficiency gas boilers, with electric compressive cooling. For cooling, the base HVAC system was a gas boiler with electric centrifugal chillers. The gas cooling alternatives considered include: gas-fired absorption chillers; gas engine-driven chillers with and without heat recovery; and packaged cogeneration with and without absorption cooling, operated in both a thermal load-following and electric load-following mode.

The energy use of all options except one was modeled using the DOE-2 building energy analysis program. The current version of the DOE-2 program (2.1D) does not offer a packaged gas engine-driven HVAC system, although both a central system engine-driven chiller and a packaged HVAC system with electric compressive cooling can be simulated. To estimate the performance of the packaged gas engine-driven HVAC system, we have used the design full-load and simulated part-load performance characteristics of the central system gas engine-driven chiller, adjusted for the full-load COP of packaged gas engine-driven chillers, to meet the cooling loads calculated for the conventional packaged gas-heated, electrically cooled HVAC system.

In addition to the data developed by Xenergy (Zoellick 1992) for the gas energy-efficiency analysis, there were seven additional sources of information on the capital and O&M costs, and lifetimes for the fuel-switching measures. These sources included a recent study of gas cooling for commercial buildings in Rhode Island (Xenergy 1991); additional information provided by Xenergy on packaged gas engine-drive HVAC systems (Reed 1992); the EPRI TAG manual for commercial sector technologies (DFI 1988); the Wisconsin Center for Demand-Side Research data base of commercial sector technologies (SRC 1990a); an EPRI survey of small cogeneration system costs (SRC 1990b); a recent NYSERDA study of small cogeneration system operating experience (SAIC 1991); and an assessment of commercial building gas technologies by Northern States Power (NSP 1990). The technology cost and lifetime information from these studies is summarized in Tables 5-2 through 5-5.

Table 5-2. Summary of Fuel-Switching Technology Costs and Lifetimes - Pkg. Heating/Cooling.

System Type	Capital Cost (1991$/ton)	Lifetime	O&M Cost (1991$/ton-yr)	Source/Notes
Pkg. Rooftop - Gas Heat (eff. = 75%), Elect. Cool (COP = 2.8)	828	15	50.4	Xenergy 1991
Pkg. Rooftop - Elect. Heat (eff. = 100%), and Elect. Cool (COP = 2.8)	840	15	50.4	Derived from Xenergy 1991
Pkg. Rooftop - Air Source Heat Pump (Cooling COP = 2.8, Heating COP = 2.7)	984	15	50.4	Xenergy 1991
Pkg. Rooftop - Gas Heat (eff. = 75%) and Gas Eng Cool (COP = 0.65)	1442	15	50.4	Reed 1992a, Xenergy 1991
Pkg. Desiccant (eff. calculated by DOE-2)	1932	15	84.0	NSP 1991

Table 5-3. Summary of Fuel-Switching Technology Costs and Lifetimes - Space Heating.

System Type	Capital Cost (1991$/kBtuh)	Lifetime	O&M Cost (1991$/kBtuh-yr)	Source/Notes (kBtuh = heating capacity)
Std. Gas Boiler - sm (eff. = 80%)	6.5	15	0.97	Zoellick 1992; DFI 1988
Std. Gas Boiler - lg (eff. = 80%)	5.0	15	0.55	Zoellick 1992; DFI 1988
HiEff Gas Boiler - sm (eff. = 85%)	12.0	15	0.97	Zoellick 1992; DFI 1988
HiEff Gas Boiler - lg (eff. = 85%)	7.0	15	0.55	Zoellick 1992; DFI 1988
Electric Boiler (eff. = 100%)	6.0	15	0.72	DFI 1988

Table 5-4. Summary of Fuel-Switching Technology Costs and Lifetimes - Space Cooling.

System Type	Capital Cost (1991$/ton)[6]	Lifetime	O&M Cost (1991$/ton-yr)	Source/Notes
Centrifugal (COP = 4.6)	828	15	3.6	Xenergy 1991
Gas-fired Absorption (COP = 1.0)	1272	15	6.0	Xenergy 1991
Engine-driven Chiller (COP = 1.4)	1260	15	14.4	Xenergy 1991
Engine-driven Chiller w/Heat Recovery (COP = 1.4)	1272	15	14.4	derived from Xenergy 1991

Table 5-5. Summary of Fuel-Switching Technology Costs and Lifetimes - Cogeneration.

System Type	Capital Cost (1991$/kW)	Lifetime	O&M Cost (1991$/kW-yr)	Source/Notes (kW = elect. gen. capacity)
Cogeneration (eff. = 35%) w/o Absorption Cooling	1693	15	84	SRC 1990; SAIC 1991
Cogeneration (eff. = 35%) w/Absorption Cooling (COP = 1.0)	1857	15	84	SRC 1990; SAIC 1991

[6] Capital cost of gas cooling options includes incremental cost of additional cooling tower capacity relative to higher COP electric centrifugal chillers.

THE COST-EFFECTIVENESS OF GAS VERSUS ELECTRIC SPACE HEATING AND COOLING TECHNOLOGIES

The breakeven cost of gas relative to electric commercial sector heating and cooling technologies is presented separately for each utility service territory. The breakeven gas cost is expressed in $/DTh. Although there is no consensus about the exact value of gas avoided costs, a range of values from $2 to $4/DTh is a reasonable starting point.[7] The discussion of results will refer to this range in assessing the economics of fuel-switching. Results are presented separately for packaged HVAC systems and for central HVAC systems.

The analysis of fuel-switching is based on technology cost and performance estimates that represent current practices. To the extent that future technological improvements or manufacturing cost reductions through dramatically increased sales volumes reduce these costs, the results of the analysis will be conservative. In the case of packaged gas engine chillers, for example, reductions in the cost of future systems would improve their economic attractiveness relative to the analysis in this study.

These effects, as well as others that might reduce the cost-effectiveness of gas alternatives are considered directly through sensitivity analyses on the cost of the gas alternatives. Three sensitivity analyses were performed. In the first sensitivity analysis, the effect of a 25 percent increase in the capital, installation, and O&M operating cost of the gas alternatives was considered. This sensitivity may also be used to consider the impacts of the additional costs of a utility-sponsored program to promote a gas technology. The effect is to lower the gas breakeven price, thereby making gas alternatives less attractive compared to the electric base technologies. Although the translation is not one-for-one, this first sensitivity is also equivalent to assuming that the difference in gas consumption is greater than that calculated by DOE-2, which might result from poorer than expected performance of the gas alternatives leading to

[7] The range of gas avoided costs considered differs from that used in the residential analyses and the commercial energy efficiency analysis. On the lower end of the range, $2/DTh is close to estimates that have been made of summer avoided gas costs. We felt this lower bound would be more instructive for use in evaluating gas fuel-switching technologies competing against electric summer cooling technologies.

greater gas use.

The effect of a 25 percent decrease in the cost of gas alternatives was also considered. The effect of this sensitivity is to increase the gas breakeven price making the gas alternatives more attractive compared to the electric base technologies. As with the first sensitivity, this case also addresses the situation in which the gas alternative technology performs better than the simulation using DOE-2, leading to a decrease in the difference in gas consumption between the base electric technology and the gas alternative. Of particular importance for desiccant technologies, this sensitivity may address the dehumidification cost savings associated with desiccant systems. That is, the dehumidification benefits of desiccants may eliminate the need for a separate mechanical dehumidification system for those applications requiring closer humidity control. For these situations, which are highly application-specific, the cost savings should be credited as offsetting the full-cost of the desiccant system.

Finally, to address concerns that using a weighted average avoided electric energy cost may produce biases when applied to technologies whose load shape impacts differ from those assumed in the weighting process, a third sensitivity analysis was performed to place an upper limit on the impact of the weighting process used to combine on and off-peak electric avoided costs from different seasons. For this sensitivity case, the weighted average avoided electric energy cost is replaced with on-peak avoided electric energy cost. In other words, all changes in electricity use are valued at the highest avoided cost. This sensitivity increases the gas breakeven price making the gas alternatives more attractive compared to the electric base technologies. The on-peak avoided electricity costs from Table 1-1, are \$.0460, \$.0407, and \$.0404/kWh up from \$.0393, \$.0362, and \$.0364/kWh for LILCo, BUG (ConEd), and NFG (NMPC), respectively.

In addition to these three sensitivity analyses, we also considered conducting a sensitivity case which analyzes fuel-switching economics from a consumer perspective, based on retail electricity costs. However, the economics of fuel-switching to consumers can vary substantially as retail rate structures vary. Since all electric utilities have multiple commercial rate structures, which have large variations in energy and demand charges, to conduct a single analysis would be a gross oversimplification. Conducting separate analyses for each rate structure is beyond the scope for this project, and hence a consumer perspective analysis was not conducted.

Commercial Fuel-Switching Results for LILCo

Table 5-6 presents intermediate results from the fuel-switching analysis. For each technology considered (base and gas alternative), costs are reported on a normalized basis (using floor area) for each component in the calculation of the gas breakeven price. The capital and installation costs of the technologies are combined and expressed in levelized (i.e., annualized) dollars per unit of floor area. The energy values (either cost for electricity or energy use for both electricity and gas) represent total building consumption. Thus, the electricity values include electricity use for non-space conditioning end uses, such as lighting. For electricity, annual kWh/sqft, as well as summer and winter capacity values (W/sqft) are reported.

Tables 5-7 through 5-10 present the cost-effectiveness of gas heating and cooling technologies compared to an electric base technology. Table 5-7 presents results from the primary analysis, tables 5-8, 5-9, and 5-10 present results from the sensitivity cases; gas technology cost increased by 25 percent, gas technology cost decreased by 25 percent; and all changes in electricity consumption valued at the on-peak avoided electricity price, respectively. Following the results from the primary analysis, the impacts of the sensitivity cases are discussed.

For the packaged HVAC system analysis, three base electricity technologies were compared to three gas alternatives. Generally speaking, packaged gas heating systems with electric cooling and, to a lesser but sometimes more dramatic extent, packaged gas engine-driven cooling and heating are more cost-effective than the electric base technologies. The packaged desiccant system is sometimes cost-effective.

Table 5-6. Intermediate Values for Commercial Fuel-Switching Analysis - LILCo.

Packaged HVAC

	Reference Cases		Gas Alternatives			
	1	2	1	2	3	
Heat Type	El Res	El HP	Gas	Descnt	Gas	
Cool Type	El Comp	El Comp	El Comp	Descnt	Gas Eng	Units
OFFICE						
Lvl. Install+O&M	0.26	0.30	0.27	0.56	0.39	$/sqft.yr
Ann. Elect. Cost	1.56	1.50	1.32	1.18	0.79	$/sqft.yr
Elect. Consumption	23.1	21.9	17.8	14.5	15.8	kWh/sqft.y
Summer Capacity	5.0	5.0	5.0	4.9	1.2	W/sqft
Winter Capacity	2.2	1.9	1.1	0.8	1.1	W/sqft
Gas Consumption	6.6	6.6	37.6	24.3	58.5	kBtu/sqft.y
RETAIL						
Lvl. Install+O&M	0.30	0.34	0.31	0.64	0.45	$/sqft.yr
Ann. Elect. Cost	1.42	1.22	1.01	1.10	0.68	$/sqft.yr
Elect. Consumption	21.4	17.0	12.4	12.3	9.9	kWh/sqft.y
Summer Capacity	4.1	4.1	4.1	4.8	2.1	W/sqft
Winter Capacity	5.9	4.1	2.1	2.0	2.1	W/sqft
Gas Consumption	5.8	5.8	53.1	26.5	78.0	kBtu/sqft.y
SUPERMARKET						
Lvl. Install+O&M	0.52	0.59	0.53	1.11	0.77	$/sqft.yr
Ann. Elect. Cost	3.92	3.67	3.30	3.33	2.86	$/sqft.yr
Elect. Consumption	68.5	62.8	54.4	54.1	51.3	kWh/sqft.y
Summer Capacity	8.8	8.8	8.8	9.1	6.2	W/sqft
Winter Capacity	11.0	9.0	6.2	6.1	6.2	W/sqft
Gas Consumption	14.4	14.4	92.3	99.8	123.4	kBtu/sqft.y
RESTAURANT						
Lvl. Install+O&M	0.45	0.51	0.46	0.95	0.66	$/sqft.yr
Ann. Elect. Cost	1.92	1.55	1.16	0.93	0.86	$/sqft.yr
Elect. Consumption	33.6	25.2	16.4	12.9	13.0	kWh/sqft.y
Summer Capacity	3.9	3.9	3.9	3.2	2.6	W/sqft
Winter Capacity	8.3	5.5	2.6	2.2	2.6	W/sqft
Gas Consumption	86.1	86.1	177.5	168.8	207.1	kBtu/sqft.y
WAREHOUSE						
Lvl. Install+O&M	0.27	0.31	0.28	0.58	0.40	$/sqft.yr
Ann. Elect. Cost	0.98	0.83	0.67	0.82	0.79	$/sqft.yr
Elect. Consumption	15.2	11.3	7.4	7.8	6.1	kWh/sqft.y
Summer Capacity	3.1	3.1	3.1	4.2	0.2	W/sqft
Winter Capacity	0.2	0.2	0.2	0.2	0.2	W/sqft
Gas Consumption	2.9	2.9	42.3	17.3	58.5	kBtu/sqft.y

Central HVAC - Heating

	Reference Case	Gas Alternatives		
	1	1	2	
Heat Type	El Boil	Std Gas	Hieff Gas	Units
OFFICE				
Lvl. Install+O&M	0.04	0.04	0.06	$/sqft.yr
Ann. Elect. Cost	2.66	1.38	1.38	$/sqft.yr
Elect. Consumption	53.8	21.1	21.1	kWh/sqft.y
Summer Capacity	4.3	4.3	4.3	W/sqft
Winter Capacity	1.6	1.6	1.6	W/sqft
Gas Consumption	6.6	75.8	72.0	kBtu/sqft.y
RETAIL				
Lvl. Install+O&M	0.05	0.06	0.09	$/sqft.yr
Ann. Elect. Cost	2.48	1.15	1.15	$/sqft.yr
Elect. Consumption	49.8	15.6	15.6	kWh/sqft.y
Summer Capacity	4.0	4.0	4.0	W/sqft
Winter Capacity	3.3	3.3	3.3	W/sqft
Gas Consumption	5.8	78.2	74.2	kBtu/sqft.y
HOSPITAL				
Lvl. Install+O&M	0.04	0.05	0.07	$/sqft.yr
Ann. Elect. Cost	2.83	1.17	1.17	$/sqft.yr
Elect. Consumption	60.2	18.0	18.0	kWh/sqft.y
Summer Capacity	3.6	3.6	3.6	W/sqft
Winter Capacity	2.0	2.0	2.0	W/sqft
Gas Consumption	23.4	113.5	108.5	kBtu/sqft.y

Table 5-6. Intermediate Values for Commercial Fuel-Switching Analysis - LILCo.

Central HVAC - Cooling

	Reference Case	Gas Alternatives			
	1	1	2	3	
Cool Type	El Comp	Gas Abs	Gas Eng	Gas Eng w/HR	Units
OFFICE					
Lvl. Install + O&M	0.07	0.19	0.18	0.20	$/sqft.yr
Ann. Elect. Cost	1.38	1.17	1.08	1.15	$/sqft.yr
Elect. Consumption	21.1	17.9	16.3	17.6	kWh/sqft.y
Summer Capacity	4.3	3.6	3.4	3.6	W/sqft
Winter Capacity	1.6	1.3	1.1	1.3	W/sqft
Gas Consumption	75.8	133.6	121.3	98.0	kBtu/sqft.y
RETAIL					
Lvl. Install + O&M	0.12	0.31	0.29	0.32	$/sqft.yr
Ann. Elect. Cost	1.15	0.90	0.81	0.88	$/sqft.yr
Elect. Consumption	15.6	13.0	11.7	12.7	kWh/sqft.y
Summer Capacity	4.0	2.9	2.5	2.8	W/sqft
Winter Capacity	3.3	2.9	2.6	2.8	W/sqft
Gas Consumption	78.2	127.4	117.7	97.7	kBtu/sqft.y
HOSPITAL					
Lvl. Install + O&M	0.17	0.43	0.41	0.44	$/sqft.yr
Ann. Elect. Cost	1.17	0.91	0.83	0.92	$/sqft.yr
Elect. Consumption	18.0	14.8	14.0	14.0	kWh/sqft.y
Summer Capacity	3.6	2.5	2.1	2.1	W/sqft
Winter Capacity	2.0	1.8	2.0	2.0	W/sqft
Gas Consumption	113.5	144.3	151.1	131.2	kBtu/sqft.y

Central HVAC - Cogen

	Reference Case	Gas Alternatives				
	1	1	2	3	4	
Heat Type	Gas Boil	Cogen	Cogen	Cogen	Cogen	
Cool Type	El Comp	El Comp	Abs/El	El Comp	Abs/El	Units
OFFICE						
Lvl. Install + O&M	0	0.33	0.35	0.33	0.35	$/sqft.yr
Ann. Elect. Cost	1.38	1.06	1.03	0.69	0.67	$/sqft.yr
Elect. Consumption	21.1	14.1	14.0	8.5	8.4	kWh/sqft.y
Summer Capacity	4.3	4.0	3.8	2.9	2.7	W/sqft
Winter Capacity	1.6	0.9	0.9	0.2	0.2	W/sqft
Gas Consumption	75.8	111.7	112.4	175.7	175.7	kBtu/sqft.y
RETAIL						
Lvl. Install + O&M	0	0.74	0.79	0.74	0.79	$/sqft.yr
Ann. Elect. Cost	1.15	0.79	0.72	0.15	0.02	$/sqft.yr
Elect. Consumption	15.6	8.0	7.3	1.2	0.1	kWh/sqft.y
Summer Capacity	4.0	4.0	3.8	0.8	0.2	W/sqft
Winter Capacity	3.3	0.1	0.0	0.1	0.0	W/sqft
Gas Consumption	78.2	117.9	123.3	215.2	221.6	kBtu/sqft.y
HOSPITAL						
Lvl. Install + O&M	0	0.32	0.34	0.32	0.34	$/sqft.yr
Ann. Elect. Cost	1.17	0.81	0.76	0.53	0.51	$/sqft.yr
Elect. Consumption	18.0	10.3	9.5	6.3	6.3	kWh/sqft.y
Summer Capacity	3.6	3.4	3.3	2.2	2.2	W/sqft
Winter Capacity	2.0	0.6	0.6	0.6	0.6	W/sqft
Gas Consumption	113.5	153.0	160.3	200.1	200.1	kBtu/sqft.y

Table 5-7. LILCO Fuel-Switching Results.

Packaged Rooftop HVAC (reference case = electric resistance heating, electric cooling)

Breakeven Gas Price ($/DTh)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	7.05	8.42	7.74	8.15	7.57
dessicant	3.91	-1.29	-0.06	5.87	-10.10
gas engine cooling	12.13	8.17	7.28	6.89	10.88

Packaged Rooftop HVAC (reference case = electric air source heat pump)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	6.61	5.14	5.51	4.80	4.62
dessicant	3.13	-8.80	-2.10	2.16	-18.13
gas engine cooling	11.87	6.02	5.69	4.36	8.68

Packaged Rooftop HVAC (reference case = gas heating, electric cooling)

	Office	Retail	Supermarket	Restaurant	Warehouse
dessicant	3.01	1.74	-4.63	-11.26	6.47
gas engine cooling	19.62	7.70	6.13	3.01	20.57

Central HVAC (reference case = electric boiler, electric cooling)

Heating	Office	Retail	Hospital
standard efficiency gas boiler	18.32	18.26	18.32
high efficiency gas boiler	19.16	19.04	19.20

Central HVAC (reference case = gas boiler, electric cooling)

Cooling	Office	Retail	Hospital
gas-fired absorption	1.62	1.11	-0.09
gas engine chiller	4.31	4.26	2.63
gas engine chiller with heater	4.74	3.54	-1.19
cogen. without absorption - thermal trk	-0.28	-9.72	1.21
cogen. with absorption - thermal trk	0.04	-7.88	1.54
cogen. without absorption - electric trk	3.57	1.88	3.76
cogen. with absorption - electric trk	3.61	2.36	3.71

Table 5-8. LILCO Fuel-Switching Results - Gas Technology Cost +25%.

Packaged Rooftop HVAC (reference case = electric resistance heating, electric cooling)

Breakeven Gas Price ($/DTh)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	4.89	6.79	6.04	6.90	5.82
dessicant	-3.96	-9.06	-3.30	2.99	-20.05
gas engine cooling	10.25	6.62	5.51	5.52	8.98

Packaged Rooftop HVAC (reference case = electric air source heat pump)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	4.45	3.51	3.81	3.55	2.87
dessicant	-4.47	-16.57	-5.34	-0.71	-28.09
gas engine cooling	9.99	4.47	3.92	2.99	6.78

Packaged Rooftop HVAC (reference case = gas heating, electric cooling)

	Office	Retail	Supermarket	Restaurant	Warehouse
dessicant	-1.06	-1.38	-16.38	-17.46	2.72
gas engine cooling	14.97	3.20	-0.09	-2.60	13.09

Central HVAC (reference case = electric boiler, electric cooling)

Heating	Office	Retail	Hospital
standard efficiency gas boiler	18.16	18.04	18.18
high efficiency gas boiler	18.93	18.73	19.00

Central HVAC (reference case = gas boiler, electric cooling)

Cooling	Office	Retail	Hospital
gas-fired absorption	0.78	-0.47	-3.57
gas engine chiller	3.30	2.40	-0.07
gas engine chiller with heater	2.50	-0.57	-7.43
cogen. without absorption - thermal trk	-2.58	-14.39	-0.81
cogen. with absorption - thermal trk	-2.35	-12.25	-0.27
cogen. without absorption - electric trk	2.74	0.53	2.84
cogen. with absorption - electric trk	2.73	0.99	2.73

Table 5-9. LILCO Fuel-Switching Results - Gas Technology Cost -25%.

Packaged Rooftop HVAC (reference case = electric resistance heating, electric cooling)

Breakeven Gas Price ($/DTh)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	9.21	10.05	9.45	9.40	9.33
dessicant	11.78	6.48	3.18	8.74	-0.14
gas engine cooling	14.01	9.72	9.06	8.72	12.78

Packaged Rooftop HVAC (reference case = electric air source heat pump)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	8.77	6.77	7.22	6.04	6.38
dessicant	11.01	-1.03	1.14	5.03	-8.18
gas engine cooling	13.74	7.58	7.46	5.73	10.58

Packaged Rooftop HVAC (reference case = gas heating, electric cooling)

	Office	Retail	Supermarket	Restaurant	Warehouse
dessicant	7.08	4.85	7.12	-5.06	10.22
gas engine cooling	24.26	12.21	12.36	8.62	28.05

Central HVAC (reference case = electric boiler, electric cooling)

Heating	Office	Retail	Hospital
standard efficiency gas boiler	18.48	18.48	18.47
high efficiency gas boiler	19.38	19.35	19.40

Central HVAC (reference case = gas boiler, electric cooling)

Cooling	Office	Retail	Hospital
gas-fired absorption	2.45	2.68	3.38
gas engine chiller	5.31	6.12	5.33
gas engine chiller with heater	6.99	7.65	5.04
cogen. without absorption - thermal trk	2.01	-5.06	3.24
cogen. with absorption - thermal trk	2.43	-3.52	3.36
cogen. without absorption - electric trk	4.40	3.23	4.69
cogen. with absorption - electric trk	4.49	3.74	4.69

Table 5-10. LILCO Fuel-Switching Results - High Avoided Cost.

Gas Breakeven Cost ($/DTh)

Packaged Rooftop HVAC

	Office	Retail	Supermarket	Restaurant	Warehouse
reference case = electric resistance heating, electric cooling					
gas heat	8.20	9.69	8.96	9.42	8.89
dessicant	7.17	1.67	1.06	7.55	-6.66
gas eng cool	13.07	9.24	8.34	8.03	12.03
reference case = electric air source heat pump					
gas heat	7.49	5.79	6.24	5.44	5.28
dessicant	5.94	-7.26	-1.41	3.16	-16.51
gas eng cool	12.65	6.68	6.40	5.03	9.33
reference case = gas heating, electric cooling					
dessicant	2.75	2.05	-3.82	-11.29	6.76
gas eng cool	20.25	8.38	6.81	3.76	21.22

Central HVAC

HEATING	Office	Retail	Hospital
reference case = electric boiler, electric cooling			
std eff gas boiler	21.46	21.40	21.47
high eff gas boiler	22.48	22.37	22.53

COOLING	Office	Retail	Hospital
reference case = gas boiler, electric cooling			
gas-fired absorption	1.99	1.47	0.60
gas eng chlr	5.01	4.92	3.33
gas eng chlr w/hr	5.80	4.55	-0.13
cogen w/o abs - thrml trk	1.03	-8.39	2.62
cogen w/abs - thrml trk	1.36	-6.52	2.85
cogen w/o abs - elect trk	4.41	2.59	4.67
cogen w/abs - elect trk	4.46	3.09	4.63

Specifically, compared to a base electric technology consisting of electric resistance heating and electric cooling, the packaged gas heating/electric cooling system is slightly more cost-effective for the retail, supermarket, and restaurant, while the packaged gas engine cooling/heating system is slightly more cost-effective for the office and warehouse. This general pattern is repeated for the base electric technology consisting of an electric air-source heat pump; however, the cost advantage of the gas technologies is smaller and the gas engine system tends to be slightly more cost-effective than the gas heating/electric cooling system. For the base electric technology consisting of gas heating and electric cooling, the packaged gas engine cooling/heating system is highly cost-effective for the office and warehouse, and moderately cost-effective for the retail and supermarket.

For the central HVAC system analysis of heating, a single base electric heating technology was considered, electric boilers. Both the standard and high-efficiency gas alternatives were highly cost-effective compared to this base electric technology.

For the central HVAC system analysis of cooling, a single base electric technology was considered, centrifugal chillers. The gas-fired absorption alternative was not cost-effective. The gas engine-driven chiller with and without heat recovery was marginally cost-effective for the office and retail building types, but not for the hospital.

In addition, two cogeneration systems, one with and the other without absorption cooling, operated in two modes, were compared to the base technology of centrifugal chillers and gas boilers. The most cost-effective system is the cogeneration system with absorption cooling, tracking electrical loads. However, this system is only marginally cost-effective for the office and hospital.

An increase in the cost of the gas alternatives reduces the gas breakeven cost and reduces the cost-effectiveness of the alternatives compared to the base case (Table 5-8). Nevertheless, for the packaged HVAC system analysis, the gas engine cooling/heating system remains generally cost-effective compared to all base electric technologies, but only marginally compared to air source heat pumps in supermarket and restaurant. The packaged gas heat/electric cooling system follows the same general pattern. For the central HVAC system analysis, gas boilers remain highly cost-effective compared to electric boilers, the gas cooling technologies are generally not cost-effective, and the best cogeneration options are slightly less marginally cost-effective.

The effect of a decrease in the cost of the gas alternatives is to increase the gas breakeven cost and thereby increase the cost-effectiveness of the gas alternatives (Table 5-9). For the packaged HVAC system analysis, the most noticeable change from this sensitivity is the increase in the cost-effectiveness of the packaged desiccant system for several building types. For the central HVAC analysis, the gas engine chiller with heat recovery becomes cost-effective, as do some of the cogeneration systems.

The effect of valuing all changes in electricity use at the on-peak avoided cost of electricity increases the cost-effectiveness of the gas alternatives (Table 5-10). However, the effects are less dramatic than those found by decreasing the cost of the gas technologies. In other words, results from the previous sensitivity case examining lower gas technology costs encompasses the results from using a higher avoided electricity cost.

Commercial Fuel-Switching Results for BUG

Table 5-11 presents intermediate results from the fuel-switching analysis. For each technology considered (base and gas alternative), costs are reported on a normalized basis (using floor area) for each component in the calculation of the gas breakeven price. The capital and installation costs of the technologies are combined and expressed in levelized (i.e., annualized) dollars per unit of floor area. The energy values (either cost for electricity or energy use for both electricity and gas) represent total building consumption. Thus, the electricity values include electricity use for non-space conditioning end uses, such as lighting. For electricity, annual kWh/sqft, as well as summer and winter capacity values (W/sqft) are reported.

Tables 5-12 through 5-15 present the cost-effectiveness of gas heating and cooling technologies compared to an electric base technology. Table 5-12 presents results from the primary analysis, while tables 5-13, 5-14, and 5-15 present results from the sensitivity cases;

gas technology cost increased by 25 percent, gas technology cost decreased by 25 percent, and all changes in electricity consumption valued at the on-peak avoided electricity price, respectively.

For the packaged HVAC system analysis, three base electricity technologies were compared to three gas alternatives. Packaged gas engine-driven cooling and heating are generally more cost-effective than electric base heating technologies. Packaged gas heating systems with electric cooling are also cost-effective, albeit by a smaller margin in some cases. The packaged desiccant system is marginally cost-effective for the restaurant only against a base technology of electric resistance heating.

Compared to the packaged gas heating/electric cooling system, the packaged gas engine heating/cooling system is highly cost-effective for the office and warehouse, moderately cost-effective for the retail and supermarket, and marginally cost-effective for the restaurant.

For the central HVAC system analysis of heating, a single base electric heating technology was considered, electric boilers. Both the standard and high-efficiency gas alternatives are highly cost-effective compared to this base electric technology.

For the central HVAC system analysis of cooling, a single base electric technology was considered, centrifugal chillers. The gas-fired absorption alternative was not cost-effective. The gas engine-driven chiller with and without heat recovery was marginally cost-effective for the office and retail buildings, but not for the hospital.

In addition, two cogeneration systems, one with and the other without absorption cooling, operated in two modes, were compared to the base technology of centrifugal chillers and gas boilers. The cogeneration systems with and without absorption cooling, tracking electrical loads are the most cost-effective, but only marginally.

Table 5-11. Intermediate Values for Commercial Fuel-Switching Analysis - SUG.

Packaged HVAC

	Reference Cases		Gas Alternatives			
	1	2	1	2	3	
Heat Type	El Res	El HP	Gas	Descnt	Gas	
Cool Type	El Comp	El Comp	El Comp	Descnt	Gas Eng	Units
OFFICE						
Lvl. Install + O&M	0.26	0.30	0.27	0.56	0.39	$/sqft.yr
Ann. Elect. Cost	1.45	1.41	1.25	1.13	0.73	$/sqft.yr
Elect. Consumption	23.1	21.9	17.8	14.5	15.8	kWh/sqft.yr
Summer Capacity	5.0	5.0	5.0	4.9	1.2	W/sqft
Winter Capacity	2.2	1.9	1.1	0.8	1.1	W/sqft
Gas Consumption	6.6	6.6	37.6	24.3	58.5	kBtu/sqft.yr
RETAIL						
Lvl. Install + O&M	0.30	0.34	0.31	0.64	0.45	$/sqft.yr
Ann. Elect. Cost	1.30	1.13	0.95	1.05	0.63	$/sqft.yr
Elect. Consumption	21.4	17.0	12.4	12.3	9.9	kWh/sqft.yr
Summer Capacity	4.1	4.1	4.1	4.8	2.1	W/sqft
Winter Capacity	5.9	4.1	2.1	2.0	2.1	W/sqft
Gas Consumption	5.8	5.8	53.1	26.5	78.0	kBtu/sqft.yr
SUPERMARKET						
Lvl. Install + O&M	0.52	0.59	0.53	1.11	0.77	$/sqft.yr
Ann. Elect. Cost	3.61	3.40	3.07	3.11	2.65	$/sqft.yr
Elect. Consumption	68.5	62.8	54.4	54.1	51.3	kWh/sqft.yr
Summer Capacity	8.8	8.8	8.8	9.1	6.2	W/sqft
Winter Capacity	11.0	9.0	6.2	6.1	6.2	W/sqft
Gas Consumption	14.4	14.4	92.3	99.8	123.4	kBtu/sqft.yr
RESTAURANT						
Lvl. Install + O&M	0.45	0.51	0.46	0.95	0.66	$/sqft.yr
Ann. Elect. Cost	1.75	1.43	1.09	0.87	0.80	$/sqft.yr
Elect. Consumption	33.6	25.2	16.4	12.9	13.0	kWh/sqft.yr
Summer Capacity	3.9	3.9	3.9	3.2	2.6	W/sqft
Winter Capacity	8.3	5.5	2.6	2.2	2.6	W/sqft
Gas Consumption	66.1	66.1	177.5	168.8	207.1	kBtu/sqft.yr
WAREHOUSE						
Lvl. Install + O&M	0.27	0.31	0.28	0.58	0.40	$/sqft.yr
Ann. Elect. Cost	0.93	0.79	0.65	0.79	0.73	$/sqft.yr
Elect. Consumption	15.2	11.3	7.4	7.8	6.1	kWh/sqft.yr
Summer Capacity	3.1	3.1	3.1	4.2	0.2	W/sqft
Winter Capacity	0.2	0.2	0.2	0.2	0.2	W/sqft
Gas Consumption	2.9	2.9	42.3	17.3	58.5	kBtu/sqft.yr

Central HVAC - Heating

	Reference Case	Gas Alternatives		
	1	1	2	
Heat Type	El Boil	Std Gas	Hieff Gas	Units
OFFICE				
Lvl. Install + O&M	0.04	0.04	0.06	$/sqft.yr
Ann. Elect. Cost	2.47	1.30	1.30	$/sqft.yr
Elect. Consumption	53.6	21.1	21.1	kWh/sqft.yr
Summer Capacity	4.3	4.3	4.3	W/sqft
Winter Capacity	1.6	1.6	1.6	W/sqft
Gas Consumption	6.6	75.8	72.0	kBtu/sqft.yr
RETAIL				
Lvl. Install + O&M	0.05	0.06	0.09	$/sqft.yr
Ann. Elect. Cost	2.30	1.07	1.07	$/sqft.yr
Elect. Consumption	49.6	15.6	15.6	kWh/sqft.yr
Summer Capacity	4.0	4.0	4.0	W/sqft
Winter Capacity	3.3	3.3	3.3	W/sqft
Gas Consumption	5.8	78.2	74.2	kBtu/sqft.yr
HOSPITAL				
Lvl. Install + O&M	0.04	0.05	0.07	$/sqft.yr
Ann. Elect. Cost	2.63	1.10	1.10	$/sqft.yr
Elect. Consumption	60.2	18.0	18.0	kWh/sqft.yr
Summer Capacity	3.6	3.6	3.6	W/sqft
Winter Capacity	2.0	2.0	2.0	W/sqft
Gas Consumption	23.4	113.5	108.5	kBtu/sqft.yr

Table 5-11. Intermediate Values for Commercial Fuel-Switching Analysis - BUG.

Central HVAC - Cooling

	Reference Case	Gas Alternatives			
	1	1	2	3	
Cool Type	El Comp	Gas Abs	Gas Eng	Gas Eng w/HR	Units
OFFICE					
Lvl. Install + O&M	0.07	0.19	0.18	0.20	$/sqft.yr
Ann. Elect. Cost	1.30	1.10	1.01	1.08	$/sqft.yr
Elect. Consumption	21.1	17.9	16.3	17.6	kWh/sqft.yr
Summer Capacity	4.3	3.6	3.4	3.6	W/sqft
Winter Capacity	1.6	1.3	1.1	1.3	W/sqft
Gas Consumption	75.8	133.6	121.3	98.0	kBtu/sqft.yr
RETAIL					
Lvl. Install + O&M	0.12	0.31	0.29	0.32	$/sqft.yr
Ann. Elect. Cost	1.07	0.84	0.75	0.82	$/sqft.yr
Elect. Consumption	15.6	13.0	11.7	12.7	kWh/sqft.yr
Summer Capacity	4.0	2.9	2.5	2.8	W/sqft
Winter Capacity	3.3	2.9	2.6	2.8	W/sqft
Gas Consumption	78.2	127.4	117.7	97.7	kBtu/sqft.yr
HOSPITAL					
Lvl. Install + O&M	0.17	0.43	0.41	0.44	$/sqft.yr
Ann. Elect. Cost	1.10	0.85	0.77	0.85	$/sqft.yr
Elect. Consumption	18.0	14.8	14.0	14.0	kWh/sqft.yr
Summer Capacity	3.6	2.5	2.1	2.1	W/sqft
Winter Capacity	2.0	1.8	2.0	2.0	W/sqft
Gas Consumption	113.5	144.3	151.1	131.2	kBtu/sqft.yr

Central HVAC - Cogen

	Reference Case	Gas Alternatives				
	1	1	2	3	4	
Heat Type	Gas Boil	Cogen	Cogen	Cogen	Cogen	
Cool Type	El Comp	El Comp	Abs/El	El Comp	Abs/El	Units
OFFICE						
Lvl. Install + O&M	0	0.33	0.35	0.33	0.35	$/sqft.yr
Ann. Elect. Cost	1.30	1.01	0.97	0.66	0.64	$/sqft.yr
Elect. Consumption	21.1	14.1	14.0	8.5	8.4	kWh/sqft.yr
Summer Capacity	4.3	4.0	3.8	2.9	2.7	W/sqft
Winter Capacity	1.6	0.9	0.9	0.2	0.2	W/sqft
Gas Consumption	75.8	111.7	112.4	175.7	175.7	kBtu/sqft.yr
RETAIL						
Lvl. Install + O&M	0	0.74	0.79	0.74	0.79	$/sqft.yr
Ann. Elect. Cost	1.07	0.76	0.69	0.15	0.02	$/sqft.yr
Elect. Consumption	15.6	8.0	7.3	1.2	0.1	kWh/sqft.yr
Summer Capacity	4.0	4.0	3.8	0.8	0.2	W/sqft
Winter Capacity	3.3	0.1	0.0	0.1	0.0	W/sqft
Gas Consumption	78.2	117.9	123.3	215.2	221.6	kBtu/sqft.yr
HOSPITAL						
Lvl. Install + O&M	0	0.32	0.34	0.32	0.34	$/sqft.yr
Ann. Elect. Cost	1.10	0.77	0.73	0.50	0.49	$/sqft.yr
Elect. Consumption	18.0	10.3	9.5	6.3	6.3	kWh/sqft.yr
Summer Capacity	3.6	3.4	3.3	2.2	2.2	W/sqft
Winter Capacity	2.0	0.6	0.6	0.6	0.6	W/sqft
Gas Consumption	113.5	153.0	160.3	200.1	200.1	kBtu/sqft.yr

Table 5-12. BUG Fuel-Switching Results.

Packaged Rooftop HVAC (reference case = electric resistance heating, electric cooling)

Breakeven Gas Price ($/DTh)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	6.25	7.23	6.73	7.10	6.96
dessicant	1.79	-4.02	-1.00	4.53	-11.61
gas engine cooling	11.46	7.26	6.45	6.00	10.29

Packaged Rooftop HVAC (reference case = electric air source heat pump)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	6.01	4.52	4.91	4.62	4.32
dessicant	1.36	-10.22	-2.66	1.39	-18.81
gas engine cooling	11.31	5.48	5.15	3.85	8.32

Packaged Rooftop HVAC (reference case = gas heating, electric cooling)

	Office	Retail	Supermarket	Restaurant	Warehouse
dessicant	3.09	1.55	-5.11	-11.19	6.23
gas engine cooling	19.13	7.31	5.73	2.61	20.03

Central HVAC (reference case = electric boiler, electric cooling)

Heating	Office	Retail	Hospital
standard efficiency gas boiler	16.86	16.81	16.87
high efficiency gas boiler	17.62	17.50	17.66

Central HVAC (reference case = gas boiler, electric cooling)

Cooling	Office	Retail	Hospital
gas-fired absorption	1.39	0.84	-0.49
gas engine chiller	3.88	3.78	2.25
gas engine chiller with heater	4.11	2.81	-1.76
cogen. without absorption - thermal trk	-1.04	-10.95	0.30
cogen. with absorption - thermal trk	-0.72	-9.06	0.70
cogen. without absorption - electric trk	3.06	1.35	3.20
cogen. with absorption - electric trk	3.10	1.83	3.15

Table 5-13. BUG Fuel-Switching Results - Gas Technology Cost +25%.

Packaged Rooftop HVAC (reference case = electric resistance heating, electric cooling)

Breakeven Gas Price ($/DTh)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	4.09	5.60	5.02	5.85	5.21
dessicant	-6.08	-11.79	-4.24	1.66	-21.56
gas engine cooling	9.58	5.70	4.67	4.63	8.38

Packaged Rooftop HVAC (reference case = electric air source heat pump)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	3.84	2.89	3.21	3.01	2.56
dessicant	-6.51	-17.99	-5.90	-1.49	-28.76
gas engine cooling	9.43	3.93	3.37	2.48	6.41

Packaged Rooftop HVAC (reference case = gas heating, electric cooling)

	Office	Retail	Supermarket	Restaurant	Warehouse
dessicant	-0.99	-1.56	-16.86	-17.39	2.47
gas engine cooling	14.49	2.81	-0.49	-2.99	12.55

Central HVAC (reference case = electric boiler, electric cooling)

Heating	Office	Retail	Hospital
standard efficiency gas boiler	16.70	16.58	16.73
high efficiency gas boiler	17.39	17.19	17.46

Central HVAC (reference case = gas boiler, electric cooling)

Cooling	Office	Retail	Hospital
gas-fired absorption	0.56	-0.73	-3.97
gas engine chiller	2.88	1.92	-0.45
gas engine chiller with heater	1.87	-1.03	-7.99
cogen. without absorption - thermal trk	-3.34	-15.61	-1.73
cogen. with absorption - thermal trk	-3.11	-13.42	-1.11
cogen. without absorption - electric trk	2.24	0.00	2.28
cogen. with absorption - electric trk	2.22	0.45	2.17

Table 5-14. BUG Fuel-Switching Results - Gas Technology Cost -25%.

Packaged Rooftop HVAC (reference case = electric resistance heating, electric cooling)

Breakeven Gas Price ($/DTh)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	8.42	8.86	8.43	8.35	8.72
dessicant	9.66	3.75	2.24	7.41	-1.66
gas engine cooling	13.33	8.81	8.22	7.38	12.19

Packaged Rooftop HVAC (reference case = electric air source heat pump)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	8.17	6.15	6.62	5.51	6.07
dessicant	9.23	-2.46	0.58	4.26	-8.85
gas engine cooling	13.19	7.04	6.92	5.23	10.22

Packaged Rooftop HVAC (reference case = gas heating, electric cooling)

	Office	Retail	Supermarket	Restaurant	Warehouse
dessicant	7.16	4.67	6.64	-4.99	9.98
gas engine cooling	23.77	11.81	11.96	8.22	27.52

Central HVAC (reference case = electric boiler, electric cooling)

Heating	Office	Retail	Hospital
standard efficiency gas boiler	17.03	17.03	17.01
high efficiency gas boiler	17.85	17.81	17.86

Central HVAC (reference case = gas boiler, electric cooling)

Cooling	Office	Retail	Hospital
gas-fired absorption	2.23	2.42	2.99
gas engine chiller	4.89	5.64	4.95
gas engine chiller with heater	6.36	6.92	4.47
cogen. without absorption - thermal trk	1.25	-6.28	2.32
cogen. with absorption - thermal trk	1.67	-4.70	2.52
cogen. without absorption - electric trk	3.89	2.70	4.13
cogen. with absorption - electric trk	3.97	3.20	4.13

Table 5-15. BUG Fuel-Switching Results - High Avoided Cost.

Gas Breakeven Cost ($/DTh)

Packaged Rooftop HVAC

	Office	Retail	Supermarket	Restaurant	Warehouse
reference case = electric resistance heating, electric cooling					
gas heat	7.02	8.09	7.54	7.95	7.85
dessicant	3.98	-2.03	-0.24	5.66	-9.30
gas eng cool	12.09	7.98	7.16	6.77	11.06
reference case = electric air source heat pump					
gas heat	6.60	4.96	5.40	4.69	4.76
dessicant	3.24	-9.19	-2.20	2.06	-17.72
gas eng cool	11.84	5.93	5.62	4.31	8.76
reference case = gas heating, electric cooling					
dessicant	2.91	1.76	-4.57	-11.21	6.42
gas eng cool	19.56	7.76	6.19	3.12	20.47

Central HVAC

HEATING	Office	Retail	Hospital
reference case = electric boiler, electric cooling			
std eff gas boiler	18.98	18.91	18.98
high eff gas boiler	19.85	19.74	19.90

COOLING	Office	Retail	Hospital
reference case = gas boiler, electric cooling			
gas-fired absorption	1.65	1.09	-0.03
gas eng chlr	4.36	4.23	2.73
gas eng chlr w/hr	4.82	3.49	-1.04
cogen w/o abs - thrml trk	-0.16	-10.05	1.24
cogen w/abs - thrml trk	0.17	-8.15	1.58
cogen w/o abs - elect trk	3.63	1.83	3.81
cogen w/abs - elect trk	3.67	2.31	3.76

The effect of an increase in the cost of the gas alternatives is to reduce the gas breakeven cost and the cost-effectiveness of the alternatives compared to the base case (Table 5-13). There are no significant changes for the packaged HVAC system analysis; however the package gas heating/electric cooling option becomes only marginally cost-effective compared to the air source heat pump. The packaged gas engine cooling/heating system remains cost-effective against the packaged gas heat/electric cooling system for the office and warehouse, but is only marginally cost-effective for the retail building. For the central HVAC system analysis, gas boilers remain highly cost-effective compared to electric boilers; only one gas cooling technology application is even marginally cost-effective (gas engine chiller in offices); and the best cogeneration options are also only marginally cost-effective.

The effect of a decrease in the cost of the gas alternatives is to increase the gas breakeven cost and the cost-effectiveness of the gas alternatives (Table 5-14). For the packaged HVAC system analysis, the most noticeable change from this sensitivity is the increase in the cost-effectiveness of the packaged desiccant system for several building types. In addition, the packaged gas engine cooling/heating system becomes very strongly cost-effective compared to the packaged gas heat/electric cooling system for all building types. For the central HVAC analysis, the gas engine chiller with heat recovery becomes more cost-effective, as do a few of the cogeneration systems although to less degree.

The effect of valuing all changes in electricity use at the on-peak avoided cost of electricity increases the cost-effectiveness of the gas alternatives (Table 5-15). Once again, the effects are less dramatic than those found by decreasing the cost of the gas technologies. In other words, results from the previous sensitivity case examining lower gas technology costs encompasses the results from using a higher avoided electricity cost.

Commercial Fuel-Switching Results for NFG

Table 5-16 presents intermediate results from the fuel-switching analysis. For each technology considered (base and gas alternative), costs are reported on a normalized basis (using floor area) for each component in the calculation of the gas breakeven price. The capital and installation costs of the technologies are combined and expressed in levelized (i.e., annualized) dollars per unit of floor area. The energy values (either cost for electricity or energy use for both electricity and gas) represent total building consumption. Thus, the electricity values include electricity use for non-space conditioning end uses, such as lighting. For electricity, annual kWh/sqft, as well as summer and winter capacity values (W/sqft) are reported.

Tables 5-17 through 5-20 present the cost-effectiveness of gas heating and cooling technologies compared to an electric base technology. Table 5-17 presents results from the primary analysis, while tables 5-18, 5-19, and 5-20 present results from the sensitivity cases; gas technology cost increased by 25 percent, gas technology cost decreased by 25 percent, and all changes in electricity consumption valued at the on-peak avoided electricity price, respectively.

For the packaged HVAC system analysis, three base electricity technologies were compared to three gas alternatives. In sharp contrast to the downstate results for LILCo and BUG, the packaged desiccant system is the most cost-effective system for the office and retail building types compared to both base electric heating systems. To a smaller degree, but more consistently, packaged gas heating systems with electric cooling and packaged gas engine cooling and heating systems are cost-effective against these same two base electric heating technologies.

For the base electric technology consisting of gas heating and electric cooling, the packaged gas engine cooling/heating system is only cost-effective for the office and warehouse, while the desiccant system is never cost-effective.

For the central HVAC system analysis of heating, a single base electric heating technology was considered, electric boilers. As was found downstate, both the standard and high-efficiency gas alternatives were highly cost-effective compared to this base electric technology.

Table 5-16. Intermediate Values for Commercial Fuel-Swithing Analysis - NFG.

Packaged HVAC

	Reference Cases		Gas Alternatives			
	1	2	1	2	3	
Heat Type	El Res	El HP	Gas	Descnt	Gas	
Cool Type	El Comp	El Comp	El Comp	Descnt	Gas Eng	Units
OFFICE						
Lvl. Install+O&M	0.25	0.28	0.26	0.53	0.37	$/sqft.yr
Ann. Elect. Cost	1.41	1.33	1.02	0.81	0.77	$/sqft.yr
Elect. Consumption	25.1	23.6	17.8	13.8	16.3	kWh/sqft.y
Summer Capacity	4.6	4.7	4.6	4.2	1.3	W/sqft
Winter Capacity	2.6	2.3	1.2	0.8	1.2	W/sqft
Gas Consumption	6.6	6.6	48.0	23.4	62.5	kBtu/sqft.y
RETAIL						
Lvl. Install+O&M	0.29	0.33	0.30	0.62	0.43	$/sqft.yr
Ann. Elect. Cost	1.76	1.39	0.82	0.80	0.68	$/sqft.yr
Elect. Consumption	24.3	19.0	19.0	11.1	9.9	kWh/sqft.y
Summer Capacity	3.6	3.6	3.6	3.7	2.2	W/sqft
Winter Capacity	7.6	5.6	5.6	2.1	2.2	W/sqft
Gas Consumption	5.8	5.8	70.8	16.5	86.1	kBtu/sqft.y
SUPERMARKET						
Lvl. Install+O&M	0.43	0.49	0.45	0.93	0.65	$/sqft.yr
Ann. Elect. Cost	4.42	3.95	2.93	2.91	2.76	$/sqft.yr
Elect. Consumption	76.1	68.6	53.0	52.3	51.0	kWh/sqft.y
Summer Capacity	7.9	7.9	7.9	8.0	6.2	W/sqft
Winter Capacity	13.6	11.4	6.2	6.2	6.2	W/sqft
Gas Consumption	14.4	14.4	138.5	141.1	157.3	kBtu/sqft.y
RESTAURANT						
Lvl. Install+O&M	0.44	0.50	0.45	0.94	0.66	$/sqft.yr
Ann. Elect. Cost	2.61	1.99	0.98	0.75	0.87	$/sqft.yr
Elect. Consumption	41.0	30.7	15.4	11.8	13.4	kWh/sqft.y
Summer Capacity	3.2	3.2	3.2	2.1	2.6	W/sqft
Winter Capacity	10.7	8.0	2.6	2.2	2.6	W/sqft
Gas Consumption	86.2	86.1	218.5	195.3	234.0	kBtu/sqft.y
WAREHOUSE						
Lvl. Install+O&M	0.27	0.31	0.28	0.57	0.40	$/sqft.yr
Ann. Elect. Cost	0.81	0.65	0.43	0.46	0.77	$/sqft.yr
Elect. Consumption	17.5	13.0	7.0	7.0	6.2	kWh/sqft.y
Summer Capacity	2.7	2.7	2.7	3.3	0.2	W/sqft
Winter Capacity	0.2	0.2	0.2	0.2	0.2	W/sqft
Gas Consumption	2.8	2.8	55.4	11.9	62.5	kBtu/sqft.y

Central HVAC - Heating

	Reference Case	Gas Alternatives		
	1	1	2	
Heat Type	El Boil	Std Gas	Hieff Gas	Units
OFFICE				
Lvl. Install+O&M	0.04	0.05	0.07	$/sqft.yr
Ann. Elect. Cost	2.57	1.15	1.15	$/sqft.yr
Elect. Consumption	60.2	21.0	21.0	kWh/sqft.y
Summer Capacity	4.2	4.2	4.2	W/sqft
Winter Capacity	1.6	1.6	1.6	W/sqft
Gas Consumption	6.6	90.3	85.6	kBtu/sqft.y
RETAIL				
Lvl. Install+O&M	0.06	0.07	0.09	$/sqft.yr
Ann. Elect. Cost	2.66	1.07	1.07	$/sqft.yr
Elect. Consumption	59.3	15.5	15.5	kWh/sqft.y
Summer Capacity	3.7	3.7	3.7	W/sqft
Winter Capacity	3.4	3.4	3.4	W/sqft
Gas Consumption	5.6	99.3	94.1	kBtu/sqft.y
HOSPITAL				
Lvl. Install+O&M	0.05	0.06	0.08	$/sqft.yr
Ann. Elect. Cost	3.05	0.98	0.98	$/sqft.yr
Elect. Consumption	73.9	16.8	16.8	kWh/sqft.y
Summer Capacity	3.2	3.2	3.2	W/sqft
Winter Capacity	2.0	2.0	2.0	W/sqft
Gas Consumption	23.4	145.1	138.3	kBtu/sqft.y

Table 5-16. Intermediate Values for Commercial Fuel-Swithing Analysis - NFG.

Central HVAC - Cooling

Cool Type	Reference Case 1 El Comp	Gas Alternatives 1 Gas Abs	2 Gas Eng	3 Gas Eng w/HR	Units
OFFICE					
Lvl. Install+O&M	0.07	0.19	0.18	0.19	$/sqft.yr
Ann. Elect. Cost	1.15	0.98	0.90	0.96	$/sqft.yr
Elect. Consumption	21.0	18.0	16.5	17.8	kWh/sqft.y
Summer Capacity	4.2	3.6	3.4	3.6	W/sqft
Winter Capacity	1.6	1.3	1.1	1.3	W/sqft
Gas Consumption	90.3	143.3	131.1	109.1	kBtu/sqft.y
RETAIL					
Lvl. Install+O&M	0.11	0.29	0.27	0.30	$/sqft.yr
Ann. Elect. Cost	1.07	0.89	0.81	0.87	$/sqft.yr
Elect. Consumption	15.5	13.0	11.9	12.8	kWh/sqft.y
Summer Capacity	3.7	2.8	2.4	2.7	W/sqft
Winter Capacity	3.4	2.9	2.7	2.9	W/sqft
Gas Consumption	99.3	143.4	134.0	114.7	kBtu/sqft.y
HOSPITAL					
Lvl. Install+O&M	0.15	0.39	0.37	0.40	$/sqft.yr
Ann. Elect. Cost	0.98	0.82	0.81	0.86	$/sqft.yr
Elect. Consumption	16.8	14.2	14.1	14.9	kWh/sqft.y
Summer Capacity	3.2	2.4	2.1	2.4	W/sqft
Winter Capacity	2.0	1.8	2.0	2.0	W/sqft
Gas Consumption	145.1	155.2	170.2	155.3	kBtu/sqft.y

Central HVAC - Cogen

Heat Type / Cool Type	Reference Case 1 Gas Boil / El Comp	Gas Alternatives 1 Cogen / El Comp	2 Cogen / Abs/El	3 Cogen / El Comp	4 Cogen / Abs/El	Units
OFFICE						
Lvl. Install+O&M	0	0.33	0.35	0.33	0.35	$/sqft.yr
Ann. Elect. Cost	1.15	0.78	0.76	0.48	0.48	$/sqft.yr
Elect. Consumption	21.0	13.1	13.0	8.4	8.3	kWh/sqft.y
Summer Capacity	4.2	3.8	3.6	2.8	2.6	W/sqft
Winter Capacity	1.6	0.9	1.0	0.2	0.3	W/sqft
Gas Consumption	90.3	130.0	130.9	184.7	184.9	kBtu/sqft.y
RETAIL						
Lvl. Install+O&M	0	0.74	0.79	0.74	0.79	$/sqft.yr
Ann. Elect. Cost	1.07	0.44	0.39	0.08	0.00	$/sqft.yr
Elect. Consumption	15.5	6.5	5.8	1.0	0.0	kWh/sqft.y
Summer Capacity	3.7	3.6	3.5	0.5	0.0	W/sqft
Winter Capacity	3.4	0.1	0.0	0.1	0.0	W/sqft
Gas Consumption	99.3	146.6	151.3	228.4	236.5	kBtu/sqft.y
HOSPITAL						
Lvl. Install+O&M	0	0.32	0.34	0.34	0.34	$/sqft.yr
Ann. Elect. Cost	0.98	0.50	0.46	0.35	0.34	$/sqft.yr
Elect. Consumption	16.8	8.0	7.2	5.2	5.0	kWh/sqft.y
Summer Capacity	3.2	3.0	2.9	1.8	1.8	W/sqft
Winter Capacity	2.0	0.6	0.6	0.6	0.6	W/sqft
Gas Consumption	145.1	190.0	196.8	225.2	225.1	kBtu/sqft.y

Table 5-17. NFG Fuel-Switching Results.

Packaged Rooftop HVAC (reference case = electric resistance heating, electric cooling)

Breakeven Gas Price ($/DTh)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	9.33	14.23	11.83	12.28	7.13
dessicant	18.97	49.24	7.97	12.52	4.96
gas engine cooling	9.20	11.60	10.06	10.32	7.00

Packaged Rooftop HVAC (reference case = electric air source heat pump)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	8.12	9.28	8.62	8.07	4.77
dessicant	15.98	23.80	4.83	7.43	-8.70
gas engine cooling	8.30	7.59	7.27	6.56	4.95

Packaged Rooftop HVAC (reference case = gas heating, electric cooling)

	Office	Retail	Supermarket	Restaurant	Warehouse
dessicant	-6.23	-2.93	-20.68	-15.78	-1.78
gas engine cooling	8.82	0.41	-1.63	-6.35	6.14

Central HVAC (reference case = electric boiler, electric cooling)

Heating	Office	Retail	Hospital
standard efficiency gas boiler	16.96	16.93	16.98
high efficiency gas boiler	17.76	17.67	17.81

Central HVAC (reference case = gas boiler, electric cooling)

Cooling	Office	Retail	Hospital
gas-fired absorption	1.05	0.05	-7.80
gas engine chiller	3.52	2.75	-2.03
gas engine chiller with heater	3.32	0.57	-12.90
cogen. without absorption - thermal trk	1.02	-2.39	3.56
cogen. with absorption - thermal trk	0.81	-1.99	3.41
cogen. without absorption - electric trk	3.52	1.95	3.81
cogen. with absorption - electric trk	3.34	2.05	3.67

Table 5-18. NFG Fuel-Switching Results - Gas Technology Cost +25%.

Packaged Rooftop HVAC (reference case = electric resistance heating, electric cooling)

Breakeven Gas Price ($/DTh)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	7.78	13.09	10.94	11.42	5.82
dessicant	11.03	37.06	6.14	10.37	-10.79
gas engine cooling	7.53	10.26	8.93	9.21	5.35

Packaged Rooftop HVAC (reference case = electric air source heat pump)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	6.57	8.14	7.72	7.22	3.46
dessicant	8.05	11.62	3.00	5.28	-24.45
gas engine cooling	6.63	6.25	6.14	5.45	3.30

Packaged Rooftop HVAC (reference case = gas heating, electric cooling)

	Office	Retail	Supermarket	Restaurant	Warehouse
dessicant	-9.64	-5.21	-35.03	-21.84	-4.56
gas engine cooling	2.40	-6.63	-10.26	-16.90	-6.26

Central HVAC (reference case = electric boiler, electric cooling)

Heating	Office	Retail	Hospital
standard efficiency gas boiler	16.81	16.75	16.86
high efficiency gas boiler	17.55	17.41	17.64

Central HVAC (reference case = gas boiler, electric cooling)

Cooling	Office	Retail	Hospital
gas-fired absorption	0.17	-1.59	-17.32
gas engine chiller	2.44	0.78	-5.67
gas engine chiller with heater	0.77	-4.27	-22.67
cogen. without absorption - thermal trk	-1.06	-6.30	1.78
cogen. with absorption - thermal trk	-1.34	-5.77	1.77
cogen. without absorption - electric trk	2.65	0.52	2.81
cogen. with absorption - electric trk	2.42	0.61	2.61

Table 5-19. NFG Fuel-Switching Results - Gas Technology Cost -25%.

Packaged Rooftop HVAC (reference case = electric resistance heating, electric cooling)

Breakeven Gas Price ($/DTh)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	10.88	15.37	12.73	13.13	8.44
dessicant	26.90	61.42	9.80	14.67	20.71
gas engine cooling	10.87	12.94	11.20	11.43	8.65

Packaged Rooftop HVAC (reference case = electric air source heat pump)

	Office	Retail	Supermarket	Restaurant	Warehouse
gas heat	9.67	10.42	9.52	8.93	6.08
dessicant	23.92	35.98	6.66	9.57	7.05
gas engine cooling	9.97	8.93	8.41	7.67	6.60

Packaged Rooftop HVAC (reference case = gas heating, electric cooling)

	Office	Retail	Supermarket	Restaurant	Warehouse
dessicant	-2.81	-0.65	-6.32	-9.72	1.01
gas engine cooling	15.23	7.46	7.00	4.20	18.53

Central HVAC (reference case = electric boiler, electric cooling)

Heating	Office	Retail	Hospital
standard efficiency gas boiler	17.11	17.12	17.10
high efficiency gas boiler	17.97	17.93	17.99

Central HVAC (reference case = gas boiler, electric cooling)

Cooling	Office	Retail	Hospital
gas-fired absorption	1.92	1.68	1.71
gas engine chiller	4.60	4.72	1.61
gas engine chiller with heater	5.86	5.41	-3.14
cogen. without absorption - thermal trk	3.09	1.52	5.34
cogen. with absorption - thermal trk	2.96	1.79	5.06
cogen. without absorption - electric trk	4.39	3.39	4.81
cogen. with absorption - electric trk	4.27	3.48	4.74

Table 5-20. NFG Fuel-Switching Results - HIgh Avoided Cost.

Gas Breakeven Cost ($/DTh)

Packaged Rooftop HVAC

	Office	Retail	Supermarket	Restaurant	Warehouse
reference case = electric resistance heating, electric cooling					
gas heat	10.04	15.02	12.58	13.05	7.93
dessicant	21.66	53.42	8.73	13.59	9.56
gas eng cool	9.83	12.32	10.77	11.07	7.75
reference case = electric air source heat pump					
gas heat	8.68	9.74	9.13	8.54	5.23
dessicant	18.31	26.31	5.34	8.12	-6.06
gas eng cool	8.82	8.04	7.77	7.03	5.40
reference case = gas heating, electric cooling					
dessicant	-6.49	-2.86	-20.34	-15.94	-1.71
gas eng cool	9.22	0.85	-1.20	-5.81	6.55

Central HVAC

HEATING	Office	Retail	Hospital
reference case = electric boiler, electric cooling			
std eff gas boiler	18.84	18.81	18.86
high eff gas boiler	19.75	19.66	19.80

COOLING	Office	Retail	Hospital
reference case = gas boiler, electric cooling			
gas-fired absorption	1.28	0.27	-6.77
gas eng chlr	3.96	3.16	-1.60
gas eng chlr w/hr	4.01	1.26	-12.16
cogen w/o abs - thrml trk	1.81	-1.60	4.40
cogen w/abs - thrml trk	1.61	-1.18	4.22
cogen w/o abs - elect trk	4.06	2.40	4.39
cogen w/abs - elect trk	3.88	2.50	4.27

For the central HVAC system analysis of cooling, a single base electric technology was considered, centrifugal chillers. The gas-fired absorption alternative and the gas engine driven chiller without heat recovery were generally not cost-effective, except for the gas engine chiller in offices.

In addition two cogeneration systems, one with and the other without absorption cooling, operated in two modes, were compared to the base technology of centrifugal chillers and gas boilers. Overall, the cogeneration systems tracking electric loads were only marginally cost-effective for the office and hospital, although the thermal tracking systems were also marginally cost-effective for the hospital.

The effect of an increase in the cost of the gas alternatives is to reduce the gas breakeven cost and reduce the cost-effectiveness of the alternatives compared to the base case (Table 5-18). Nevertheless, most of the gas technologies remained cost-effective compared to the base electric heating technologies. Compared to the packaged gas heat/electric cooling system, however, neither gas cooling alternative, gas engine cooling nor desiccant, remains cost-effective. For the central HVAC system analysis, gas boilers remain highly cost-effective compared to electric boilers, and only one gas cooling technology application is even marginally cost-effective, as are only a few of the cogeneration options.

The effect of a decrease in the cost of the gas alternatives is to increase the gas breakeven cost and the cost-effectiveness of the gas alternatives (Table 5-19). For the packaged HVAC system analysis, all gas alternatives become strongly cost-effective compared to the base electric heating systems. Compared to the packaged gas heating/electric cooling system, the desiccant system remains not cost-effective but the packaged gas engine cooling/heating system becomes cost-effective for all building types. For the central HVAC analysis, the most significant changes are found in cooling. The gas engine chillers become moderately cost-effective for the office and retail building type; most of the cogeneration systems become marginally cost-effective, except thermal tracking in retail buildings.

The effect of valuing all changes in electricity use at the on-peak avoided cost of electricity increases the cost-effectiveness of the gas alternatives (Table 5-20). In this case, as was found for both LILCo and BUG, the effects are less dramatic than those found by decreasing the cost of the gas technologies. In other words, results from the previous sensitivity case examining lower gas technology costs encompasses the results from using a higher avoided electricity cost.

SIZE OF THE RESOURCE

Based on the economic analysis, we assessed the size of the cost-effective fuel-switching resource in the commercial sector. This analysis covers the three electric service areas most closely corresponding to the three gas utilities covered by this study -- LILCo, Consolidated Edison (whose service area partially overlaps with BUG's) and Niagara Mohawk (whose service area partially overlaps with NFG's). For this analysis we looked at total electric sales for each of the major end-uses for which fuel switching is an option (space heating and cooling); the proportion of businesses that now use electric equipment that are likely to have gas service available; and the proportion of businesses for which fuel switching is likely to be cost-effective. The product of these three variables is a rough estimate of the size of the available resource. Specific assumptions and calculations are summarized in Tables 5-21, 5-22 and 5-23 respectively.

The resource estimates provided by these simple models are approximate. The economics of fuel-switching, particularly for electric cooling, can be site specific. Based on our analyses of the economics of typical applications, we have made rough estimates of the proportion of buildings of each type that could benefit from cost-effective fuel switching. However, without data on the range of conditions in the real world, any estimates will be highly approximate and subject to a large error band -- on the order of plus or minus 50 percent. Furthermore, the other assumptions in the analysis are also imprecise. Thus, these estimates are intended to identify the order of magnitude of the fuel-switching resource to lay the groundwork for more detailed assessments.

Table 5-21. Estimate of Electricity Savings from Cost-Effective Fuel Switching in the Commercial Sector of Niagara Mohawk Power Corp.

		Office	Retail	Health	Supermarket	Restaurant	Warehouse	Total - Six Building Types	Notes/Sources (#'s are row #'s)
1	% of bldgs w/ gas on street	79%	79%	79%	79%	79%	79%		NYSEO 1990.
	SPACE HEATING								
2	Gas share	62%	75%	51%	78%	46%	69%		Jackson 1992a.
3	Electric share	20%	9%	15%	8%	10%	5%		Jackson 1992a.
4	Elec. use - GWh (1992)	527	139	142	55	43	8	914	NYSEO 1991c.
5	Cost-eff. poten. (% elec)	90%	90%	90%	90%	90%	90%		ACEEE estimate based on Table 5-14 & allowances for outliers.
6	% elec. w/ nearby gas	45%	17%	57%	7%	61%	33%		(1 - 2)/(100% - 2)
7	Savings potential (GWh)	211	21	73	3	24	2	335	(4 * 5 * 6)
8	Ratio M DTh/GWh	6.27	6.27	6.27	6.27	6.27	6.27		Based on efficiencies in Tables 5-2 and 5-3; assumes 75% base-board heat, 25% heat pumps.
9	Added gas sales (M DTh)	1,327	133	456	21	149	15	2,101	(7 * 8)
	AIR CONDITIONING								
10	Gas share	0%	0%	0%	0%	0%	0%		Jackson 1992a.
11	Electric share	78%	43%	76%	80%	61%	11%		Jackson 1992a.
12	Use - GWh (1992)	408	140	48	58	29	13	696	NYSEO 1991c.
13	Cost-eff. poten. (% elec)	20%	0%	30%	0%	0%	0%		ACEEE estimate based on Table 5-14 & allowances for outliers.
14	% elec. w/ nearby gas	79%	79%	79%	79%	79%	79%		(1 - 10)/(100% - 10)
15	Savings potential (GWh)	64	0	11	0	0	0	76	(12 * 13 * 14)
16	Ratio M DTh/GWh	12.36	14.31	11.21	14.70	14.70	14.70		Based on efficiencies in Tables 5-2 & 5-4 and ratios in Table 4-15.
17	Added gas sales (M DTh)	797	0	128	0	0	0	924	(15 * 16)
34	**Total sav'gs potent'l (GWh)**	**276**	**21**	**84**	**3**	**24**	**2**	**411**	(7 + 15)
35	% of comm'l elec sales	9%	2%	10%	0%	4%	1%	5%	(34/total sales from NYSEO 1991c)
36	**Total sales added (M DTh)**	**2,124**	**133**	**584**	**21**	**149**	**15**	**3,025**	(9 + 17)
37	% of comm'l gas sales	16%	1%	15%	1%	5%	2%	9%	(36/total sales from NYSEO 1991c)

Table 5-22. Rough Estimate of Electricity Savings from Cost-Effective Fuel Switching in the Commercial Sector of LILCo.

		Office	Retail	Health	Supermarket	Restaurant	Warehouse	Total - Six Building Types	Notes/Sources (#'s are row #'s)
1	% of buildings with gas on street	54%	54%	54%	54%	54%	54%		LILCo.
	SPACE HEATING								
2	Gas share	46%	49%	25%	43%	50%	40%		Jackson 1992a.
3	Electric share	20%	7%	9%	14%	6%	5%		Jackson 1992a.
4	Electric use - GWh (1992)	376	66	26	42	16	22	548	NYSEO 1991.
5	Cost-effective potential (% electric)	80%	80%	80%	80%	80%	80%		ACEEE estimate based on Table 5-6 & allowances for outliers.
6	% electric with nearby gas	15%	10%	39%	20%	7%	23%		(1 - 2)/(100% - 2)
7	Savings potential (GWh)	46	5	8	7	1	4	71	(4 * 5 * 6)
8	Ratio M DTh/GWh	6.27	6.27	6.27	6.27	6.27	6.27		Based on efficiencies in Tables 5-2 and 5-3; assumes 75% baseboard heat, 25% heat pumps.
9	Added gas sales (M DTh)	286	34	50	42	6	25	444	(7 * 8)
	AIR CONDITIONING								
10	Gas share	3%	0%	3%	0%	0%	1%		Jackson 1992a.
11	Electric share	68%	64%	68%	61%	64%	39%		Jackson 1992a.
12	Use - GWh (1992)	292	168	104	37	38	37		NYSEO 1991.
13	Cost-effective potential (% electric)	65%	60%	50%	50%	40%	80%		ACEEE estimate based on Table 5-6 & allowances for outliers.
14	% electric w/ nearby gas	53%	54%	53%	54%	54%	53%		(1 - 10)/(100% - 10)
15	Savings potential (GWh)	100	54	27	10	8	16	216	(12 * 13 * 14)
16	Ratio M DTh/GWh	13.76	13.90	11.21	14.70	14.70	14.70		Based on efficiencies in Tables 5-2 & 5-4 and ratios in Table 4-15.
17	Added gas sales (M DTh)	1,379	754	307	147	121	233	2,941	(15 * 16)
34	**Total savings potential (GWh)**	**146**	**60**	35	17	9	20	**287**	(7 + 15)
35	% of commercial electric sales	6%	6%	9%	15%	2%	6%	5%	(34/total sales from NYSEO 1991c)
36	**Total sales added (M DTh)**	**1,665**	**789**	357	189	127	**258**	**3,384**	(9 + 17)
37	% of commercial gas sales	28%	22%	53%	17%	6%	18%	28%	(36/total sales from NYSEO 1991c)

Table 5-23. Rough Estimate of Electricity Savings from Cost-Effective Fuel Switching in the Commercial Sector of Consolidated Edison.

#		Office	Retail	Health	Supermarket	Restaurant	Warehouse	Total - Six Building Types	Notes/Sources (#'s are row #'s)
1	% of buildings with gas on street	95%	95%	95%	95%	95%	95%		NYSEO 1990.
	SPACE HEATING								
2	Gas share	30%	43%	21%	68%	50%	43%		Jackson 1992a.
3	Electric share	3%	6%	3%	20%	3%	3%		Jackson 1992a.
4	Electric use - GWh (1992)	92	75	62	72	12	18	331	NYSEO 1991c.
5	Cost-effective potential (% electric)	75%	75%	75%	75%	75%	75%		ACEEE estimate based on Table 5-10 & allowances for outliers.
6	% electric with nearby gas	93%	91%	94%	84%	90%	91%		(1 - 2)/(100% - 2)
7	Savings potential (GWh)	64	51	44	46	8	12	225	(4 * 5 * 6)
8	Ratio M DTh/GWh	6.27	6.27	6.27	6.27	6.27	6.27		Based on efficiencies in Tables 5-2 and 5-3; assumes 75% baseboard heat, 25% heat pumps.
9	Added gas sales (M DTh)	402	322	273	286	51	77	1,412	(7 * 8)
	AIR CONDITIONING								
10	Gas share	1%	0%	17%	0%	0%	0%		Jackson 1992a.
11	Electric share	60%	62%	35%	96%	85%	21%		Jackson 1992a.
12	Use - GWh (1992)	1,119	250	299	121	110	36	1935	NYSEO 1991c.
13	Cost-effective potential (% electric)	60%	55%	40%	45%	35%	70%		ACEEE estimate based on Table 5-10 & allowances for outliers.
14	% electric with nearby gas	95%	95%	94%	95%	95%	95%		(1 - 10)/(100% - 10)
15	Savings potential (GWh)	638	131	112	52	37	24	993	(12 * 13 * 14)
16	Ratio M DTh/GWh	13.76	13.90	11.21	14.70	14.70	14.70		Based on efficiencies in Tables 5-2 & 5-4 and ratios in Table 4-15.
17	Added gas sales (M DTh)	8,770	1,815	1,260	760	538	352	13,495	(15 * 16)
34	**Total savings potential (GWh)**	702	**182**	156	97	**45**	36	**1,218**	**(7 + 15)**
35	% of commercial electric sales	7%	9%	8%	4%	5%	4%	7%	(34/total sales from NYSEO 1991c)
36	**Total sales added (M DTh)**	**9,172**	2,137	**1,533**	**1,046**	**588**	**429**	**14,907**	(9 + 17)
37	% of commercial gas sales	79%	30%	28%	31%	12%	14%	49%	(36/total sales from NYSEO 1991c)

Results of these analyses indicate that the economic potential for fuel-switching is approximately 5 percent of commercial electric sales for LILCo and Niagara Mohawk and approximately 7 percent of commercial electric sales for Con Edison. The savings potential is higher for Con Edison because its territory contains a large proportion of office buildings, a building type where the economics of gas cooling are relatively advantageous. For the downstate utilities most of the savings are due to switching from electric to gas cooling. For the upstate utility, most of the savings are due to space heating conversions; the economics of gas cooling are not nearly as favorable upstate as downstate.

Looked at another way, the economic potential for fuel-switching can result in increased commercial gas sales for the three utilities including a 28 percent increase for LILCo, a 49 percent increase for Con Edison, and a 9 percent increase for Niagara Mohawk. The increase is particularly large for Con Edison because of the large number of office buildings in its territory and because nearly all commercial buildings presently have gas service, thus fuel-switching potential is not limited by gas availability. The increase is relatively small for Niagara Mohawk because most of the fuel-switching potential is in space heating, and the majority of commercial buildings in the Niagara Mohawk service area already use gas for space heating. Also, due to the high saturation of gas space heat upstate, the baseline upon which sales increases are calculated is relatively high, making it more difficult to achieve high percentage increases in gas sales. The increase in gas sales for LILCo is in-between the increase for the other two utilities. Like Con Edison, LILCo has advantageous economics for gas cooling in many buildings and the baseline commercial gas sales are relatively low (compared to Niagara Mohawk), making it easier to achieve large percentage increases in gas sales.

Thus these preliminary analyses indicate that there is a substantial economic potential for fuel-switching in each of the three utility service areas examined. Program and policy experience from efforts to tap into this resource are discussed in chapter 7.